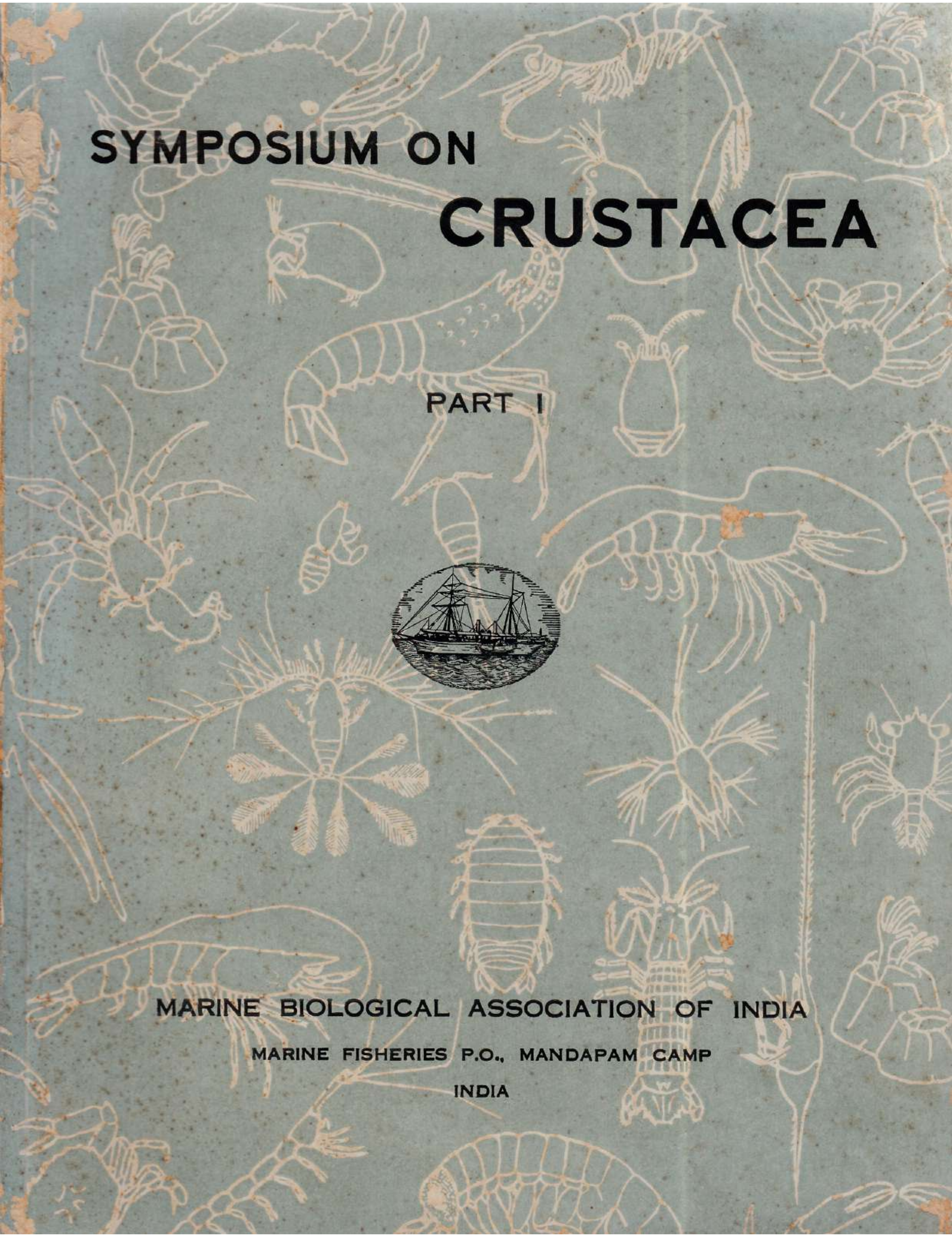


SYMPOSIUM ON
CRUSTACEA

PART I

MARINE BIOLOGICAL ASSOCIATION OF INDIA

MARINE FISHERIES P.O., MANDAPAM CAMP
INDIA

SYMPOSIUM ON
CRUSTACEA

PART I

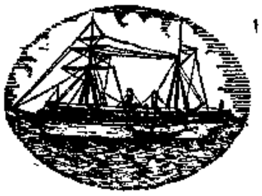
MARINE BIOLOGICAL ASSOCIATION OF INDIA
MARINE FISHERIES P.O., MANDAPAM CAMP
INDIA

PROCEEDINGS

SYMPOSIUM ON CRUSTACEA

HELD AT
ERNAKULAM
FROM JANUARY 12 TO 15, 1965

PART I



SYMPOSIUM SERIES 2

MARINE BIOLOGICAL ASSOCIATION OF INDIA
MARINE FISHERIES P.O., MANDAPAM CAMP
INDIA

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PREFACE

THE rôle of Crustacea in the nutrition of a number of animals, including man, needs no emphasis. The zooplankton, a major part of which is composed of crustaceans as adults or in larval stage, forms food of a large number of fishes when they are plankton feeders or form food of smaller species which are eaten by the carnivorous ones. In the recent years the crustacean shellfish as a food item of man has gained considerable importance and today the shrimps (prawns), lobsters and other edible varieties play a significant role in the fishery wealth of many a nation. In India they rank first in marine fish production and their potentialities are still greater, though the resources have not been fully developed. Man is now seriously thinking of utilising the smaller crustaceans as a source of food. As boring and fouling organisms the crustaceans remain still a major problem to man in his attempts to keep clear his ships of them. There is a large variety of parasites and commensals among this group of animals and since a majority of them are harboured by fishes of economic importance they have been studied in some detail. With the object of bringing together the available information on the various aspects of systematics, biology and fishery of these animals from different parts of the world, to discuss their relative merits and to plan for future programmes of research the Marine Biological Association of India conceived the idea of holding a SYMPOSIUM ON CRUSTACEA.

The Symposium on Scombroid Fishes conducted by the Association in January, 1962, at Mandapam Camp was a success to the extent that quite a good number of the foreign and Indian contributors participated personally at the meetings and that the recommendations made at this Symposium were also considered at the F.A.O. World Scientific Meeting on the Biology of Tunas and related species held at La Jolla, California, in July, 1962. The *Proceedings of the Symposium on Scombroid Fishes* consisting of 72 papers presented at the Symposium have been published.

When the idea of holding the Symposium on Crustacea was broadcast, there was a very good response from scientists of many parts of the world and over 150 contributions were registered. It is our good fortune that in a short time after announcement it was possible to conduct the Symposium as the contributors were as enthusiastic as the organisers were. The Symposium was held from 12th to 15th January, 1965, at Ernakulam in the Oceanographic Laboratory of the University of Kerala. Ernakulam was chosen as the venue since there are a number of institutions at this place carrying out fisheries, marine biological and oceanographic research. This area accounts for a large percentage of prawn landings in India and an export trade for this product excelling any other centre in the South-East Asia has come to stay. A number of freezing and canning industries have sprung up and the trade is expanding at a fast rate. Hence by holding this Symposium here, it was intended to bring together people from all these fields and make it a purposeful one. All those who attended the Symposium are sure to have departed with the feeling of having disseminated the information in their possession and having been taken to new thoughts to conduct further investigations on fresh lines. To a wider circle of scientists the Proceedings, it is hoped, would compensate what would otherwise have been missed.

In view of the large number of papers it has been decided to publish them in a series of six parts. The papers have been arranged as presented under different sections at the time of the Symposium. Part I of this series encompasses the sections Taxonomy and Phylogeny, and Zoogeography.

Considerable help and assistance have been received from many quarters in conducting the Symposium. The role played by Dr. S. Jones, President of the Association, in organising the Symposium deserves special mention. He gave not only the initiative to this work but was also a constant source of inspiration to those engaged in this endeavour. He personally corresponded with a large number of foreign scientists and was in no small measure responsible to get many of the articles from abroad. Despite his recent illness, he bestowed his personal attention even to the minutest details of the arrangements. Mr. K. Alagarswami looked after the duties of the Convener and completed the printing of the Abstracts until the official Convener took charge at the time of the Symposium. To him and to Mr. P. V. Ramachandran Nair, Assistant Secretary of the Association, who was of immense help in organising the Symposium we are very much thankful.

We express our sincere thanks to the authorities of the University of Kerala who wholeheartedly co-operated with us in conducting this Symposium. To Prof. Samuel Mathai, Vice-Chancellor, we are thankful for according permission to hold the Symposium in the Oceanographic Laboratory and for kindly inaugurating the same. Prof. A. Abraham, Dean of Faculty of Sciences, was of great help and we express our thanks to him. Dr. C. V. Kurian, Head of the Department of Marine Biology and Oceanography, took an active interest in this venture and made elaborate arrangements for the Symposium. As Chairman of the Reception Committee he made excellent arrangements for the participants. To him and his colleagues who co-operated with him we are very much thankful.

As Chairman of the Exhibition Committee, Mr. G. K. Kuriyan made sincere efforts in organising the Exhibition and our thanks are due to him. The Indo-Norwegian Project played an active role in this connection. To Mr. Per Sandven, Director of the Project, who kindly inaugurated the Exhibition and to Mr. A. I. George, Chief Fisheries Project Officer, we are thankful for their kind co-operation. The Indo-Norwegian Project, the Central Institute of Fisheries Technology, the University of Kerala, and the Central Marine Fisheries Research Institute took part in the Exhibition at our request, and we express our sincere thanks to them.

It has not been possible to mention here the names of all those who actively co-operated with us and we record our gratefulness to them all.

N. KRISHNA PILLAI,
Convener.

SUMMARY OF THE PROCEEDINGS

The inaugural function of the Symposium on Crustacea took place on the 12th January, 1965 in a well decorated pandal in the Oceanographic Laboratory of the University of Kerala. Dr. S. Jones, President of the Marine Biological Association of India, was in the chair and Prof. Samuel Mathai, Vice-Chancellor, University of Kerala, and Mr. Per Sandven, Director, Indo-Norwegian Project, were the chief guests. The function began at 4 P.M. with the invocation song. Dr. C. V. Kurian, Chairman of the Reception Committee, welcomed the gathering which consisted of eminent men in the field of Science, Education and civic life. Dr. N. Krishna Pillai, Convener of the Symposium, introduced the foreign delegates to the audience. Prof. Samuel Mathai delivered the Inaugural Address and declared the Symposium open. He expressed his appreciation of the various institutions conducting marine biological and oceanographic research and stressed the importance of such symposia which would bring together eminent scientists in the field to enable fruitful discussions. Mr. Per Sandven declared open the Exhibition on the Biology and Fishery of Crustacea. Dr. S. Jones delivered the Presidential Address in which he traced the birth, growth and present status of the Marine Biological Association of India. He laid stress on the importance of the study of the marine sciences in this part of the world in view of the increasing demand for food and the vast resources of the seas around us. He rightly pointed out the role the Association is playing in promoting contacts among scientists from various parts of the world thereby disseminating knowledge and useful information on marine biological sciences. Mr. P. V. Ramachandran Nair, Assistant Secretary of the Association, tendered the vote of thanks. The function came to an end with the singing of the National Anthem.

The Scientific Sessions began in the forenoon of the 13th and were spread over a period of three days, ending on the afternoon of the 15th January, 1965. The various sections were presided over and reported on as follows: (1) *Taxonomy and Phylogeny*: (*a*) *Decapoda*—Dr. R. Serene (Chairman), Dr. C. Sankarankutty and Mr. K. N. Sankolli (Rapporteurs); (*b*) *Copepoda*—Dr. S. Krishnaswamy (Chairman), Dr. A. N. P. Ummerkutty and Mr. M. J. Sebastian (Rapporteurs); (*c*) *Amphipoda*—Dr. N. Krishna Pillai (Chairman), Dr. A. N. P. Ummerkutty (Rapporteur); (*d*) *Other Crustacea*—Dr. D. G. Frey (Chairman), Mr. M. J. Sebastian (Rapporteur). (2) *Zoogeography*—Dr. D. S. Johnson (Chairman), Dr. E. G. Silas (Rapporteur). (3) *Morphology* and (4) *General Biology*—Dr. G. H. Stubbings (Chairman), Mr. M. J. George (Rapporteur). (5) *Reproduction* and (6) *Larval Development*—Dr. B. Rasmussen (Chairman), Mr. K. N. Sankolli (Rapporteur). (7) *Ecology and Behaviour*—Dr. J. Crane (Chairman), Mr. K. H. Mohamed (Rapporteur). (8) *Endocrinology* and (9) *Physiology*—Dr. L. B. Kirschner (Chairman), Dr. S. Z. Qasim and Dr. A. L. Rice (Rapporteurs). (10) *Fouling*—Dr. H. G. Stubbings (Chairman), Dr. N. Balakrishnan Nair (Rapporteur). (11) *Parasitism and Symbiosis*—Dr. E. G. Silas (Chairman), Mr. K. Alagarswami (Rapporteur). (12) *Tagging, Marking and Migration* and (13) *Fishery and Economics*—Mr. M. J. George (Chairman), Messrs. M. M. Kunju and P. Vedavyasa Rao (Rapporteurs). (14) *Bibliography and Review*.

Special Lectures were delivered on the evenings by distinguished scientists. Following the lectures films relating to crustacean fisheries and aspects of socio-economics of fishermen were screened. The lectures and film shows were open to the public and were largely attended.

The Exhibition drew a good crowd every day. The Indo-Norwegian Project, The Central Institute of Fisheries Technology, the University of Kerala and the Central Marine Fisheries Research Institute, arranged their exhibits depicting various aspects of fishery and biology of Crustacea highlighting the investigations carried out in the various institutions.

The participants were entertained at Tea by the Marine Biological Association of India, Department of Marine Biology and Oceanography of the University of Kerala and the Sea Food Canners and Freezers Association and at Dinner by the Indo-Norwegian Project.

The Reception Committee consisting of Dr. C. V. Kurian (Chairman), Capt. K. Larssen, Messrs. K. H. Mohamed, P. Vedavyasa Rao and K. P. Balakrishnan made all possible arrangements to receive and look after the comforts of the participants. The Exhibition Committee with Mr. G. K. Kuriyan (Chairman), Mr. M. J. George and Mr. K. C. George arranged an informative Exhibition.

At the concluding session Dr. S. Jones expressed his deep appreciation of the various individuals and institutions whose efforts made the Symposium a success. He spoke as follows:

I am taking the privilege of proposing the vote of thanks since I have been, from the beginning, associating myself with the organisation and conduct of the Symposium in my capacity as the President of the Association and since perhaps more than any one else, I am aware of the efforts put in by various persons and the trouble taken by them in making the Symposium a success. I feel it is my duty to thank them all on behalf of the Association.

I should mention here that it was our intention to have Dr. John S. Garth of the Allan Hancock Foundation as the External Convener for this Symposium. Though he had agreed to this, towards the later stage he found it difficult to be present here at this time and so we had to go without enjoying the benefits of his vast experience in the field of carcinology. Nevertheless he was doing the job of an External Convener by corresponding with several scientists on behalf of the Association and it is mainly by his efforts we received a good number of contributions especially from the United States. I express my sincere thanks to him for all that he has done for the success of the meeting. I must also thank Mr. K. Alagarswami who was looking after the duties of the Convener until Dr. Krishna Pillai assumed charge a few weeks back. He has come here on his own and has been most helpful in various ways. As Convener Dr. N. Krishna Pillai has been doing his very best and I express my sincere thanks to him.

I am very much thankful to Mr. P. V. Ramachandran Nair, Assistant Secretary of the Association, who came over here on his own, well ahead of the schedule of the Symposium, and made all arrangements in collaboration with the various committees. In the absence of the Secretary he discharged his duties in connection with the Symposium with great devotion. I am also thankful to Mr. Clement Adolph who helped in various ways in the organisational stage and also attended to the projection arrangements here.

We are thankful to Prof. Samuel Mathai, Vice-Chancellor of the Kerala University, for kindly inaugurating the Symposium and to Mr. Per Sandven, Director of the Indo-Norwegian Project, for opening the Exhibition. Our thanks are due to Prof. A. Abraham, Dean of Faculty of Sciences, Dr. C. V. Kurian, Head of the Oceanographic Laboratory, his colleagues, and other authorities of the Kerala University who took an active interest in arranging to hold the Symposium in their premises in the most fitting manner and for all the facilities they have afforded to the participants. The Engineering Department of the University has been very co-operative in making these arrangements and we are thankful to them.

We express our sincere thanks to the Chairman, Dr. C. V. Kurian and the members of the Reception Committee who ably did the job of receiving the delegates and arranged for their accommodation in the best possible manner. Our thanks are due to Capt. Kåre Larssen, Drs. S. Z. Qasim and E. G. Silas for providing transport facilities to the foreign delegates.

We are thankful to the Chairman, Mr. G. K. Kuriyan and the members of the Exhibition Committee who organised an interesting and educative exhibition.

We are thankful to Mr. Per Sandven, Director, and to Mr. A. I. George, Chief Project Officer of the Indo-Norwegian Project, for their personal efforts in taking part in the Exhibition. The Central Institute of Fisheries Technology, the University of Kerala and the Central Marine Fisheries Research Institute participated in the Exhibition and we are thankful to them.

Our thanks are due to the distinguished scientists who served as Chairmen of the various sections and also to the rapporteurs. Our thanks are also due to Drs. D. G. Frey, Jocelyn Crane, L. B. Kirschner and H. G. Stubbings for their interesting lectures.

We thank the U.S. Fish and Wildlife Service, the Fisheries Department of the State of Maine, U.S.A. and the United States Information Service, Madras, for sending the films connected with crustacean fisheries for screening, and Mr. Rodney Jonklaas for the film—'Beneath the Seas'.

We also thank Messrs. Kerala Travels, the State Bank of India, Ernakulam Branch, the postal authorities at Ernakulam and the Bharat Cafe for kindly offering their services to the participants.

During these few days we have enjoyed the hospitality of the Indo-Norwegian Project who entertained us to a Dinner, of the Department of Marine Biology and Oceanography of the University of Kerala at their Tea, and the Invitation by the Sea Food Canners and Freezers Association for a Tea this evening is in our hands. To all our hosts we are very thankful.

Last, but not least, we are thankful to all the participants who attended the sessions. To those who have come from abroad under stress of time and hardships in spite of the comparative shortness of notice and gave rightly an international touch to the Symposium we owe our sincere thanks. Notwithstanding the fact that the schedule was a little pressing for them they did not miss even a single session and they bore the inconvenience of an alien climate, with extraordinary fervour. I am sure they will cherish pleasant memories of their stay in India and carry along with them the warmth of our hearts.

Thank you all.

Dr. H. G. Stubbings, speaking at the end, on behalf of the participants, especially the foreign delegates, expressed his appreciation of the manner in which the Symposium was conducted. His speech was in the following manner:

Dr. Jones, Gentlemen,

I have been asked on behalf of those present and particularly on behalf of the foreign delegates to this Symposium to say how very much we have enjoyed this very short stay in your midst. I have also to express our most appreciative thanks to you all for the very hearty welcome you have extended to us and for the very kind way in which you have made sure we have wanted for nothing it was in your power to provide. The warmth of your welcome has surpassed even the warmth of your climate. We shall not easily forget—either!

We all know that Symposia are for two purposes: to discuss the matters on the agenda and to meet fellow workers in specialised fields under circumstances and in an atmosphere that is only possible in such a gathering as this. I am not absolutely sure which is the more important, the papers or the meetings. Personally, I think the meetings. The papers we shall be able to read at a future date. The memory of yourselves we carry away with us and I am sure we shall all long remember the circumstances of this very happy gathering of which we have been part.

You have worked us hard, Sir. But we expected to have to work and we have enjoyed it. Work under such circumstances, both early and late, has been a pleasure. In fact it is with pleasure we shall remember all the incidents of this gathering.

I am sure I speak for all the foreign delegates when I say we have enjoyed our stay among you, and if the opportunity offers we shall come again to India. I personally, if the chance arises, shall strain every nerve to come again to your country, to meet you again and to enjoy living among you.

Dr. Jones, Gentlemen, from us all, the foreign delegates thank you very much indeed for your hospitality, your kindness, and your care for our creature comforts; for working so hard to make this Symposium a success and for ensuring that we, the delegates, and in particular, the foreign delegates, should take away happy memories of it.

Thank you all.

PROGRAMME

January 12, 1965

10-00 a.m. to 12-30 p.m. and 2-00 p.m. to 3-00 p.m.	Registration of participants.
2-30 p.m.	Meeting of the Sectional Chairmen.
4-00 p.m.	Inaugural Session.
6-30 p.m.	Special Lecture by Dr. David G. Frey—*Cladocera in Space and Time.*
7-30 p.m.	Film Show—'Shrimp Fisherman'—Part I **(*from* United States Information Service).**

January 13, 1965

9-00 a.m. to 12-30 p.m. and 2-00 p.m. to 5-00 p.m.	Scientific Sessions.
5-15 p.m.	Tea by the Department of Marine Biology and Oceanography, University of Kerala.
6-30 p.m.	Special Lecture by Dr. Jocelyn Crane—*Social Behaviour in Fiddler Crabs of the World,* accompanied by film.
7-30 p.m.	Film Show—'Shrimp Fisherman'—Part II **(*from* United States Information Service).**
8-00 p.m.	Dinner by the Director, Indo-Norwegian Project.

January 14, 1965

9-00 a.m. to 12-30 p.m. and 2-00 p.m. to 5-00 p.m.	Scientific Sessions.
5-15 p.m.	Tea by the Marine Biological Association of India.
5-30 p.m. to 6-30 p.m.	Visit to the Dutch Palace and Jewish Synagogue.
6-30 p.m.	Special Lecture by Dr. Leonard B. Kirschner—*Physiology of the Crayfish Antennal Gland.*
7-30 p.m.	Film Show—'Shrimp Please' **(*from* U.S. Fish and Wildlife Service).** 'Beneath the Seas' **(*from* Mr. Rodney Jonklaas).**

January 15, 1965

9-00 a.m. to 12-30 p.m. and 2-00 p.m. to 4-00 p.m.	Scientific Sessions.
4-00 p.m. to 5-00 p.m.	Concluding Session.
5-15 p.m.	Tea by Seafood Canners and Freezers Association.
6-30 p.m.	Special Lecture by Dr. H. G. Stubbings—*Role of Crustacea in Marine Fouling.*
7-30 p.m.	Film Show—'Maine Shrimp' **(*from* Fisheries Department of the State of Maine, U.S.A.).**

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CLADOCERA IN SPACE AND TIME[*]

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COMPARED with all other groups of crustaceans, the freshwater Cladocera offer one big advantage for study: their exoskeletal components occur in substantial numbers in all kinds of lacustrine sediments, and they generally exhibit sufficient diversity of morphological detail that the fragments can be identified positively at the species level. Thus, here is a significant reservoir of material for working out the present and past distributions of species and communities in relation to various environmental parameters, the changing community composition in a lake in relation to its ontogenetic changes and watershed development, and hopefully even the evolution of these organisms when long and continuous sedimentary records eventually become available. Moreover, study of these exoskeletal fragments has revealed a number of morphological characters of phylogenetic value that give promise of helping resolve the uncertainties and confusion in the present taxonomy, particularly in the family Chydoridae and perhaps also the Bosminidae. Much more study is needed of the other families before corresponding predictions can be made for them, but at least in the Polyphemidae this seems a very good possibility.

THE MATERIAL

The order Cladocera consists of eight well-defined families, containing an estimated 400 or so species in the world. Most of the species are confined to freshwater, although two unrelated families—the Sididae and Polyphemidae—have species that are regularly marine and may at times bulk large in the zooplankton biomass. Nearly all the other species are intolerant of high salt concentrations, either inland or marine, although there are some that regularly occur in endorrheic basins of steppe and desert or in brackish-water habitats. In general, though, increasing salt content progressively restricts the occurrence of these crustaceans.

In the process of molting, as is true of all arthropods, the chitinous exoskeleton is cast off and replaced by a new one. These exuviae accumulate in the sediments, as do also the exoskeletons of animals that have died of causes other than predation and probably even those that have passed through the guts of predators, providing the molar action has not been too extreme. The chitin is very inert chemically. Ordinary methods of sediment preparation by hot 10% KOH and hot HF have no effect on the remains. The fact that these fragments are still abundant and apparently unchanged chemically in sediments from the last interglacial age (Frey, 1962 *a*), perhaps 100,000 years ago, also attests to their stability.

What is present in the sediments are not the intact exuviae but rather their disarticulated components. Most abundant of these are shells and head shields, and generally much less abundant are post-abdomens and post-abdominal claws. At still lower levels of abundance are ephippia, antennal segments and antennules, male copulatory hooks of the chydorids, and caudal spines of

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some of the predacious Cladocera. Mandibles are abundant, but to date they have served for species identification only in the Leptodoridae and Polyphemidae. Other fragments, such as filter combs of daphniids and thoracic limbs of chydorids, the latter seldom intact, also are common and may eventually yield useful information on past populations. Occasionally, two or more components are found associated with one another, which greatly aids in the initial identification of species (Frey, 1958) and in sorting out the fragments among the various species.

Even at this early stage in the study of animal remains in lake sediments, at least one species from each family has been positively identified (Table I), and there are suggestions that perhaps all species of Cladocera leave some kind of remains in sediments (Frey, 1960) which hopefully eventually can be used for identification of species. In all freshwater situations investigated to date the remains of Bosminidae, Chydoridae, and Daphniidae are numerically dominant, and generally in that order.

TABLE I

Number of species in each family of Cladocera that have been positively identified from their remains in freshwater sediments, and the various exoskeletal components that have been helpful in these identifications
(Largely from Frey, 1964)

Family	Exoskeletal components									
	Number of species identified to date	Head shield	Shell	Ephippium	Postabdomen	Postabdominal claw	Caudal spine	Antennal segments or antennules	Mandibles*	♂ Copulatory hooks
Leptodoridae	1	..	..	..	..	..	X	..	X	..
Sididae	3	..	..	..	X	X	..	X	..	..
Holopediidae	2	..	..	..	X	..	..	..	..	..
Daphniidae	17	..	..	X	X	X	..	..	..	..
Bosminidae	3	X	X	X	X	X	..	X	..	..
Macrothricidae	3	..	X	X	X	..	..	..	..	..
Chydoridae	59	X	X	X	X	X	..	X	..	X
Polyphemidae	2	..	..	..	..	..	X	..	X	..

* Mandibles of the Sididae, Daphniidae, Bosminidae and Chydoridae are abundant in sediments but as yet have not been sorted out by species.

Table I indicates that apparently only in the Bosminidae and Chydoridae are all the skeletal components capable of preservation. The heads and shells of the Daphniidae, for example, are never found except occasionally in the most recent surficial sediments that are not yet stabilized. This suggests that all cladoceran chitin may not be equally resistant to biological degradation, contrary to the statement made earlier. The dilemma here is that the only records thus far of Cladocera from the Tertiary are the ephippia (which are shell structures) of Daphniidae, principally the genus *Daphnia* (Frey, 1962 *a*, 1964).

Of all the families of the Cladocera, the Chydoridae has by far the greatest number of species. These are well enough differentiated morphologically that nearly all their major exoskeletal comPnoents can be identified to species without particular difficulty. The chydorids almost invariably dominate any list of species compiled from intact animals or from the remains in sediments. For these reasons, the chydorids have received most attention to date.

Cladoceran remains commonly number several thousands to 10,000 or more per c.c. of fresh organic sediment (Frey, 1964), with generally much smaller numbers in clastic sediments (Megard, 1964). The maximum reported to date is approximately 500,000 per c.c. from Schelinsee *in* Southern Germany (Frey, 1961 *b*), although there are indications that sometimes a sediment may consist almost entirely of cladoceran fragments, for which Wesenberg-Lund proposed the term chitin-gyttja. In such instances the numbers of remains per c.c. of fresh sediment must be almost astronomical. With such numbers to work with, close-interval biostratigraphy can be studied in almost any detail desired. Cladoceran diagrams, describing the progressive changes in percentage composition of the population by species with time, can be constructed in the same way as pollen diagrams or diatom diagrams. Where absolute dates (C^{14}) are available, the number of fragments sedimented per cm.^{2} per year can be calculated (Livingstone *et al.*, 1958; Deevey, 1964).

SYSTEMATICS AND EVOLUTION

Because of the close similarity in morphology between adult Cladocera and the larvae of some Conchostraca, the Cladocera are regarded as neotenic derivatives of the Conchostraca (Brooks, 1959). But although the Conchostraca are known from as far back as Cambrian time, the Cladocera are tersely dismissed in text-books of palaeontology as not occurring in the geological record. This is not true. There are at least six reliable records of daphniid ephippia from the Tertiary (Oligocene and later) (Frey, 1964), and it seems likely that when suitable lacustrine deposits are knowingly examined Cladocera will be found from the Mesozoic or even earlier.

Even these few Tertiary records, however, suggest a long prior period of evolution and indicate a marked physiological and ecological stability in the group. The *Daphnia* ephippia from the Tertiary of the Western United States all are from species of the subgenus *Ctenodaphnia*, which today characteristically occur in marginal habitats that experience intermittency by drying or freezing and/or have a high salt content. Similar environmental conditions (except freezing) are indicated for the Tertiary localities. Moreover, the ephippia of all species of *Ctenodaphnia* present and past are very similar morphologically, making it virtually impossible to identify a species solely from its ephippia. The only present basis for regarding the Tertiary forms as separate species is the very long interval of time involved.

The first detailed study of Cladocera from late-glacial time (Frey, 1958) could detect no significant morphological changes over the past 11,000 years among the 18 species and varieties recovered from a small pond. Similarly, the 25 species of chydorids recovered from a Danish deposit deriving from the last interglacial age (Eemian) were indistinguishable from their present-day counterparts in Denmark (Frey, 1962 *a*). Thus, particularly in the chydorids, one has the impression that the major speciation in the group occurred long ago, and that the species have been relatively stable morphologically since at least well back into the Pleistocene and probably earlier.

A by-product of the attempt to identify all the cladoceran fragments in lake sediments has been the discovery in the chydorids of two series of pores on or near the mid-line of the head shield toward the posterior end (Frey, 1959, 1962 *b*). These pores are constant in arrangement for any species throughout its postembryonic ontogeny, showing only a progressively greater displacement from the posterior margin in the later instars of some species (Smirnov, 1964). Two major types of pore arrangement occur, one in which there are 2 or 3 large pores on the mid-line generally connected with one another by a channel, and a pair of small pores located laterally; and the other in which there are only 2 large pores on the mid-line completely and widely separated from one another, with the smaller pores now close to the mid-line between the large pores.

This demonstration of a major phylogenetic dichotomy in the chydorids has since been substantiated by the structure of the thoracic limbs (Smirnov, 1965) and by the way in which the mandibles are attached to the head, permitting the realistic definition of a number of subfamilies (Frey, 1965 *c*). The species of the chydorids are quite distinct, but the relationships between species at the generic level have been obscure, based to a considerable extent on subjective characters. As a result, quite a number of species have been shifted from one genus to another at the whims of various investigators. This has been particularly true for species in the genera *Alona* and *Alonella*, which on the basis of the three major characters listed above are now placed in separate subfamilies.

The head shield is the most useful single exoskeletal part for identifying species and indicating relationships between species and between genera. In a number of instances discrepancies in taxonomy have first been indicated by head-pore patterns. Thus, the species *rostrata*, which formerly was included in the genus *Rhynchotalona*, had to be reassigned to the genus *Alonella* in a different subfamily (Frey, 1959). The species *Alona rustica*, which previously had been reported only from Great Britain, was shown to be confused in the literature elsewhere with a closely related species *Alona costata* (Frey, 1965 *a*). *A. rustica* is now known to be widely distributed in Western Europe, the United States, and South America. The species *Alonopsis ambigua* was shown to be unrelated to the other species (*A. elongata*) in this genus but to be closely related to a species (*Euryalona colletti*) in another genus, which itself is not related to the other species in *Euryalona*. Accordingly, these two species have been removed from their previous genera and combined in a new genus *Tretocephala* (Frey, 1965 *b*).

These are but a few instances of many, which are largely unpublished as yet, of the greater insight into phylogenetic relationships that is developing from the study of the morphological details of the exuvial fragments in sediments. Even with intact animals it is often desirable to "fossilize" them, that is, to treat them in such a way that the individual skeletal components can be mounted and studied unobscured by internal soft tissues. This can now be accomplished in most instances by treating the intact specimens with hot concentrated HCl for a short period of time and then mounting in polyvinyl lactophenol (Megard, 1965).

Head pores also occur in the Macrothricidae, Bosminidae, and Daphniidae, but the pattern is different than in the Chydoridae, and the pores may not be homologous. In the Bosminidae there is a prominent pore located laterally in the general region of the mandibular articulation. The location of the pore and its shape are different in *Bosmina coregoni* sens. lat. than in *B. longirostris* sens. lat. (Goulden and Frey, 1963). This character is of value not only in indicating phylogenetic relationships in the genus but also for studying the quantitative aspects of the replacement of *B. coregoni* by *B. longirostris* during the ecological aging of a lake (Goulden, 1964). Each head shield recovered from sediments can now be assigned readily to one or another of these species groups.

DISTRIBUTION

In biogeographic and ecologic studies one would like to have complete lists of species from various localities as well as some quantitative expression of the importance of each species in its total community integrated over a substantial period of time. These data are difficult to obtain by ordinary collecting methods and especially for small aquatic organisms, which may be restricted to specialized microhabitats and which experience marked fluctuations in numbers over the course of a season or year. To get the desired information under these circumstances one would have to collect at frequent intervals in all conceivable habitats where the organisms might occur, and even then he would have reservations about his results.

In the lakes at Madison, Wisconsin, E. A. Birge studied the Cladocera intensively for about 30 years before shifting his attention to other matters. His combined list of species should be about as nearly complete as could reasonably be expected using the traditional methods of collecting intact animals. To check on the feasibility and validity of using exoskeletal fragments in sediments for compiling a list of species present in a given body of water, a sample of surficial sediment from deep water in each lake was analyzed for its Cladocera (Frey, 1960). Birge had 23 species in his list. All these species except one were recovered from the sediment samples, and in addition six species that Birge had not collected in his intensive effort. The species not recovered from the sediment was one that Birge had collected only once in one of the lakes. Since it is primarily a southern species, it may have had a brief and isolated development after a chance introduction *via* resting eggs during a favourable period, and it does not therefore necessarily represent a species permanently established in the lake.

In fact, evidence is accumulating (*e.g.*, DeCosta, 1964; Mueller, 1964) that such temporary local developments in favorable seasons of "southern" species far to the north of the zone in which they are regular constituents of the biotas year after year may be quite common. There is a distinct tendency for species from the south to press northward as rapidly and as far as possible, the northern limit probably being extremely variable in position from one year to another. The counter-tendency for "northern" species to extend their range southward either is not so well developed or else is obscured by the fact that there is really no diversified assemblage of species characteristic of high latitudes that corresponds to the large reservoir of tropical and pan-tropical species.

The sediments of a lake to a considerable extent represent an integration of time and space. Analysis of the remains in the sediments affords the best, and certainly the easiest, means of compiling a list of species including even the rare ones in a body of water, and moreover the total number of remains of each species gives a quantitative expression of its relative importance in the overall population.

A study was conducted on three lakes of contrasting size in northern Indiana to determine just how thoroughly cladoceran remains of different origins (such as littoral *vs.* pelagic) become mixed or integrated before they become incorporated into the permanent sediment (Mueller, 1964). The littoral remains, chiefly chydorids, become quite thoroughly integrated before they are moved offshore by currents, but they apparently never become completely integrated with remains of planktonic species, such as *Bosmina*, originating in the open water. For assembling a list of species of chydorids from a given body of water a sample of surficial sediment from almost anywhere in the lake is equally suitable, although for ease in preparation we prefer the offshore sediments. Unfortunately, no place in a lake offers a complete integration of cladoceran remains from all parts of the lake. Deepwater sediments away from shore approach this condition the closest, and hence for studying the dynamics of a cladoceran fauna during the history of a lake, offshore rather than littoral cores are recommended.

Using their remains in surficial sediments of 45 lakes, DeCosta (1964) attempted to work out the distribution of chydorids along the Mississippi River Valley from Northern Minnesota to below New Orleans, a distance of more than 17 degrees of latitude. Some species occurred predominantly in the north, others mainly in the south, and quite a few occurred over the entire transect. When the percentage abundance of the species in each lake was related to latitude, three groups of species could be distinguished: (1) *northern* species, which increased in relative abundance toward the north, (2) *southern* species, which increased in relative abundance toward the south, and (3) *eurytopic* species, which showed no change in relative abundance with respect to latitude along this transect. Hence, the responses that chydorids make to their complex of environmental conditions, to the extent these are reflected in growth and reproduction, are evidenced in the relative abundance of the individual species in the integrated populations of sedimentary remains. DeCosta recovered a total of about 40 species of chydorids from these lakes, including a number that represent new records for the United States. This further substantiates the usefulness of sedimentary remains in defining the total population present in any water body.

Although many species of Cladocera are considered wide-ranging and even frequently intercontinental in distribution, the validity of this belief has been substantiated by detailed morphological studies only in the genus *Daphnia* (Brooks, 1957) and in some of the chydorids (*e.g.*, Frey, 1961 *a*, 1965 *a*). In other instances it is known, for example, that species in North America (such as *Camptocercus rectirostris*) currently listed under the same scientific name as their European counterparts are in reality different. When these eventually will have been sorted out, it is likely that significant and interpretable patterns of distribution will emerge, such as the relatively restricted and completely allopatric distributions of the two species in the genus *Tretocephala*, one occurring only in Western Europe and the circum-Mediterranean region and the other only in Southern Africa (Frey, 1965 *b*).

ECOLOGY AND PALAEOLIMNOLOGY

Although the present-day ecology of the chydorid Cladocera is very imperfectly known, in part because many of the species are not yet realistically defined and in part because there very likely are physiological races or ecotypes within particular species, studies of the changes with time of cladoceran populations in particular lakes give great insight into the ecology of at least the local populations and their response to changing environmental conditions.

Interpretation of past conditions from the present-day ecology of organisms must always be based on the assumption that the response and reactions of organisms have not changed appreciably over the time interval involved. At least for the chydorid Cladocera this appears to be a reasonable assumption. The 25 species of chydorids recovered from the Eemian Interglacial of Denmark, all of which also occur in that country today, exhibit roughly the same relative abundance then as now (Frey, 1962 *a*). That is, in general the species most abundant today were also most abundant in the Eemian, and the species that are uncommon today were also rare in the Eemian. Thus, the various species of Cladocera in Western Europe have been ecologically adjusted to one another for a long time in their total occupation of the aquatic habitat. The present assemblage is not something new that has developed through recolonization of aquatic habitats created by the wasting of the most recent glaciers but is much older. And, by inference, other aquatic microorganisms likewise have been in dynamic balance with one another for long periods of time, even though displaced elsewhere during the glacial ages. The occurrence and evolution of species cannot be divorced from the communities to which they belong.

Colonization of water bodies by Cladocera is rapid, effected by the passive distribution of diapause eggs in their ephippia. Thus, in a small extinct lake in Northern Germany in late-glacial time there were few species present in the Lower Dryas stadial, but in the following Alleröd interstadial the number of species increased rapidly and dramatically as the climate ameliorated, reaching a maximum and then declining to low numbers again in the Upper Dryas with the return of tundra conditions (Frey, 1958). The late-glacial response of terrestrial vegetation to the climatic amelioration of this interstadial is much less obvious. The advantage possessed by Cladocera and other aquatic organisms that reproduce by unisexual means (parthenogenesis) during at least part of their life-cycle is that the introduction of a single viable resting egg is sufficient for starting a population. One has the feeling that the passive distribution of the Cladocera is so effective *via* these resting eggs that almost as soon as ecological conditions in the total ecosystem have become suitable for a particular species it will appear and become established.

The meagre evidence available (Frey, 1961 *b*; Goulden, 1964) suggests that near the beginning of post-glacial time the north temperate humid lakes acquired virtually their entire present-day complement of Cladocera. Since then the response of the population to changing climate and other ecological conditions has been primarily an internal adjustment of the abundance (success) of the species to one another. Changes in abundance are usually progressive and obviously in response to changing conditions, but our present knowledge of the ecology of the various species does not afford a very satisfying interpretation of these fluctuations. Eurytopic and stenotopic species can be distinguished by their behavior over a long interval characterized by pronounced changes in environmental conditions. Sometimes there is a replacement of one species by another in the aging of a lake, as of *Bosmina coregoni* by *B. longirostris* (Deevey, 1942; Goulden, 1964). At other times there is a very gradual diversification of the population in post-glacial time (Frey, 1961 *b*), which becomes accelerated in response to changes in the watershed effected by man (Goulden, 1964). A lake obviously is very sensitive to changes in its watershed, and manifests them in part by adjustments in its aquatic biota.

In Linsley Pond, Connecticut, Deevey (1942) found an exponential increase in *Bosmina* remains near the beginning of the deciduous forest phase in post-glacial time. He postulated this was a response to the increasing productivity of algae (the food of *Bosmina*) during the early nutrient-limiting phase in the development of the lake. A similar increase in the organic content of the sediments was interpreted as reflecting the growth of the entire lake as a sort of superorganism. Later, Livingstone (1957) concluded from a recalculation of the *Bosmina* data on an absolute basis that the increase in the *Bosmina* population with respect to time was real but that the increase in organic content of the sediments resulted at least in part from a decrease in rate of inorganic sedimentation in post-glacial time. A still later study on the phosphorus content of the sediments (Livingstone and Boykin, 1962) demonstrated that the low initial productivity may well have resulted to a large degree from the silts and clays curtailing the rate of regeneration of the phosphorus. Thus, studies on the changing populations of Cladocera in lake sediments have implications far beyond the organisms themselves, and they can lead to real advances in our understanding of the dynamics and controls of lake development.

Rotifers and copepods, in addition to Cladocera, feed heavily on algae and algal detritus, but unfortunately they do not leave sufficient remains in sediments for estimating the magnitude and composition of past populations. Hence, small quantities of remains of Cladocera in sediments conceivably might have resulted from large populations of these other competing filter feeders, rather than being direct indications of low levels of productivity. However, a study of a chain of four lakes at Madison, Wisconsin, suggests that perhaps the cladoceran populations in sediments are quite closely related to productivity (Frey, 1960), in spite of the reservation mentioned above. These four lakes exhibit certain differences in dissolved organic matter in the water, average standing crops of net phytoplankton, nanno-plankton and zooplankton, and the amount of organic matter in the sediments. These are all parameters that can be considered related to the productivity of lakes. For each of them the rank order of the four Madison lakes is the same, as it also is for the absolute quantities of cladoceran remains in their offshore surficial sediments. Thus, the overall cladoceran population of a harmonic lake with a balanced biota apparently reacts closely to changing levels of productivity, and hence the accumulated exoskeletal fragments in the sediments can be used as a rough index of past levels of productivity.

Lakes can also exhibit abrupt changes in composition and abundance of the Cladocera from one level to another in the sediments. These were so marked in Dead Man Lake, New Mexico, that Megard (1964) was able to define five successive faunal zones, each with its characteristic assemblage of Cladocera and midges. He concluded that rather than representing successive intermittent lacustrine phases, which would necessitate recolonization each time with the possible introduction of different species, they represent faunal changes in a temporally continuous lake brought about by subtle environmental changes during the Wisconsin glaciopluvial.

PROSPECTUS

Many further investigations of the Cladocera are suggested by these studies, some of which can be tackled by the remains of the animals in sediments. In the Ponto-Caspian region, for example, are many bizarre endemic Cladocera of the family Polyphemidae. Since the freshwater genus *Polyphemus* is known to leave recognizable mandibles and *Bythotrephes* caudal spines in sediments, it might be anticipated that these other species are likewise so represented. Hence, conceivably, the Caspian Sea sediments contain a record of the morphological evolution of these forms.

The genus *Bosmina* is extremely complex, particularly in the Baltic region, where almost every lake has its own differentiated population. The origin of this variability—whether it derives from introgression between a number of ancestral species that entered the region in late-glacial time, from environmental selection acting on a large reservoir of heterozygosity, or from some other cause—might well be interpretable from a study of the microfossils in the sediments, and especially now that the isolated head shields of the two major groups of species can be distinguished by means of their lateral pores.

Some of the most fascinating studies to contemplate are those concerning the very old lakes of the world, such as Lake Baikal in Siberia, Lake Biwa in Japan, and Lake Tanganyika in East Africa. Each of these lakes originated in the middle Tertiary or even earlier. There might be almost as much justification for obtaining continuous cores of the sediments of these lakes as there is for the current Mohole project in the oceans, not merely for the Cladocera but for the entire complex of information—physical, chemical, and biological—that is contained in basin sediments.

Much effort is being expended today in studying the biostratigraphy of marine sediments, especially with respect to the Foraminifera. Perhaps the predacious marine Cladocera are also represented, and if so would help in the interpretation of past conditions.

Various studies are underway to determine the extent of climatic change and the biotal response to these changes during the Pleistocene in regions unaffected directly by continental or alpine glaciers. The altitudinal zones of vegetation were appreciably depressed during the glacial ages, and there was certainly a general displacement of latitudinal zones southward (Frey, 1965*d*). Since the Cladocera are so labile in their distribution and since the community response is more rapid than that of the terrestrial vegetation, it should be possible from the changing cladoceran fauna of a lake to get some independent estimate of climatic change in such non-glaciated regions as Florida, Lake Victoria and the other East African lakes, Indonesia, etc.

Besides these there are many studies to be made on the living Cladocera, other than their straight taxonomy and distribution. For example, what is the function of the pores on the heads of the chydorids? Are the widespread eurytopic species in reality a collection of smaller geographic populations with different ecologies and physiologies? Since closely-related species of chydorids can be collected with the same dip of a net, what are the isolating mechanisms in these species? Are they largely behavioral or genetic, or have the closely related species moved into and become adapted to different microniches that are still not appreciated by man? Genetic studies in the Cladocera are confronted by the dual problem of controlling the generation cycle with sufficient precision so that males of one population or species and receptive females of another are available at the same time, and then, if cross-breeding is accomplished, of breaking the diapause, frequently very resistant that the bisexual eggs enter into.

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THE ROLE OF CRUSTACEA IN MARINE FOULING

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MARINE ship-fouling is a complex of animal and plant organisms, predominantly attached forms, in the branches of or between which other errant species may live. This assemblage derives basically from the natural community of organisms found on rocky shores. Except in the extreme case of fouling after long exposure in the sea, ship-fouling represents only a stage in the sequence of development of this shore community or alternatively selective growth of parts of that community. When developed on or in Service or commercial structures this growth becomes of economic significance. Without entering into a detailed discussion of fouling and its economic consequences, suffice it to say that a fouled hull reduces the maximum speed attainable, demands increased fuel consumption to maintain a given speed with increased attendant wear on machinery, promotes corrosion and impairs or prevents the functioning of essential services, *e.g.*, firemains or condensers.

It is virtually impossible to arrive at a realistic estimate of the cost of fouling to marine interests and few "guesses" have been made. Visscher (1928) gave $ 100 million as the annual price paid by American shipping interests alone. Allowing for the rise in costs over the years and despite the very real improvements in preventive techniques the cost can scarcely be less today.

The basic problem of fouling and its prevention is not new. Whilst the last war stimulated great activity particularly in the biological aspects of the problem, there were earlier workers in this field. Hentschel (1923) had examined ship-fouling and from 1928 to shortly before the last war Visscher was publishing the results of inspections of fouled ships and of studies on barnacle behaviour. The results of this early work and of the wartime studies are summarised in *Marine Fouling and Its Prevention* written by Woods Hole experts and published by the United States Naval Institute (1952). That work covers the whole field of fouling and its prevention. Here I can only consider the development of fouling on a more or less plane surface and, as this symposium is devoted to Crustacea, the matter of barnacle settlement and growth in particular.

Prominent among the early settlers on a ship's hull are one or more species of barnacle of the genus *Balanus*. They are of primary importance in that many of them have more tolerance of the usual antifouling poison, cuprous oxide, than say the lamellibranch molluscs or serpulid worms. They share with these latter groups the doubtful distinction of producing the greatest bulk of hard calcareous "fouling". Pedunculate species of barnacle, *Lepas* or *Conchoderma*, may settle on the paint at a much later period, or more probably attach themselves to pre-existing organisms. They and the epizoic or interstitial Crustacea such as *Jassa* or *Corophium* and young crabs, together with sponges, hydroids and so on are of only secondary importance in that they attach only after the protective antifouling paint is exhausted.

Of the 600 or so species of barnacle, comparatively few enter the fouling community. The book *Marine Fouling and Its Prevention* lists 106 species as "Foulers", but only half of these have been found on ships, the remainder being recorded from cables, buoys, wrecks, test-surfaces or other objects. For obvious reasons the real ship-fouling species come from the intertidal or immediately sublittoral habitat. *B. balanoides, B. crenatus* and *B. improvisus* in the northern hemisphere, *B. eburneus*, the *B. amphitrite* complex of species and varieties, *B. tintinnabulum, B. trigonus, B. algicola* and *B. maxillaris* in subtropical and tropical waters are typical fouling species. Of these species, the biology of *B. balanoides* is the best documented. Whilst not so frequently a source of fouling as *B. crenatus* it has distinct advantages as a research animal being easy to obtain from the shore and having only a single short annual breeding season. Among earlier workers using this species may be mentioned Moore (1934–36) and Parke and Moore (1935); postwar, Crisp and Barnes and their collaborators and Connell (1961). Time does not permit of a review of all the facets of work on *B. balanoides* and I shall confine my detailed remarks to work on the several phases of attachment, settlement and orientation, those activities most apposite to the problem of ship-fouling.

To put this story into perspective, the life-history of a typical barnacle should be recalled. The eggs are retained in the parental mantle cavity, hatching into a free-swimming stage I Nauplius larva, a stage of very short duration. This moults successively through stages II–V nauplii, the so-called Metanauplius or Nauplius VI and finally the cypris larva or cyprid which attaches, settles and metamorphoses into the adult form of barnacle. The activities of the cyprid alone concern us here.

Certain phenomena of barnacle settlement on hulls and other structures have been familiar for a long time, *e.g.*, settlement abaft rivet heads and the faying edges of ships' plates, in grooves or depression in wood, on the outer curve of the bore in pipe bends, on the darker side of raft-exposed test panels. The factors determining this behaviour are now becoming clearer. Briefly they are responses of the cyprid to surface texture, directional stimuli and to the presence of others of its own kind.

Cyprids of *B. balanoides* are at first photopositive, swimming towards the light and, therefore, the sea surface. A little later, presumably in response to an as yet unidentified stimulus, they become photonegative and seek deeper layers in search of a suitable substrate (Knight-Jones and Crisp, 1953; Barnes, 1955). On finding a solid surface the cyprids become indifferent to light and proceed to crawl over the surface. They may detach and swim off again a number of times in this phase, before finding a surface that is texturally suitable for settlement. When such a surface is found the exploratory activity becomes more detailed, a small area being minutely explored. Finally if a settled member of the same or a closely allied species is met with, permanent attachment and settlement is induced. It has been shown that only a nearly allied species can evoke the settlement behaviour. Substrates treated with extracts of the same or closely allied species or with remains of those species on them, are colonised, but treatment of the substrate with extracts of unrelated barnacles, other animals or seaweeds evokes no settlement response (Knight-Jones, 1955). This behaviour pattern has been suggested as a possible means of elucidating the relationship of species in difficult genera. Knight-Jones himself proposed using it to investigate affinities within the serpulid genus *Spirorbis*.

The nature of this attractive substance or "settling factor" has been investigated by Crisp and Meadows (1962, 1963). Their conclusions may be summarised as follows:

(1) the stimulating substance was probably arthropodin, the water-soluble protein fraction of arthropod cuticle;

(2) it was active only when adsorbed on a solid substrate. Cyprids gave no response to solutions of arthropodin;

(3) the settling reaction was much stronger if the substrate was favourable as regards surface texture, *i.e.*, with irregularities, grooves, pits, etc, They cite some most striking figures (1963) in support of this;

No. of cyprids	Treated panel		Untreated panel	
	with pits	no pits	with pits	no pits
(*a*) Exploring after ½ hr.	43	21	12	2
(*b*) Exploring after 4 hrs.	54	3	10	1
(*c*) Settled after 24 hrs.	54	3	0	0

(4) As the substance is only active when adsorbed on a substrate the response must be to a particular molecular configuration presented only when the molecule is bound to the substrate;

(5) this configuration must be the same as that present in the barnacle epicuticle to which cyprids respond in the field.

There is thus a series of stimuli which have to be presented in a particular order if settlement is to be achieved, namely (*a*) a stimulus, as yet uncertain, bringing about the reversal of the reaction to light; (*b*) a stimulus to attach (by the antennal suckers only) and to explore, evoked by contact with a solid substrate; (*c*) a stimulus for detailed examination of a small area of substrate evoked by surface irregularities or the presence of the "settling factor"; (*d*) a climactic stimulus to settle, *i.e.*, to secrete cement, evoked by the presence of both a surface concavity and the settling factor. It is worth noting that the several intermediate steps appear to be reversible if the next in the series is not presented quickly enough. The necessity for the complete series of stimuli to be presented is clearly not absolute or no new colonisation could ever occur. It has been suggested that in the absence of a suitable substrate and as the cyprid aged, there was a loss of discriminatory ability resulting in settlement on any available surface regardless of suitability. This supposition could account for the occasional large-scale settlement of cyprids on highly toxic paint films, a phenomenon experienced at some time by all who have conducted panel trials of paints. Such loss of discriminating ability has been shown to occur in larvae of *Spirorbis borealis* (Knight-Jones, 1953). There are few well-substantiated instances of such a loss of selectivity in older larvae but delayed metamorphosis of planktonic larvae of benthic animals is well known (Thorson, 1946; Wilson, 1952). It is a matter requiring further investigation to survey the general occurrence of this phenomenon. Crisp and Meadows (1963) were unable to find any evidence of loss of ability to detect the presence or absence of the settling factor in older cyprids of *B. balanoides*. As colonisation of toxic panels occurs—or at least is most noticeable—when large numbers of cyprids are about to settle, it might be suggested that settlement is stimulated through contact with the settling factor on other cyprids whilst the whole mass of cyprids is jostling for position on the substrate. As yet this possibility does not appear to have been put to the proof.

Cyprids of many species tend to settle in grooves or depressions in a surface, a reaction termed by Crisp and Barnes (1954) *rugophilic*. If the depression is in the form of a groove then the cyprid may orientate its long axis along the groove (*rugotropism*). The term 'groove' as used here covers a wide variety of possible microhabitats from actual furrows such as cracks in rock, the grain of wood, or flutes in mollusc shells to brush marks or scratches on a paint film and even the angle between a bristle from the brush and the paint film to which it adheres. It is noteworthy that the rugophilic reaction is extremely sensitive and is evoked by irregularities of surface much shallower and narrower than are necessary to give initial protection to the settling cyprid.

In contrast to the effect of 'grooves', sharply convex surfaces, *e.g.*, angles and ridges, tend to cause cyprids to detach and swim off. Connell (1961) has demonstrated the survival value of the rugophilic reaction in *B. balanoides*. Counts were made of settlements on adjacent concave and

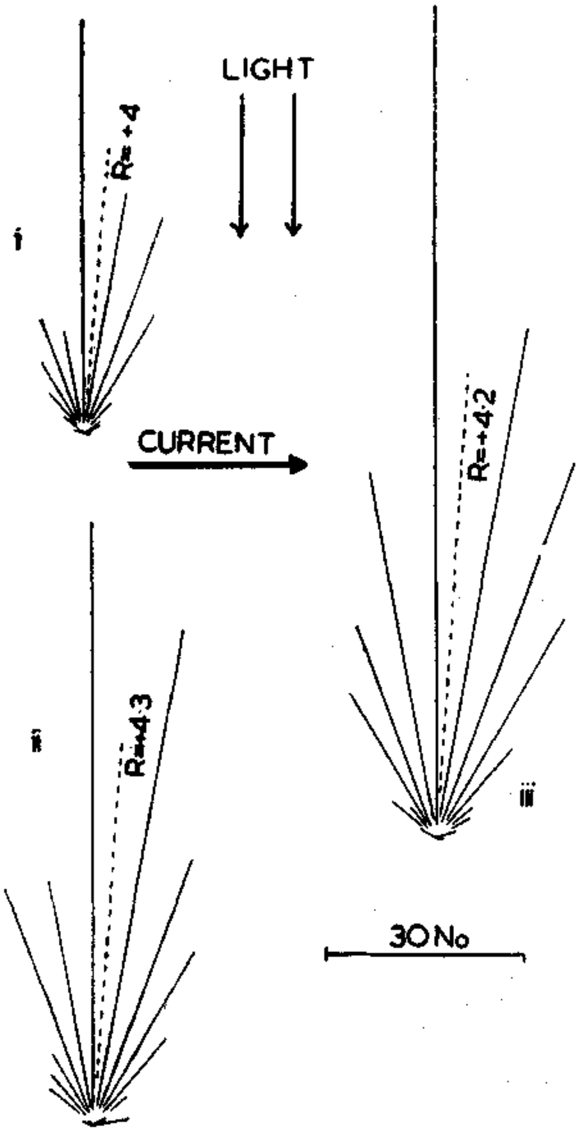

FIG. 1. Orientation of *Elminius modestus* Darwin at 10° intervals about the vertical on a vertical board at (i) 2 ft., (0·61 m.), (ii) 2′ 9″ (0·84 m.) and (iii) 5′ 3″ (1·60 m.) below surface. The resultant angle of distribution (R) is shown by the broken line.

convex surfaces of equal area as settlement progressed. As would be expected settlement on the convex area commenced later, not starting until the depressed areas were fully occupied. The numbers settled on each area became approximately equal as the space became filled up. When a gale sprang up, the colony in the depression was practically untouched but that on the convex surface suffered heavy mortality. Further investigation of the settlements by age groups confirmed that this was an effect of situation and not of the age of the individuals. Connell (1961) quotes figures as follows:

Age-wks. from settlement	% mortality	
	in concavity	on convexity
2	0	62
3	7	60
4	8	92

The survival value of attachment in depressions for the early metamorphosed barnacle is obvious.

Brief examination of a settlement of barnacles will show that the majority are aligned in roughly the same direction. On a vertical surface, lit from above, they may be expected to lie with the carino-rostral axis more or less vertical and the carina uppermost. Figure 1 shows the frequency of orientation of a settlement of *Elminius modestus* Darwin at 10° intervals about the vertical at three different levels on a vertical board. The resultant angle of the orientations of all barnacles measured was only 4° off the vertical, actually on the down-current side of the vertical. This is the characteristic position resulting from the cyprid attaching with the anterior end towards the

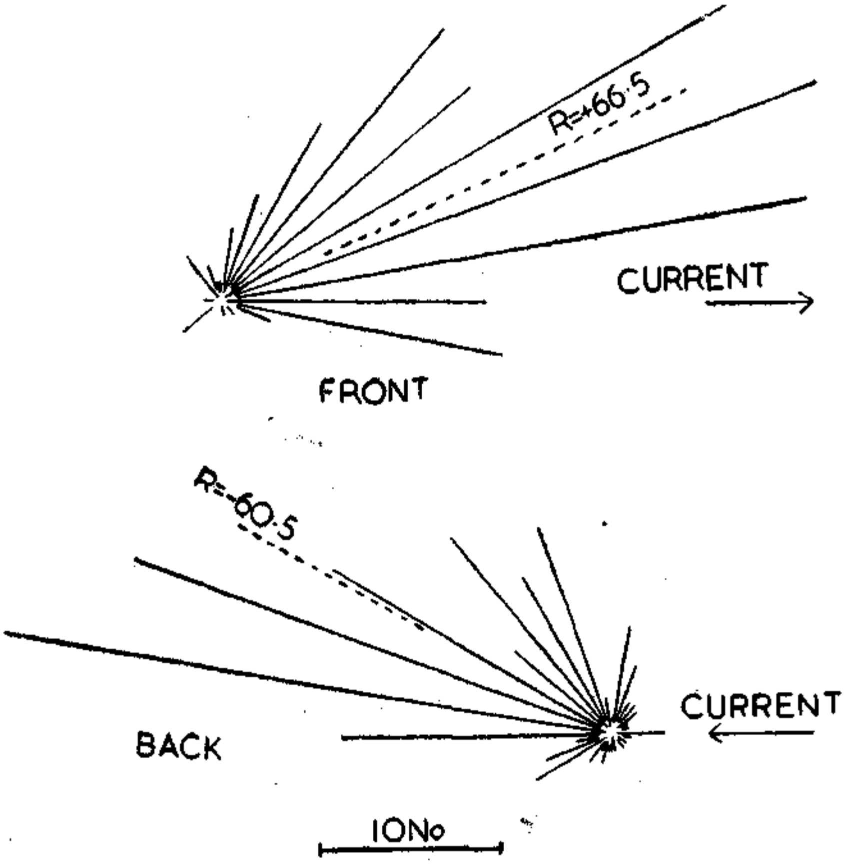

FIG. 2. The orientation of *Balanus amphitrite* Darwin at 10° intervals about the vertical on the two sides of a panel placed in a constant stream of water and shaded from light from above.
The resultant angle of distribution (R) is shown by the broken line.

light. In consequence a newly metamorphosed barnacle will cast the cirral net away from the direction of illumination, except in so far as it is able to twist the body within the shell, and vary the direction of cast (Barnes, Crisp and Powell, 1951).

Only under exceptional circumstances will the orientation be affected by a single factor. Under shore conditions water movements also play a part. Work by Crisp (1953, 1955) and Crisp and Stubbings (1957) showed that the cyprid has only a very weak orientating response to current direction which is only demonstrable in the dark, *e.g.*, on settlements in sea-water culverts. It is completely obscured by the strong orientating influence of light. Growing and adult barnacles, on the other hand, show strong orientation to a water current, especially if this is constant in direction as in pipes and conduits. The experiment was tried of placing a vertical panel in a continuous effluent stream of sea-water with a metal hood shading the panel from incident light. The orientation of adult barnacles (in this instance, *Balanus amphitrite* Darwin) obtained is shown in Fig. 2. The orientation was more than 60° off the vertical in a direction such that the barnacles fished into the current, *i.e.*, with the rostral end of the long axis upstream.

There is practically no change of orientation at metamorphosis and reorientation to take advantage of current direction occurs during growth. It is greatest during the early growth of the metamorphosed barnacle but may continue at a diminished rate during the life of the individual. This change of orientation during growth may be seen in the curvature of the radial pores in the basis of species with a calcareous basis. In situations offering appropriate conditions such as conduits and the outer bottoms of boats swinging in a tidal stream barnacles can effect a close orientation to current, but in general the position taken up has to be a compromise between orientation to light and to current. As already stated the current stimulus is relatively weak compared to the light stimulus and in the field its effect is largely nullified.

From the point of view of ship-fouling the cyprid is the most interesting phase in the life of a barnacle. A fairly detailed description has been given above of the events taking place during this phase. Two gaps in our knowledge are obvious. Firstly, what causes the initial reversal of photo-sensitivity from positive to negative? Secondly, is there in any species of barnacle a loss of discriminatory sensitivity on the part of the aging cyprid if settlement is delayed? The second point needs to be clarified for several species if a general assumption is to be made. It has clear implications for the worker on fouling.

A subject of even greater importance for anti-fouling has not been discussed, mainly because of our lack of information. This is the nature of the adhesive cement secreted at fixation and during growth. It has been little studied in barnacles but is believed to be of a similar nature to the cuticle of insects. The evidence linking the two is rather sparse and barnacle cement *per se* should be examined in much greater detail. To look a long way ahead, if a chemical means of preventing the setting (hardening) of this cement were discovered and if the appropriate material could be incorporated effectively in a ship-bottom paint, then a major part of the problem of fouled ships would be solved. There is a long way to go!

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PHYSIOLOGY OF THE CRAYFISH ANTENNAL GLAND

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THE mode of operation of nephridial organs in most forms is completely unknown, and in no group of invertebrates does there exist the wealth of detail that characterizes our picture of vertebrate renal physiology. The magnificent experiments of J. A. Ramsey (1955, 1956) have provided insight into events in the insect malpighian tubule; his experiments may be even more important in showing what can be done when modern techniques of micro-sampling and ultramicroanalysis are applied to such problems. An equally exciting picture is developing in the laboratory of Professor A. W. Martin who is studying excretion in cephalopod molluscs. I propose here to describe research which has shed a little light on the mechanism of urine formation in the crayfish.*

FILTRATION-REABSORPTION OR SECRETION

Although crayfish urine has not been completely characterized, we know something about its composition. Sodium, potassium and chloride concentrations are low, as is the total osmotic pressure. The fluid is normally devoid of glucose even when it is circulating in the blood in appreciable concentrations. Even such scanty data indicates that urine composition differs markedly from that of the blood from which it was derived. This immediately raises the question of whether the antennal gland operates on a filtration-reabsorption basis, or as a secretory organ. That is, whether an ultrafiltrate of blood is expressed into the tubular lumena after which the fluid is processed by reabsorbing many of the constituents back into the blood; or alternatively, whether urine is formed by transporting each constituent, including water, across the peritubular cells into the lumenal fluid. Maluf (1939, 1941) concluded that the excretion of dyes as well as inulin and xylose showed that the antennal gland was a secretory organ. Such a point of view is also commensurate with the lack of a morphologically distinct filtration site analogous to the vertebrate glomerulus. However, Martin (1958) pointed out that many of Maluf's observations could also be explained on a filtration-reabsorption basis, and that the secretion of dyes also occurs in the vertebrate kidney which is basically a filtration-type organ. Thus, as recently as 1958 extant data did not permit us to resolve even so fundamental a problem.

More recent studies appear to show that urine formation occurs by a process analogous with filtration-reabsorption in the vertebrate. Thus, a series of polymers, all foreign to the animals, are excreted after injection into the blood. Text-Figure 1 shows the blood and urine concentrations of inulin, a polyfructosan with a molecular weight of about 5,000, after such an injection. It is apparent that the urine to blood (U/B) ratio is greater than 1 throughout the period of measurement. In addition, the U/B ratio was shown by Riegel and Kirschner (1960) to be independent of its blood concentration even when the latter varied over three orders of magnitude. Two dextrans, one in the molecular weight range 15–20,000, the other in the range 60–90,000, are also excreted as shown in Text-Figs. 2 and 3. Text-Figure 4 shows that human serum albumin, with a molecular weight of 68,000, is also excreted in the urine. Formation of urine by a secretory process would require a transport mechanism for each of these compounds. Since they are foreign to the

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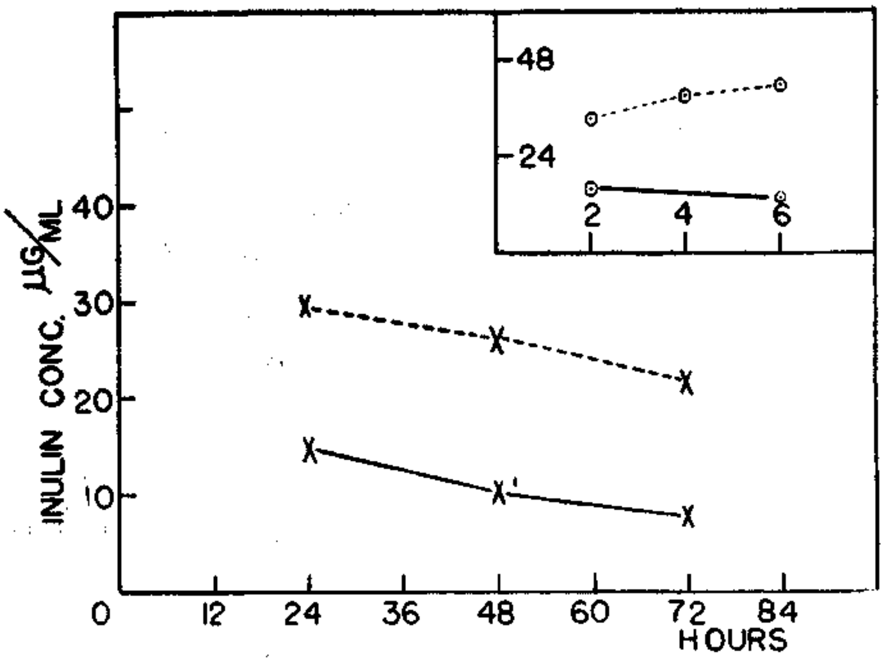
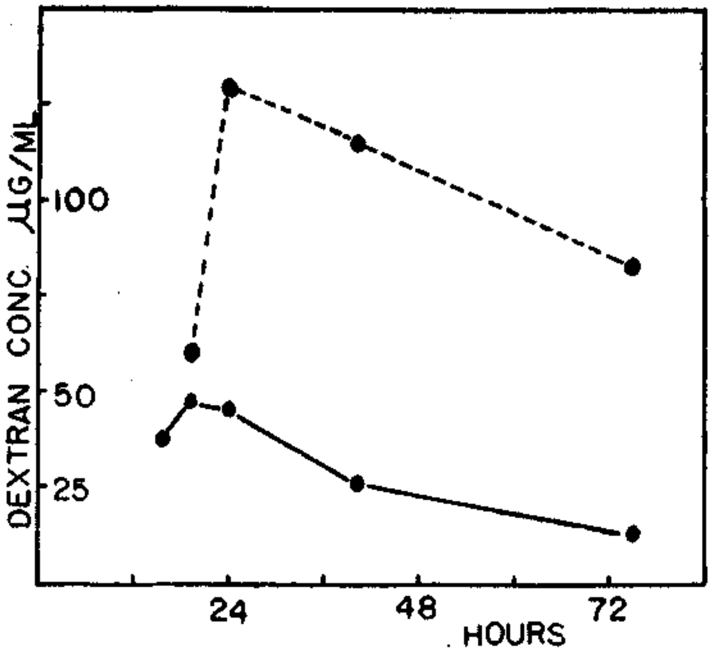
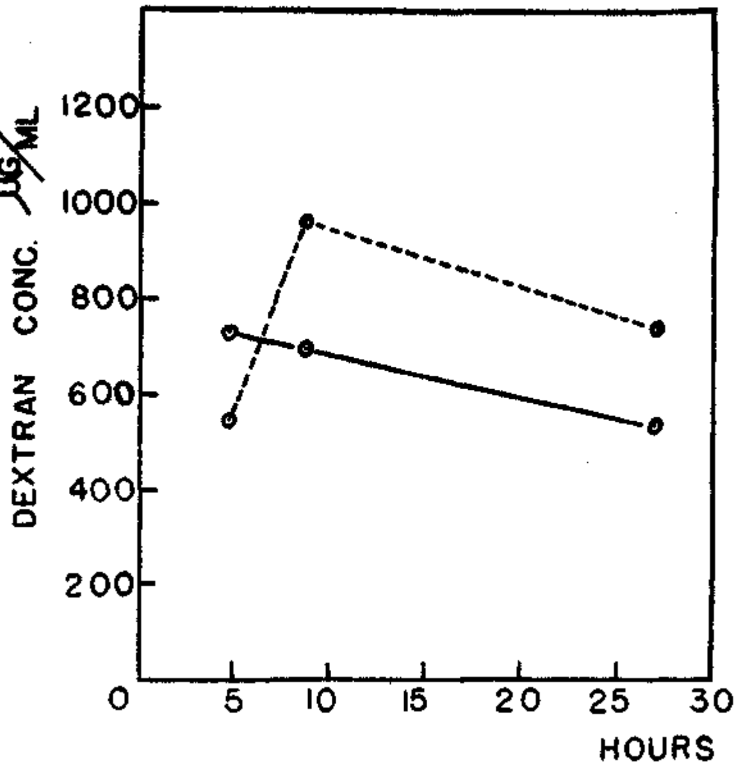
*Most of the work on filtration is described by Kirschner and Wagner (1965) unless another source is cited.



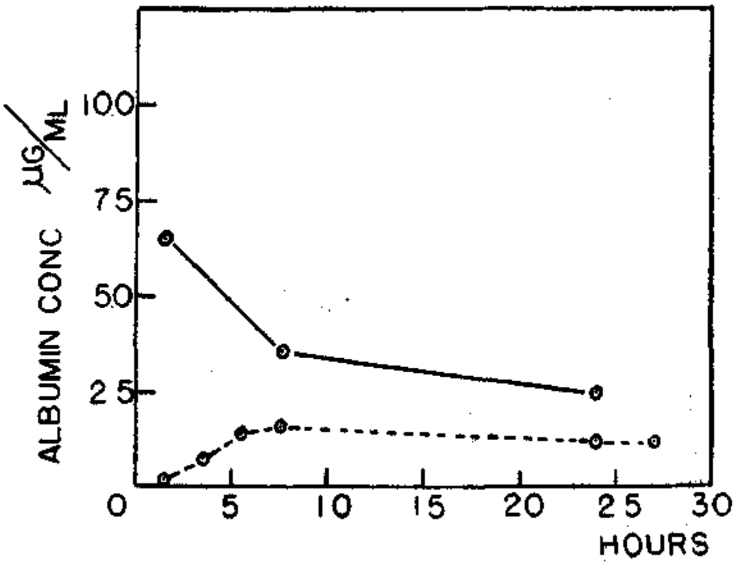
TEXT-FIG. 1. Concentration of inulin in blood (——x——) and urine (- - - -x- - - -) following injection into the ventral hemocoel at 0 hours. The inset shows the time course during the first six hours. The U/B varied between 2·1–2·5 during the period 24–72 hours.



TEXT-FIG. 2. Concentration of low molecular weight dextran in blood (——●——) and urine (- - - -●- - - -) following injection of 0·52 mg. into the ventral hemocoel. The U/B varied between 2·8–6·0 during the period 24–72 hours.



TEXT-FIG. 3. Concentration of high molecular weight dextran in blood (——●——) and urine (- - - ●- - - -) following injection of 3·0 mg. into the ventral hemocoel. The U/B varied between 0·7–1·7 during this experiment. The first urine sample was taken early and the low concentration may have been the result of dilution by bladder urine formed before the dextran was injected.



TEXT-FIG. 4. Concentration of albumin in blood (——⊙——) and urine (- - - -⊙- - - -) following injection of 0·024 mg. into the ventral hemocoel. The U/B was 0·52 at 24 hours. It was 0·61 after 98 hours when the blood concentration had fallen to 1·84 μg./ml.

animal and chemically unrelated to each other the existence of such mechanisms must be considered unlikely. On the other hand, in a filtration type organ transport mechanisms are responsible for reabsorbing compounds from the primary filtrate and their absence would ensure excretion of compounds small enough to be filtered.

Studies on glucose excretion by the antennal gland provide independent evidence for filtration. The absence of glucose from normal urine might be the result of total reabsorption after filtration; but it might equally be due to the absence of a secretory transport system. However, it was shown by Riegel and Kirschner (1960) that when the blood concentration is elevated glycosuria occurs. A summary of their data is shown in Table I, and it appears that the renal threshold is about 200 mg./100 ml. Table II shows that phloridzin, a compound known to block glucose reabsorption in the vertebrate kidney, results in prolonged excretion by the crayfish even at normal blood levels. The absence of glucose from normal urine cannot be rationalized with glycosuria at elevated blood concentrations or in the presence of phloridzin if the antennal gland operates as a secretory organ. But they are completely consistent with a filtration-reabsorption type of operation.

TABLE I

Blood and urine glucose

(Mg. per 100 ml.)

Animals	Zero		1 hour		4 hours		7 hours	
	B	*U*	*B*	*U*	*B*	*U*	*B*	*U*
1	5	0	93	0	80	0	62	..
2	..	0	192	0	56	7	18	0
3	0	0	210	0	50	0	..	..
4	10	0	560	0	220	30	..	..

Glucose excretion in crayfish urine. Each animal was injected with glucose after removing zero samples. Blood and urine samples were taken at the times noted. Transient glycosuria in animals 2 and 4 in the samples taken 4 hours later. Dashes indicate that no sample was obtained.

TABLE II

Effect of phloridzin on glucose excretion

(Mg. per 100 ml.)

Animals	Mg./Kg.	Zero		4 hours		10 hours		23–26 hours	
		B	*U*	*B*	*U*	*B*	*U*	*B*	*U*
1	12	42	..	31	16	39	5	40	3
2	32	22	0	36	43	17	48	27	18
3	77	23	0	47	106	28	59	25	27
4	102	27	0	36	65	33	14	38	6

Glycosuria after injection of phloridzin (dosages are shown in column 2).

Micropuncture studies on the composition of fluid in the antennal gland lumen are also consistent with filtrate formation. These will be discussed later in a slightly different context.

Permeability of the Filtration Site

If a filtrate is formed some mechanism must ensure that blood protein is not lost. In the vertebrate nephron glomerular permeability is normally low enough to prevent protein passage. To assess filtration permeability in the antennal gland we injected a series of different sized polymers and measured their excretion. As indicated earlier, dextrans in the molecular weight range 15–20,000 are excreted with U/B ratios essentially the same as those for inulin. On the other hand, larger dextrans, with a molecular weight range 60–90,000 appear to have lower urine concentrations at a given blood level. This suggests that large polymers may be restrained at the "filter". To test this surmise two animals were injected simultaneously with tritium-labelled inulin and C^{14}-labelled dextran of low molecular weight. Another pair of animals were injected with labelled inulin and the high molecular weight dextran. Table III shows that the ratio of low molecular weight dextran to inulin was essentially the same in urine as in blood which would be expected if the two were handled identically. On the other hand, the urinary ratio of dextran to inulin for animals injected with the larger carbohydrate polymer is significantly less than in blood and indicates that excretion of this dextran occurs only about 70% as rapidly as inulin.

Table III

Blood and urine concentration of dextran and inulin

Dextran	Number Animals	Number Sample Periods	Dextran: Inulin ratios		U/B±s.d.
			Blood	Urine	
HMWD ..	4	16	1·37	0·93	0·69±0·19
LMWD ..	3	7	2·22	2·04	0·92±0·24

See text for description of the experimental protocol. The U/B ratio (column 6) is a ratio of dextran: inulin values; *i.e.*, column 5: column 4.

Human serum albumin, labelled with I^{125}, was also excreted, but its concentration in the urine was never as high as in blood. This also shows that compounds in the molecular weight range 60–90,000 are not freely filtered. It also suggests that restraint on filtration of proteins is more rigorous than for carbohydrate polymers since the urine concentration of the high molecular weight dextran always exceeded that in the blood although this compound is approximately as large as albumin. Mammalian serum globulin (MW 180,000), labelled with a fluorescent dye was injected into a group of crayfish. No fluorescence could be measured in the urine, indicating that a protein of this size cannot be excreted. Evan's Blue was also injected into a group of animals but was not excreted. This compound is known to bind to blood protein in vertebrates, and the same thing happens in crayfish (unpublished observations).

These experiments indicate that compounds in the molecular weight range 15–20,000 are freely filtered in the antennal gland but that species with molecular weights much above 50,000 are restrained. Smaller proteins, including human serum albumin, can be excreted but proteins as large as mammalian serum globulin do not appear in the urine. Since most of the blood protein in crayfish is hemocyanin (MW 875,000) the antennal gland is obviously structured to prevent loss of blood protein.

Location of the Filtration Site

The coelomosac has been suggested as a possible filtration locus, but without much evidence beyond the fact that it is the most proximal region of the organ. Its gross morphological appearance certainly does not resemble that of a filter, although Kümmel (1964) has observed, with the electron microscope, membranes in the coelomosac which look like filtration sites. Indeed the absence of *any* obvious morphological specialization was one of the original arguments advanced against the operation of the antennal gland as a filtration organ (*cf.* Prosser, 1961). Nevertheless, several observations support the idea that the filter is located in the coelomosac. One of the most important is that analyses of fluid taken from this region show that it approximates an ultrafiltrate of blood. Peters (1935) showed that chloride concentration in the coelomosac is nearly the same as in blood. Riegel (1963) confirmed this, and observed that the osmolality is also the same. More recently Riegel (unpublished observations) measured sodium and inulin concentrations and found them nearly identical in the two fluids. He noted that potassium was more concentrated in coelomosac fluid, but this was the only discrepancy. We have found that when glucose and inulin are introduced into the hemocoel, extracts of coelomosac contain essentially the same relative concentrations of the two as blood. Since inulin concentration is unaltered in coelomosac fluid the same must be true for glucose.

A different approach provided independent evidence for filtration in the coelomosac. During our studies on protein excretion we were surprised to find that Evan's Blue becomes very concentrated in the coelomosac following injection into the hemocoel. Since the dye is bound to circulating protein we suspected that protein might be concentrated in this region. This was tested by injecting labelled proteins and measuring their appearance in different parts of the gland. Inulin, injected simultaneously, served as a reference compound. The following experiment illustrates the procedure. Several animals were injected with I^{125} labelled human serum albumin and C^{14} inulin. After several hours the animals were sacrificed; a blood sample and portions of coelomosac, labyrinth and tubular region were analyzed for the labelled compounds. The data are shown in Table IV where the ratio of albumin to inulin in blood is arbitrarily assigned the value 1·0. It can be seen that the injected protein becomes much more concentrated in the coelomosac than does inulin while it is less concentrated in the other regions of the organ. The latter observation is expected on the basis of data presented earlier that inulin is filtered much more freely than albumin. The high protein concentration in the coelomosac might be explained by filtration in this region which would remove both water and inulin leaving the protein concentration high. Indeed, the data are difficult to rationalize on any other basis.

Table IV

Albumin-inulin ratios in blood and antennal gland

Animals	Time (hours)	Gland	Albumin: Inulin ratios			
			Blood	Coelomosac	Labyrinth	Tubule
1	2·5	Right	1·00	47·3	0·45	0·58
		Left		23·0	0·53	0·57
2	6·0	Right	1·00	17·7	0·60	1·61
		Left		12·3	0·57	1·29

See text for experimental protocol. Values for the ratios have been normalized to a blood value of 1·00 in order to facilitate comparison of the two animals.

If filtration really occurs in the coelomosac then use of an appropriately marked protein might permit us to delimit more precisely its locus. Fluorescent dye-labelled mammalian serum globulin was injected into several animals, permitted to circulate for several hours, following which the animals were sacrificed and the glands sectioned and mounted for histological observation. The fluorescent protein was localized with an ultra-violet microscope. *Plate I, Fig.* 1 shows a cross-section of an antennal gland through the labyrinth and tubular region and it can be seen that only punctile spots of fluorescence appear. These may be blood vessels or sinusoids. Plate I, Fig. 2 shows a section through the coelomosac and it can be seen that the fluorescent protein is highly concentrated here. Note that the fluorescence is more or less confined to the peritubular regions, which is compatible with the formation of an ultrafiltrate at this site. It can be seen that the fluorescence is intracellular, an observation that was totally unexpected. If the vertebrate nephron serves as a model, we should expect that filtration would occur directly out of blood vessels leaving the protein concentrated in the capillary. Its appearance within the peritubular cells here suggests that the mechanism may differ considerably from that in the vertebrate.

These studies, together with the data obtained from analysis of tubular urine, point to the coelomosac as the site of filtration in the antennal gland. However, they indicate that more work will be necessary before we understand the mechanism of filtrate formation.

SITE OF GLUCOSE REABSORPTION

The ability of the antennal gland to excrete glucose when the blood level is high or after phloridzin is injected shows that this compound can enter the presumptive urine. Indeed, free filtration of compounds as large as inulin suggests that it must appear in an ultrafiltrate even at normal blood levels. Yet examination of hundreds of urine samples indicates that normal urine is glucose-free. It must be completely reabsorbed from the tubular lumen and translocated back into the blood. One is then faced with questions regarding the site and mechanism of reabsorption. Preliminary evidence makes it appear likely that glucose reabsorption occurs in the labyrinth. The evidence for this will not be presented in detail since it is still unpublished, but a brief description of the results will indicate both our approach and the nature of the evidence. First, glucose and inulin are injected simultaneously and their concentrations examined in deproteinized extracts of blood, coelomosac, labyrinth, and tubules. Analysis shows that the glucose/inulin ratio is the same in coelomosac extracts as in the blood, but that it rises very sharply in the labyrinth, and is reduced once more in the tubule. Since we know that inulin is freely filtered into the coelomosac lumen (*cf.* above), identity in glucose/inulin ratio in coelomosac and blood is expected if glucose is freely filtered in the coelomosac. Assuming that inulin is inert (neither reabsorbed nor secreted) in the antennal gland a larger ratio in the labyrinth suggests that the quantity of glucose has increased in this region. This may mean that it is reabsorbed here, becoming concentrated in the cells because its movement from lumen to cell occurs more rapidly than from cell to blood. A decrease in glucose/inulin ratio in the tubule would then be expected since the lumen in this region would contain inulin and only such sugar as had passed by the reabsorption mechanism.

It was pointed out by Bourne (1943) that epithelia that translocate glucose in the vertebrate invariably show high alkaline phosphatase activity located at cell borders. This is true, for example, of the proximal tubule of the vertebrate nephron and in the small intestine and rectum. In every case the enzyme is located on the lumenal membrane. When the antennal gland was examined histochemically alkaline phosphatase was found in high concentration only in the labyrinth. As shown in Pl. I, Fig. 3, the enzyme concentration is especially high on the lumenal border.

These experiments indicate that filtration of glucose in the coelomosac may be followed by its reabsorption somewhere in the labyrinth. Dr. Riegel has now undertaken micropuncture studies of the lumenal fluid to see whether glucose, in fact, disappears from the fluid in the labyrinth as would be predicted from our observations.

SITE OF DILUTION OF URINE

Since all freshwater animals are hypertonic to their environment they must cope with an osmotic influx of water. They preserve an osmotic steady state by excreting a dilute urine, and if the primary filtrate is isosmotic, solute must be reabsorbed or water secreted somewhere in the nephridial organ. Schmidt-Nielsen (1961) recently surveyed a diffuse literature showing among other things that where marine and freshwater representatives of several taxa can be compared the nephridial organs of the latter have a segment of tubule intercalated between the proximal regions and the urinary bladder or nephropore. Decapod Crustacea are no exception. Crayfish have a long tubular segment between the labyrinth and bladder; lobsters do not. Since only freshwater animals must dilute the urine, this morphological specialization points to the tubular segment as the dilution site. By taking samples of lumenal fluid throughout the antennal gland Peters (1935) showed that chloride concentration did, in fact, become hypotonic in the tubule. Riegel has recently confirmed this and also showed (1963) that osmotic pressure dropped as chloride concentration decreased. Their data are shown in Table V. Note that bladder urine is even more dilute than samples from the tubule. This will be discussed later.

TABLE V

Chloride and sodium concentrations in tubular lumena

(Values in mM)

Variable	Blood	Coelomosac	Labyrinth	Distal tubule		Bladder
				Proximal	Distal	
Chloride (R)	184±24	168±20	162±21	132±24	81±15	3·4±1·8
Chloride (P)	196± 3	198± 2	209± 7	..	90± 6	10±0·6
Osmotic pressure	200±10	208±22	181±11	169± 7	121±14	19±1·5

Chloride concentrations and osmolality of tubular fluid taken from different regions of the antennal gland. Osmolality is expressed as mM/l NaCl. The chloride data designated R and osmolality are from Riegel, 1963. Chloride concentrations designated P are from Peters, 1935.

Dilution of the isosmotic filtrate requires either that solute be reabsorbed through an epithelium less permeable to water or that water be transported into the tubule by some kind of water "pump". Now if water pumps are not quite an anathema to general physiologists, neither are they very respectable, and one of the main points of Schmidt-Nielsen's review is that both concentrated and dilute urine may be produced without need for invoking water pumps in kidneys. Her argument, although indirect, is convincing. It has been strengthened by some unpublished work in Dr. Riegel's laboratory showing that inulin becomes concentrated in the tubular segment (remember that the final urine concentration is about twice that in blood). The simplest explanation encompassing these observations is that water as well as chloride is reabsorbed from the tubule. Faster chloride reabsorption would dilute the fluid, but removal of some water would cause the inulin concentration to rise. This is analogous to events in the distal tubule of freshwater vertebrates and entirely compatible with observations of linked salt and water fluxes across a variety of epithelia.

A ROLE FOR THE URINARY BLADDER

One other structure has been investigated recently, this one not properly a part of the antennal gland at all. Several observations suggest that the urinary bladder in crayfish, like that in amphibia, may be important in diluting the urine by reabsorbing sodium chloride. Thus, Table V shows that chloride concentration in the distal tubular region is much higher than it is in the final bladder urine. This could be explained if chloride is reabsorbed from the bladder itself. Two observations make this appear likely. Kamemoto *et al.* (1962) showed that the concentration of cholinesterase in the urinary bladder in crayfish was much higher than in any part of the antennal gland (Table VI). This enzyme has been implicated in sodium transport across the frog skin (Kirschner, 1953) and *Eriocheir* gills (Koch, 1954). In addition, introduction of Na^{22} into the urinary bladder was followed by its appearance in the animal's blood and the rate of absorption from the bladder was diminished by eserine. Clearly the bladder wall is permeable to sodium, and its permeability is somehow depressed by eserine. Kamemoto (1961) has also shown that the same cholinesterase inhibitor (eserine) causes a large increase in urine sodium concentration suggesting that its reabsorption has been inhibited. This group of observations points to the existence of a sodium transport mechanism in the bladder cells, and its action would explain why normal bladder urine was more dilute than tubular urine taken from the most distal regions of the kidney.

TABLE VI

Cholinesterase activities in kidney of Procambarus clarkii

(pH 9·0, 0·015 M AChBr, 25° C.)

	μ M AChBr hydrolyzed/mg. N/min.
Kidney— 12 pairs	0·27
Kidney— Eserine inhibition (4 pairs)	0·11
Kidney— Series 1 (12 pairs):	
Coelomosac	0·23
Labyrinth	0·14
Tubule	0·64
Bladder	1·10
Kidney— Series 11 (8 pairs):	
Coelomosac	0·44
Labyrinth	0·09
Tubule	0·65
Bladder	2·15

Cholinesterase concentrations in antennal gland and bladder. Enzyme activity is expressed in terms of rate of hydrolysis.

SUMMARY

The crayfish antennal gland appears to form an ultrafiltrate from which a final urine is manufactured primarily by a differential reabsorption of solutes and water by the peritubular cells. Filtration apparently occurs in the coelomosac, but by a process different from that occurring in the vertebrate glomerulus. The filtration locus is freely permeable to molecules at least as large as carbohydrate polymers with molecular weights of 20,000. Larger polymers, including injected protein, can be excreted if their molecular weights are below 100,000, but their filtration appears to be restricted. Very high molecular weight compounds, including the animal's own blood protein, are not excreted, probably because they are too large to appear in the primary ultrafiltrate.

As the fluid passes progressively through more distal regions of the gland, glucose appears to be reabsorbed in the labyrinth. Little change occurs here in NaCl concentration or in osmotic pressure. Chloride and water are absorbed from the tubular segment of the gland, but the former more rapidly so that the tubular fluid becomes progressively more dilute. Final dilution of the urine may occur in the bladder through further NaCl reabsorption.

Although certain aspects of antennal gland physiology have been clarified much more remains to be done. We have barely begun to describe the variety of processes that occur, let alone search for their sites and mechanisms. To take only two examples: we have no idea about the fate of most of the small, blood-borne solutes that must appear in an ultrafiltrate; nor do we know whether this organ has a role in regulating blood pH similar to the one played by its vertebrate counterpart. Comparative studies on marine decapods are badly needed and these might well be extended to freshwater and marine representatives in other groups of invertebrates. The tools for attacking these problems have been refined by vertebrate renal physiologists. We need only be sufficiently interested to learn to use them incisively on invertebrate problems.

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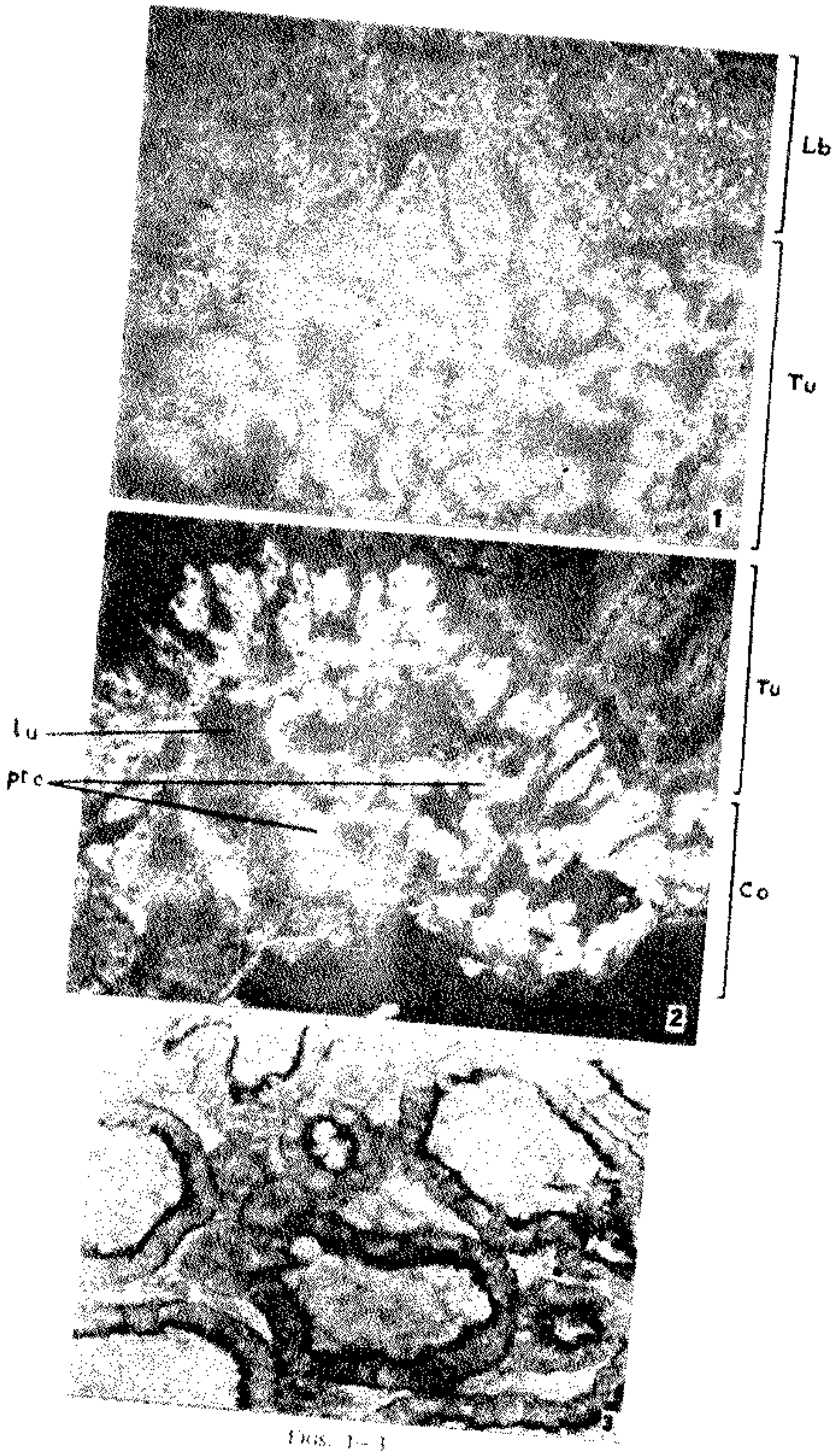

FIGS. 1–3

EXPLANATION TO PLATE I

FIGS. 1–3. Fig. 1. Section through the labyrinth and tubule of an antennal gland removed four hours after injection of fluorescein-labelled globulin. The labyrinth comprises the *outer border (upper edge) of the section;* the tubular tissue is more loosely arranged around larger lumina. The section is illuminated with ultra-violet light. Magnification 80×. The symbols delimit regions of the organ. *Lb,* labyrinth; *Tu,* tubule. Fig. 2. Section through the coelomosac of the same organ shown in Fig. 1. The coelomosac- tubule border can be seen in the upper edge of the photomicrograph. Illumination and magnification as in Fig. 1. *Tu,* tubule; *Co,* coelomosac; *ptc,* peritubular cells of coelomosac; *lu,* lumen of coelomosac. Fig. 3. Cross-section through the labyrinth of an antennal gland treated to show sites of alkaline phosphatase activity. The black deposits, confined to the lumenal border of the peritubular cells, show that the enzyme is located here. Sections through the coelomosac and tubule show no detectable activity.

COMPARATIVE ASPECTS OF SOCIAL BEHAVIOUR IN FIDDLER CRABS OF THE WORLD (OCYPODIDAE, GENUS *UCA*)*

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THE film was composed of sequences on the following topics, all illustrating aspects of social behaviour in *Uca*: (1) The wide range of species-specific visual displays in fifteen selected species of fiddler crabs, photographed in the field in South-East Asia, the South Pacific, Australia, Africa and Tropical America; (2) characteristics of general and specialized types of social behaviour; (3) persistence of the characteristics of visual display in populations which are geographically widely separated; (4) examples, in contrast to the latter sequence, of subspecific differences in display; (5) aspects of agonistic behaviour in relation to display.

A simple method of keeping marked fiddler crabs in captivity was described, under conditions which elicit approximately normal social behaviour. Out-of-door tanks, measuring not less than six by ten feet in dimensions, are provided at one end with a bank of mud and one or more young mangrove plants, from a local swamp; sea-water, of any desired salinity, is pumped to and from an adjacent storage tank. If the population is not overcrowded and if a fresh layer of mud is occasionally added, no additional feeding is needed. Individuals from a number of localities in Asia and the Americas have been kept this way successfully for a maximum of two years.

The film was supplemented by tape recordings of certain acoustic signals used variously in territorial, threat and courtship behaviour, in species from Trinidad. Some are made through rappings of the lower outer part of the major manus against the ground; others through vibration of water or air against membranes at the base of the chelipeds; others through stridulation of tubercles and ridges on various parts of the body.

Territorial behaviour, intermale threat, fighting and courtship activities depend largely on short-cycle rhythms which have not yet been physiologically investigated. It was suggested that this field would be particularly rewarding for further research.

Details of the work presented at the Symposium will be found in the references given below.

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* Summary of the film screened. This study has been made possible principally by grants from the National Science Foundation (NSF G-1316 and G-14588), and from the New York Zoological Society.

PHYLOGENETIC RELATIONSHIPS IN THE FAMILY CHYDORIDAE (CLADOCERA)*

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ABSTRACT

Relationships of the chydorid Cladocera at and above the genus level have been based hitherto largely on superficial resemblances, except possibly for the single genus *Eurycercus*. The arrangement of two series of pores on the head shields, described earlier by the author, shows a major dichotomy in the family, which is here substantiated by a parallel dichotomy in the suspension of the mandibles.

INTRODUCTION

THE species in the family Chydoridae are generally distinct and easily recognizable entities once they have been realistically circumscribed, whereas relationships between species at the generic level are often much less clear cut. As a result, interpretations of relationships have often been based as much on subjective impressions as on objective evidence. Except for a number of morphologically very distinctive genera, some of them mono- or di-specific, species have been shifted freely from one genus to another at the whim of the particular investigator.

At still higher taxonomic levels, little has been accomplished that is generally accepted except the splitting off into a separate subfamily of the highly distinctive genus *Eurycercus*. Recent studies on species from all over the world have revealed morphological details that indicate phylogenetic relationships between genera and also aid in assigning species to their proper genera. The time seems propitious, therefore, for subdividing the family into a small number of natural subfamilies.

REVIEW OF PREVIOUS WORK

O. F. Müller (1785) included nine species of crustaceans in his genus *Lynceus*. The first species he described—*Lynceus brachyurus*—is a conchostracan, which is now the type species of the family Lynceidae, based on an assignment by Leach (1816) and a subsequent interpretation by Stebbing (1902). The second species—*Lynceus sphaericus*—was designated by Leach (1816: *fide* Stebbing, 1902) as *Chydorus sphaericus*. The taxon *Chydorus sphaericus* (O. F. Müller, 1785) is now the type species of the family Chydoridae, as it was not only the first cladoceran Müller described in the genus *Lynceus* but also the first to which a new generic name was applied (*see* Stebbing, 1902, for a detailed discussion of the matter). Baird (1843) subsequently assigned most of Müller's other species of *Lynceus* to the new genera *Alona*, *Eurycercus*, *Pleuroxus*, *Peracantha*, and *Camptocercus* listed in order of their mention in Müller's paper (*see* Table 1). *Lynceus longirostris*, the seventh species in the genus, was later assigned to the new genus *Bosmina* in a different family (Baird, 1845). Only the ninth species—*Lynceus socors*—has not been positively identified with any modern species.

P. E. Müller (1867) included in the family Daphnidae all the Cladocera currently distributed among the families Sididae, Daphnidae, Bosminidae, Macrothricidae, and Chydoridae. The

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* Contribution 757 from the Department of Zoology, Indiana University, Bloomington, Indiana, U.S.A. This study has been aided by grants GB-87 and GB-2773 from the National Science Foundation. I am also indebted to Indiana University for a travel grant enabling me to attend the conference at Ernakulam and to Dr. N. N. Smirnov of Borok for graciously letting me examine the manuscripts of his as-yet-unpublished studies.

TABLE I

Schematic survey of the historical development of concepts relating to suprageneric categories in the family Chydoridae
(The numbers in parentheses before O. F. Müller's species denote their sequence of description in the genus (*Lynceus*)

O. F. MÜLLER (1785) Genus Lynceus	LEACH (1816) BAIRD (1843)	P. E. MÜLLER (1867)	KURZ (1874)	DYBOWSKI & GROCHOWSKI (1894)	DYBOWSKI & GROCHOWSKI (1895)	FREY (1965)
		DAPHNIDAE				
		LYNCEINAE	LYNCEIDAE	LYNCEIDAE	EURYCERCIDAE	CHYDORIDAE
		1st SERIES	EURYCERCINAE	EURYCERCINAE		EURYCERCINAE
(4) L. LAMELLATUS	EURYCERCUS	EURYCERCUS	EURYCERCUS	EURYCERCUS	EURYCERCUS	EURYCERCUS
		2nd SERIES	LYNCEINAE		LYNCEIDAE	
			GROUP A	ACROPERINAE	ACROPERINAE	ALONINAE
(8) L. MACROURUS	CAMPTOCERCUS	CAMPTOCERCUS ACROPERUS	CAMPTOCERCUS ACROPERUS	CAMPTOCERCUS ACROPERUS	CAMPTOCERCUS ACROPERUS	CAMPTOCERCUS ACROPERUS
				ALONINAE	LYNCEINAE	
		ALONOPSIS	ALONOPSIS	ALONOPSIS	ALONOPSIS	ALONOPSIS TRETOCEPHALA
				KURZIA	KURZIA	KURZIA EURYALONA
				OXYURELLA CORONATELLA	OXYURELLA CORONATELLA	OXYURELLA
(3) L QUADRANGULARIS	ALONA	ALONA	ALONA LEYDIGIA	ALONA LEYDIGIA	ALONA LEYDIGIA	ALONA LEYDIGIA LEYDIGIOPSIS
		PHRIXURA	PHRIXURA GRAPTOLEBERIS HARPORHYNCHUS	GRAPTOLEBERIS HARPORHYNCHUS	GRAPTOLEBERIS HARPORHYNCHUS	GRAPTOLEBERIS RHYNCHOTALONA MONOSPILUS - ?
			GROUP B	PLEUROXINAE	LYNCOPLEUROXINAE	CHYDORINAE
				LANDEA LYNCEUS	LANDEA LYNCEUS	
					PLEUROXINAE	DADAYA
			ALONELLA	ALONELLA	ALONELLA	ALONELLA DUNHEVEDIA
(5) L. TRIGONELLUS (6) L. TRUNCATUS	PLEUROXUS PERACANTHA	PLEUROXUS PERACANTHA	PLEUROXUS PERACANTHA	RHYPOPHILUS PLEUROXUS PERACANTHA	RHYPOPHILUS PLEUROXUS PERACANTHA	PLEUROXUS
				CHYDORINAE	CHYDORINAE	
(2) L. SPHAERICUS	CHYDORUS	CHYDORUS ANCHISTROPUS	CHYDORUS	CHYDORUS	CHYDORUS	CHYDORUS ANCHISTROPUS
					MONOSPILINAE	
		MONOSPILUS	MONOSPILUS	MONOSPILUS	MONOSPILUS	
						POSITION UNCERTAIN
						SAYCIA

chydorids were listed under the subfamily Lynceinae and the others under the subfamilies Sidinae and Daphninae. Müller recognized that the genus *Eurycercus* differed markedly from the other genera of the Lynceinae, and accordingly he defined two "series", the first including only the genus *Eurycercus* and the second the remaining genera recognized at that time (Table I). In this action he anticipated Kurz (1874), who on elevating the Lynceinae of P. E. Müller to family rank likewise elevated the two "series" to subfamily rank, giving to the first the name Eurycercinae and to the second Lynceinae. The latter was subsequently changed to Chydorinae, following the change in family name recommended by Stebbing (1902).

Most subsequent authors (*e.g.*, Herrick, 1884; Herrick and Turner, 1895; Lilljeborg, 1900; Keilhack, 1909; Birge, 1918; Berg, 1929; Wagler, 1937; Behning, 1941; Šrámek-Hušek, 1962) have adopted this primary breakdown without attempting any further elaboration. Thus, all chydorids except *Eurycercus* have been included in the single subfamily Lynceinae, or more recently Chydorinae.

Dybowski and Grochowski (1894) split Kurz' subfamily Lynceinae into four subfamilies—Acroperinae (2 genera), Aloninae (8 genera), Pleuroxinae (6 genera) and Chydorinae (2 genera)—on the basis of relatively minor and to a certain extent subjective characters. The Acroperinae were distinguished by having a prominent keel or ridge on the head, which resulted in the eye and ocellus being located far from the margin. Although these characters apply to the common European species, they do not apply to *Camptocercus oklahomensis* Mackin, 1930, which has an unkeeled head, nor to *Alonopsis elongata* (Sars, 1861), which Smirnov (1965 *a*) has recently transferred to the genus *Acroperus* on the basis of the structure of its thoracic limbs.

The remaining subfamilies Aloninae, Pleuroxinae, and Chydorinae are distinguished on the basis of the shape of the animal (egg-shaped, modified egg-shaped or subspherical), shape and height of the posterior margin of the shell (with exceptions noted), and the presence of one or two basal spines on the postabdominal claw (again with exceptions noted). The latter two characters, as will be noted later, are reasonably good subjective characters associated with a primary division of the Lynceinae, but they are sufficiently variable that they are not universally applicable.

In the following year Dybowski and Grochowski (1895) elevated Kurz' subfamilies Eurycercinae and Lynceinae to family rank and made a number of other changes at the subfamily level without giving any justification for their action. Thus, they changed the name Aloninae to Lynceinae, even though their restricted monospecific genus *Lynceus* was located in a different subfamily Lyncopleuroxinae along with the genus *Landea*, both of which had been separated from the Pleuroxinae. The subfamily Chydorinae was made monogeneric by removing *Monospilus* to its own subfamily (*see* Table I). Subsequent authors have either been unaware of these studies or have disregarded them.

In his key to the genera of the Lynceinae, Kurz (1874) made a primary separation into two groups on the basis of the length of the posterior margin of the shell in relation to the maximum height of the shell and the means whereby the eggs or embryos are retained in the brood chamber. Group A has the posterior margin scarcely shorter than the height of the shell, and the brood chamber is closed by the posterior portion of the abdomen being bent rather strongly upward to establish contact with the shell. Group B has the posterior margin considerably shorter than the maximum height of the shell, and the brood chamber is closed by the downward-sloping posterior-dorsal portion of the shell, rather than by any special modification of the abdomen.

This first subdivision of the family (excluding *Eurycercus*) although considerably subjective and not realistic for some species not occurring in Europe is largely valid, since all the more recent attempts at subdividing the family have either retained this dichotomy or have worked within it (Table I). Dybowski and Grochowski (1894, 1895) merely split Group A into two subfamilies and Group B into at first two and subsequently four subfamilies.

Recent studies concerned with the configuration of the head pores (Frey, 1959, 1962), the morphology of the thoracic limbs (Smirnov, 1965 *a*, 1965 *b*), and the articulation of the mandibles with the head (Frey, this study) demonstrate that Kurz' Group A is a phylogenetic unit, here designated at the Aloninae, and that Group B is another major phylogenetic unit, here designated as the Chydorinae. The anomalous genus *Monospilus* has been placed at least temporarily in the subfamily Aloninae. The even more anomalous genus *Saycia*, known only from Victoria, Australia, seems to be related to *Eurycercus* in the morphology of its thoracic limbs and the fact that it is polyembryonic, but otherwise is quite different. Considerable study is still required to determine its true relationships. In the meantime, I have placed it in its own subfamily, the Sayciinae.

HEAD-SHIELD PORES

Frey (1959, 1962) has demonstrated two series of pores on the head shields of all the chydorids available at that time—45 species, representing 16 genera. These pores consist of a series of large pores, most generally 2 or 3, on the midline and a pair of generally minute pores that are either lateral to the major pores or are on the midline between the major pores if these are widely separated. Except for the genera *Eurycercus* and *Monospilus*, which seemed monotypic at the time, the pore patterns of all the other species fell into two major groups (Fig. 13), which correspond precisely to Kurz' (1874) dichotomy in his subfamily Lynceinae: the *Alona* Section is equivalent to Kurz' Group A, and the *Chydorus* Section to Group B, excluding *Monospilus*. Within each of these sections two or three types were recognized based on details of pore pattern and on the location of the pore configuration with respect to the posterior margin of the head shield. The dichotomy in the *Chydorus* Section, in particular, seems to have phylogenetic value.

In our further studies on the chydorid Cladocera we have found a number of pore configurations that do not conform to the strict definition of this primary dichotomy. These instances are mainly among tropical and sub-tropical species. Thus, *Chydorus hybridus*, *C. poppei* and *C. barroisi* have lost their major pores entirely. Interestingly, these three species seem closely related on the basis of other morphological evidence as well. *Euryalona occidentalis* (= *orientalis*) has just a single major pore (Fig. 14 in DeCosta, 1964; Fig. 8 in this paper) as in *Eurycercus* and *Monospilus*, and in some specimens even this is absent, leaving just the two minor pores. *Alona globulosa* (Fig. 17 in Mueller, 1964; Fig. 6 in this paper), which has generally been assigned to the genus *Alonella*, is also atypical, in that the major pores have been lost completely, and the minor pores are enclosed by prominent parenthesis-like thickenings on either side of the midline. It would be difficult to assign these particular species to their proper subfamily or even genus on the basis of pore patterns alone. Most species can be assigned readily, however, and fortunately for the anomalous cases other fundamental characters are available to help decide the relationships.

THORACIC LIMBS

N. N. Smirnov (1965 *b*) has recently turned his attention to the morphological details of the five (sometimes six) pairs of thoracic limbs of the chydorids, with exciting results. Since these structures are the chief means whereby the various species obtain their food or otherwise have become specialized for a particular niche, they would be expected to vary considerably in their morphology from one species to another, and they do. (Fryer, 1963, has recently studied the morphology of these limbs in *Eurycercus lamellatus* in relation to the feeding habits of this cladoceran.) Yet the 3rd, 4th, and 5th limbs have retained a remarkably constant number of setae on the exopodite, which permits the family to be divided into three sections (Table II). Section I, containing only the genera *Eurycercus* and *Saycia*, has more setae on each of the three limbs than do the other genera. Section II, which is equivalent to the subfamily Chydorinae as defined in this paper, differs from Section III—the Aloninae—by having 7 setae on the 4th limb instead of 6. The 4th limb by itself provides a good key for differentiating the three sections, being represented by 8, 7 and 6 setae, respectively. On this basis, *Saycia* seems closely related to *Eurycercus*, and

TABLE II

Sections of the family Chydoridae according to number of setae on the exopodites of thoracic limbs III, IV and V (Listed in that order in the table). Figures in parentheses after genera represent the number of species examined in each (from Smirnov, 1965 *b*)

Section I Setae: 8–8–7 (6)	Section II Setae: 7–7–4	Section III Setae: 7 (5)–6–4
Eurycercus (2)	*Chydorus* (5)	*Alona* (6, including *Alonella globulosa* and *Alonopsis ambigua*)
Saycia (1)	*Dunhevedia* (1) *Pleuroxus* (7) *Alonella* (4, including *Alonella rostrata*) *Anchistropus* (1)	*Oxyurella* (1) *Rhynchotalona* (1) *Leydigiopsis* (1) *Leydigia* (2) *Graptoleberis* (1) *Euryalona* (1) *Acroperus* (2, including *Alonopsis elongata*) *Camptocercus* (2) *Monospilus* (1)

Alonella globulosa, which is anomalous in its head-pore configuration as already explained, is assignable to Section III (= Aloninae), as also is *Monospilus. Alonella rostrata,* which was earlier removed from the genus *Rhynchotalona* on the basis of its head pores (Frey, 1961), fits properly in Section II (= Chydorinae). *Alona karua* (Fig. 4), which has often been placed in the genus *Alonella,* belongs in the *Alona* Section on the basis of head pores and in Section III on the basis of thoracic limb setae. Thus, the patterns of relationship deduced from the two series of morphological data are completely concordant.

SUSPENSION OF MANDIBLES

A third basic character has been discovered incidental to our study of head shields and pore configurations. Head shields isolated from exuviae have their labrum, antennules, antennae, mandibles, and sometimes maxillae still attached, enabling the spatial relationships of these parts to be observed readily. Head shields recovered from lake sediments generally have lost their appendages, although the proximal articulation contacts of the mandibles are always present and readily visible. The latter are shown in the illustrations of the head shields as originally published (Frey, 1959, 1962). They demonstrate a dichotomy in the suspension of the mandibles, which was not appreciated at that time. Later (Frey, 1961) a brief statement was made that there are two types of mandibular articulations, corresponding to the *Alona* and *Chydorus* Sections of the family based on head pores.

Further study of this character has involved the examination of 74 species from various parts of the world, including at least one species from each of the 21 genera of Chydoridae we currently accept as valid (Table I: the genus *Tretocephala* has only recently been described—Frey, 1965). These studies have confirmed the previous preliminary observation that there are two principal and contrasting types of mandibular suspension in the chydorids.

Type I.—In this type the pointed base of the mandible articulates at the point where the free margins of the head and shell come together. This is readily observable in the intact animal when viewed from the side. Both the head shield and the shell have chitinous thickenings at this point of contact, which together form the articular surface. Isolated head shields and shells recovered from lake sediments still show these chitinous thickenings. At the time of molting, the ecdysial line between the head shield and shell splits apart, leaving the head and shell connected only at the point of mandibular articulation. When the head is teased from the shell for microscopic preparation only the head appendages (labrum, antennules, antennae, mandibles and sometimes maxillae) remain attached to the head. The thoracic limbs along with the postabdomen remain attached to the shell.

This type of suspension occurs in *Eurycercus* (Fig. 1) and in the 13 genera listed in the family Aloninae in Table 1, including *Monospilus* (Fig. 7). Other examples of this type of suspension are shown for *Alona affinis* (Fig. 3), *Alona karua* (Fig. 4), *Alona globulosa* (Fig. 5), and *Euryalona orientalis* (Fig. 8). *Saycia* (Fig. 2) also appears to have this type of suspension, although there are some differences from *Eurycercus* that have not yet been resolved.

Type II.—In this type the proximal pointed end of the mandible is attached to and articulates with the head shield at some distance from its free margin. There is no common articular surface shared by the shell and head, so that these separate parts do not have the chitinous articular thickenings present in species of Type I. The mandibles are attached to a thin flap of the exoskeleton, which permits a much greater flexibility of movement than the more rigid suspension of Type I. When the head shield of an exuvia is teased from the shell, generally all the appendages and the postabdomen remain attached to the head shield, leaving the shell completely free. This, too, is in marked contrast to Type I.

Examples of this type of suspension are shown for *Alonella excisa* (Fig. 9), *Dadaya macrops* (Fig. 10), *Chydorus sphaericus* (Fig. 11), and *Chydorus latus* (Fig. 12). *Dadaya* is apparently rather closely related to *Alonella*, based on its head-pore configuration. Only one major pore is present—the anterior one—posterior to which is a pair of small pores close together on the midline. Unfortunately, the mandibles were not present in the specimen photographed, but the articulation surfaces show distinctly that this species belongs in Type II. This was confirmed by examination of intact specimens.

DIAGNOSIS OF HIGHER CATEGORIES

Eurycercus is different in so many respects from the other chydorids that it may be necessary eventually to place it in a separate family, as Dybowski and Grochowski (1895) have done, or to establish superfamilies in the family Chydoridae, with a special one for *Eurycercus*.

Family CHYDORIDAE Stebbing, 1902

Type species: *Chydorus sphaericus* (O. F. Müller, 1785)

Body completely enclosed by a shell and head shield. The latter projects over the bases of the antennules as a rostrum and laterally over the bases of the antennae as fornices. Antennules single-jointed, more or less movable, generally not extending beyond tip of rostrum. Both rami of antennae 3-jointed. Antennal formula either 0–0–3/0–1–3 or 0–0–3/1–1–3. Labrum with expanded flattened plate projecting ventrally. Five (sometimes 6) pairs of thoracic limbs, the first 2 pairs more or less prehensile, the next 3 pairs flattened, the 6th if present usually vestigial. Postabdomen strongly compressed laterally, usually provided with teeth or denticles along the dorsal margin and with bundles of movable or non-movable setae lateral to these. Ocellus always present, compound eye usually so. Male is smaller than female, with a special seta on the antennules and a strong copulatory hook on the first pair of thoracic limbs; it also generally exhibits a marked reduction of denticles and setae on the postabdomen and often a marked change in shape of the postabdomen from the condition in the female. An ephippium is produced but is weakly developed.

Subfamily **Eurycercinae** Kurz, 1874

Type species: *Eurycercus lamellatus* (O. F. Müller, 1785)

Single large major pore on head shield, with minor pores closely adjacent laterally. Mandibles articulate at junction of head shield and shell. Six pairs of thoracic limbs, the 6th less strongly developed. Setae on thoracic limbs III, IV, and V number 8, 8, and 7, respectively. Gut has 2 caeca anteriorly. Anus at end of postabdomen, which is extremely broad and flattened, with a single row of saw-like denticles along the dorsal edge. Polyembryonic, both for parthenogenetic and bisexual (resting) eggs. Genital pore of male opens at base of postabdomen ventrally.

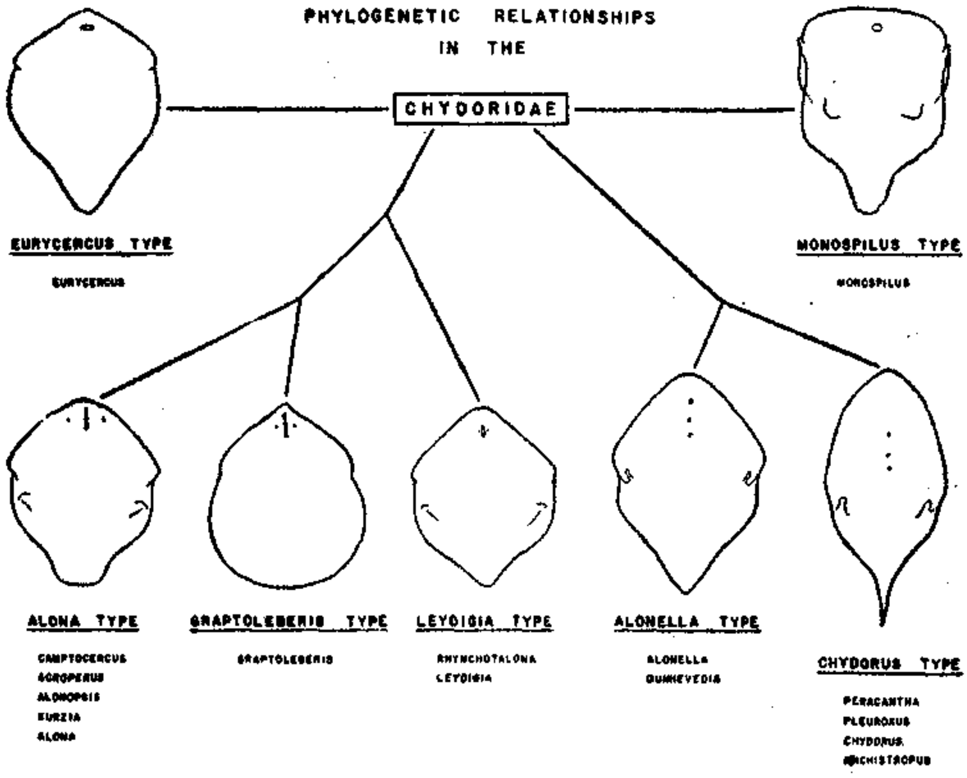

FIG. 13. Phylogenetic relationships in the Chydoridae according to head-pore configurations (from Frey, 1962)

Subfamily **Saycinae** nov.

Type species: *Saycia cooki* (King, 1866)

(*Saycia orbicularis* Sars, 1904, was synonymized with this species by Smirnov, 1965 *b*)

No visible pores on head shield. Mandibles articulate at or near junction of head shield and shell. Setae on thoracic limbs III, IV, and V number 8, 8, and 6, respectively. Gut without anterior caeca. Anus at some distance from end of postabdomen. Postabdomen flattened, with groups of marginal spinules on both sides of dorsal margin distally, a single row proximally. Larger specimens polyembryonic. Males not known.

Subfamily **Aloninae** nov.

Type species: *Alona quadrangularis* (O. F. Müller, 1785)

Generally 2 or 3 large pores on midline of head shield, usually connected by a channel, sometimes isolated, sometimes (*Oxyurella*) with middle pore fragmented into 2 separate pores, sometimes only 1 pore (*Euryalona*) or even none (*Alona globulosa*). Minor pores lateral to major pores. Mandibles articulate at junction of head shield and shell. Typically only 5 pairs of thoracic limbs, sometimes a 6th represented by an undifferentiated lobe. Setae on limbs III, IV and V number 7 (5), 6, and 4, respectively. Gut without anterior caeca, but usually with a single posterior caecum. Anus in an embayment on dorsal side of postabdomen near its base. Postabdomen compressed laterally, typically with a row of denticles on either side of dorsal margin, and usually with an approximately equal number of bundles of movable spinules or setae lateral to these. Postabdominal claw typically with only 1 basal spine, sometimes without any. Posterior margin of shell usually more or less convex, generally but little shorter than maximum height of shell. No more than 2 parthenogenetic eggs or embryos at one time, and always only a single bisexual (resting) egg. Sperm ducts open near tip of postabdomen on ventral side.

Subfamily **Chydorinae** nov.

Type species: *Chydorus sphaericus* (O. F. Müller, 1785)

Two major pores on midline of head shield, widely separated from one another; sometimes only 1 (*Dadaya*) or even none (*Chydorus barroisi* and related species). Minor pores have moved to midline between major pores. Mandibles articulate with a chitinous extension of the head shield at some distance from the margin. Typically only 5 pairs of thoracic limbs, sometimes a 6th represented by an undifferentiated lobe. Setae on limbs III, IV, and V number 7, 7, and 4, respectively. Gut without anterior caeca, but usually with a single posterior caecum. Anus in an embayment on dorsal side of postabdomen near its base. Postabdomen laterally compressed, with a row of denticles on either side of dorsal margin; lateral surface with groups of non-movable, rarely movable (*e.g.*, *Chydorus globosus*) spinules. Postabdominal claw typically with 2 basal spines, the more proximal one smaller and sometimes virtually or completely absent. Posterior margin of shell less convex, often essentially straight, generally only about half as long as maximum height of shell. No more than 2 parthenogenetic eggs or embryos at one time, and always only a single bisexual (resting) egg. Sperm ducts open near tip of postabdomen on ventral side.

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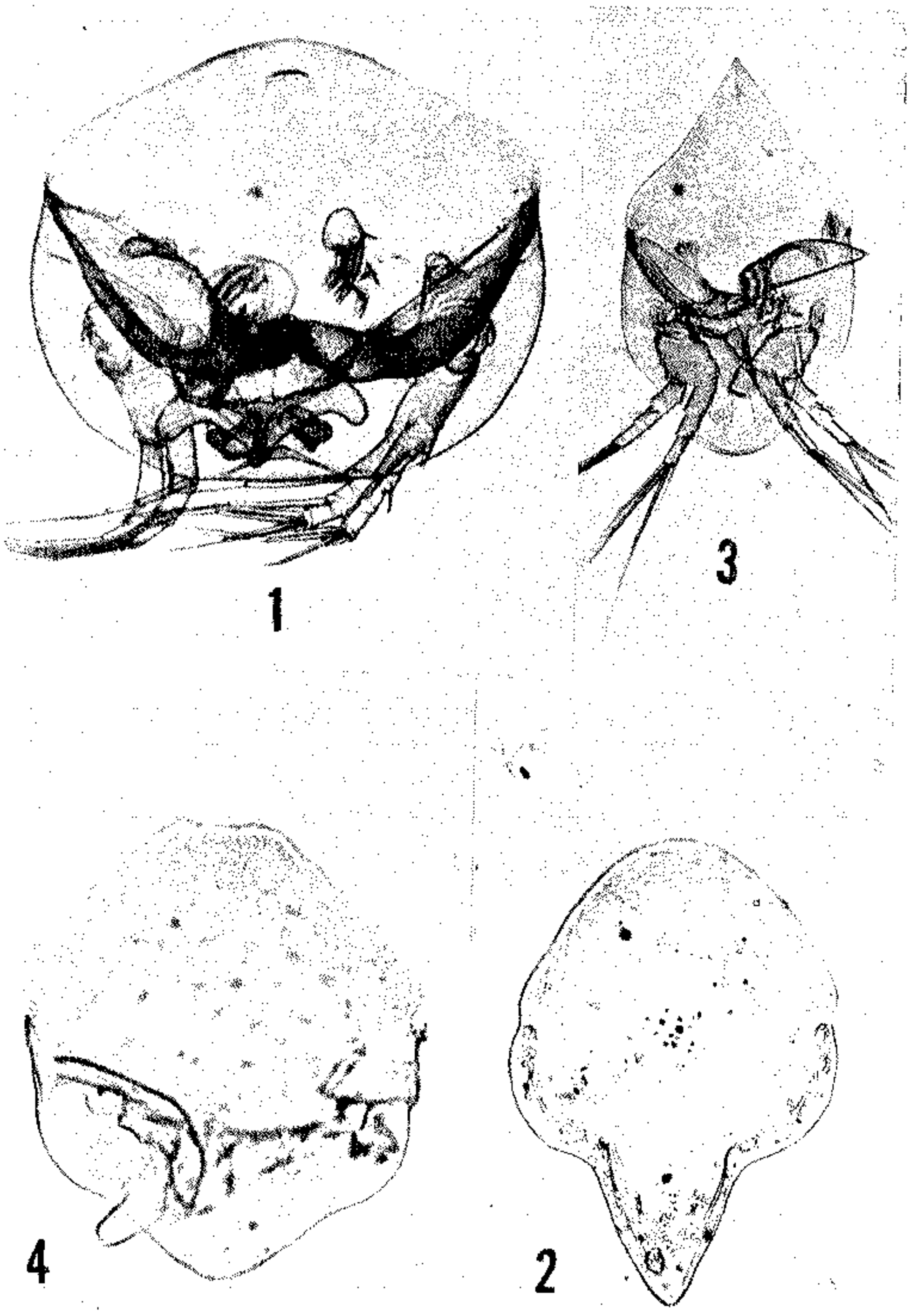
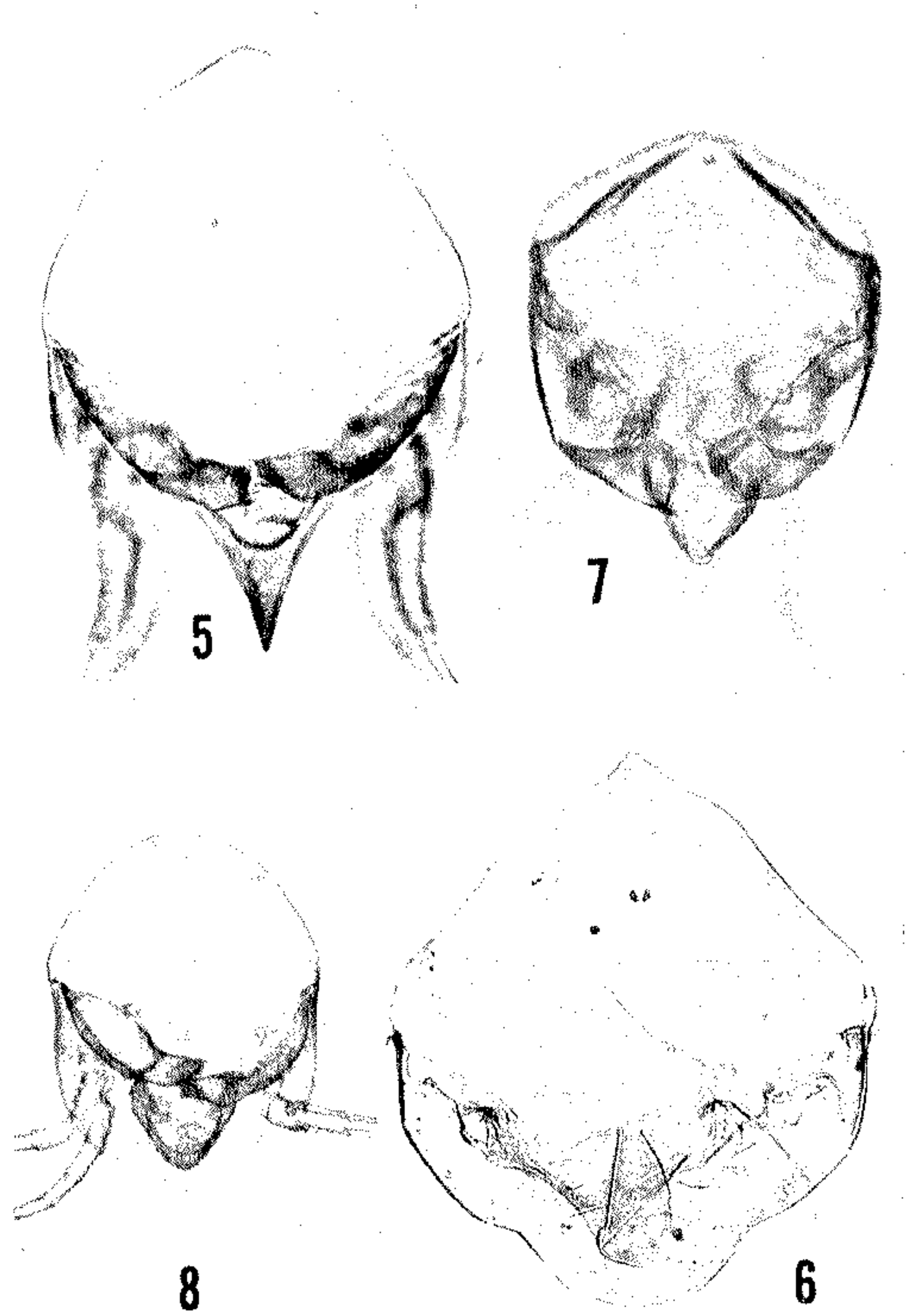


Figs. 1-4. Fig. 1. *Eurycercus lamellatus* (O. F. Müller, 1785). Crooked Lake, Noble Co., Indiana, 1964, ×70. Fig. 2. *Saycia orbicularis* Sars, 1904. Elwood near Melbourne, Australia, 1902. From type material of G. O. Sars Collection, No. F4144, in Naturhistorisk Museum, Oslo, ×100. Fig. 3. *Alona affinis* (Leydig, 1860). Crooked Lake, Noble Co., Indiana, 1964, ×100. Fig. 4. *Alona karua* King, 1853. Lake Hicpochee, Florida, 4 Aug. 1960. Frey Collection No. 150, ×250.



FIGS. 5–8. Fig. 5. *Alona globulosa* Daday, 1898. Lake Hickpochee, Florida, 4 Aug. 1960. *Frey Collection* No. 150, ×250. Fig. 6. *Alona globulosa* Daday, 1898. Lake Hickpochee, Florida, 4 Aug. 1960. Frey Collection No. 150, ×250. Fig. 7. *Monospilus dispar* Sars, 1861, Lake Balaton, Hungary, 1963 Collected by O. Sebestyén, ×250. Fig. 8. *Euryalona orientalis* (Daday, 1898) Lake Hickpochee, Florida, 4 Aug 1960. Frey Collection No. 150, ×100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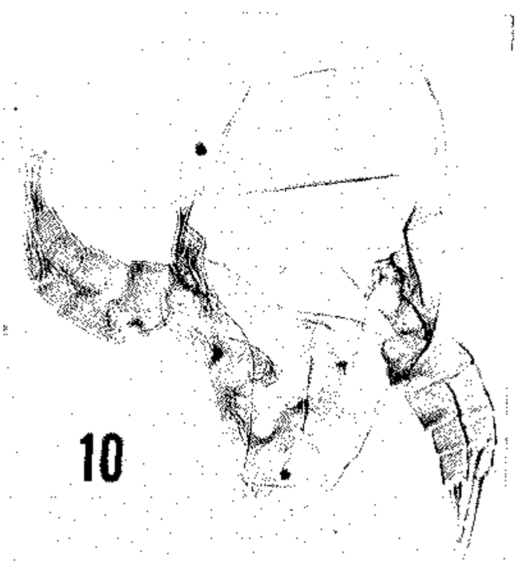
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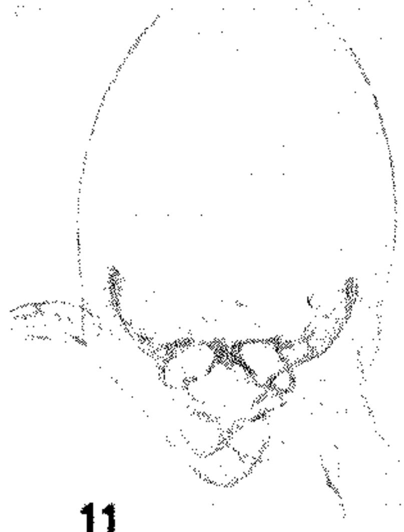
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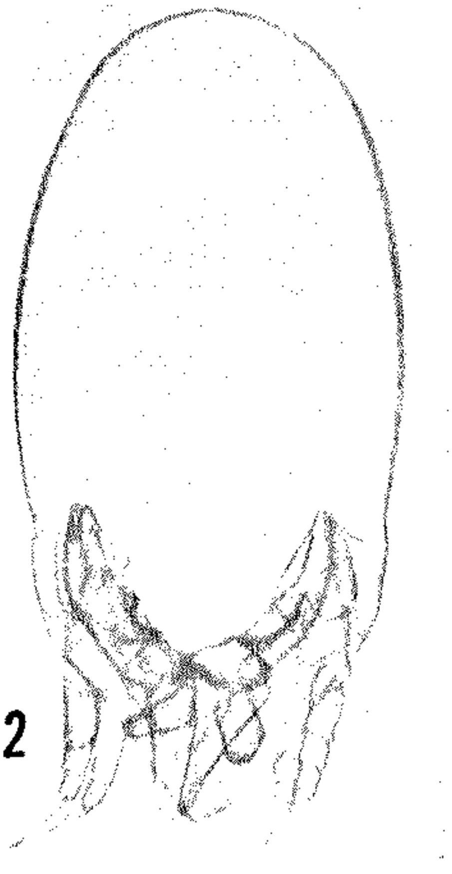
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FIGS. 9–12. Fig. 9. *Alonella excisa* (Fischer, 1854). Bloomington, Indiana, 1964, ×250. Fig. 10. *Dadaya macrops* (Daday, 1898). Mayumba, French Equatorial Africa, 20 June 1890. J. Richard Collection S-68. Frey Collection No. 854, ×250. Fig. 11. *Chydorus sphaericus* (O. F. Müller, 1785), Bloomington, Indiana, 1964, ×200. Fig. 12. *Chydorus latus* Sars, 1862. Markeso, Denmark, 24 July 1963. Frey Collection No. 1303, ×200.

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DISCUSSION

Dr. S. Jones: Have you been able to examine the recent collections from Ceylon and South India ?

Dr. D. G. Frey: No. I have not yet examined them.

NERITIC COPEPODA CALANOIDA FROM THE NORTH-WEST COAST OF KYUSHU

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ABSTRACT

Six species of Calanoida were collected by straining sea-water led into the Fishery Research Laboratory in Tsuyazaki near Fukuoka City. These species have never been obtained by usual net collection in the north-west coast of Kyushu. Some of them are very suggestive in the zoogeographical distribution of copepods in the sea.

THE present study is aimed at the investigation of copepods, both qualitatively and quantitatively, contained in sea-water led into the aquarium from the tank which is connected directly with natural sea-water of the coastal region of Tsuyazaki where the Fishery Research Laboratory of Kyushu University stands. The sea-water was filtered by running the water for 24 hours through fine bolting silk X 13. The samples contained species of Calanoida, Cyclopoida and Harpacticoida. In the present paper several species of Calanoida are dealt with.

Family STEPHIDAE

Genus *Stephus* Th. Scott

***Stephus tsuyazakiensis* sp. nov.**

(Fig. 1, *a–n*)

Description: FEMALE.—Length, 0·78 mm. The body is robust. The head is fused with the 1st thoracic segment, and the 4th segment with the 5th. The cephalothorax and abdomen are in the proportional lengths 68 to 32. The last thoracic segment is asymmetrical; the left side is more elongated, extending almost to the middle of the genital segment; the distal corner of the segment is narrowly rounded in the lateral view. The rostral prominence is low, without filaments.

The abdomen is 4-jointed; the segments and furca are in the proportional lengths as 52: 16: 12: 8: 12 = 100. The genital segment is swollen on the left lateral margin about in the middle and is furnished with minute spinules around the apex; the ventral surface of the segment is considerably produced below near the distal margin. The furcal rami are slightly asymmetrical; the right ramus is larger, slightly longer than wide; the left ramus is about as long as wide; the innermost seta arises apart from the distal margin of the ramus.

The 1st antenna is 24-jointed and almost reaches the distal margin of the genital segment. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
	95	63	39	24	32	32	36	47	24	28	36	47	44	39	39	39	39	39	39	39	39	47	55	39	= 1000

The 12th segment has a small spine on the anterior distal margin.

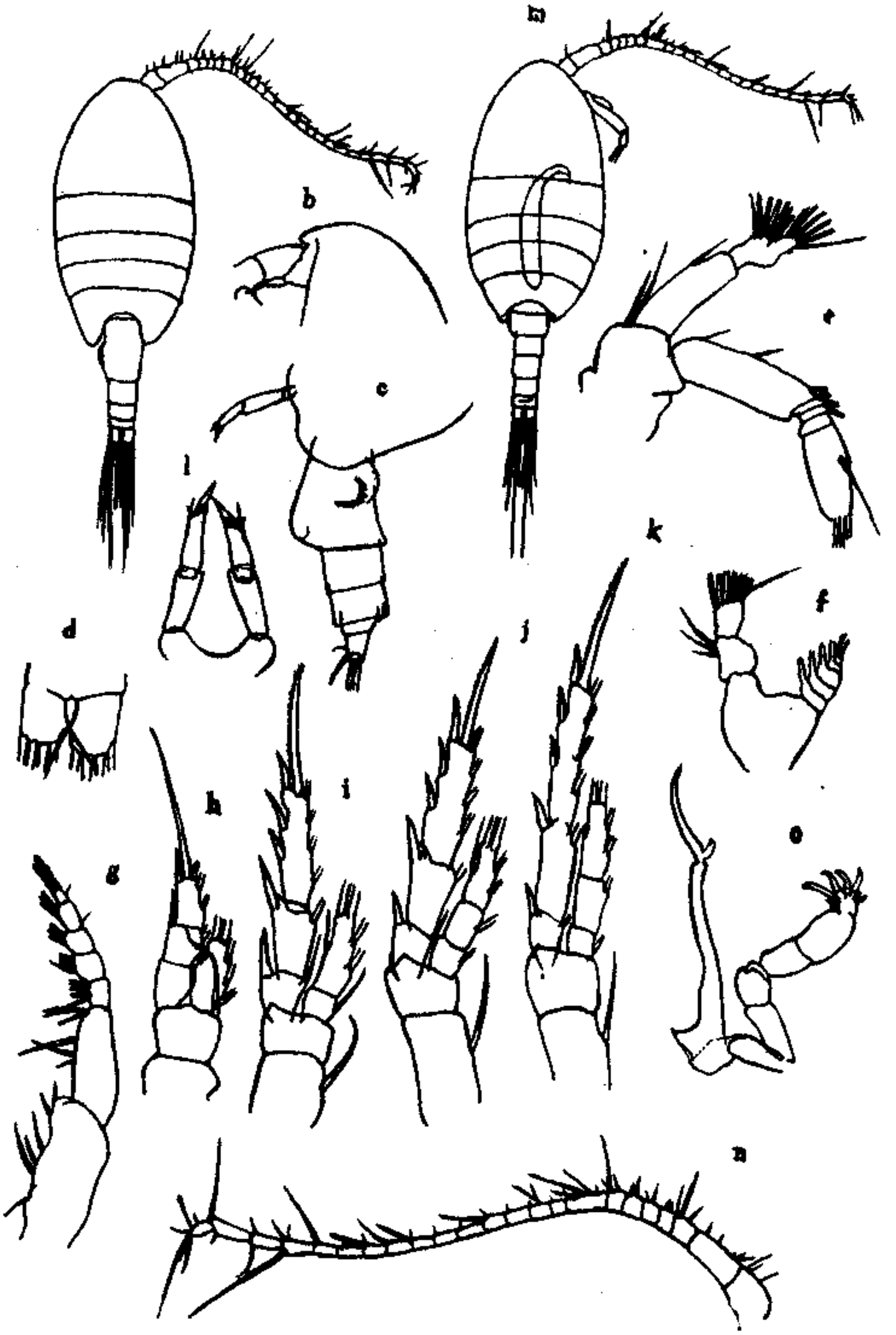

FIG. 1. *Stephus tsuyazakiensis* sp. nov.

Female: *a*, dorsal aspect, ×50; *b*, head, lateral aspect, ×100; *c*, last thoracic segment and abdomen lateral aspect, ×100; *d*, furcal rami, ×200; *e*, 2nd antenna, ×200; *f*, mandible, ×200; *g*, maxilliped, ×200; *h*, 1st leg, ×200; *i*, 2nd leg, ×200; *j*, 3rd leg, ×200; *k*, 4th leg, ×200; *l*, 5th pair of legs, ×200.
Male: *m*, dorsal aspect, ×50; *n*, 1st antenna, ×100; *o*, 5th pair of legs, ×100.

In the 2nd antenna the exopod is 1·5 times as long as the endopod. The mandible is strong, the exopod is shorter than the endopod. The maxilliped is well developed; the endopod is about as long as the 1st basal segment.

The 1st leg has 3-jointed exopod and 1-jointed endopod; the 1st segment of the exopod has no outer marginal spine. The 2nd leg has 3-jointed exopod and 2-jointed endopod; the outer marginal spine of the 1st segment of the exopod is very strong; the outer marginal line between the 2nd and 3rd marginal spines of the 3rd segment of the exopod is not straight but suddenly changes in outline. The 3rd and 4th legs have each 3-jointed exopod and endopod. The exopod of the 4th leg is slender and long.

The 5th pair of legs is symmetrical, 3-jointed; the distal segment ends in an acute spine directed somewhat inwards; a row of spinules, about 5 in number, runs obliquely at the distal $\frac{1}{5}$ of the segment; an outer marginal seta arises from the middle of the segment.

MALE.—Length, 0·73 mm. The male resembles the female in general appearance. The last thoracic segment is slightly produced on the left side. The abdomen is 5-jointed. The segments and furca are in the following proportional lengths: 28 : 22 : 14 : 11 : 8 : 17 = 100. The genital segment is more produced on the left lateral margin. The furcal rami are as long as wide.

The 1st antenna is 23-jointed and extends to the distal margin of the 2nd abdominal segment when fully reflexed. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13
	78	94	39	24	20	28	32	63	28	35	43	39	47

	14	15	16	17	18	19	20	21	22	23
	43	39	39	35	39	43	43	47	63	39 = 1000

The 12th segment has a small spine on the anterior distal margin.

The mouth parts and swimming legs are as in the female.

The 5th pair of legs is asymmetrical. The right leg is long and slender, composed of 4 segments; the 3rd segment is very slender and long; the last segment is claw-like and carries a process on the inner proximal margin. The left leg is 4-jointed; the distal segment is furnished with a dense fascicle of lanceolate appendages varying in size.

Remarks.—The present species is easily distinguished from the species hitherto reported by the armature of both the female and male 5th pair of legs. It is uncertain whether the species is identical with *Stephus fultoni* Th. Scott, whose description and figures I could not consult.

Occurrence.—Fairly common in the neritic water of the north-west coast of Kyushu.

Distribution.—North-west coast of Kyushu.

Family PSEUDODIAPTOMIDAE

Genus *Pseudodiaptomus* Herrick

Pseudodiaptomus cornutus **Nicholls**

(Fig. 2, *a–f*)

Pseudodiaptomus cornutus, Nicholls, 1944, p. 12, fig. 4.

Description: FEMALE.—Length, 1·14 mm. The anterior and posterior regions of the body are in the proportional lengths as 70 to 30. The head is separated from the 1st thoracic segment;

the 4th and 5th thoracic segments are fused. The 1st thoracic segment bears dorsally two knob-like processes on the posterior margin. The lateral distal margin of the last thoracic segment is triangularly produced, extending beyond the middle of the genital segment. The rostrum consists of two fine filaments.

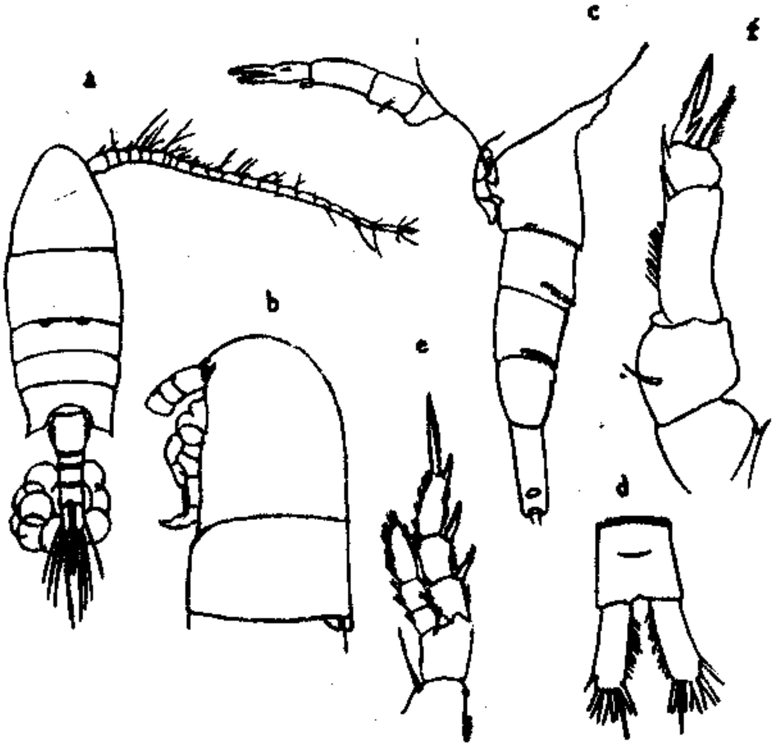

FIG. 2. *Pseudodiaptomus cornutus* Nicholls.

Female: *a*, dorsal aspect, ×35; *b*, head, lateral aspect, ×50; *c*, last thoracic segment and abdomen, lateral aspect, ×100; *d*, anal segment and furcal rami, ×100; *e*, 2nd leg, ×100; *f*, 5th leg, ×200.

The abdomen is 4-jointed and symmetrical. The segments and furca are in the proportional lengths as 31 : 14 : 17 : 16 : 22 = 100. The genital segment is globular in shape; a group of minute spinules is observed on the lateral swelling on each side. The genital, 2nd and 3rd segments are each furnished with small denticles on the distal margin. The furcal rami are about 3 times as long as wide.

The 1st antenna is 22-jointed and extends posteriorly to the end of the 3rd abdominal segment. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
	70	38	38	32	27	16	38	16	32	43	48	59	54	54	59	64	54	43	43	48	54	70	= 1000

The 1st to 4th legs have each 3-jointed exopod and endopod.

The 5th pair of legs is symmetrical; the distal segment is short, has 2 strong spines; the outer one is slightly longer than the inner.

Occurrence.—Fairly common in the neritic water of northwest coast of Kyushu.

Distribution.—The species has been recorded from the South Australia.

Pseudodiaptomus inopinus **Bruckhardt**

(Fig. 3, *a–h*)

Pseudodiaptomus inopinus, Bruckhardt, 1913, p. 379, pls. 11, 12.

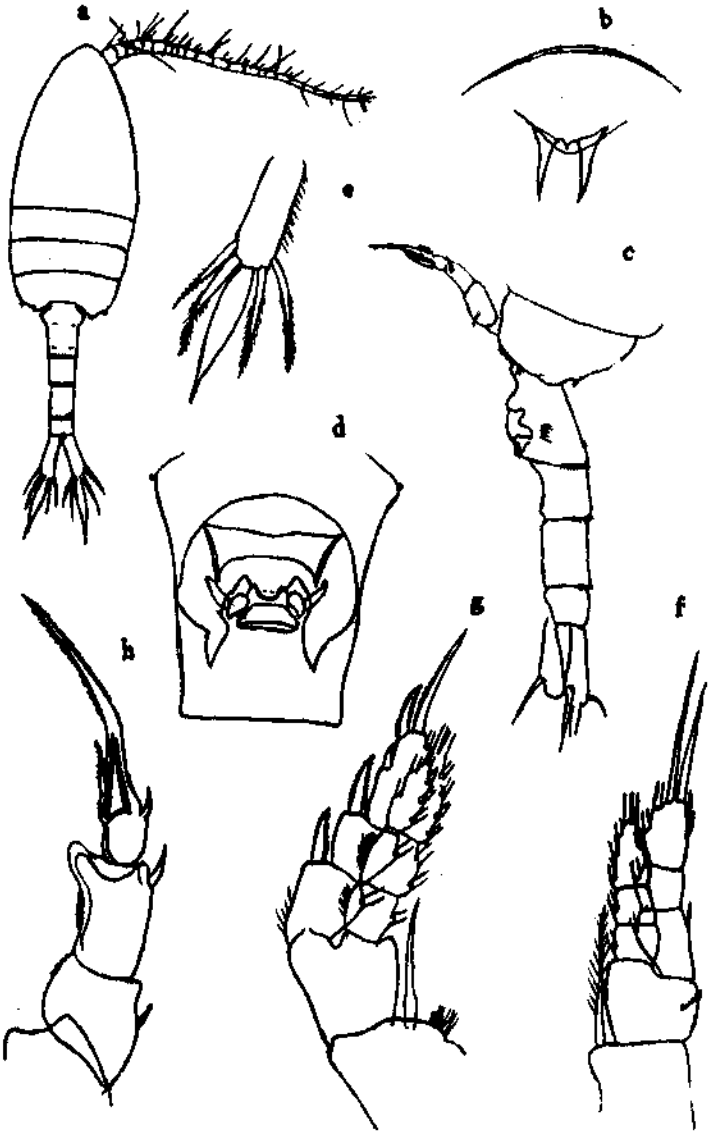

FIG. 3. *Pseudodiaptomus inopinus* Bruckhardt

Female: *a*, dorsal aspect, ×35; *b*, head anterior aspect, ×200; *c*, last thoracic segment and abdomen, lateral aspect, ×70; *d*, genital segment, ventral aspect, ×200; *e*, furcal ramus, ×100; *f*, 1st leg, ×200; *g*, 2nd leg, ×200; *h*, 5th leg, ×200.

Description: FEMALE.—Length, 1·22 to 1·28 mm. The anterior and posterior regions of the body are in the proportional lengths as 62 to 38. The cephalothorax gradually attenuates in front. The frontal margin of the head is narrowly rounded in dorsal aspect. The lateral distal margin of the last thoracic segment is irregular in outline; the antero-distal corner of the segment is provided with a small spine and the ventro-distal corner with a row of fine hairs. The rostrum is composed of two rather strong spines.

The abdomen is 4-jointed; the segments and furca are in the proportional lengths as 31 : 14 : 20 : 10 : 25 = 100. The genital segment is dilated much on the proximal margin, and is furnished on each side with several short hairs at the apex. The genital, 2nd and 3rd segments are finely striated on the distal margin. The furcal rami are about 2·5 times as long as wide; the rami are broad near the distal end; the 3rd inner seta is broad.

The 1st antenna is 22-jointed and reaches the middle of the last thoracic segment when fully extended; the segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13
	68	44	25	39	31	25	37	19	25	31	44	56	56
	14	15	16	17	18	19	20	21	22				
	62	62	62	56	43	43	50	56	68	= 1000			

The 5th pair of legs is symmetrical; the 3rd segment has a blunt process on the inner distal margin; the distal segment has three spines of which the outer is long and curved.

Occurrence.—Very common in the coastal waters around Japan.

Distribution.—This species has been recorded from east and west coasts of Asia.

Pseudodiaptomus marinus **Sato**

(Fig. 4, *a–n*)

Pseudodiaptomus marinus, Sato, 1913, p. 28, pl. 7, figs. 69–71.

Description: FEMALE.—Length, 1·32 mm. The anterior and posterior regions of the body have the proportional lengths as 62 to 38. The head is separated from the 1st thoracic segment; the last two thoracic segments are fused. The frontal margin of the head is narrowly rounded in dorsal aspect, but evenly rounded when viewed from the lateral; the lateral distal corner of the last thoracic segment is symmetrical with a strong spine directed outwards at the apex. The rostrum consists of two fine filaments.

The abdominal segments and furca are in the following proportional lengths:

Abd. 1	2	3	4	Furca	
26	18	20	14	22	= 100

The genital segment is slightly asymmetrical, the left proximal margin is more inflated; the right lateral margin is furnished with rows of short hairs; the ventral surface of the segment is furnished with an acute triangular process just below the genital opening. The distal margin of the genital, 2nd and 3rd segments is striated with small denticles. The furcal rami are more than 3 times as long as wide (11 : 3). The present specimen carried an egg sac.

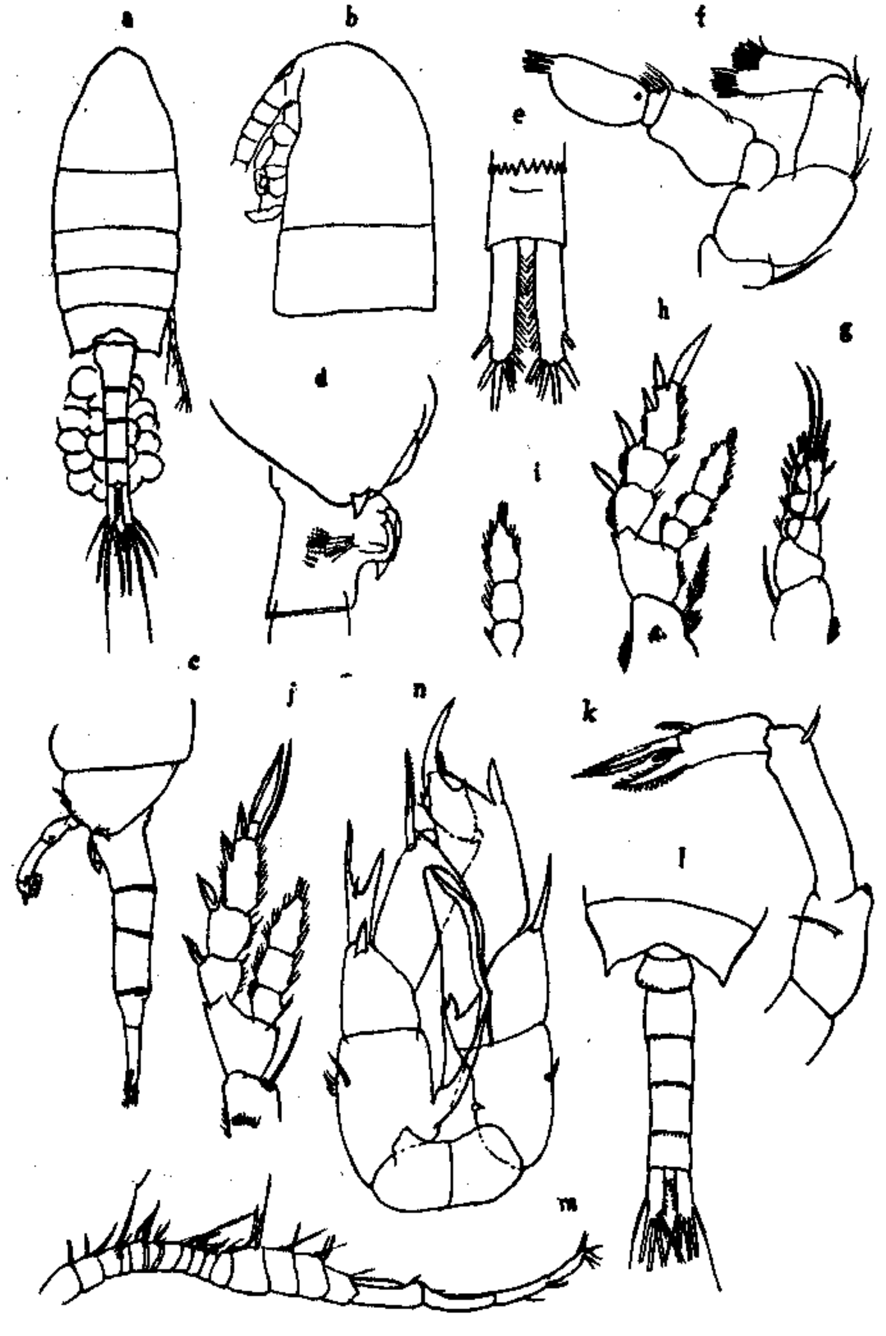

FIG. 4. *Pseudodiaptomus marinus* Sato.

Female; *a*, dorsal aspect, ×35; *b*, head, lateral aspect, ×50; *c*, last thoracic segment and abdomen, lateral aspect, ×50; *d*, last thoracic segment and genital segment, lateral aspect, right side, ×100; *e*, anal segment and furcal rami, ×100; *f*, 2nd antenna, ×200; *g*, 1st leg, ×100; *h*, 2nd leg, ×100; *i*, endopod of 3rd leg, ×100; *j*, 4th leg, ×100; *k*, 5th leg, ×200.

Male: *l*, last thoracic segment and abdomen, dorsal aspect, ×70; *m*, 1st antenna, ×70; *n*, 5th pair of legs, ×200.

The 1st antenna is 22-jointed and extends when fully reflexed about to the distal margin of the 2nd abdominal segment. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13
	69	40	35	29	29	23	29	17	35	40	58	64	64

14	15	16	17	18	19	20	21	22	
64	58	64	52	40	40	46	46	38	= 1000

The 2nd antenna has 4-jointed exopod which is 1·4 times as long as the endopod.

The 1st to 4th swimming legs have each 3-jointed exopod and endopod. The 1st basal segment of each leg is furnished with rows of fine hairs.

The 5th pair of legs is 4-jointed; the distal segment has two apical spines, of which the outer one carries a small subsidiary spine; the inner distal spine is coarsely serrated on the inner margin.

Male.—Length, 1·02 mm. The anterior and posterior regions of the body are in the proportional lengths as 66 to 34. The last thoracic segment is symmetrical with a wing-like expansion on each side of the segment.

The abdominal segments and furca are in the proportional lengths:

Abd. 1	2	3	4	5	Furca	
13	18	18	20	11	20	= 100

The furcal rami are about 3 times as long as wide (14: 5).

The right 1st antenna is 21-jointed; the middle section is not so much inflated; the 18th segment has a delicate ctenate process on the anterior margin.

The 5th pair of legs is bifurcate on each side. The right leg has 3-jointed exopod; the 2nd basal segment has two spines of which the inner one is trifurcated at the apex; the endopod is absent; the segment of the exopod has, besides a normal outer edge spine, a bifurcated large spine; the 3rd segment ends in a strong claw. The left leg has 2-jointed exopod and 1-jointed rudimentary endopod.

Occurrence.—The species is very common in the coastal waters of Kyushu.

Distribution.—This species was recorded for the first time from the coastal water of Hokkaido, and is common in the coastal waters of Japan.

Family ARIETELLIDAE

Genus *Paramisophria* Th. Scott

***Paramisophria cluthae* Th. Scott**

(Fig. 5, *a–n*)

Paramisophria cluthae, Sars, 1903, p. 128, pl. lxxxvi, lxxxvii.

Description: Female.—Length, 1·59 mm. The cephalothorax is fairly robust. The head is separated from the 1st thoracic segment; the 4th and 5th thoracic segments are fused. The frontal margin of the head obtusely rounded in lateral aspect. The cephalothorax is considerably

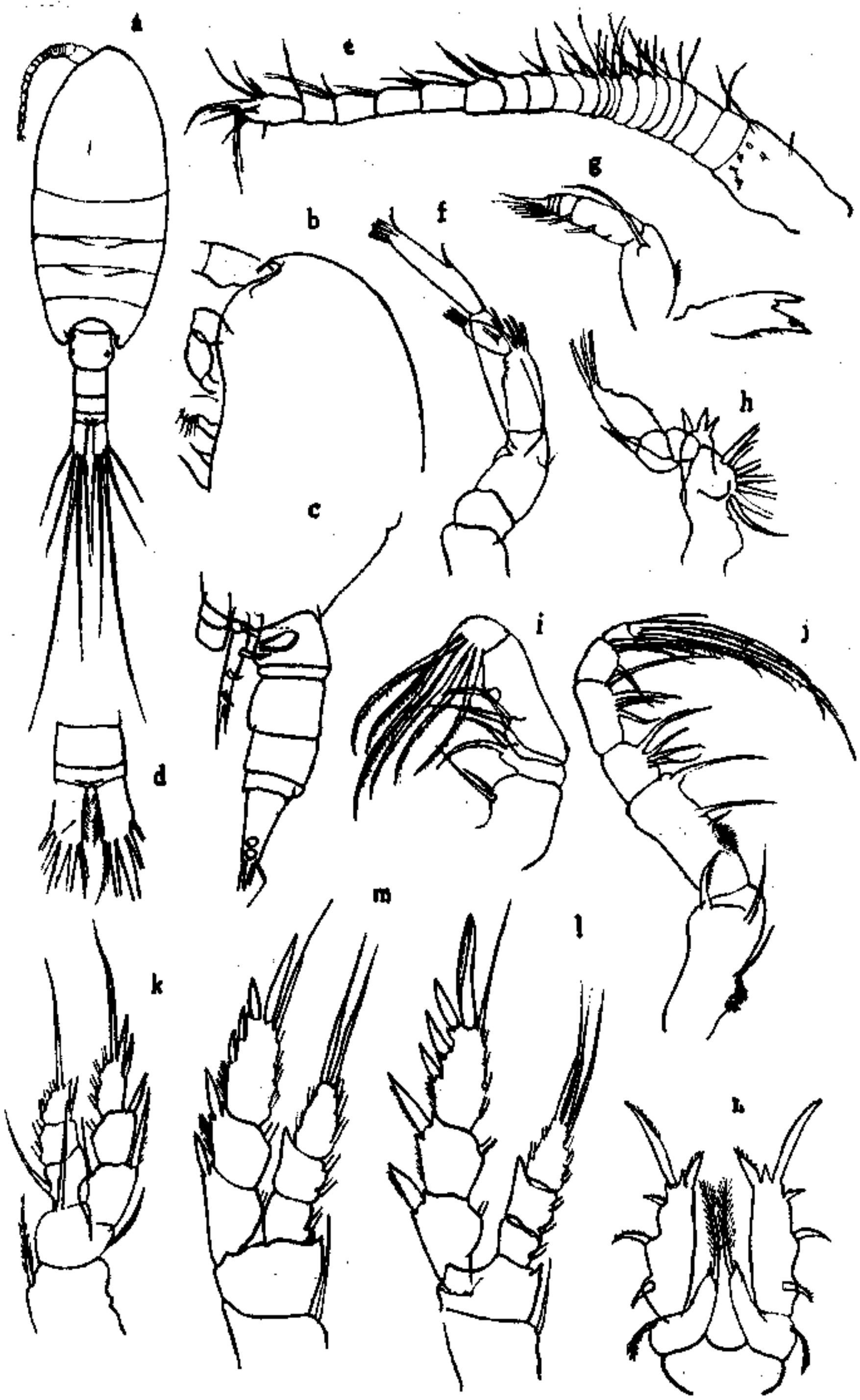

Fig. 5. *Paramisophria cluthae* Th. Scott.

Female: (*a*) dorsal aspect, ×25; (*b*) head, lateral aspect, ×50; (*c*) last thoracic segment and abdomen, lateral aspect, ×50; *d*, furcal rami, ×50; *e*, 1st antenna, ×100; *f*, 2nd antenna, ×100; *g*, mandible, ×100; *h*, 1st maxilla, ×100; *i*, 2nd maxilla, ×100; *j*, maxilliped, ×100; *k*, 1st leg, ×100; *l*, 2nd leg, ×100; *m*, 4th leg, ×100; *n*, 5th pair of legs, ×100.

vaulted, the dorsal surface of the thoracic segments forms an even curve to the rostral prominence; the distal margin of the 2nd and 3rd thoracic segments is each furnished, beside a normal line of demarcation, with another line arising from the normal line when viewed from the dorsal aspect. The last thoracic segment is symmetrical; the lateral distal margin is obtusely rounded with an acute process on the dorso-lateral margin. The rostrum is composed of two small filaments.

The abdomen is 4-jointed; the segments and furca are in the proportional lengths:

Abd. 1	2	3	4	Furca	
31	23	17	6	23	= 100

The genital segment is about as long as wide. The furcal rami are about 2 times as long as broad.

The 1st antenna is 21-jointed and very short, only attaining the distal ⅓ of the head. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13
	226	42	50	25	17	25	17	34	13	8	17	34	34

14	15	16	17	18	19	20	21	
42	34	50	70	70	70	42	92	= 1000

The 2nd antenna has the endopod much larger than the exopod. In the mandible the endopod is represented by a small knob furnished with a long seta. The 1st maxilla is reduced, the inner ramus has 3 spines on the distal margin; the exopod is elongated with 3 setae on the apex; the endopod has 2 small setae on the apex. The 2nd maxilla is strong. The maxilliped is elongated; the 1st and basal segments are each furnished with a tuft of hairs on the inner proximal margin.

The 1st to 4th legs have each 3-jointed exopod and endopod. The 1st leg has a long outer marginal spine on the 1st segment of the exopod. In the 2nd leg the outer marginal spine of the 2nd segment of the exopod is strong.

The 5th pair of legs is symmetrical and composed of 1-jointed exopod and endopod; the exopod is longer, and is furnished with 3 apical spines of which the outer one is much longer than the inner; the outer margin of the segment carries 3 spines. The endopod terminates in a small spine and has a fairly long seta at the base of the spine.

Occurrence.—Fairly common in the coastal water of north-western Kyushu.

Distribution.—This species has been recorded from the coasts of Scotland and Norway.

Family PSEUDOCYCLOPIDAE

Genus *Pseudocyclops* Brady

Pseudocyclops australis Nicholls

(Fig. 6, *a–l*; Fig. 7, *m–o*)

Pseudocyclops australis, Nicholls, 1944, p. 12, fig. 4.

Description: FEMALE.—Length, 0·80 to 0·83 mm. The proportional lengths of the anterior and posterior regions of the body are as 73 to 27. The anterior region of the body is oval in shape. The head is separated from the 1st thoracic segment, so are the 4th from the 5th. The lateral distal

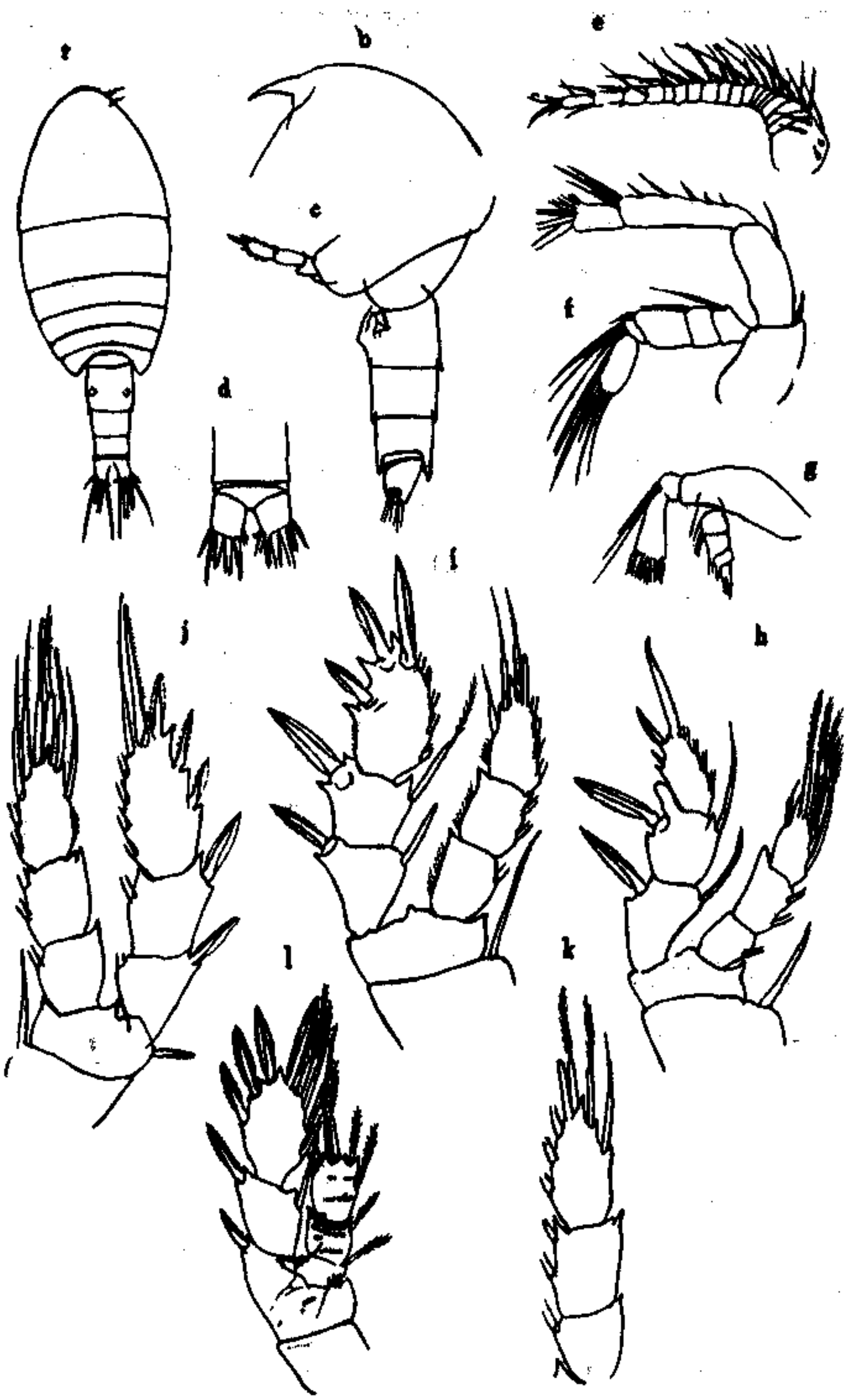

FIG. 6. *Pseudocyclops australis* Nicholls.

Female: *a*, dorsal aspect, ×50; *b*, head, lateral aspect, ×100; *c*, thoracic segments and abdomen, lateral aspect, ×100; *d*, abdominal segments and furca, ×100; *e*, 1st antenna, ×100; *f*, 2nd antenna, ×100; *g*, mandibular palp, ×100; *h*, 1st leg, ×200; *i*, 2nd leg, ×200; *j*, 3rd leg, ×200; *k*, endopod of 4th leg, ×200; *l*, 5th leg, ×200.

margin of the last thoracic segment is narrowly rounded, but the segment is much smaller than the preceding. The rostrum is very strong and pointed.

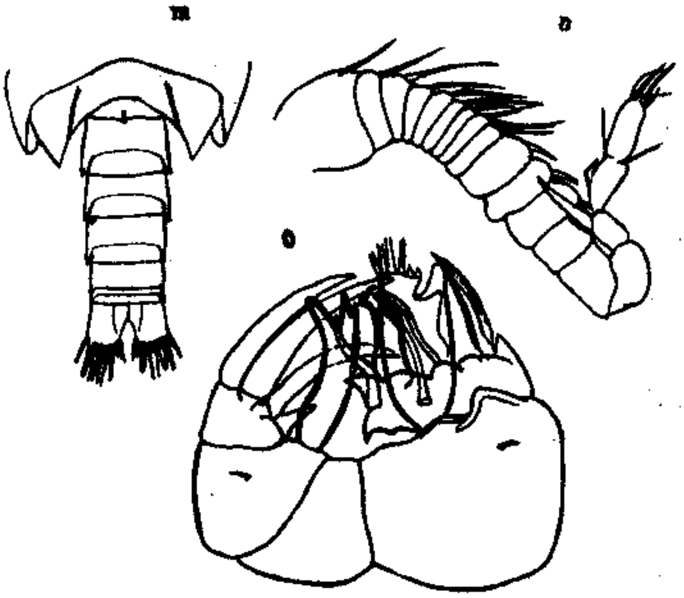

FIG. 7. *Pseudocyclops australis* Nicholls.
Male: *m*, thoracic segments and abdomen, dorsal aspect, ×100; *n*, 1st antenna, ×200; *o*, 5th pair of legs, ×200.

The abdomen is 4-jointed; the segments and furca are in the proportional lengths:

Abd. 1	2	3	4	Furca	
44	15	17	4	20	= 100

The lateral margins of the genital segment are nearly parallel; the ventral surface is slightly produced below. The anal segment is telescoped into the 3rd segment. The furcal rami are about as long as wide.

The 1st antenna is 18-jointed and short, not reaching the distal margin of the head when fully extended. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	148	44	44	44	17	17	17	34	44	44	52	44	52	44	60	78	104	113	= 1000

The mouth parts and the 1st to 5th legs are as illustrated by Nicholls. In the 5th leg the 2nd segment of the endopod is furnished with short dense spinules on the posterior surface.

MALE.—Length, 0·71 mm. The anterior and posterior regions of the body are in the proportional lengths 70 to 30. The general appearance is as in the female. The abdomen is 5-jointed;

the segments and furca are in the proportional lengths:

Abd. 1	2	3	4	5	Furca	
27	18	18	14	5	18	= 100

The segments and furca are much telescoped in the present specimen. The furcal rami are slightly longer than wide (8:6); the distal margin of the ramus is furnished beside the usual seta, with spinules and hairs.

The 1st antenna is 18-jointed. The clasping antenna is on the right side; the segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	153	35	47	29	35	24	18	27	24	53	47	59	53	70	88	62	82	94	= 1000

The 16th segment has a strong spine on the upper margin.

The 5th pair of legs is asymmetrical and resembles that of *Pseudocyclops obtusus* Brady and Robertson. The left leg has 1-jointed exopod, and is of a very complicated structure; the endopod is large and carries 4 setae and 2 small spines on the distal margin; the exopod has a strong outer marginal spine, one large process and two claws on the anterior margin. The right leg has 2-jointed exopod; the 2nd segment of the exopod is represented by two strong claws and a short spine; the outer marginal spine of the 1st segment of the exopod is very strong; the endopod is apically trifid.

Occurrence.—Fairly common in the coastal water of north-western Kyushu.

Distribution.—This species has been recorded by Nicholls from South Australia.

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SOME RARE SPECIES OF HARPACTICOIDA FROM THE IZU REGION

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ABSTRACT

Among harpacticoid copepods the genera *Aegisthus* Giesbrecht and *Misophria* Boeck were known to be bathypelagic. Two new species of *Misophria* taken from deep waters of the Izu region are described.

Aegisthus aculeatus Giesbrecht and *A. mucronatus* Giesbrecht have been recorded from deep waters of the Atlantic Ocean, Pacific Ocean, Malay Archipelago and Laccadive Sea. One of these *A. mucronatus* was taken from the deep water off the Izu region. The other deep-sea harpacticoid copepod, *Misophria pallida* Boeck, was reported by Sars from the west coast of Norway in depths varying from 20 to 50 fathoms. Brady recorded the same species from the English coast, Th. Scott from the Scottish coast and Giesbrecht from the Gulf of Naples.

Family MISOPHRIIDAE

Genus *Misophria* Boeck

The genus *Misophria* is very interesting in having the external appearance of a cyclopoid. However, the genus has been included by Sars in Harpacticoida on the ground that the animal has biramous 2nd antenna and carries a single ventral ovisac. Indeed the species of this genus resemble in some respects the Cyclopoida and partly the Calanoida. It seems reasonable to place it at present in Harpacticoida but it would be more reasonable to transfer it to a new sub-order for the following reasons: general appearance comes nearer to Cyclopoida; the anterior antenna is longer and has more articulations than in Harpacticoida; the swimming legs resemble those of Cyclopoida; the 5th pair of legs resembles in structure that of Cyclopoida.

The family comprises at present of a single species *Misophria pallida* Boeck. The following two species are clearly congeneric with *Misophria* Boeck.

Misophria japonica **sp. nov.**

(Fig. 1, *a–n*; Fig. 2, *a–d*)

Description: FEMALE.—Length, 2·67 mm. The body is soft-skinned. The anterior region of the body measured 1·87 mm.; the posterior region, 0·80 mm. The anterior region of the body considerably expanded. Anteriorly the head terminates in a broad immovable rostrum. The posterior region very narrow and sub-cylindrical in form; the segments of the posterior region are in the following proportional lengths:

Th. 5	Abd. 1	2	3	4	5	Furca	
16	16	18	17	12	10	11	= 100

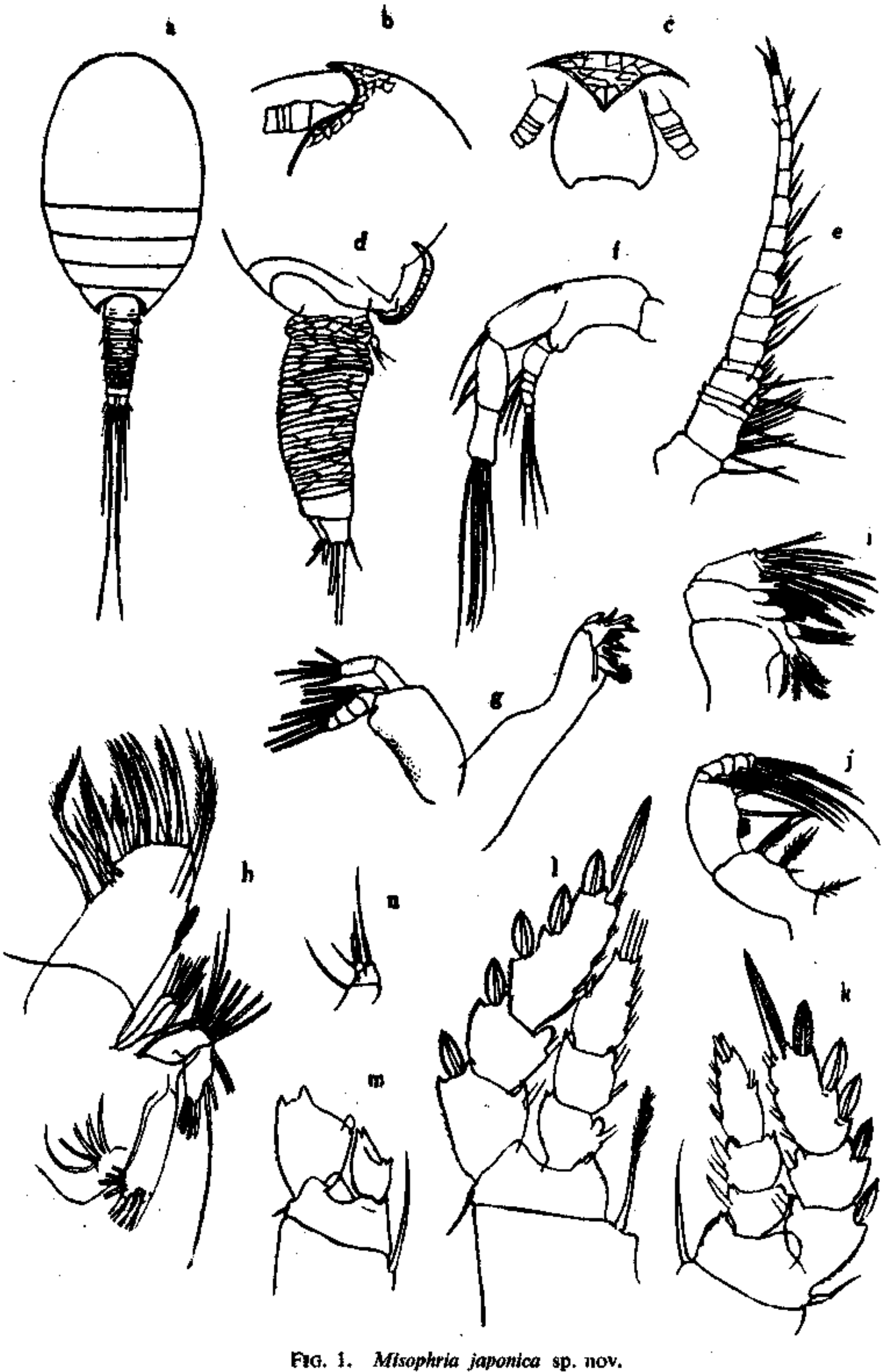

FIG. 1. *Misophria japonica* sp. nov.

Female: (*a*) dorsal aspect, ×14; (*b*) head, lateral aspect, ×35; (*c*) head, anterior aspect, ×25; (*d*) last thoracic segment and abdomen, lateral aspect, ×50; (*e*) 1st antenna, ×50; (*f*) 2nd antenna, ×100; (*g*) mandible, ×50; (*h*) 1st maxilla, ×100; (*i*) 2nd maxilla, ×50; (*j*) maxilliped, ×50; (*k*) 1st leg, ×50; (*l*) 2nd leg, ×50; (*m*) 4th leg, ×50; (*n*) 5th leg, ×100.

The anterior and posterior regions of the body except the anal segment and furca are furnished with fine reticulations. The 5th thoracic segment is acutely and outwardly pointed at the distal margin. The furcal rami are slightly longer than wide: the apical seta is short but well developed.

The 1st antenna is 18-jointed, short, just extending to the distal margin of the head. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	107	99	21	20	64	35	53	53	47	53	42	53	69	53	69	41	41	80	= 1000

The proximal segments are fringed with minute spinules only along the posterior margin.

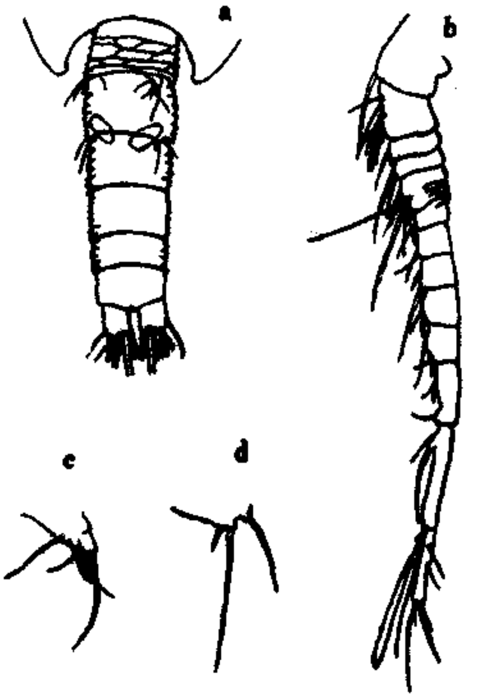

FIG. 2. *Misophria japonica* sp. nov.

Male: (*a*) last thoracic segment and abdomen, dorsal aspect, ×35; (*b*) 1st antenna, ×50; (*c*) 5th leg, ×100; (*d*) 6th leg, ×100.

The 2nd antenna is composed of 2 basal segments, 6-jointed exopod and 3-jointed endopod; the endopod is strong, 2·5 times as long as the exopod and carries 5 setae on the distal margin of the 2nd segment. The mandibular palp is large; the exopod is 5-jointed; the endopod is 2-jointed; the masticatory lobe is slender, with 8 teeth and an inner marginal spine. The 1st maxilla is well developed as in Calanoida; the 1st inner lobe is furnished with 10 strong spines, 3 delicate ones; 2 setae arise from the anterior margin; the 2nd inner lobe has 3 setae on the distal margin; the 3rd inner lobe has 2 setae on the distal margin; the 2nd outer lobe is furnished with 4 marginal and 4 terminal setae; the 1st outer lobe is furnished with 5 setae. The 2nd maxilla is

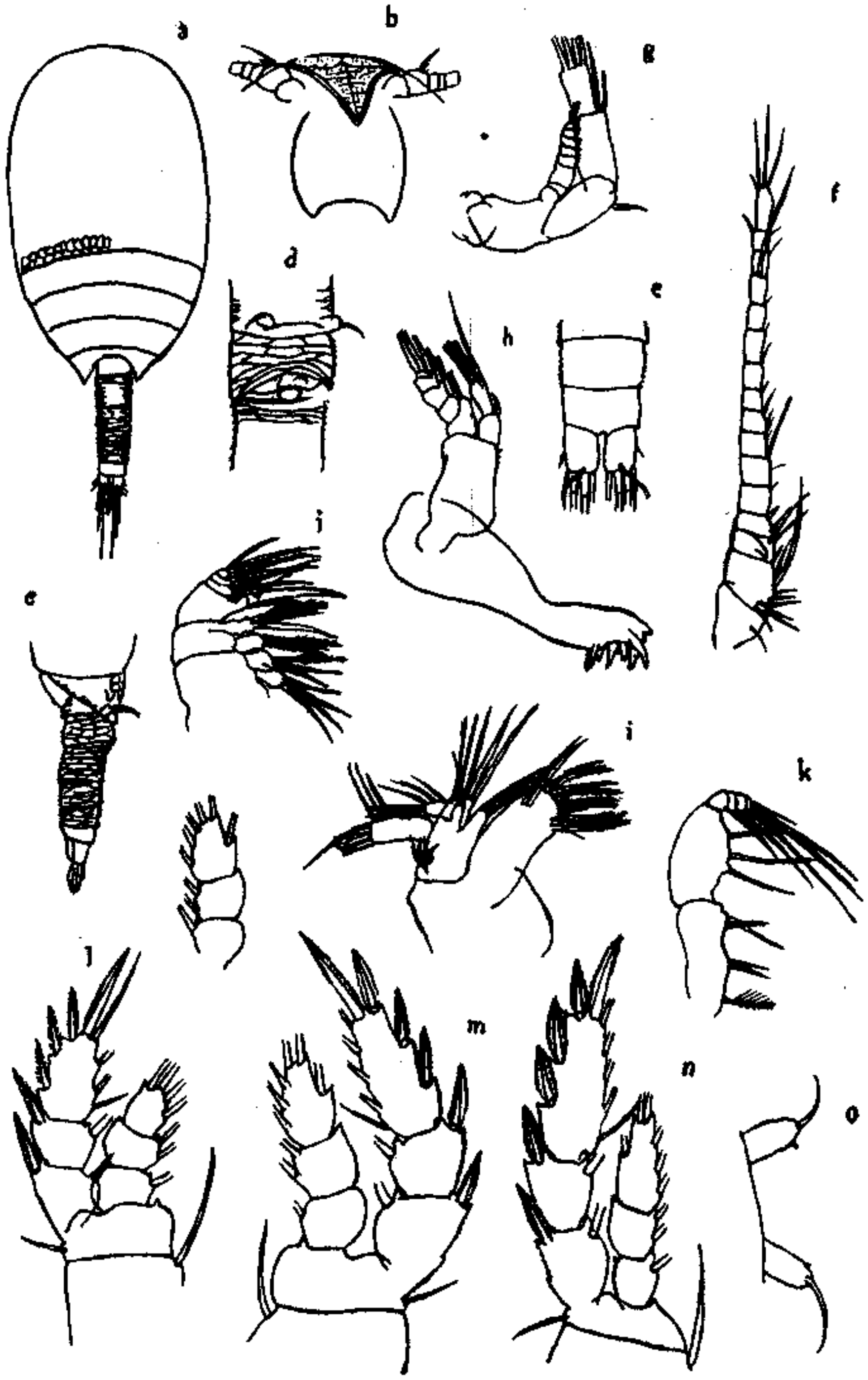

FIG. 3. *Misophria maculata* sp. nov.

Female: (*a*) dorsal aspect, ×35; (*b*) head, anterior aspect, ×100; (*c*) last thoracic segment and abdomen, lateral aspect, ×35; (*d*) abdomen, proximal segments, ventral aspect, ×100; (*e*) abdomen, distal segments, ventral aspect, ×100; (*f*) 1st antenna, ×100; (*g*) 2nd antenna, ×100; (*h*) mandible, ×100; (*i*) 1st maxilla, ×100; (*j*) 2nd maxilla, ×100; (*k*) maxilliped, ×100; (*l*) 1st leg, ×100; (*m*) 2nd leg, ×100; (*u*) 3rd leg, ×100; (*o*) 5th pair of legs, ×100.

robust, has a general resemblance to that found in Calanoida and is furnished with 4 marginal and 4 terminal setae; the 5th outer lobe is not modified into a strong claw as is seen in *Misophria pallida* figured by Sars. The maxilliped is as in Calanoida and is composed of 2 basal joints and 5-jointed endopod.

The 1st to 4th swimming legs have each 3-jointed exopod and endopod; the segments are broad. In the 1st leg the 2nd basal segment has a pointed process, bifid at the apex on the inner distal corner. The 2nd to 4th legs have each 5 inner marginal setae on the 3rd segment of the exopod.

The 5th pair of legs is small, 3-jointed and biramous; a small endopod arises from the middle of the 2nd segment and carries 3 distal setae. The 6th leg carries 2 setae and a small spine.

MALE.—Length, 2·82 mm. The proportional lengths of the anterior and posterior regions of the body are as 69 to 31. General appearance as in the female. The posterior region has the segments and furca in the following proportional lengths:

Th. 5	Abd. 1	2	3	4	5	Furca	
16	22	16	16	10	10	10	= 100

The furcal rami are slightly longer than wide.

The 1st antenna is 13-jointed, and modified into a clasping organ; the proximal 5 segments are broad; the middle section is 6-jointed; the hinge joint is situated between segments 11 and 12; the distal section is 2-jointed.

The mouth parts and swimming legs are as in the female. The 5th pair of legs is just as in the female.

Remarks.—The present species closely resembles *Misophria pallida* Boeck but is easily distinguished from it by the structure of the 2nd maxilla and the 5th pair of legs.

Occurrence.—One female and a male from depths 1000–0 m. in the Izu region.

Distribution.—Izu region, the Pacific coast of Middle Japan.

Misophria maculata **sp. nov.**

(Fig. 3, *a–o*)

Description: FEMALE.—Length, 1·39 mm. The body is soft-skinned. The proportional lengths of the anterior and posterior regions of the body are as 74 to 26. The body is furnished with fine reticulations except the anal segment and furca. The anterior region is rounded oval in shape. The head is fused with the 1st thoracic segment. The immovable rostrum is triangular and projects downwards. The lateral distal corner of the 4th thoracic segment is pointed at the apex.

The posterior region of the body has the segments and furca in the following proportional lengths:

Th. 5	Abd. 1	2	3	4	5	Furca	
19	19	17	13	12	10	10	= 100

The genital segment is produced below on the ventral surface; the genital opening lies on the ventral distal margin. The furcal rami are longer than wide (8 : 6) and carry on each side a well-defined apical seta, The 1st antenna is 16-jointed, does not extend to the distal margin of the head and is 0·44 mm. long. The segments are in the following proportional lengths:

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	138	80	46	34	58	52	52	46	58	58	68	58	68	46	46	92	= 1000

The proximal segments are furnished with minute spinules along the posterior margin.

The 2nd antenna is biramous; the exopod is 2-jointed; the distal segment of the exopod carries 2 setae, the remaining 5 segments of the exopod have each a single seta on the inner distal margin; the endopod is 3-jointed, much stronger than the exopod. The mandible is biramous; the palp is large; the exopod is 5-jointed; the endopod is 2-jointed; the biting blade has 7 teeth and a spine. The 1st maxilla is well developed; the 1st inner lobe has 9 strong spines and a smaller one and 3 setae; the 2nd inner lobe has 2 setae; the 3rd inner lobe has 2 setae; the endopod is small and has 5 setae; the exopod is moderately large, has 4 terminal and 3 marginal setae; the outer lobe carries 5 setae. The 2nd maxilla has 5 lobes on the inner margin; the 5th lobe has a strong claw and 2 feeble setae. The maxilliped consists of 2 large basal segments and a small 5-jointed endopod.

The 1st to 4th swimming legs have each 3-jointed exopod and endopod; the segments of the exopod and endopod are broad. In the 1st leg the 3rd segment of the exopod has 4 inner marginal setae; the distal segment of the endopod was abnormal in structure in the present specimen; the segment has only 4 setae instead of 6. The 2nd to 4th legs have each 5 setae on the inner margin of the 3rd segment of the exopod.

The 5th pair of legs is simple in structure, very small, 1-jointed, and carries a long seta on the apex and a small spine on the inner margin.

The 6th leg was not observed.

Remarks.—The present species comes nearer to *Misophria pallida* than the foregoing species in the structure of the mouth parts and also in the swimming legs. But it can be easily recognized by the size and by the simple structure of the 5th pair of legs in the female.

Occurrence.—One female from depths 1000–0 m. in the Izu region.

Distribution.—Izu region, the Pacific coast of Middle Japan.

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PRELIMINARY REPORT ON THE COPEPODS FOUND IN THE TIDE POOL ALONG THE NORTH-WEST COAST OF KYUSHU

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ABSTRACT

In Japan, pelagic copepods are fairly well known. However, the neritic and littoral species are unfortunately obscure. In the present paper the following species are reported: two species of *Acartia*, one species of *Pseudodiaptomus* and six species of Harpacticoida. These samples were collected from the tide pool in the rocky shore of the north-west coast of Kyushu in August 1964.

THE samples were collected from tide pools along the coast of Shingu, a small town near Fukuoka City, by using a small silk-net in August, 1964. These pools directly communicate with sea-water outside during spring tide but are isolated from it during the neap tide. The samples were rich in species. In the present paper only a few species of Calanoida and Harpacticoida will be described.

CALANOIDA

Family PSEUDODIAPTOMIDAE

Genus *Pseudodiaptomus* Herrick

***Pseudodiaptomus marinus* Sato**

Pseudodiaptomus marinus Sato, 1913, p. 28, pl. 7, figs. 69–71.

Length.—MALE, 1·16 mm.

Occurrence.—Two male specimens were taken at Shingu tide pool.

Distribution.—Coastal waters of Japan.

Family ACARTIIDAE

Genus *Acartia* Dana

***Acartia clausii* Giesbrecht**

Acartia clausii Giesbrecht, 1889, *Atti Accad. Lincei. Rome*, p. 25; 1892, p. 507, pls. 30, 42, 43.

Acartia clausii Mori, T. 1937, p. 103, pl. 50, figs. 8–13.

Length.—FEMALE, 0·96 to 1·04 mm.; MALE, 0·85 to 1·02 mm.

Occurrence.—Thirteen females and four males at Shingu tide pool.

Distribution.—This species has a wide distribution in the Arctic Ocean, Pacific, Atlantic and Indian Oceans.

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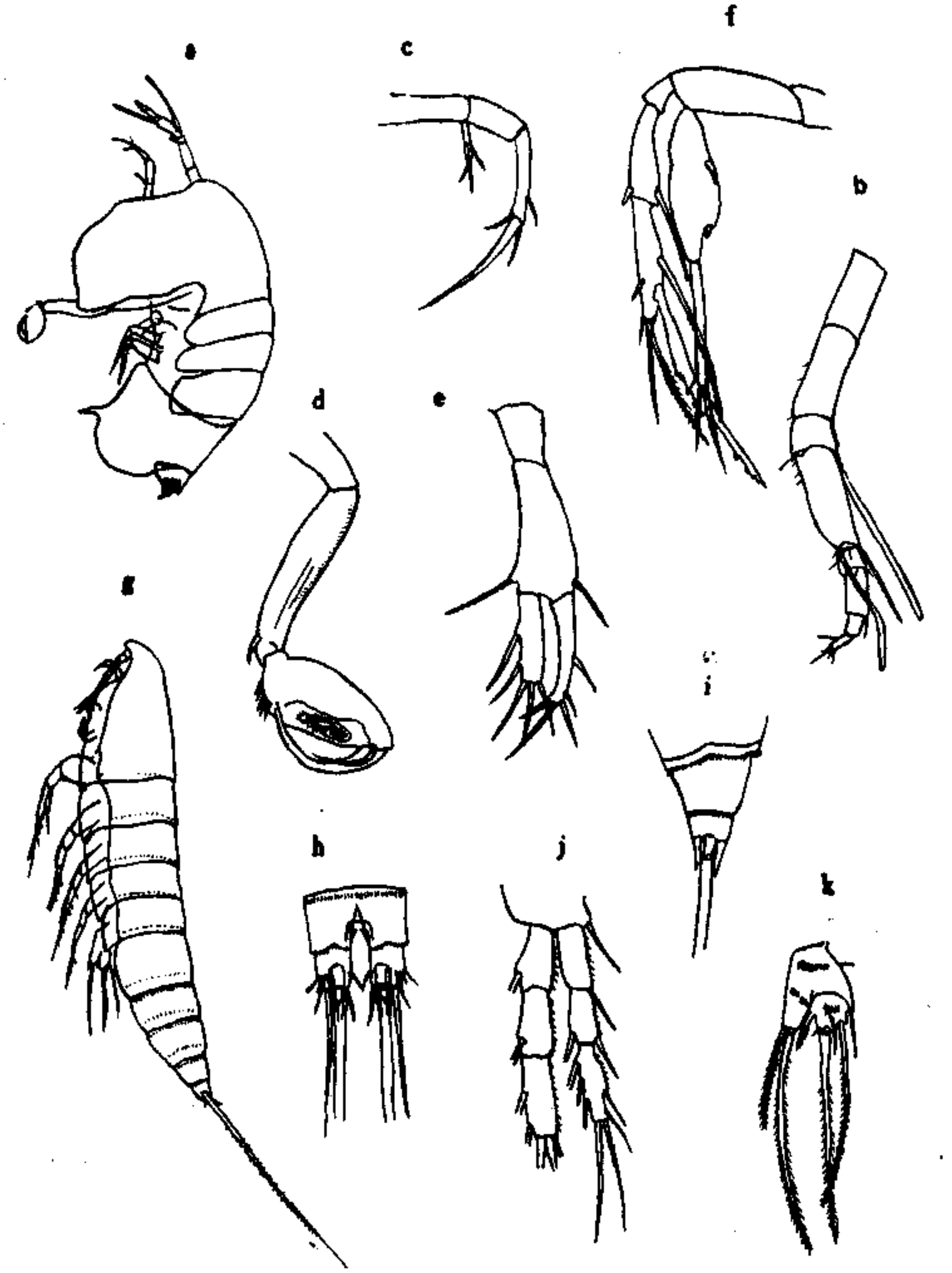

FIG. 1. *Syngastes pietschmanni* Pesta (*a–f*).

Female: (*a*) Lateral view, ×100; (*b*) 1st antenna, ×300; (*c*) 2nd antenna, ×300; (*d*) Maxilliped, ×300; (*e*) 1st leg, ×300; (*f*) 4th leg, ×300.

Microsetella norvegica (Boeck) (*g–k*).

Female: (*g*) Lateral view, ×75; (*h*) Furca, dorsal view, ×150; (*i*) Furca, lateral view, ×150; (*j*) 4th leg, ×50; (*k*) 5th leg, ×150.

Acartia erythraea Giesbrecht

Acartia erythraea Giesbrecht, 1889; 1892, p. 508, pls. 30, 40. Mori, 1937, p. 102, pl. 50, figs. 1–4.

Length.—FEMALE, 1·31 to 1·48 mm.; MALE, 1·18 to 1·27 mm.

Occurrence.—More than twenty females and six males were taken at Shingu tide pool.

Distribution.—South Coast of China, Arabian Sea, Malay Archipelago and Pacific Ocean.

HARPACTICOIDA

Family ECTINOSOMIDAE

Genus *Microsetella* Brady and Robertson

Microsetella norvegica **(Boeck)**

(Fig. 1, *g-k*)

Setella norvegica Boeck, 1864, p. 281.

Microsetella norvegica, G. O. Sars, 1911, p. 44, pl. 24; Wilson, 1932, p. 176; Lang, 1948, p. 230.

FEMALE.—Length, 0·55 mm.

The body is extremely slender and compressed, almost linear in form, the cephalic segment is dorsally flattened. The rostrum is short and abruptly deflexed. The first antenna is six-segmented. The segments of the urosome with rows of minute spinules arranged transversely. The caudal rami are scarcely shorter than broad, in the lateral view two of the distal setae are situated between these two triangular plates, as is shown in the figure given by Giesbrecht (1892, Taf. 44).

The inner expansion of the proximal segment of the fifth leg reaches the tip of the distal segment, its inner seta is shorter than the outer and is nearly half the length of the outer seta.

Occurrence.—One specimen was taken at Shingu tide pool.

Distribution.—This species is widely distributed in all the oceans.

Family PELTIDIIDAE Sars

Genus *Peltidium* Philippi

Peltidium laudatum **sp. nov.**

(Fig. 2, *a-o*; Fig. 3, *a-l*)

FEMALE.—Length, 1·1 to 1·46 mm.

The body is elliptical in outline and very broad; the lateral margins of the head are turned ventrally; the anterior margin of the cephalic segment is very wide and is contained one and four-fifth times in the total body length.

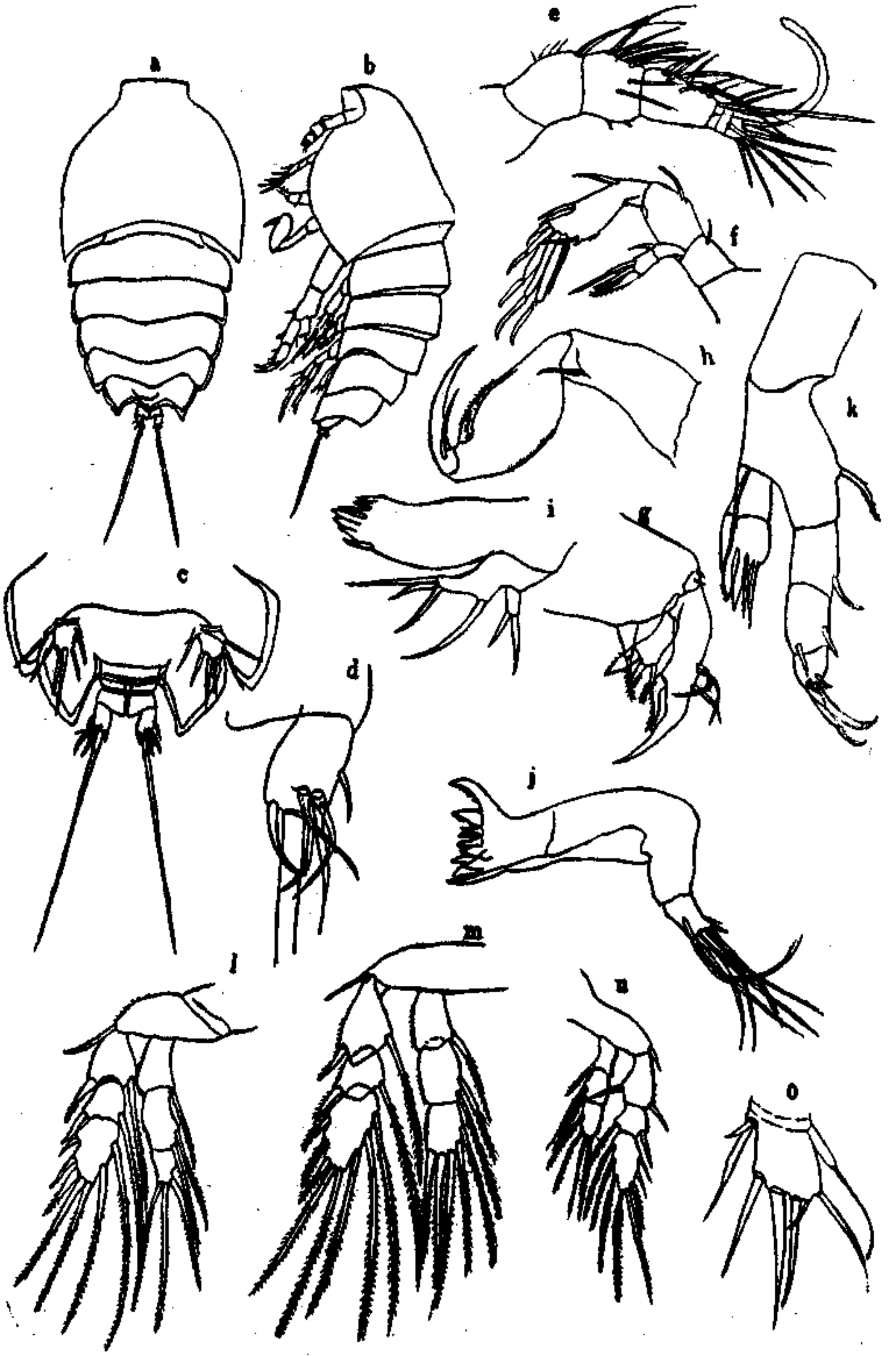

FIG. 2. *Peltidium laudatum*, sp. nov. (*a–o*).

Female: (*a*) Dorsal view, ×25; (*b*) Lateral view, ×25; (*c*) Dorsal view of genital seg. and furca, ×50; (*d*) Furca, ×200; (*e*) 1st antenna, ×150; (*f*) 2nd antenna, ×150; (*g*) 2nd maxilla, ×150; (*h*) Maxilliped, ×150; (*i*) Maxilla, ×150; (*j*) Mandible, ×150; (*k*) 1st leg, ×100; (*l*) 2nd leg, ×75; (*m*) 3rd leg, × 75; (*n*) 4th leg, ×75; (*o*) 5th leg, ×150.

The proportional lengths in the dorsal median line of the body are as follows:

Ceph.	2nd seg.	3rd	4th	5th	Genital seg.	
46	15	12	10	8	9	= 100.

The rostrum is very large and produced, the frontal margin is truncate and extremely broad: the distal ends of the cephalic and thoracic segments are pointed and produced posteriorly.

The genital segment is very large and much produced posteriorly reaching the end of the *furcal joints; the furcal joints are 1·5 times as long as wide; the middle part of the outer margin* of the ramus is furnished with one small and short seta. The antennae are six-jointed, first three joints are very long and stout. The joints have the following proportional lengths:

Joint	1	2	3	4	5	6	
	33	24	25	7	3	8	= 100.

In the first leg, the exopod is 3-jointed and stout; the lengths of first and second joints are nearly the same, the third joint is very short, armed with two short spines and two slender curved claws on the apex. *The endopod is 2-jointed, and much shorter than the exopod, the joints* are equal in length and width, the apex of the second joint is furnished with two stout, broad spines and two setae. The second, third and fourth legs are as figured. The distal joint of the 5th pair of legs is wide and diamond-shaped, furnished with 5 setae, of which the second outer marginal seta is stout and long; the fourth seta is short and bends inwardly.

MALE.—Length, 1·10 to 1·27 mm.

The body is a little smaller than in the female; more or less different in structure from that of female. The body is oval and broad in outline, the lateral margins of the head are turned ventrally; the cephalic segment is much wider than the remaining segments, and is contained nearly 1·9 times in the total length.

The proportional lengths in the dorsal median line of the body are as follows:

Ceph.	2nd	3rd	4th	5th	Geni.	
43	13	10	10	9	15	= 100.

The rostrum is very large and produced, the frontal margin is broadly rounded. The furcal rami are 2·3 times as long as wide, and turn inwardly.

The 1st antennae are 7-segmented, the 6th joint is very small. 2nd antenna, mandible and maxillae are similar to those of the female, but the maxilliped is well developed, the 2nd joint is stout and swollen, the anterior margin is densely covered with small needle-like spinules, and is armed with a very strong claw, strongly curved and somewhat screwed at the distal portion, the claw is furnished with one long seta and one small seta at the anterior proximal margin.

In the first pair of legs the exopod is much wider than the endopod, the 2nd joint is much longer than the 1st joint; the 3rd joint is very short, armed with three short spines and two slender curved claws on the apex, the endopod has the 1st and 2nd joints of equal length. The 2nd, 3rd and 4th legs are similar in structure to those of the female.

The 5th pair of legs is small but robust; the proximal segment has one seta on the outer distal margin and two setae on the inner margin, of the latter one is small; *the distal segment is armed* with five setae, the second outer marginal seta is broad and strongly developed, the distal half is differentially branched.

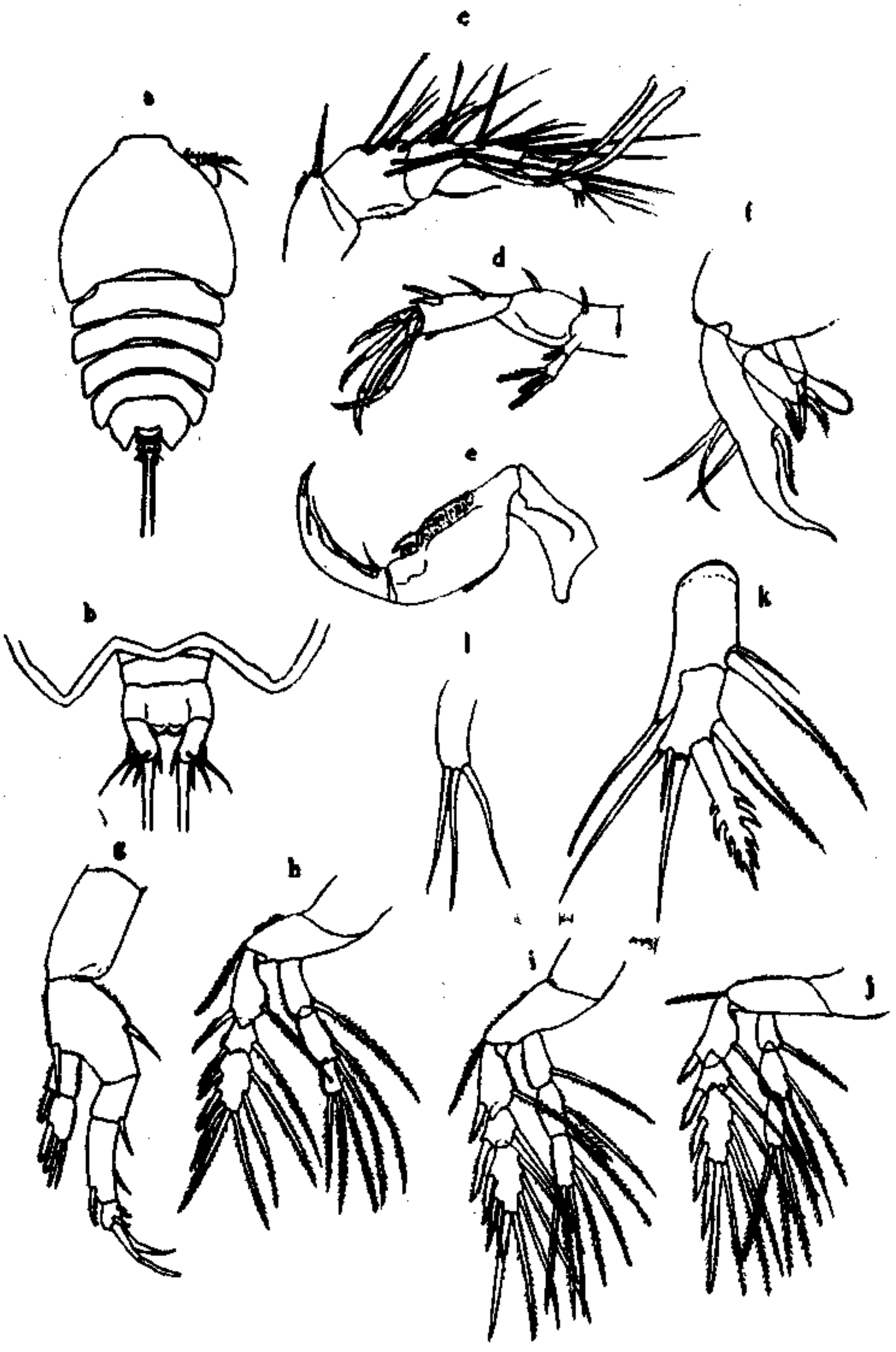

FIG. 3. *Peltidium laudatum* sp. nov. (*a–l*).

Male: (*a*) Dorsal view, ×25; (*b*) Furca, dorsal view, ×100; (*c*) 1st antenna, ×100; (*d*) 2nd antenna, ×75; (*e*) maxilliped, ×150; (*f*) 2nd maxilla, ×100; (*g*) 1st leg, ×75; (*h*) 2nd leg, ×85; (*i*) 3rd leg, ×75; (*j*) 4th leg, ×75; (*k*) 5th leg, ×200; (*l*) 6th leg, ×200.

Remarks.—The female resembles *Peltidium intermedium* (A. Scott, 1909) when viewed from the dorsal, but in *P. intermedium* the urosome is longer in proportion to that of the present species. The endopod of the first leg is much broader in *P. intermedium*: the fifth pair of legs of the present species is different in shape from that of *P. intermedium*. The furcal ramus of *P. intermedium* is devoid of a seta on the middle of the outer margin, whereas, the middle seta is present in the present specimen.

The male resembles *P. exiguum* (A. Scott, 1909) and *P. minutum* (A. Scott, 1909), but in the present species the endopod of the first leg is much narrower, and the 2nd segment of the maxilliped is distinctly different; in the present species the anterior margin of the 2nd segment of the maxilliped bears one stout claw-like spine.

Occurrence.—Four females and three males were taken at Shingu tide pool.

Family TAGASTIDAE

Genus *Syngastes* Monard

Syngastes pietschmanni **Pesta**

(Fig. 1, *a-f*)

Syngastes pietschmanni Pesta, 1932, S. 155 Abb. 5, 6: 1, Taf. 4, Abb. 2. Lang, 1948, p. 487, Abb. 203.

IMMATURE FEMALE.—Length, 0·29 mm.

The body in lateral view is almost circular in outline, with the back much curved; the head is fused with the first thoracic segment, and is greatly produced downwards and backwards, the anterior margin is denticulated.

The 1st antenna is 8-segmented; the first 2 segments and the 4th segment are considerably longer than the others. The 2nd antenna has one-segmented exopod with three setae on the distal margin; the endopod is very slender; the terminal segment is armed with three setae on the tip and one on the outer $\frac{1}{3}$ of the distal margin, the middle of the distal margin is very strong and prolonged.

The maxilliped is exceedingly long, the 1st segment is fringed with plumose hairs on the posterior margin, and a short spine on the anterior distal part; the 2nd segment is broad, fringed with small needle-like spinules on the anterior margin, the end claw is strongly curved and with a seta near the base.

The 1st leg has one-jointed exopod and endopod, the rami of the 1st leg are shorter than the 2nd basal joint; the exopodal segment is more or less slender and longer than the endopod; both rami are armed with five spiniform setae; three of them are on the distal margin.

In the 4th leg, the exopod consists of three segments, the 1st segment of the exopod is very small, distal segment is more or less longer than the 2nd segment, the distal segment with two small outer marginal spines, two apical setae, and a long inner marginal seta bearing a strongly developed long spine, which looks like a blunted sword, its outer margin has 8 teeth-like bumps; the endopod is 2-segmented, the proximal segment is broad and swollen in the middle, it has two short spines on the inner margin, the distal segment is slender and stick-like, it is as long as the proximal segment and has two apical setae and one seta on the outer margin.

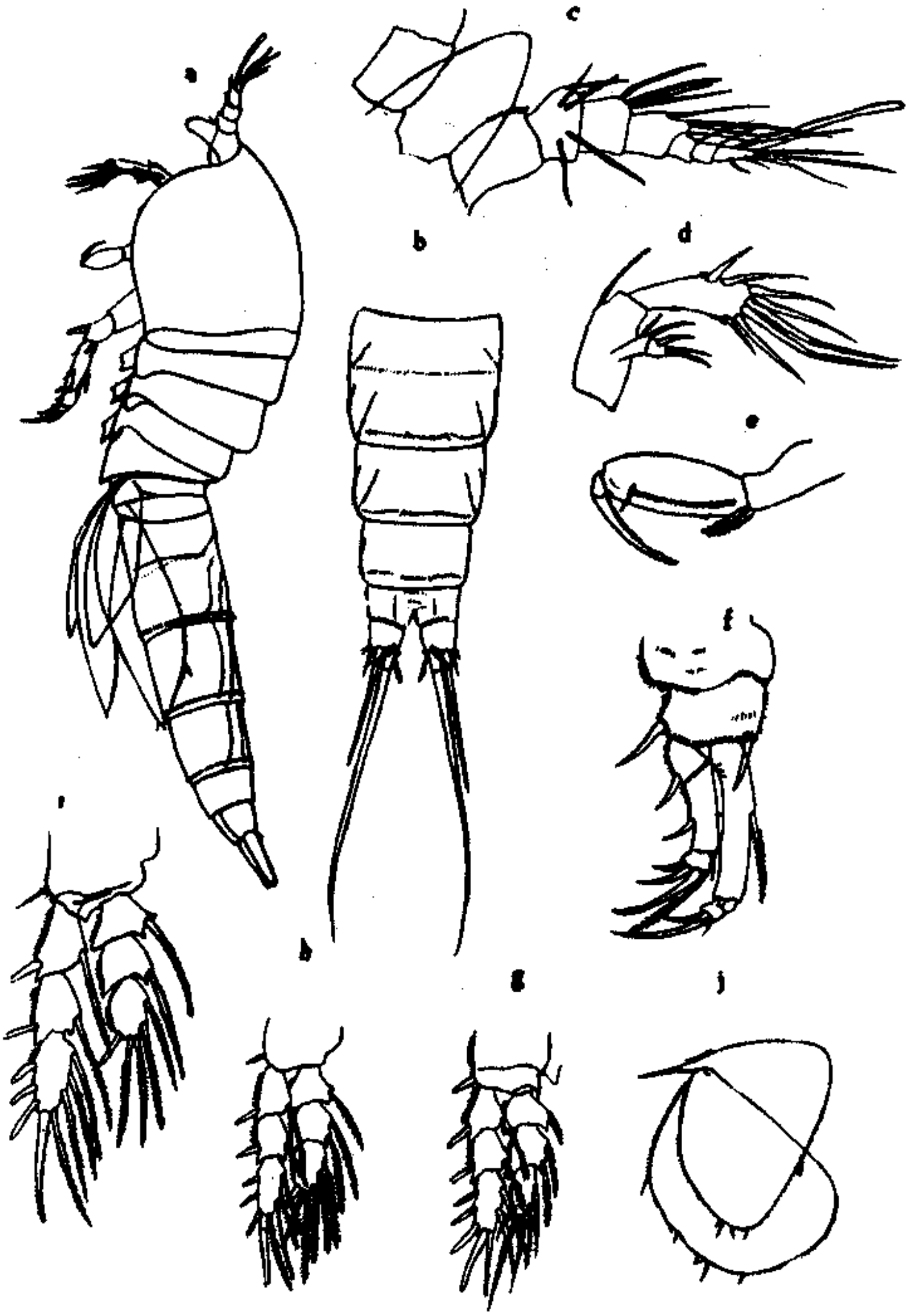

FIG. 4. *Eudactylopus latipes* (T. Scott) (*a–j*).

Female: (*a*) Lateral view, ×50; (*b*) Abdomen, dorsal view, ×50; (*c*) Rostrum and 1st antenna, ×150; (*d*) 2nd antenna, ×75; (*e*) Maxilliped, ×200; (*f*) 1st leg, ×100; (*g*) 2nd leg, ×75; (*h*) 3rd leg, ×75; (*i*) 4th leg, × 150; (*j*) 5th leg, ×50.

Remarks.—The present specimen is smaller in size than that reported by Pesta (1932) and appears to be an immature stage.

Occurrence.—One specimen was taken at Shingu tide pool.

Distribution.—Coast of Hawaii Island (Pesta, 1933).

Family THALESTRIDAE Sars

Subfamily DACTYLOPODIINAE Lang

Genus *Eudactylopus* A. Scott

Eudactylopus latipes (T. Scott)

(Fig. 4, *a-j*)

Dactylopus latipes, T. Scott (non Boeck), 1893, p. 99, pl. X, figs. 38-43.

Eudactylopus latipes; Sewell, 1940, pp. 201-07, text-figs. 31-32.

Eudactylopus latipes, T. Scott, 1909, p. 219, pl. LXIII, figs. 8-14.

Eudactylopus latipes, Lang, 1948, p. 561, Abb. 227.

FEMALE.—Length, 1·45 mm.

The anterior division is stout and more or less depressed, posterior part is rather slender, the anterior region is a little shorter than the posterior region. The cephalic segment is well developed; the rostrum is long and sharply pointed at the apex. The abdomen is composed of four segments; the genital segment is very wide and long, but the anal segment is very short; the genital, 2nd and 3rd segments are each fringed with three rows of fine spinules, one of which is parallel to the distal margin of the segment, and the other two run obliquely near the lateral margin.

The furcal rami are slightly shorter than broad, and more or less divergent; the 2nd furcal seta is much longer than the others, and is about as long as the combined lengths of the abdominal segments and furca.

The first antenna is 7-segmented, the 1st segment is long, broad and stout, the 2nd, 3rd and 4th segments also well developed, 5th and 6th segments are short and small, but terminal segment is elongated. In the second antenna the exopod is 2-segmented; the basal segment has two setae; the terminal segment bears three setae, agreeing well with the figure given by Sewell (1940, p. 210, Text-Fig. 35).

The maxilliped has no characteristic features.

In the first leg the exopod is 3-segmented; the distal segment is very short and bears three claws and one seta; the endopod is 2-segmented, the 1st segment is much longer than the 2nd, the terminal joint is short, and is armed with one large stout claw, one small claw and a short seta on the distal margin.

In the 2nd and 3rd legs both rami are 3-segmented, and the 2nd segment of the endopod bears two setae, but in the 4th leg the 2nd segment of the endopod bears only one seta.

The setal formula of the 2nd to 4th legs is as follows:

	Endopod			Exopod		
	1	2	3	1	2	3
P_2	1	2	2·2·1	1	1	2·2·3
P_3	1	2	3·2·1	1	1	3·2·3
P_4	1	1	2·2·1	1	1	3·2·3

The fifth pair of legs is 2-segmented and extends to the end of the second abdominal segment; the segments are very large and foliaceous, the proximal segment is broad and wedge-shaped; the outer margin of the segment is furnished with five short feeble setae; the distal segment is sub-quadrate in outline and bears six short feeble setae, and is fringed with short hairs on the periphery.

Occurrence.—Three specimens were taken at Shingu tide pool.

Distribution.—Nankauri Harbour, Nicobar Islands, East coast of Aru Islands (T. Scott, 1909).

Family DIOSACCIDAE Sars

Genus *Metamphiascopsis* Lang

Metamphiascopsis hirsutus **(Thompson and A. Scott)**

(Fig. 5, *a-m*)

Dactylopusia hirsutus, Thompson and Scott, 1909, pl. 9, figs. 19–24.

Amphiascus hirsutus, T. Scott, 1909, p. 221.

Amphiascus hirsutus, Sewell, 1940, pp. 247–51.

Metamphiascopsis hirsutus Lang, 1948, p. 683, Abb. 275.

FEMALE.—Length, 1·25 mm.

The body is slender and cylindrical; the anterior division is broader than the posterior, the proportional lengths of the anterior and posterior regions of the body are as 54 to 46.

The proportional lengths of the body are as follows:

Ce.	2nd	3rd	4th	5th	Abd.	1–2nd	3rd	4th	5th	Fu.
28	9	9	7	7	..	17	8	8	5	2=100.

The rostrum is very prominent and slightly curved downwards; a small seta arises on each side near the apex. The first antenna is 9-segmented, first two and 4th joints are very long. The proportional lengths of the segments are as follows:

Segment:	1	2	3	4	5	6	7	8	9
	21	19	10	17	5	8	5	5	10 = 100.

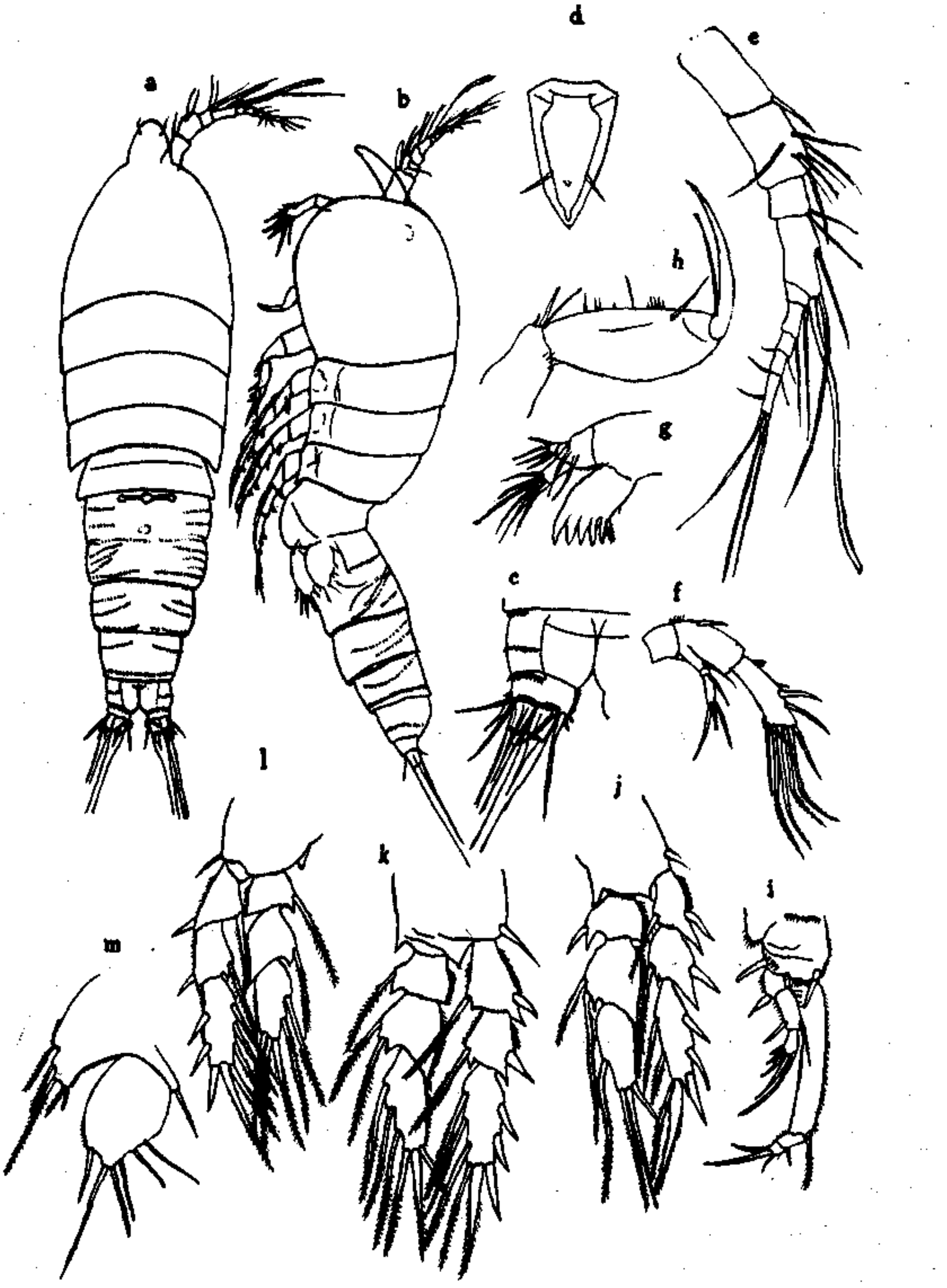

FIG. 5. *Metamphiascopsis hirsutus* (Thompson and A. Scott) (*a–m*).

Female: (*a*) Dorsal view, ×50; (*b*) Lateral view, ×50; (*c*) Furca, ×100; (*d*) Rostrum, ×150; (*e*) 1st antenna, ×100; (*f*) 2nd antenna, ×150; (*g*) Mandible, ×75; (*h*) Maxilliped, ×200; (*i*) 1st leg, ×75; (*j*) 2nd leg, ×100; (*k*) 3rd leg, ×100; (*l*) 4th leg, ×100; (*m*) 5th leg, ×75.

According to Sewell (1940, p. 248) the proportional lengths of the antennal segments are as follows:

Segment:	1	2	3	4	5	6	7	8	9
	26	17	18	15	6	8	5	5	10 = 100.

Thompson and A. Scott have given the following proportions:

Segment:	1	2	3	4	5	6	7	8	9
	20	20	10	15	4	7	6	4	13 = 100

The proportional lengths of the antennal segments are more or less different from those of the above two specimens.

The exopod of the second antenna is 3-segmented, 1st and 3rd segments are long but the 2nd segment is very short; 1st segment bears one seta, and the distal segment bears four setae, of which three are on the distal margin and one seta on the inner proximal margin.

The maxilliped has needle-like spines on anterior margin of the 2nd segment and the terminal claw bears two setae near the base.

The 1st leg has 3-segmented exopod and endopod, exopod is very short, it is about two-thirds the length of the 1st segment of the endopod; the outer margin of the 1st and 2nd segment is armed with a strong spine; the distal segment bears four spines and one seta; the inner margin of the 1st segment of the endopod is fringed with a row of small setae; the distal segment is armed with two strong claws and one small seta.

In the 2nd to 4th legs the setal formula is exactly the same as described by Sewell (1940, p. 250) but according to Lang (1948, p. 684, Abb. 275) the 2nd segment of the endopod of the 4th leg bears two setae.

The setal formula of the 2nd to 4th legs is as follows:

	Endopod			Exopod		
	1	2	3	1	2	3
P_2	1	2	1·2·1	1	1	2·2·3
P_3	1	2	3·2·1	1	1	3·2·3
P_4	1	1	2·2·1	1	1	3·2·3

The proximal segment of the 5th leg is wide; the inner expansion of the segment extends beyond the middle of the distal segment, and is armed with 5 setae, the distal segment is broadly oval and bears six marginal setae.

Occurrence.—Three females were taken at Shingu tide pool.

Distribution.—Nicobar Island (Sewell, 1940).

Family METIDAE Sars

Genus *Metis* Philippi (*Ilyopsyllus* Brady and Robertson)

***Metis holothuriae* (Edwards)**

(Fig. 6, *a-l*)

Abacola holothuriae sp. nov., Edwards, 1891, S. 92, Taf. V, Abb. 1–17.

Metis jusseaumei, Sewell, 1940, pp. 346–51, Text-Figs. 86, 87, 88.

Metis holothuria, Lang, 1948, p. 777, Abb. 315, Fig. 2.

FEMALE.—Length, 0·35 to 0·46 mm.

The body is short and stout; the cephalic segment is very large and swollen, the anterior and posterior regions of the body are as 67–33, it has the same proportion reported by Sewell (1940).

The rostrum is large and acute-angled, triangular and tipped with two movable juxtaposed spines; its basal joint is furnished with one short seta on each side.

The caudal rami are about as long as broad, the inner apical setae is a little shorter than the body length, the outer one is much shorter.

The first antenna is 6-segmented, 1st and 2nd segments are very stout and swollen; the last three segments are small. In the second antenna the terminal segment is armed with 6 spines, one of the distal spines is very long.

The first leg has 3-segmented exopod, the terminal segment is armed with two coarse spines and two long satae, the endopod is 2-jointed and has two strong terminal spines, of which one is longer than the other.

In the 2nd, 3rd and 4th legs the exopod and endopod are 3-segmented, the setal formula of the legs is as follows:

	Endopod			Exopod		
	1	2	3	1	2	3
P_2	0	0	1·2·1	0	1	(1·1·3) 1·2·2
P_3	1	0	2·2·0	0	1	2·2·2
P_4	1	0	(2·1·1) 2·2·0	0	1 (0)	(2·1·3) 2·2·2

According to the descriptions of Sewell (1940, pp. 346–51) and Lang (1948, p. 776), the setal formula of the legs seems to be different according to the localities in which the specimens were taken.

The 5th pair of legs is fused into a single lamina, its shape varies even in specimens taken in the same locality, three different shapes are observed and figured (Fig. 6, i); it is caused by body length.

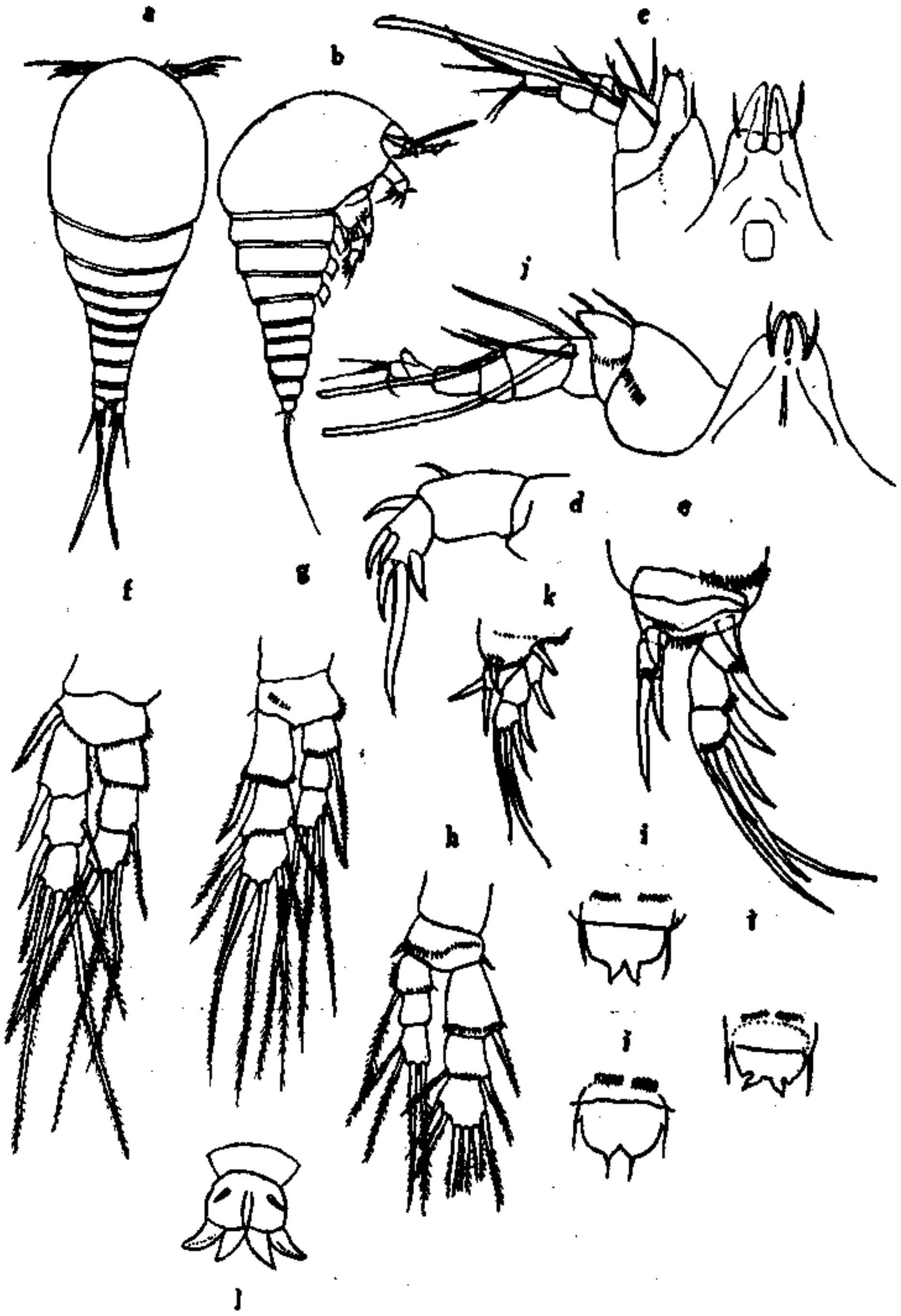

FIG. 6. *Metis holothuriae* Sars (*a–l*).

Female: (*a*) Dorsal view, ×75; (*b*) Lateral view, ×75; (*c*) Rostrum and 1st antenna, ×300; (*d*) 2nd antenna, ×300; (*e*) 1st leg, ×300; (*f*) 2nd leg, ×300; (*g*) 3rd leg, ×300; (*h*) 4th leg, ×300; (*i*) 5th leg, ×300. Male: (*j*) Rostrum and 1st antenna, ×300; (*k*) 1st leg, ×150; (*l*) 5th leg, ×300.

MALE.—Length, 0·34 to 0·39 mm.

The body is smaller and more slender than in the female, the male resembles the female in general appearance. The 1st antenna is 8-segmented, 1st and 2nd joints are large and swollen, the 3rd and 4th segments have each a slender aesthetask, the 7th segment has a dentiform projection. The rostrum is a little wider in proportion to that of the female, and the two movable apical spines are blunt at their tips, and more or less inwardly curved. The first three pairs of legs are exactly of the same structure as in the female.

The fifth pair of legs is fused into a lamina with two small digitiform lappets on both sides.

Occurrence.—12 females and 4 males were taken at Shingu tide pool.

Distribution.—Nankauri Harbour, Nicobar Island, in weed washing.

Family AMERIDAE

Genus *Nitocra* Boeck

Nitocra spinipes **Boeck**

(Fig. 7, *a-l*)

Nitokra spinipes mihi, Boeck, 1864, 8, 274.

Nitocra spinipes, Sars, 1907, p. 213, pl. 139.

Nitocra spinipes, Wilson, 1932, p. 240, fig. 160.

Nitocra spinipes, Lang, 1948, p. 810, Abb. 325.

FEMALE.—Length, 0·63 to 0·74 mm.

The body is very slender and cylindrical, the cephalic segment is shorter than the rest of the thoracic segments combined. The urosome is a little longer than the metasome, the caudal rami are spinulose on the surface, and are much wider than long; the apical setae are jointed near their base. First antenna is 8-segmented, the 1st and 2nd joints are much swollen, the 3rd joint is shorter than the 4th. The exopod of the second antenna is 1-segmented with three apical setae. The 1st leg has 3-jointed endopod and exopod, the 1st segment of the endopod is long, more than twice as long as the combined lengths of the remaining two segments of the endopod. In the 2nd to 4th legs the 1st to 3rd segments of the exopod and endopod have each a row of spinules on its outer margin.

The setal formula is as follows:

	Endopod			Exopod		
	1	2	3	1	2	3
P_2	1	1	1·2·1	0	1	2·2·3
P_3	1	1	2·2·1	0	1	2·2·3
P_4	1	1	2·2·1	0	1	2·2·3

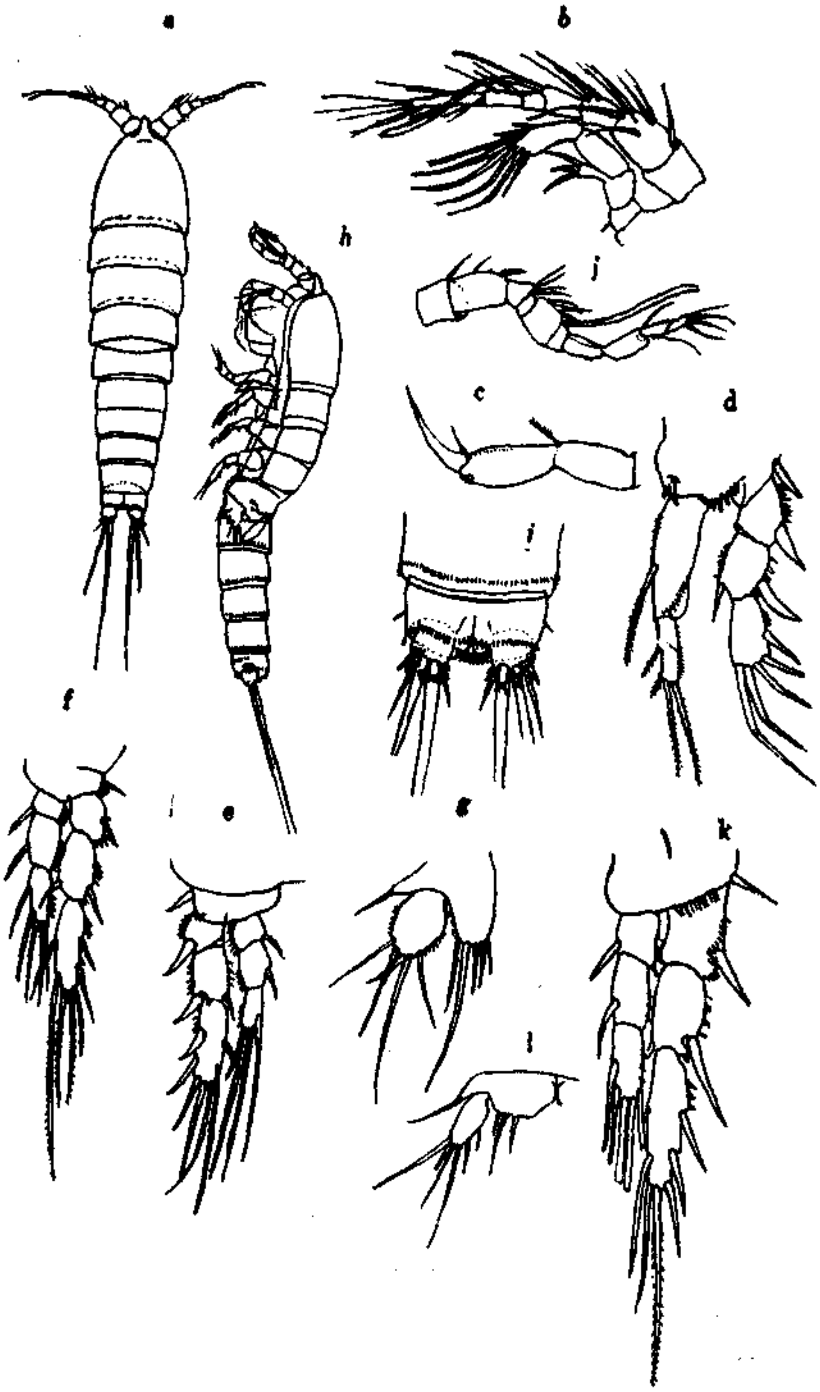

FIG. 7. *Nitocra spinipes* (Boeck) (*a*–*l*).

Female: (*a*) Dorsal view of furca, ×50; (*b*) 1st and 2nd antennae, ×150; (*c*) Maxilliped, ×200; (*d*) 1st leg, ×75; (*e*) 2nd leg, ×150; (*f*) 4th leg, ×150; (*g*) 5th leg, ×150.

Male: (*h*) Lateral view, ×75; (*i*) Dorsal view of furca, ×200; (*j*) 1st antenna, ×150; (*k*) 3rd leg, ×300; (*l*) 5th leg, ×200.

In the fifth pair of legs the basal expansion extends to the center of the distal segment, and is armed with five setae, the second outer seta is longer than the others; the distal segment is oval in shape with five setae on the distal margin; the middle seta is the shortest.

MALE.—*Length, 0·55 to 0·68 mm.*

The body is smaller than the female. The first antenna is 10-segmented, and geniculate; the first two segments and the 5th segment are much broader and long; 4th and 6th segments are very short, 7th and 8th segments are elongated, and have the band of a chela. The shape of 1st to 4th leg is similar to that of the female. The 5th leg differs from that of the female in shape and size, the basal segment is wide, elongated laterally; its expansion with three setae; the distal segment is more or less elongated and oval in shape, with 6 setae, of which the 1st and 4th outer setae are elongated, the second seta is very short.

Remarks.—According to Wilson (1932, p. 240) the 1st antenna of the male is 9-segmented, but in the present specimen it is 10-segmented, and very well agrees with the figure given by Lang (1948).

Occurrence.—Eight females and five males were taken at Shingu tide pool.

Distribution.—Scottish coast, Norwegian coast, Adriatic (Carazzi, Pesta), Baltic coast, Coast of England.

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PELAGIC COPEPODS FROM THE INSHORE WATERS OFF TRIVANDRUM COAST

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ABSTRACT

Ninety-eight species of copepods belonging to the Calanoida, Harpacticoida and Cyclopoida are recorded. The Calanoida is represented by 19 families, 28 genera and 61 species; the Harpacticoida by 7 families, 10 genera and 11 species and Cyclopoida by 8 families, 13 genera and 26 species. Two species, *Kelleria* sp. and *Pseudanthessius* sp., are provisionally described as new. The male of the genus *Ratania* is here recorded for the first time and the male of *Diosaccus truncatus* in the present collection makes it possible that the males previously described should be assigned to some other species. *Ratania flava*, *Pontoeciella abyssicola*, *Corissa parva* and *Hersiliodes latericia* are recorded for the first time from the Indian coasts during the course of this study. Three copepodite stages of *H. latericia* were obtained and these are also included with notes and figures.

THE present paper embodies the results of the investigations carried out between 1955 and 1958 by the author at the Marine Biological Laboratory of the University of Kerala. The classification adopted in this work is that of Sars, which, as expressed by Wilson, "is much the simplest one ever offered and furnishes a place for every valid genus".

The author records her deep sense of gratitude to Dr. C. C. John, M.A., D.Sc. (Lond.), D.I.C., then Professor of Marine Biology and Fisheries, for his constant encouragement and supervision of the work. She is also greatly indebted to Dr. N. Krishna Pillai, Research Officer, Marine Biological Laboratory, for his helpful criticisms and assistance during the course of investigation and also for the critical examination of the manuscript. The author takes this opportunity to thank Dr. J. H. Stock, Dr. R. U. Gooding and Dr. J. Eiselt for constructive suggestions regarding some of the species. Thanks are also due to the Syndicate of the University of Kerala for the award of a Scholarship, which enabled her to pursue this study.

Suborder CALANOIDA

AMPHASCANDRIA

Family CALANIDAE

Genus *Canthocalanus* A. Scott

***Canthocalanus pauper* (Giesbrecht)**

Giesbrecht, 1892, p. 91, (*Calanus*); Sewell, 1947, p. 16; Krishnaswamy, 1953 *a*, p. 107.

Specimens belonging to both sexes were obtained from November to April; a very rich collection was obtained on 7-1-1957.

Length: 1·1–1·4 mm.

Genus *Undinula* A. Scott

***Undinula vulgaris* (Dana)**

Giesbrecht, 1892, p. 92, (*Calanus*); Krishnaswamy, 1953 *a*, p. 109.

The two varieties of this species, *giesbrechti* Sewell and *typica* Sewell were common, maximum occurrence being from December to September.

Length: Female 2·2 mm., Male 2·1 mm.

***Undinula darwini* (Lubbock)**

Giesbrecht, 1892, p. 91, (*Calanus*); Sewell, 1929, p. 42, Krishnaswamy, 1953 *a*, p. 110.

This species occurred along with *U. vulgaris* in moderate numbers.

Length: Female 2 mm., Male 1·8 mm.

Family EUCALANIDAE

Genus *Eucalanus* Dana

***Eucalanus attenuatus* (Dana)**

Giesbrecht, 1892, p. 131; Sewell, 1929, p. 47; Krishnaswamy, 1953 *a*, p. 110.

Only female specimens were obtained, mostly between April and October and sparingly during the rest of the year.

Length: 4·1–4·3 mm.

***Eucalanus crassus* Giesbrecht**

Giesbrecht, 1892, p. 132; Sewell, 1929, p. 50; Krishnaswamy, 1953 *a*, p. 111.

Specimens of both sexes obtained along with *E. attenuatus*.

Length: Female 3 mm., Male 2·5 mm.

***Eucalanus subcrassus* Giesbrecht**

Giesbrecht, 1892, p. 21; Sewell, 1929, p. 51; Krishnaswamy, 1953 *a*, p. 112.

This is the commonest of the three species of *Eucalanus* obtained. This is present in moderate numbers from November to December and April to June. Stray specimens are met with even during the other months.

Length: Female 2·5 mm., Male 2·4 mm.

Genus *Rhincalanus* Dana

***Rhincalanus nasutus* Giesbrecht**

Giesbrecht, 1892, p. 152; Lehnhofer, 1927, p. 368; Sewell, 1947, p. 49.

A rare species, appearing only in small numbers during August and September. Some of the specimens exhibit the dichotomous branching of the caudal setae found occasionally in species of *Canthocalanus* and *Undinula*.

Length: Male 4 mm., Female 4·2 mm.

***Rhincalanus cornutus* Dana**

Lehnhofer, 1927, p. 359; Sewell, 1947, p. 48; Krishnaswamy, 1953 *a*, p. 112.

This is also a rare species occurring along with the former. Only female specimens were obtained.

Length: 3·2 mm.

Family PARACALANIDAE

Genus *Paracalanus* Boeck

***Paracalanus parvus* Giesbrecht**

Sars, 1903, p. 17; Wilson, 1932, p. 38; Krishnaswamy, 1953 *a*, p. 133.

Present throughout the year, common during October to January.

Length: Male 0·8 mm., Female 0·9 mm.

Genus *Acrocalanus* Giesbrecht

***Acrocalanus longicornis* Giesbrecht**

Giesbrecht, 1892, p. 171; Wolfenden, 1906, p. 1000; Sewell, 1929, p. 82; Krishnaswamy, 1953 *a*, p. 114.

Common during November to March; rare during other months.

Length: Male 1·1 mm., Female 1·2 mm.

Family PSEUDOCALANIDAE

Genus *Calocalanus* Giesbrecht

***Calocalanus pavo* (Dana)**

Giesbrecht, 1892, p. 175; Sewell, 1929, p. 89; Krishnaswamy, 1953 *a*, p. 116.

Occurs mainly between July and September. Only females were collected.

Length: 1 mm.

Genus *Clausocalanus* Giesbrecht

***Clausocalanus arcuicornis* (Dana)**

Esterly, 1924, p. 87; Sewell, 1947, p. 54; Krishnaswamy, 1953 *a*, p. 116.

Present in the collections only during December to February. The specimens resemble forma minor of Sewell. Only females present.

Length: 1 mm.

Family AETIDEIDAE

Genus *Euaetideus* Sars

***Euaetideus giesbrechti* (Cleve)**

A. Scott, 1909, p. 36, (*Aetideus*); Wolfenden, 1910–11, p. 209, (*Aetideus*); Vervoort, 1952, p. 3.

A rare form collected only in the months of July, August and September. No males were obtained.

Length: 1·9 mm.

Family EUCHAETIDAE

Genus *Euchaeta* Philippi

***Euchaeta marina* Prestandrea**

Giesbrecht, 1892, p. 246; A. Scott, 1909, p. 67; Sewell, 1947, p. 113; Krishnaswamy, 1953 *a*, p. 117.

This is the commonest species of *Euchaeta* in the locality appearing in moderate numbers from November to beginning of April. Sewell (1947) has enumerated the structural differences in the different size groups. All the specimens in the present collection are referable to the small form of Sewell (p. 114, Fig. 25 *c*).

Length: Female 3·8 mm., Male 3·5 mm.

***Euchaeta consimilis* Farran**

Wolfenden, 1906, p. 1008, (*concinna*); Farran, 1935-39, p. 90; Sewell, 1947, p. 116.

Found in small numbers along with *E. marina*.

Length: Female 3 mm., Male 2·8 mm.

***Euchaeta wolfendeni* A. Scott**

Wolfenden, 1906, p. 1008; A. Scott, 1909, p. 68; Sewell, 1947, p. 115.

One male and six females were obtained.

Length: Female 2·8 mm., Male 2·4 mm.

Family SCOLECITHRICIDAE

Genus *Scolecithrix* Brady

***Scolecithrix danae* (Lubbock)**

Brady, 1883, p. 57; Sewell, 1929, p. 209; Wilson, 1932, p. 82.

Present only during February and March.

Length: Female 2·0 mm., Male 1·8 mm.

HETERARTHRANDRIA

Family CENTROPAGIDAE

Genus *Centropages* Kroyer

***Centropages furcatus* (Dana)**

Brady, 1883, p. 83; Sewell, 1914; p. 220; Krishnaswamy, 1953 *a*, p. 117.

This is the commonest species of *Centropages* and occurs in moderate numbers from December to May.

Length: Male 1·8 mm., Female 1·9 mm.

Centropages calaninus (Dana)

Giesbrecht, 1892, p. 305; Wolfenden, 1906, p. 1014; Sewell, 1947, p. 163; Krishnaswamy, 1953 *a*, p. 121.

Two females were obtained in February 1957.

Length: 1·8 mm.

Centropages gracilis (Dana)

Wolfenden, 1906, p. 1013; Sewell, 1947, p. 163.

Only three female specimens were present.

Length: 2·0 mm.

Centropages orsinii Giesbrecht

Giesbrecht, 1892, p. 305; Wolfenden, 1906, p. 1015; Krishnaswamy, 1953 *a*, p. 122.

Common during October to February.

Length: Male 1·2 mm., Female 1·8 mm.

Centropages dorsispinatus Thompson and Scott

Thompson and Scott, 1903, p. 247; Sewell, 1932, p. 228; Krishnaswamy, 1953 *a*, p. 120.

Specimens of both sexes were obtained in small numbers during May and June. The females in the present collection do not show the spines on the two urosome segments observed by previous authors.

Length: Male 1·2 mm., Female 1·3 mm.

Centropages tenuiremis Thompson and Scott

Thompson and Scott, 1909, p. 247; Sewell, 1912, p. 363; Krishnaswamy, 1953 *a*, p. 120; Shen and Bai, 1956, p. 220.

Occurs from December to March. Slight variations in the shape of the exopod spine on the right fourth leg of male and in the hirsute second endopod of the female fifth leg have been observed. These are apparently intraspecific variations.

Length: Male 1·5 mm., Female 1·8 mm.

Centropages trispinosus Sewell

Sewell, 1914, p. 223; Krishnaswamy, 1951, p. 75.

Found in small numbers from June to October. The females in the present collection possess numerous spinules on the genital segment which was not mentioned by Sewell.

Length: Male 1·5 mm., Female 1·5 mm.

Centropages alcocki Sewell

[Fig. 1 (1–2)]

Sewell, 1912, p. 338, pl. XVII.

Specimens belonging to both sexes were obtained in August, September and October. Sewell figures the inner spines on the second exopod segment of female fifth leg without any spinules.

But in the present specimens there are two rows of minute teeth. The ultimate segment of the antennule is provided with a thick spine-like process and a few setae as in *C. trispinosus*, but this is not shown in Sewell's illustration. It may be remarked that *C. alcocki* shows a close resemblance to *C. trispinosus*.

Length: Male 1·0 mm., Female 1·1 mm.

Family PSEUDODIAPTOMIDAE

Genus: *Pseudodiaptomus* Herrick

Pseudodiaptomus mertoni **Fruchtl**

Sewell, 1932, p. 241.

Very common from May to August.

Length: Male 1 mm., Female 1·2 mm.

Genus *Schmackeria* Poppe and Richard

Schmackeria serricaudatus **(T. Scott)**

T. Scott, 1894, p. 40, (*Heterocalanus*); Sewell, 1932, p. 235, (*Pseudodiaptomus*); Sewell, 1947, p. 164; Krishnaswamy, 1953 *a*, p. 123.

Occurs almost throughout the year, common during May and June.

Length: Male 1·2 mm., Female 1·3 mm.

Schmackeria annandalei **(Sewell)**

Sewell, 1919, p. 5, (*Pseudodiaptomus*); Marsh, 1934, p. 42; Krishnaswamy, 1953 *a*, p. 124.

A single female was obtained in December 1957.

Length: 1·2 mm.

Family TEMORIDAE

Genus *Temora* Baird

Temora turbinata **(Dana)**

A. Scott, 1909, p. 118; Sewell, 1947, p. 165; Krishnaswamy, 1953 *a*, p. 124.

This species is common during the months July to November. Occasionally found during the rest of the year.

Length: Male 1·3 mm., Female 1·4 mm.

Temora discaudata **Giesbrecht**

Giesbrecht, 1892, p. 328; A. Scott, 1909, p. 118; Sewell, 1947, p. 164; Krishnaswamy, 1953 *a*, p. 125.

Abundant from July to November and rare during the rest of the year.

Length: Male 1·8 mm., Female 2·0 mm.

Family METRIDIIDAE

Genus *Pleuromamma* Giesbrecht

***Pleuromamma gracilis* (Claus)**

A. Scott, 1909, p. 123; Sewell, 1932, p. 264; Steuer, 1932, p. 30.

A very rare species found only in July. Only male specimens.

Length: 1·5 mm.

***Pleuromamma indica* Wolfenden**

Wolfenden, 1906, p. 1011; Steuer, 1932, p. 17; Sewell, 1947, p. 168.

Two female specimens collected in July 1958.

Length: 2 mm.

Family LUCICUTIIDAE

Genus *Lucicutia* Giesbrecht

***Lucicutia flavicornis* (Claus)**

Brady, 1883, p. 50, (*Leuckartia*); Farran, 1926, p. 274; Krishnaswamy, 1953 *a*, p. 126.

This species was found abundantly during July and August.

Length: Male 1·4 mm., Female 1·5 mm.

Family HETERORHABDIDAE

Genus *Heterorhabdus* Giesbrecht

***Heterorhabdus papilliger* (Claus)**

A. Scott, 1909, p. 131; Sars, 1925, p, 229; Farran, 1948, p. 3.

A rare form met with only in July and August.

Length: Male 1·9 mm., Female 2 mm.

Genus *Haloptilus* Giesbrecht

***Haloptilus longicornis* Claus**

Brady, 1883, p. 44, (*Hemicalanus*); Sars, 1903, p. 121; Krishnaswamy, 1953 *a*, p. 126.

Two females obtained in August 1957.

Length: 2·0 mm.

Family ARIETELLIDAE

Genus *Metacalanus* Cleve

[Fig. 1 (3)]

***Metacalanus aurivilli* Cleve**

Thompson and Scott, 1903, p. 242, Pl. II; Sewell, 1932, p. 330; Krishnaswamy, 1953 *a*, p. 127.

present almost throughout the year and in large numbers during July and August. The projection on the distal segment of female fifth leg is a character, hitherto unrecorded. In all probability this is a rudimentary third segment.

Length: Male 0·5 mm., Female 0·6 mm.

Family CANDACIIDAE

Genus *Candacia* Dana

Candacia bradyi **A. Scott**

A. Scott, 1909, p. 156; Krishnaswamy, 1953 *a*, p. 130.

Present in moderately large numbers from February to August.

Length: Male 1·8 mm., Female 2 mm.

Candacia truncata **(Dana)**

Brady, 1883, p. 69, (*Candace*); A. Scott, 1909, p. 155; Sewell, 1932, p. 338; Krishnaswamy, 1953 *a*, p. 129.

Represented in the present collection by a single specimen obtained in July 1956.

Length: 1·4 mm.

Candacia pachydactyla **(Dana)**

Brady, 1883, p. 68; Wilson, 1932, p. 141; Krishnaswamy, 1953 *a*, p. 128.

Very abundant from end of November to February. In small numbers during the other months.

Length: Male 1·5 mm., Female 1·8 mm.

Family PONTELLIDAE

Genus *Labidocera* Lubbock

Labidocera acuta **(Dana)**

Brady, 1883, p. 89, (*Pontella*); Sewell, 1947, p. 248; Krishnaswamy, 1953 *a*, p. 130.

Found in large numbers from end of December to April.

Length: Male 3 mm., Female 3·4 mm.

Labidocera pectinata **Thompson and Scott**

Thompson and Scott, 1903, p. 252; Sewell, 1932, p. 372; Krishnaswamy, 1953 *a*, p. 135.

Common from August to September, present in small numbers till April.

Length: Male 1·5 mm., Female 2 mm.

Labidocera detruncata **(Dana)**

Dana, 1852, p. 1143, (*Pontellina*); Sewell, 1947, p. 249; Krishnaswamy, 1953 *a*, p. 134.

Rare form occurring only during December and January.

Length: Male 2·3 mm., Female 2·4 mm.

Labidocera pavo Giesbrecht

Sewell, 1932, p. 365; Krishnaswamy, 1953 *a*, p. 131.

Specimens obtained only during February, 1957.

Length: Male 2·0 mm., Female 2·5 mm.

Labidocera minuta Giesbrecht

Wolfenden, 1905, p. 1018; Sewell, 1947, p. 249; Krishnaswamy, 1953 *a*, p. 134.

Occurs in small numbers from end of December to March.

Length: Male 1·8 mm., Female 2 mm.

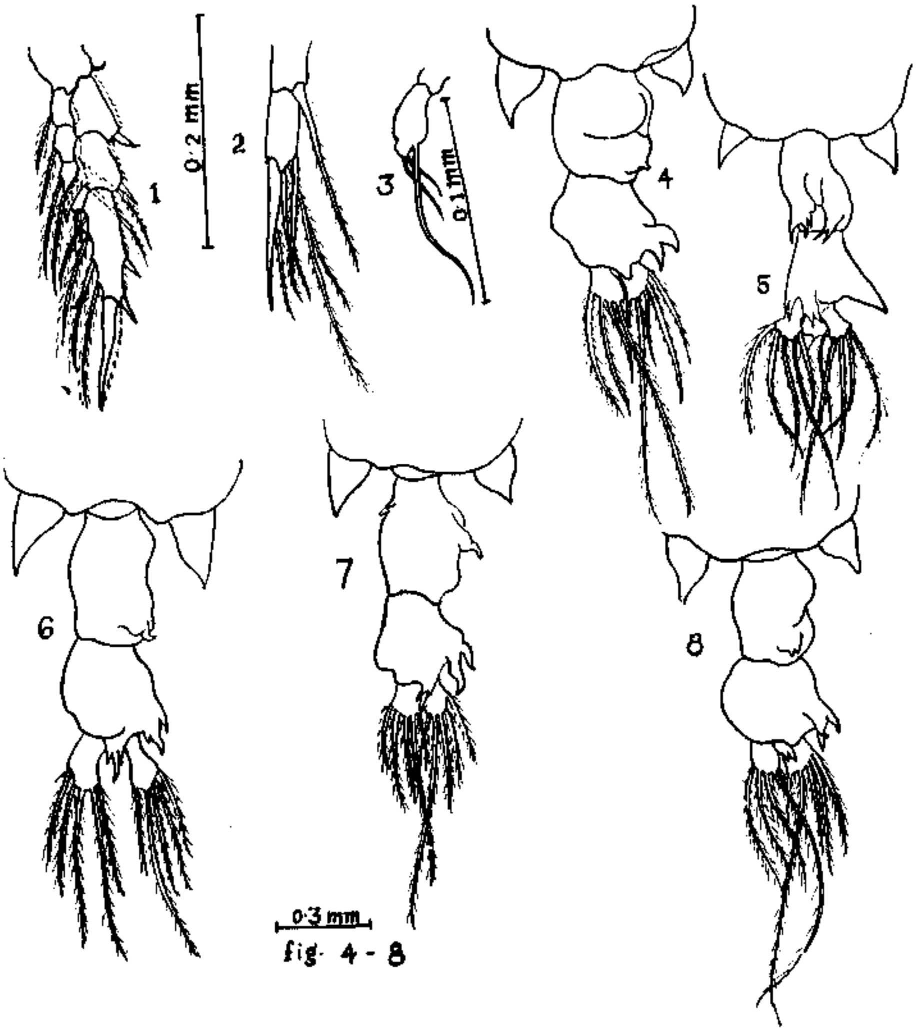

FIG. 1. *Centropages alcocki* Sewell: (1) Female P 5; (2) Ultimate segment of antenna. *Metacalanus aurivilli* Cleve: (3) Female P5. *Labidocera kroyeri*: (4–8) Posterior parts of five specimens.

Labidocera kroyeri (Brady)

[Fig. 1 (4–8)]

Brady, 1883, p. 93; A. Scott, 1909, p. 165; Krishnaswamy, 1953 *a*, p. 131.

In *L. kroyeri*, both males and females exhibit a wide range of variation. From the Indian waters, var. *similis* Wolfenden, *bidens* Sewell and var. nov. by Krishnaswamy were described from females; *gallensis* Thompson and scott, *stylifera* Thompson and Scott and *burmanica* Sewell were described from males. The present collection includes some male specimens, which could without any diffidence be assigned to *burmanica* Sewell. Female specimens which could be assigned to var. nov. Krishnaswamy were also obtained. The characters on which the varieties are based do not appear to be constant and intermediates between any two varieties are very common. If these minor variations are to be accepted as varietal characters, a considerably large number of varieties will have to be recognised. The correct procedure appears to be to make a comparative study of all the known varieties and define the range of variation within the species. This may bring down the number of varieties considerably. To illustrate this point, appropriate camera lucida drawings of a few specimens from the same collection are included. This species occurred in small numbers from November to February and June.

Length: 2 mm. to 2·5 mm.

Genus *Pontella* Dana

Pontella investigatoris Sewell

Sewell, 1912, p. 371; Sewell, 1932, p. 382.

Two male specimens were obtained in March 1958.

Length: 3·2 mm.

Pontella princeps Dana

A. Scott, 1909, p. 160; Sewell, 1932, p. 382.

Only one male and one female were obtained in May 1958.

Length: Male 4·8 mm., Female 5·2 mm.

Pontella securifer Brady

Brady, 1883, p. 96; Sewell, 1947, p. 250; Krishnaswamy, 1953 *a*, p. 136.

Stray specimens were obtained in February and March.

Length: Male 3·4 mm., Female 3·6 mm.

Pontella danae Giesbrecht, var. *ceylonica* Thompson & Scott

Sewell, 1932, p. 374; Krishnaswamy, 1953 *a*, p. 136.

A rare form occurring from November to June. Only female specimens were collected.

Length: 3·2 mm. to 3·4 mm.

Pontella fera Dana

Giesbrecht, 1892, p. 462; A. Scott, 1909, p. 159; Sewell, 1947, p. 250.

Present in small numbers from January to March.

Length: Female 2 mm.

Genus *Pontellopsis* Brady

***Pontellopsis macronyx* A. Scott**

A. Scott, 1909, p. 173; Sewell, 1932, p. 387; Farran, 1935-39, p. 118.

Very rare, represented in the present collection by three specimens, one obtained on 22-6-1957 and two others on 11-11-1958. No females.

Length: 1·8 mm.

***Pontellopsis krameri* (Giesbrecht)**

Wolfenden, 1906, p. 1021; Sewell, 1932, p. 386.

Five female specimens were collected on 11-11-1958.

Length: 2·1 mm.

***Pontellopsis armata* (Giesbrecht)**

Wolfenden, 1906, p. 1022; Sewell, 1932, p. 385.

A rare form occurring during January and February.

Length: Female 2·5 mm.

***Pontellopsis herdmani* Thompson and Scott**

Thompson and Scott, 1903, p. 253; Sewell, 1932, p. 385; Krishnaswamy, 1953 *a*, p. 137.

Stray specimens are met with during January and February.

Length: Female 2 mm.

Genus *Pontellina* Dana

***Pontellina plumata* Dana**

Dana, 1852, p. 1135; Wilson, 1932, p. 156; Sewell, 1947, p. 251.

Period of occurrence is January to April.

Length: Male 1·3 mm., Female 1·5 mm.

Genus *Calanopia* Dana

***Calanopia thompsoni* A. Scott**

A. Scott, 1909, p. 178; Sewell, 1932, p. 342; Krishnaswamy, 1953 *a*, p. 139.

Represented by only three female specimens.

Length: 2·2 mm.

Calanopia aurivilli Cleve

A. Scott, 1909, p. 181; Sewell, 1932, p. 341; Krishnaswamy, 1953 *a*, p. 138.

Occurs from December to April in small numbers.

Length: Male 1·1 mm., Female 1·2 mm.

Calanopia elliptica (Dana)

A. Scott, 1909, p. 176; Krishnaswamy, 1953 *a*, p. 58.

This is the most abundant species of *Calanopia*. Present in moderate numbers from December to June.

Length: Male 1·5 mm., Female 1·8 mm.

Family ACARTIIDAE

Genus *Acartia* Dana

Acartia erythraea Giesbrecht

Krishnaswamy, 1953 *a*, p. 139.

A common species most abundant during February, April, July and November.

Length: Male 1·1 mm., Female 1·2 mm.

Family TORTANIDAE

Genus *Tortanus* Giesbrecht

Tortanus gracilis (Brady)

Brady, 1883, p. 71; Sewell, 1932, p. 398; Krishnaswamy, 1953 *a*, p. 140.

Specimens were collected only between February and April.

Length: Male 1·5 mm., Female 1·8 mm.

Tortanus forcipatus (Giesbrecht)

Sewell, 1932, p. 399; Krishnaswamy, 1953 *a*, p. 140.

Found in small numbers along with *T. gracilis*. Only female specimens were obtained.

Length: 1·1 mm.

Suborder HARPACTICOIDA

ACHIROTA

Family ECTINOSOMIDAE

Genus *Microsetella* Brady and Robertson

Microsetella rosea (Dana)

Wilson, 1932, p. 177; Krishnaswamy, 1957, p. 13.

Period of occurrence, July to September. Only female specimens were obtained.

Length: 0·9 mm.

CHIROGNATHA

Family Tachidiidae

Genus *Euterpina* Norman

Euterpina acutifrons (Dana)

Sars, 1921, p. 97; Krishnaswamy, 1957, p. 14.

Present almost throughout the year, abundant from June to October.

Length: Male 0·6 mm., Female 0·8 mm.

Family Macrosetellidae

Genus *Macrosetella* A. Scott

Macrosetella gracilis (Dana)

Brady, 1883, p. 108; Wilson, 1932, p. 281; Sewell, 1940, p. 141; Krishnaswamy, 1953 *b*, p. 73.

Occurs from December to September. In April and July some collections contained this species in plenty.

Genus *Miracia* Dana

Miracia efferata Dana

Brady, 1883, p. 102; Sewell, 1940, p. 141; Krishnaswamy, 1953 *b*, p. 72.

December to February in moderate numbers, reaching maximum in January.

Length: Male 2·0 mm., Female 2·2 mm.

Family Clytemnestridae

Genus *Clytemnestra* Dana

Clytemnestra scutellata Dana

Dana, 1852, p. 1194; Sewell, 1947, p. 291.

Specimens obtained from April to December.

Length: Male 0·9 mm., Female 1·0 mm.

Clytemnestra rostrata (Brady)

Giesbrecht, 1892, p. 566; Wilson, 1932, p. 292; Krishnaswamy, 1953 *b*, p. 74.

Occurs along with *C. scutellata.*

Length: Male 0·8 mm., Female 1·0 mm.

Family Peltidiidae

Genus *Alteutha* Baird

Alteutha interrupta (Goodsir)

Sars, 1911, p. 62; Shen and Bai, 1956, p. 229.

Found in moderate numbers during June to August.

Length: Male and Female 1·1 mm.

Family THALESTRIDAE

Genus *Rhynchothalestris* Sars

***Rhynchothalestris rufocincta* (Norman)**

Brady, 1878, p. 125, (*Thalestris*); Sars, 1911, p. 120; Sewell, 1940, p. 184.

During January and February, a few specimens are collected.

Length: Male 0·9 mm., Female 1·0 mm.

Family DIOSACCIDAE

Subfamily AMPHIASCINAE Nicholls

Genus *Amphiascopsis* Gurney

***Amphiascopsis similis* (Claus)**

[Fig. 2 (1–2)]

Sars, 1911, p. 151, Pl. XCIV; Sewell, 1940, p. 260; Nicholls, 1941 *a*, p. 76.

Some female specimens were obtained in November 1957. The present specimens show slight differences when compared with those of Sewell and Sars. The distal segment of the exopod of first leg has only three spines and one seta as shown by Sars. Sewell has noticed four spines and a seta. The end segment of the endopod of first leg has two spines and a seta. This seta is absent in Sars' specimen. In the fifth leg the prolongation of the basal segment is distally subtruncate, but Sars describes and figures it as triangular. It is rather difficult to decide whether these differences justify the creation of a new variety or species.

Length: Female 1·0 mm.

Genus *Amphiascoides* Nicholls

***Amphiascoides robinsoni* (A. Scott)**

Sewell, 1940, p. 267; Nicholls, 1941 *a*, p. 81.

This species was collected only during July.

Length: Female 0·6 mm., Male 0·5 mm.

Subfamily DIOSACCINAE Nicholls

Genus *Diosaccus* Boeck

***Diosaccus truncatus* Gurney**

[Fig. 2 (3–6)]

Gurney, 1927, p. 511, Fig. 136; Sewell, 1940, p. 240; Krishnaswamy, 1951, p. 76, Fig. 2; 1957, p. 40.

A rare species found occasionally between January and February. Gurney in his account of this species makes special mention of the structure of the caudal furca. He states that the furcal rami are fused with the last abdominal segment and that the lateral ridge bounding the anal region is continued across the ramus. He has also figured the furcal rami of an individual in the last stage before maturity. None of the specimens in the present collection showed the modification of the furcal rami and is thus like that of the immature examples. Another difference is in the number of setae on the middle segment of the fourth endopod. While Gurney describes two inner setae on this segment, the present specimens invariably have only one inner seta and thus agree with the description of Sewell. The males in the present collection pose some doubt regarding their identity. Krishnaswamy (1951) has described the male of *D. truncatus*. The present collection also includes a number of males collected along with females. The females are undoubtedly those of *D. truncatus*, but the males show marked difference from those described by Krishnaswamy. The major differences are in the structure of the antennule and the endopod of the second legs. According to Krishnaswamy, the antennule is eight-segmented and the long sensory seta is borne on the fifth segment, the two previous segments being very small and indistinctly separated. In the present specimens, the sensory seta of the male is on the fourth segment, as in the female. The middle segment of second exopod in the male has only a single inner seta as in the female, but in Krishnaswamy's specimens, this segment has two setae. The difference in the endopod of the second leg appears to be more important. In the males in the present collection this segment carries four setae, two small and two very long and two modified spines which are about three times as long as the segment. The whole structure appears different. The problem is whether the male of *D. truncatus* is the one described by Krishnaswamy or the specimen described here.

Length : Male 0·8 mm., Female 1 mm.

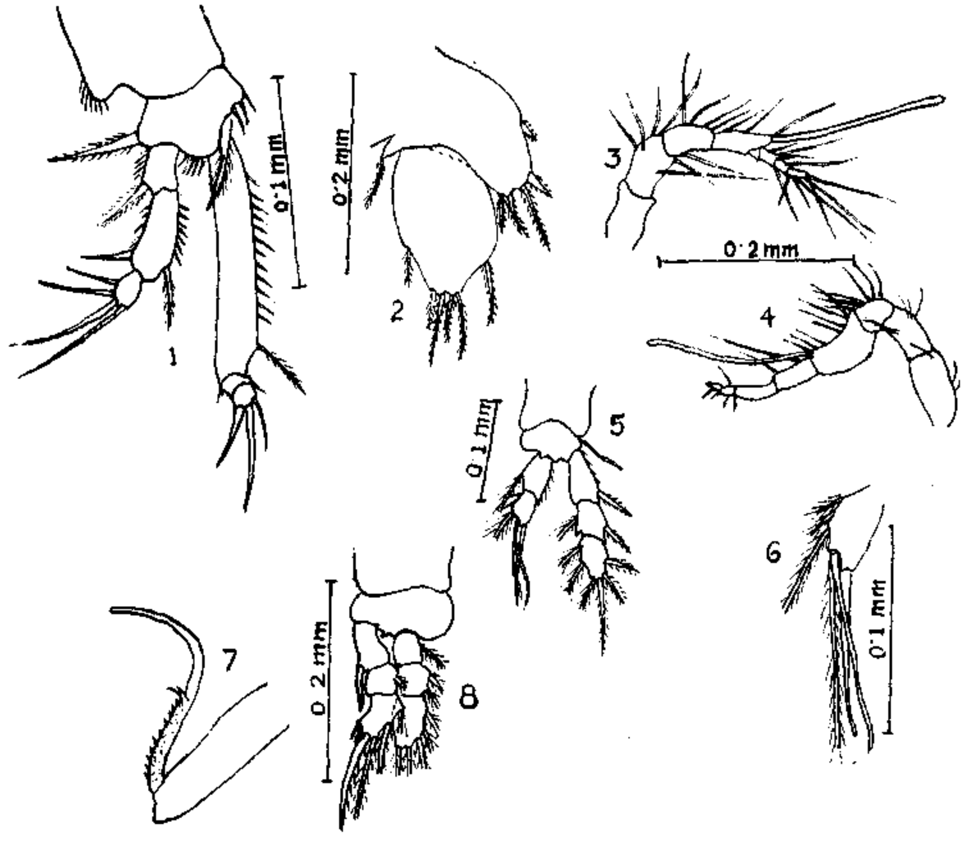

FIG. 2. *Amphiascopsis similis* (Claus): (1) P1; (2) P5. *Diosaccus truncatus* Gurney: (3) Female Antennule; (4) Male Antennule; (5) Male P2; (6) Distal endopod segment of same enlarged. *Pontoeciella abyssicola* (T. Scott), Female: (7) maxilla; (8) P1.

Suborder CYCLOPOIDA

GNATHOSTOMA

Family OITHONIDAE

Genus *Oithona* Baird

***Oithona plumifera* Baird**

Giesbrecht, 1892, p. 537; Rosendorn, 1917, p. 10; Sewell, 1947, p. 255; Krishnaswamy, 1953, p. 64.

Occurs from June to August in swarms, rarely found also during the other months. Only female specimens.

Length: 1·1 mm.

***Oithona rigida* Giesbrecht**

Resendorn, 1917, p. 39; Sewell, 1947, p. 256; Krishnaswamy, 1953, p. 65.

Throughout the year present in moderate numbers.

Length: Female 1 mm.

SIPHONOSTOMA

Family ASCOMYZONTIDAE

Subfamily PONTOECIELLINAE

Genus *Pontoeciella* Giesbrecht

***Pontoeciella abyssicola* (T. Scott)**

[Fig. 2 (7-8)]

T. Scott, 1894, p. 128, Pl. XIV, Figs, 11–18, (*Artotrogus abyssicolous*); Farran, 1926, p. 296; Farran, 1935–39, p. 125, Fig. 24 *a–e*.

Eight females were collected in September 1956. The description given by Scott (1894) clearly applies to the present specimens except in the following details. The terminal segment of the maxilla has a spine and the proximal segment of the endopod of first leg carries an inner seta. It is worth mentioning here that the specimens described by Rose (1939) as the male of *Ratania*, closely resemble the female of *Pontoeciella* in the present collection.

Length: 1 mm.

Family RATANIIDAE

Genus *Ratania* Giesbrecht

***Ratania flava* Giesbrecht**

Giesbrecht, 1892, p. 616; Wilson, 1950, p. 318; Saraswathy, 1961, p. 141.

Four females and two males from a collection made in July 1956.

Length: Male 1 mm., Female 1·1 mm.

POECILOSTOMA

Family CLAUSIDIIDAE

Genus *Hersiliodes* Canu

***Hersiliodes latericia* (Grube)**

(Figs. 3 and 4)

Canu, 1888, p. 418, Pl. XXIX, (*H. pelseneeri*); Bocquet, Stock and Kleeton, 1963, p. 20, Figs. 1-4.

A single male specimen measuring 3·0 mm. was collected on 10-9-1956.

This species has been recorded for the first time from the Indian seas by this author (Saraswathy, 1964). A short account of the male obtained is given below to point out the differences with the description given by Bocquet, Stock and Kleeton (1963) and also with the description given by Perez (1905).

Body long and dorsoventrally flattened, anterior end with a prominent rostrum directed ventralwards and appear anteriorly as a semicircular elevation. Three free metasome segments with rounded lateral margins. Urosome six-segmented, more or less cylindrical, first segment fairly broad and postero-laterally drawn out into triangular expansions. Caudal rami almost as long as the last urosome segment, slightly diverging and carrying four apical setae, second seta from the inner side longest. Antennule six-segmented, each of the three last segments with a long aesthete. Antenna with the first two segments carrying a long seta each, inner distal angle of second segment spiny, so also the inner border of third segment, its distal angle produced carrying a stout barbed claw and three setae, the fourth segment longer than broad, with seven long setae. Mandible with four movable plates, first a stout chitinised claw, second a strongly barbed tooth and the third and fourth pectinate spines. Maxillule a simple plate carrying eight setae. Maxilla two-segmented, basal segment with one small and two large spines, second segment with four stout spines. Maxilliped large and subchelate, three-segmented, basal segment internally produced into a spatulate process, the small third segment carries a very long, curved apical claw and two slender plumose setae. The terminal claw has two naked setae at its base. Armature of legs 1-4 as shown in the figure. Fifth leg two-segmented, uniramous, basal segment fused with the body. Sixth leg formed by a pair of flaps on the ventral side of second urosome segment with a small curved spine on the distal border.

Bocquet and Stock (1957) had expressed the opinion that only two species *H. latericia* (Grube) (= *H. pelseneeri* Canu) and *H. cylindracea* (Pelseneer) (= *Tochocheres cylindracea*) could rightly be assigned to the genus *Hersiliodes*, but in their recent study of the genus, Bocquet *et al.* (1963) conclude that the two characters namely the six-segmented antennule and the unisegmented fifth leg are sufficient to characterise the genus *Hersiliodes* and to differentiate it from the neighbouring genera *Hemicyclops* and *Giardella* and that the genus *Hersiliodes* is monospecific, the single species being *H. latericia* (Grube).

The only difference which the present specimens show when compared with that of Perez (1905) is that while Perez mentions the presence of a plumose seta and two simple unequal setae at the base of the terminal claw, in the specimen obtained here only two simple setae are present on the base of the claw and two plumose setae on the small third segment. The comb of 8-10 small pointed teeth found by Perez on the ventral part of the hindmost segment of the urosome is not seen in the present specimen. Comparison with the description and figures of Bocquest, Stock and Kleeton shows that the two agree in almost every respect. The presence of the rudimentary sixth leg in the specimen obtained here is a fact not mentioned by the previous authors, Some copepodites were also collected during July–September 1956. One of the copepodites in the present collection is exactly similar to the second copepodite described by Canu (1888). Another, slightly larger than the former, but similar in character is described here as the third copepodite. A third, very much similar to the second but slightly smaller, is described as the first copepodite. All the three copepodites apparently belong to the same species and they show an exact resemblance to the adult of *H. latericia* that they can confidently be assigned to that species.

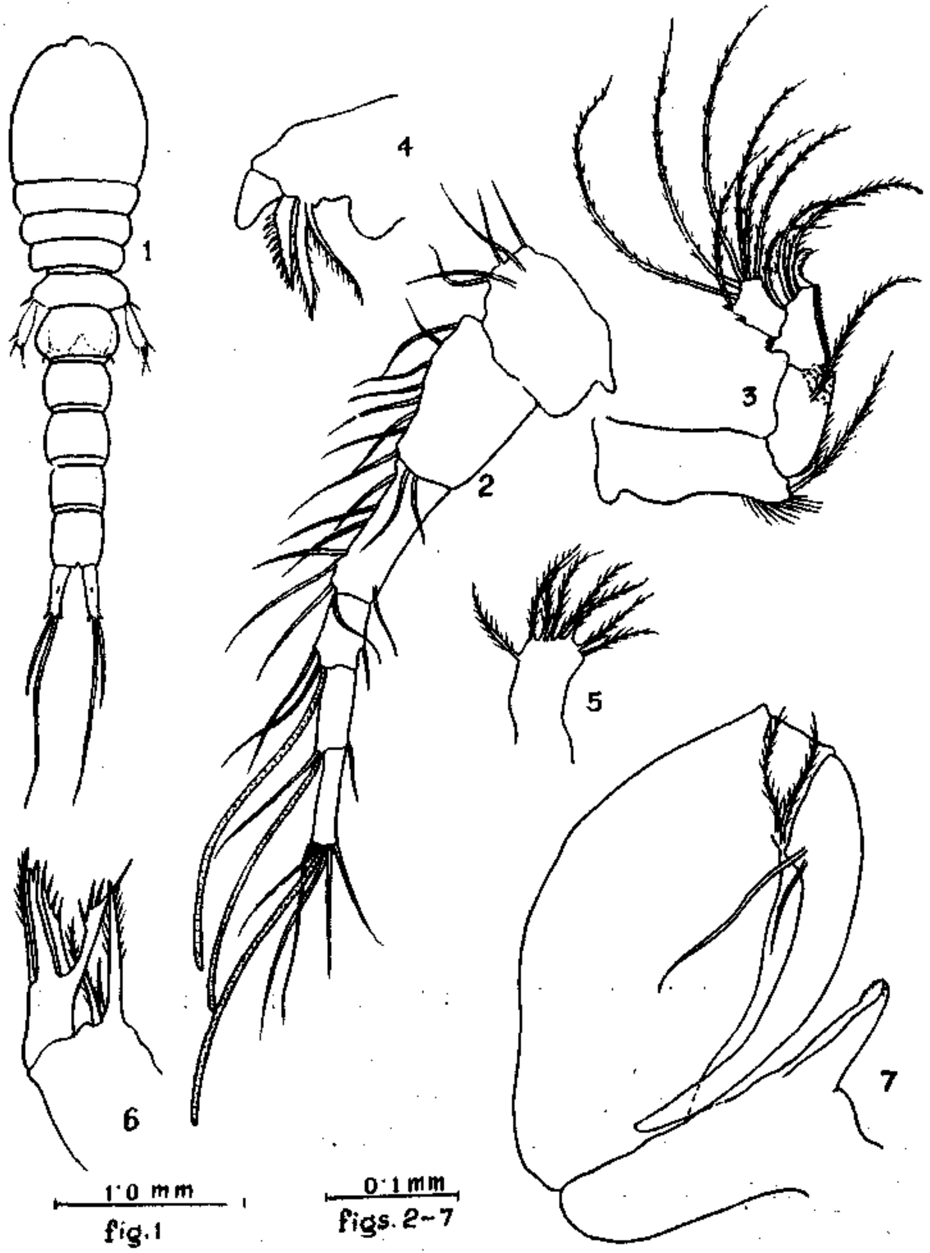

FIG. 3. *Hersiliodes latericia* (Grube). Male: (1) Dorsal view; (2) Antennule; (3) Antenna; (4) Mandible; (5) Maxillule; (6) Maxilla; (7) Maxilliped.

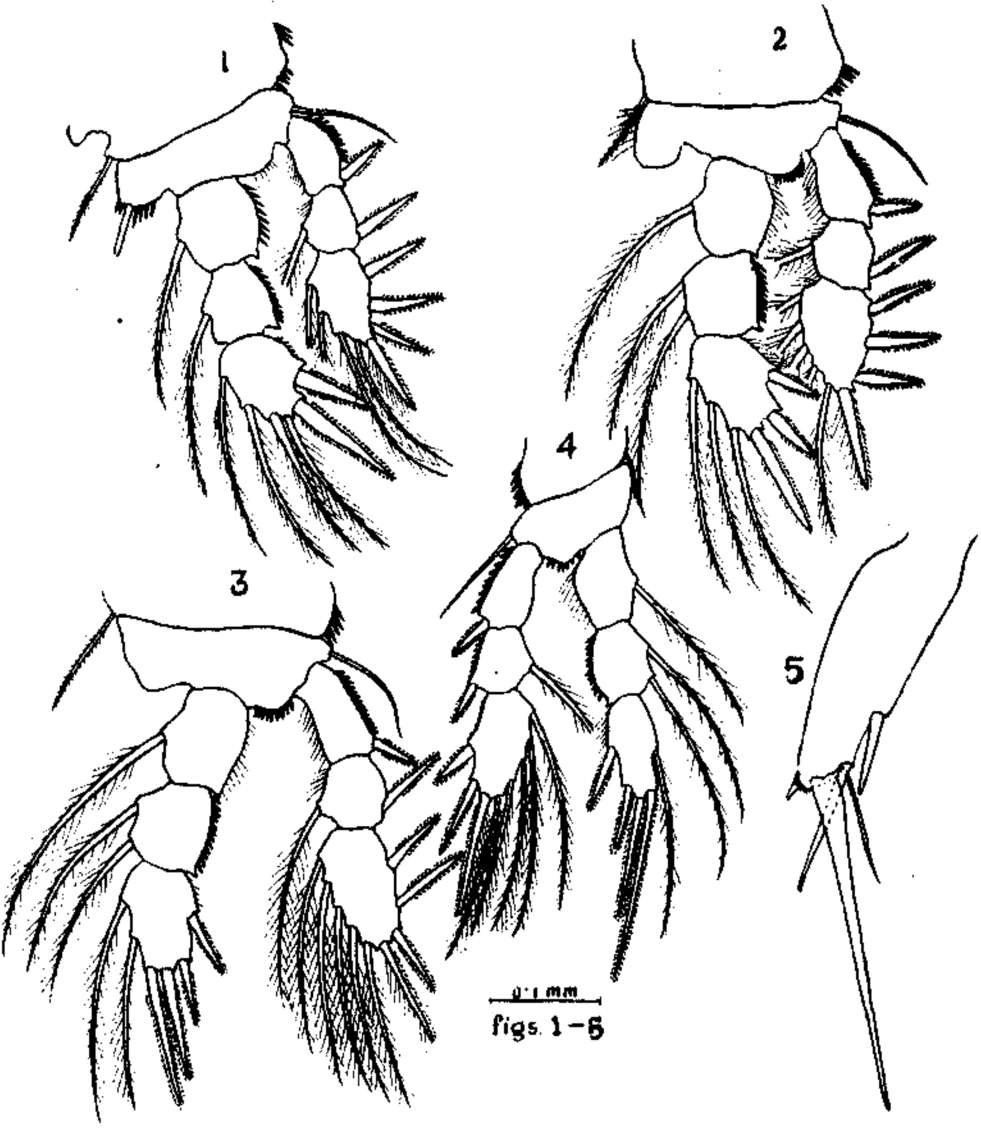

FIG. 4. *Hersiliodes latericia* (Grube) Male: (1) P1; (2) P2; (3) P3; (4) P4; (5) P5.

Copepodite 1

(Fig. 5)

26 specimens collected from the plankton on 9-7-1956.

Length: 0·6 mm. to 0·7 mm.

Shape of body as in the figure. Antennule five-segmented; antenna three-segmented, third segment with 4-6 small teeth on its inner margin. Mandible with three armed lappets. Maxillule a simple rounded plate with 9 setae; maxilla two-segmented, basal segment with two and distal with three curved setose spines. Maxilliped three-segmented, basal segment with three slender setae, second segment elongated and carrying two plumose setae, third segment very small, with two very long spines. Swimming legs only two pairs. Setation as shown in the figure. A rudimentary third leg represented by 1 spine and two setae.

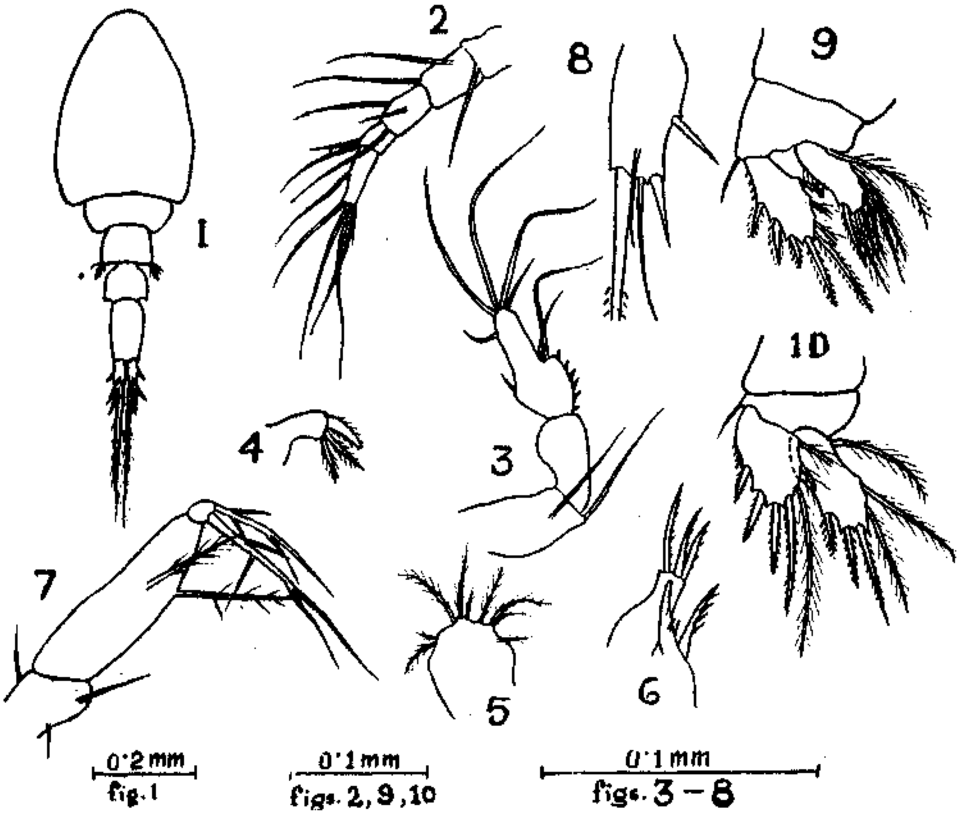

FIG. 5. *Copepodite* I. (1) Dorsal view; (2) Antennule; (3) Antenna; (4) Mandible; (5) Maxillule; (6) Maxilla; (7) Maxilliped; (8) Caudal ramus; (9) P1; (10) P2.

Copepodite 2

(Fig. 6)

3 specimens from the plankton collected on 9–7–1956.

Length: 0·9 mm. to 1 mm.

Shape as shown in the figure. Antennule five-segmented, each of the three last segments with an aesthete. Antenna four-segmented, generally like that of the adult in armature. Mandible with a conical claw, a denticulate plate and two pectinate setae as in the adult. Maxillule indistinctly bilobed, with eight plumose setae. Maxilla two-segmented, basal segment with a small spinule and two barbed spines, distal segment with three strong spines and one slender plumose seta. Maxilliped three-segmented, first two segments with a pair of plumose setae each, third a stout claw carrying two small setae. Swimming legs three pairs, setation as in figure. Rudimentary fourth leg present.

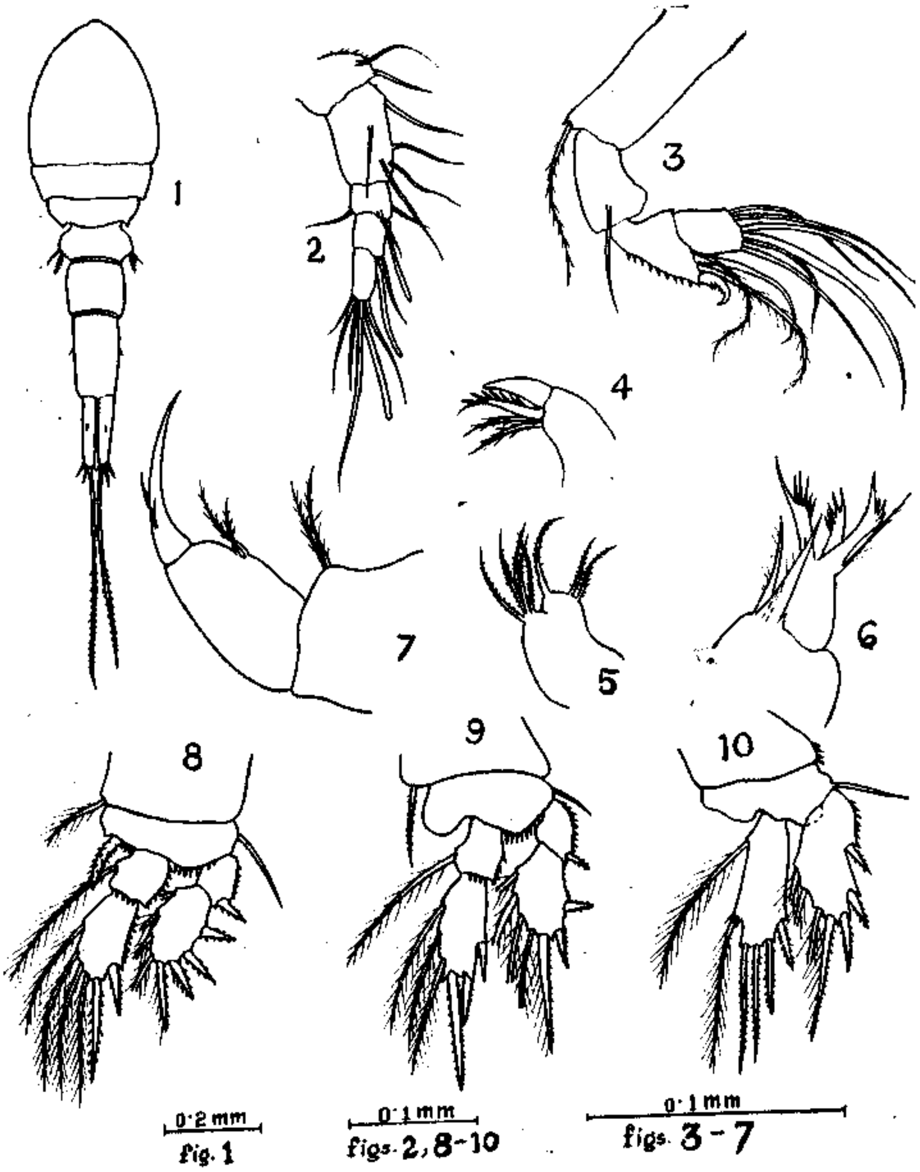

FIG. 6. *Copepodite* 2. (1) Dorsal view; (2) Antennule; (3) Antenna; (4) Mandible; (5) Maxillule; (6) Maxilla; (7) Maxilliped; (8) P1; (9) P2; (10) P3.

Copepodite 3

(Fig. 7)

Two specimens from the plankton collected on 9-7-1956.

Length: 1·5 mm.

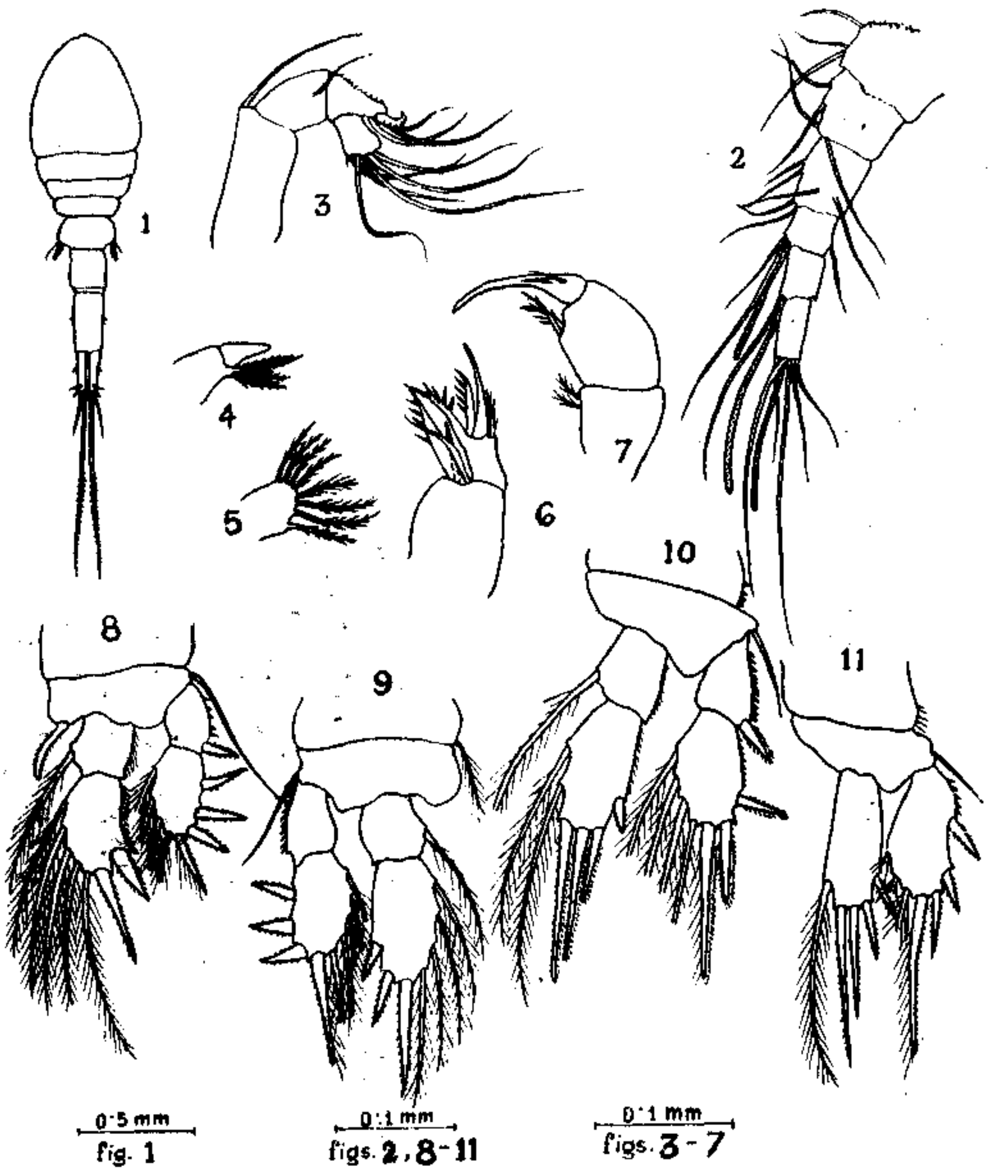

FIG. 7. *Copepodite* 3. (1) Dorsal view; (2) Antennule; (3) Antenna; (4) Mandible; (5) Maxillule; (6) Maxilla; (7) Maxilliped; (8) P1; (9) P2; (10) P3; (11) P4.

Shape of the animal as in the figure. Antennule six-segmented with aesthets on the three terminal segments. Structure of antenna, mandible, maxillule, maxilla and maxilliped as in Copepodite 2. Swimming legs four pairs, setation as in the figure. Rudimentary fifth leg present.

It is worth mentioning here that Copepodite 1 is "*Saphirella*"-like. Gooding (1960) is of opinion that "lack of information on the morphology of larval stages in the Clausidiidae prevents an adequate evaluation of Nicholl's (1944) suggestion that the genus *Saphirella* T. Scott represents the young form of *Hemicyclops*". It may not be wrong to conclude that "*Saphirella*" represent the larvae of *Hemicyclops*, *Hersiliodes* and probably *Giardella*. These three genera, it must be remembered, are very closely related and difficult to distinguish from one another (Bocquet *et al.*, 1963). Copepodite 1 shows much similarity to "*Saphirella indica*" Sewell.

Two other "*Saphirella*"-like forms were also obtained.

"*Saphirella*" *A*

(Fig. 8)

12 specimens obtained in July 1956.

Length: 0·7 mm.

General shape "*Saphirella*"-like, third segment of urosome with two groups of spines on the ventral side. Caudal rami twice as long as broad, with one marginal and three terminal setae, of which the innermost is the longest. Rostrum trifid and bent downwards. Antennule five-segmented, second segment longest; antenna four-segmented, fourth segment minute and provided with long setae, third segment with very characteristic flattened blade-like spines, inner surface of the segment with a close array of minute spines. Mandible composed of a curved conical claw and two small denticulated spines. Maxillule a small flat appendage with setae. Maxilla two-segmented, basal segment and the small distal segment with spines and setae. Maxilliped two-segmented, basal segment with two plumose setae, the elongated distal segment with two plumose setae at its apex and two smaller plumose setae on its inner margin. Two pairs of swimming legs present, both rami one-segmented. Rudimentary third leg present.

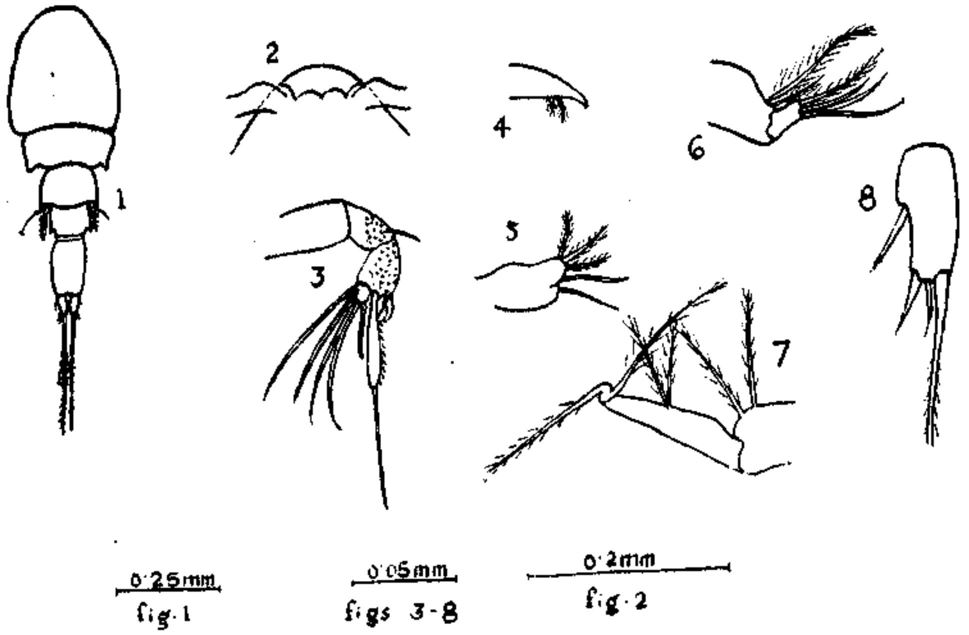

FIG. 8. *Saphirella* A. (1) Dorsal view; (2) Anterior end ventral view; (3) Antenna; (4) Mandible; (5) Maxillule; (6) Maxilla; (7) Maxilliped; (8) Caudal ramus.

These specimens resemble the young form assigned to *Giardella callianassae* by Canu (1888) in the general shape and the nature of the appendages. However, the specimens in the present collection could be easily separated by the trifid rostrum and the difference in the armature of the antenna. In the present specimens the fourth segment of the antenna is minute.

"*Saphirella*" *B*

(Fig. 9)

Three specimens were obtained in July 1956.

Length: 1·3 mm.

Shape as in the figure. Urosome three-segmented, sides of first segment rounded; caudal rami short, slightly longer than broad, with a long seta at its inner distal corner, one seta on its outer margin, two short setae towards the outer corner and one on the dorsal surface. Antennule five-segmented, antenna four-segmented, third and fourth segments with numerous slender setae,

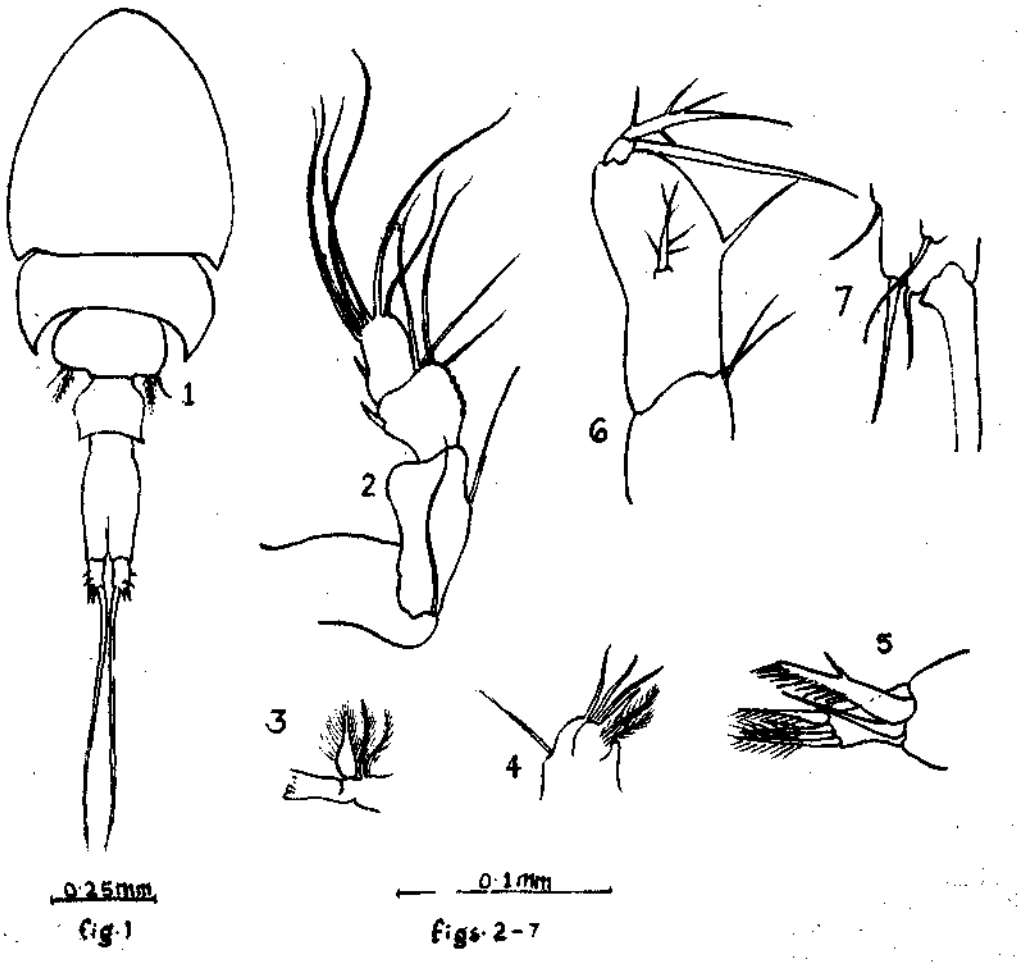

FIG. 9. *Saphirella* B. (1) Dorsal view; (2) Antenna; (3) Mandible; (4) Maxillule; (5) Maxilla; (6) Maxilliped; (7) Caudal ramus.

outer margin of third segment with fine teeth. Mandible composed of a broad denticulated plate, a broad claw-like spine with setae and two slender setae. Maxillule indistinctly two-segmented, one segment with a rather thick spine and two setae, and the other with four setae. Maxilla two-segmented, basal segment with a stout serrated spine and a slender spine, the narrow second segment with three spines, all provided with fine setae. Maxilliped three-segmented, third segment very small, with one long simple seta and a plumose seta, second segment expanded and with two setae, one of which is plumose, basal segment with two slender setae at the inner distal corner. Swimming legs two pairs with one-segmented rami. Rudimentary third leg present.

The structure of the various appendages except the mandibles shows a general similarity to that of *S. tropica* as described by Wolfenden (1906) and Nicholls (1944). In the present specimens the mandible consists of a stout flattened plate with blunt distal teeth, while it is shown as a bifid conical process by Nicholls. Wolfenden's description of the mandible agrees with that of the present form, but his Fig. 17, a part of which alone is the mandible, appears slightly different in the shape of the denticulated plate.

Family LICHOMOLGIDAE

Subfamily LICHOMOLGINAE (Gurney)

Genus: *Kelleria* Gurney

***Kelleria* sp.**

(Fig. 10)

Thirteen males and eight females of this type were collected on 14-7-1956. Descriptions of the male and female are given below:

Length: Male 0·7 mm., Female 0·8 mm.

FEMALE.—Anterior division of body expanded; urosome five-segmented, genital segment as long as the next three segments combined; caudal rami two times as long as broad. Antennule seven-segmented, second segment longest and third shortest. Antenna four-segmented, segments one and two with one seta each, third with two setae and a stout claw, fourth segment with two stout claws and five long setae; third segment comparatively small. Mandible composed of a stout base and a curved toothed process, the basal part internally expanded and carrying spines in two groups, distal prolongation with seven large teeth followed by a closely arranged row of spines. Maxillule a small flat plate with three distal spines, of which the middle one is the longest. Maxilla a flattened lobe, apically drawn out into a stout spine, the outer border of which carries two stout teeth and five to six small spines, on the inner side just below the apical spine is present an equally large spine with a row of stout teeth on the upper border and spinules on the lower. Maxilliped apparently three-segmented, third segment small and slender, carrying four long spines, first and second segments broad, latter with two spines, the proximal one clearly bifid, distal one with a spinule near its proximal third. Swimming legs one to three with both rami three-segmented, endopod of fourth leg one-segmented with two distal spines and a proximal inner seta. Setation of swimming legs as shown in the figure. Fifth leg one-segmented and leaf-like with two distal spines and an indentation on the inner margin.

MALE.—General shape like that of female. Urosome six-segmented, genital segment swollen and with two pairs of distal setae. Antennae and mouth parts as in female, but the distribution of the subsidiary spines on maxilla slightly different. Maxilliped sub-chelate and three-segmented, second segment oblong, with a stout curved proximal inner claw, inner border of the segment with a row of small sharp spines, third segment long, slender and claw-like, folding against the appendage and carrying a seta at its base. Endopod of first leg longer than exopod, the segments bent

Fig. 10. *Kelleria* sp. Female: (1) Antennule; (2) Antenna; (3) Mandible; (4) Maxillule; (5) Maxilla; (6) Maxilliped; (7) P1; (8) P2; (9) P3 endopod; (10) P4; (11) P5. Male: (12) P1; (13) P5; (14) Maxilla; (15) Maxilliped.

at right angles to each other, third segment with four inner setae and two terminal spines. Fifth leg narrow and with two distal spines.

Of the species so far included under this genus only *K. regalis* Gurney (1927) and *K. rubimaculata* Krishnaswamy (1952 *a*) show some resemblance to the present specimens. *K. rubimaculata* could at once be distinguished by the structure of the antenna, the fourth segment of which carries two claw-like setae in male. In the present specimens this segment carries invariably two claw-like setae and five long simple setae in both sexes. Similarly in *K. rubimaculata* the distal spine on the second segment of the maxilliped of the female is not bifid, while a subsidiary spine, though small, is clearly visible in the present specimens. The fifth leg of the male is comparatively slender in *K. rubimaculata*.

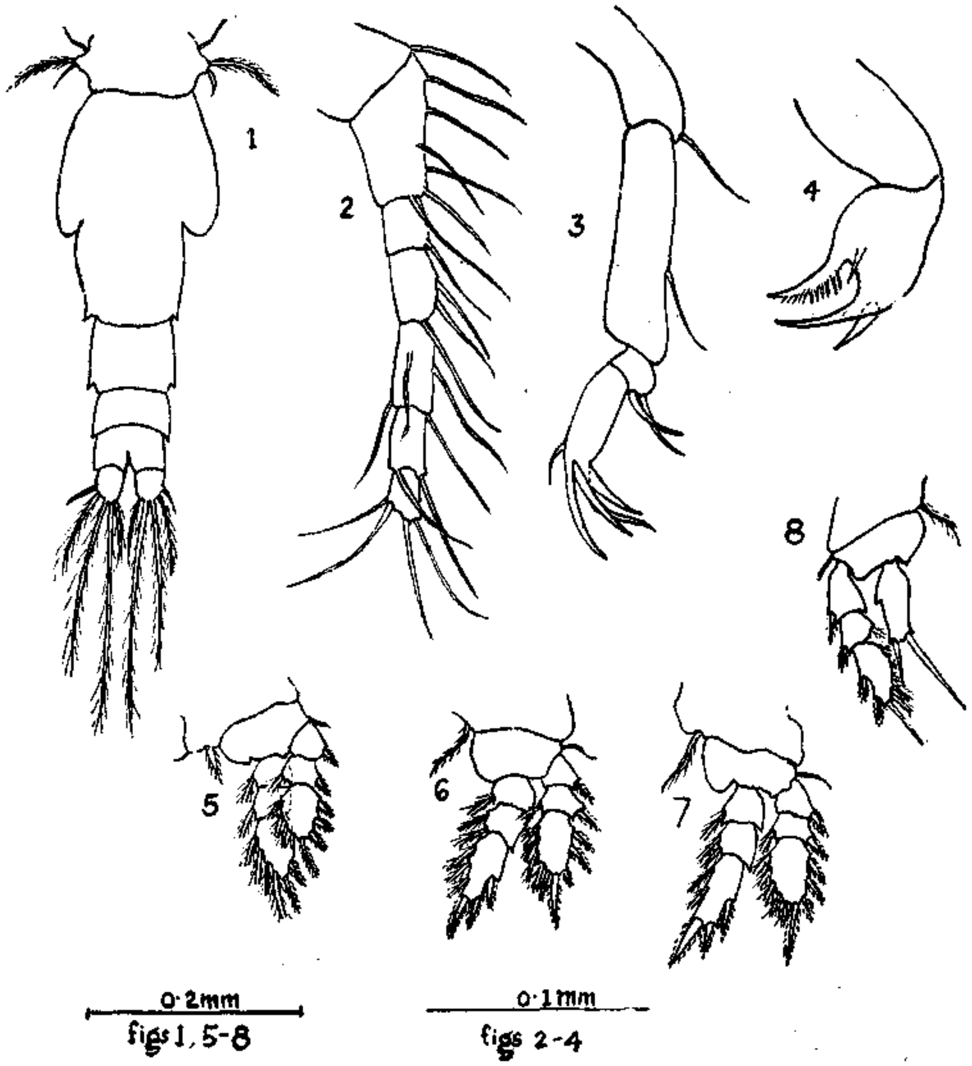

FIG. 11. *Pseudanthessius* sp. Female: (1) Urosome with P5; (2) Antennule; (3) Antenna; (4) Mandible; (5) P1; (6) P2; (7) P3; (8) P4.

The specimens in the present collection generally resemble *K. regalis* Gurney, but in the antenna of the latter, claw-like setae are absent and the third segment has only three setae and the fourth has six setae. The distal spine on the second segment of the maxilliped in the female is clearly bifid in *K. regalis*, while in the present specimens the spine is not bifid, but is with a small subsidiary spine. It is evident that these specimens could form a new species closely allied to *K. regalis* Gurney.

Genus *Macrochiron* Brady

Subgenus *Paramacrochiron* Sewell

Macrochiron (Paramacrochiron) maximum (Thompson and Scott)

Thompson and Scott, 1903, p. 276 (*Pseudanthessius*); Krishnaswamy, 1953, p. 67.

A rare form occurring in small numbers during August–October.

Length: Female 2·2 mm., Male 2 mm.

Genus *Pseudanthessius* Claus

Pseudanthessius gracilis Claus

Thompson and Scott, 1903, p. 276; Sars, 1918, p. 167.

Occurs in small numbers during August and September.

Length: Male 0·5 mm., Female 0·7 mm.

Pseudanthessius sp.

(Fig. 11)

The collection includes five females which could not be assigned to any of the known species and are hence described without a specific name. The salient characters are the following:

General shape of the body as in the genus *Pseudanthessius*. Urosome five-segmented, genital segment as long as the other four segments combined; caudal rami short, only as long as broad, outer seta very short and simple, the two middle apical setae longer than the other two. Antennule seven-segmented, with long setae, second segment longest, seventh shortest. Antenna four-segmented, terminal segment with four apical claws and one seta. Teeth on maxilla well developed. Propodal joint of maxilliped with a well developed hairy spine with a minute simple spine at its base on its inner border and another strong spine with a subsidiary spine at its base towards the distal end. First three pairs of swimming legs with three-segmented rami, fourth leg with a well-defined indentation on the outer margin of the single-segmented endopod; exopod three-segmented. Fifth leg represented by three setae.

The specimens were obtained from a collection made in July 1957.

Length: 1 mm.

Family ONCAEIDAE

Genus *Oncaea* Philippi

Oncaea venusta Philippi

Giesbrecht, 1892, p. 602; Sewell, 1947, p. 263; Krishnaswamy, 1953, p. 68.

This is a common species abundant during June, July and August.

Length: Male 0·9 mm., Female 1·2 mm.

Oncaea conifera Giesbrecht

Giesbrecht, 1892, p. 591; Sewell, 1947, p. 259; Krishnaswamy, 1953, p. 68.

Occurs along with *O. venusta* in small numbers.

Length: Male 1·1 mm., Female 1·2 mm.

Genus *Lubbockia* Claus

Lubbockia squillimana Claus

Brady, 1883, p. 118; Farran, 1935–39, p. 129; Krishnaswamy, 1953, p. 69.

Five female specimens were obtained from a collection made on July 1956.

Length: 1·6 mm.

Genus *Corycaeus* Dana

Corycaeus (Onychocorycaeus) obtusus Dana

Brady, 1883, p 116; Wilson, 1932, p. 356.

November to March in moderate numbers, rare during the rest of the year.

Length: Male 0·8 mm., Female 1 mm.

Corycaeus (Urocorycaeus) longistylis Dana

Giesbrecht, 1892, p. 674; Sewell, 1947, p. 277.

A single female obtained on 8–7–1958.

Length: 2·4 mm.

Corycaeus (Corycella) gibbula Giesbrecht

Giesbrecht, 1892, p. 675; Sewell, 1947, p. 288; Krishnaswamy, 1953, p. 72.

Present throughout the year.

Length: 0·9 mm.

Genus *Corissa* Farran

Corissa parva Farran

Farran, 1935–39, p. 131; Johnson, 1942, p. 436.

A rare form present only during July, August and September. In the presence of a fringe of spinules on the second antennal segment in the female, the specimens differ from the original description (Farran). On the terminal endopod segment of second leg in male, Johnson (1942) has shown the terminal spine exactly as the inner setae. In the present specimens this spine is normal. This is the first record of this species from Indian waters.

Length: Male 0·8 mm., Female 0·9 mm.

Family SAPPHIRINIDAE

Genus *Sapphirina* J. V. Thompson

Sapphirina angusta Dana

Dana, 1852, p. 1240; Lehnhofer, 1929, p. 273; Sewell, 1947, p. 265.

Six female specimens obtained during March-April 1956.

Length: 3 mm. to 3·5 mm.

Sapphirina bicuspidata Giesbrecht

Lehnhofer, 1929, p. 274; Sewell, 1947, p. 266.

Single female obtained in January 1957.

Length: 1·8 mm.

Sapphirina iris Dana

Dana, 1852, p. 1239; Lehnhofer, 1929, p. 279; Sewell, 1947, p. 266.

Found in small numbers during February and March.

Length: Male 5·3 mm., Female 4·9 mm. to 5·6 mm.

Sapphirina metallina Dana

Dana, 1852, p. 1242; Lehnhofer, 1929, p. 284; Krishnaswamy, 1953, p. 73.

Ten male specimens were obtained from a collection made on 23-10-1956.

Length; 3 mm.

Sapphirina stellata Giesbrecht

Brady, 1883, p. 123; Lehnhofer, 1929, p. 286; Sewell, 1947, p. 269.

Some female specimens were obtained. They were collected between January and April.

Length: 2 mm.

Sapphirina gastrica Giesbrecht

Thompson and Scott, 1903, p. 286; Lehnhofer, 1929 p. 287.

A single female obtained in July 1958.

Length: 2·5 mm.

Sapphirina opalina Dana

Dana, 1852, p. 1254; Lehnhofer, 1929, p. 295; Sewell, 1947, p. 267.

Six females collected during June-July 1958.

Length: 2 mm.

Sapphirina ovatolanceolata Dana

Dana, 1852, p. 1251; Lehnhofer, 1929, p. 298; Sewell, 1947, p. 268; Krishnaswamy, 1953, p. 73.

Found during December and January in moderate numbers.

Length: 2·5 mm.

Sapphirina nigromaculata Claus

Lehnhofer, 1929, p. 304; Sewell, 1947, p. 267; Krishnaswamy, 1953, p. 73.

Found in moderate numbers in July after the rains and occasionally in December and January.

Length: Male 1·9 mm., Female 2 mm.

Genus *Copelia* Dana

Copelia mirabilis Dana

Dana, 1852, p. 1232; Lehnhofer, 1926, p. 125; Krishnaswamy, 1953, p. 74.

Found in small numbers during December to April.

Length: Male 3·2 mm., Female 2·2 mm.

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DESCRIPTION OF TWO SPECIES OF CYCLOPOID COPEPODS, *PSEUDANTHESSIUS ANORMALUS* N. SP. AND *P. BREVICAUDA* N. SP.*

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ABSTRACT

The genus *Pseudanthessius* contains twenty-two species. Two additional species, *P. anormalus* n. sp. and *P. brevicauda* n. sp. are described in the present communication.

The most salient features of *P. anormalus* n. sp. are given below: (i) Genital segment is slightly broader than long, the narrow posterior division being very short compared to the anterior broad division. (ii) Caudal ramus is slightly broader than long and is distinctly shorter than last urosomal segment. (iii) Endopod of fourth leg is slightly swollen in the proximal half but does not display any notch or knob. (iv) Fifth leg consists of a very highly reduced spine seen only from the ventral side and two unequal setae, one of which is jointed at base.

P. brevicauda n. sp. is diagnosed as follows: (i) First prosomal segment is very large and broader than long. (ii) Second and third segments gradually diminish both in length and width and produced backwards at their postero-lateral corners. (iii) Last prosomal segment is short and overlapped partly by the preceding segment. (iv) Caudal ramus is very short, length and width being subequal. (v) Cephalosomal appendages are stoutly built, especially maxillule and maxilla. (vi) The endopod of fourth leg is half as long as exopod. Its inner margin is broken by notches, one at one-third and the other at two-third lengths. (vii) Fifth leg consists of a spindle-shaped spine and two setae. (viii) The proximal half of genital segment is broad and its width is only a little less than the length of the segment.

ACCORDING to the original definition of Claus (1889) the genus *Pseudanthessius* is characterised by the rudimentary condition of the last pair of legs. The reduction of the endopod of the fourth leg and the weak development of some of the mouth parts were recognised by some of the later authors (*see* Sars, 1917). The last two features, however, were noticed in varying degrees in some related genera also, leading to ambiguity as to the clear distinctions of the genus. Stock *et al.* (1964) in a recent review say that *Pseudanthessius* represents those lichomolgids in which the maxilla and the female maxilliped are weakly armed; the endopod of fourth leg is unimerous and bears two elements only, both terminal; and fifth leg lacks a free segment.

The genus *Pseudanthessius* comprises twenty-two species. The present communication contains two new species bringing the total to twenty-four. *Pseudanthessius anormalus* n. sp. and *P. brevicauda* n. sp. are close to *P. pectinifer* (Stock *et al.*). These three species have the caudal rami as wide as long. The other members of the genus *Pseudanthessius* have their caudal rami at least twice as long as broad. The differences between *pectinifer*, *anormalus* and *brevicauda* are presented in Table I.

The three species also differ in their host preferences. *P. pectinifer* is obtained from the washings of the sea biscuit, *Clypeaster rosaceus* in shallow water; *P. anormalus* from sponge washings; and *P. brevicauda* from the washings of littoral weeds. However, no specificity of hosts has been established.

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TABLE I

Structural differences between Pseudanthessius pectinifer, P. anormalus *and* P. brevicauda

P. pectinifer	*P. anormalus*	*P. brevicauda*
First prosomal segment longer than broad.	First prosomal segment broader than long.	First prosomal segment as long as broad.
Distal segment of maxiliped as large as the proximal with an obtuse terminal complex.	Distal segment of maxilliped half the size of the proximal segment with sharp but small spines.	Similar to *P. anormalus.*
Endopod of fourth leg is of approximately the same width throughout, with the exception of a small spinous construction near the middle of each side.	Endopod of fourth leg is slightly smaller in the proximal half, but does not display any notch or knob.	The inner margin of fourth endopod is broken by notches, one at one-third and the other at two-third lengths.
Fifth leg is represented by two setae and a smoothly elongated spine.	Fifth leg consists of a very highly reduced spine seen only from the ventral side and two unequal setae, one of which is jointed at base.	Fifth leg consists of a spindle-shaped spine and two fragile setae.

Pseudanthessius anormalus n. sp.

Material examined: Twenty-five females of this copepod were gathered from the sponge washings at the Gulf of Mannar on 19th October 1960. Holotype female and paratypes are deposited in the Reference Collection Museum of the Central Marine Fisheries Research Institute, Mandapam Camp, and bear the register numbers J. 763/26 and J. 764/26 respectively.

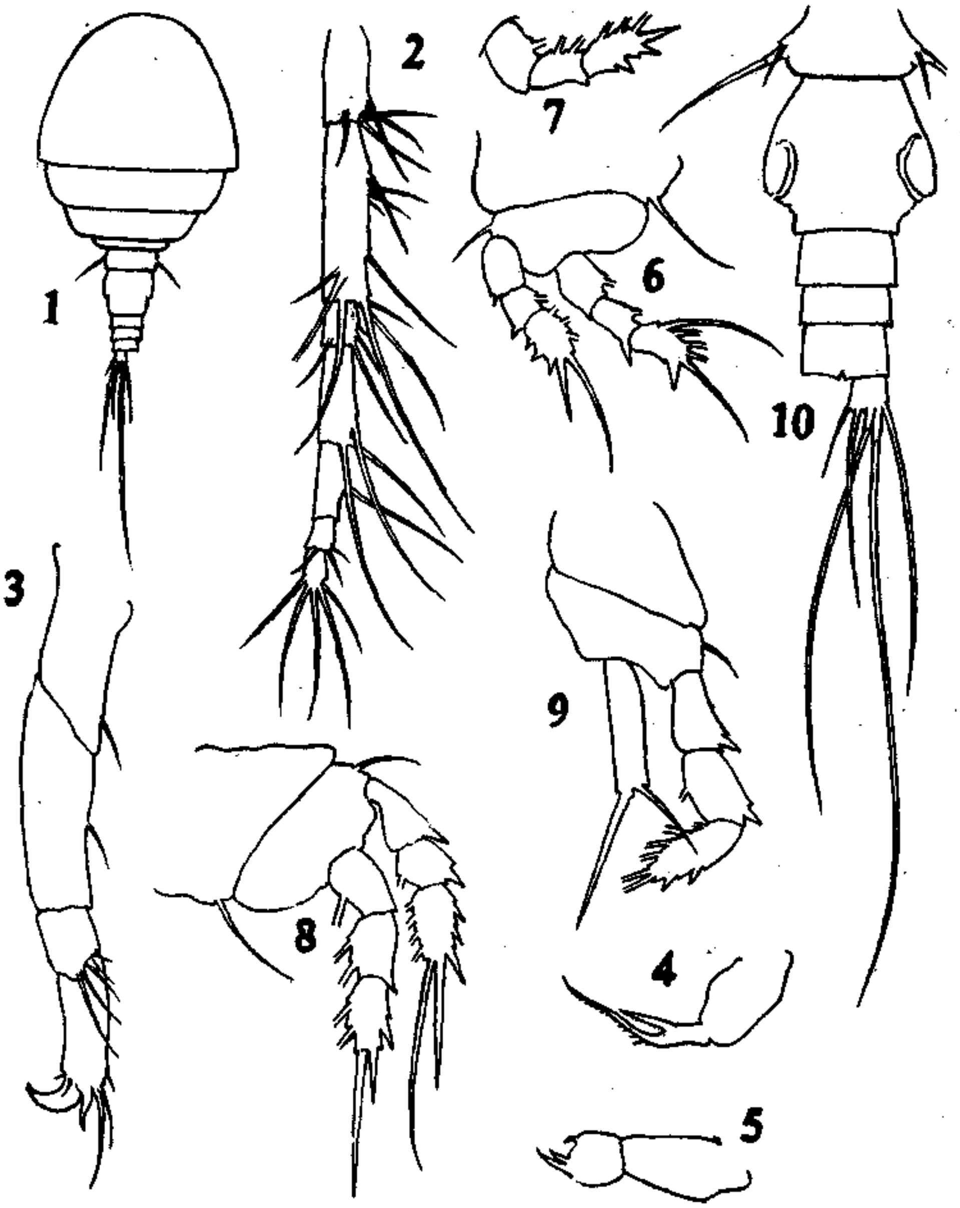
Descriptive notes: The specific name of this form is derived from the structure of the fifth pair of legs, caudal rami and the genital segment. These structures are found to show great deviations from what is generally observed for other species of this genus.

FEMALE: Prosome (Fig. 1) is broadly oval, cephalosome contributing more than half the total. Posterior margin of cephalosome is the widest part of body, next three free metasomal segments diminishing in length and width successively backwards. Urosome (Fig. 10) is 5-segmented, first segment bearing the fifth pair of legs. Genital segment is very broad and its length exceeds that of the abdominal segments combined. The narrower posterior division of the genital segment is very short compared to the broad anterior part. Caudal rami are peculiar. They are hardly as long as broad and are distinctly shorter than the last abdominal segment. Caudal setae are fairly long, the middle two setae being jointed near their base.

Antennule (Fig. 2) is 7-segmented, segments showing the following relative lengths:

1	2	3	4	5	6	7
16·5	30·7	8·0	17·0	14·2	6·8	6·8 = 100

Antenna (Fig. 3) is 4-segmented, terminal segment bearing two spines and a few setae. First and second segments are each with a single small seta and the third with two setae and several hairs. Mandible and maxillule show little peculiarities. In the maxilla (Fig. 4) both the terminal lappet and the process just behind it carry spinules on their anterior margin. Maxilliped (Fig. 5) is apparently 2-segmented, the first segment is naked, the second carries one seta in the middle of its posterior margin and two stout spines on its innermost part (actual apex of the appendage).



FIGS. 1–10. *Pseudanthessius anormalus* n. sp. Female: (1) Dorsal view; (2) Antennule; (3) Antenna; (4) Maxilla; (5) Maxilliped; (6) First leg; (7) Second endopod; (8) Third leg; (9) Fourth leg; (10) Urosome with fifth legs.

Swimming legs (Figs. 6–8) are, on the whole, typical of the genus. The 1-segmented endopod of the fourth leg (Fig. 9) is slightly swollen in the proximal region, but no knob or notch is present. The second endopod segment of first, second and third legs is produced at its outer distal angle into a beak-like structure. The following is the ornamentation of the swimming legs:

	Protopod				Endopod							Exopod						
	1		2		1		2		3			1		2		3		
	Si	Se	Si	Se	Si	Se	Si	Se	Si	St	Se	Si	Se	Si	Se	Si	St	Se
P_1	1	0	0	1	1	0	1	0	4	1	I	0	I	1	I	4	I	III
P_2	1	0	0	1	1	0	2	0	3	I	II	0	I	1	I	5	I	III
P_3	1	0	0	1	1	0	2	0	2	I	II	0	I	1	I	5	I	III
P_4	1	0	0	1	............II...............							0	I	1	I	5	1	II

Fifth legs are rather modified; the spine is very much reduced and is seen only if observed ventrally; on the upper and lower sides of this reduced spine are borne two setae, the much longer lower one being jointed at base. Size: 0·75 mm.

MALE: Unknown.

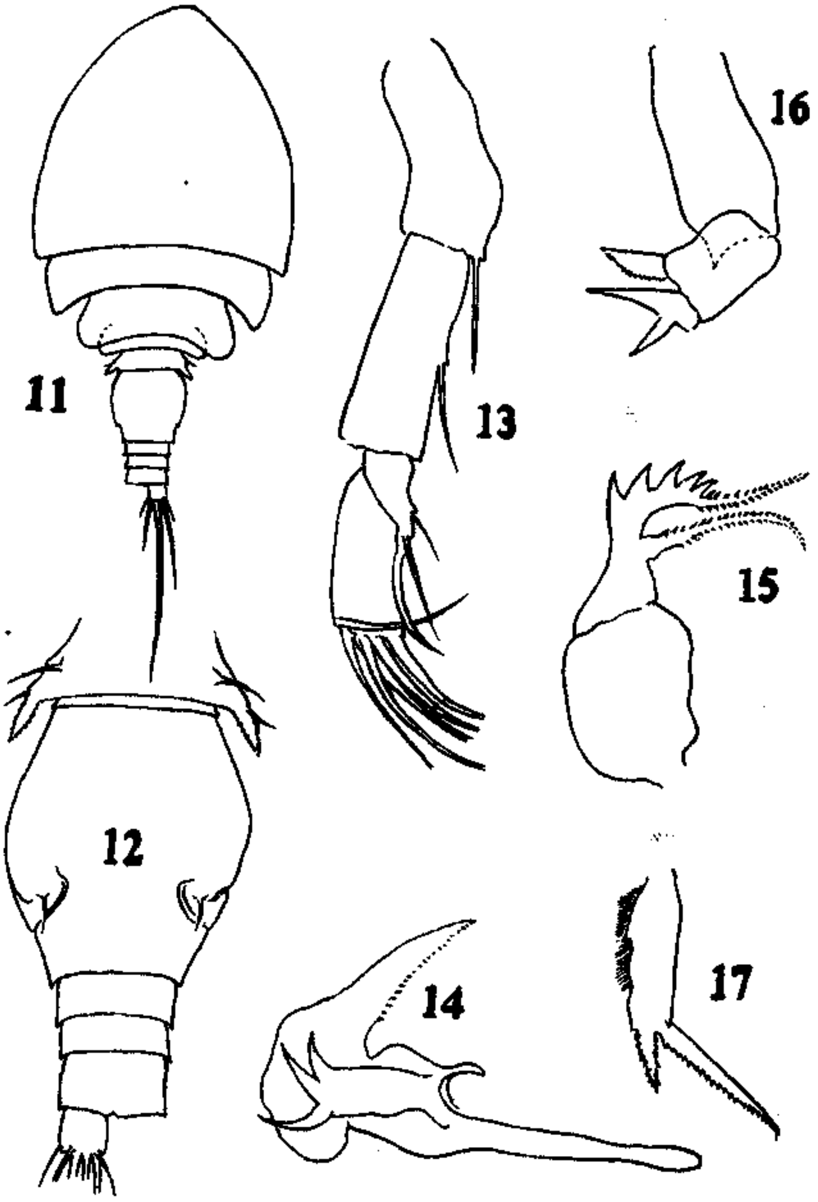
Pseudanthessius brevicauda **n. sp.**

Material examined: Four females of this copepod were obtained from washings of the littoral weeds from the Gulf of Mannar on 3rd November 1960. Holotype and paratypes are deposited in the Reference Collection Museum of the Central Marine Fisheries Research Institute, Mandapam Camp, and bear the register numbers J. 765/27 and J. 769/27 respectively.

Descriptive notes: The specific name of this species has reference to the very short caudal rami.

FEMALE: Prosome (Fig. 11) is large and ovoid and very distinctly demarcated from the urosome. First pedigerous segment is fused with the cephalosome and the combined cephalothorax is broader than long; it is the widest part of the prosome. The next two segments diminish gradually both in length and width. The postero-lateral corners of both these segments are prolonged backwards. The last prosomal segment is very small and is partly overlapped by the preceding segment. The first urosomal segment (Fig. 12) is normal. The genital segment is swollen in the anterior half but the demarcation between the two parts is not very pronounced. Guarding the genital apertures there is a pair of sharp spines. The next three urosomal segments are small and their combined length is just half that of the genital segment. Caudal ramus is short, nearly as long as broad.

Antennule is 7-jointed and similar to that of the preceding species. Antenna (Fig. 13), mandible, maxillule (Fig. 14), maxilla (Fig. 15) and maxilliped (Fig. 16) are as illustrated. They do not show many peculiarities except that they are stoutly built. In the antenna the third segment is exceedingly short. Mandible has a chitinous rod-like process extending postero-laterally; the distal end of the process shows fine denticulation. The terminal spines of the maxillule are strong and broad-based. In the maxilla the teeth on the apical lash are very strong, somewhat like those in species of *Macrochiron*.



FIGS. 11-17. *Pseudanthessius brevicauda* n. sp. Female: (11) Dorsal view; (12) Urosome with fifth legs; (13) Antenna; (14) Mandible and maxillule; (15) Maxilla; (16) Maxilliped; (17) Fourth endopod.

Ornamentation of the swimming legs is presented below:

	Protopod				Endopod							Exopod						
	1		2		1		2		3			1		2		3		
	Si	Se	Si	Se	Si	Se	Si	Se	Si	St	Se	Si	Se	Si	Se	Si	St	Se
P_1	1	0	0	1	1	0	1	0	4	1	I	0	I	1	I	4	I	III
P_2	1	0	0	1	1	0	2	0	3	I	II	0	I	1	I	5	I	III
P_3	1	0	0	1	1	0	2	0	2	1	II	0	I	1	I	5	I	III
P_4	1	0	0	1	..............II...............							0	I	1	I	5	I	II

The fourth endopod (Fig. 17) is half the length of the exopod. Its inner margin shows two breaks at equal distances, both accompanied by notches. The first two-thirds of the length of the inner margin are lined with fine setae. Fifth leg consists of a graceful spindle-shaped spine serrated along both margins and two short setae. One of the setae is close to the base of the spine while the other is a little removed. Size: 1·13 mm.

MALE: Unknown.

DIAGNOSTIC CHARACTERS OF *P. anormalus* AND *P. brevicauda*

The more salient features of *P. anormalus* n. sp. are given below: (i) Genital segment is slightly broader than long, the narrow posterior division being very short compared to the anterior broad division. (ii) Caudal ramus is slightly broader than long and is distinctly shorter than the last urosomal segment. (iii) Endopod of the fourth leg is slightly swollen in the proximal half but has no notch or knob. (iv) Fifth leg consists of a highly reduced spine seen only from the ventral side and two unequal setae, one of which is jointed at base.

P. brevicauda n. sp. is diagnosed as follows: (i) First prosomal segment is very large and broader than long. (ii) Second and third segments gradually diminish both in length and width and are produced backwards at their postero-lateral corners. (iii) Last prosomal segment is short and partly overlapped by the preceding segment. (iv) Caudal ramus is very short, as long as broad. (v) Cephalosomal appendages, especially maxillule and maxilla, are robust. (vi) The endopod of the fourth leg is half as long as exopod. Its inner margin is broken by two notches placed at equal distances. (vii) Fifth leg consists of a spindle-shaped spine and two setae. (viii) The proximal half of the genital segment is broad and its width is only a little less than the length of the segment.

ACKNOWLEDGEMENTS

The specimens described above were obtained from the South-east Coast of India while working at the Central Marine Fisheries Research Institute, Mandapam Camp. I wish to extend my sincere thanks to Dr. S. Jones, Director, for his unfailing encouragement and guidance throughout the course of study at the Institute. I also wish to express my gratitude to Dr. S. Z. Qasim, Assistant Director, International Biological Programme, Ernakulam, for his continued interest in the work and many helpful suggestions.

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ON A NEW SPECIES OF *LERNAEENICUS, L. BATAVIENSIS* (COPEPODA-LERNAEIDAE) WITH A KEY FOR THE IDENTIFICATION OF THE INDIAN SPECIES*

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ABSTRACT

A new species of *Lernaeenicus* parasite (Copepoda-Lernaeidae), *viz.*, *L. bataviensis* obtained from the fish *Anchoviella bataviensis* is described and figured. The earlier works on *Lernaeenicus* parasites from the Indian region are reviewed and a key is provided for the identification of the eleven Indian species.

TEN species of *Lernaeenicus* have been recorded so far, from the Indian region.§ They are *L. polynemi* (Bassett-Smith) 1898, *L. hemirhamphi* Kirtisinghe, 1933, *L. seeri* Kirtisinghe, 1934, *L. nemipteri* Gnanamuthu, 1953, *L. stromatei* Gnanamuthu, 1953, *L. ramosus* Kirtisinghe, 1956, *L. sayori* Yamaguti, 1939, *L. alatus* Rangnekar, 1961, *L. longiventris* Wilson, 1917, and *L. anchoviellae* Sebastian and George, 1964. *L. bataviensis* n. sp. described below is the eleventh species from the present locality.

Lernaeenicus bataviensis n. sp.

(Figs. 1–7)

Host and record.—A single specimen of the parasite was found attached to the fish *Anchoviella bataviensis* (Hardenberg) with its head embedded in the dorsal muscles just behind the opercular opening. The host fish was obtained from a shore-seine operated in the Palk Bay on the South-East Coast of India.

Holotype female is deposited in the Reference Collection Museum of the Central Marine Fisheries Research Institute, Mandapam Camp, S. India.

Description.—The general body colour is yellowish with the genital segment orange brown.

The head is situated at right angles to the free thorax; however, the anterior part of the neck has two nearly right-angled bends that the cephalothorax is turned backwards towards the abdomen (Fig. 1). The head, after a dorsal depression, is drawn out into a single posteriorly directed horn; the two together measure 1·5 mm. in length.

Antero-dorsally on the head are the first and second antennae, the first turned backwards and the second somewhat forwards. The second antenna is three-jointed, the middle joint carrying a knob on the inner side against which the terminal claw closes. Behind the antennae is the extended proboscis containing the mandibles and the maxillae. Arising from behind the base of the proboscis is a pair of maxillipeds, elongate and three-jointed, the third joint forming a claw (Fig. 4).

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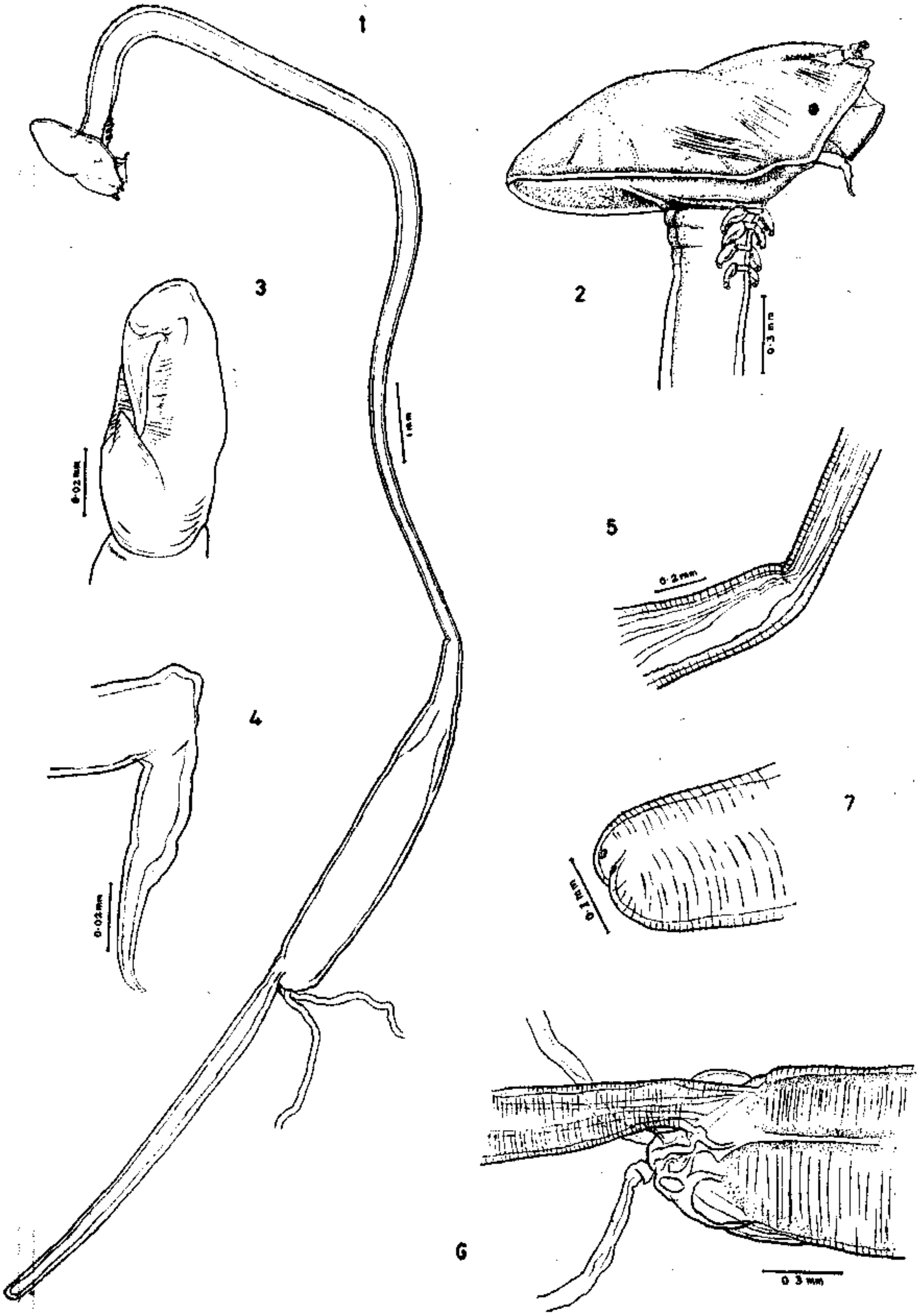
§ Including the records from Ceylon.



FIGS. 1–7. ***Lernaeenicus bataviensis*** n. sp. (1) Entire animal; (2) **Cephalothorax and free thorax, enlarged; (3) Second antenna;** (4) **Maxilliped; (5) Beginning of the genital segment, showing the notch;** (6) **Posterior end of the genital segment, showing genital** prominences carrying the **egg-sacs;** (7) **Tip of the abdomen.**

The free thorax, arising at right angles to the head, is indicated by incomplete segmentation and four pairs of thoracic appendages with their sternal plates. The first and second pairs of thoracic legs are biramous and the third and fourth are uniramous, all the rami are two-jointed.

The neck is much elongated and together with the free thorax measures 11·4 mm. The anterior half of the neck is enlarged, about 0·38 mm. wide and thereafter tapers to a minimum width of 0·18 mm.

The beginning of the genital segment is marked by a bend and a deep notch. It soon enlarges to a maximum width of 0·78 mm. and is more than four times its width at the beginning. The genital segment measures 4·9 mm. in length.

The abdomen is narrow, slightly longer than the genital segment (5·3 mm.) and studded with a pair of prominences at its hind end.

A pair of empty egg-sacs remained attached to the posterior end of the genital segment on marked prominences on either side, ventrally.

Remarks.—The present new species is unique among the Indian forms in possessing only a single cephalic horn. The only other species known with a single cephalic horn is *L. gracilis* Heller, 1865, but in this the horn is in the form of a single dorsal tubercle. Moreover, the abdomen is very minute (*vide* Wilson, 1917) quite unlike that of the present new species.

L. bataviensis n. sp. shows superficial resemblance to *L. anchoviellae* Sebastian and George in general size and colour of the body. However, the presence of only a single posteriorly directed cephalic horn, the enlarged anterior half of the neck and the notch and bend at the beginning of the genital segment are noteworthy differences.

The Indian species.—The discovery of *L. bataviensis* brings the total number of species known from the Indian region to eleven. The first species recorded from this region is *L. polynemi* (Bassett-Smith, 1898) collected from *Polynemus tetradactylus* caught at Bombay. Subsequently, Kirtisinghe (1933) described *L. hemirhamphi* from *Hemirhamphus xanthopterus* C. & V. collected from Ceylon, and Gnanamuthu (1953) redescribed the same from *Hemirhamphus far* caught at Madras. Gnanamuthu (*l.c.*) also described *L. nemipteri* and *L. stromatei* from the host fishes *Nemipterus marginatus* and *Stromateus niger*, respectively. His paper includes the description of the metamorphosed larva of *L. stromatei*. Rao (1951) reported the occurrence of a species of *Lernaeenicus* on *Scomber scomber* in the Waltair region. Kirtisinghe (1934) described *L. seeri* from an unidentified species of *Cybium* and in 1956 another species, *L. ramosus* from *Epinepheles morrhua* caught in Ceylon waters. Rangnekar (1961) described a new species *L. alatus* from *Cybium commersoni* and redescribed *L. ramosus* from *Synagris japonica*, and *L. sayori* Yamaguti (1939) from *Rastrelliger kanagurta*. Recently, Kirtisinghe (1964) reported the occurrence of *L. longiventris* Wilson (1917) on two Ceylonese host fishes, *Caranx ignobilis* and *Gnathanodon speciosus*. From *Anchoviella bataviensis* caught in the Palk Bay two new species were obtained; the first species *L. anchoviellae*, together with its three post-larval stages, is described by Sebastian and George (1964). The other species *L. bataviensis* is described in this paper.

The identification of some of these parasites is difficult since the descriptions of these species afford very little of contrasting characters. The cephalic and thoracic appendages show very little variation in the different species. The proportionate lengths of the various body regions were supposed to be specific in nature. For instance, *L. sayori* Yamaguti (1939) differs from *L. hemirhamphi* in possessing a shorter neck which is less than half the entire body length. However, Gnanamuthu (1953) has observed that the length of the neck in *L. hemirhamphi* may vary, even to the extent of being less than half the entire body length. Hence, in these species we have to look for other characters which are specific. Attempt is made here to provide a key for the identification of the Indian species, mainly based on the number, nature and position of the horns. The key is based solely on published descriptions.

KEY TO THE INDIAN SPECIES

1*a*. Horns in a single plane, short, stout and unbranched.

2*a*. A single horn directed posteriorly from the cephalothorax....*L. bataviensis* n. sp.

2*b*. Two horns directed postero-laterally from the cephalothorax......*L. anchoviellae* Sebastian and George, 1964.

2*c*. Three horns from the cephalothorax.

3*a*. Anterior part of body asymmetrical with cephalothorax and free thorax twisted in opposite directions......................*L. stromatei* Gnanamuthu, 1953.

3*b*. Anterior part of body symmetrical.

4*a*. Horns sharply pointed, arising posteriorly from under-surface of cephalothorax; genital segment flask-shaped, gradually enlarging posteriorly...*L. polynemi* (Bassett-Smith), 1898.

4*b*. Horns bluntly rounded, arising posteriorly from upper surface of cephalothorax; genital segment more or less cylindrical.

5*a*. Abdomen about twice the length of genital segment......*L. longiventris* Wilson, 1917.

5*b*. Abdomen much less than twice the length of genital segment, subequal.

6*a*. First antenna three-jointed; mandible without a proximal spiniform process; neck usually more than half total length...*L. hemirhamphi* Kirtisinghe, 1933.

6*b*. First antenna five-jointed; mandible with a small spiniform process at proximal end; neck shorter................*L. sayori* Yamaguti, 1939.

1*b*. Horns arising in two separate planes, an anterior set of cephalic horns and a posterior whorl of slender and elongate thoracic horns which are usually branched.

7*a*. Cephalic horns stout and nodular; thoracic horns four in number, not much elongated or branched.

8*a*. Thoracic horns not arranged in pairs, unequal in length and dissimilar in shape; abdomen about $4\frac{1}{2}$ times as long as genital segment...*L. seeri* Kirtisinghe, 1934.

8*b*. Thoracic horns arranged in pairs, with similar ones on either side; abdomen only about $1\frac{3}{4}$ times as long as the genital segment..*L. alatus* Rangnekar, 1961.

7*b*. Cephalic as well as thoracic horns arise as whorls of many slender, elongated and branched horns.

9*a*. Abdomen longer than genital segment........*L. nemipteri* Gnanamuthu, 1953.

9*b*. Abdomen shorter than genital segment........*L. ramosus* Kirtisinghe, 1956.

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My sincere thanks are due to Dr. S. Jones, Director, C.M.F.R. Institute, for encouragement and to Drs. N. Krishna Pillai and A. Daniel for the benefit of helpful advice. My thanks are also due to Mr. K. C. George, C.M.F.R. Institute, for placing the material at my disposal.

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DISCUSSION

Dr. Ruth D. Turner: I would like to know if your species is described as new with reference to the Indian region or on a global basis.

Mr. M. J. Sebastian: The only review of the genus is that of C. B. Wilson in the year 1917. The present species is considered new in the light of this review and all the subsequent literature that I could gather.

A NEW GENUS OF GALAPAGAN AMPHIPOD INHABITING THE BUCCAL CAVITY OF THE SEA-TURTLE, *CHELONIA MYDAS*

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U.S. National Museum, Washington D.C., U.S.A.

Abstract

A remarkable inquilinous amphipod extracted from the buccal cavity of *Chelonia mydas*, a sea-turtle captured in the Galapagos Islands, is described as a new genus in the family Hyalidae. This is the first record of a talitroidean amphipod living as an ectocommensal; other superfamily members are represented by phycophilous scuds, beachhoppers and limnophiles. The pereopods of the new genus are formed as grasping organs similar to those in amphipods that are known to grasp lobsters, fish and medusae. Although a marine hyalid, this genus has become specialized in many features suggestive of antiboreal freshwater hyalellids. Attention is called to the need for more exploration in the tropics of marine reptiles as hosts for ectocommensal amphipods.

Introduction

During the Galapagos International Scientific Expedition of January–March, 1964, three of my colleagues discovered an ectocommensal amphipod inhabiting the buccal cavity of the sea-turtle, *Chelonia mydas*. Eleven specimens of the crustacean were collected by Dr. Victor A. Zullo, Dr. John R. Hendrickson and Mr. Ross Kiester. These biologists were investigating sea-turtles for encrusting organisms, especially barnacles, that might give clues as to the migratory behaviour and origin of the particular reptile. According to Dr. Hendrickson, amphipods have been observed previously by turtle-experts in buccal cavities but apparently they have never been reported in the amphipodal taxonomic literature. One other species, *Podocerus chelonophilus* (Chevreux and de Guerne) (*see* Chevreux and Fage, 1925) has been collected from the external ventral shell of turtles but that is a tube-dwelling, fouling organism and presumably not an ectoparasite.

The new genus of amphipod is remarkable in that it belongs to the family Hyalidae in the superfamily Talitroidea and represents the first record of an inquilinous amphipod in a superfamily composed of families and genera that occur not only in the shallow sea but also in freshwater and on land. Those amphipods known as sand-hoppers belong to this group.

The pereopods of the amphipod are modified as grasping organs similar to the independent development seen in many genera and species of other family groups (*viz.*, several cyphocarid types in the Lysianassidae, a species of *Parapleustes* in the Pleustidae, and the genus *Isaea* in the Isaeidae).

Apparently, the amphipod grasps the soft tissues of the buccal cavity especially at the base of the tongue and on the insides of the gums and feeds on residues of the turtle's food. Guts of four of the specimens of the type series were empty. Owing to the translucency of all the specimens it was determined that food was probably not present in any of the other specimens and none of the remainder was dissected (and hence destroyed). Nevertheless, the mouth parts of the amphipod are adapted for chewing and biting, not for piercing and sucking, hence the thesis that the amphipod eats food residues.

Family HYALIDAE

Hyachelia, new genus

Diagnosis.—Talitroidean with first maxillary palp vestigial, fourth article of maxillipedal palp reduced in size, blunt, not claw-shaped; gnathopods 1 and 2 of both sexes normally subchelate, gnathopod 2 enlarged in male, lacking a produced lobe of article 5; all pereopods somewhat subchelate, with short palms armed with several short, blunt, curved, grasping spines; pleopods long and biramous; urosomal segment 3 obsolescent, bearing vestigial third uropod that lacks rami; telson formed of 2 separated lobes attached obliquely in a vertical plane, urosomal segments 1 and 2 each produced ventrally and posteriorly to form a false peduncle for uropods 1 and 2.

Type-species.—*Hyachelia tortugae*, new species.

Relationship.—Although by virtue of its strongly cleft telson with separated lobes and the shape of its branchiae this genus belongs with the Hyalidae, it has several features that show a course of specialization similar to that of the freshwater Hyalellidae and to some extent the terrestrial Talitridae. The fourth article of the maxillipedal palp is reduced and blunt unlike other hyalids and the first maxillary palp is nearly obsolete. No other hyalid has lost both rami of uropod 3. Except for its telson this genus might be assigned to the Hyalellidae with close relationship to *Austrochiltonia* Hurley (1958) and secondarily to *Chiltonia* Stebbing (as amended by Hurley, 1958). The telson of those genera is a simple lobe formed of the fusion of two lobes; their fourth maxillipedal palp-article is reduced and not claw-shaped, their first maxillary palp is absent, the third uropod is either a single segment (peduncle) or bears a scale-like ramus or a well-developed ramus. In *Chiltonia* the first male pleopod is modified as a whip-like lash but not in *Austrochiltonia*. *Afrochiltonia* K. H. Barnard (1955) has a normal first pleopod but the gnathopods of both sexes are alike. The chiltoniids are freshwater organisms of New Zealand, Australia and South Africa.

Hyachelia tortugae, new species

(Figs. 1–4)

Diagnosis.—With the characters of the genus.

Description.—Body similar to that of other talitroideans but pleon somewhat thinner and generally smaller except for urosomal segment 1; segments 6 and 7 of pereon dipping ventrally more than in other talitroideans; third pleonal epimeron especially small, with nearly straight posterior edge and subquadrate posteroventral corner; posterior edges of first and second pleonal epimera slightly convex, rounded posteroventrally, anteroventral corners slightly but bluntly produced; head with distinct, asymmetrically subconical, small lateral lobe, first article of second antennal peduncle invaginating into anteroventral corner of the head (unusual!), eyes intermediate in size, asymmetrically oval; antennae short, first shorter than second, article 3 of first longer than article 2, flagellum with about 8 articles; article 5 of second antennal peduncle longer than article 4, article 2 obsolescent, hidden from lateral view; coxa 1 with the typical anterodorsal lobe overriding pereonal segment 1, much narrower than coxa 2, pointedly rounded below, coxa 2 nearly quadrate, coxa 4 with rather large posterior, quadrate extension, coxa 5 unusually long to fit large, shallow excavation of coxa 4 and much larger than coxae 6 and 7; medial setae present only on coxae 2 and 3; upper lip slightly truncate below; each mandible with well-developed lacinia mobilis and 2–3 spines in spine row, molar triturating, armed with a long seta; outer plate of maxilla 1 with 9 spines, progressively more serrate medially, maxilla 2 with especially slender lobes for the family, maxillipedal plates extending approximately the same distance, medial edges of inner plates rather barren of setae, apices each with 2 articulated spines and 1 lateral, partially fused, spinal process, articles 2 and 3 of palp slightly produced mediodistally, article 4 very small, short, blunt, armed apically with 2 spines. Gnathopods of the two sexes strikingly different in

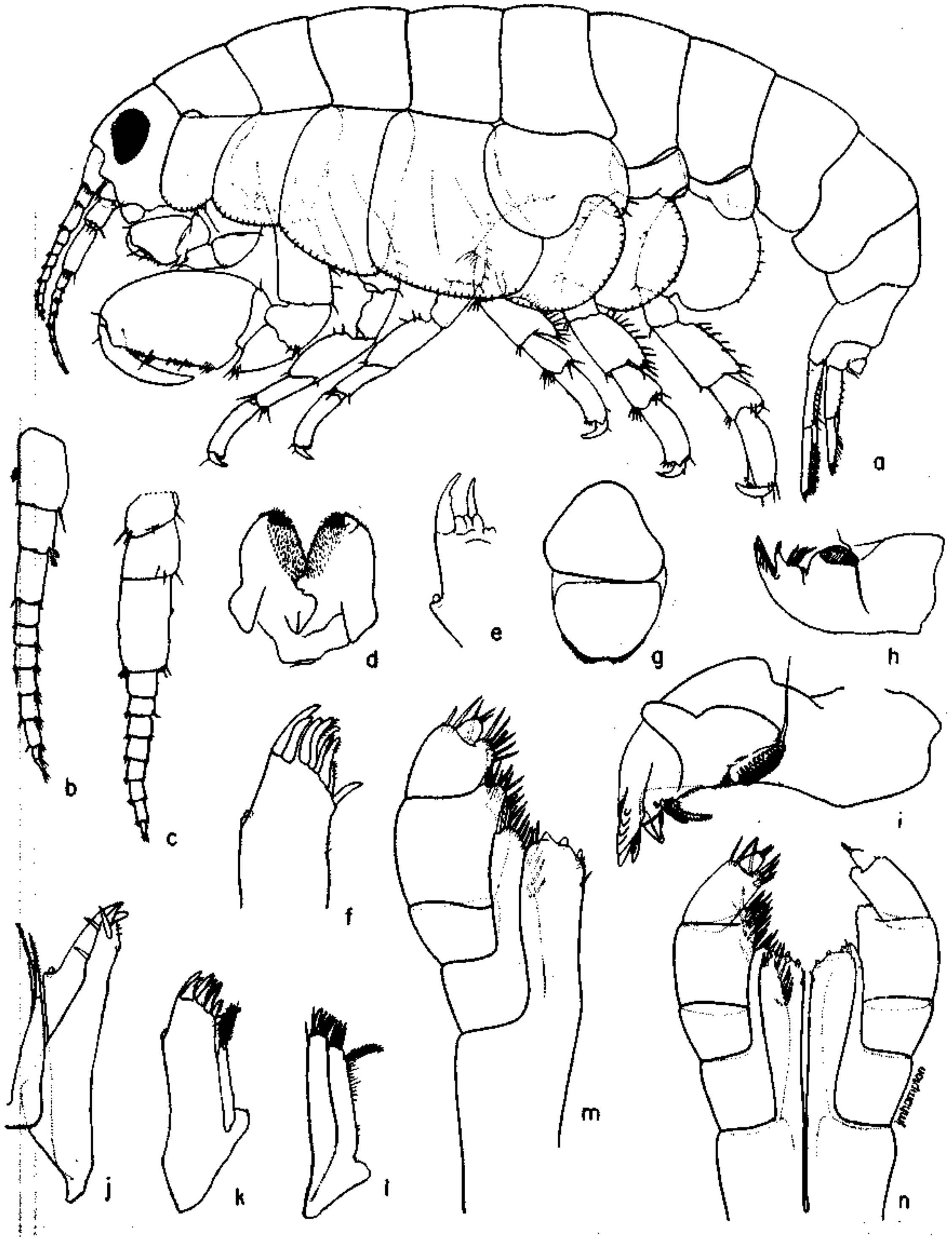

FIG. 1. *Hyachelia tortugae* n. gen. n. sp. Male, 7·1 mm., Galapagos Islands: (*a*) lateral view; (*b, c*) antennae 1, 2; (*d*) lower lip; (*e, f*) palps of maxilla 1; (*g*) upper lip; (*h, i*) mandibles; (*j, k*) maxilla 1; (*l*) maxilla 2. Female, 6·9 mm.: (*m, n*) maxilliped, flattened and normal views.

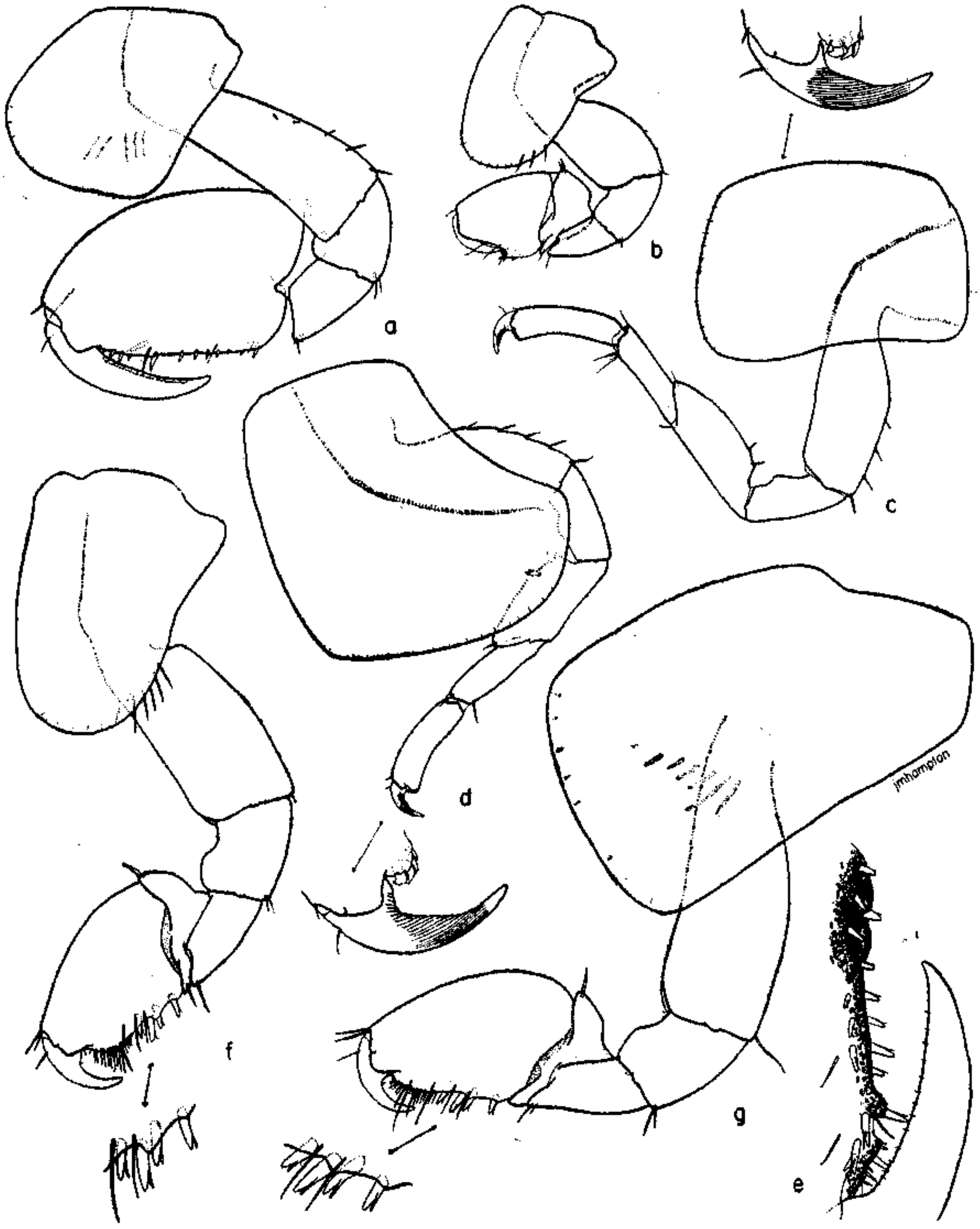

FIG. 2. *Hyachelia tortugae* n. gen. n. sp. Male, 7·1 mm.: (*a*) gnathopod 2; (*b*) gnathopod 1; (*c, d*) pereopods 1, 2; (*e*) palm of gnathopod 2. Female, 6·9 mm.: (*f*) gnathopod 1; (*g*) gnathopod 2.

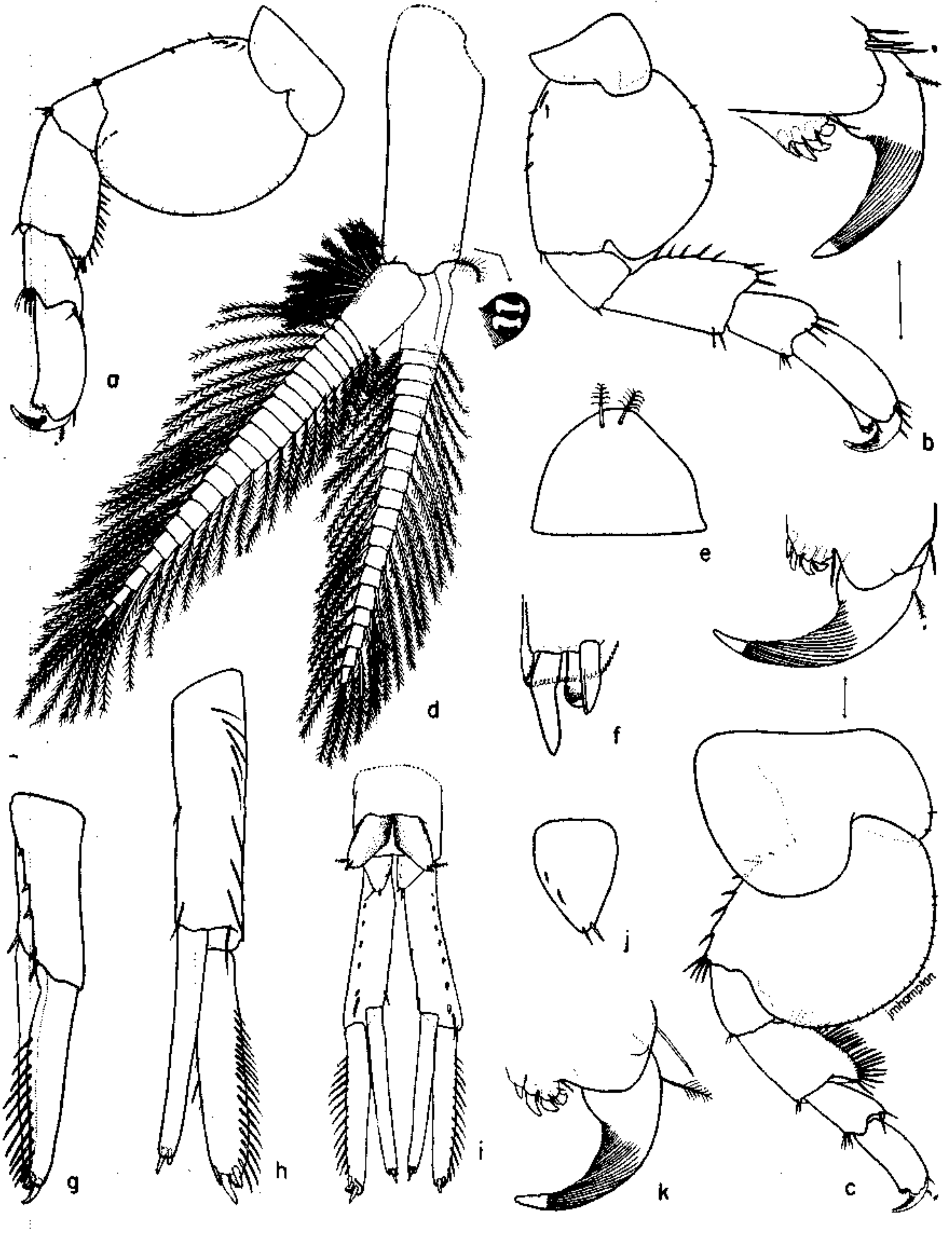

FIG. 3. *Hyachelia tortugae* n. gen. n. sp. Male, 7·1 mm.: (*a*, *b*, *c*) pereopods 4, 5, 3; (*f*) apex of outer ramus of uropod 1; (*g*, *h*) uropods 2, 1; (*i*) dorsal view of telson, uropod 3 and uropod 2; (*k*) end of pereopod 4. Female, 6·9 mm.: (*d*) pleopod 1; (*e*) telson; (*j*) uropod 3.

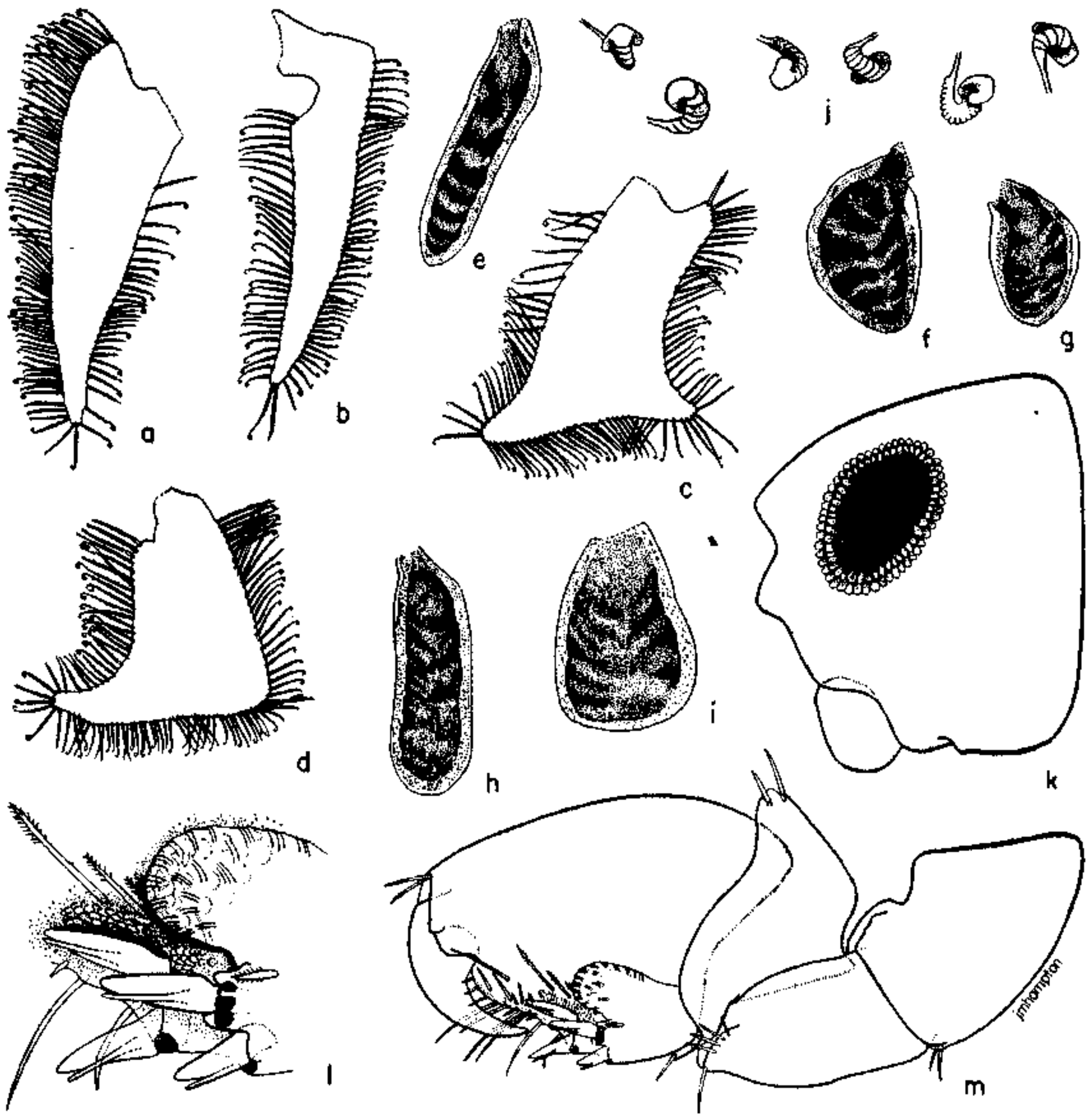

FIG. 4. *Hyachelia tortugae* n. gen. n. sp. Female, 6·9 mm.: (*a, b, c, d*) brood lamellae of thoracic segments 2, 5, 3, 4; (*e, f, g, h, i*) gills of segments 2, 5, 6, 3, 4; (*j*) various aspects of curl-tip ends of feminine brood-lamellae setae. Male, 7·1 mm.: (*k*) head; (*l*) enlargement of medial tuberous surface of gnathopod 1; (*m*) gnathopod 1.

various details: MALE.—Gnathopod 1 with article 5 short, narrowly produced posteriorly between articles 4 and 6, article 6 stout, slightly longer than broad, palm oblique and longer than hind margin of article 6, finger rather short and not fitting palm, simple, stout and curved; laterally palm showing few setae, medially palm strongly armed with setae along distal two-thirds, the edge minutely and irregularly serrate, palm defined proximally by a large spine, then a broad incision and another spine; the 2 defining spines matched on the medial, submarginal surface of the palm by 2 more spines; anteriorly subtended by a row of 4 setae, two proximal members of which partly covered by a large, rugose tuberosity; 2 of the spines (as figured) have small, strongly ridged bosses at their bases; large tuberosity covered densely with pairs and triads of short ridges, lower half of medial face of article 6 also covered with ridge patterns, dactyl covered with linear striated pattern of ridges (possibly these act to roughen the surface of appendages to prevent slippage on the mucoid tissues of the host); gnathopod 2 of the hyalid form, with article 5 very small and not produced posteriorly, article 6 stout, but longer than broad, palm very oblique and extending nearly full length of article, armed sparsely with spines and 2 small distal tuberosities, one elongated; dactyl about two-thirds as long as palm. FEMALE.—Gnathopods small, subequal in size, second slightly longer than first, nearly identical in structure and somewhat similar to male gnathopod 1 but lacking minute armature and medial tuberosity, palm very oblique, slightly convex, not departing from tangent of posterior margin of article 6, but slightly longer than posterior margin as defined by last distal spine and notch, palm armed with small setae, dactyl scarcely half as long as palm; article 5 short and produced into slender lobe between articles 4 and 6; female gnathopods appear to mimic, to some extent, the grasping pereopods because of the taper and armature of the palm. Pereopods 1–5 of both sexes generally of hyalid shape but anterior and posterior edges of article 6 bare of spines or setae and distal ends truncated to form subchela armed with 4 stout, hooked spines, dactyls short, curved, striated; pleopods biramous, subequal, rami long, setose. Uropods 1 and 2 with lateral margins of outer rami densely setose, inner rami more slender and lacking setae; uropod 3 formed of a small, bluntly subconical piece armed with 2 setules, attached to last body segment ventral to the telson; pleonites 5 and 6 apparently completely fused, at least from lateral view no sixth segment is demarcated; telson composed of 2 detached bracts set in an oblique but vertical plane, each armed with 2 setules. Gills consisting of lamellar sacs as shown in the figures; female brood lamellae attached to pereonal segments 2, 3, 4 and 5 and of strikingly varied shape as shown in the figures (drawn from the left side); edges of gills armed with curl-tipped setae of complex terminal morphology as shown in the figures.

Holotype.—USNM No. 111527, male, 7·1 mm.

Type-locality.—Zullo 363, from the mouth of a sea-turtle, *Chelonia mydas* collected on February 24, 1964, at Porto Nuñez, Santa Cruz Island, Galapagos Islands.

Material.—10 specimens from the type-locality and one further specimen from Zullo 364, another turtle of the same species.

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RE-EXAMINATION OF THE TAXONOMIC STATUS OF *NIPHARGUS INDICUS* CHILTON (AMPHIPODA, GAMMARIDAE) AND ITS ZOOGEOGRAPHICAL RELATIONS

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Abstract

Niphargus indicus is a freshwater amphipod crustacean, described by Chilton (1923) from a pit in the Asansol Subdivision of Bengal. This species was found later in Bádámpahár in Orissa, and Stephensen (1931), in describing the specimens, attributed it to *Neoniphargus*, an Australian genus. Another Asiatic species was attributed to the same genus, *viz.*, *Neoniphargus kojimai* Uéno, 1955, from the vicinity of Tokyo, Japan, as a representative of the separate subgenus *Eoniphargus*. In connection with a study of the Australian Gammaridae of the *Neoniphargus* group (Straškraba, 1964), *Eoniphargus* was raised to the generic rank and several characters separating *Neoniphargus indicus* from the Australian representatives, and *Eoniphargus* as well, were pointed out.

In re-examining the specimens from Bádámpahár and the third locality of Rohod near Chaibassa, I did not find the species congeneric with the Australian *Neoniphargus*. The diagnosis of the new genus, *Indoniphargus* n. g. is given. It is rather difficult to find an explanation for the presence of the same genus in the springs of Australia, North India, and Japan, since rather old "land-bridges" should be brought into relation with this. When distinguishing three genera, no such problematical explanations are necessary. Some relations among these genera might be explained by derivation from a common littoral ancestor, inhabiting these parts of the Western Pacific. Among the recent brackish water and partly freshwater amphipods, a similar pattern is evident in the genus *Paracalliope*.

The distribution of the amphipods in India seems to be a neglected subject of study in comparison with other freshwater Crustacea, despite their importance. Two groups may be distinguished from among the freshwater amphipods in India; one, inhabiting the waters of the Himalayan mountains, the other, inhabiting the more southern, chiefly coastal regions. The first group, of a distinct Palearctic origin, is represented by *Rivulogammarus lacustris* G. O. Sars. The surprising dominance of this species over an extensive territory of the Middle Asiatic Mountains, in a wide variety of habitats, is brought into relation with the Ice Age. The probability of finding other species of the genus *Rivulogammarus* in the north-western corner of India is pointed out. The second group is represented, besides *Indoniphargus*, by brackish water and partly freshwater species of the genera *Melita* and *Paracalliope*, both showing relations to the littoral fauna of New Zealand, *Quadrivisio bengalensis*, distributed over Africa, India and Siam, and *Grandidierella*, a widely distributed genus of the tropical seas.

The necessity of additional studies of the Indian freshwater Gammaridae for a more profound knowledge of the zoogeographical relation is emphasized.

Several authors have paid attention to Amphipoda inhabiting the littoral and brackish water habitats, but the distribution of the freshwater Amphipoda of India received very little attention in comparison with other freshwater Crustacea. (Giles, 1888; Stebbing, 1904, 1907, 1908; Chilton, 1920 *a*, *b*, 1921, 1923, 1925; Stephensen, 1931; Uéno, 1934; Barnard, 1935; DiCaporiacco, 1936). Increased attention paid to Indian freshwater zoogeography in recent years and the interesting findings in a related group, the freshwater Isopoda (Chopra and Tiwari, 1950; Tiwari, 1955 *a*, *b*) revealed the necessity for a re-examination of the taxonomical and zoogeographical relations of Indian amphipods. Previously this group was considered cosmopolitan, but recent findings indicate otherwise. The distribution of most of the known genera and species is limited and the group appears to have considerable value in zoogeographical studies.

During a revision of the generic position of the species of *Gammarus* and *Niphargus* from the southern hemisphere the present author found a lot of taxonomic defects. *Gammarus* of Australia and South Africa proved to belong to genera related to marine *Melita*, which has little in common with the Holarctic generic group *Gammarus*. Several species previously attributed to *Niphargus* on the basis of some homologous characters were transferred to *Neoniphargus*, a genus bearing no direct relations with the western Palearctic *Niphargus*. This was also true of *Niphargus indicus* Chilton, 1923, collected from a pit in the Asansol Subdivision of Bengal, transferred to *Neoniphargus* by Stephensen as early as 1931. Most of the species of *Neoniphargus* live in Australia, the only representatives outside Australia being *N. indicus* Chilton and *N. kojimai* Uéno, 1955, from Japan. Uéno (1955) separated the Japanese species into a new subgenus, *Eoniphargus*. Straškraba (1964) while re-examining Australian representatives of *Neoniphargus* found that they belong to three different genera, *Neoniphargus*, *Uroctena* and *Perthia* and elevated *Eoniphargus* to generic rank on the basis of several distinctive characters. He also indicated several characters, separating *Neoniphargus indicus* from all the *Neoniphargus* species of Australia on the one hand and from *Eoniphargus* from Japan on the other.

Through the kindness of Dr. T. Wolff, Zoological Museum, Copenhagen, I obtained specimens of *Neoniphargus indicus* from Bádámpahár described by Stephensen in 1931, as well as an additional collection from Rohod near Chaibassa. This enabled me to re-examine the generic position of *Neoniphargus indicus*. It proved to belong to a separate genus, closely related to *Neoniphargus*. I name it *Indoniphargus* in honour of India, which is the only area known to be inhabited by this genus. The aim of the present paper is to describe the new genus and to discuss its zoogeographical relations. In this context, available data on the zoogeographical relations of Indian freshwater amphipods are summarised.

***Indoniphargus* gen. nov.**

Diagnosis.—Near to *Neoniphargus*, but differing in the mouth parts and gnathopods, with coxal plates nearly as high as the respective segments; segments of meso- and metasome spiny. Mandibular palp with the terminal joint as long as 2nd segment; lower lip without distinct inner lobes. Maxilliped, outer lobe reaching to the middle of the 2nd segment of palp. Carpus of gnathopods rather elongated, nearly as long as propodus; swollen calosity covering the whole posterior margin of merus, carpus and propodus.

Type species.—*Niphargus indicus* Chilton, 1923.

Remarks.—The characters given above separate *Indoniphargus* from all the *Neoniphargus* species of Australia. The present data seem to point out the evolution and early isolation of both genera from a common littoral ancestor which inhabited the shallow areas of these parts of the Western Pacific.

The separation of *Eoniphargus* seems to be much higher. But for a more definite assessment of these points, additional information about the Asiatic and Malayan amphipod fauna is necessary.

***Indoniphargus indicus* (Chilton, 1923)**

Niphargus indicus Chilton, 1923, *Rec. Indian Mus.*, **25**: 195, Figs. *a–c*.

Neoniphargus indicus, Stephensen, 1931, *Rec. Indian Mus.*, **33**: 15, Figs. 1–4.

***Material.*—Bádámpahár**, Morbhanj State, Orissa (10 spm.), 2–8–1929, leg. Senior-White; Out of a well of drinking water at Rohod, near Chaibassa in Bihar and Orissa (3 spm.), 18–3–1935, leg. Dr. B. N. Chopra, Indian Museum, Calcutta (Zool. Museum, Copenhagen, Nr. 17–12–1935).

Variability.—This species was well described and figured by Stephensen (1931), and hence only a few remarks are necessary. The short setae and spines irregularly distributed on the dorsal surface of the meso- and metasome segments in addition to the usual groups of spines on the posterior margins of urosome segments (1–2–1, 1–2–1, 1–0–1 in all specimens) are remarkable. Posterior margins of the mesosome segments carry many equally spaced spinules. This is very much as in *Rivulogammarus*, *Echinogammarus* and *Anisogammarus*, placed by Schellenberg in "Sectio spinosa".

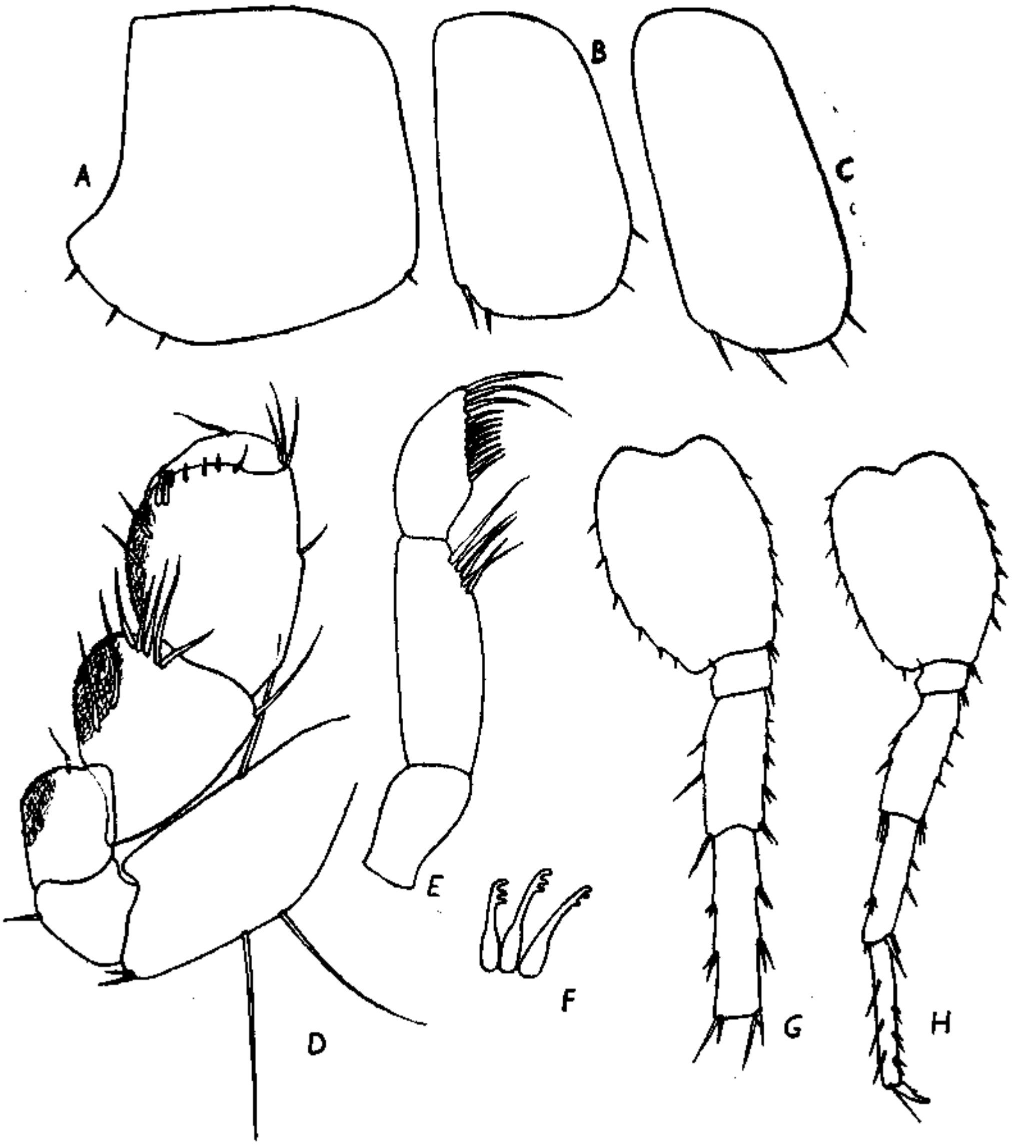

FIG. 1. *Indoniphargus indicus* (Chilton, 1923) from Rohod. (A) coxa 4; (B) coxa; (C) coxa 1; (D) gnathopod 1; (E) mandibular palp; (F) retinacula; (G) pereopod 7; (H) pereopod 5. Orig.

Stephensen's figure of the mandibular palp is obviously wrong. The 2nd segment is larger and subterminally armed with a group of 4–6 setae. Terminal joint is only half as long as the preceding one, naked in the proximal half, distal half provided with a row of 9 equal setae, shorter than the width of the segment, and three additional much longer setae terminally. The armature is the same in specimens from **Bádámpahár** and Rohod.

In specimens from Rohod I was not able to observe any sexual characters. Coxal plates one to three have 2-3 long setae at the anterior corner and two spine-like setae situated in a notch at the posterior corner. The first gnathopod has its carpus slightly shorter than propodus. Carpus is provided terminally with an outer and an inner group of setae, the inner group is composed of 5 setae, reaching to the middle of the propodus. The outer group consists of 6 setae, one of which is twice as long as the others and reaches nearly to three-quarters of the propodus. Inner margins of both carpus and propodus are similarly built, with a swollen calosity along the whole margin and a few "marginal" setae situated somewhat below the margin, at the base of the calosity. Two such setae are presen- on both carpus and propodus of the first gnathopod and three on those of second gnathopod' Propodus of both gnathopods has two outer and two inner palmar spines, palm has a regular row of four spines. The presence of several groups of spines on the joints of pereopods 3–7 different from what has been shown by Stephensen indicates that these characters vary as in *Rivulogammarus*. First uropod is setose, which is a character never seen in any *Neoniphargus* of Australia. In the Rohod specimens setae are few in contrast to the many setae in the specimens from Bádámpahár

ZOOGEOGRAPHICAL RELATIONS

The amphipod fauna of the Indian territory may be divided into two groups: The northern Indian mountains are inhabited by the genus *Rivulogammarus* with relatives in the North and West and the mainland by some other genera with relatives in the South and East. A distinction into Palearctic and Oriental provinces is thus clearly indicated.

It is rather surprising, that all the present records of the Holarctic genus *Rivulogammarus* (*Gammarus* auct. part) in the higher altitudes of the Himalayan and Karakoram mountains seem to belong to one species, *Rivulogammarus lacustris* G. O. Sars, 1863. They have been described under various names [*G. pulex* from many localities in Kashmir and Ladak by Uéno, 1934, *Rivulogammarus stoliczkae* from lake Tschomoriri by Karaman, 1934, *Gammarus pulex* subsp. *extensus* from Dochen by Barnard, 1935, *G. pulex* from Val Sind in Karakoram by DiCaporiacco, 1936, *G.* (*Rivulogammarus*) *lacustris* from Sancha, N. Kumaon and River Dorbuck by Schellenberg, 1937], but the characters given by the authors indicate that they all probably dealt with *Rivulogammarus lacustris*. The present author has examined additional specimens from Tingri, Kipiskong and Tranepo-Chumcha taken during the Mt. Everest Expedition and preserved in Zoologisches Museum, Berlin, and from Muktinath in Nepal (13–9–1956 leg. Hyatt), preserved in the British Museum of Natural History. The same dominance of this species seems to be valid for all the higher central parts of the Middle Asiatic mountains as will be reported elsewhere. The numerous collections of Dr. Jankovskaya, Leningrad, taken during the Pamir Expedition of the Central Asiatic University, which she kindly sent to me for identification belong to the same species, although they were taken in a variety of habitats, *e.g.*, large lakes, small pools, springs, streams, rivers and even warm springs. The obvious explanation is that this species as the most cold-resistant one was alone able to repopulate the areas made barren by the retreat of the glaciers.

In the Western and North-Western marginal positions of the Middle Asiatic mountains (Turkestan, Tadjikistan, Kazachstan and Kirgizia) a well-defined speciation center of the genus *Rivulogammarus* seems to occur with about 15 valid species. Collections from some lower positions in Kashmir preserved in the British Museum of Natural History which I was able to study recently contain new *Rivulogammarus* species, which indicate that another independent speciation centra is to be expected in the South-Western margin (probably Páthánistán, Kashmir, Himachal Pradesh).

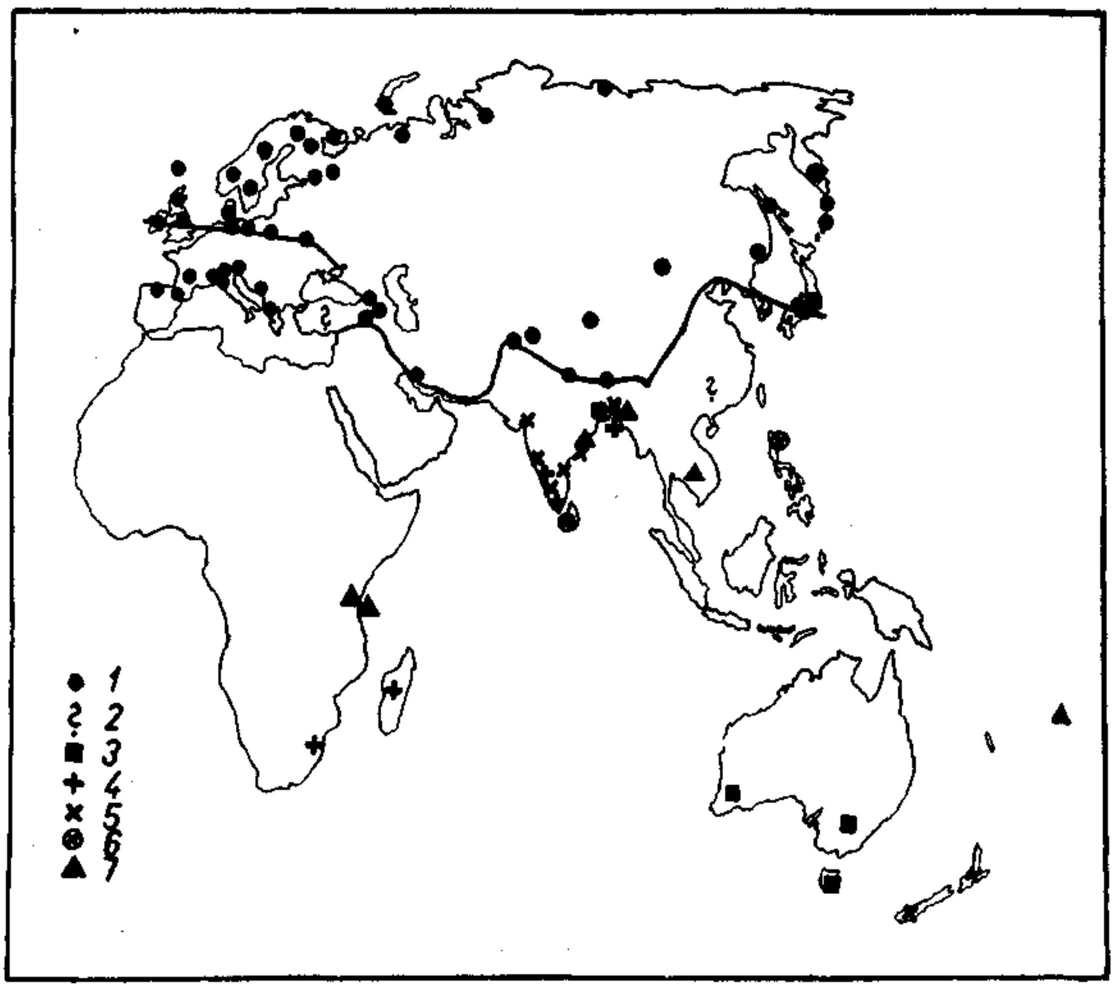

FIG. 2. Zoogeographical relations of Indian freshwater Amphipoda. (1) Some extreme positions of *Rivulogammarus lacustris* (G. O. Sars, 1893), based on data from the literature and author's findings. The solid line indicates probable southernmost limits of the continuous distribution of the species. (2) Areas of possible occurrence of *R. lacustris*. (3) *Indoniphargus* and relatives from the *Neoniphargus* group. (4) *Grandidierella bonnieri* Stebbing, 1908. (5) *Paracalliope fluviatilis* Thomson, 1879; (6) *Paracalliope fernandoi* Wignajarah, 1958 and *Paracalliope* sp. (7) *Quadrivisio bengalensis* Stebbing, 1907.

Among the amphipod fauna of the Oriental region genus *Paracalliope* has a similar distribution pattern as the *Indoniphargus-Eoniphargus-Neoniphargus* group. *Paracalliope indica* Barnard, 1935, inhabits brackish water localities along the entire coast of India: Bombay to Malabar—Ruffo (1956); Adyar river near Madras?—as *P. fluviatilis* Thomson, 1879 by Chilton (1920*a*); salt lakes near Calcutta—Barnard (1935); Lake Chilka—as *P. fluviatilis* by Chilton (1921), *see* Barnard (1935). *Paracalliope fernandoi* Wignajarah, 1958, was described from a single specimen from tap-water in Labugama in Ceylon, another, not well-defined species referred to *P. fluviatilis* by Chilton (1920*a*) was found in Philippine Islands (*see* Barnard, 1935). *Paracalliope fluviatilis*

Thomson, 1879 is common in freshwaters all around New Zealand, invading brackish water localities also.

Similar to this is the occurrence of *Melita gayi* (Nicolet, 1849) (= *M. inaequaestylis* Dana), which besides inhabiting some marine and brackish water localities extends into freshwater areas in New Zealand and India. Freshwater genera related to *Melita* have been found by the present author occurring in Australia; *Paramelita* occurs in South Africa and *Paraniphargus* in Jawa and the Andaman Islands, and the discovery of additional relatives in India could not be excluded.

Other littoral genera with restricted freshwater distribution show more affinity to the African fauna. *Grandidierella bonnieri* Stebbing, 1908, was found along the East Coast of India, in Madagascar and South Africa. Several other much more restricted species of the genus inhabit Indian waters, *i.e., G. gravipes* Barnard, 1935, *G. macronyx* Barnard, 1935 and *G. gilesi* Chilton, 1921. The last species described from the Chilka lake was found in a purely freshwater locality by Barnard (1935). Other species are known from all subtropical and tropical parts of both oceans except Australia, inhabiting mostly salt waters, but some of them like *G. mahafalensis* Coutiére, 1904, inhabit freshwaters (Madagascar) too. Similarly *Corophium triaenonyx* Stebbing, 1904, occurs in littoral localities along the coasts of South Africa and India.

Most extensive is the distribution of *Quadrivisio bengalensis* Stebbing, 1907, which is found along the coast of East Africa, Zanzibar, India, Siam and the Fiji Islands. A related species, *Quadrivisio lutzi* Shoemaker, 1933 (= *Q. occidentalis* Stephensen, 1933) occurs in Venezuela and the West Indies.

Zoogeographical relations of several representatives of the families Hyalidae and Talitridae are not clear since many taxonomic questions remain to be solved. *Hyale brevipes* Chevreux, 1901, occurring in freshwaters of India is distributed over the islands of the Indian Ocean and has some freshwater relatives in Zanzibar and Madagascar. Several other representatives of amphipods like the ground-water *Bogidiella*, *Ingolfiella* and others remain to be discovered in Indian waters.

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ON THE GAMMARIDEAN AMPHIPODA OF THE GULF OF MANNAR, WITH SPECIAL REFERENCE TO THOSE OF THE PEARL AND CHANK BEDS*

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ABSTRACT

During the underwater survey of the pearl and chank beds off Tuticorin carried out by 'Scuba' diving, a number of amphipods were also seen amongst various material collected from the sea bottom. These amphipods were studied in detail. Incorporating the amphipods of the pearl banks of Ceylon described by Walker (1904) a complete list with synonymies of all the reported species of amphipods from the Gulf of Mannar, together with the description and sketches of species wherever found necessary, has been given in this account.

INTRODUCTION

THE present paper deals with the amphipods collected while engaged in the underwater exploration of the pearl and chank grounds off Tuticorin by 'Scuba'† diving during the years 1962-64. A good number of amphipods were collected from different habitats at depths varying from 10 metres to 30 metres. Additional materials were also obtained from shallow areas, sandy beach of Tuticorin and from plankton collections made off Tuticorin. The aim was not only to make the account of the amphipod fauna of this part of the Sub-Continent a comprehensive one, but also to compare the amphipod fauna with that of the Gulf of Mannar coast of Ceylon, almost an identical habitat, as reported by Walker (1904).

Separated as it is only by a distance of a few scores of miles with the nearest points between India and Ceylon coasts being hardly more than 20 miles and interconnected by Adam's bridge through submerged coral reefs lying in shallow waters between Dhanushkodi and Thalaimannar at the head of the Gulf, one would find close similarity of fauna from identical habitat. Naturally most of the forms reported by Walker (1904) are reported here. But such of those forms which Walker (1904) recorded but which were not collected during the present study have also been included to make the account of some use to the systematic worker on this group. It was not possible before the present paper was released to complete the description of some of the unreported species collected now from Gulf of Mannar both due to insufficient material and the limited time at the disposal of the author. It is hoped to bring it out shortly.

Detailed descriptions of the species have been omitted to lessen the bulk, but sketches of some of the characteristic appendages which would help in the identification of the species have been given wherever possible. Included in this account are amphipods referable to 78 species of 54 genera under 27 families.

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** Present Address: Central Marine Fisheries Research Unit, Tuticorin.

† Self-contained underwater breathing apparatus.

Suborder GAMMARIDEA

Family LYSIANASSIDAE

Genus *Shoemakerella* Pirlot

***Shoemakerella nasuta* (Dana)**

(Fig. 1)

Lysianassa nasuta Dana, 1853–55, p. 915, pl. 62, fig. 2 *a-m*.

Lysianax cubensis Stebbing, 1897, p. 29, pl. 7B.

Lysianassa cubensis & *nasuta* Stebbing, 1906, pp. 38 & 40.

Lysianassa alba Pearse, 1912, p. 369.

Lysianassa alba Shoemaker, 1921, p. 99.

Shoemakerella nasuta Pirlot, 1936, p. 264.

Shoemakerella nasuta Shoemaker, 1948, pp. 1–2.

Shoemakerella nasuta Nayar, 1959, pp. 6–7, pl. 1, figs. 1–15.

Locality.—A few specimens were collected from the pearl and chank beds off Tuticorin on 20-10-1963.

Distribution.—This species has been described by Dana (1853–55) from Rio de Janeiro, Brazil, and it has since been recorded from Barbados, Puerto Rico, Cuba, Tortugas, the coast of Florida, Gulf of Mexico and from Madras coast. This is the first record of this species from the Gulf of Mannar.

Genus *Ichnopus* Costa

***Ichnopus taurus* Costa**

Ichnopus taurus Della Valle, 1893, p. 802, pl. 27.

Ichnopus taurus Walker, 1904, p. 238, pl. 1, fig. 3.

Locality.—One male specimen was collected from Galle Harbour at a depth of 100 fathoms.

Remarks.—This species is not represented in the present collection. For further details regarding the synonymy of the species, Chevreux and Fage (1925) may be consulted.

Genus *Socarnella* Walker

***Socarnella bonnieri* Walker**

Socarnella bonnieri Walker, 1904, pp. 239–40, pl. I, figs. 4.

Locality.—One female specimen was obtained from Reef, Galle along with compound Ascidians.

Remarks.—Walker created *Socarnella* (1904) to accommodate the single female specimen collected from Ceylon on 16-2-1902. This species has not been reported from anywhere else and no other species has also been added to this genus to date.

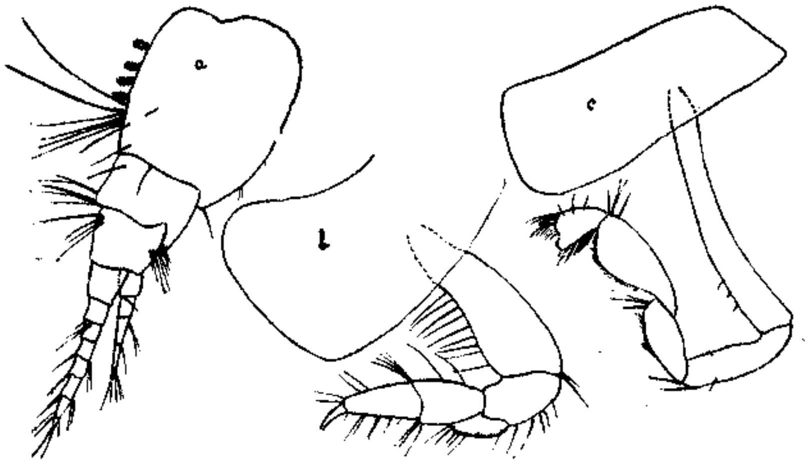

FIG. 1. *Shoemakerella nasuta* (Dana). Male: (*a*) Antenna 1; (*b*) gnathopod 1; (*c*) gnathopod 2.

Genus *Lysianassa* Milne Edwards

Lysianassa cinghalensis **(Stebbing)**

Lysianax cinghalensis Stebbing, 1897, p. 28, pl. 7 A.

Lysianax cinghalensis Walker, 1904, pp. 242–43, pl. 1, fig. 6.

Lysianax cinghalensis Walker, 1909, p. 328.

Lysianassa cinghalensis Barnard, 1937, pp. 142–43.

Locality.—A number of specimens were collected at various localities round the coast of Ceylon.

Size.—Length of male about 6 mm. and of female about 10 mm.

Recorded localities in the Indian Ocean.—This species has been previously collected and recorded from Ceylon by Walker (1904) and from Red Sea, Gulf of Oman, by Barnard (1937).

Remarks.—This species is not represented in the present collection.

Lysianassa coelochir **(Walker)**

Lysianax coelochir Walker, 1904, pp. 243, pl. 1, figs. 7.

Lysianassa coelochir Barnard, 1937, p. 143.

Locality.—Ceylon coast.

Distribution.—This species was first recorded by Walker (1904) from Ceylon and it has since been recorded from the Gulf of Oman by Barnard (1937).

Remarks.—This species is not represented in the present collection.

Genus *Orchomenella* Sars

Orchomenella nana **(Kroyer)**

Orchomenella nana Walker, 1904, p. 244.

Locality.—A number of specimens were collected from the Ceylon coast at Cheval Paar.

Size.—Length of male is about 5·5 mm.

Remarks.—For more details regarding this species and its distribution Gurjanova (1951) may be referred to. This species is not represented in the present collection.

Genus *Tryphosa* Boeck

Tryphosa cucullata **Walker**

Tryphosa cucullata Walker, 1904, p. 244, pl. IV, fig. 8.

Locality.—Only one male specimen of this species was collected from Kondatchi Paar on 17th November 1902 near Ceylon.

Size.—Male about 5·5 mm.

Remarks.—This species was created by Walker (1904) based on a single male specimen collected from Kondatchi Paar. This is the only record of this species. This species is not represented in the present collection.

Genus *Amaryllis* Haswell

Amaryllis tenuipes **(Walker)**

Vijaya tenuipes Walker, 1904, pp. 241–42, pl. I, figs. 5.

Locality.—From the coast of Ceylon two specimens were obtained.

Size.—4 mm.

Remarks.—Two specimens, a male and a female collected from Ceylon, have been described by Walker (1904) as a new species under a new genus. Barnard (1932) considers the genus *Vijaya* as a synonym of *Amaryllis*. This species is not represented in the present collection.

Genus *Anonyx* Kroyer

Anonyx schmardae **Heller**

Socarnes schmardae Walker, 1904, p. 238.

Locality.—Only one male specimen has been recorded from Ceylon coast.

Distribution.—This has been first recorded from the Mediterranean coast and has since been recorded from the Ceylon coast.

Remarks.—No specimen belonging to this species has been collected during the underwater survey work carried out at Tuticorin during 1962–64. This is considered a doubtful species by J. L. Barnard (1958). Since no specimen has been collected during the present survey it is not possible to comment on the validity of this species.

Genus *Lepidepecreum* Bate & Westw.

Lepidepecreum foraminiferum **Stebbing**

Lepidepecreum foraminiferum Stebbing, 1888, p. 686, p. 24.

Anonyx longicornis Della Valle, 1893, p. 814.

Lepidepecreum foraminiferum Stebbing, 1906, p. 79.

Lepidepecreum foraminiferum Nayar, 1959, p. 7, pl. I, figs. 16–26.

Locality.—This has been previously recorded from Tuticorin by Nayar (1959).

Remarks.—It is not represented in the present collection.

Family AMPELISCIDAE

Genus *Ampelisca* Kroyer

***Ampelisca tridens* Walker**

Ampelisca tridens Walker, 1904, pp. 249–50, pl. IV, fig. 11.

Ampelisca tridens Stebbing, 1906, p. 722.

Ampelisca tridens Pirlot, 1936, pp. 281–82.

Ampelisca tridens Nayar, 1959, p. 10, pl. II, figs. 19–29.

Locality.—This species has been first recorded from the Ceylon coast by Walker (1904). A few specimens were collected from the pearl banks off Tuticorin during the present survey from the Thollayiram Paar at depths ranging from 19 metres to 22 metres.

Distribution.—Ceylon, Madras, East Indies.

***Ampelisca scabripes* Walker**

Ampelisca scabripes Walker, 1904, pp. 250–51, pl. II, figs. 12.

Locality: Ceylon.

Remarks.—"Characterized by the spinous 4th joints of the 3rd and 4th peraeopods, the form and proportions of the joints of the 5th and the serrated and dentate 3rd uropods" (Walker, 1904). This species has not been recorded since 1904.

***Ampelisca brachyceras* Walker**

Ampelisca brachyceras Walker, 1904, pp. 251–52, pl. II, fig. 13.

Locality.—Only two specimens belonging to this species were collected in 1902 from Kondatchi Paar and Cheval Paar. This species is not represented in the present collection.

Size.—About 4·5 mm.

Remarks.—'This species can easily be recognised by the short antenna 1, the peculiar structure of the 4th joint of the 3rd and 4th and the 1st joint of the 5th peraeopods, and the curiously formed and ornamented 3rd uropods' (Walker, 1904). This species has not been recorded since 1904.

***Ampelisca brevicornis* (Costa)**

Ampelisca loevigate Sars, 1891, p. 169, pl. 59, fig. 1.

Ampelisca brevicornis Walker, 1904, p. 253.

Ampelisca brevicornis Stebbing, 1906, p. 100.

Ampelisca brevicornis Chevreux & Fage, 1925, p. 78, fig. 69.

Ampelisca brevicornis Schellenberg, 1925, p. 130, fig. 9 (with vars.).

Ampelisca brevicornis Schellenberg, 1928, p. 634.

Ampelisca brevicornis Pirlot, 1936, p. 277.

Ampelisca brevicornis Barnard, 1937, p. 148.

Locality.—Cyelon. This species is not represented in the present collection.

Distribution.—Ceylon, Bagamoyo, Suez, N. Atlantic, Mediterranean, West, South and East coasts of Africa, Java and Japan.

Ampelisca cyclops Walker

Ampelisca cyclops Walker, 1904, p. 253, pl. 2, fig. 14.

Ampelisca cyclops Pirlot, 1936, p. 280.

Ampelisca cyclops Barnard, 1937, p. 149.

Ampelisca cyclops Nayar, 1959, pp. 8–9, pl. II, figs. 12–18.

Locality.—Ceylon and Tuticorin pearl banks.

Distribution.—This species was first recorded off the coast of Ceylon by Walker (1904) and it has since been recorded from East Indies by Pirlot (1936), from Suez Canal by Barnard (1937) and from Madras coast by Nayar (1959).

Size.—Length from the front of the head to the end of uropods is about 9 mm.

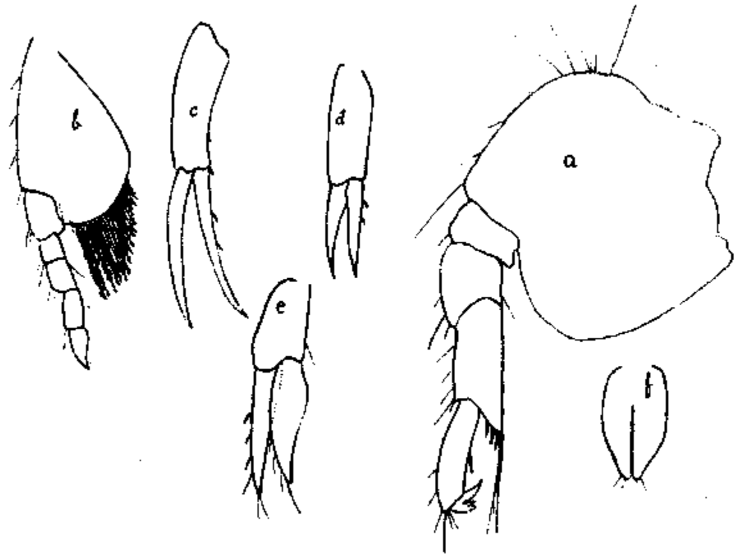

FIG. 2. *Ampelisca zamboangae* Stebbing. (*a*) Peraeopod 4; (*b*) peraeopod 5; (*c*) uropod 1; (*d*) uropod 2; (*e*) uropod 3; (*f*) telson.

Ampelisca zamboangae Stebbing
(Fig. 2)

Ampelisca zamboangae Stebbing, 1888, p. 1057, pl. 106.

Ampelisca chevreuxi Walker, 1904, p. 254, pl. 3, fig. 15, *Ampelisca zamboangae* Pirlot, 1936, p. 280.

Ampelisca zamboangae Barnard, 1937, p. 149.

Ampelisca zamboangae Pillai, 1957, p. 30, fig. I, 1–2.

Ampelisca zamboangae Nayar, 1959, pp. 7–8, pl. II, figs. 1–11.

Locality.—A number of specimens were collected from the pearl and chank beds off Tuticorin. This has been previously recorded from the Ceylon coast.

Distribution.—This species was described by Stebbing (1888) from Philippine Island and it has since been recorded from Ceylon by Walker (1904), East Indies by Pirlot (1936), Red Sea by Barnard (1937), Trivandrum by Pillai (1957) and Madras coast by Nayar (1959).

Size.—Length of the male as well as the female from front of the head to the end of the uropods is about 6 mm.

Genus *Byblis* Boeck

Byblis lepta **(Giles)**

(Fig. 5 *a*)

Ampelisca lepta Giles, 1888, p. 223, t. 8 & 9.

Ampelisca lepta Della Valle, 1893, p. 894.

Byblis lepta Stebbing, 1906, p. 115.

Byblis lepta Nayar, 1959, p. 2, pl. 2, figs. 30–34.

Locality.—A single female specimen belonging to this species was obtained from the sand samples collected from Thollayiram Paar on 23–2–1963.

Distribution.—This has been previously recorded from the Bay of Bengal by Giles (1888), the Suez Canal by Barnard (1937) and Madras coast by Nayar (1959).

Remarks.—This is the first record of this species from the Gulf of Mannar.

Family HAUSTORIIDAE

Genus *Platyischnopus* Stebbing

Platyischnopus herdmani **Walker**

Platyischnopus herdmani Walker, 1904, p. 247, pt. II, fig. 10.

Platyischnopus capensis, Barnard, 1925, p. 338, pl. xxxiv, figs. 13–14.

Platyischnopus herdmani, Pillai, 1957, pp. 35–37, fig. III.

Platyischnopus herdmani, Nayar, 1959, pp. 11–12, pl. iii, figs. 1–15.

Locality.—Ceylon.

Distribution.—Ceylon, Madras, Trivandrum and South Africa.

Size.—Length of the male about 5 mm.

Remarks.—This species is not represented in the present collection. But the occurrence of this species in Indian waters has been reported by Pillai (1957) and Nayar (1959). Pillai (1957) considers *P. capensis* Barnard collected from Africa as a synonym of this species.

Genus *Urothoe* Dana

***Urothoe spinidigitus* Walker**

Urothoe spinidigitus Walker, 1904, pp. 235–46, pl. I, fig. 9.

Urothoe spinidigitus Nayar, 1959, p. 13, figs. 16–28, pl. III.

Locality.—Only one specimen was collected from Ceylon coast. Two specimens were obtained during the present collection from Thollayiram Paar off Tuticorin.

Remarks.—This has been previously recorded from Madras.

Size.—Length of female about 5 mm.

Family ARGISSIDAE

Genus *Argissa* Boeck

***Argissa hamatipes* (Norman)**

Argissa typica Sars, 1891–95, p. 141, pl. 48.

Argissa hamatipes Walker, 1904, p. 246.

Locality.—Only one female specimen was collected from Ceylon from Kondatchi Paar on 17th November 1902.

Size.—2·5 mm.

Remarks.—This genus is represented by 2 species only, of which one species, *viz.*, *A. hamatipes* (Norman) has been reported to occur at Ceylon by Walker (1904). No specimen belonging to this species has been collected during the present underwater survey work. For details regarding this species Gurjanova (1951), may be referred to.

Family PHOXOCEPHALIDAE

Genus *Paraphoxus* Sars

***Paraphoxus uncirostrata* (Giles)**

Phoxus uncirostratus, Giles, 1890, p. 65, pl. II, fig. 2.

Leptophoxus uncirostratus, Walker, 1904, p. 249.

Leptophoxus uncirostratus, Nayar, 1959, p. 14, pl. IV, figs. 1–16.

Paraphoxus uncirostratus, Barnard, 1958, p. 118.

Locality.—Ceylon.

Distribution.—This has been previously recorded by Giles (1890) from Burma and from Ceylon by Walker (1904) and from Madras by Nayar (1959).

Remarks.—A single specimen belonging to this species was obtained from the sand sample collected and examined from the Thollayiram Paar on 17–12–1963. Barnard (1958) has brought this species under the genus *Paraphoxus*.

Family AMPHILOCHIDAE

Genus *Amphilochus* Bate

***Amphilochus neapolitanus* Della Valle**

(Fig. 3)

Amphilochus neapolitanus Walker, 1904, p. 255.

Amphilochus neapolitanus Chevreux & Fage, 1925, p. 112, figs. 106–108.

Amphilochus neapolitanus Barnard, 1937, pp. 151–52.

Locality.—Ceylon.

Remarks.—A single specimen was collected from the Muttuvaratu pearl oyster washings which Walker (1904) has referred to as *Amphilochus neapolitanus*. During the present survey specimens belonging to the species were obtained from the pearl banks off Tuticorin during 1962–64.

Distribution.—North Sea, Mediterranean, Canaries and Sahara coast.

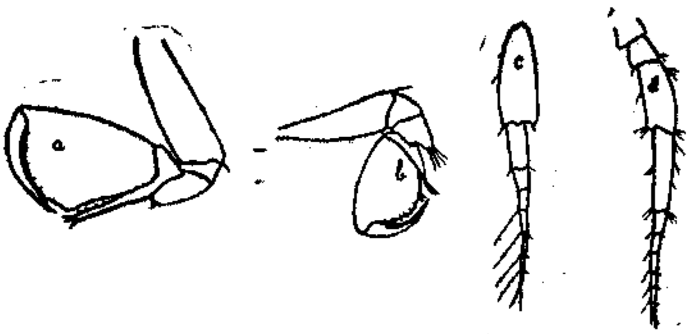

FIG. 3. *Amphilochus neapolitanus* Della Valle. (*a*) Gnathopod 2; (*b*) gnathopod 1; (*c*) antenna 1; (*d*) antenna 2.

Genus *Cyproidea* Haswell

***Cyproidea ornata* Haswell**

(Fig. 4)

Cyproidea ornata, Haswell, 1880, p. 320, Taf. 18, fig. 1.

Callea tecticauda Walker, 1904, p. 256, pls. 3 & 8, fig. 16.

Cyproidea ornata Stebbing, 1910, p. 578.

Cyproidea ornata Barnard, 1925, p. 341.

Cyproidea ornata Schellenberg, 1938, p. 18 (literature).

Cyproidea ornata, Nayar, 1959, pp. 15–16, pl. IV, figs. 17–30.

Locality.—A number of specimens were got from Ceylon. This has been collected from Krusadai Island and also from Tuticorin coast.

Distribution.—This has been previously recorded from South Australia, Ceylon, Suez Canal, Capeland, Bismarck Archipelago and Madras coast.

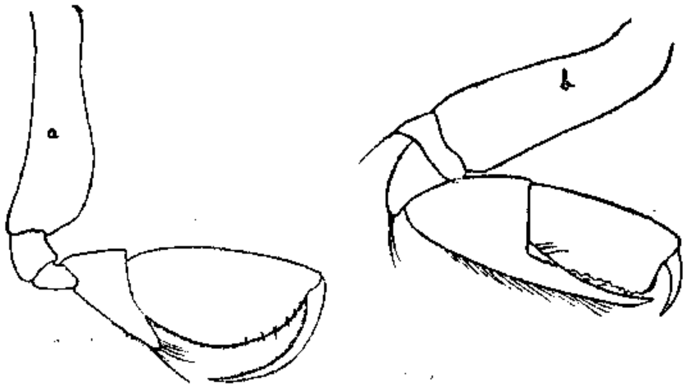

FIG. 4. *Cyproidea ornata* Haswell. male. (*a*) gnathopod 2, (*b*) gnathopod 1.

Family LEUCOTHOIDAE

Genus: *Leucothoe* Leach

Leucothoe spinicarpa **(Abildg.)**

(Fig. 5 *b*, *c*)

Leucothoe spinicarpa Walker, 1904, p. 258.
Leucothoe spinicarpa Walker, 1905, p. 925.
Leucothoe spinicarpa Walker, 1909, p. 331.
Leucothoe spinicarpa Gravely, 1927, p. 123.
Leucothoe spinicarpa Schellenberg, 1928, p. 687.
Leucothoe spinicarpa Schellenberg 1931, p. 92.
Leucothoe spinicarpa Shoemaker, 1933, pp. 8–9.
Leucothoe spinicarpa Barnard, 1937, p. 152.
Leucothoe spinicarpa Nayar, 1959, pp. 16–17.

Locality.—A number of specimens were collected from Ceylon. Several specimens were collected from the pearl and chank beds off Tuticorin and from Mandapam Camp during the present survey.

Distribution.—This is a cosmopolitan species.

Size.—About 10 mm.

Leucothoe furina **(Sav.)**

(Fig. 5 *d*)

Leucothoe hornelli Walker, 1904, pp. 258–59, pl. 3, fig. 17.
Leucothoe hornelli Walker, 1905, p. 925.
Leucothoe hornelli Walker, 1909, p. 331.

Leucothoe hornelli, Chevreux, 1907, p. 470.

Leucothoe furnia Schellenberg, 1928, p. 635.

Leucothoe furina Barnard, 1937, p. 152.

Locality.—A number of specimens were collected from the branchial sacs of tunicates from Ceylon.

Distribution.—Ceylon, Maldives, Red Sea (Walker), Red Sea (Spandl.), Suez, (Schellenberg), Gambier Archipelago (Chevreux), East Indies and Australia (Schellenberg, var. *indica*).

Remarks.—This species is represented in the present collection by a single male specimen obtained from Thollayiram Paar on 2-4-1964.

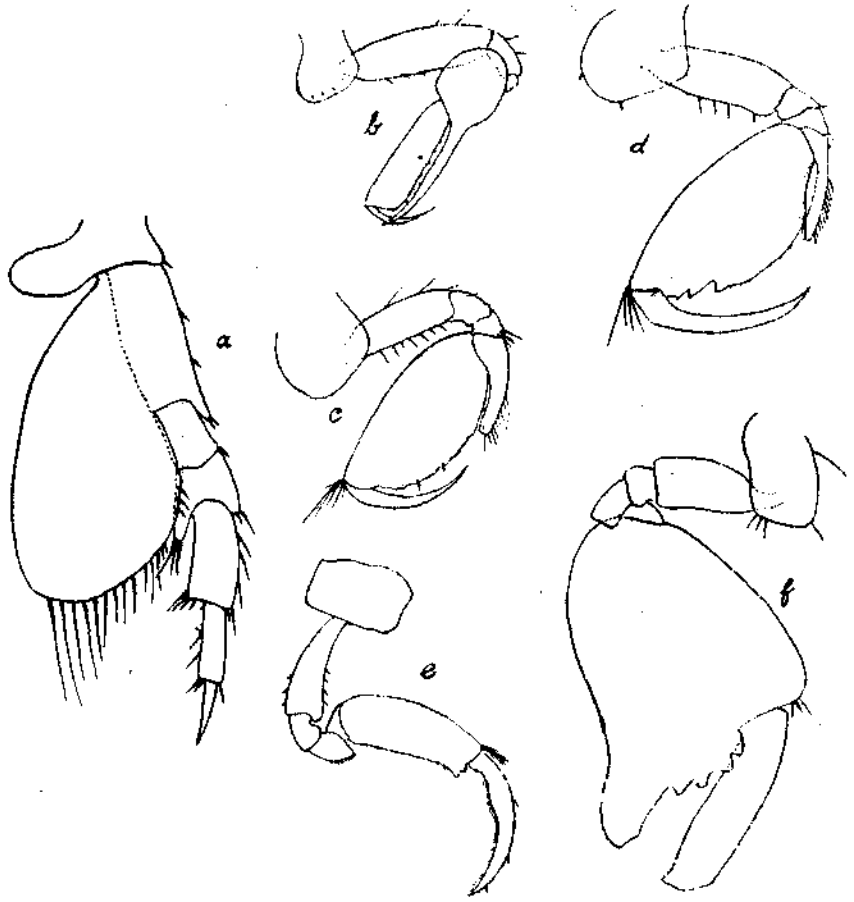

FIG. 5. **(*a*) *Byblis lepta*** (Giles).—**Peraeopod 5; (*b*) *Leucothoe spinicarpa*** (Abildg.) **male, gnathopod 1; (*c*) same, gnathopod 2; (*d*) *Leucothoe furina*** (Sav.), **male, gnathopod 2; (*e*) *Stenothoe gallensis*** Walker, **male, gnathopod 2; (*f*) *Melita fresnelii*** (Aud.), **male, gnathopod 2, right side.**

Family ANAMIXIDAE

Genus *Anamixis* Stebbing

Anamixis stebbingi **Walker**

(Fig. 6)

Anamixis stebbingi Walker, 1904, p. 259, pl. II, figs. 18.

Locality.—Only one imperfect specimen was collected from Ceylon. One male specimen was found in the collections made from Thollayiram Paar on 1-4-1964.

Remarks.—The family Anamixidae comprises of a single genus with five species. *A. stebbingi* has been created by Walker (1904) based on an imperfect specimen collected from the Muttuvaratu pearl oyster washings from Ceylon. One male specimen of this species was collected from Tuticorin. As the specimen was slightly damaged it was not possible to make detailed sketches but sketches of most of the appendages are given here. The description given by Walker (1904) agrees well with the specimen collected.

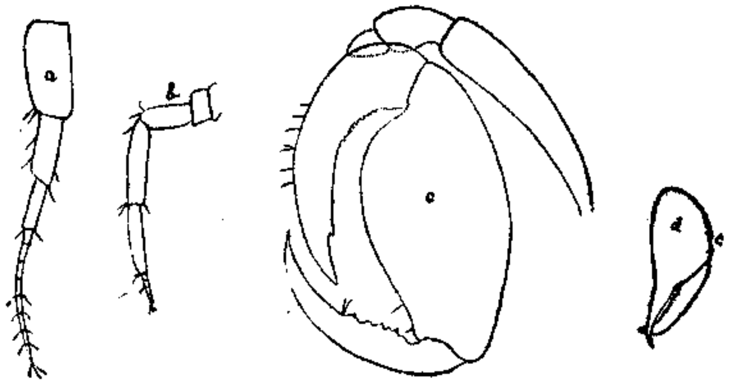

FIG. 6. *Anamixis stebbingi* Walker. (*a*) Antenna 1; (*b*) antenna 2; (*c*) gnathopod 2, right side; (*d*) end of gnathopod 1.

Family STENOTHOIDAE

Genus *Stenothoe* Dana

Stenothoe gallensis **Walker**

(Fig. 5 *e*)

Stenothoe gallensis Walker, 1904, p. 261, pl. 3, fig. 19.

Stenothoe cruenulata Chevreux, 1907, p. 471.

Stenothoe gallensis Barnard, 1916, p. 154.

Stenothoe gallensis Schellenberg, 1928, p. 640.

Stenothoe gallensis Barnard, 1937, pp. 153-54.

Stenothoe gallensis Nayar, 1959, p. 17, pl. I, figs. 7-19.

Locality.—An abundant species on the Ceylon coast. A number of species were collected from the Tuticorin coast.

Distribution.—South Africa (Barnard), Gambier Archipelago (Chevreux). Recorded localities in the Indian Ocean: This has been previously recorded from Ceylon, Seychelles, Zanzibar, Red Sea, Dar-es-Salaam and also from Madras coast.

Remarks.—Based on the single female specimen obtained from Ceylon, Walker (1904) created this species. This could be easily identified by the peculiar size and shape of gnathopod 2 of the male.

Stenothoe marina **(Bate)**

Stenothoe marina Walker, 1904, p. 261.

Remarks.—A single female specimen belonging to this species was collected from Cheval Paar in 1902 and described by Walker (1904) as *Stenothoe marina* var. *sinhalensis*. But Gurjanova (1951) considers this as a synonym of *Stenothoe marina*. This species is not represented in the present collection. For further details regarding the species and its distribution Gurjanova (1951) may be referred to.

Stenothoe monoculoides **(Mont)**

Stenothoe monoculoides Walker, 1904, p. 261.

Remarks.—A few species were obtained from Ceylon and recorded by Walker (1904). This species is not represented in the present collection. For further details Gurjanova (1951) may be consulted.

Family COLOMASTIGIDAE

Genus *Colomastix* Grube

Colomastix pusilla **Grube**

(Fig. 7)

Colomastix pusilla Walker, 1904, p. 299.
Colomastix crassimanus Walker, 1909, p. 332.

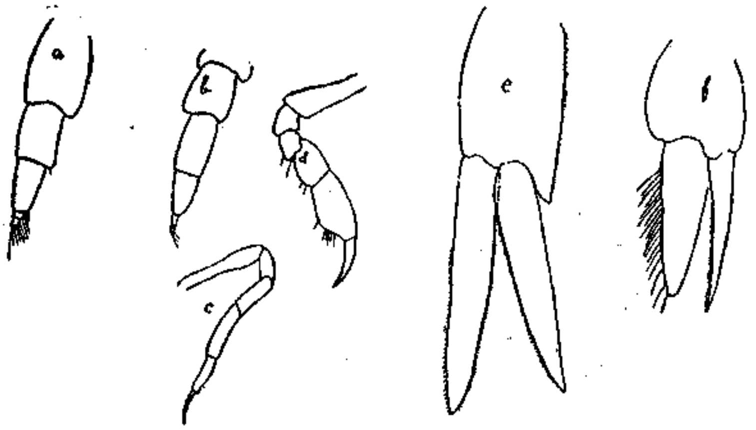

FIG. 7. *Colomastix pusilla* (Grube). (*a*) Antenna 1; (*b*) antenna 2; (*c*) gnathopod 1; (*d*) gnathopod 2; (*e*) uropod 1; (*f*) uropod 3.

Colomastix pusilla Chilton, 1925, p. 533.
Colomastix pusilla Schellenberg, 1928, p. 687.
Colomastix pusilla Barnard, 1937, p. 154.
Colomastix pusilla J. L. Barnard, 1955, pp. 39–42, fig. 20.

Locality.—This has been previously recorded from Ceylon. A single specimen of this species was obtained from the Tuticorin pearl banks on 21–9–1962.

Distribution.—Cosmopolitan; in tropical and temperate seas.

Family LILJEBORGIIDAE

Genus *Liljeborgia* Bate

***Liljeborgia pallida* Bate**

Liljeborgia pallida Sars, 1891–95, p. 530, pl. 187.
Liljeborgia pallida Della Valle, 1893, p. 658, pl. 19.
Liljeborgia pallida Walker, 1904, p. 279.

Remarks.—This has been previously collected and recorded from Ceylon by Walker (1904). This species has not been described after Stebbing (1906).

Family OEDICEROTIDAE

Genus *Perioculodes* Sars

***Perioculodes serra* Walker**

Perioculodes serra Walker, 1904, pp. 262–63, pl. IV, fig. 20.

Locality.—This has been previously recorded from the Ceylon coast by Walker (1904).

Size.—Length of adult male is about 5 mm.

Remarks.—This genus is represented by four species only. *P. serra* is not reported from anywhere except from Ceylon by Walker (1904). Since this species is not represented in the present collection, it is not possible to say anything about this species. According to Walker (1904) the upper margins of the rami of the first uropod, in the adults, are strongly serrated.

Genus *Synchelidium* G. O. Sars

***Synchelidium brevicarpum* (Sp. Bate)**

Synchelidium brevicarpum Walker, 1904, p. 263.

Remarks.—A single specimen belonging to this species was collected from Cheval Paar in 1902 and recorded by Walker (1904). This species is not represented in the present collection.

Family TIRONIDAE

Genus *Tiron* Liljeborg

***Tiron thompsoni* Walker**

Tiron thompsoni Walker, 1904, p. 263, pl. IV, figs. 21.

Locality.—Only two specimens were collected from Ceylon (Walker, 1904).

Remarks.—This species was created by Walker (1904) to accommodate two specimens collected from Ceylon. It has not been recorded from anywhere else since then. This species is not represented in the present collection.

Family EUSIRIDAE

Genus *Eusiroides* Stebbing

***Eusiroides diplinyx* Walker**

Eusiroides caesaris var. Walker, 1904, p. 264, pl. IV, fig. 22.

Eusiroides diplonyx Walker, 1909, p. 333, pl. 43, fig. 4.

Eusiroides diplonyx Pirlot, 1936, pp. 302–304, figs. 126–28.

Locality.—This species was previously recorded from Ceylon coast.

Remarks.—Pirlot (1936) considers *Eusiroides caesaris* var. described by Walker (1904) as a synonym of *Eusiroides diplonyx*. This species is not represented in the present collection.

***Eusiroides orchomenipes* Walker**

Eusiroides orchomenipes Waker, 1904, pp. 264–65, pl. IV. fig. 23.

Locality.—This has been previously recorded from Ceylon.

Remarks.—Based on the single female specimen obtained from Ceylon, Walker (1904) created this species. The occurrence of this species has not yet been reported from anywhere else. This species is not represented in the present collection.

Family ATYLIDAE

Genus *Atylus* Leach

***Atylus granulosa* (Walker)**

Paratylus granulosus, Walker, 1904, p. 265.

Atylus granulosa, Barnard, 1916.

Locality.—This has been previously collected and recorded from Cheval Paar, Ceylon.

Remarks.—Walker (1904) has described it as a new species and included it under the genus *Paratylus* but Barnard (1916) transferred it to *Atylus*. This species is not represented in the present collection.

Family GAMMARIDAE

Genus *Megaluropus* Hoek

***Megaluropus agilis* Hoek**

Megaluropus agilis Della Valle, 1893, p. 695, t. 3, fig. 9; t. 34, figs. 1–17.

Megaluropus agilis Walker, 1904, pp. 278–79.

Megaluropus agilis Stebbing, 1906, p. 420.

Megaluropus agilis Chevreux & Fage, 1925, p. 226, figs. 236–237.

Phylluropus capensis Barnard, 1930, p. 146, figs. 84–85.

Megaluropus agilis Barnard, 1940, p. 453.

Megaluropus agilis Schellenberg, 1942, p. 46, figs. 25–28.

Megaluropus agilis Pillai, 1957, p. 50, fig. X.

Megaluropus agilis Nayar, 1959, p. 21, p. VI, figs. 18–29.

Locality.—Ceylon and Tuticorin.

Distribution.—This species has been previously recorded from Kattegat; North Sea, Holland; Firth of Clyde; Liverpool Bay; English Channel; British Channel; Gulf of Naples; Travancore coast and Madras coast.

Remarks.—A few specimens, both males and females belonging to this species, were collected from Thollayiram Paar from sponges found at depths 15 meters to 25 metres.

Genus *Melita* Leach

***Melita fresnelii* (Aud)**

(Fig. 5*f*)

Melita cotesi Giles, 1890, p. 64, pl. 2, fig. 1.

Melita anischir, Walker, 1904, p. 270, pl. 4, figs. 28.

Melita fresnelii Walker, 1909, p. 334.

Melita fresnelii Barnard, 1916, p. 189, pl. 28, fig. 32.

Melita fresnelii Schellenberg, 1928, p. 644.

Melita fresnelii Shoemaker, 1935, p. 239.

Melita fresnelii Barnard, 1937, p. 159.

Melita fresnelii Nayar, 1959, p. 22, pl. VII, figs. 1–5.

Locality.—This has been recorded from Ceylon previously and it has since been collected from Tuticorin during 1962–64.

Recorded localities in the Indian Ocean.—Andaman Island (Giles); Ceylon, Seychelles; Wasin, Suakim (Walker); Suez Bay (Schellenberg).

Distribution.—This species has been previously recorded from East Indies, South Africa, Australia, California, Red Sea, Gulf of Aden, Zanzibar area and Madras coast.

Size.—The length of the male from front of the head to the end of the uropods is about 5 mm.

***Melita obtusata* (Mont)**

Melita obtusata Walker, 1904, p. 270.

Melita obtusata Schellenberg, 1942.

Locality.—This species has been previously reported from Ceylon.

Remarks.—This species is not represented in the present collection.

Genus *Maera* Leach

Maera othonides Walker

Maera othonides Walker, 1904, p. 271, pl. V, fig. 29.

Maera othonides Walker, 1905, p. 927.

Maera othonides Chilton, 1921, p. 535, fig. 5.

Maera othonides Barnard, 1935, pp. 285–286.

Maera othonides Nayar, 1959, pp. 24–25, pl. VIII, figs. 1–18.

Locality.—This has been previously reported from Ceylon. During the present survey, a number of specimens were obtained from Tuticorin pearl banks and also from Mandapam coast.

Distribution.—This species has been recorded from Ceylon and Maldive Islands by Walker (1904 & 1908), Chilka Lake by Chilton (1921), from Travancore and Cochin by Barnard (1935) and from Madras coast by Nayar (1959).

Maera subcarinata (Hasw.)

Elasmopus subcarinatus Walker, 1904, p. 275, pl. 5, fig. 34.

Elasmopus subcarinatus Walker, 1909, p. 335.

Elasmopus subcarinatus Gravely, 1927, p. 123.

Elasmopus subcarinatus Stephensen, 1931, p. 11.

Elasmopus subcarinatus Barnard, 1935, p. 286.

Elasmopus subcarinatus Barnard, 1937, p. 160.

Maera subcarinata Harley, 1954 *a*, p. 603.

Locality.—Very common in Ceylon. A number of specimens belonging to this species have been collected during the present survey work from different pearl banks off Tuticorin. A number of specimens have also been collected from Mandapam coast.

Recorded localities in Indian Ocean.—Ceylon and Seychelles (Walker); Krusadai Island (Gravely); Travancore (Barnard).

Distribution.—East Indies; Australia, South Africa.

Maera tenella (Dana)

(Fig. 8)

Maera tenella Walker, 1904, pp. 272–73, pl. 5, fig. 31.

Locality.—This has been previously recorded from Ceylon. One male specimen belonging to this species was obtained from the underwater collections made at Thollayiram Paar on 11–10–1963.

Maera inaequipes (Costa)

Maera scissimana Walker, 1904, p. 273, pl. 5, fig. 32.

Maera inaequipes Walker, 1909, p. 1334.

Maera inaequipes Schellenberg, 1928, p. 646.

Maera inaequipes Barnard, 1937, p. 159.

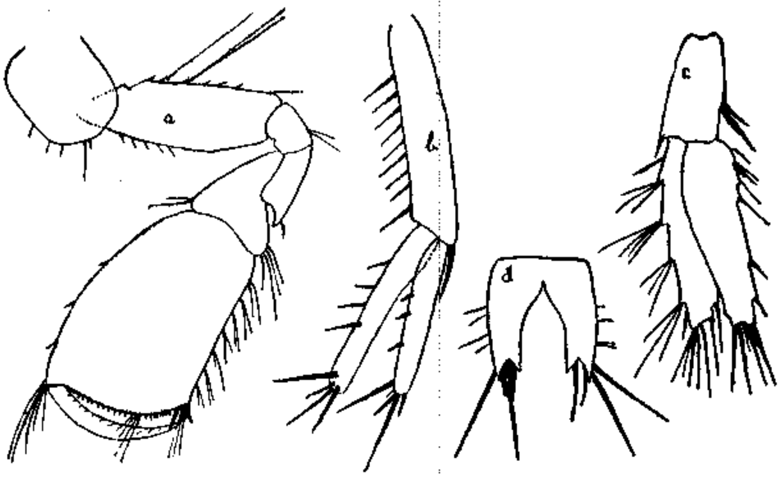

FIG. 8. *Maera tenella* (Dana). Male: (*a*) Gnathopod 2; (*b*) uropod 1; (*c*) uropod 3; (*d*) telson.

Locality.—This has been previously recorded from Ceylon.

Recorded localities in Indian Ocean.—Red Sea (Kossmann, Spandl); Seychelles (Miers); Maldives, Seychelles, Wasin, Suez, Suakim (Walker); Suez (Schellenberg).

Distribution.—Bermuda; Azores and Canaries; Mediterranean; South Africa; Australasia; Chile.

Remarks.—This species is not represented in the present collection.

Maera quadrimana (Dana)

(Fig. 9 *a*, *b*)

Garrarus quadrimanus Dana, 1853, p. 955, t. 65, fig. 9.

Maera quadrimanus Bate, 1862, p. 194, t. 35, fig. 5.

Maera quadrimana Stebbing, 1906, p. 434 (literature).

Maera quadrimana Schellenberg, 1938, pp. 45–48. figs. 21–22.

Maera quadrimana J. L. Barnard, 1955, p. 13.

Maera quadrimana Nayar, 1959, p. 23, pl. 7, figs. 6–15.

Locality.—Number of specimens belonging to this species have been collected from Tuticorin and also from Mandapam coast. This is the first record of this species from the Gulf of Mannar.

Distribution.—This has been previously recorded from Tropical and South Pacific, Fiji Islands, New Zealand, Hawaiian Islands and from Madras coast.

Maera pacifica Schellenberg

(Fig. 9 *c*, *d*)

Maera pacifica Schellenberg, 1938, pp. 42–45, figs. 19 & 20.

Maera pacifica Nayar, 1959, pp. 23–24, pl. 8, figs. 16 & 17.

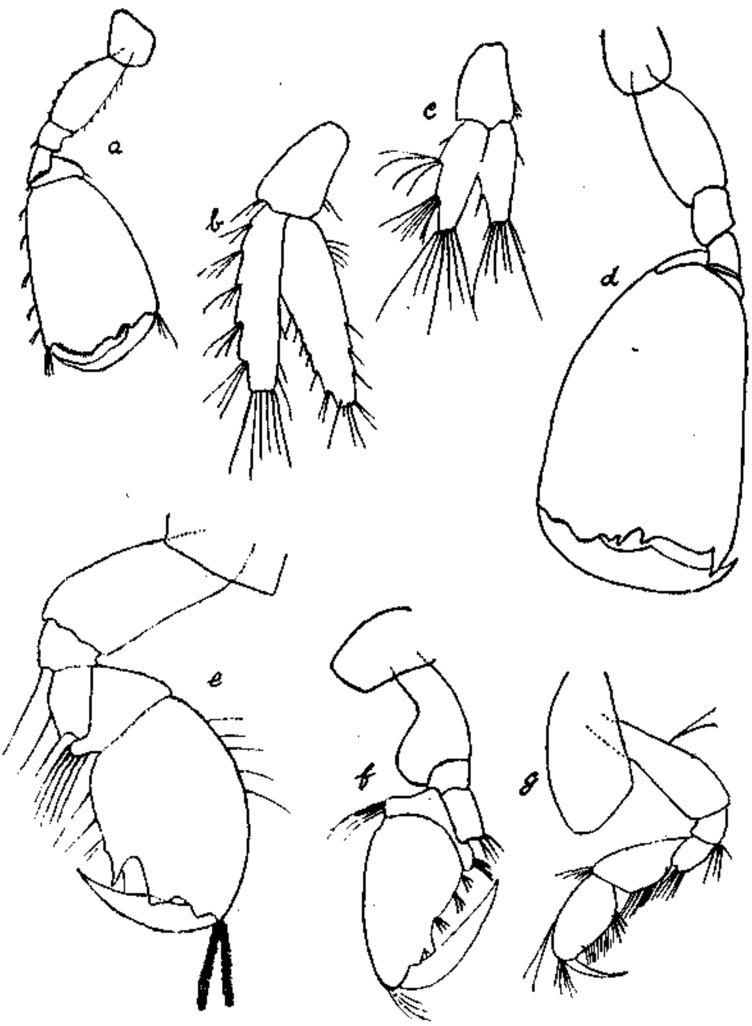

FIG. 9. (*a*) *Maera quadrimana* (Dana) male, gnathopod 2; (*b*) same, uropod 3; (*c*) *Maera pacifica* Schellenberg, male, uropod 3; (*d*) same, gnathopod 2; (*e*) *Lembos podoceroides* Walker, male, gnathopod 1, right side; (*f*) *Photis longimanus* Walker, gnathopod 2; (*g*) same, gnathopod 1.

Locality.—A few specimens belonging to this species were collected from Tuticorin and also from Mandapam Camp. This is the first record of this species from the Gulf of Mannar.

Distribution.—This has been previously recorded from Hawaii Islands by Schellenberg (1938) and from Krusadai Island by Nayar (1959).

Genus *Ceradocus* Costa

Ceradocus rubromaculatus **(Stimpson)**

Maera rubro-maculata Walker, 1904, p. 272, pl. 5, fig. 30.

Maera rubro-maculata Chevreux 1907, p. 479, fig. 6.

Maera rubro-maculata Chilton, 1921 *a*, p. 71, fig. 9, lib.

Maera rubro-maculata Tattersall, 1922, p. 6, pl. 1, figs. 15–16.

Maera rubro-maculata Schellenberg, 1925, p. 154.

Maera rubro-maculata Schellenberg, 1928, p. 644.

Maera rubro-maculata Pirlot, 1934, p. 222.

Maera rubro-maculata Barnard, 1937, p. 160.

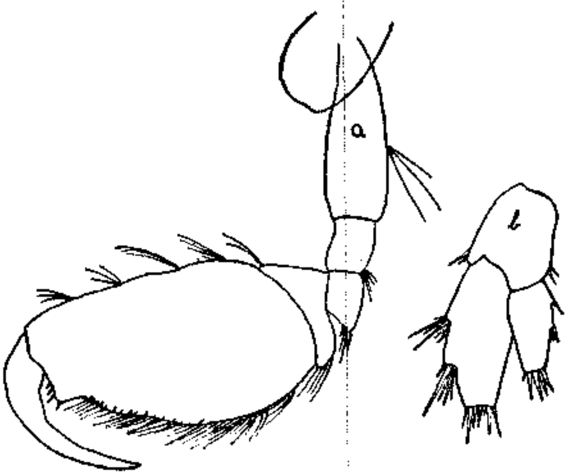

FIG. 10. *Elasmopus pectenicrus* (Bate), male, (*a*) gnathopod 1; (*b*) uropod 3.

Locality.—Collected from Ceylon.

Recorded localities in Indian Ocean.—Maldives, Ceylon, Seychelles, Red Sea (Walker), Suez (Schellenberg).

Distribution.—South Africa, East Indies, Australia, New Zealand and Gambier Archipelago.

Genus *Elasmopus* Costa

Elasmopus spinimanus Walker

Elasmopus spinimanus Walker, 1904, p. 277, pl. 5, figs. 36.

Elasmopus spinimanus Gravely, 1927, p. 123.

Locality.—This species was collected from Ceylon and described by Walker (1904) as a new species. It has also been recorded by Gravely (1927) from Krusadai Island. It is not represented in the present collection.

Elasmopus pectenicrus (Bate)

(Fig. 10)

Elasmopus serrula Walker, 1904, p. 277, pl. 18, fig. 34.

Elasmopus serrula Walker, 1909, p. 336.

Elasmopus pectenicrus Barnard, 1916, p. 197, pl. 28, fig. 33.

Elasmopus pectenicrus Gravely, 1927, p. 123.

Elasmopus pectenicrus Schellenberg, 1928, p. 647.

Elasmopus pectenicrus Shoemaker, 1935, p. 238.

Elasmopus pectenicrus Pirlot, 1936, p. 312.

Elasmopus pectenicrus Barnard, 1937, p. 161.

Elasmopus pectenicrus J. L. Barnard, 1955, pp. 8–10, fig. 4.

Elasmopus pectenicrus Nayar, 1959, pp. 27–28, pl. 9, figs. 20–35.

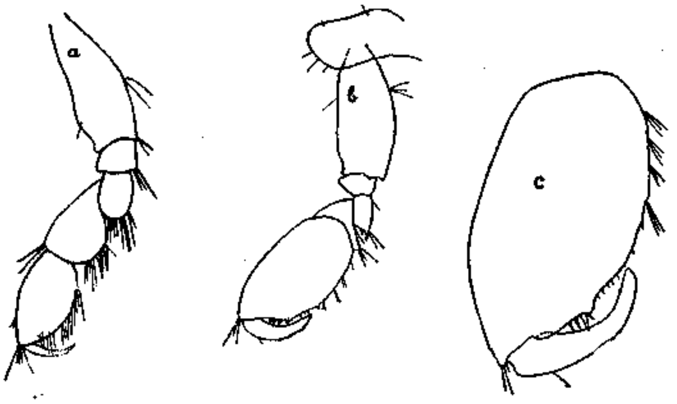

FIG. 11. *Parelasmopus suluensis* (Dana). Male: (*a*) gnathopod 1; (*b*) gnathopod 2; (*c*) end of gnathopod 2.

Locality.—Ceylon and Tuticorin. This has been previously recorded from Ceylon. A number of specimens were obtained from the pearl and chank beds off Tuticorin during 1962–64.

Recorded localities in Indian Ocean.—Red Sea (Kossmann, Spandl); Ceylon, Zanzibar, Suez (Walker); Krusadai Island (Gravely); Suez, Dar-es-Salaam (Schellenberg) and Madras coast (Nayar).

Distribution.—This is a cosmopolitan species and has been recorded from New Guinea; South Africa; East Indies; Peurto Rico and Hawaiian Island.

***Elasmopus dubius* Walker**

Elasmopus dubius Walker, 1904, p. 276, pl. 5, fig. 35.

Locality.—Ceylon.

Remarks.—This species has been created by Walker (1904) based on the single male specimen obtained from the pearl oysters, East Cheval Paar, on 8-11-1902. It has not been reported from anywhere else since 1904. It is not represented in the present collection also.

Genues *Parelasmopus* Stebbing

***Parelasmopus suluensis* (Dana)**

(Fig. 11)

Parelasmopus suluensis Stebbing, 1888, p. 1029, pl. *c*.

Parelasmopus suluensis Walker, 1904, p. 278, pl. 6, fig. 38, *Parelasmopus suluensis* Barnard, 1935, p. 286, fig. 6.

Parelasmopus suluensis Barnard, 1940, p. 463.

Parelasmopus suluensis Pillai, 1957, p. 52, fig. 11.

Locality.—Mandapam. A single male specimen belonging to this species was collected from Mandapam during October 1964. This has been previously recorded from Cheval Paar, Ceylon.

Distribution—Sulu Sea, Marshal and Solomon Islands, India, Ceylon, Australia, Red Sea, Africa.

Family DEXAMINIDAE

Genus *Dexamine* Leach

***Dexamine serraticrus* Walker**

Dexamine serraticrus Walker, 1904, pp. 265–66, p. 14, fig. 24.

Locality.—This has been previously collected and recorded from Cheval and Talaivillu Paars, Ceylon.

Remarks.—Walker (1904) has created a new species to accommodate the two specimens collected from Ceylon. The occurrence of this species has not yet been reported from anywhere else. This species is not represented in the present collection also.

Genus *Polycheria* Haswell

Polycheria atolli Walker

Tritaeta antarctica Walker, 1904, p. 266, pl. 4, fig. 25.

Polycheria atolli Walker, 1905, p. 926, pl. 88, figs. 1–5.

Polycheria atolli Walker, 1909, p. 337.

Polycheria atolli Schellenberg, 1925, p. 157, fig. 15.

Polycheria atolli Barnard, 1930, p. 390, fig. 49.

Polycheria atolli Barnard, 1937, p. 162.

Polycheria atolli Barnard, 1940, p. 464.

Polycheria atolli Pillai, 1957, pp. 52–54, fig. 12.

Locality.—This has been previously recorded from Ceylon. A single female specimen was obtained in the present collections from Thollayiram Paar on 28–1–1963.

Distribution.—Ceylon, Maldives, Seychelles, East Africa, South Africa, Arabian Sea, Trivandrum coast.

Family MELPHIDIPPIDAE

Genus *Hornella* Walker

***Hornella incerta* Walker**

Hornella incerta, Walker, 1904, p. 269, pl. 4, fig. 27.

Hornella incerta Stebbing, 1906, p. 728.

Hornella incerta Pillai, 1957, pp. 48–49, fig. 9.

Locality.—A few specimens were collected from Ceylon and also from Tuticorin.

Remarks.—A new genus was created by Walker (1904) to accommodate this species collected from Ceylon. A few specimens belonging to this species were collected by Pillai (1957) from plankton collections made at Trivandrum. In the present collection also a few specimens were obtained from the plankton off Tuticorin collected during the months May to June 1964. No other species has yet been added to this genus.

Family AORIDAE

Genus *Lembos* Bate

Lembos podoceroides **Walker**

(Fig. 9 *e*)

Lembos podoceroides Walker, 1904, p. 279, pl. 6, fig. 39.

Lembos podoceroides Walker, 1909, p. 338.

Locality.—Based on a single specimen collected from Ceylon, this species has been created by Walker (1904). A single male specimen was obtained from Thollayiram Paar on 26–2–1963.

Recorded localities in the Indian Ocean: Ceylon, Maldives, Red Sea (Walker).

Lembos chelatus **Walker**

Lembos chelatus Walker, 1904, pp. 280–81, pl. 6, fig. 40.

Locality.—This has been previously collected and recorded from Ceylon.

Remarks.—This species was created by Walker (1904) based on a single specimen obtained from Chiltan Paar. The occurrence of this species has not yet been reported from anywhere else. This species is not represented in the present collection also.

Family TALITRIDAE

Genus *Talorchestia* Dana

Talorchestia martensii **(Weber)**

(Fig. 12)

Talorchestia martensii Stebbing, 1906, p. 553.

Talorchestia martensii Chilton, 1921, pp. 541–45, fig. 8.

Talorchestia martensii Chilton, 1925, p. 535.

Talorchestia martensii Gravely, 1927, p. 123.

Talorchestia martensii Barnard, 1935, pp. 289–90.

Talorchestia martensii Nayar, 1959, pp. 28–29, pl. 10, figs. 1–9.

Locality.—A number of specimens were collected from Tuticorin and also from Mandapam coast.

Distribution.—This has been recorded from Flores, East Indies, Chilka Lake, Gulf of Mannar, Tale Sap, Siam, Vizagapatnam, Travancore coast and Madras coast.

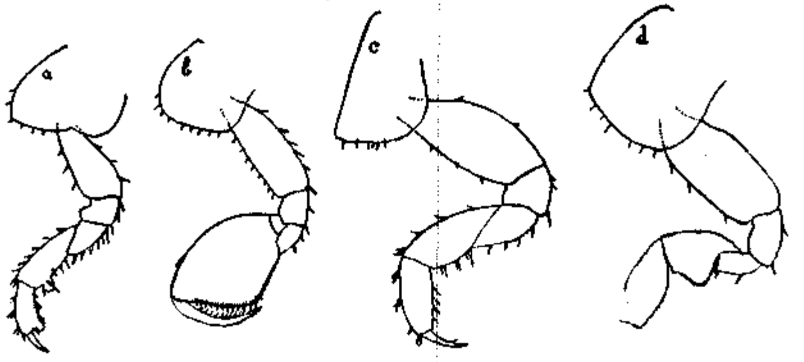

FIG. 12. *Talorchestia martensii* Stebbing. Male: (*a*) Gnathopod 1; (*b*) **gnathopod 2**; Female: (*c*) gnathopod 1; (*d*) gnathopod 2.

Family HYALELLIDAE

Genus *Parhyalella* Kunkil

***Parhyalella indica* Barnard**

Parhyalella indica Barnard, 1935, pp. 294–95, text-fig. 11.

Locality.—Tuticorin.

Remarks.—The species was collected from Tuticorin harbour in 1926, and described as a new species by Barnard (1935). It is not represented in the present collection.

Family HAYLIDAE Bulycheva

Genus *Hyale* Rathke

***Hyale honoluluensis* Schellenberg**

Hyale honoluluensis Schellenberg, 1938, p. 69, fig. 35.

Hyale honoluluensis Nayar, 1959, p. 31, pl. 11, figs. 1–9.

Locality.—Tuticorin.

Remarks.—Number of specimens belonging to this species were collected from the shore, pier, and the buoys at the harbour areas. This is the first record of this species from the Gulf of Mannar region.

Distribution.—This has been previously recorded from Hawaiian Islands by Schellenberg (1938) and from Madras by Nayar (1959).

Genus *Parhyale* Stebbing

***Parhyale hawaiensis* (Dana)**

Allorchestes hawaiensis Dana, 1853, p. 900, Taf. 61, fig. 5.

Hyale brevipes Shoemaker, 1933, p. 18, figs. 10 and 11, *Hyale brevipes* Barnard, 1935, p. 292.

Hyale hawaiensis Schellenberg, 1938, p. 66, fig. 34.

Hyale hawaiensis Shoemaker, 1942, p. 18.

Hyale hawaiensis Nayar, 1959, pp. 30–31, pl. 10, figs. 10–24.

Locality.—Number of specimens belonging to the species have been collected from Tuticorin and also from Mandapam Camp.

Distribution.—The occurrence of this species has been recorded from Hawaii, Seychelles, Ceylon, Maldives, Tale Sap (Siam), Vizagapatnam, Travancore, Krusadai, Suez, West Indies, Narborough Island, Galapogos Island and Madras coast.

Family PHOTIDAE

Genus *Eurystheus* Bate

***Eurystheus atlanticus* (Stebbing)**

(Fig. 13)

Gammaropsis zeylanicus Walker, 1904, p. 282, pl. 6, fig. 41.

Gammaropsis gardinery Walker, 1905, p. 929, pl. 88, figs. 11, 14, 16 and 17.

Gammaropsis zeylanicus Walker, 1909, p. 339.

Eurystheus atlanticus Stebbing, 1908, p. 86, pl. 14 B.

Eurystheus atlanticus Barnard, 1937, p. 164.

Eurystheus atlanticus Pirlot, 1938, pp. 345–46.

Locality.—Generally distributed round the coast of Ceylon. A number of specimens were collected from the pearl banks. They were found in association with some of the common sponges found in Paar area.

Distribution.—Ceylon, Maldives, Seychelles, Cape Verdigs and South Africa.

Genus *Photis* Kroyer

***Photis longicaudata* (Bate & Westwood)**

Photis longicaudata Sars, 1894, p. 571, pl. 203, fig. 1.

Photis longicaudata Walker, 1904, p. 286, pl. 6, fig. 43.

Photis longicaudata Walker, 1908, p. 339.

Photis longicaudata Chevreux and Fage, 1925, p. 310, fig. 319.

Photis longicaudata Schellenberg, 1926 *a*, p. 231.

Photis longicaudata Schellenberg, 1928, p. 662.

Photis longicaudata Barnard, 1937, p. 164.

Photis longicaudata Shoemaker, 1945, p. 11, fig. 5.

Photis longicaudata Nayar, 1959, p. 34, pl. 12, figs. 1–7.

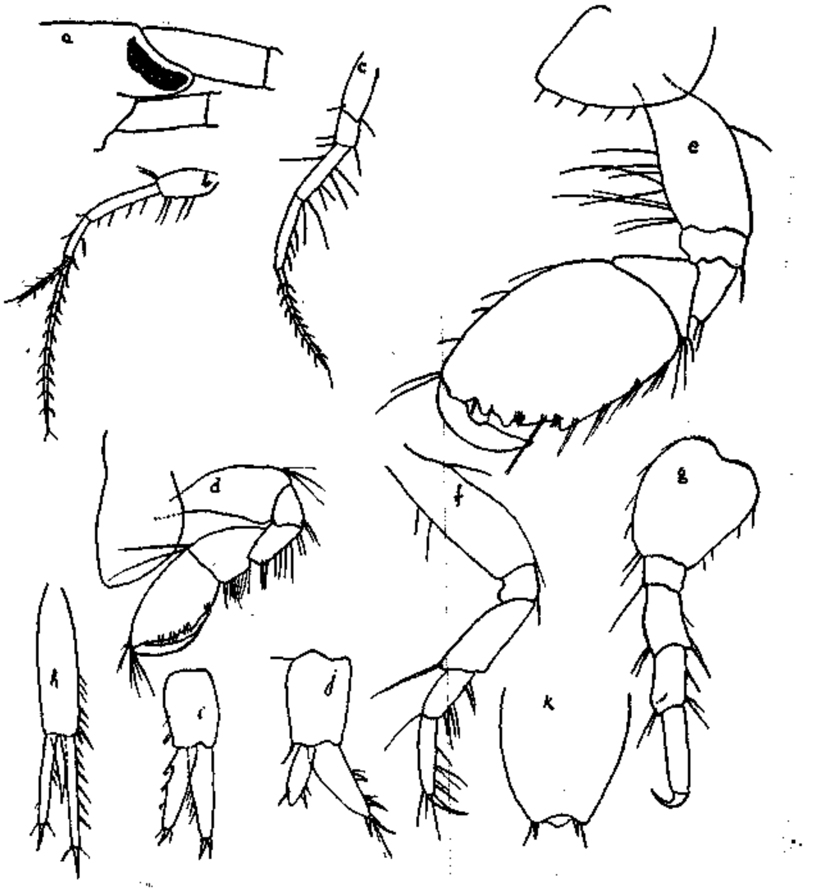

FIG. 13. *Eurystheus atlanticus* (Stebbing). (*a*) Head; (*b*) antenna 1; (*c*) antenna 2; (*d*) gnathopod 1; (*e*) gnathopod 2; (*f*) peraeopod 1; (*g*) peraeopod 3; (*h*) uropod 1; (*i*) uropod 2; (*j*) uropod 3; (*k*) telson.

Locality.—Ceylon. This has been previously collected and recorded from Ceylon. Number of specimens were also collected during the present survey from Thollayiram Paar and also from the shore during 1962–64.

Distribution.—This species has been recorded from Northern Europe, Mediterranean, Gulf of Guinea (Schellenberg), Suez Canal (Schellenberg), South Arabian coast (Barnard), British East Africa and Seychelles (Walker), Ceylon (Walker), Gulf of Mexico, Tortugas, Florida (Shoemaker) and Madras coast (Nayar).

***Photis longimanus* Walker**

(Fig. 9 *f*, *g*)

Photis longimanus Walker, 1904, pp. 286–87, pl. 7, fig. 44.

Locality.—This has been previously recorded from Ceylon. Two specimens were obtained from Thollayiram Paar off Tuticorin on 16-11-1963.

Photis nana Walker

Photis nana Walker, 1904, pp. 287–88, pl. 17, figs. 45.

Locality.—Ceylon.

Remarks.—Only 2 specimens were collected from Ceylon and recorded by Walker (1904) and since then the species has not been reported from anywhere. It is not represented in the present collection also.

Genus *Cheiriphotis* Walker

Cheriphotis megacheles (Giles)

(Fig. 17 *a*)

Melita megacheles Giles, 1885, p. 70, pl. 3.

Eurystheus hirsutus Giles, 1887, p. 227, pl. 8.

Cheriphotis megacheles Walker, 1904, p. 284, pl. 6, fig. 42.

Cheriphotis walkeri Stebbing, 1910, p. 461.

Cheriphotis durbanensis Barnard, 1916, p. 247.

Cheriphotis megacheles Schellenberg, 1928, p. 381.

Cheriphotis delloei Pirlot, 1934, p. 231.

Cheiriphotis megacheles, Barnard, 1937, p. 169.

Cheiriphotis megacheles Nayar, 1959, p. 33, pl. 11, figs. 23–25.

Locality.—Ceylon. Number of specimens, both males and females, were obtained from the pearl and chank beds off Tuticorin. They are generally found in association with the common sponges found in the Paar area.

Distribution.—This has been previously recorded from Bay of Bengal (Giles), Ceylon (Walker), South Africa, East Indies, South Arabian coast, and from Madras coast (Nayar).

Genus *Chevalia* Walker

Chevalia aviculae Walker

(Fig. 17 *b*)

Chevalia aviculae Walker, 1904, p. 288, pls. 7–8, fig. 50.

Chevalia aviculae Walker, 1909, p. 341.

Chevalia aviculae Barnard, 1916, p. 252.

Chevalia aviculae Barnard, 1937, p. 169, fig. 15.

Locality.—Ceylon. A few specimens belonging to this species have been obtained in the present collection from oyster beds of Tuticorin.

Recorded localities in Indian Ocean.—Ceylon, Seychelles (Walker).

Distribution.—South Africa.

Family AMPITHOIDAE

Genus *Ampithoe* Leach

Ampithoe ramondi **Audouin**

(Fig. 14)

Ampithoe ramondi, Schellenberg, 1928, pp. 665–66.
Ampithoe ramondi Barnard, 1935, p. 305.
Ampithoe ramondi Pirlot, 1938, pp. 346–47.
Ampithoe ramondi Barnard, 1937, p. 170.
Ampithoe vaillanti Chevreux and Fage, 1925, pp. 333–34.
Amphithoe vaillanti Walker, 1904, p. 291.
Amphithoe intermedia Walker, 1904, pp. 290–91.
Ampithoe ramondi, Barnard, 1955, pp. 28–29.

Locality.—This species has been previously recorded from Ceylon. Number of specimens belonging to this species have been collected from the pearl and chank beds off Tuticorin during 1962–63 and also from Mandapam during 1964.

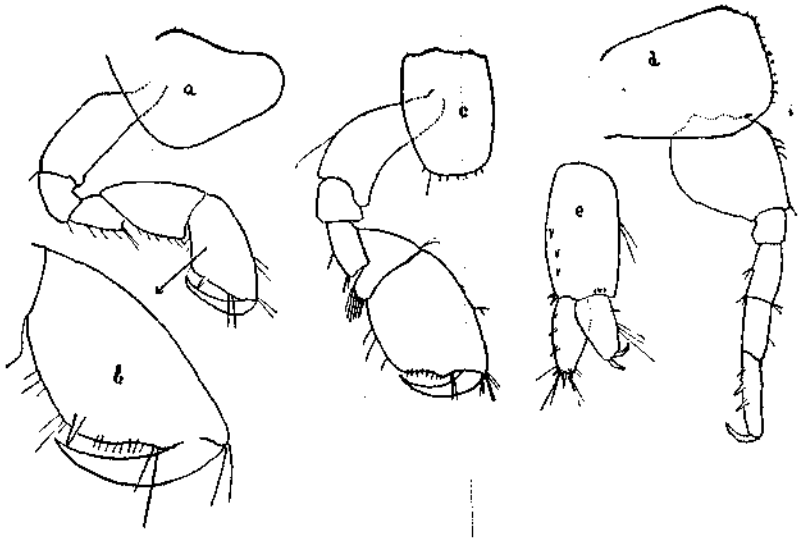

FIG. 14. ***Ampithoe ramondi*** Audouin. Male: (*a*) Gnathopod 1; (*b*) end of gnathopod 1; (*c*) gnathopod 2; (*d*) peraeopod 3; (*e*) uropod 3.

Distribution.—This is a cosmopolitan species found in the tropical and subtropical seas.

Remarks.—J. L. Barnard (1955) considers *Ampithoe vaillanti* Lucas and *Ampithoe intermedia* Walker described from the collections made from the Ceylon pearl oyster beds by Walker (1904) as a synonym of *Ampithoe ramondi* Audouin. For a complete list of synonymy of this species J. L. Barnard (1955) may be referred to.

Genus *Cymadusa* Savigny

Cymadusa filosa **Savigny**

Grubia filosa Schellenberg, 1928, pp. 666–68, fig. 206.

Grubia filosa Nayar, 1959, pp. 37–38, pl. 13, figs. 12–19.

Grubia filosa Shoemaker, 1935, p. 245, figs. 4–5.

Grubia filosa Barnard, 1937, pp. 171–72.

Cymadusa filosa, J. L. Barnard, 1955, pp. 29–30, fig. 15.

Locality.—This has been previously recorded from Krusadai Island and Mandapam Camp by Nayar (1959). Number of specimens were collected during the present underwater survey work from pearl and chank beds off Tuticorin during 1962–64.

Distribution.—Mediterranean Sea, Indian Ocean, Red Sea, Australia, Caribbean Sea, West Africa, Bermuda, Hawaiian Islands and Madras coast.

Family ISCHYROCERIDAE

Genus *Jassa* Leach

Jassa falcata **(Montagu)**

Jassa falcata Walker, 1904, p. 292, pl. 7, fig. 47.

Remarks.—Walker got only a single female and in the absence of a male in the collection he was not certain about the identity of the specimen although he has referred it to as *Jassa falcata*. This species is not represented in the present collection of material from Tuticorin waters.

Family COROPHIDAE

Genus *Grandidierella* Countiere

Grandidierella bonnieri **Stebbing**

(Fig. 17 *f*)

Grandidierella bonnieri Stebbing, 1908, p. 120, pl. 6.

Grandidierella megnae Chilton, 1921, p. 548.

Unciolella lunata Schellenberg, 1928, p. 669, fig. 207.

Grandidierella megnae Stephensen, 1933, p. 434.

Grandidierella bonnieri Barnard, 1935, p. 299, figs. 12 *d* and 13 *b*.

Grandidierella megnae Panikkar & Aiyar, 1937, p, 294.

Grandidierella bonnieri Shoemaker, 1948, p. 11.

Grandidierella bonnieri Nayar, 1959, pp. 38–39, pl. 14, figs. 1–5.

Locality.—Number of specimens were collected from Tuticorin and Mandapam coast.

Distribution.—This species has been recorded from the brackish pools as Port Canning, Lower Bengal (Stebbing, 1908); Chilka Lake (*G. megnae*) (Chilton, 1932); Suez Canal (*Unciolella lunata*)

(Schellenberg, 1928); Island of Bonaire (Stephensen, 1933); Vizagapatnam, Cochin & Travancore (Barnard, 1935); Brazil (Schellenberg, 1938); Cuba (Shoemaker, 1937); the West Indian and Caribbean regions (Shoemaker, 1937), and from Madras coast (Nayar, 1959).

Genus *Cerapus* Say

Cerapus abditus **Templeton**

Cystophium calamicola Giles, 1885, p. 54, pl. 1.

Cerapus flindersi Stebbing, 1888, p. 1163, pl. 125.

Cerapus abditus Stebbing, 1910, p. 616, pl. 55–A.

Cerapus calamicola, Walker, 1904, p. 293.

Cerapus abditus, Barnard, 1916, p. 271.

Cerapus abditus Barnard, 1937, p. 173.

Cerapus abditus, Pirlot, 1938, p. 349, figs. 157–58.

Cerapus abditus, Pillai, 1957, p. 59, fig. 16, 1–2.

Cerapus abditus, Nayar, 1959, pp. 41–42, pl. 14, figs. 7–15.

Locality.—Collected from Ceylon. This species is represented by a few specimens in the present collection.

Distribution.—Bay of Bengal, Ceylon, Sacotra, Australia, South Africa, Mauritius, South Arabian coast, Travancore and Madras.

Genus *Erichthonius* M. Edwards

Erichthonius macrodactylus **(Dana)**

(Fig. 17 *a*)

Erichthonius macrodactylus Walker, 1904, p. 292, pl. 7, fig. 48.

Erichthonius macrodactylus Stebbing, 1906, pp. 672 and 740.

Erichthonius macrodactylus Pirlot, 1938, p. 352–53.

Locality.—This has been previously collected and recorded from Ceylon. In the present collection a few specimens were obtained from Tuticorin.

Distribution.—Ceylon.

Erichthonius brasiliensis **(Dana)**

(Fig. 15)

Erichthonius abditis Walker, 1904, p. 292.

Erichthonius brasiliensis Walker, 1909, p. 343.

Erichthonius brasiliensis Schellenberg, 1928, p. 668.

Erichthonius brasiliensis Shoemaker, 1935, p. 249.

Erichthonius brasiliensis Barnard, 1937, p. 173.

Erichthonius brasiliensis Barnard, 1955, pp. 37–38.

Erichthonius brasiliensis Nayar, 1959, p. 42, pl. 15, figs. 1–13.

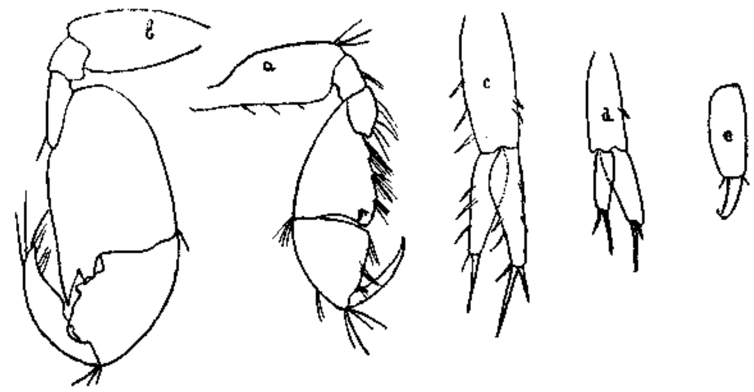

FIG. 15. *Erichthonius brasiliensis* (Dana). Male: (*a*) Gnathopod 1; (*b*) gnathopod 2; (*c*) uropod 1; (*d*) uropod 2; (*e*) uropod 3.

Locality.—This species has been collected and recorded from Ceylon (1904). In the present collection also number of specimens, both male and female, were obtained from the collections made at different stations in the Paar area during 1962–64.

Distribituion.—Cosmopolitan.

Remarks.—For a complete list of synonymy of this species, Barnard, J. L. (1955) may be consulted.

Genus *Siphonoecetes* Kroyer

Siphonoceetes orientalis **Walker**

Siphonoecetes orientalis Walker, 1904, p. 294, pl. 7, fig. 49.

Siphonoecetes orientalis Barnard, 1916, p. 270.

Siphonoecetes orientalis Barnard, 1937, p. 174.

Locality.—Ceylon.

Distribution.—This has been first recorded from Ceylon (Walker) and since been described from South Africa (Barnard) and South Arabian coast (Barnard).

Remarks.—This species is not represented in the present collection.

Genus *Corophium* Latreille

Corophium triaenonyx **Stebbing**

(Fig. 16)

Corophium triaenonyx Stebbing, 1904, p. 25, pl. 6 *a*.

Corophium crassicorne Walker, 1904, p. 294.

Corophium crassicorne Chilton, 1921, p. 554.

Locality.—This has been previously recorded from Ceylon. This has been collected from different paars off Tuticorin in the present underwater survey work during 1962–64.

Remarks.—Stebbing (1904) described this species as a new one from the collections made from Ceylon. The same year Walker (1904) included the forms he got from Ceylon under *Corophium crassicorne*. Based on Walker (1904), Chilton (1921) has referred the specimens collected from Chilka lake as *Corophium crassicorne*. But Shoemaker (1947) in his studies on the genus *Corophium* has transferred the specimens described by Walker (1904) and Chilton (1921) as *Corophium triaenonyx*.

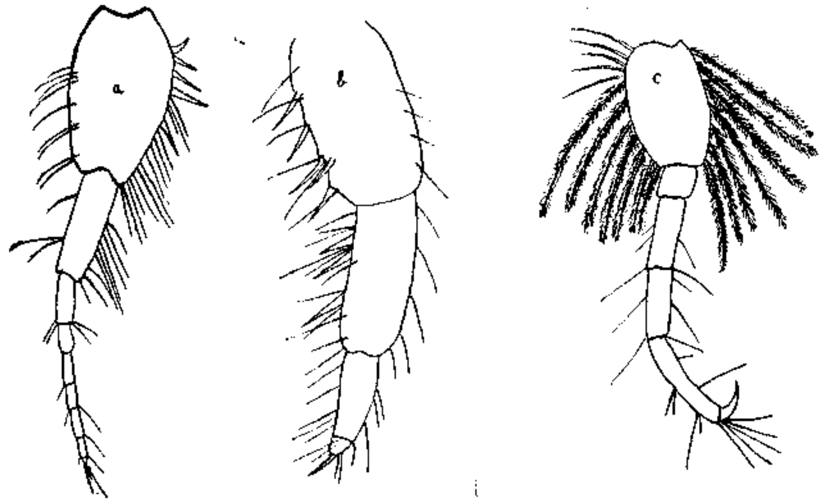

FIG. 16. *Corophium triaenonyx* Stebbing. Female: (*a*) Antenna 1; (*b*) antenna 2; (*c*) peraeopod 5.

Family PODOCERIDAE

Genus *Podocerus* Leach

***Podocerus laevis* (Haswell)**

Platophium laeve Walker, 1904, pp. 295–96, pl. 7, figs. 51.

Locality.—This has been previously recorded from the Ceylon coast.

Remarks.—This species is not represented in the present collection.

***Podocerus zeylanicus* (Walker)**

Platophium zeylanicum Walker, 1904, pp. 297–98, pl. 8, figs. 53.

Locality.—Number of species were collected from the pearl oyster beds from East Cheval Paar during 1902.

Remarks.—This species described by Walker (1904) as a new one has not yet been reported from anywhere else. This species is not represented in the present collection also.

***Podocerus brasiliensis* (Dana)**

(Fig. 17 *d*, *e*)

Platophium brasiliensis Dana, 1853, 55, p. 838, t. 55.

Platophium synaptochir Walker, 1904, pp. 296–97, pl. 8, fig. 52.

Platophium synaptochir Walker, 1909, p. 243.
Platophium synaptochir Barnard, 1916, p. 279.
Podocerus brasiliensis Barnard, 1925, p. 366.
Podocerus brasiliensis Gravely, 1927, p. 123.
Podocerus brasiliensis Schellenberg, 1928, p. 674.
Podocerus brasiliensis Barnard, 1935, p. 305.

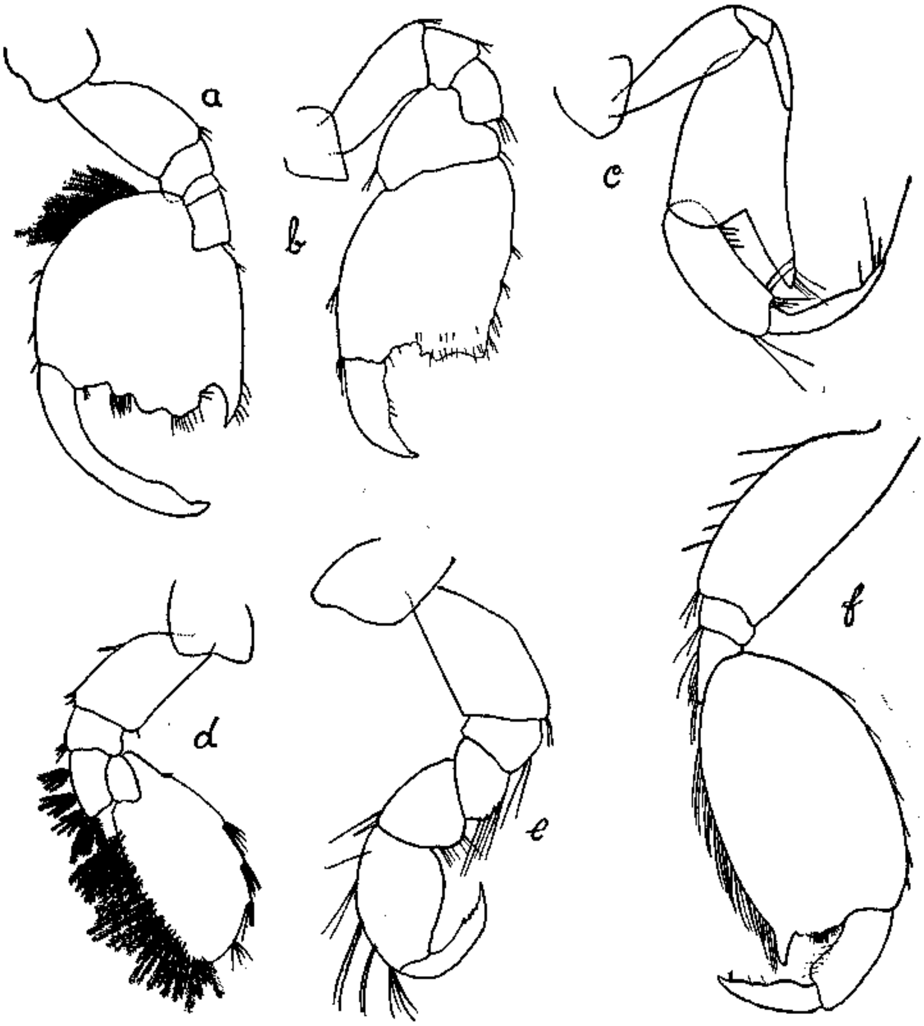

FIG. 17. (*a*) *Cheiriphotis megacheles* (Giles). Male: Gnathopod 2; (*b*) *Chevalia aviculae* Walker, male, gnathopod 2; (*c*) *Erichthonius macrodactylus*, (Dana) male, gnathopod 2, left side; (*d*) *Podocerus brasiliensis* (Dana) male, gnathopod 2; (*e*) same, gnathopod 1; (*f*) *Grandidierlla bonnieri* Stebbing, male, gnathopod 1.

Locality.—This has been previously recorded from Ceylon and Krusadai Island. In the present collection number of specimens, both males and females, were collected from different Paars during 1962–64.

Distribution.—This species has been previously recorded from tropical Atlantic; Ceylon; Gulf of Mannar; Suez, Port Said, Dar-es-Salaam, Zanzibar, Natal; Rio de Janeiro, Antigua and Madras coast.

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PELAGIC AMPHIPODS IN THE COLLECTIONS OF THE CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, INDIA: PART I. FAMILY OXYCEPHALIDAE

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ABSTRACT

Since Bovallius published his monograph on the Oxycephalidae, this family has not been studied in detail. Fage reviewed the family and added substantially to our knowledge of the synonymy, distribution and biology of the species, but only briefly dealt with the taxonomy. The present collection, made in the Arabian Sea, includes all except two species, considered valid by Fage. Hence this opportunity is availed of to giving full illustrated descriptions of all the species which number fifteen.

THOUGH oxycephalids are very common in the offshore plankton of tropical and subtropical waters they have not been studied in detail since Bovallius (1890) published his monograph. Apart from Stebbing (1888) and Bovallius no other worker seems to have studied them in detail. This is to be regretted since most of the species are highly variable and specific identification is difficult, except for the specialist. However, the recent work of Fage (1960) has added considerably to our knowledge of the biology and distribution of the members of this family.

Though a large number of genera have been referred to this family Fage (1960) recognised only ten as valid. Of these, all, except *Metalycaea* Stephensen (1925), are represented in the present collection. *Metalycaea* has not been recorded from anywhere since its discovery and hence the present collection can be considered as quite representative of the family. Surprisingly all, except two species of *Rhabdosoma* Adams and White, recognised as valid by Fage, are present in this collection. I have, therefore, taken this opportunity to make a detailed study of all the species.

The collection was confined to a restricted part of the Indian Ocean (Figs. 17 and 18) and some of the species are represented by only a small number of individuals. There is hence very little scope for a discussion of the intraspecific variation or distribution of the species. In the present paper the taxonomic part alone is hence attended to. It is earnestly hoped that this would be of some help, especially to non-specialists who may also have to deal with tropical plankton in general. With this end in view detailed illustrations, together with an enumeration of the salient characters of each species, are included.

Family OXYCEPHALIDAE Spence Bate

Spence Bate, 1861; Claus, 1887; Stebbing, 1888; Bovallius, 1890; Stephensen, 1925; Spandl, 1927; Fage, 1960.

Members of this family, except *Metalycaea* and *Simorhynchotus*, are rather elongated, with the cephalon produced into a prominent rostrum. The first antenna is articulated on the ventral side of the rostrum and in the male the basal flagellar segment is swollen and curved, with a close matting of long aesthetasks, the rest of the flagellum consists of three or rarely four small segments, subterminal in position. The second antenna in the male is very much elongated and kept folded like a carpenter's rule underneath the cephalon. The mandibular palp is long and three-segmented.

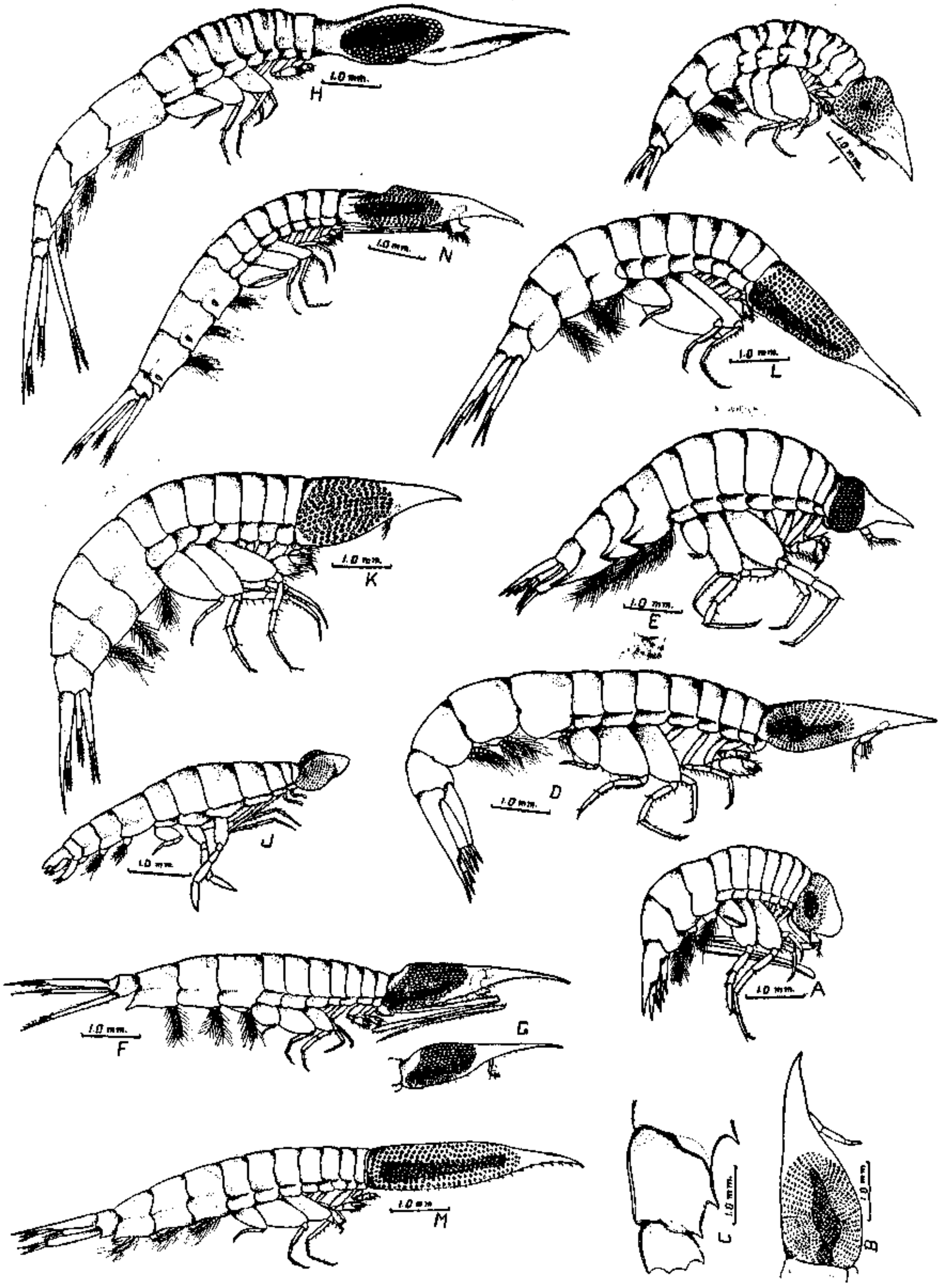

PLATE I

(A) *Simorhynchotus antennarius*, male; (B) *Oxycephalus clausi*, cephalon; (C) *Oxycephalus clausi*, abdomen; (D) *Oxycephalus latirostris*; (E) *Tullbergella cuspidata*; (F) *Leptocotis tenuirostris*, male; (G) *Leptocotis tenuirostris*; female; (H) *Calamorhynchus pellucidus*; (I) *Cranocephalus scleroticus*; (J) *Glossocephalus milne-edwardsi*, small form; (K) *Streetsia porcella*; (L) *Streetsia challengeri*; (M) *Streetsia steenstrupi*; (N) *Streetsia mindanaonis*.

Second segment of peraeopods five to seven is elytra-like. Seventh peraeopod, though reduced in size, has the full complement of segments, except in *Tullbergella* and *Rhabdosoma.*

Based on the absence of maxillae *Simorhynchotus* was transferred from Lycaeidae to Oxycephalidae. It is doubtful whether this character alone is of such crucial importance. *Simorhynchotus* so closely resembles members of the family Lycaeidae and markedly differs from members of the family Oxycephalidae that it would be more appropriate to place it in Lycaeidae. As the consensus of expert opinion is otherwise I do not propose any change in the existing arrangement.

After Bovallius (1890) only Spandl (1927) provided a key for the identification of the oxycephalid genera. Both keys are out of date since some of the genera included in their key ceased to be valid. I, therefore, give a key for the identification of the genera treated here.

1. Inner ramus of second and third uropods coalesced with the peduncle..............2

1. Inner ramus of third uropod coalesced with the peduncle..........................4

1. Inner ramus of all the uropods free...6

2. Rostrum hardly present, peraeopods one and two not cheliform........*Simorhynchotus*

2. Rostrum prominent, peraeopods one and two cheliform...........................3

3. Cephalon produced into a very long rostrum, seventh peraeopod reduced to a flat small segment..*Rhabdosoma*

3. Cephalon produced into a short rostrum, seventh peraeopod seven-segmented..*Oxycephalus*

4. Seventh peraeopod five-segmented...................................*Tullbergella*

4. Seventh peraeopod seven-segmented...5

5. Cephalon with lateral wings..*Calamorhynchus*

5. Cephalon without lateral wings...*Leptocotis*

6. Rostrum short and blunt, peraeopods five and six long and paddle-like....*Glossocephalus*

6. Rostrum long and pointed, peraeopods five and six not paddle-like.................7

7. Hind part of cephalon constricted, coxal plates fused with the peraeon segments........ ....*Cranocephalus*

7. Hind part of cephalon not constricted, coxal plates not fused with the peraeon segments.... ....*Streetsia*

Simorhynchotus, Tullbergella, Leptocotis, Calamorhynchus, Glossocephalus and *Cranocephalus* are monotypic. *Rhabdosoma* includes four species, two of which are represented here. *Oxycephalus* includes three species and *Streetsia* four, all are contained in the present collection.

Genus *Simorhynchotus* Stebbing

***Simorhynchotus antennarius* Claus**

(Plate I—A; Figs. 1–2)

Simorhynchotus antennarius Stebbing, 1888, p. 1772, pl. 200; Bovallius, 1890, p. 49; Stephensen, 1925, p. 185, f. 72; Spandl, 1927, p. 211, f. 32; Barnard, 1930, p. 433; 1931, p. 120; 1937, p. 191; Pirlot, 1938, p. 366; Fage, 1960, p. 11, figs. 1–3.

Simorhynchotus lilljeborgi Bovallius, 1890, p. 52, pl. 1, figs. 1–7, t. figs.; Spandl, 1927, p. 212, f. 33.

Simorhynchotus stebbingi Bovallius, 1890, p. 50.

Material.—St. 742, 1 female; St. 749, 2 males; St. 759, 1 male; St. 1044, 2 females; St. 1157, 1 male; St. 1233, 1 female; St. 1256, 1 female; St. 1300, 1 female; St. 1329, 1 female; St. 1337, 2 females; St. 1344, 4 males; St. 1344, 1 male; St. 1344, 2 males; St. 1344, 3 males; St. 1344, 1 male; St. 1351, 1 male; St. 1370, 1 male; St. 1377, 2 males; St. 1385, 1 male, 1 female; St. 1385, 1 female; St. 1393, 1 male; St. 1395, 1 male; St. 1397, 3 males; St. 1411, 6 females, 6 males; St. 1688, 2 females; St. 1703, 1 female; St. 1721, 1 male; St. 1723, 1 female; St. 1732, 1 female; St. 1737, 2 males; St. 1738, 1 male; St. 1739, 1 male; St. 1739, 2 females; St. 1740, 3 females; St. 1749, 1 male; St. 1750, 1 female; St. 1761, 3 females; St. 1773, 2 females; St. 1774, 1 female; St. 1779, 1 male; St. 1805, 3 males; St. 1809, 3 males, 1 female; St. 1811, 1 female; St. 1813, 3 females, 1 male.

Specific characters.—Body is short and subcylindrical. A distinct rostral prolongation is absent. Basal flagellar segment of the first antenna of the male is produced at its distal corners, upper projection is acute. First antenna of female is slender and five-segmented. Second antenna of male as usual in the family.

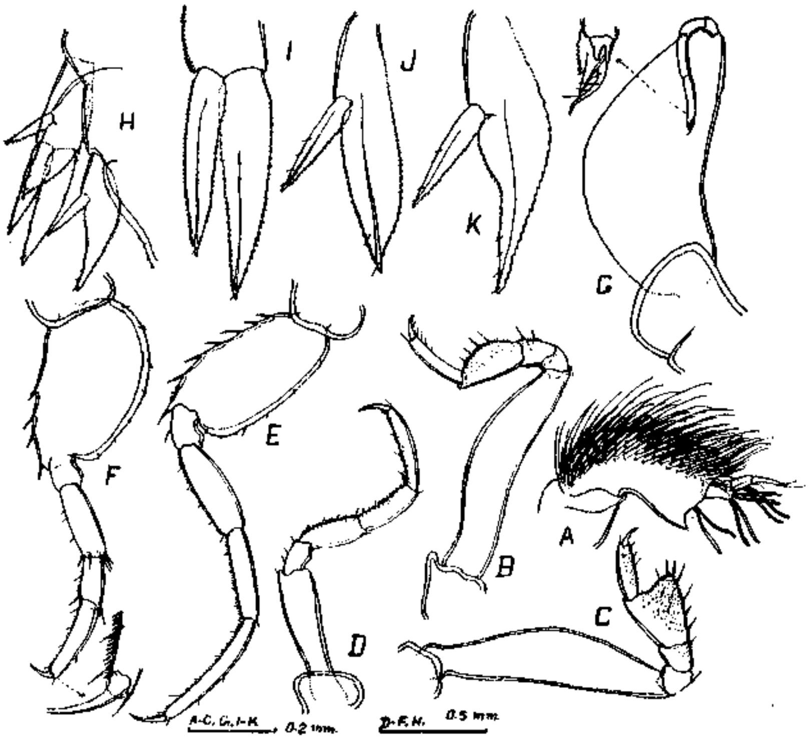

FIG. 1. *Simorhynchotus antennarius* Claus. Male: (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson; (I–K) uropods 1–3.

Peraeopods one and two are almost similar in both sexes, second peraeopod is longer and stouter than the first, fifth segment of first peraeopod is only slightly expanded but that of the second peraeopod is well produced, with its distal border transverse, thus producing a subchela. Peraeopods three and four are slender and subsimilar, with the inner border of segments four to six spiny. Second segment of fifth peraeopod is expanded and oblong, with scattered spine-setae along the upper border, inner border of segments four to six is spiny. Second segment of sixth peraeopod is more flattened than that of the fifth and the inner border of segments five and six is spiny. Second segment of seventh peraeopod is very large and leaf-like, sixth segment is distally produced into a conical process against which the seventh segment closes.

In the female peraeopods three to seven are of the same pattern as in the male, but are comparatively very stout and the fifth peraeopod, unlike as in the male, is not spiny.

In the male the telson is slightly longer than the last abdominal segment and is elongate triangular in shape. Peduncle of the first uropod is as long as the outer ramus and its outer border is serrated; inner ramus is longer and stouter than the outer and the borders of both rami are serrated. Peduncle of the second uropod is short and fused with the broad inner ramus, outer ramus is narrow and its outer border is smooth. Peduncle of the third uropod is short, about half the length of the inner ramus, the latter is narrowed at its middle and further on characteristically curved outwards, outer ramus is similar to that of the second uropod but slightly broader.

In the female the uropods are generally like those of the male but the outer border of the peduncle of the first uropod is not serrated. The rami of the uropods are more conspicuously narrowed towards the tip and their borders are not closely serrated as in the male. Telson is much different from that of the male, roughly triangular with rounded apex. In the male the telson suddenly narrows in the middle and tapers to form an acute apex.

Length 6·7 mm.

Remarks.—As Stephensen (1925) has shown this species shows very pronounced sexual dimorphism in the peraeopods, uropods and telson. The description given by Stebbing applies very well to the males in the present collection except with regard to the size of the fifth segment of the first peraeopod and the shape of the inner ramus of the third uropod. Barnard (1930) pointed out that the inner ramus of the third uropod shows all degrees of variation between the figures of Stebbing (1888) and of Spandl (1927).

Distribution.—This widely distributed species has been previously recorded from the Mediterranean, Indian Ocean, Atlantic Ocean and the Pacific Ocean. In the present locality it is the most widely distributed species.

Genus *Oxycephalus* Milne Edwards

Bovallius, 1890; Stephensen, 1925; Spandl, 1927; Fage, 1960.

Fage (1960) recognised only three species in this genus. They can be distinguished by the following key.

1. Lateral borders of the first three abdominal segments with a sharp spine..........*clausi*

1. Lateral borders of the first three abdominal segments without a spine................2

2. Lateral borders of first three abdominal segments with the distal half sinuous, cutting edge of chela of peraeopods one and two feebly toothed............................*piscator*

2. Lateral borders of first three abdominal segments evenly rounded, cutting edge of chela of peraeopods one and two with conspicuous comb of spines................*latirostris*

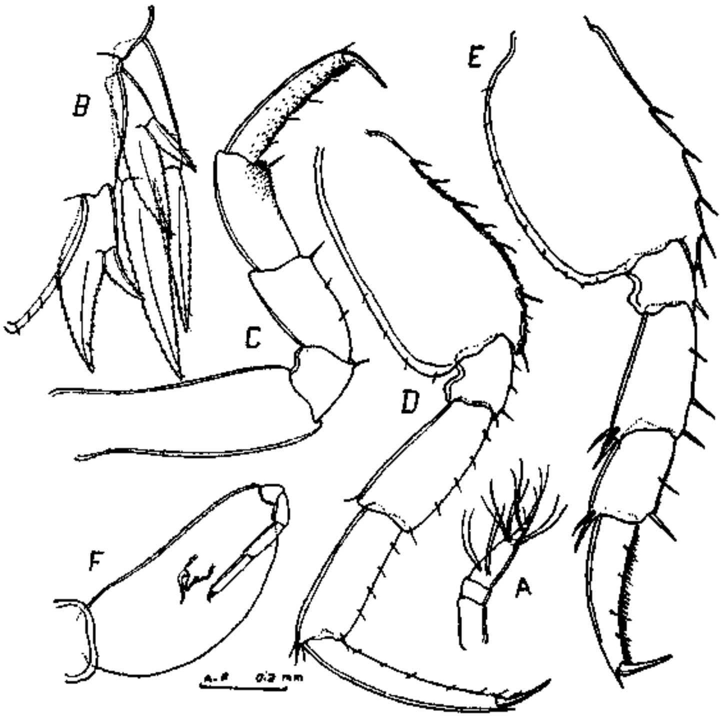

FIG. 2. *Simorhynchotus antennarius* Claus. Female: (A) Antenna 1; (B) uropods and telson; (C) peraeopod 4; (D) peraeopod 5; (E) peraeopod 6; (F) peraeopod 7.

Oxycephalus clausi Bovallius

(Plate I, B & C; Fig. 3)

Oxycephalus clausi Bovallius, 1890, p. 60, pl. 1, figs. 19–24, pl. 2, fig. 1, t.-figs.; Stephensen, 1925, p. 188; Spandl, 1927, p. 180; Barnard, 1930, p. 433; 1932, p. 130; 1937, p. 192; Pirlot, 1938, p. 192; Shoemaker, 1945, p. 251; Fage, 1960, p. 20, figs. 11–14.

Material.—St. 976, 1 female; St. 1164, 1 female; St. 1245, 1 female; St. 1278, 6 females, 1 male; St. 1278, 4 males, 9 females; St. 1278, 1 male, 9 females; St. 1278, 10 females, 6 males; St. 1292, 1 female; St. 1300, 1 male; St. 1351, 1 male; St. 1385, 3 males; St. 1385, 1 female; St. 1397, 1 male; St. 1415, 1 male; St. 1417, 1 female; St. 1719, 1 female; St. 1737, 1 male; St. 1737, 1 male; St. 1738, 1 male; St. 1739, 1 female; St. 1748, 1 female; St. 1749, 1 female; St. 1749, 1 male; St. 1749, 1 female; St. 1750, 2 males; St. 1750, 1 male, 1 female; St. 1750, 2 males; St. 1763, 1 male; St. 1788, 1 female; St. 1802, 1 female; St. 1807, 1 male.

Specific characters.—Cephalon is rather deep with the rostrum nearly half the length of the cephalon. In full grown individuals the peraeon segments are fairly deep. Pleura of the first three abdominal segments have a median lateral and a postero-lateral conical spine with the intervening border deeply concave. Telson is nearly as long as the last abdominal segment and the distal two-thirds of its lateral borders is serrated.

Peraeopod one is fairly stout, its fifth segment has a prominent outer distal tooth-like projection, inner distal part is produced into a conical process with irregularly serrated border, clearly over-reaching the tip of the sixth segment, inner border of the sixth segment is nearly straight and finely serrated, inner surface of both fifth and sixth segments carries a large number of setae. Fifth segment of the second peraeopod has an outer distal tooth as in the first peraeopod, its inner distal process is a stout thumb with the cutting edge armed with about ten blunt teeth, sixth segment is slightly shorter than the prolongation of the fifth segment and its cutting edge is finely crenulate. Second segment of fifth peraeopod is oblong and its upper border is serrated, segments four to six carry well-spaced spines. Second segment of sixth peraeopod is nearly rounded and the distal half of its inner border is serrate, inner border of segments four to seven is armed with a closely packed row of strong short teeth mixed with long spines. Second segment of seventh peraeopod conspicuously narrows distalwards, the succeeding segments are unarmed.

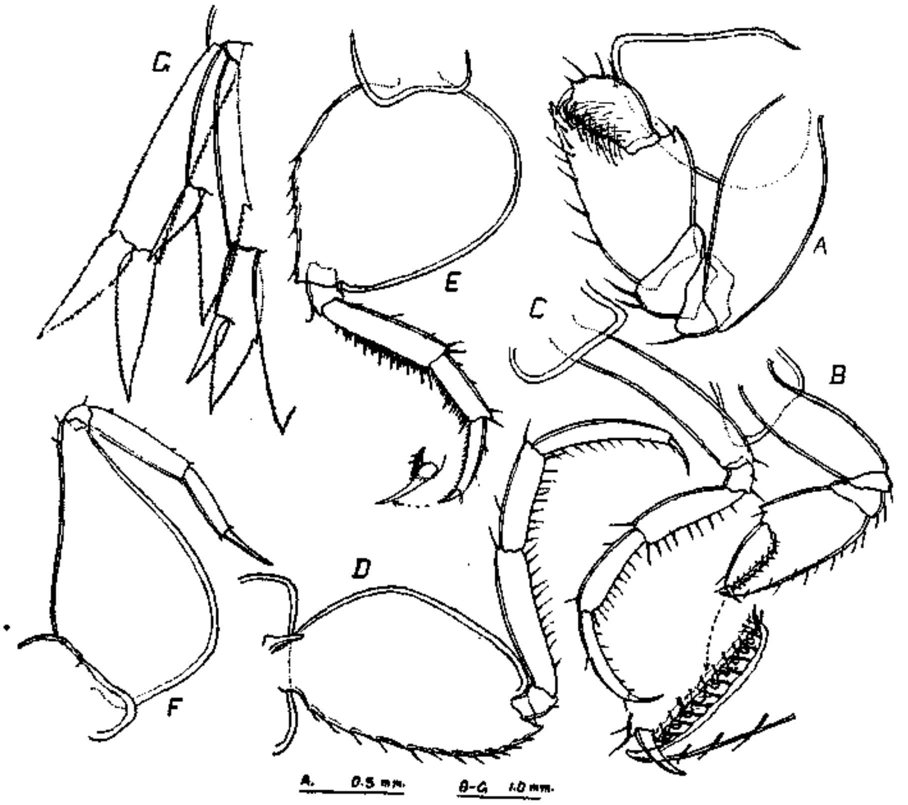

FIG. 3. *Oxycephalus clausi* Bovallius. (A) Peraeopod 1; (B) peraeopod 2; (C) peraeopod 4; (D) peraeopod 5; (E) peraeopod 6; (F) peraeopod 7; (G) uropods and telson.

Peduncle of the first uropod overreaches the base of the third uropod, its borders are serrated, rami are subsimilar and the inner ramus is slightly longer than the outer, both borders of the rami are serrated. Peduncle of the second and third uropods is fused with the inner ramus and the place of fusion is indicated by a strong tooth on the inner border, outer ramus of both uropods is considerably smaller than the inner and their outer border is not serrated.

Length 21·4 mm.

Remarks.—*O. clausi* can be easily distinguished by the apically acute rostrum, the presence of a sharp spine-like process at the middle of the lateral borders of the first three abdominal pleura and the presence of a tooth-like process at the outer distal part of the fifth segment of the first and second peraeopods. Stebbing has shown the apex of the telson as drawn out and pointed but in the present specimens it is less produced and in this respect resembles the specimens of Bovallius. Both Stebbing and Bovallius have shown the lower border of the second segment of the sixth peraeopod as serrated. In the present specimens they may be serrated or not irrespective of the size of the specimens. As observed by Fage the present collection includes dimorphic forms.

The peraeopods of *O. longipes* Spandl (1927, p. 181) are peculiar in that they are somewhat different from those of all the other species, particularly in the extreme elongation of the end segment of the seventh peraeopod. But the denticulation of the second peraeopod is very much like that of *O. clausi.*

Distribution.—This is a very widely distributed species which has been previously recorded from the North and South Atlantic, Mediterranean, Tropical and South Pacific and the Indian Ocean. In the present locality this is the most abundant member of the genus.

Oxycephalus piscator Milne Edwards

(Fig. 4)

Oxycephalus piscator Milne Edwards, 1840, p. 100; Bovallius, 1890, p. 56, pl. 1, figs. 8–16, t.-figs; Spandl, 1927, p. 180, fig. 13; Barnard, 1930, p. 433; Shoemaker, 1945, p. 246, figs. 42–43; Fage, 1960, p. 14, figs. 5–10.

Material.—St. 1278, 1 male, 1 female; St. 1278, 4 males; St. 1278, 1 male; St. 1278, 1 male; St. 1312, 1 female; St. 1356, 1 male; St. 1356, 1 female; St. 1375, 2 males; St. 1389, 1 female; St. 1722, 1 female; St. 1735, 1 male; St. 1750, 1 female; St. 1763, 1 female.

Specific characters.—The cephalon is only moderately deep and the rostrum proper is comparatively short, in adult specimens the basal part of the cephalon is constricted to form a neck followed by a dorsal hump. The pleura of the first three abdominal segments are postero-laterally produced but there is no lateral spine, posterior half of the lateral border is concave. Telson is roughly triangular but the proximal one-third of its lateral borders is plain and nearly parallel.

Fifth segment of the first peraeopod is produced at its inner distal part but this process does not quite reach the distal border of the sixth segment, its outer distal angle is rounded. Peraeopod two is comparatively weak, its second segment is as long as the rest of the limb, fifth segment has parallel sides and its inner distal border is feebly crenate, outer distal part of the segment is not produced. Inner border of fourth and fifth segments of the fourth peraeopod carries well-spaced spine-setae, that of the sixth segment is spiny. Outer border of second segment of the fifth peraeopod is dentate, that of the sixth segment is feebly spiny. Distal half of outer border of the second segment of the sixth peraeopod is dentate, that of segments four to six is armed with closely packed spines. Second segment of seventh peraeopod narrows towards the tip, the rest of the limb is subequal to the second segment in length.

Peduncle of the first uropod overreaches the base of the third uropod, distal half of both borders is serrate, inner ramus is more than half the length of the peduncle. Inner ramus of second uropod is less than half the length of the peduncle. Inner ramus of the third uropod is as long as the peduncle and slightly overreaches the telson.

Length 15·6 mm.

Remarks.—*O. piscator* closely resembles *O. clausi* but judging from the present collection it can be distinguished by the following characters. The outer distal part of the fifth segment of the first and second peraeopods does not form a tooth-like process; Spandl (1927, p. 180, fig. 13 *a*, *b*), has shown a tooth and this probably shows that he based his illustrations on a specimen of *O. clausi.*

Neither Shoemaker (1945) nor Fage (1960) has shown this tooth. The cutting edge of the prolongation of the fifth segment of the second peraeopod is only feebly crenulate whereas in *O. clausi* this edge is armed with a row of strong blunt teeth. In this character Spandl's figures are in agreement with mine. The lateral border of the first three abdominal segments has no spine-like process; each segment has a prominent tooth in *O. clausi*. The telson is proximally parallel sided whereas in *O. clausi* the telson steadily narrows towards the tip.

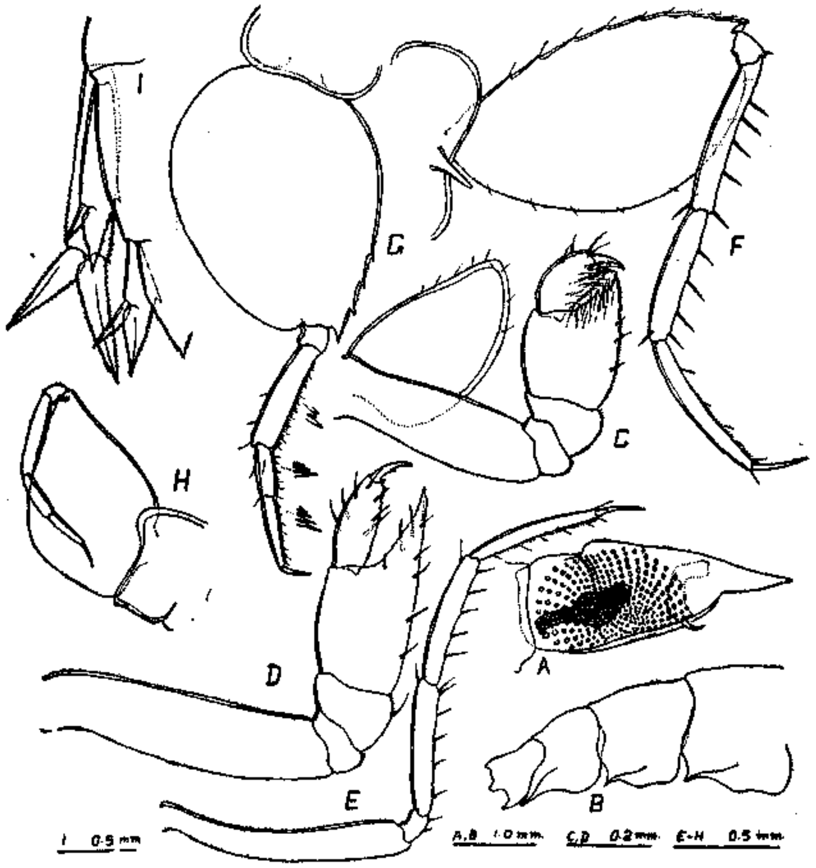

FIG. 4. *Oxycephalus piscator* M. Edwards. (A) Cephalon of male; (B) abdominal segments 1–4; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

The description and figures given by Shoemaker clearly apply to the present specimens except for the shape of the second segment of the seventh peraeopod. In the single specimen Shcemaker had, the second segment strongly narrows towards the tip so that the distal one-third of the segment is no more wider than the third segment. In the present specimens the second segment is considerably less narrowed, even less than in *O. clausi*. Shoemaker's specimen was abnormal or as remarked by him the seventh peraeopod is undergoing reduction in the suborder Hyperiidea and hence cannot have much specific importance.

Distribution.—North, Tropical and South Atlantic, Subtropical and Tropical Pacific, New Zealand, Indian Ocean and the Mediterranean.

Oxycephalus latirostris Claus

(Pl. I—D; Fig. 5)

Oxycephalus latirostris Claus, 1879, p. 71, pl. 24, fig. 1; Bovallius, 1890, p. 66, pl. 2, figs. 7–12, t.-figs.; Pirlot, 1938, p. 367; Fage, 1960, p. 26.

Oxycephalus pectinatus Bovallius, 1890, p. 64, pl. 2, figs. 4–6, t.-figs.

Oxycephalus notabilis Spandl, 1927, p. 182, figs. 15–16.

Material.—St. 1256, 1 male; St. 1278, 1 male; St. 1278, 2 males; St. 1278, 1 male, 1 female; St. 1278, 3 males, 1 female; St. 1762, 1 female; St. 1808, 1 female.

Specific characters.—Body is slender. Rostral part of the cephalon is short and apically rather blunt. The lateral borders of the first three abdominal segments are rounded, without lateral and postero-lateral processes. Telson is triangular and steadily narrows towards the tip with the proximal one-third of the border smooth.

Peraeopods one and two are very characteristic. Second segment of the first peraeopod is comparatively slender and long, fifth segment steadily broadens distalwards so that together with the sixth segment it forms a stout club, the inner distal prolongation of the fifth segment is stout and as long as the segment itself. The cutting edge of the fifth and sixth segments carries a closely packed

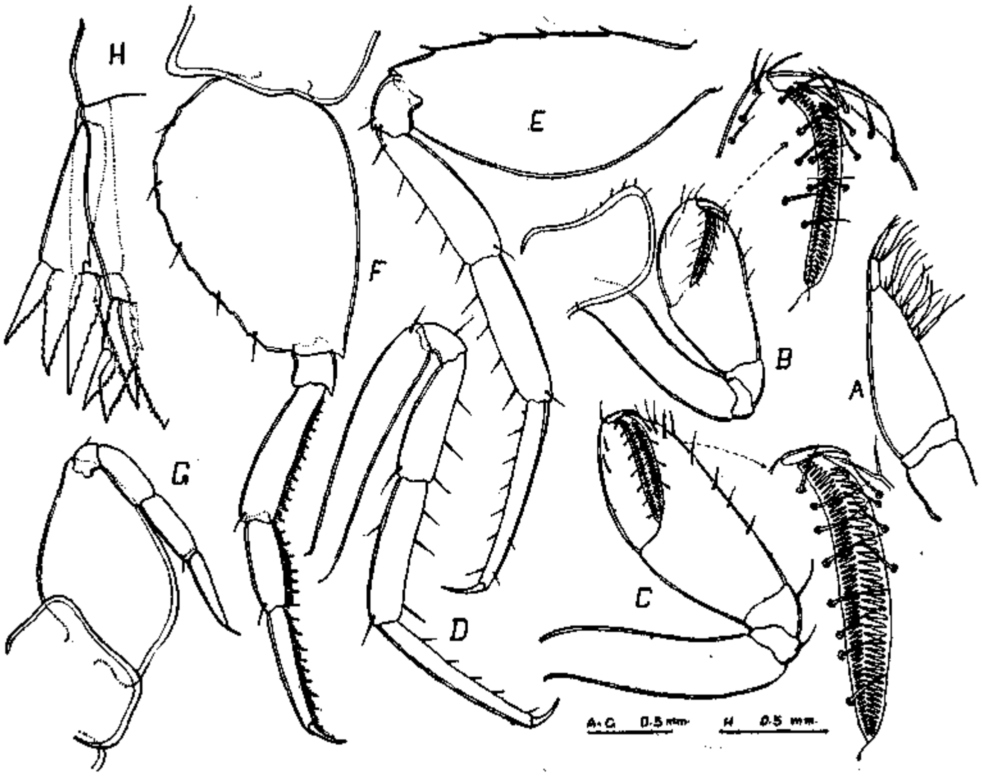

FIG. 5. *Oxycephalus latirostris* Claus. (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson.

row of sharp spines and several long submarginal setae. Second peraeopod is similar to the first but is longer and stouter, its sixth segment is nearly parallel sided and as long as the prolongation of the fifth segment, the armature of the chela is similar to that of the first peraeopod. Third and fourth peraeopods are similar to those of *O. clausi* and *O. piscator*. Second segment of the fifth peraeopod is somewhat elongated, with non-serrate border. The second segment of the sixth peraeopod is also rather elongated, with irregularly serrated inner border; seventh peraeopod is similar to that of other species, but its second segment is less narrowed distally.

Peduncle of the first uropod slightly overreaches that of the second, distal two-thirds of its inner border is serrated, outer ramus is shorter than the inner and its outer border is not serrated. Peduncle of the second uropod is one and a half times the length of the inner ramus, outer border of the outer ramus is not serrated. Peduncle of the third uropod is almost as long as the inner ramus, outer ramus is broader than that of the second uropod.

Length 13·9 mm.

Remarks.—The long slender body and the shape and armature of the first two peraeopods easily distinguish *O. latirostris* from *O. clausi* and *O. piscator*. In *O. latirostris* the inner border of the peduncle of the first uropod, unlike as in the other two species, is unarmed.

Distribution.—Tropical and Subtropical Pacific, Indo-Malayan and Indian Oceans, Atlantic, Mediterranean and the Red Sea.

Genus *Tullbergella* Bovallius

***Tullbergella cuspidata* Bovallius**

(Pl. I—E; Fig. 6)

Tullbergella cuspidata Bovallius, 1887, p. 38; 1890, p. 69, pl. 2, fig. 13, t.-figs.; Spandl, 1927, p. 191, fig. 22; Fage, 1960, p. 30.

Material.—St. 1799, 2 females.

Specific characters.—Body is somewhat tumid, quite unlike that of other oxycephalids, except *Simorhynchotus*. Cephalon is rather small and produced into a short rostrum, triangular in dorsal view and narrow in lateral view. Telson is as long as the last abdominal segment but completely fused with it and apically drawn out and acute.

First antenna is fairly stout and five-segmented, with long setae, fifth segment is slender and long. Mandible has no palp and the maxilliped is provided with foliaceous palps.

First two peraeopods are subsimilar but the second is much longer than the first, fifth segment of both is flattened and triangular, with several stiff spine-setae, inner distal angle is drawn out into a long slender spine, the inner border of the sixth segment is armed with a row of sharp spines, that of the first peraeopod is comparatively broader and more spiny. Second segment of second peraeopod is as long as the rest of the limb. Third and fourth peraeopods are subsimilar, inner border of segments five and six is armed with small spines arranged in series, seventh segment is long. Second segment of the fifth peraeopod is flattened and oblong, its inner border carries a row of stiff setules and fine spines, fourth and fifth segments are fairly broad with their inner border spiny, sixth segment is equal to the combined lengths of the two previous segments. Sixth peraeopod is very characteristic, its second segment carries only very few setae along the inner border, its distal outer part is drawn out into an outwardly curved process and the distal border is obliquely truncate, fourth and fifth segments are spiny, sixth segment, compared to that of the fifth peraeopod, is short.

Seventh peraeopod is also very characteristic, its second segment is nearly twice as long as broad, with nearly straight inner border and convex outer border, this segment is followed by three small segments.

Peduncle of the first uropod is curved outwards and reaches the base of the third uropod, distal part of its outer border is serrated, rami are subequal in length and width, and as long as the peduncle, their borders are serrated, the teeth being irregularly long and short. The peduncle of the second uropod is only half as long as that of the first, but the rami are nearly as long as those of the first. The third uropod is subequal to the peduncle of the first uropod in length, inner ramus is fused with the peduncle and the outer border of the outer ramus is not spiny.

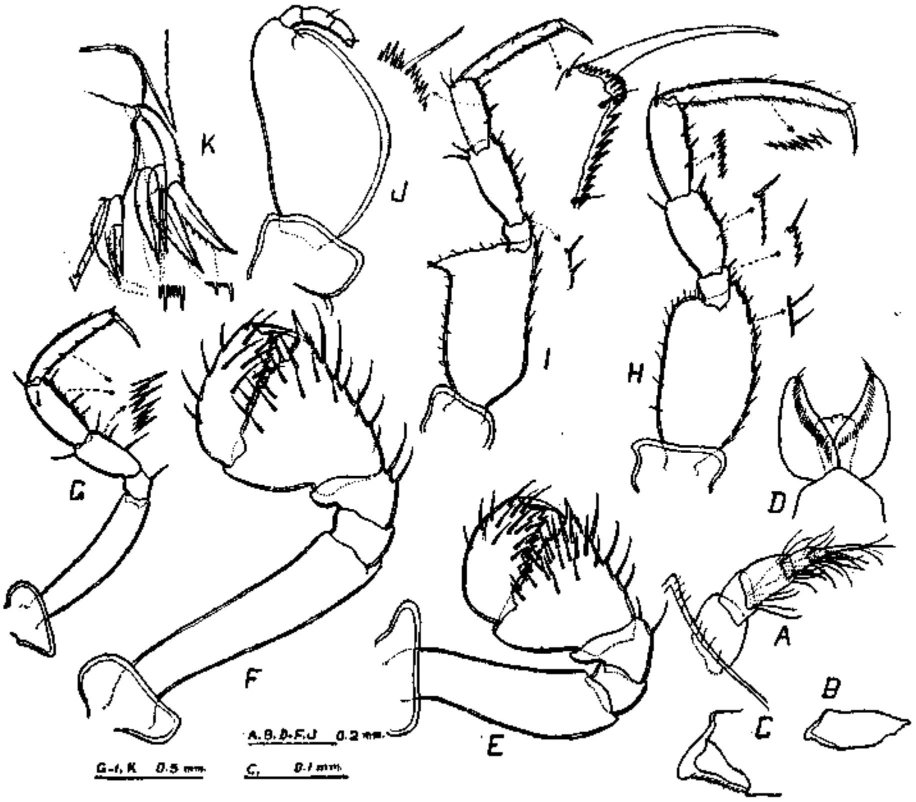

FIG. 6. *Tullbergella cuspidata* Bovallius. (A) Antenna 1; (B) mandible; (C) same, tip enlarged; (D) maxilliped; (E) peraeopod 1; (F) peraeopod 2; (G) peraeopod 4; (H) peraeopod 5; (I) peraeopod 6; (J) peraeopod 7; (K) uropods and telson.

Length 8·0 mm.

Remarks.—Compared to Spandl's figures the telson of the present specimens is apically drawn out and acute and the inner ramus of the third uropod is narrower. Spandl has shown the latter as very broad. It may be pointed out that Bovallius (1890) has also shown the telson apically rather blunt. Compared to the figure given by Bovallius the apex of the rostrum in my specimens is also more blunt. The illustrations of both these authors were those of a male while mine are of a female. This may perhaps account for the differences.

Distribution.—This species has been previously recorded from Malay Archipelago, Batavia, Gulf of Siam, Indian Ocean and Great Barrier Reef. This is one of the rare species.

Genus *Leptocotis* Streets

***Leptocotis tenuirostris* (Claus)**

(Pl. I—F and G; Fig. 7)

Leptocotis tenuirostris Stephensen, 1925, p. 191, fig. 74; Spandl, 1927, p. 206, fig. 30; Barnard, 1930, p. 435; 1931, p. 132; 1937, p. 194; Pirlot, 1938, p. 371; Shoemaker, 1945, p. 253; Fage, 1960, p. 37, figs. 21–24.

Leptocotis spinifera Streets, 1877, p. 137; 1878, p. 283, pl. 2, fig. 4.

Leptocotis ambobus Stebbing, 1888, p. 1594, pl. 205.

Leptocotis lindstroemi Bovallius, 1890, p. 76, pl. 2, figs. 16–18, pl. 3, fig. 1, t.-figs.

Leptocotis similis Spandl, 1927, p. 204, fig. 29.

Material.—St. 1157, 1 male; St. 1245, 1 female; St. 1254, 1 male; St. 1256, 1 male; St. 1278, 1 female; St. 1302, 1 male; St. 1329, 1 male; St. 1337, 6 males, 11 females; St. 1337, 1 male; St. 1340, 4 males; St. 1344, 2 males; St. 1351, 1 female; St. 1373, 2 females, 1 male; St. 1381, 1 male, 3 females; St. 1383, 2 females; St. 1385, 1 male; St. 1385, 2 males; St. 1385, 1 male; St. 1389, 1 male, 1 female; St. 1391, 2 females, 1 male; St. 1393, 1 male, 1 female; St. 1411, 1 female; St. 1413, 1 female; St. 1413, 1 male; St. 1415, 22 males; St. 1415, 1 male; St. 1415, 2 males, 1 female; St. 1415, 3 females; St. 1417, 1 male; St. 1750, 1 male; St. 1808, 1 female.

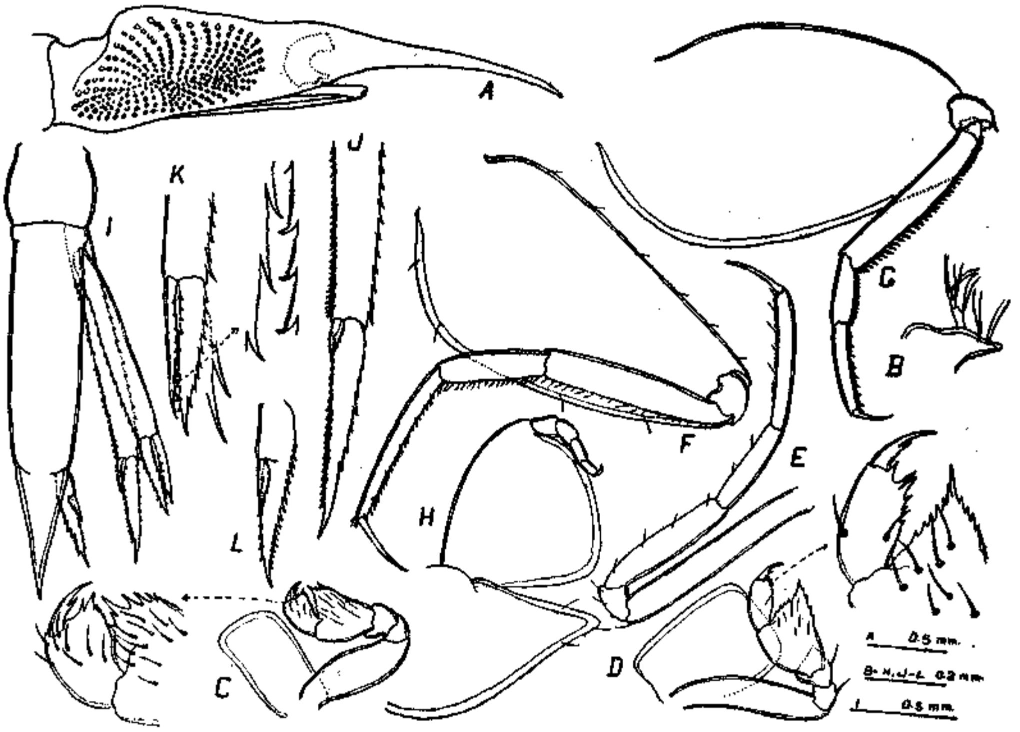

FIG. 7. *Leptocotis tenuirostris* (Claus). (A) Cephalon of male ; (B) antenna 1 ; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson; (J–L) uropods 1–3.

Specific characters.—Cephalon is comparatively long and produced into a long rostrum which is slightly curved downwards near the tip; the ventral border of the cephalon and the rostrum carries scattered fine hairs but no serrations. In the female the cephalon has an indistinct neck constriction but in the male the neck constriction is made more conspicuous by a sudden elevation of the dorsal side of the cephalon. The first two abdominal segments are postero-laterally rounded but the third is drawn out into sharp spines reaching clearly beyond the middle of the fourth abdominal segment. The fifth abdominal segment is fused with the sixth and this composite segment is about two and a half times as long as the telson and subequal to the peduncle of the first two uropods in length.

Basal flagellar segment of the first antenna of the male is produced at its outer distal angle and the succeeding four-segmented part originates from the middle of the distal border. Second antenna of the male is only sparsely setose.

Fifth and sixth segments of the first peraeopod are internally expanded and their inner border is cut into a large number of strong acute teeth. In the second peraeopod the fifth and sixth segments are similarly armed, but the fifth segment is broader than that of the first peraeopod and the sixth segment is narrower. Third and fourth peraeopods are slender and weakly armed. Segments four to six of peraeopods five and six are internally armed with spines, the spines on the fourth segment of the sixth peraeopod are very strong and bent basalwards, those on the sixth segment are arranged in series of small spines alternating with long ones. The coxal plate of the seventh peraeopod is subequal to the second segment in size and is produced backwards. Though this appendage is reduced in size all the segments are distinct.

The peduncle of the first uropod is longer than that of the second and both margins of the first and the inner margin of the second are serrated. In the first uropod the endopod is very small and the exopod is long and closely serrated on the inner side and sparsely serrated on the outer margin. The endopod of the second uropod is slightly longer than the exopod and armed with widely spaced teeth, each tooth having a frilled border, inner border of the exopod carries large curved spines armed with a row of subsidiary spines. The peduncle of the third uropod is fused with the endopod, exopod is small and less than half the length of the endopod. Telson strongly tapers to the apex. Dorso-median part of the abdomen and the telson is keeled.

Length 10·1 mm.

Remarks.—The consensus of expert opinion is that genus *Leptocotis* is monotypic. The present study has shown that *L. ambobus* Stebbing (1888) was created on the males of *L. tenuirostris.* The present collection is very rich in specimens of both sexes and all the males show the "ambobus" shape of the cephalon. The two sexes show conspicuous difference in the shape and size of the cephalon.

As pointed out by Barnard (1930) the lower margins of the abdominal segments are not serrated and the peduncle of the third uropod is coalesced with the inner ramus.

Distribution.—This is a very widely distributed species which has been previously recorded from North and South Atlantic, Pacific, East Indies and Indian Ocean. In the present locality this is the most abundant oxycephalid. The males always outnumber the females.

Genus *Calamorhynchus* Streets

***Calamorhynchus pellucidus* Streets**

(Pl. I—H; Fig. 8)

Calamorhynchus pellucidus Streets, 1878, p. 285, pl. 2, fig. 5; Bovallius, 1890, p. 73, pl. 2, figs. 14–15, t.-figs.; Spandl, 1927, p. 198, figs. 25–26; Barnard, 1930, p. 434; Pirlot, 1938, p. 371; Shoemaker, 1945, p. 251; Fage, 1960, p. 31, figs. 19–20.

Calamorhynchus rigidus Stebbing, 1888, p. 1600, pl. 206; Bovallius, 1890, p. 74; Stephensen, 1925, p. 189, fig. 73; Spandl, 1927, p. 203, fig. 27.

Material.—St. 1730, 1 female; St. 1749, 1 male.

Specific characters.—The cephalon is about a third of the total length of the animal and is divisible into a short but distinct neck, an oblong cephalon proper occupied by the eyes and a long rostrum expanded into broad wings with feebly serrated border. The cephalon has a prominent dorso-median longitudinal keel. Each peraeon segment has an indistinct transverse furrow. The postero-lateral angles of the first three abdominal pleura are produced and apically acute. Telson is about two-thirds the length of the previous segment and is apically drawn out and acute.

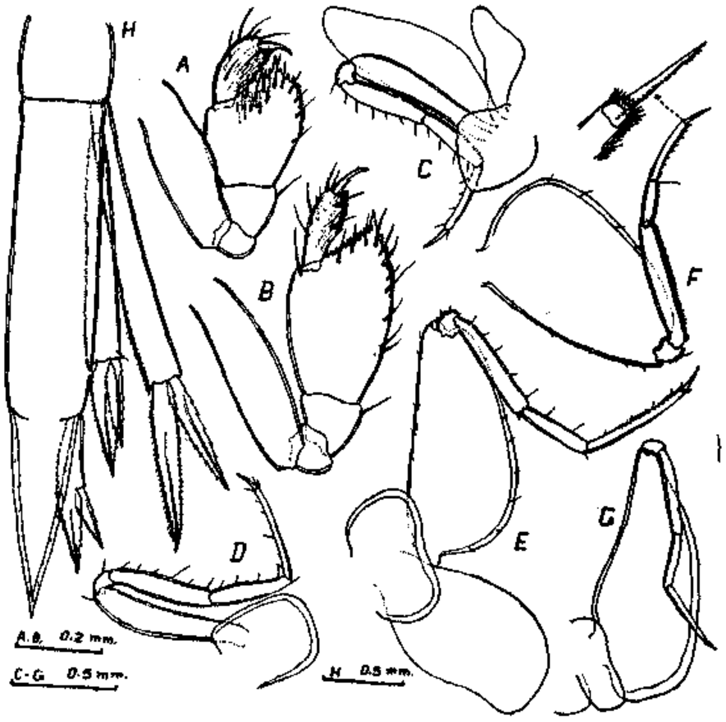

FIG. 8. *Calamorhyncuhs pellucidus* Streets. (A) peraeopod 1; (B) peraeopod 2; (C) peraeopod 3; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson.

First peraeopod has a highly swollen fifth segment armed with a row of teeth at the broadly produced inner distal part, inner border of the sixth segment is also toothed. Fifth segment of the second peraeopod is swollen and its inner distal corner is produced, distal border is armed with a row of small blunt teeth, inner border of the sixth segment has the same armature. Peraeopods three and four are subsimilar, slender and weakly armed. Second segment of fifth peraeopod has a nearly straight and feebly serrated upper border and a convex lower border, the segment slightly narrows towards the tip, the sixth segment has its inner border spiny. Second segment of the sixth peraeopod is shorter but broader than that of the fifth peraeopod, segments four to six have their inner border strongly spiny. Second segment of the seventh peraeopod is nearly as long as the rest of the limb and conspicuously narrows towards its distal end so that the distal border is only slightly broader than the third segment.

Peduncle of the first uropod clearly overreaches that of the second and stops a little short of the base of the third uropod, its inner margin is strongly serrate, inner ramus is larger than the outer, with closely serrate border, outer ramus has sparsely serrate border. Inner margin of the peduncle of the second uropod is very indistinctly serrate, rami are weakly serrate. Peduncle of the third uropod is completely fused with the inner ramus and is as long as the latter, outer ramus is comparatively small.

Length 10·1 mm.

Remarks.—Except in very minor characters the present specimens are exactly like those described by Stebbing. The margin of the rostrum is serrated and each peraeon segment has a faint transverse groove. I could not find the close spinulation of the third and fourth peraeopods illustrated by Stebbing, instead, there are long spine-setae. In Stebbing's figures the spines arming the cutting edge of the chela of the second peraeopod are pointed. They are actually blunt as illustrated by Fage (1960). In the fifth peraeopod the dorsal border of the second segment is sparsely serrated and not smooth as shown by Stebbing and the fourth and fifth segments possess only a few spine-setae and are not closely spiny as shown by Stebbing. Similarly, the sixth peraeopod is much more strongly armed than shown by Stebbing.

Distribution.—North and South Atlantic, North Pacific, East Indies, Indian Ocean and the Mediterraenan.

Genus *Cranocephalus* Bovallius

Cranocephalus scleroticus (Streets)

(Pl. I—I; Fig. 9)

Oxycephalus scleroticus Streets, 1878, p. 281, pl. 2, fig. 3.

Oxycephalus typhoides Claus, 1879, p. 195; 1887, p. 72, pl. 24, figs. 11–14.

Cranocephalus goesi Bovallius, 1890, p. 95, pl. 4, figs. 7–9, t.-figs.

Stebbingella sclerotica Bovallius, 1890, p. 98, pl. 4, figs. 13–16.

Stebbingella typhoides Bovallius, 1890, p. 100, pl. 4, figs. 10–12, t.-figs.; Stephensen, 1925, p. 199, fig. 76; Spandl, 1927, p. 193, fig. 23.

Stebbingella theeli Bovallius, 1890, p. 101, pl. 5, figs. 1–4, t.-figs.

Cranocephalus scleroticus Shoemaker, 1945, p. 251, fig. 44; Fage, 1960, p. 72, figs. 44–53.

Material.—St. 1393, 1 female; St. 1723, 1 male.

Specific characters.—The proximal dorsal side of the cephalon is abruptly raised so that a deep neck constriction is evident. Each peraeon segment has a transverse furrow slightly behind its anterior border. Coxal plates, except the first, are fused with the peraeon segments, but a deep posterior incision demarcates them, the fifth coxal plate has a conspicuous median spine directed backwards. Inferior border of the first three abdominal segments is nearly straight. The telson is linguiform and only very slightly narrows towards the broadly rounded apex.

Lower distal corner of the basal segment of the flagellum of the first antenna of the male is bluntly produced. Peraeopods one and two are subequal in size and shape but the second segment of the second peraeopod is longer than that of the first and the anterior border of the fifth segment of the first peraeopod is more prominently serrated. Peraeopods three and four are long and slender and subsimilar, second segment is as long as the fourth and fifth segments combined. Peraeopods five to seven have broad flattened second segment which is somewhat irregular in shape, that of the sixth peraeopod is the longest, the anterior border of the second segment of peraeopods five and six is feebly serrated, segments three to six of the fifth peraeopod carry scattered setae while those of the sixth are serrated as in other oxycephalids. Seventh peraeopod, though comparatively small, has all the segments.

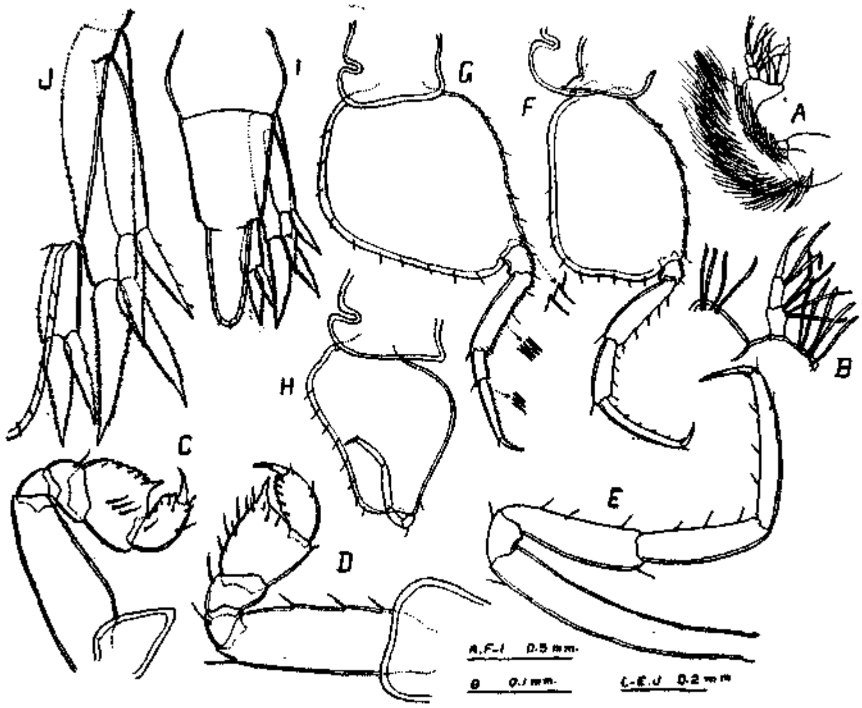

Fig. 9. *Cranocephalus scleroticus* Bovallius. (A) Antenna 1; (B) same, tip enlarged; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson; (J) same, enlarged.

Peduncle of the first uropod is stout and reaches beyond the base of the telson, distal two-thirds of its inner border and distal half of its outer border are serrated, rami are strongly serrated on both borders, inner ramus is longer than the outer and slightly overreaches the telson. Borders of the inner ramus and inner border of the outer ramus of the second uropod are prominently serrated, outer border of the outer ramus is smooth. Peduncle of the third uropod is as long as the inner ramus, distal half of its inner border is serrated, outer border of the outer ramus is sparsely toothed.

Length 11·3 mm.

Remarks.—Fage (1960) described the growth changes and sex difference this species exhibits. When compared with the illustrations published by Shoemaker (1945) the inner distal prolongation of the fifth segment of peraeopods one and two in the present specimens is more prominent. The specimen described above is an young male very well agreeing with the figures given by Fage (1960, p. 73, fig. 45 B and p. 77, fig. 51).

Distribution.—North Pacific, Mediterranean, Tropical Atlantic, Indian Ocean, North Atlantic and South Atlantic.

Genus *Glossocephalus* Bovallius

***Glossocephalus milne-edwardsi* Bovallius**

(Pl. I—J; Fig. 10)

Glossocephalus milne-edwardsi Bovallius, 1887, p. 35; 1890, p. 106, pl. 5, fig. 5, t.-figs; Chevreux and Fage, 1925, p. 432, fig. 421; Spandl, 1927, p. 196, fig. 24; Pirlot, 1938, p. 371; Shoemaker, 1945, p. 253, fig. 45; Fage, 1960, p. 83, fig. 56.

Glossocephalus spiniger Bovallius, 1887, p. 35; 1890, p. 108, pl. 5, figs. 6–9; t.-figs.

Elsia indica Giles, 1888, p. 250, pl. 6, figs. 2–4.

Glossocephalus adriaticus Steuer, 1911, p. 682, pl. 3.

Material.—St. 1688, 1 female, 1 male; St. 1710, 1 male; St. 1711, 1 female; St. 1737, 1 male; St. 1766, 1 female.

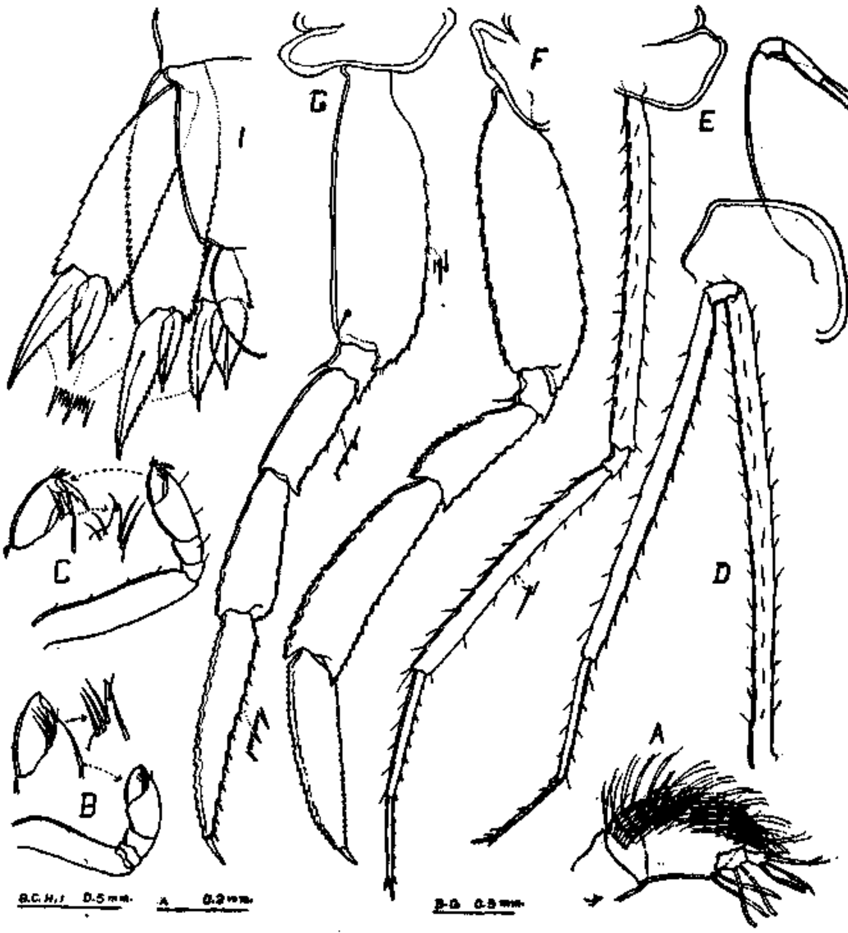

FIG. 10. *Glossocephalus milne-edwardsi* Bovallius. (A) Antenna 1; (B) peraeopod 1; (C)) peraeopod 2; (D) peraeopod 3; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

Specific characters.—The cephalon is comparatively small and hardly forms a rostrum, its anterior end is blunt. First two peraeon segments are short but the others are long so that unlike as in other oxycephalids the peraeopods are well spaced. Abdominal segments are fairly deep and have neither lateral nor postero-lateral spine-like prolongations.

First antenna has a four-segmented flagellum, first flagellar segment is broad and fringed with olfactory setae. Second antenna is folded as usual and armed with well-spaced setules. Peraeopods one and two are similar in structure but the second is slightly longer, the process of the fifth segment is spooned and armed with three to four strong spines. Peraeopods three and four are subsimilar, third is slightly longer than the fourth, segments are armed along the borders with stiff setules, seventh segment is very small. Fifth peraeopod is flattened and oar-like, both borders of the segments are serrated and each serration is secondarily armed with microscopic spinules, sixth segment is only slightly shorter than the fifth, seventh segment is very small. Sixth peraeopod is almost similar to the fifth, but its sixth segment is more slender than that of the fifth peraeopod and much longer than the fifth segment. The seventh peraeopod remotely resembles that of other oxycephalids and is formed of a large flat segment followed by four slender segments.

The peduncle of uropods one and two has strongly serrate border, outer ramus is longer than the inner, inner ramus of first uropod is narrow and that of the third is broad. Telson is slightly longer than broad and distally rounded, distal half of its lateral borders is serrated.

Length 12·7 mm.

Remarks.—Shoemaker (1945) illustrated this species but did not attempt a description. The present specimens differ as follows: The first flagellar segment of the first antenna of the male is distally produced. Shoemaker has neither described nor figured the armature of the distal segments of legs five and six. He pointed out the difference in the shape of the cephalon and attributed this to the difference in the size of the specimens. In the present specimens, which include very small ones, the cephalon has evenly curved dorsal side which is not abruptly raised as shown by Shoemaker. The cephalon is apically blunt and not sharply angular as illustrated by Shoemaker.

The small specimens, of both sexes, in the present collection appear to be dimorphic forms. They are seemingly mature, but only a third of the length of the normal ones. In general shape these fully agree with the figure of *G. spinifer* given by Bovallius (1890, pl. 5, fig. 6).

Distribution.—North and South Atlantic, South Pacific, Indian Ocean, Mediterranean and Red Sea.

Genus *Streetsia* Stebbing

Stebbing, 1888; Bovallius, 1890; Stephensen, 1925; Spandl, 1927; Fage, 1960.

A large number of species have been referred to this genus but Fage recognised only four of them as valid. All the four are represented in the present collection by small numbers. The following key serves to distinguish them.

1. Body stout..*porcella*

1. Body slender..2

2. Cephalon with a distinct neck constriction, abdominal segments one to three with a pair of sense-organs..*mindanaonis*

2. Cephalon without a neck constriction, abdominal segments without sense organs......3

3. Postero-lateral angles of third abdominal segment blunt....................*challengeri*

3. Postero-lateral angles of third abdominal segment pointed.....................*steenstrupi*

Streetsia porcella (Claus)

(Pl. I—K; Fig. 11)

Oxycephalus porcellus Claus, 1887, p. 71, pl. 24, figs. 7–9; Bovallius, 1887, p. 36; Stebbing, 1888, p. 1587, pl. 203.

reetsia porcellus Bovallius, 1890, p. 83, pl. 4, figs. 4–6.

Streetsia porcella Stephensen, 1925, p. 192; Barnard, 1930, p. 435; 1932, p. 295; 1937, p. 192; Pirlot, 1938, p. 370; Shoemaker, 1945, p. 255; Fage, 1960, p. 63.

Streetsia intermedia Spandl, 1927, p. 188, figs. 20–21.

Material.—St. 941, 1 female; St. 976, 1 female; St. 1029, 1 female; St. 1245, 1 female; St. 1278, 1 female; St. 1278, 1 female; St. 1292, 2 males, 1 female; St. 1389, 1 male; St. 1415, 1 female; St. 1417, 1 male; St. 1720, 1 male, 1 female; St. 1789, 1 female.

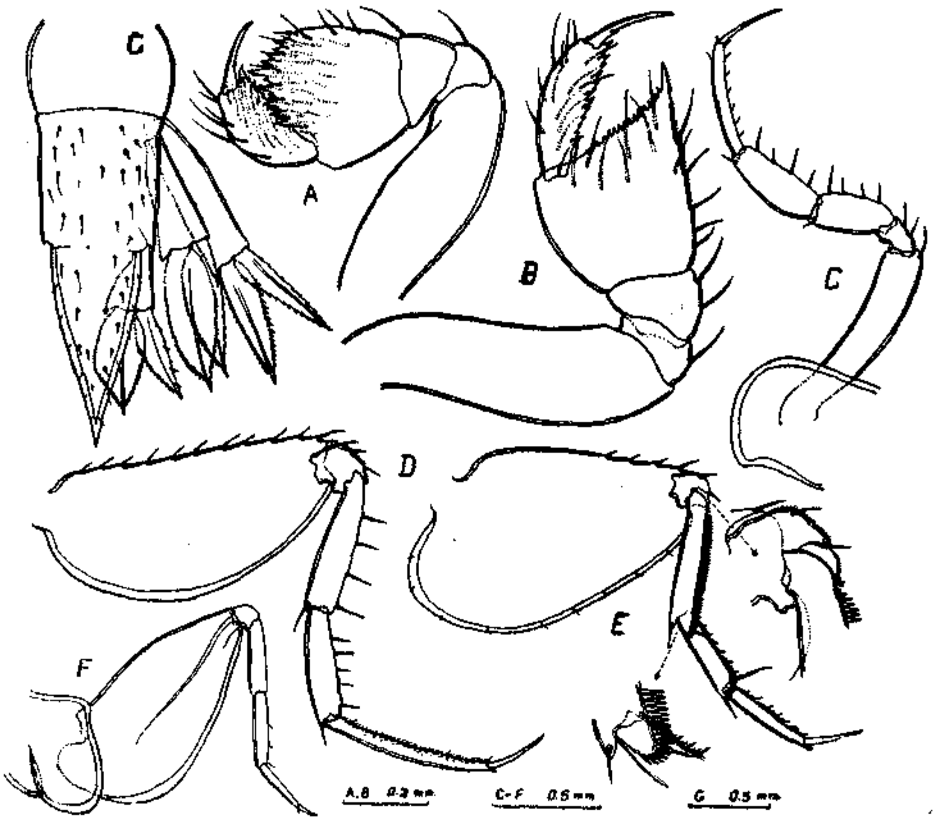

FIG. 11. *Streetsia porcella* (Claus). (A) peraeopod 1; (B) peraeopod 2; (C) peraeopod 4; (D) peraeopod 5; (E) peraeopod 6; (F) peraeopod 7; (G) uropods and telson.

Specific characters.—The body is comparatively stout and strongly built, quite unlike that of other species. The cephalon is comparatively short and produced into a short downwardly curved rostrum which is nearly half the length of the cephalon proper. First three abdominal segments are rather deep with their postero-lateral prolongations acute. Telson is about one and a half times the length of the last abdominal segment and is apically drawn out and acute.

Peraeopods one and two are rather robust, fifth segment of first peraeopod is produced into a more or less rounded lobe armed with about ten unequal teeth, inner border is finely serrate, inner surface of the segment carries a large number of stiff spine-setae, inner margin of sixth segment is also armed with sharp teeth and its inner surface carries stiff spine-setae. Inner distal angle of fifth segment of second peraeopod is drawn out into a long spine, distal border is irregularly serrate, the serrations successively but very gradually increase in size, sixth segment is armed as in the first peraeopod. Peraeopods three and four are slender and weakly armed. Second segment of the fifth peraeopod has a serrate straight upper border, sixth segment is weakly spiny. Distal half of the upper border of the second segment of the sixth peraeopod is serrated, segments four to six have their inner border strongly spiny, inner distal part of the fourth segment is produced into a large rounded lobe overlapping the base of the fifth segment. Second segment of the seventh peraeopod is as long as the rest of the limb.

Peduncle of the first uropod reaches beyond the base of the peduncle of the third, its rami are comparatively narrow and the inner ramus, which is broader, has its borders more closely serrate, inner border of the peduncle is pectinate. Peduncle of the second uropod slightly overreaches the base of that of the third uropod, rami are longer than the peduncle and rather broad and flattened, with serrate borders, inner border of the peduncle is pectinate. Third uropod has a short peduncle with the distal half of its inner border pectinate, rami are longer than the peduncle and reach the tip of the rami of the first uropod, inner ramus is very much flattened.

Length 9·1 mm.

Remarks.—The neck constriction shown by Stebbing is absent. The dorsal margin of the second segment of the fifth peraeopod and the distal half of that of the sixth peraeopod is serrated but this has not been shown by Stebbing. Likewise the third segment of the sixth peraeopod is produced into a large spiny lobe overlapping the fourth segment which also has not been shown by Stebbing. Second segment of the seventh peraeopod is slightly more elongated than in Stebbing's figure of this appendage.

Distribution.—North and South Atlantic, Mediterranean, Sea of Japan, New Zealand and the Arabian Sea.

Streetsia challengeri **Stebbing**

(Plate I—L; Fig. 12)

Streetsia challengeri Stebbing, 1888, p. 1591, pl. 204 B; Bovallius, 1890, p. 82; Stephensen, 1925, p. 194, fig. 75; Spandl, 1927, p. 186, figs. 18–19; Barnard, 1930, p. 435; 1932, p. 295; 1937, p. 295; Pirlot, 1938, p. 369; Fage, 1960, p. 51, fig. 37.

Streetsia pronoides Bovallius, 1890, p. 84, pl. 3, figs. 7–12, t.-figs.

Streetsia stebbingi Chevreux, 1900, p. 161, pl. 18, fig. 4.

Streetsia washingtoni Senna, 1903, p. 15, pl. 2.

Streetsia subada, Colosi, 1918, p. 218, pl. 2, figs. 5–8.

Streetsia gaussi Spandl, 1927, p. 184, fig. 17.

Material.—St. 1044, 1 female; St. 1278, 2 females; St. 1278, 1 female; St. 1385, 1 female.

Specific characters.—The cephalon is nearly a third of the total length of the animal and is produced into a long slender rostrum with feebly serrate inferior border. Postero-lateral angles of the first two abdominal segments are not produced. Telson is nearly as long as the last abdominal segment and is apically drawn out.

Fifth segment of first peraeopod is expanded at its inner distal part but is not produced, its border is armed with a few sharp spines; sixth segment is broad and its cutting edge is straight and feebly serrated. Inner distal angle of the fifth segment of the second peraeopod is produced into a long spine, distal border has two to three spines, sixth segment is rather slender, with two inner distal spines, inner border is finely serrate. Third and fourth peraeopods are subsimilar and armed with slender spine-setae. Second segment of the fifth peraeopod is considerably flattened and elongated, its upper border is nearly straight, and feebly serrated, outer distal angle of the second segment is slightly produced, succeeding segments are armed with short stiff setae along the inner border. Second segment of the sixth peraeopod is shorter but broader than that of the fifth peraeopod, its upper border is distally serrated, its lower distal part is prolonged into a prominent conical process which is very characteristic of this species, outer distal angle of the second segment is produced in a sharp process, segments three to six are armed with closely packed spines. Second segment of seventh peraeopod is rather short and longer than the rest of the limb, seventh segment is represented by a spine.

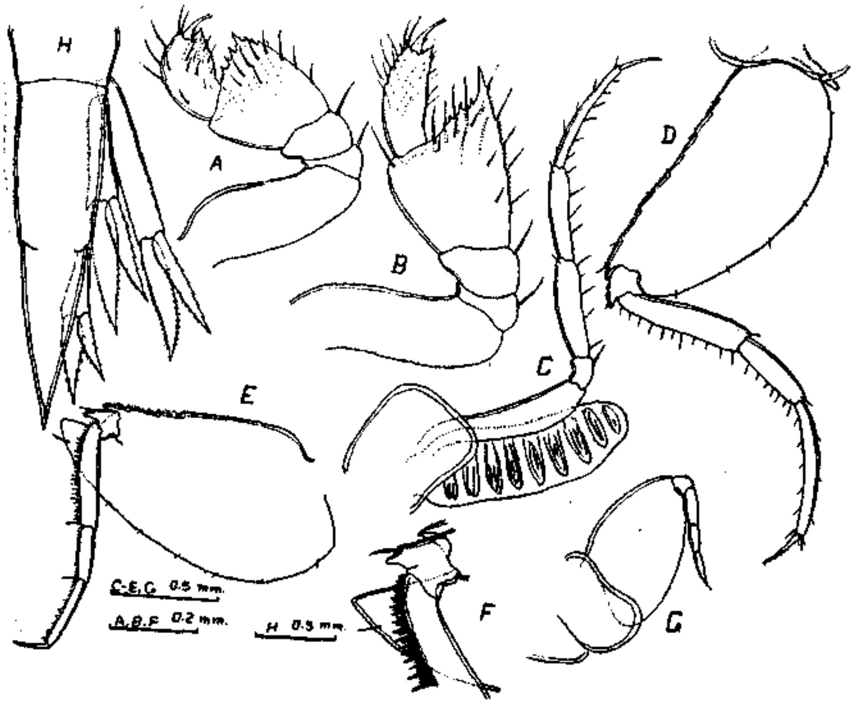

FIG. 12. *Streetsia challengeri* Stebbing. (A) Peraeopod 1; (B) peraeopod 2; (C) peraeopod 3; (D) peraeopod 5; (E) peraeopod 6; (F) same, segments 2 and 3 enlarged; (G) peraeopod 7; (H) uropods and telson.

Peduncle of the first uropod just reaches the base of the third uropod, its inner border is finely spiny, inner ramus is broader and longer than the outer and closely serrate, outer ramus is sparsely serrate. Peduncle of the second uropod is shorter than the inner ramus, latter is longer and broader than the outer. Peduncle of the third uropod is as long as the inner ramus, latter stops far short of the tip of the telson.

Length 10·9 mm.

Remarks.—This species is apparently quite variable. When compared to the detailed description by Stebbing (1888) the following differences emerge. In Stebbing's figure the cephalon is nearly cylindrical with the rostrum subequal to the cephalon proper in length. In the present specimens the cephalon perceptibly narrows distalwards and the rostrum is comparatively short. In this character Spandl's figure agrees with mine. Stebbing has shown the postero-lateral corners of the third abdominal segment slightly produced; they are blunt in mine. In Stebbing's specimen the last abdominal segment is only half as long as the telson but in mine they are nearly equal in length. In the appendages also variations are observed. The most important difference is the absence of the distal prolongation of the second segment of the second peraeopod. This is only a sign of immaturity (Stephensen, 1925). The lower distal prolongation of the second segment of the sixth peraeopod is very characteristic of this species and hence there is very little difficulty in referring the present specimens to *S. challengeri*. *S. challengeri* very closely resembles *S. steenstrupi* (Bovallius).

Distribution.—Hawiian Islands, North and South Atlantic, South Pacific, Indian Ocean. Arabian Sea and the Mediterranean.

***Streetsia steenstrupi* (Bovallius)**

(Pl. I—M; Fig. 13)

Oxycephalus steenstrupi Bovallius, 1887, p. 37.

Oxycephalus longiceps Stebbing, 1888, p. 1591, pl. 204 B.

Streetsia steenstrupi Bovallius, 1890, p. 89, pl. 3, figs. 2–6, t.-figs.; Fage, 1960, p. 42, figs. 25–27.

Material.—St. 1044, 1 female; St. 1278, 1 female.

Specific characters.—Cephalon is elongated and about a third of the total length of the animal, Rostrum is comparatively short with feebly serrate border. Postero-lateral corners of the first three abdominal segments are acute but not produced, except those of the third. Telson is elongated and tapering, almost as long as the last abdominal segment.

First peraeopod is rather stout and of uniform width, fifth segment is cylindrical with feebly serrated inner border, inner distal part is produced into a narrow process, distal border is very indistinctly dentate, sixth segment is rather broad and its inner distal angle is prolonged beneath the seventh segment. Fifth segment of second peraeopod is minutely pectinate along the inner border, inner distal angle is prolonged into a large triangular process almost reaching the tip of the sixth segment, distal border is weakly dentate, sixth segment is comparatively slender, seventh is long. Peraeopods three and four are subsimilar, third is slightly shorter but broader than the fourth. Second segment of fifth peraeopod is expanded, the dorsal side is straight and weakly dentate, outer distal part of the third segment is expanded into a flat lobe with spiny border, overlapping the fourth segment. Second segment of sixth peraeopod is broader than that of the fifth, third segment is greatly expanded, segments four to six are strongly spiny. Seventh peraeopod is of the usual pattern with large leaf-like second segment.

Peduncle of the first uropod just reaches the base of the third uropod, its inner distal border is spiny, inner ramus is more strongly dentate than the outer. Peduncle of the second uropod is as long as the outer ramus, both rami are sparsely dentate. Peduncle of the third uropod is as long as the outer ramus and its inner border is finely pectinate.

Length 10·7 mm.

Remarks.—In the shape of the cephalon of the female there is much difference between the illustrations of Stebbing and Fage; mine are like those of Fage. There is, however, no doubt about the identity because of the very exact similarity in the shape of the fifth segment of the first peraeopod and of the third segment of the sixth peraeopod.

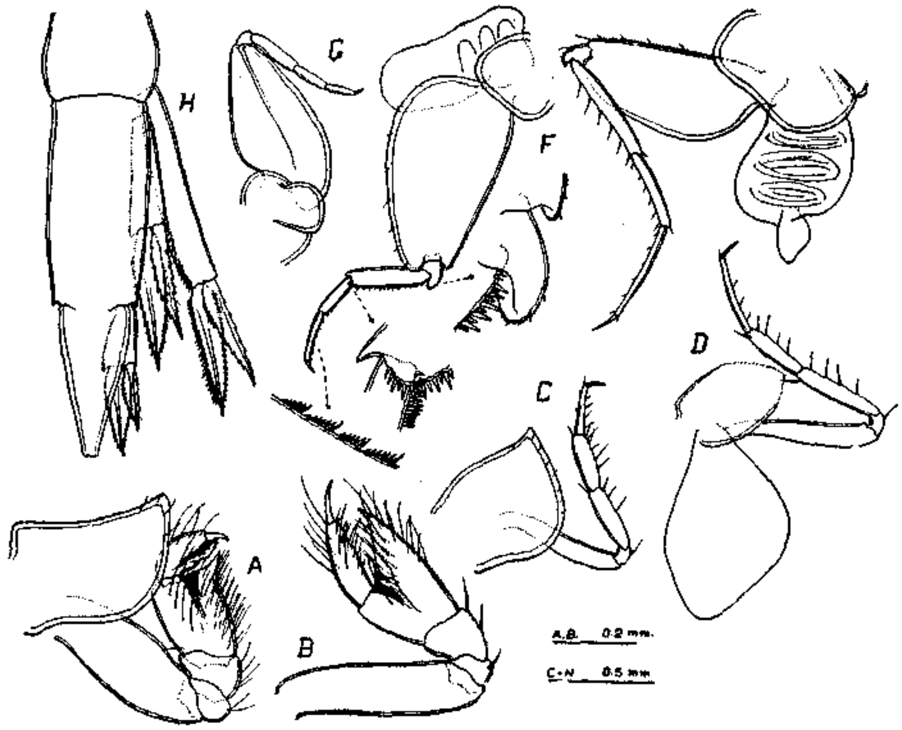

FIG. 13. *Streetsia steenstrupi* (Bovallius). (A) Peraeopod 1; (B) peraeopod 2; (C) peraeopod 3; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson.

Streetsia mindanaonis (Stebbing)

(Pl. I—N; Fig. 14)

Leptocotis mindanaonis Stebbing, 1888, p. 1598, pl. 204 *c*.

Streetsia mindanaonis Bovallius, 1890, p. 93; Fage, 1960, p. 45, figs. 28–32.

Material.—St. 1302, 1 male; St. 1385, 1 male; St. 1393, 1 male; St. 1397, 1 male; St. 1723, 1 male.

Specific characters.—Cephalon is slightly more than one-third the total length of the animal and in the male is divisible into a neck, a cephalon proper housing the eyes and a long curved rostrum. First three abdominal segments have their postero-lateral angles acute but are not produced backwards, each carries a pair of sense organs. Telson is about two-thirds the length of the last abdominal segment and is apically drawn out and acute.

The basal flagellar segment of the first antenna of the male is rounded at the lower distal part and bluntly produced at the upper distal. First peraeopod is shorter but stouter than the second, fifth segment is produced into a conical unarmed process at the inner distal part, inner part of sixth segment is expanded and feebly toothed. The inner distal angle of the fifth segment of the second peraeopod is considerably produced, with the cutting edge minutely spiny, inner border of the sixth segment is similarly armed. Third and fourth peraeopods are subsimilar and armed with long stiff setae, sixth segment is feebly spiny. Second segment of fifth peraeopod is elongated and flattened, nearly twice as long as broad, its upper border is partly serrate, inner border of sixth segment is spiny. Second segment of sixth peraeopod is comparatively broad and its upper border is serrate, fourth segment is armed with strong spines, interspersed with longer ones, fifth and sixth segments have uniform spines. Second segment of seventh peraeopod is as long as the rest of the limb.

Peduncle of the first uropod stops short of the base of the third uropod, its inner border is strongly serrated, outer border of outer ramus and inner border of inner ramus are closely serrated. Peduncle of second uropod stops slightly short of the base of that of the third, its inner border is feebly serrated, teeth on the inner border of the rami are armed with subsidiary teeth, the outer border of the inner ramus has secondarily armed teeth near the tip but the rest of the border is closely spiny. Peduncle of the third uropod is slightly shorter than the rami, all the uropods stop far short of the tip of the telson.

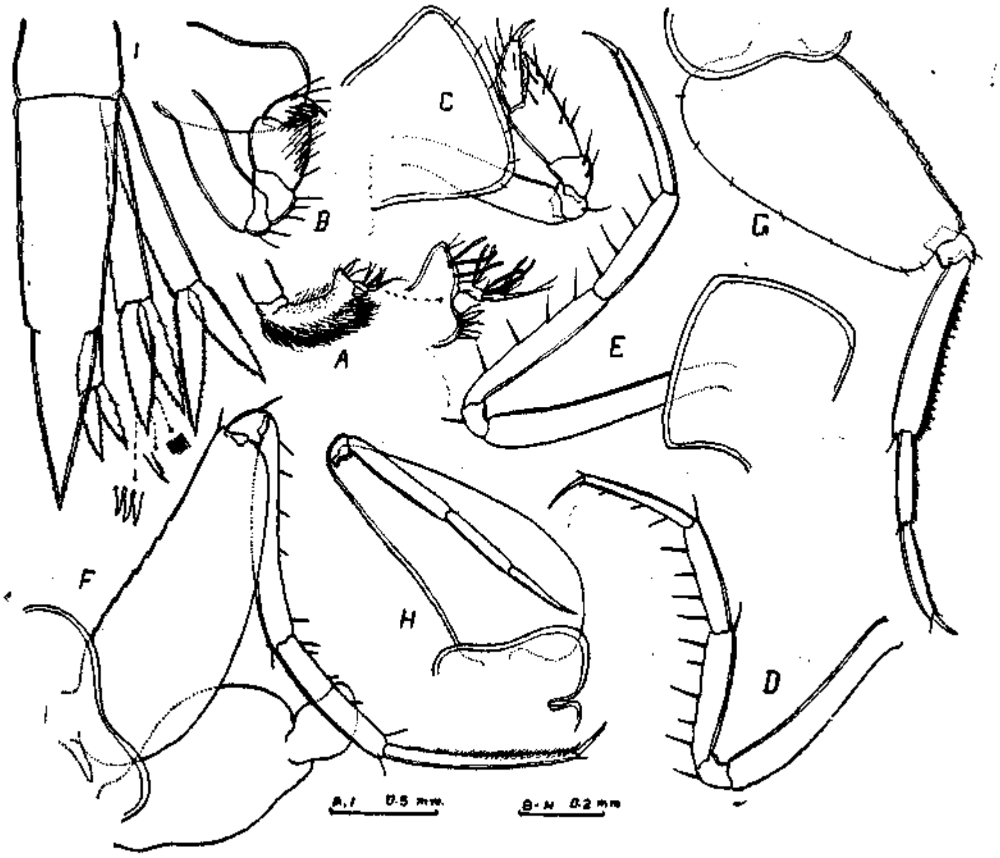

FIG. 14. *Streetsia mindanaonis* (Stebbing). (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 3; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

Length 10·0 mm.

Remarks.—In previous descriptions of this species by Stebbing (1888) and Fage (1960) adequate attention has not been paid to the finer details like the very specific armature of the rami of the uropods.

S. mindanaonis shows very close resemblance to *Leptocotis tenuirostris* but can be easily distinguished by the comparatively longer neck, the spines on the fourth segment of the sixth peraeopod which are at right angles to the long axis of the segment (at an angle in *Leptocotis*) the nearly transverse hind border of the third abdominal segment (very oblique in *Leptocotis*) and the subsimilar rami of the first uropod (inner ramus is very small in *Leptocotis*).

Distribution.—Recorded from all the oceans.

Genus *Rhabdosoma* Adams and White

Stebbing, 1888; Spandl, 1927; Fage, 1960.

Of the six species Fage recognised in this genus only two are contained in the present collection. They differ thus:

1. Fifth segment of first peraeopod with an accessory process on the inner side, outer ramus of second and third uropods rudimentary..............................*armatum*

1. Fifth segment of first peraeopod without accessory process, outer ramus of second and third uropods normally developed......................................*whitei*

Rhabdosoma whitei Spence Bate

(Fig. 15)

Rhabdosoma whitei Spence Bate, 1862, p. 345, pl. 54, fig. 7; Spandl, 1927, p. 208, fig. 31; Barnard, 1930, p. 436; Stephensen, 1925, p. 207; Barnard, 1931, p. 132; 1937, p. 193; Pirlot, 1938, p. 373; Shoemaker, 1945, p. 255; Fage, 1960, p. 97, fig. 71.

Xiphocephalus whitei Bovallius, 1890, p. 125, pl. 7, figs. 1–20, t.-figs.

Material.—St. 1254, 1 female; St. 1378, 5 males, 1 female; St. 1278, 1 female; St. 1278, 1 male; St. 1312, 1 female; St. 1329, 1 female; St. 1355, 1 female; St. 1373, 1 male; St. 1383, 2 females; St. 1385, 2 females; St. 1399, 1 male, 1 female; St. 1409, 1 female, 2 males; St. 1411, 1 male; St. 1763, 1 female; St. 1766, 1 male; St. 1799, 1 female; St. 1802, 1 male.

Specific characters.—The fifth segment of the first peraeopod is internally produced into a large conical lobe reaching far beyond the distal border of the sixth segment, sixth segment is likewise strongly produced at the inner distal part and its borders are feebly serrate. In the male the prolongation of the sixth segment is rounded. The prolongation of the fifth segment of the second peraeopod is narrow and as long as the sixth segment, the prolongation of the latter segment is very small and more rounded in the male. Peraeopods three and four are subsimilar but the fourth is longer. Fifth peraeopod is very much elongated with sparsely distributed spinules. Sixth peraeopod is shorter and more slender than the fifth, segments three to six are internally armed with small spines arranged in series, on fifth and sixth segments the members of a series show a tendency to get fused basally. Peraeopods two to six carry large branchial lobes attached to the inner side of the coxal plates and overlapping successively but they do not overlap ventrally. Seventh peraeopod is reduced to an oval lamina, its coxal plate is somewhat crescentic, with the hinder part produced.

Inner ramus of first uropod is subequal to the outer in length and width and is apically curved outwards in a characteristic fashion, its borders are closely toothed, outer ramus has its borders armed with well-spaced spines. Inner ramus of second uropod is fused with the peduncle and is longer and wider than the outer. The rami of the third uropod are similar to those of the second. Telson is an apically acute long process clearly overreaching the third uropod.

Length 65·6 mm.

Remarks.—Reviewing the observations of Schellenberg (1933) and Stephensen (1925), concerning the breeding habits of this species, Fage (1960) observed that between the first pair of branchiae exists an anterior window which permits the entry of water into the marsupium and that the branchiae of the posterior pair are free, through which the expulsion of the young takes place. I have had the opportunity to study only preserved specimens, many of which contain embryos numbering upto 40, arranged compactly in two rows. Every embryo faces obliquely upwards and forwards. By slightly pressing the marsupium one could easily make them come out through the anterior opening of the marsupium. In one large specimen the marsupium contained larvae as well as eggs and unhatched larvae and the eggs were at the hinder part. This probably indicates that the expulsion of the embryos takes place through the anterior opening of the marsupium. But I have no other positive evidence in support of this observation.

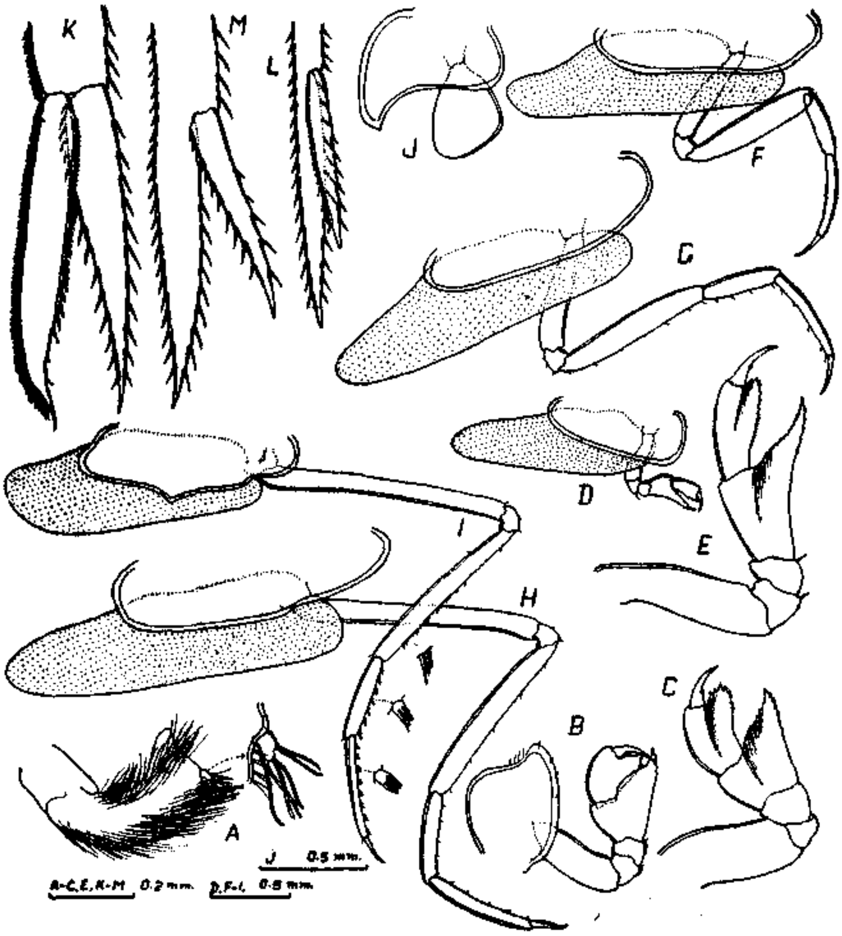

FIG. 15. *Rhabdosoma whitei* Spence Bate. (A) Antenna 1; (B) peraeopod 1, female; (C) same, male; (D) peraeopod 2, female; (E) same, male; (F) peraeopod 3; (G) peraeopod 4; (H) peraeopod 5; (I) peraeopod 6; (J) peraeopod 7; (K–M) uropods 1–3.

Distribution.—Very common in the tropical part of the Atlantic, Indian and Pacific Oceans.

Rhabdosoma armatum Milne Edwards

(Fig. 16)

Rhabdosoma armatum Spandl, 1927, p. 210; Barnard, 1930, p. 436; 1931, p. 132; Pirlot, 1938, p. 374; Fage, 1960, p. 88, figs. 60–67.

Xiphocephalus armatus Bovallius, 1890, p. 119, pl. 6, t.-figs.

Material.—St. 1278, 1 female.

Specific characters.—The first peraeopod is comparatively stout, its fifth segment is produced into a large process reaching the tip of the seventh segment, its inner border is dentate and the outer distal part carries a stout process. Inner distal part of the sixth segment is also produced into a large triangular process. Seventh segment is apically blunt. The prolongation of the fifth segment of the second peraeopod is very long, that of the sixth segment is triangular. Peraeopods three and four are subsimilar, fourth segment is very stout and is the longest. Fifth peraeopod is the longest and its second and fourth segments are swollen, the borders of the second segment are feebly dentate. Second segment of the sixth peraeopod is swollen, following segments are slender and armed along the inner border with sharp spines falling into series. Seventh peraeopod is reduced to a pear-shaped lamina, its coxal plate is roughly rectangular with concave inferior border. Inferior border of the abdominal segments is serrate. Peraeopods two to six carry large branchial plates

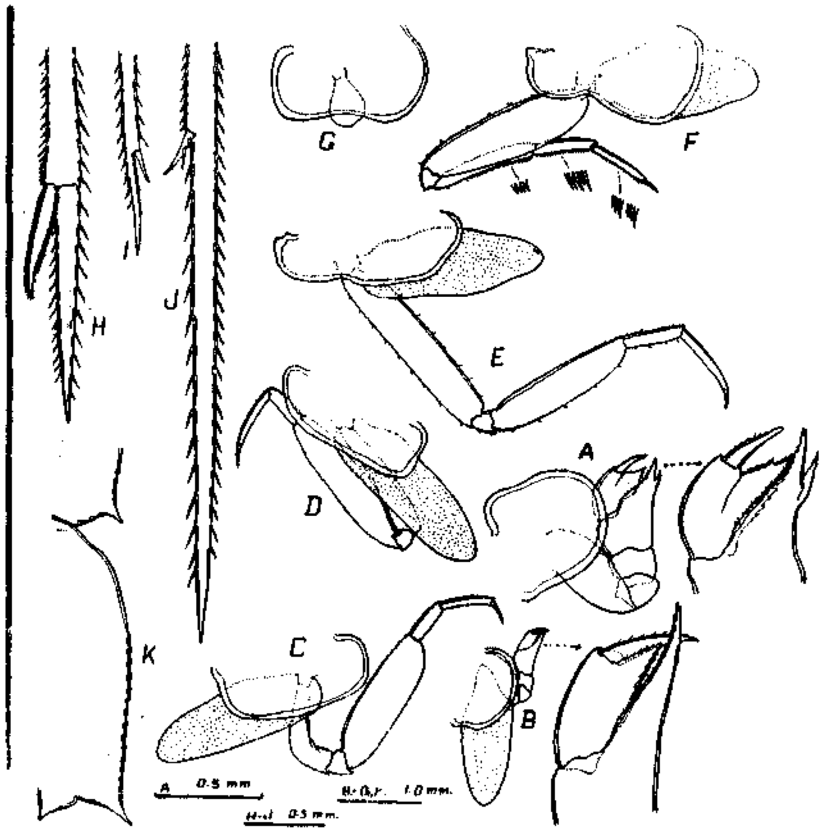

FIG. 16. *Rhabdosoma armatum* Milne Edwards. (A) Peraeopod 1; (B) peraeopod 2; (C) peraeopod 3; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H–J) uropods 1–3; (K) lateral border of abdominal segments 2 and 3.

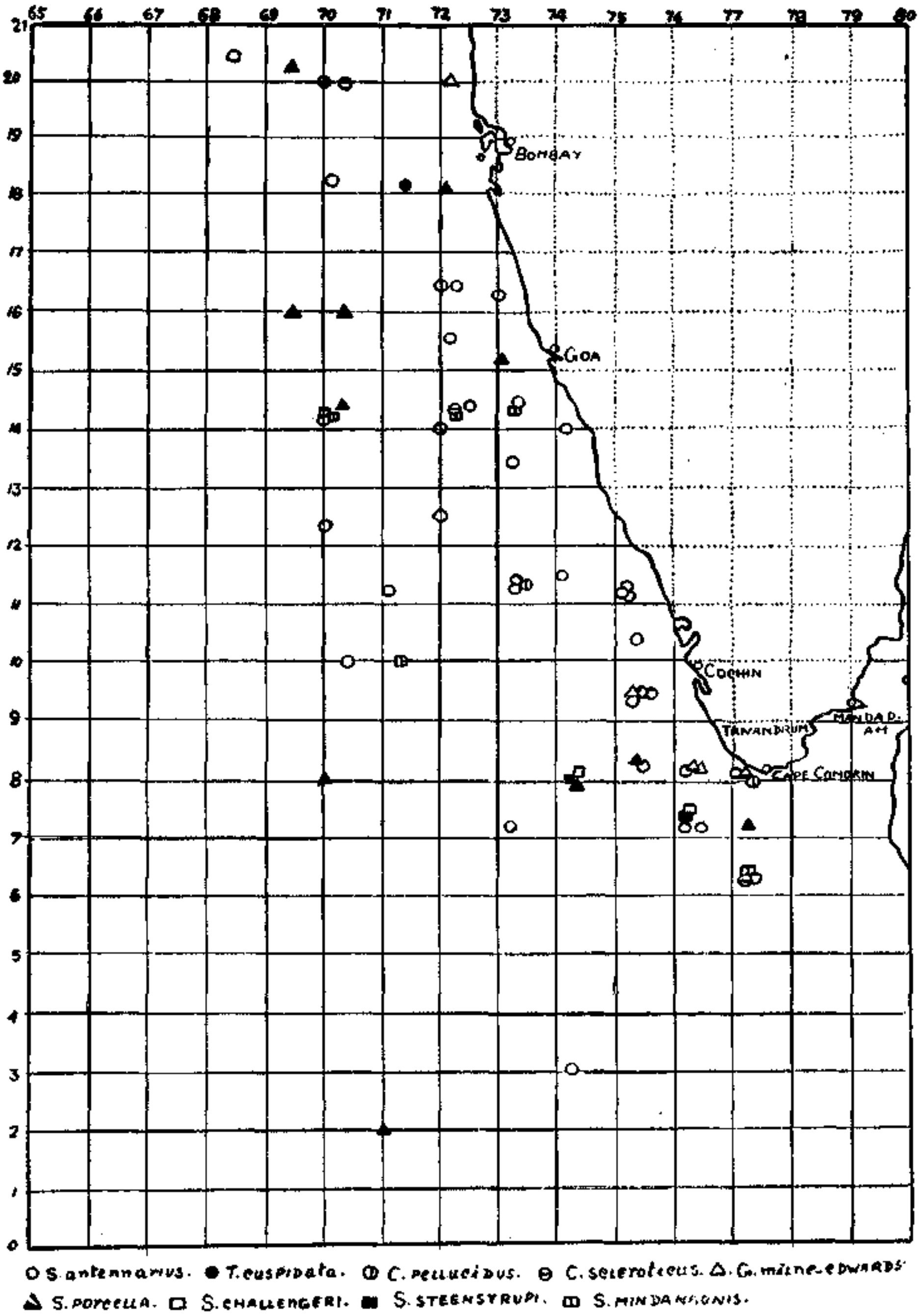

Fig. 17, Showing the distribution of species in the area of collection,

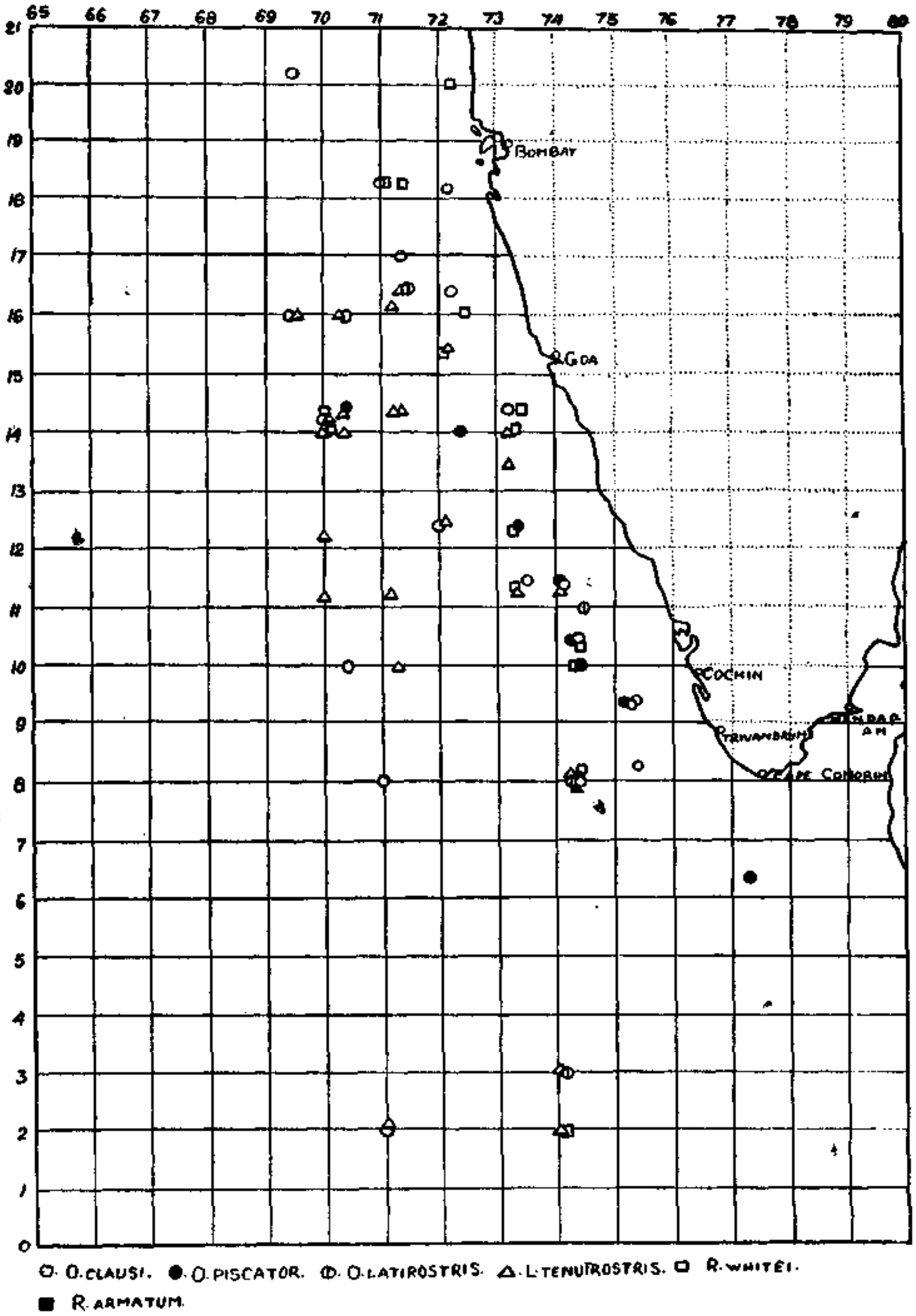

FIG. 18. Showing the distribution of species in the area of collection.

Both rami of the first uropod are free from the peduncle, inner ramus is similar to that of *R. whitei* but the outer ramus is twice as long as the inner. Inner ramus of the second and third peraeopods is fused with the peduncle, outer ramus is very small. The telson is apically acute and overreaches the third uropod.

The surface of the body including that of the telson is prominently spiny.

Length 116·9 mm.

Remarks.—In general aspects *R. armatum* resembles *R. whitei* but can be easily distinguished by the spiny body, the presence of an accessory process on the fifth segment of the first peraeopod, by the swollen fourth segment of peraeopods three, four and five and the shape of the coxal plate of the seventh peraeopod. The rudimentary nature of the outer ramus of the second and third uropods is also very characteristic of *R. armatum.*

Propagation is similar to that of *R. whitei.* The single female in the present collection has its brood pouch filled with 43 embryos.

The length of the present specimen is rather high for a tropical individual. The rostrum was partly broken and when complete the animal would have been 15–20 mm. longer than given above.

Distribution.—Previously recorded from the tropical and subtropical parts of the Atlantic, Indian and Pacific Oceans.

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APPENDIX

List of Stations where R. V. Varuna *Collected Amphipods*

Serial No.	Station No.	Position		Date	Time (hrs.)	Depth and type of haul (m.)	Depth of station (m.)	Type of gear
		Latitude N	Longitude E					
1	742	11° 24′	75° 11′	1- 2-1962	20·33-20·40	53-0 (V)	58	Not specified
2	745	11° 09′	75° 03′	2- 2-1962	00·30	100-0 (V)	112	,,
3	748	11° 07′	75° 22′	2- 2-1962	04·00-04·15	50-0 (V)	54	,,
4	749	11° 15′	75° 11′	2- 2-1962	05·50-06·05	55-0 (V)	60	,,
5	759	10° 45′	75° 30′	3- 2-1962	02·00-02·16	40-0 (V)	54	,,
6	941	15° 15′	73° 01′	2- 4-1962	18·10-18·30	100-0 (V)	118	,,
7	945	15° 50′	72° 35′	3- 4-1962	05·49-06·25	100-0 (V)	445	,,
8	953	14° 38′	73° 21′	4- 4-1962	19·00-19·20	97-0 (V)	102	,,
9	960	16° 42′	72° 44′	11- 5-1962	23·45-00·15	60-0 (V)	65	,,
10	968	17° 23′	72° 04′	13- 5-1962	01·45-02·15	90-0 (V)	95	,,
11	975	18° 03′	72° 22′	13- 5-1962	21·20-22·00	35-0 (V)	40	,,
12	976	18° 03′	72° 06′	13- 5-1962	23·45-24·00	71-0 (V)	76	,,
13	977	18° 03′	71° 51′	14- 5-1962	02·00-02·20	77-0 (V)	82	,,
14	1029	07° 13′	77° 30′	12- 6-1962	21·30-22·20	100-0 (V)	210	,,
15	1032	07° 18′	76° 41′	13- 6-1962	11·00-13·15	100-0 (V)	1700	,,
16	1044	07° 59′	76° 15′	14- 6-1962	21·45-23·40	100-0 (V)	1390	,,
17	1045	07° 52′	76° 08′	15- 6-1962	01·00-04·00	100-0 (V)	1510	,,
18	1046	08° 24′	75° 49′	15- 6-1962	08·45-11·00	100-0 (V)	1190	,,
19	1055	08° 56′	75° 54′	21- 6-1962	22·00-22·34	100-0 (V)	295	,,
20	1066	09° 54′	75° 55′	23- 6-1962	13·24-13·59	30-0 (V)	35	,,
21	1085	10° 45′	75° 37′	16- 7-1962	02·45-03·40	35-0 (V)	42	,,
22	1118	12° 05′	74° 18′	24- 7-1962	23·10-24·00	100-0 (V)	555	,,
23	1157	13° 52′	73° 22′	22- 8-1962	12·15-12·45	..	..	,,
24	1161	16° 52′	72° 42′	24- 8-1962	10·54-11·10	65-0 (V)	70	,,
25	1164	16° 45′	72° 11′	24- 8-1962	17·30-18·30	100-0 (V)	860	,,
26	1167	15° 40′	72° 42′	25- 8-1962	09·46-10·35	100-0 (V)	550	,,
27	1233	07° 06′	72° 14′	5-10-1962	11·00-13·20	100 (H)	1750	Mosquito net
28	1241	03° 59′	71° 07′	7-10-1962	03·10-06·00	50 (H)	4040	,,
29	1245	02° 00′	71° 00′	7-10-1962	23·30-02·30	100 (H)	3840	,,
30	1245	02° 00′	71° 00′	7-10-1962	22·30-02·30	50 (H)	3840	,,
31	1254	02° 00′	74° 00′	12-10-1962	15·55-17·55	50 (H)	2280	,,
32	1256	03° 00′	74° 05′	13-10-1962	01·10-03·00	50 (H)	2420	,,
33	1256	03° 00′	74° 05′	13-10-1962	01·10-03·00	100 (H)	2420	,,
34	1256	03° 00′	74° 05′	13-10-1962	01·10-03·00	75 (H)	2420	,,
35	1265	07° 14′	74° 00′	16-10-1962	16·44-16·50	..	2670	,,
36	1272	08° 29′	76° 02′	13-11-1962	23·40-01·05	200-0 (V)	880	Argo net
37	1278	08° 00′	74° 40′	14-11-1962	18·45	50 (H)	2700	Mosquito net
38	1278	08° 00′	74° 40′	14-11-1962	18·45	30 (H)	2700	,,
39	1278	08° 00′	74° 40′	14-11-1962	18·45	200 (H)	2700	,,
40	1278	08° 00′	74° 40′	14-11-1962	18·45	0 (H)	2700	,,
41	1278	08° 00′	74° 40′	14-11-1962	18·45	200-0 (V)	2700	Argo net
42	1285	08° 00′	72° 20′	15-11-1962	23·45-24·00	..	2050	..
43	1290	08° 00′	70° 40′	16-11-1962	18·00-20·55	0 (H)	3880	Mosquito net
44	1290	08° 00′	70° 40′	16-11-1962	18·00-20·55	50 (H)	3880	,,
45	1292	08° 00′	70° 00′	17-11-1962	01·35-03·52	200-0 (V)	4500	Argo net
46	1294	08° 40′	70° 00′	17-11-1962	08·35-11·30	50 (H)	4530	Mosquito net
47	1298	10° 00′	70° 00′	17-11-1962	23·55	50 (H)	4420	,,
48	1298	10° 00′	70° 00′	17-11-1962	23·55	200-0 (V)	4420	Argo net
49	1300	10° 00′	70° 40′	18-11-1962	08·05-10·10	200-0 (V)	3970	,,
50	1302	10° 00′	71° 22′	18-11-1962	14·55-18·[illegible]0	100 (H)	2860	Mosquito net

Serial No.	Station No.	Position		Date	Time (hrs.)	Depth and type of haul (m.)	Depth of station (M)	Type of gear
		Latitude N	Longitude E					
51	1306	10° 00′	72° 40′	19-11-1962	03·30	100 (H)	1780	Mosquito net
52	1310	10° 00′	74° 00′	19-11-1962	17·00	200 (H)	2320	,,
53	1312	10° 00′	74° 40′	20-11-1962	00·55–02·14	200–0 (V)	2380	Argo net
54	1329	11° 22′	73° 46′	28-11-1962	18·35–21·00	200 (H)	2050	Mosquito net
55	1329	11° 22′	73° 46′	28-11-1962	18·35–21·00	50 (H)	2050	,,
56	1329	11° 22′	73° 46′	28-11-1962	18·35–21·00	0 (H)	2050	,,
57	1329	11° 22′	73° 46′	28-11-1962	18·35–21·00	75 (H)	2050	,,
58	1329	11° 22′	73° 46′	28-11-1962	18·35–21·00	200–0 (V)	2050	Argo net
59	1333	11° 22′	72° 25′	29-11-1962	07·40–09·30	200 (H)	1700	Mosquito net
60	1335	11° 22′	71° 45′	29-11-1962	11·05–15·15	200 (H)	1520	,,
61	1337	11° 22′	71° 04′	29-11-1962	20·02–22·45	50 (H)	3260	,,
62	1337	11° 22′	71° 04′	29-11-1962	20·02–22·45	0 (H)	3260	,,
63	1337	11° 22′	71° 04′	29-11-1962	20·02–22·45	200 (H)	3260	,,
64	1340	11° 22′	70° 00′	30-11-1962	07·50–11·10	100 (H)	4300	,,
65	1344	12° 34′	70° 00′	30-11-1962	21·50–00·50	0 (H)	3250	,,
66	1344	12° 34′	70° 00′	30-11-1962	21·50–00·50	200 (H)	3250	,,
67	1344	12° 34′	70° 00′	30-11-1962	21·50–00·50	75 (H)	3250	,,
68	1344	12° 34′	70° 00′	30-11-1962	21·50 00·50	50 (H)	3250	,,
69	1314	12° 34′	70° 00′	30-11-1962	21·50–00·50	200–0 (V)	3250	Argo net
70	1344	12° 34′	70° 00′	30-11-1962	21·50–00·50	30 (H)	3250	Mosquito net
71	1345	12° 53′	70° 00′	1-12-1962	03·00–05·00	200–0 (V)	3580	Argo net
72	1347	12° 47′	70° 47′	1-12-1962	09·55–11·55	200 (H)	2370	Mosquito net
73	1349	12° 53′	71° 20′	1-12-1962	15·55–16·45	200–0 (V)	1650	Argo net
74	1351	12° 53′	72° 00′	1-12-1962	21·15–24·00	50 (H)	1440	Mosquito net
75	1351	12° 53′	72° 00′	1-12-1962	21·15–24·00	75 (H)	1440	,,
76	1351	12° 53′	72° 00′	1-12-1962	21·15–24·00	200 (H)	1440	,,
77	1351	12° 53′	72° 00′	1-12-1962	21·15–24·00	100 (H)	1440	,,
78	1351	12° 53′	72° 00′	1-12-1962	21·15–24·00	30 (H)	1440	,,
79	1351	12° 53′	72° 00′	1-12-1962	21·15–24·00	0 (H)	1440	,,
80	1353	12° 53′	72° 40′	2-12-1962	4·15– 6·00	200–0 (V)	1600	Argo net
81	1355	12° 55′	73° 25′	2-12-1962	10·45–12·55	200–0 (V)	1850	,,
82	1356	12° 56′	73° 46′	2-12-1962	15·05–16·00	0 (H)	1700	Mosquito net
83	1356	12° 56′	73° 46′	2-12-1962	15·05–16·00	75 (H)	1700	,,
84	1356	12° 56′	73° 46′	2-12-1962	15·05–16·00	200 (H)	1700	,,
85	1368	13° 50′	74° 26′	13-12-1962	03·35	20–0 (V)	28	Argo net
86	1370	14° 00′	74° 13′	13-12-1962	07·45	30–0 (V)	41	,,
87	1373	14° 00′	73° 20′	13-12-1962	13·48	30 (H)	230	Mosquito net
88	1373	14° 00′	73° 20′	13-12-1962	13·48	100 (H)	230	,,
89	1373	14° 00′	73° 20′	13-12-1962	13·48	50 (H)	230	,,
90	1375	14° 00′	72° 40′	13-12-1962	..	200-0 (V)	1200	Argo net
91	1377	14° 00′	72° 00′	14-12-1962	01·45	200-0 (V)	1600	,,
92	1377	14° 00′	72° 00′	14-12-1962	01·45	50 (H)	1600	Mosquito net
93	1377	14° 00′	72° 00′	14-12-1962	01·45	200 (H)	1600	,,
94	1377	14° 00′	72° 00′	14-12-1962	01·45	30 (H)	1600	,,
95	1379	14° 00′	71° 20′	14-12-1962	08·40	200-0 (V)	1950	Argo net
96	1381	14° 00′	70° 40′	14-12-1962	15·15	200–0 (V)	3040	,,
97	1381	14° 00′	70° 40′	14-12-1962	15·15	75 (H)	040	Mosquito net
98	1383	14° 00′	70° 00′	14-12-1962	22·20	200-0 (V)	3900	Argo net
99	1385	14° 25′	70° 00′	15-12-1962	03·35	100 (H)	3580	Mosquito net
100	1385	14° 25′	70° 00′	15-12-1962	03·35	75 (H)	3580	,,
101	1385	14° 25′	70° 00′	15-12-1962	03·35	50 (H)	3580	,,
102	1385	14° 25′	70° 00′	15-12-1962	03·35	200-0 (V)	3580	Argo net
103	1385	14° 25′	70° 00′	15-12-1962	03·35	0 (H)	3580	Mosquito net
104	1385	14° 25′	70° 00′	15-12-1962	03·35	200 (H)	3580	,,
105	1385	14° 25′	70° 00′	15-12-1962	03·35	30 (H)	3580	,,
106	1389	14° 49′	70° 40′	15-12-1962	17·40	75 (H)	3000	,,
107	1389	14° 49′	70° 40′	15-12-1962	17·40	0 (H)	3000	,,
108	1389	14° 49′	70° 40″	15-12-1962	17·40	200–0 (V)	3000	Argo net

Serial No.	Station No.	Position Latitude N	Position Longitude E	Date	Time (hrs.)	Depth and type of haul (m.)	Depth of station (m.)	Type of gear
109	1389	14° 49′	70° 40′	15-12-1962	17·40	50 (H)	3000	Mosquito net
110	1389	14° 49′	70° 40′	15-12-1962	17·40	100 (H)	3000	"
111	1389	14° 49′	70° 40′	15-12-1962	17·40	30 (H)	3000	"
112	1389	14° 49′	70° 40′	15-12-1962	17·40	200 (H)	3000	"
113	1391	14° 49′	71° 20′	16-12-1962	01·12	200-0 (V)	2080	Argo net
114	1393	14° 49′	72° 20′	16-12-1962	08·00	75 (H)	2020	Mosquito net
115	1393	14° 49′	72° 20′	16-12-1962	08·00	200-0 (V)	2020	Argo net
116	1393	14° 49′	72° 20′	16-12-1962	08·00	50 (H)	2020	Mosquito net
117	1393	14° 49′	72° 20′	16-12-1962	08·00	200 (H)	2020	"
118	1395	14° 49′	72° 40′	16-12-1962	15·20	200-0 (V)	770	Argo net
119	1397	14° 49′	73° 20′	16-12-1962	21·10	75-0 (V)	83	"
120	1397	14° 49′	73° 20′	16-12-1962	21·10	50 (H)	83	Mosquito net
121	1397	14° 49′	73° 20′	16-12-1962	21·10	30 (H)	83	"
122	1397	14° 49′	73° 20′	16-12-1962	21·10	75 (H)	83	"
123	1397	14° 49′	73° 20′	16-12-1962	21·10	0 (H)	83	"
124	1399	14° 49′	73° 41′	17-12-1962	00·35	40-0 (V)	48	Argo net
125	1400	14° 49′	74° 00′	17-12-1962	03·05	14-0 (V)	19	"
126	1404	13° 20′	74° 32′	4- 1-1963	20·15-20·30	0 (H)	20	Mosquito net
127	1407	16° 00′	73° 05′	6- 1-1963	19·55-20·10	0 (H)	70	"
128	1407	16° 00′	73° 05′	6- 1-1963	19·55-20·10	65-0 (V)	70	Argo net
129	1409	16° 00′	72° 43′	6- 1-1963	23·05	75 (H)	125	Mosquito net
130	1411	14° 11′	72° 03′	7- 1-1963	05·00-07·30	75 (H)	1720	"
131	1411	14° 11′	72° 03′	7- 1-1963	05·00-07·30	200-0 (V)	1720	Argo net
132	1413	16° 02′	71° 22′	7- 1-1963	12·50-14·55	200-0 (V)	2200	"
133	1413	16° 02′	71° 22′	7- 1-1963	12·50-14·55	100 (H)	2200	Mosquito net
134	1413	16° 02′	71° 22′	7- 1-1963	12·50-14·55	200 (H)	2200	"
135	1413	16° 02′	71° 22′	7- 1-1963	12·50-14·55	75 (H)	2200	"
136	1413	16° 02′	71° 22′	7- 1-1963	12·50-14·55	0 (H)	2200	"
137	1415	16° 00′	70° 40′	7- 1-1963	19·40-22·25	50 (H)	3350	"
138	1415	16° 00′	70° 40′	7- 1-1963	19·40-22·25	75 (H)	3350	"
139	1415	16° 00′	70° 40′	7- 1-1963	19·40-22·25	30 (H)	3350	"
140	1415	16° 00′	70° 40′	7- 1-1963	19·40-22·25	200 (H)	3350	"
141	1415	16° 00′	70° 40′	7- 1-1963	19·40-22·25	0 (H)	3350	"
142	1415	16° 00′	70° 40′	7- 1-1963	19·40-22·25	200-0 (V)	3350	Argo net
143	1417	16° 00′	69° 59′	8- 1-1963	03·05-06·40	200-0 (V)	3600	"
144	1688	8° 11′	77° 01′	10- 4-1963	02·00	50-0 (V)	55	"
145	1691	7° 58′	76° 46′	10- 4-1963	12·50	135-0 (V)	142	"
146	1703	7° 58′	76° 43′	11- 4-1963	20·20	200-0 (V)	330	"
147	1704	8° 00′	76° 38′	11- 4-1963	22·36	200-0 (V)	600	"
148	1710	8° 26′	76° 54′	12- 4-1963	09·25-09·50	30-0 (V)	36	"
149	1711	8° 25′	76° 51′	12- 4-1963	10·40-10·55	38-0 (V)	45	"
150	1719	8° 30′	75° 58′	18- 4-1963	14·35	30-0 (V)	1100	Mosquito net
151	1720	8° 24′	75° 48′	18- 4-1963	17·20-19·20	200-0 (V)	1250	Argo net
152	1721	8° 19′	75° 41′	18- 4-1963	20·40-21·15	30-0 (V)	1460	Mosquito net
153	1721	8° 19′	75° 41′	18- 4-1963	20·40-21·15	200-0 (V)	1460	Argo net
154	1721	8° 19′	75° 41′	18- 4-1963	20·40-21·15	100-0 (V)	1460	Mosquito net
155	1721	8° 19′	75° 41′	18- 4-1963	20·40-21·15	75-0 (V)	1460	"
156	1722	06° 41′	77° 32′	19- 4-1963	14·35-17·00	200-0 (V)	2400	Argo net
157	1723	06° 51′	77° 32′	19- 4-1963	18.08-20·16	200-0 (V)	2280	"
158	1724	07° 02′	77° 32′	19- 4-1963	21·15-23·15	200-0 (V)	1560	Mosquito net
159	1724	07° 02′	77° 32′	19- 4-1963	21·15-23·15	200-0 (V)	1560	Argo net
160	1725	07° 12′	77° 32′	20- 4-1963	00·25-01·30	200-0 (V)	280	"
161	1726	07° 22′	77° 32′	20- 4-1963	02·40-03·25	150-0 (V)	175	"
162	1727	07° 32′	77° 32′	20- 4-1963	04·30-05·15	30-0 (V)	93	Mosquito net
163	1730	08° 00′	77° 32′	20- 4-1963	09·45-10·15	15-0 (V)	24	Argo net
164	1732	08° 08′	76° 36′	20- 4-1963	20·45-21·30	200-0 (V)	220	"
165	1735	09° 41′	75° 03′	21- 4-1963	14·45	200-0 (V)	2400	"
166	1737	09° 46′	75° 25′	21- 4-1963	20·15-21·35	100-0 (V)	1416	Mosquito net

Serial No.	Station number	Position		Date	Time (hrs.)	Depth and type of haul (m.)	Depth of station (m.)	Type of gear
		Latitude N	Longitude E					
167	1737	09° 46′	75° 25′	21-4-1963	20·15-21·35	30-0 (V)	1416	Mosquito net
168	1737	09° 46′	75° 25′	21-4-1963	20·15-21·35	75-0 (V)	1416	,,
169	1737	09° 46′	75° 25′	21-4-1963	20·15-21·35	50-0 (V)	1416	,,
170	1737	09° 46′	75° 25′	21-4-1963	20·15-21·35	200-0 (V)	1416	,,
171	1737	09° 46′	75° 25′	21-4-1963	20·15-21·35	200-0 (V)	1416	Argo net
172	1738	09° 49′	75° 36′	21-4-1963	22·50-23·30	100-0 (V)	160	Mosquito net
173	1738	09° 49′	75° 36′	21-4-1963	22·50-23·30	30-0 (V)	160	,,
174	1739	09° 52′	75° 48′	22-4-1963	00·42-01·10	50-0 (V)	64	Argo net
175	1739	09° 52′	75° 48′	22-4-1963	00·42-01·10	30-0 (V)	64	Mosquito net
176	1740	09° 55′	75° 57′	22-4-1963	02·20-02·50	30-0 (V)	40	,,
177	1746	12° 35′	74° 05′	25-4-1963	11·10-12·45	150 (H)	716	,,
178	1747	12° 32′	73° 56′	25-4-1963	13·55-15·35	200-0 (V)	1300	Argo net
179	1749	11° 40′	73° 59′	26-4-1963	00·45-03·00	200 (H)	1250	Mosquito net
180	1749	11° 40′	73° 59′	26-4-1963	00·45-03·00	50 (H)	1250	,,
181	1749	11° 40′	73° 59′	26-4-1963	00·45-03·00	500-0 (V)	1250	Argo net
182	1749	11° 40′	73° 59′	26-4-1963	00·45-03·00	30 (H)	1250	Mosquito net
183	1749	11° 40′	73° 59′	26-4-1963	00·45-03·00	100 (H)	1250	,,
184	1750	11° 43′	74° 09′	26-4-1963	04·10-06·30	200 (H)	1250	,,
185	1750	11° 43′	74° 09′	26-1-1963	04·10-06·30	50 (H)	1250	,,
186	1750	11° 43′	74° 09′	26-4-1963	04·10-06·30	100 (H)	1250	,,
187	1750	11° 43′	74° 09′	26-4-1963	04·10-06·30	200-0 (V)	1250	Argo net
188	1752	11° 48′	74° 29′	26-4-1963	10·25-11·40	50 (H)	250	Mosquito net
189	1752	11° 48′	74° 29′	26-4-1963	10·25-11·40	75 (H)	250	,,
190	1752	11° 48′	74° 29′	26-4-1963	10.25-11·40	30 (H)	250	,,
191	1752	11° 48′	74° 29′	26-4-1963	10·25-11·40	200-0 (V)	250	Argo net
192	1756	10° 58′	75° 07′	26-4-1963	17·55-18·15	..	24	,,
193	1761	11° 01′	75° 01′	27-4-1963	05·18-06·55	200-0 (V)	850	Argo net
194	1762	11° 00′	74° 50′	27-4-1963	08·05-09·40	75 (H)	1250	Mosquito net
195	1763	10° 57′	74° 40′	27-4-1963	10·50-12·07	200 (H)	1250	,,
196	1763	10° 57′	74° 40′	27-4-1963	10·50-12·07	200 (H)	1250	Argo net
197	1766	20° 00′	72° 15′	7-5-1963	06·00	25-0 (V)	33	I.O.S. net
198	1773	20° 00′	70° 31′	7-5-1963	20·25-20·50	80-0 (V)	85	,,
199	1775	20° 00′	70° 00′	8-5-1963	00·48-01·22	60-0 (V)	72	,,
200	1779	20° 56′	68° 53′	8-5-1963	17·35-19·50	200-0 (V)	1250	,,
201	1788	20° 20′	69° 59′	9-5-1963	17·45	68-0 (V)	73	,,
202	1789	20° 14′	69° 55′	9-5-1963	19·10-19·30	68-0 (V)	73	,,
203	1794	20° 19′	72° 29′	10-5-1963	14·45-15·15	29-0 (V)	34	,,
204	1796	18° 30′	72° 30′	13-5-1963	05·05-05·30	40-0 (V)	46	,,
205	1799	18° 30′	71° 45′	13-5-1963	11·25-11·55	80-0 (V)	85	,,
206	1801	18° 30′	71° 15′	13-5-1963	15·35-16·00	75-0 (V)	84	,,
207	1802	18° 30′	71° 00′	13-5-1963	17·30-17·45	30-0 (V)	88	Mosquito net
208	1802	18° 30′	71° 00	13-5-1963	17·30-17·45	50-0 (V)	88	,,
209	1802	18° 30′	71° 00′	13-5-1963	17·30-17·45	80-0 (V)	88	I.O.S. net
210	1805	18° 30′	70° 14′	13-5-1963	23·30-01·05	200-0 (V)	1250	,,
211	1806	18° 30′	70° 00′	13-5-1963	02·45	200-0 (V)	1250	,,
212	1807	17° 00′	71° 30′	14-5-1963	18·00-19·10	30-0 (V)	1250	Mosquito net
213	1808	16° 58′	71° 45′	14-5-1963	20·50-22·00	75-0 (V)	1250	,,
214	1808	16° 58′	71° 45′	14-5-1963	20·50-22·00	30-0 (V)	1250	,,
215	1808	16° 58′	71° 45′	14-5-1963	20·50-22·00	200-0 (V)	1250	I.O.S. net
216	1808	16° 58′	71° 45′	14-5-1963	20·50-22·00	50-0 (V)	1250	Mosquito net
217	1809	16° 55′	72° 00′	14-5-1963	24·00-00·35	180-0 (V)	185	I.O.S. net
218	1809	16° 55′	72° 00′	14-5-1963	24·00-00·35	50-0 (V)	185	Mosquito net
219	1811	16° 49′	72° 29′	15-5-1963	04·05-04·30	65-0 (V)	70	I.O.S. net
220	1813	16° 43′	73° 00	15-5-1963	08·05-08·20	35-0 (V)	40	,,

Mosquito net—Net with ½ m. diameter ring, filtering part made of mosquito netting.

Argo net—Net supplied by the U.S. Research Ship Argo. 1 m. diameter ring, filtering portion made of synthetic fibre.

I.O.S. net—International Indian Ocean Expedition standard net, 113 cm. diameter ring, mesh size, 0·33×0·33.

V—Vertical haul.

H—Horizontal haul.

PELAGIC AMPHIPODS IN THE COLLECTIONS OF THE CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, INDIA: PART II. EXCLUDING OXYCEPHALIDAE

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Abstract

The first of this series described the oxycephalids contained in the present collection. The present report deals with the families Vibiliidae, Paraphronimidae, Hyperiidae, Phronimidae, Phrosinidae, Lycaeopsidae, Pronoidae, Lycaeidae, Brachyscelidae and Platyscelidae. All the species described are well known forms but a detailed study has enabled me to correct certain defects in the earlier descriptions and also provide accurate illustrations. Part of the material is yet to be identified. These will be included in the third part.

The present report, the second part of this series, deals with the hyperiid amphipods, excluding oxycephalids, collected on board *R. V. Varuna* from various stations in the Arabian Sea. The first part dealt with the oxycephalids (Pillai, 1966). Part of the material yet to be identified, along with a few gammarids present in the collection, will form the subject-matter of a third part.

As is to be expected in a predominantly holoplanktonic group like the hyperiids, all the species represented are well known. But most of them are very rich in the number of individuals and this has permitted detailed study. Each species is almost fully illustrated and briefly described.

Vibilia armata Bovallius

(Fig. 1)

Vibilia armata Bovallius, 1887, p. 69, pl. 10, figs. 15–22; Chevreux and Fage, 1925, p. 387, fig. 391; Schellenberg, 1927, p. 618, fig. 27; Pirlot, 1930, p. 11.

Vibilia gracilis Bovallius, 1887, p. 65, pl. 9, figs. 14–18.

Vibilia gracilenta Bovallius, 1887, p. 67, pl. 10, figs. 1–14.

Material (Number of specimens given in parentheses).—St. 941, (3); St. 945, (3), St. 953, (1); St. 1044, (1); St. 1046, (4); St. 1161, (1); St. 1278, (1); St. 1278, (1); St. 1278, (1); St. 1290, (1); St. 1292, (2); St. 1294, (1); St. 1298, (1); St. 1298, (6); St. 1300, (2); St. 1310, (1); St. 1312, (2); St. 1329, (1); St. 1329, (1); St. 1329, (3); St. 1335, (2); St. 1337, (1); St. 1337 ,(12); St. 1337, (3); St. 1344, (2); St. 1344, (4); St. 1344, (3); St. 1344, (3); St. 1345, (17); St. 1347, (3); St. 1351, (4); St. 1351, (2); St. 1351, (6); St. 1351, (1); St. 1353, (2); St. 1355, (1); St. 1373, (1); St. 1375, (2); St. 1377, (5); St. 1377, (14); St. 1377, (1); St. 1379, (1); St. 1379, (3); St. 1383, (51); St. 1385, (5); St. 1385, (1); St. 1385, (1); St. 1385, (2); St. 1385, (2); St. 1385, (4); St. 1389, (10); St. 1389, (2); St. 1389, (1); St. 1389, (2); St. 1391, (8); St. 1393, (1); St. 1411, (31); St. 1413, (2); St. 1413, (1); St. 1415, (11); St. 1415, (18); St. 1415, (3); St. 1415, (1); St. 1415, (1); St. 1417, (23); St. 1721, (1); St. 1721, (1); St. 1723, (1); St. 1726, (1); St. 1727, (5); St. 1732, (1); St. 1737, (1); St. 1737, (1); St. 1738, (1); St. 1749, (1); St. 1749, (1); St. 1750, (3).

Specific characters.—First antenna of the male is five-segmented, first segment is stout and carries branched setae, fourth segment abruptly narrows before the middle and its borders are armed with small setules, there is a small fifth segment carrying four denticles. Second antenna is eight-segmented, third and fourth segments are subequal. Third segment of the palp of the mandible is as long as the first two segments combined and is armed with closely packed spinules.

First peraeopod is not gnathopodal in nature, its fifth and sixth segments are subequal in size and armed with strong barbed setae, seventh segment is strong. Fifth segment of second peraeopod is internally produced forwards into a narrow spiny lobe forming with the sixth segment a subchela, the sixth segment is serrated on both borders. Peraeopods three to seven are robust, third and fourth have comparatively slender second segment, fifth and sixth segments are armed along the inner border with small spines. Second segment of fifth peraeopod is broad, with six spines on the inner distal half of its inner border, inner border of segments four to six is spiny, dactylus is nearly straight and carries a few spines near its base. Sixth peraeopod is very much similar to the fifth but its second segment is slightly narrower. Seventh peraeopod is modified, its second segment is broad, third is very short, inner border of segments four to seven is armed with scales and spinules, seventh segment is large and club-shaped, with characteristic armature.

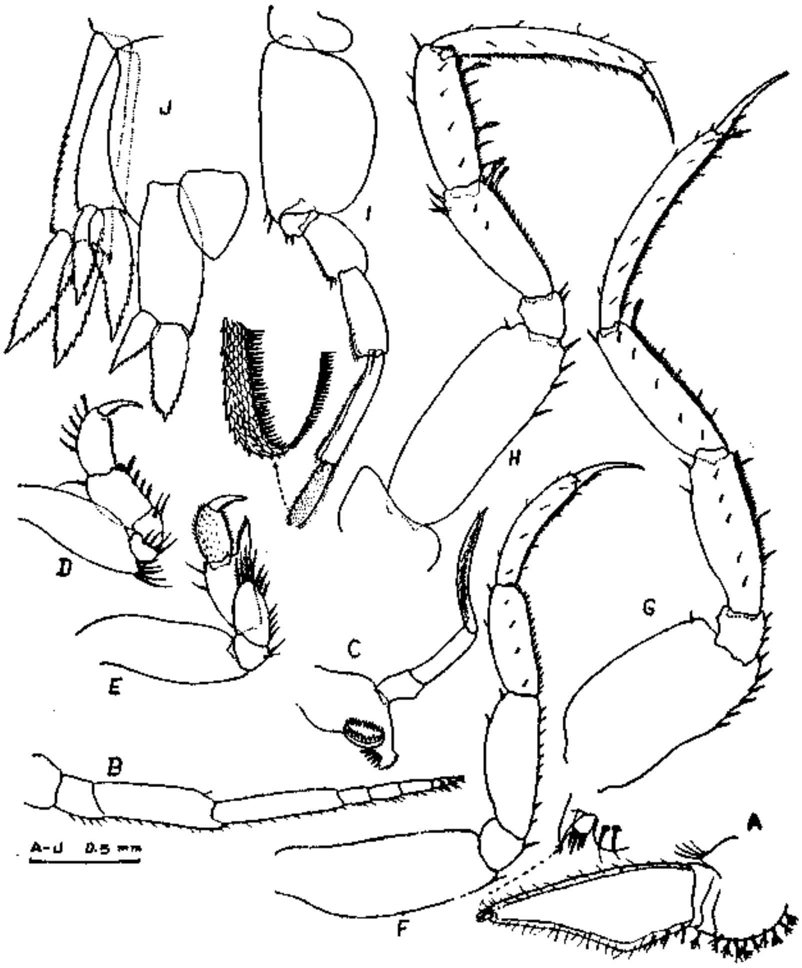

FIG. 1. *Vibilia armata* Bovallius. (A) Antenna 1; (B) antenna 2; (C) mandible; (D) peraeopod 1; (E) peraeopod 2; (F) peraeopod 4; (G) peraeopod 5; (H) peraeopod 6; (I) peraeopod 7; (J) uropods and telson.

Peduncles of the uropods are stout, that of the first uropod is nearly as broad as that of the third, peduncle of the second uropod is as long as that of the third. Distal two-thirds of the outer border of the peduncle of the first uropod shows sparse serrations. Rami of first uropod are subsimilar, exopod of the second and third uropods is smaller than the endopod, endopod of third uropod is broad and suddenly narrows near its apex, both borders of all the rami are serrated. Telson is roughly triangular and apically blunt.

Length 7·4 mm.

Remarks.—In most of the characters the present specimens resemble those which Bovallius described as *V. gracilenta*. However, the proportionate lengths of the segments of the second antenna are different and the telson is slightly broader.

Vibilia viatrix **Bovallius**

(Fig. 2)

Vibilia viatrix Bovallius, 1887, p. 63, pl. 9, figs. 1-13; Chevreux and Fage, 1925, p. 385, fig. 390; Barnard, 1930, p. 403; Shoemaker, 1948, p. 234; Pirlot, 1930, p. 10.

Material (Number of specimens given in parentheses).—St. 745, (1); St. 953 (1); St. 968, (4); St. 1278, (1); St. 1329, (1); St. 1329, (1); St. 1329, (2); St. 1344, (7); St. 1385, (3); St. 1399, (1); St. 1417, (1); St. 1704, (1); St. 1719, (1); St. 1723, (1); St. 1737, (1); St. 1749, (1); St. 1796, (1); St. 1808, (1); St. 1808, (1).

Specific characters.—The first antenna of the male is five-segmented, fourth segment is very stout and fifth minute, the distal border of the fourth segment is obliquely truncate and hairy, its inner surface carries two longitudinal patches of sensory setae. Second antenna is seven-segmented.

Second segment of first peraeopod has a proximal dorsal bulge, distal part of the inner border of the fifth and the whole of the inner border of the sixth segment are spiny. Fifth segment of the second peraeopod is produced into a large spiny conical process. Inner border of the sixth and seventh segments of the fourth peraeopod is spiny. Second segment of the fifth peraeopod is flattened, with three spine-setae along the lower border, sixth segment is long and spiny. Second segment of the sixth peraeopod is longer than that of the fifth, its fifth segment is spiny along the inner border and carries five strong spines. Second segment of the seventh peraeopod is considerably expanded and flattened; its distal inferior part is produced into a thin conical lobe reaching slightly short of the tip of the fourth segment, borders of the segments are minutely spiny.

Peduncle of the first uropod is about one and one-fourth times the length of the peduncle of the third, that of the second is slightly shorter than that of the third, inner distal border of the peduncle of the first and third uropods is finely pectinate. Rami of the first uropod are long and serrated along both borders, those of second and third are comparatively short. Telson is roughly semicircular.

Length 3·1 mm.

Remarks.—The denticulation of the rami of the uropods in the present specimens is very prominent and the shape of the telson is slightly different from the illustrations given by Chevreux and Fage. More important is the greater prolongation of the second segment of the seventh peraeopod. Since the present specimens are all comparatively small I suspect that this might be a juvenile character. In the illustrations published by Shoemaker the prolongation is prominent but is smaller than in the present specimens. I am not fully satisfied with the identification of the specimens dealt with here.

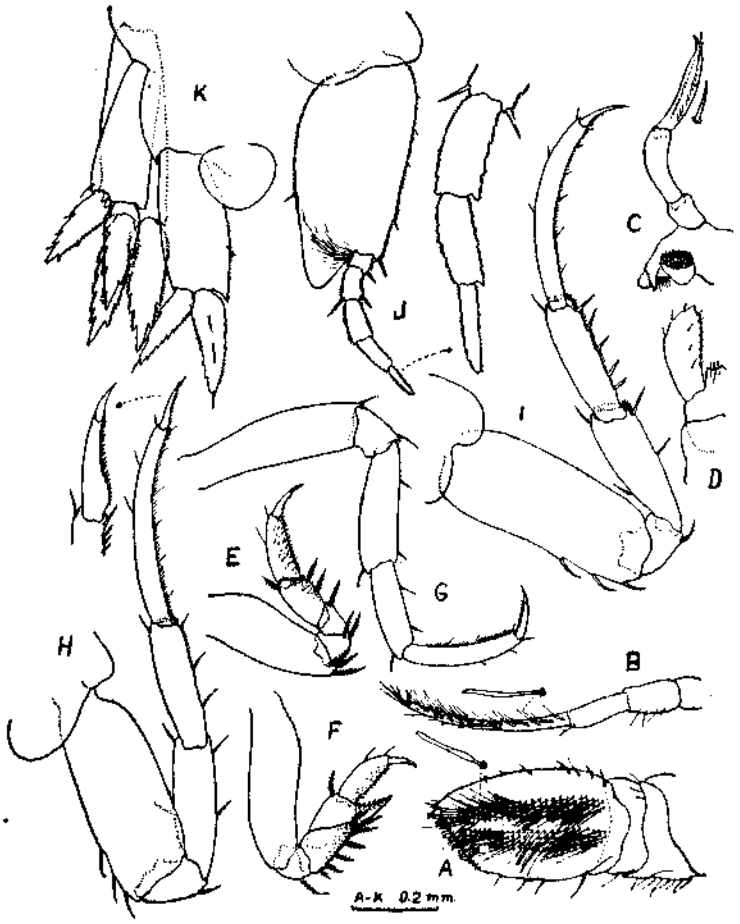

FIG. 2. *Vibilia viatrix* Bovallius. (A) Antenna 1; (B) antenna 2; (C) mandible; (D) maxilliped; (E) peraeopod 1; (F) peraeopod 2; (G) peraeopod 4; (H) peraeopod 5; (I) peraeopod 6; (J) peraeopod 7; (K) uropods and telson.

Vibilia australis Stebbing

(Fig. 3)

Vibilia australis Stebbing, 1888, p. 1287, pl. 149.

Material.—St. 2131, 4 specimens.

Specific characters.—First antenna is six-segmented, inner border and inner ventral surface of the fourth segment are prominently hairy, the distal third of its inferior border is concave and the segment abruptly narrows distalwards, fifth and sixth segments are small. Second antenna is four-segmented, fourth segment is as long as the combined lengths of the second and third segments. First peraeopod is not gnathopodal in shape, inner part of the sixth segment is produced into conspicuous apically serrate processes, seventh segment is large, with distinct unguis. Second gnathopod is subchelate, fifth segment is produced at its inner distal part into a long stout apically sharp process with irregularly dentate inner border, inner border of the sixth segment is cut into sharp teeth. Peraeopods three to six are comparatively stout, third and fourth are subsimilar, second segment is the longest, inner border of the sixth and seventh segments is feebly spiny. Fifth and sixth peraeopods are subsimilar, their second segment is flattened and the sixth segment is elongated, inner border of the fifth, sixth and seventh segments of the sixth peraeopod is conspicuously spiny. Seventh peraeopod is characteristic, its seventh segment is apically drawn out and is covered with stiff setules.

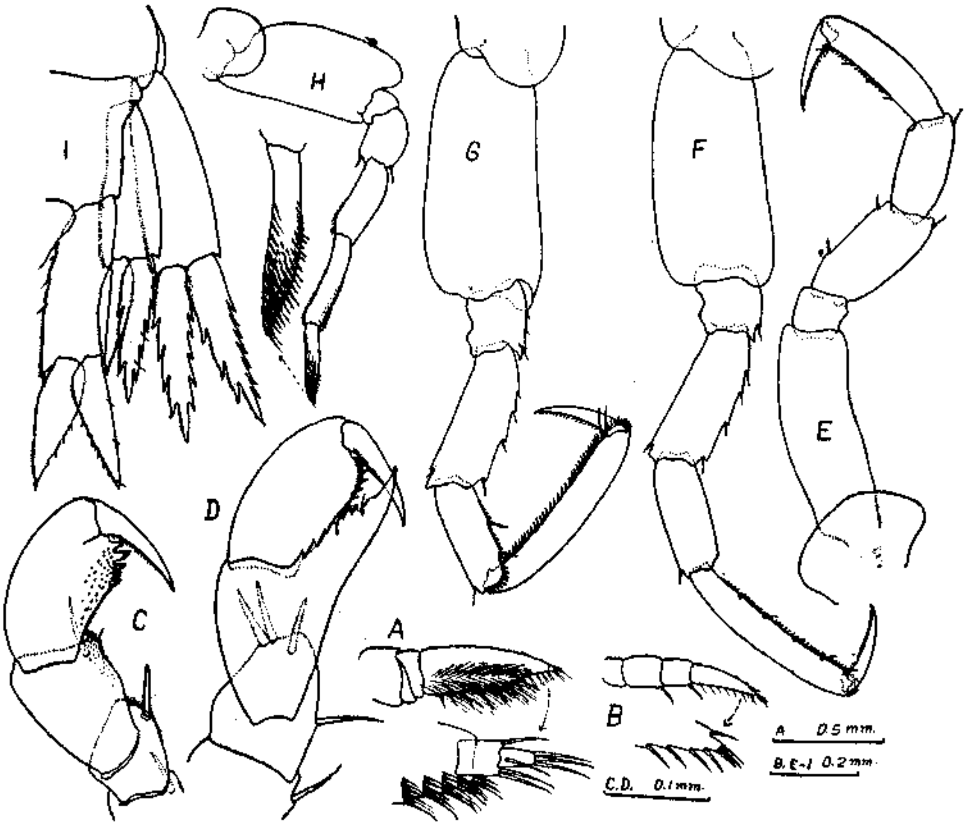

Fig. 3. *Vibilia australis* Stebbing. (A) Antenna 1; (B) antenna 2; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

Telson is nearly triangular, as long as broad and only slightly immersed in the urosome. Peduncle of the first uropod very slightly overreaches the peduncle of the second, the rami are subsimilar, with prominent serrations along both borders, serrations on the outer border are smaller and closer, inner border of the peduncle is closely serrate. Peduncle of the second uropod is longer than the rami, its inner border is minutely serrate, outer ramus is longer than the inner and serrate like the rami of the first uropod, inner ramus has both borders finely serrate. Peduncle of the third uropod is only slightly shorter than that of the first, inner ramus is broader than the outer, outer border of outer ramus is smooth, inner border of outer ramus and both borders of the inner ramus are irregularly serrate.

Length 3·6 mm.

Remarks.—The present specimens resemble those described by Stebbing except in minor details. The denticulation of the sixth segment of the first two peraeopods is slightly different and the seventh segment of the seventh peraeopod abruptly narrows near the tip and ends in an acute point.

Paraphronima crassipes Claus

(Fig. 4)

Paraphronima crassipes Bovallius, 1889, p. 30, pl. 2, figs. 11–15; Stephensen, 1924, p. 77; Chevreux and Fage, 1925, p. 390, fig. 393; Spandl, 1927, p. 166; Irie, 1948, p. 347, fig. 4.

Material (Number of specimens given in parentheses).—St. 1278, (1); St. 1294, (1); St. 1335, (1); St. 1337, (1); St. 1351, (1); St. 1373, (1); St. 1385, (1); St. 1385, (1); St. 1389, (1); St. 1393, (1); St. 1411, (1); St. 1415, 1); St. 1417, (1); St. 1721, (1); St. 1748, (2); St. 1749, (1); St. 1762, (1); St. 1779, (2); St. 1805, (1).

Specific characters.—Cephalon is nearly as long as deep. Peraeon is about half as deep as the cephalon. Telson is very small and triangular with rounded apex. The penultimate segment of the first antenna of the male is enlarged and hairy, last segment is minute. Second antenna of the male has its second segment equal to the rest of the limb. First peraeopod is comparatively short and stout, fourth segment has its inner distal angle conically produced and surmounted by about five strong spines, fifth segment carries two stout inner distal spines. Second peraeopod is long and slender, with subcylindrical segments. Peraeopods three to seven successively decrease in length, and seventh is only slightly shorter than the sixth. All the peraeopods have a robust build.

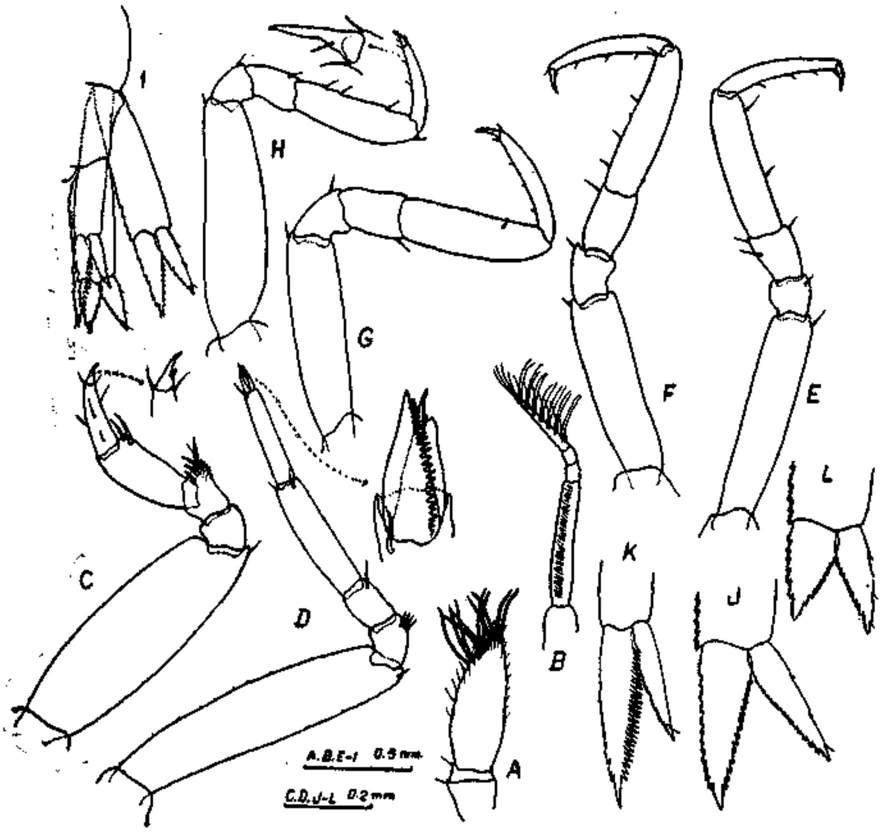

FIG. 4. *Paraphronima crassipes* Claus. (A) Antenna 1; (B) antenna 2; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson; (J–L) uropods 1-3.

Peduncle of the first uropod is nearly twice as long as the inner ramus, distal part of the inner border is serrated, both borders of the inner ramus and inner border of the outer ramus are serrated. Peduncle of the second uropod is nearly one and a half times the length of the inner ramus, outer ramus is feebly serrated, inner ramus is comparatively long, its inner border carries a few teeth and the outer border is armed with a closely packed row of sharp long teeth. Peduncle of the third uropod is stout, slightly more than twice as long as the rami, its inner border is fully serrated, both borders of the inner ramus and the inner border of the outer ramus are serrated.

Length 6·6 mm.

Hyperioides longipes Chevreux

(Fig. 5)

Hyperioides longipes Chevreux, 1900, p. 143, pl. 17, fig. 2; Stephensen, 1924, p. 94; Chevreux and Fage, 1925, p. 407, fig. 405; Schellenberg, 1927, p. 637, fig. 42; Spandl, 1927, p. 164; Pirlot, 1930, p. 19; Barnard, 1930, p. 414; Shoemaker, 1945, p. 238.

FIG. 5. *Hyperioides longipes* Chevreux. (A) Antenna 1; (B) antenna 2; (C) mandible; (D) maxilla 1; (E) maxilliped; (F) peraeopod 2; (G) peraeopod 1; (H) peraeopod 3; (I) peraeopod 4; (J) peraeopod 5; (K) peraeopod 6; (L) peraeopod 7; (M) uropods and telson.

Material (Number of specimens given in parentheses).—St. 1294, (1); St. 1710, (3); St. 1746, (1); St. 1773, (4); St. 1808, (1).

Specific characters.—The cephalon is rather deep with the eyes covering almost the whole of its surface. Peraeon segments are rather short and as broad as the first three abdominal segments. Telson is very small and semicircular.

First antenna of the female is three-segmented, third segment is long. Second antenna is three-segmented but the second partition is indistinct. Mandible is well developed, with all the parts distinct, palp is absent. First maxilla is of the usual type, its inner lobe carries five strong teeth. Second segment of the first two peraeopods is very long, longer than the rest of the limb, fifth segment of first peraeopod is internally produced into a conical lobe, that of the second peraeopod forms a hollowed long process embracing the slender sixth segment. Third and fourth peraeopods are of the same pattern, but the fourth is longer and more prominently armed. Peraeopods five to seven are similarly constructed but become progressively shorter, inner border of segments of the fifth and sixth peraeopods carries well spaced spine-setae, inner border of segments five and six of seventh peraeopod is spiny.

Peduncle of first uropod is slightly longer than that of third, outer border of outer ramus has widely spaced teeth and inner border of inner ramus very fine serrations. Inner border of outer ramus and outer border of inner ramus are closely serrated and as in *Hyperia* have a basal concavity armed with longer spines. Peduncle of the second uropod is only slightly longer than the rami, the armature of the rami is identical to that of the first. Peduncle of the third uropod is fairly stout, rami are short, outer ramus is slightly longer than the inner.

Length 3·4 mm.

Phronima sedentaria **(Forskal)**

(Fig. 6)

Phronima sedentaria Stebbing, 1888, p. 1357, pl. 162 B; Bovallius, 1889, p. 354, pl. 16, figs. 1–3; Stephensen, 1924, p. 414, figs. 50–51; Chevreux and Fage, 1925, p. 393, fig. 396; Mogk, 1927, p. 127; Schellenberg, 1927, p. 639, fig. 44; Pirlot, 1930, p. 12; Irie, 1948, p. 349, fig. 7; Hurley, 1955, p. 166, figs. 188–218.

Material (Number of specimens given in parentheses).—St. 1254, (2); St. 1278, (1); St. 1335, (1); St. 1389, (1); St. 1750, (1); St. 1750, (1); St. 1752, (1); St. 1752, (1).

Specific characters.—First antenna of female is two-segmented, distal segment is nearly four times as long as the basal and carries on its outer edge about nine to ten pairs of aesthetasks. First two peraeopods are very much similar, but the second is much longer than first, second segment of both is as long as the rest of the limb, inner distal angle of segments three and four is slightly produced and that of fifth segment is strongly produced and prominently spiny, the whole surface of segments five and six is spiny. Peraeopods three and four are of the same type, but the third is more slender than second. In the third peraeopod the inner border of segments five and six is spiny but in the fourth peraeopod the sixth segment alone is spiny. Second segment of the fifth peraeopod is nearly as long as the rest of the limb, inner distal angle of third segment is strongly produced, sixth segment is clearly longer than broad and its inner distal part is produced into a long slightly curved thumb, distal border is produced into a conspicuous conical process carrying a row of setae on its outer border, seventh segment is a long claw bulged at the middle of its inner border, the bulge carries a row of setae, the nail is very small. The sixth and seventh peraeopods again are of the same type but the second segment of the sixth pereaopod is comparatively short but in the seventh peraeopod much longer than the rest of the limb, in both peraeopods the inner distal angle of segments two and three is produced and acute, basal inner part of the fourth segment in both peraeopods is backwardly produced, dactylus is very small, apically trifid and bent at right angles in the

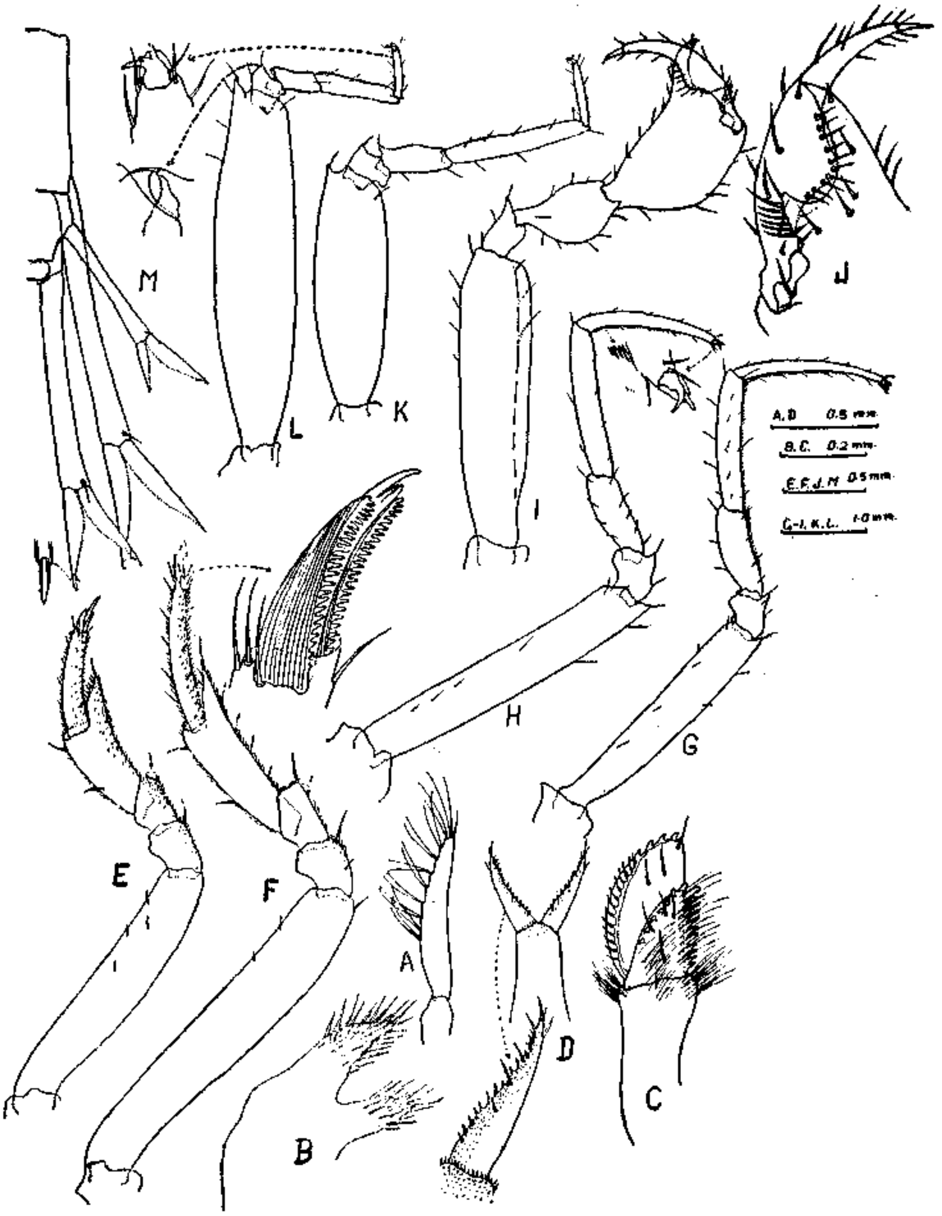

FIG. 6. *Phronima sedentaria* (Forskal). (A) Antenna 1; (B) maxilla 2; (C) maxilla 1; (D) maxilliped; (E) peraeopod 1; (F) peraeopod 2; (G) peraeopod 3; (H) peraeopod 4; (I) peraeopod 5; (J) same, chela; (K) peraeopod 6; (L) peraeopod 7; (M) uropods and telson.

uropods are long and slender, peduncle of the first uropod reaches slightly short of the tip of the peduncle of the third. Second uropod is short, its peduncle is nearly half the length of that of first. The rami of the first and third uropods are subsimilar, with smooth outer border and finely pectinate inner border. The rami of the second uropod are similarly armed but the inner ramus is smaller than the outer. Telson is transversely ovate, with the hind border bilobed.

Length 20·2 mm.

Phronima atlantica Guerin

(Fig. 7)

Phronima atlantica Voesseler, 1901, p. 21, pl. 2, figs. 1–10; Stephensen, 1924, p. 121; Chevreux and Fage, 1925, p. 395, fig. 397; Schellenberg, 1927, p. 641, fig. 45; Pirlot, 1930, p. 14.

Material (Number of specimens given in parentheses).—St. 953, (1); St. 976, (2); St. 1245, (3); St. 1245, (1); St. 1256, (1); St. 1256, (1); St. 1278, (2); St. 1278, (1); St. 1278, (1); S). 1278,$_{s}$(1); St. 1302, (1); St. 1329, (1); St. 1329, (1); St. 1333, (1); St. 1351, (2); St. 1389, (2); St. 1389, (1); St. 1411, (2); St. 1413, (1); St. 1415, (1); St. 1415, (2); St. 1415, (1); St. 1703, (1); St. 1721, (1); St. 1724, (1); St. 1730, (1); St. 1735, (1); St. 1738, (1); St. 1748, (1); St. 1749, (1); St. 1749, (1); St. 1750, (1); St. 1752, (1); St. 1775, (1); St. 1796, (1); St. 1811, (1).

Specific characters.—The first flagellar segment of the first antenna of the male is stout and profusely hirsute, this is followed by five segments, of which the third and fourth are long. Second antenna has a three-segmented peduncle. Peraeopods one and two are subsimilar, but the second is longer than first, but compared to those of *P. sedentaria* they are stout. Segments four to six are pectinate and the inner distal corner of the fifth segment is produced into a triangular spiny lobe which in the first peraeopod is larger than in the second. Second segment of third peraeopod is only slightly longer than the sixth segment, inner border of segments four to six is prominently hirsute. Fifth peraeopod is stout, inner distal corner of segments two and three is not produced, sixth

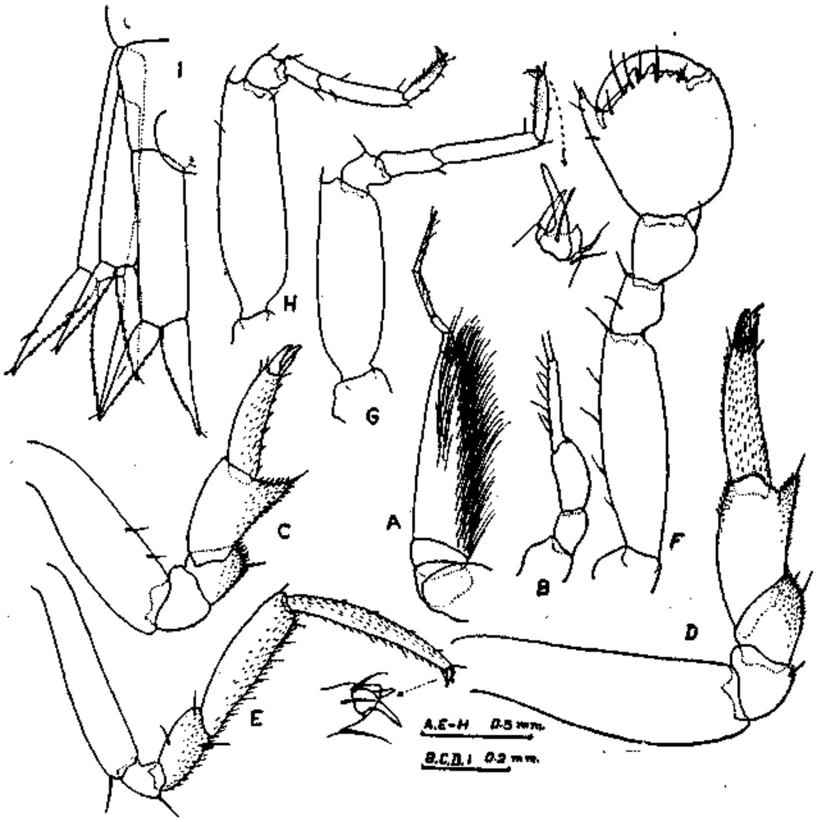

FIG. 7. *Phronima atlantica* Guerin. (A) Antenna 1; (B) antenna 2; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

segment is nearly equal in length and breadth, inner distal angle is prolonged into a prominent slightly curved thumb about a third of the length of the segment proper, distal border is produced into two apically blunt processes followed by two low triangular elevations, there are also about four submarginal long setae. The sixth and seventh peraeopods are subsimilar but show difference in the length of the second segment just as in *P. sedentaria*, inner distal corner of the second and third segments is only very slightly produced and instead of the strong basal backward prolongation, there is only a small elevation on the fourth segment, the claw is longer than in *P. sedentaria* and there is a strong spine originating from the inner distal angle of the sixth segment.

Peduncle of the first uropod is the longest, about one and one-fourth times the length of that of the third, the latter is broadest and subequal to that of the second in length, the rami of all the uropods are subsimilar, the inner ramus being slightly longer than the outer, inner border of all the rami is serrate and the outer border smooth. Telson is nearly circular and deeply immersed in the abdomen.

Length 9·0 mm.

Phronimella elongata Claus

(Fig. 8)

Phronimella elongata Stebbing, 1888, p. 1370, pl. 163; Bovallius, 1889, p. 389, pl. 16, figs. 52–67; Stephensen, 1924, p. 130; Chevreux and Fage, 1925, p. 399, fig. 400; Mogk, 1927, p. 141; Pirlot, 1930, p. 15; Shoemaker, 1945, p. 236; Irie, 1948, p. 349, fig. 10.

Material (Number of specimens given in parentheses).—St. 743, (2); St. 1245, (1); St. 1254, (2); St. 1256, (2); St. 1256, (1); St. 1258, (3); St. 1278, (13); St. 1278, (2); St. 1278, (8); St. 1278, (2); St. 1278, (1); St. 1310, (1); St. 1356, (2); St. 1373, (1); St. 1727, (1); St. 1735, (1); St. 1739, (1); St. 1749, (2); St. 1749, (1); St. 1750, (1); St. 1750, (2).

Specific characters.—The body is long and slender with long slender peraeopods. First segment of the flagellum of the first antenna of the male is enlarged and hirsute, distally produced below the next segment. Second antenna has a three-segmented peduncle and long multisegmented flagellum. Peraeopods one and two are of the same type, but the second is longer, fifth segment is conically produced at the inner distal angle, slightly more produced in the second peraeopod than in the first, sixth segment is spiny and the seventh is fairly long. Third and fourth peraeopods are very long and slender, the former longer than the latter. Second segment of the third peraeopod carries two teeth along its inner border and the third peraeopod carries four teeth, inner distal angle of the third segment of the fourth peraeopod is slightly produced. Fifth peraeopod is stout, its second segment carries five inner and three outer teeth, third segment has one inner tooth, fourth has two inner teeth, fifth segment broadens distalwards, its inner and distal borders carry a row of eight sharp teeth steadily increasing in length up to the fifth, last two teeth are small, seventh segment is fairly long and reaches two-thirds the length of the fifth segment when folded backwards. As in *Phronima* the sixth and seventh peraeopods differ only in the proportionate length of the second segment in comparison with the rest of the limb, the distal inner corner of the second and third segments is sharply produced.

Peduncle of the first uropod is slightly longer than that of the third but narrower, rami are subequal in length and finely pectinate along both borders. Second uropod is reduced to a one-segmented lamina.

In the female the first antenna is a two-segmented short appendage. The fifth segment of the fifth peraeopod is more slender and elongated than in the male and carries ten to eleven teeth. The teeth arming the fifth peraeopod are obviously subject to considerable variation. Outer borders of the rami of the first and third uropods are smooth. Second uropod is still more reduced in size than in the male.

Length 10·7 mm.

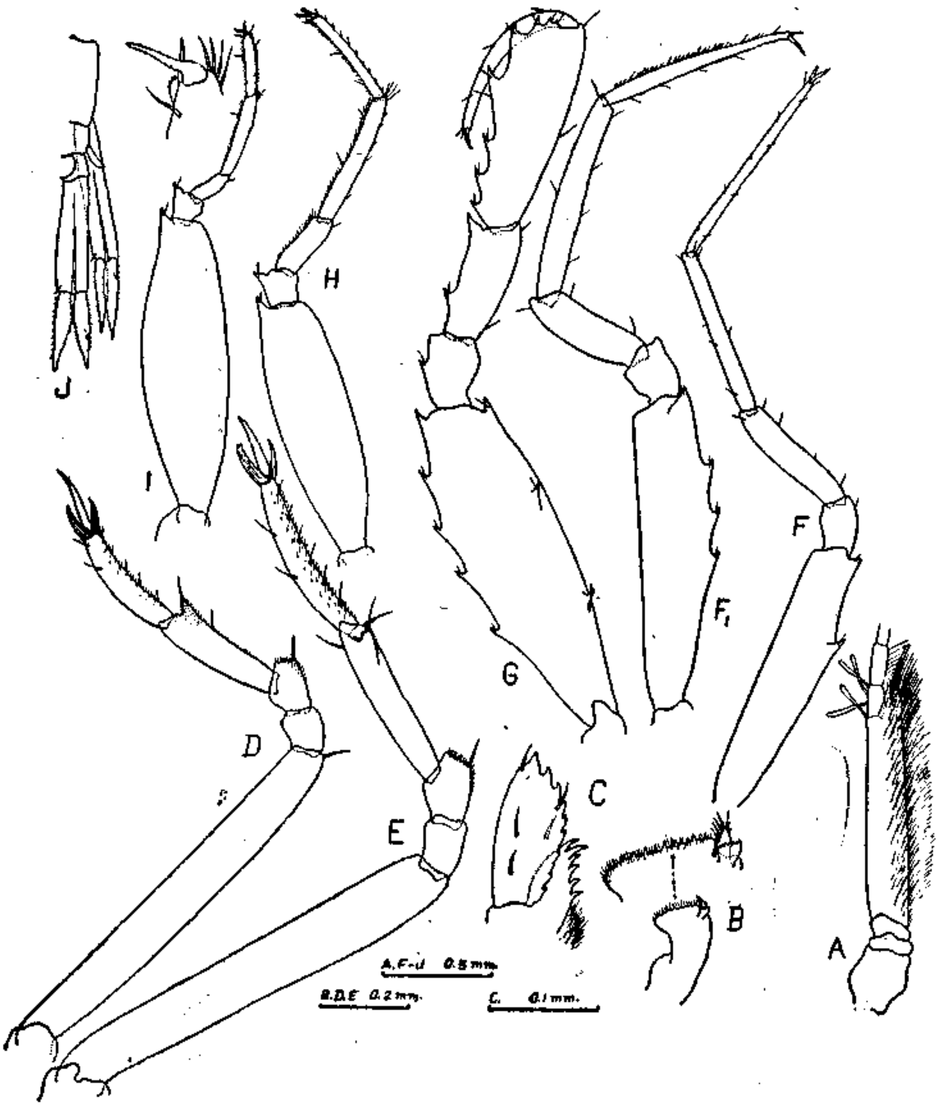

FIG. 8. *Phronimella elongata* Claus. (A) Antenna 1; (B) mandible; (C) maxilla 1; (D) peraeopod 1; (E) peraeopod 2; (F) peraeopod 3; (F_1) peraeopod 4; (G) peraeopod 5; (H) peraeopod 6; (I) peraeopod 7; (J) uropods and telson.

Primno macropa Guerin

(Fig. 9)

Euprimno macropus Bovallius, 1889, p. 400, pl. 17, figs. 23–40, pl. 18, figs. 1–2; Chevreux and Fage, 1925, p. 416, fig. 411; Schellenberg, 1927, p. 643, fig. 46.

Primno macropa Barnard, 1930, p. 424; Hurley, 1955, p. 172, figs. 219–235.

Material (Number of specimens given in parentheses).—St. 941 (1); St. 1045, (1); St. 1245 (1); St. 1329, (1); St. 1337 (2); St. 1373, (1); St. 1375 (1); St. 1395, (1); St. 1413, (1); St. 1719, (1); St. 1721, (1); St. 1723, (1); St. 1725, (1); St. 1727, (1); St. 1732, (1).

Specific characters.—First antenna of male is three-segmented, first two segments are stout and the third is small. First peraeopod is very slender and non-chelate, sixth segment carries along its outer border stiff hairs, seventh segment is likewise hairy and bifid. Second peraeopod is non-chelate, its second segment is comparatively stout. Third and fourth peraeopods are slender and identical, inner border of fourth segment is cut into four teeth, segments four to seven carry stiff spinules especially on the inner surface. Fifth peraeopod is massive, dorsal distal part of its second segment is expanded and cut into three broad teeth with finely serrated border, fourth segment is transversely broadened, fifth segment is very stout and oblong, its inner border is produced into a row of about eleven strong teeth of which the first, third, seventh and ninth are longer than the others, each tooth carries a subapical spinule, sixth segment is covered with very small spinules, seventh segment has a curved tip and reaches the base of the fifth segment when closed. Second segment of the sixth peraeopod is rather broadened and its dorsal distal border is cut into four broad teeth with pectinate border, fourth and fifth segments are fairly broad and spiny along the inner border, seventh segment is fairly long. Seventh peraeopod is modified but all the segments are present, second segment is enlarged and flattened, seventh segment carries a few spinules.

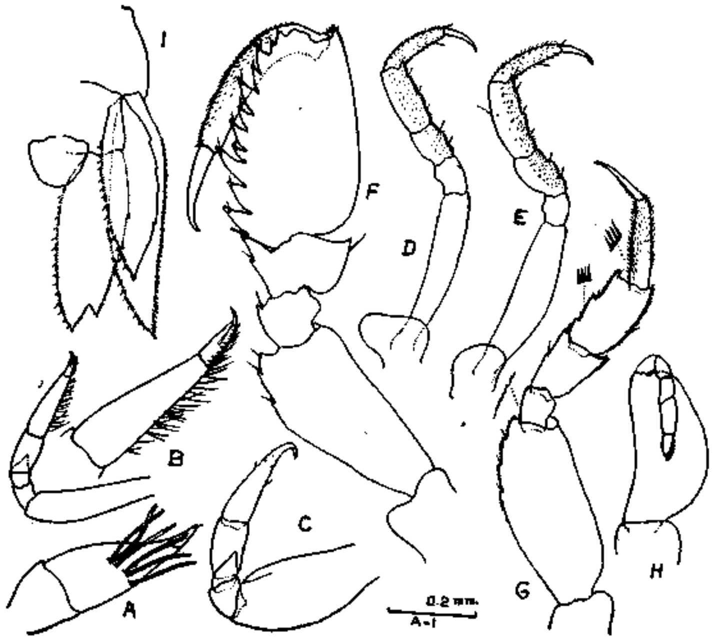

FIG. 9. *Primno macropa* Guerin. (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 3; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

Telson is semicircular and slightly immersed in the urosome. Uropods are simple uniramous lamellae not demarcated into peduncle and rami. First uropod slightly overreaches the tip of the third, its outer border is finely serrate and the inner border pectinate. Second uropod is the narrowest and is as long as the third, its inner border is pectinate and the outer border has four teeth. Third uropod is the broadest and has a subapical outer pointed process, outer border of the second and third uropods is lobed.

Length 2·3 mm.

Remarks.—The specimen described above is not fully adult and this obviously accounts for the slight difference in the armature of the fifth segment of the fifth peraeopod and of the shape of the seventh peraeopod and the uropods. Adults do not show any important differences from previous records.

Anchylomera blossevillei M. Edwards

(Fig. 10)

Anchylomera blossevillei Stebbing, 1888, p. 1453, pl. 177; Chevreux and Fage, 1925, p. 414, fig. 410; Spandl, 1927, p. 167, fig. 7; Barnard, 1930, p. 425; Pirlot, 1930, p. 21; Irie, 1948, p. 353, fig. 18.

Material (Number of specimens given in parentheses).—St. 941, (1); St. 1241, (2); St. 1256, (1); St. 1278, (8); St. 1278, (11); St. 1278, (2); St. 1278, (7); St. 1278, (59); St. 1278, (1); St. 1285, (4); St. 1290, (7); St. 1290, (21); St. 1292, (7); St. 1294, (4); St. 1298, (1); St. 1300, (1); St. 1329, (1); St. 1337, (2); St. 1337, (1); St. 1351, (1); St. 1370, (1); St. 1389, (1); St. 1389, (1); St. 1395, (1); St. 1397, (1); St. 1415, (3); St. 1415, (3); St. 1415, (18); St. 1721, (1); St. 1738, (2); St. 1746, (1);] St. 1747, (3); St. 1752, (1); St. 1762, (1).

Specific characters.—The third segment of the first antenna of the male is distally produced. The first peraeopod is comparatively stout, segments five to seven are covered with fine setules producing a hispid appearance, the seventh segment is short. Second peraeopod is longer than first but is distally more slender, its seventh segment is drawn out into a long slender claw. Peraeopods three and four are very much similar except that in the third, the inner distal prolongation of the fifth segment is less pronounced than that of the fourth peraeopod. Segments five to seven of both third and fourth peraeopods are covered with microscopic stiff setules. Fifth peraeopod is very character-

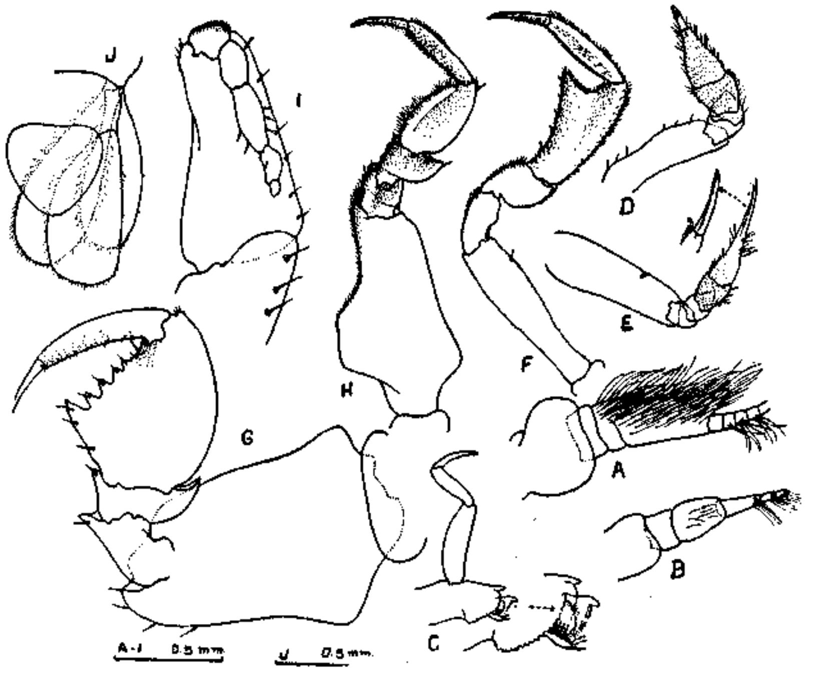

FIG. 10. *Anchylomera blossevillei* M. Edwards. (A) Antenna 1; (B) antenna 2; (C) mandible; (E) peraeopod 1; (E) peraeopod 2; (F) peraeopod 4; (G) peraeopod 5; (H) peraeopod 6; (I) peraeopod 7; (J) uropods and telson.

istic, the second segment is expanded and proximally produced on both sides so that the length of the segment is only slightly more than its maximum width, third segment is produced at the inner distal part and the fourth segment is produced at the outer distal part, the fifth segment is massive and nearly as long as broad, its obliquely truncate distal border is cut into six to seven large rounded cusps, each carrying a spine-seta, the first cusp is large, sixth segment is slender and covered with fine setules, the claw is short. Second segment of the sixth peraeopod is expanded beyond its base and its inner border has a matting of fine stiff setules, segments three to five are flattened and comparatively broad and nearly completely covered with setules, sixth and seventh segments are slender, but like the previous segments, are covered with setules. All the usual number of segments are present in the seventh peraeopod, the second segment is flattened and narrows distalwards, succeeding segments are folded backwards, seventh segment is very small. Uropods are flat uniramous laminae with finely setose border. Telson is large and roughly equal in length and width.

Length 6·4 mm.

Remarks.—The description given by Bovallius clearly applies to the present specimens except in minor details. The inner distal projection of the fifth segment of peraeopods one and two is slightly different in shape, with a pronounced concavity on the distal border. The fifth segment of the sixth peraeopod is longer. The telson is more rounded in my specimens. In the last character the present specimens resemble those which Bovallius described as *A. hunteri* M. Edwards.

Phrosina semilunata **Risso**

(Fig. 11)

Phrosina semilunata Stebbing, 1888, p. 1424, pl. 176; Bovallius, 1889, p. 426, pl. 18, figs. 3–30; Chevreux and Fage, 1925, p. 143, fig. 409; Schellenberg, 1927, p. 644, fig. 47; Spandl, 1927, p. 168, figs. 60–61; Pirlot, 1930, p. 23; Barnard, 1930, p. 424; Irie, 1948, p. 353, fig. 17.

Material (Number of specimens given in parentheses).—St. 742, (1); St. 960, (1); St. 1044, (1); St. 1157, (1); St. 1245, (4); St. 1254, (1); St. 1256, (1); St. 1265, (3); St. 1278, (2); St. 1278, (1); St. 1298, (1); St. 1300, (2); St. 1329, (2); St. 1329, (1); St. 1333, (4); St. 1335, (1); St. 1337, (3); St. 1349, (1); St. 1351, (1); St. 1385, (1); St. 1373, (2); St. 1375, (1); St. 1377, (1); St. 1383, (5); St. 1385, (4); St. 1385, (1); St. 1385, (2); St. 1385, (4); St. 1385, (3); St. 1393, (1); St. 1393, (3); St. 1395, (1); St. 1411, (4); St. 1411, (1); St. 1413, (1); St. 1413, (4), St. 1415, (2); St. 1415, (1); St. 1691, (1); St.1704, (1); St. 1736, (4); St. 1739 (2); St. 1749, (1); St. 1752, (1); St. 1752, (1).

Specific characters.—In the male the head is antero-dorsally produced into a pair of apically acute horns overhanging the first pair of antennae. Eyes nearly completely occupy the sides of the head. Peraeon is deep and swollen and the abdomen is dorsally carinate.

First antenna of the female consists of a short basal segment and a long distal segment. First two peraeopods are constructed on the same pattern, but the first is smaller than the second, the lower border of the third and fourth segments carries long hairs, the succeeding segments are spiny. In the second peraeopod the fourth segment alone is hairy and the succeeding segments are not spiny. The third and fourth peraeopods are of the same type, but the fourth is stouter, borders of all the segments carry long spines mixed with spinules, the fifth segment is expanded and distally cut into a row of teeth, the first tooth is very long and the sixth folds against this tooth to form a subchela. Fifth peraeopod is comparatively very large, second segment is expanded and serrated along the border, third segment is triangular and produced at the distal corners, its dorsal side is channelled with the distal ends of the two ridges produced into strong processes, fourth segment is drawn out at its upper distal part, fifth segment is as long as the two previous segments combined and is distally drawn out into a strong spine, its lower border is cut into six teeth of which the

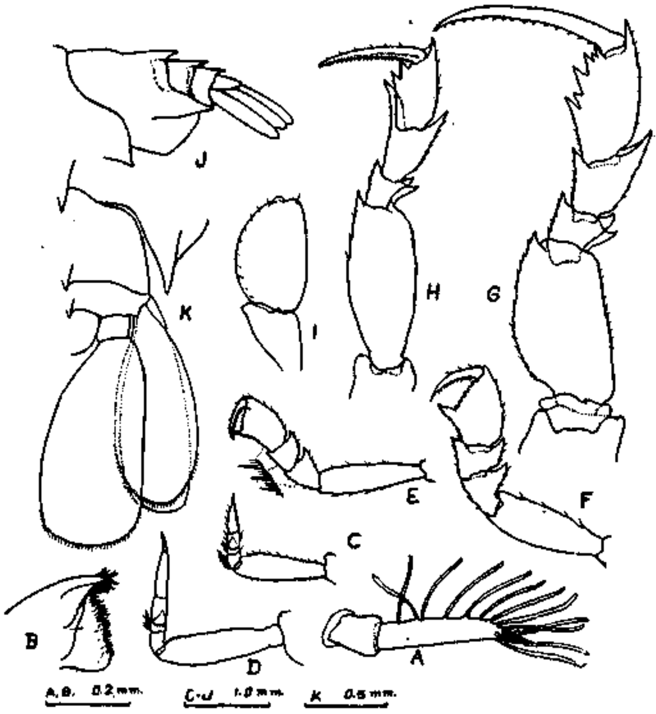

FIG. 11. *Phrosina semilunata* Risso. (A) Antenna 1; (B) mandible; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 3; (F) peraeopod 4; (G) peraeopod 5; (H) peraeopod 6; (I) peraeopod 7; (J) abdomen, pleopods and telson, lateral view; (K) same, dorsal view.

second, fifth and sixth are short, seventh segment is very long and only slightly shorter than the combined length of segments three to six. Sixth peraeopod is similar to the fifth in construction but its fifth segment is smaller and has only three teeth on the inner side, the inner distal angle of the fourth segment is produced below the fifth into a long process, sixth segment is stout. Seventh peraeopod is modified into a one-segmented small lamina carrying a small distal lobe. Uropods are uniramous membranous laminae with finely setose border, the third uropod is much longer than the first two which are subequal in size. Telson is semicircular and sunk into the abdomen.

Length 8·6 mm.

Eupronoe armata Claus

(Fig. 12)

Eupronoe intermedia Stebbing, 1888, p. 1517, pl. 188; Spandl, 1927, p. 222.

Eupronoe armata Stephensen, 1925, p. 159; Spandl, 1927, p. 224, fig. 42; Barnard, 1930, p. 427.

Material (Number of specimens given in parentheses).—St. 749, (1); St. 977, (1); St. 1032, (1); St. 1044, (1); St. 1045, (3); St. 1164, (2); St. 1233, (1); St. 1241, (1); St. 1245; (1); St. 1258, (1); St. 1278, (1); St. 1278, (2); St. 1278, (1); St. 1278, (3); St. 1285, (2); St. 1294, (4); St. 1298, (6); St. 1300, (2); St. 1306, (3); St. 1310, (3); St. 1312, (1); St. 1329, (2); St. 1329, (1); St. 1329, (1); St. 1335, (1); St. 1344, (1); St. 1351, (1); St. 1375, (2); St. 1397, (3); St. 1397, (1); St. 1404, (1);

St. 1411, (4); St. 1691, (7); St. 1711, (1); St. 1719, (3); St. 1720, (8); St. 1721, (2); St. 1721, (5); St. 1721, (6); St. 1722, (4); St. 1723, (5); St. 1724, (4); St. 1725, (3); St. 1727, (5); St. 1732, (25); St. 1736, (1); St. 1737, (4); St. 1737, (2); St. 1737, (1); St. 1737, (12); St. 1737, (2); St. 1737, (1); St. 1738, (2); St. 1738, (5); St. 1747, (2); St. 1749, (3); St. 1749, (1); St. 1750, (1); St. 1750, (6); St. 1752, (1); St. 1761, (1); St. 1762, (2); St. 1763, (2); St. 1807, (1); St. 1809, (2).

Specific characters.—First antenna of the male is comparatively stout, first segment of the flagellum is distally swollen and the rest of the flagellum is therefore shifted to the lower distal part. Second segment of the first peraeopod is rather thin and characteristically twisted, third segment is small, fourth and fifth segments are highly flattened with their inner border closely serrated, sixth segment has its inner border sparsely serrated, seventh segment is long and slender. Second peraeopod is quite different from the first, its fourth segment is exactly like that of the first peraeopod but the inner distal part of the fifth segment is produced into a large conical process with serrate border almost reaching the tip of the sixth segment, sixth and seventh segments resemble those of the first peraeopod. Third and fourth peraeopods are subsimilar, with short second segment, inner border of segments four to six is minutely spiny. Second segment of fifth peraeopod is oblong, with a few broad serrations along the upper distal part of its border, inner border of segments four to six is spiny. Second segment of sixth peraeopod is highly expanded, its dorsal border is nearly straight and the dorsal distal part is expanded and cut into broad teeth and overhangs the third segment, segments four to six have their inner border armed with prominent spines and the distal inner part of the fourth and fifth segments is produced forwards into a large apically rounded, internally spiny lobe. Seventh peraeopod is reduced to a two-segmented lamina, its distal segment is very small, inner border of both segments is spiny.

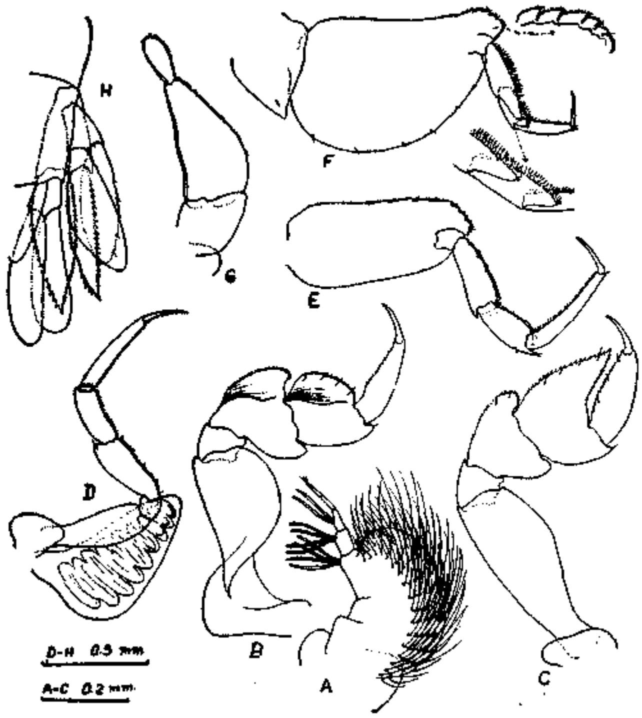

FIG. 12. *Eupronoe armata* Claus. (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson.

Telson is triangular, with blunt apex. Peduncle of the first uropod is only about half the length of the inner ramus, rami are nearly subequal in length, with serrate borders, inner ramus is nearly twice as broad as the outer. Second uropod has a very short peduncle, rami are laminate and elliptic, inner ramus is broader than the outer, outer border of outer ramus has about five setae. Third uropod is sub-similar to the second, with short peduncle and laminate rami, the rami increase in width distalwards and their outer border is characteristically concave. All the uropods overreach the telson.

Length 7·4 mm.

Remarks.—According to Barnard (1930) *E. intermedia* Stebbing is synonymous with *E. armata* Claus. The present specimens are in perfect agreement with those described by Stebbing.

Lycaeopsis zamboangae (Stebbing)

(Figs. 13, 13 *a*)

Phorcorhaphis zamboangae Stebbing, 1888, p. 1452, pl. 180; Chevreux, 1900, p. 148, pl. 8, fig. 1.

Lycaeopsis zamboangae Spandl, 1927, p. 213; Pirlot, 1930, p. 28.

Material (Number of specimens given in parentheses).—St. 1046, (1); St. 1278, (1); St. 1298, (1); St. 1312, (1); St. 1351, (1); St. 1353, (1); St. 1383, (1); St. 1393, (1); St. 1407, (1); St. 1413, (1); St. 1710, (1); St. 1721, (1); St. 1750, (1).

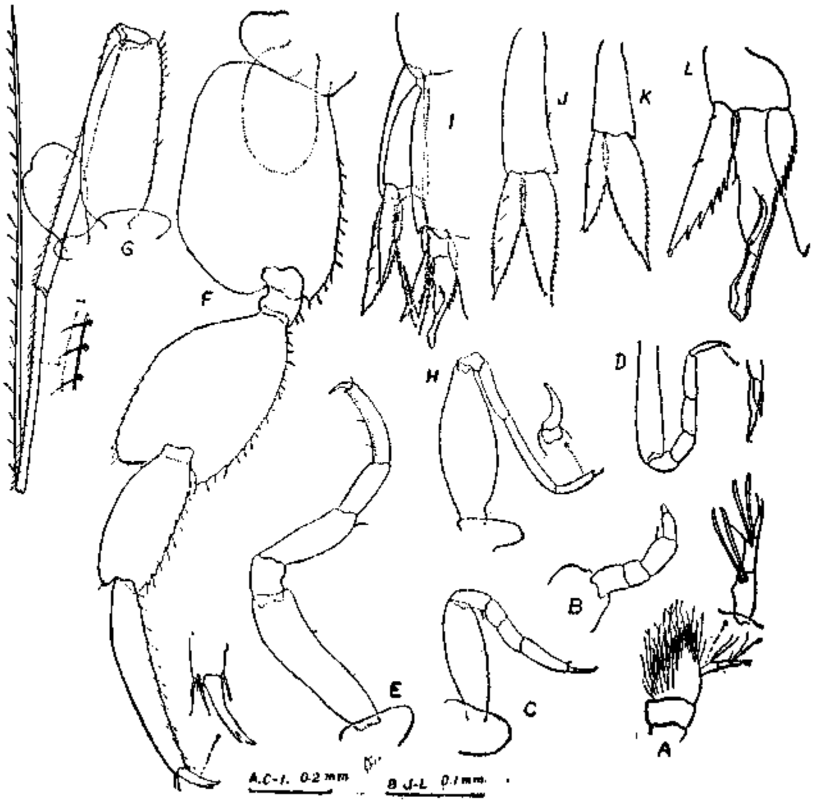

FIG. 13. *Lycaeopsis zamboangae* (Stebbing). (A) Antenna 1; (B) antenna 2; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 6; (G) peraeopod 5; (H) peraeopod 7; (I) uropods and telson; (J-L) uropods 1-3.

Specific characters.—First antenna of the male has the basal segment of the flagellum conically produced and hirsute, the rest of the flagellum originates far below the apex of the first segment. Second antenna is five-segmented, third segment carries a seta, fifth segment is very small. Peraeopods one and two are very slender and non-chelate, second segment of first peraeopod is broader than that of second. Third and fourth peraeopods are rather stout, sixth segment has an inner row of microscopic setules. Fifth peraeopod is very characteristic, its second segment is elongate oblong with a row of short stiff setae along the upper border, segments four and five are slender and very long, with fine setules along the outer border, fifth segment is only two-thirds as long as the fourth, sixth segment is longer than the two previous segments combined and is armed with scattered setae. Sixth peraeopod is also very characteristic, its second segment is very much flattened, fourth segment is flattened like the second but narrower, its ventral border is feebly serrate, upper border of sixth segment is prominently but sparsely serrate, sixth segment is armed like the fifth but slender and long, seventh segment is apically cleft. Seventh peraeopod is complete but reduced in size, second segment is fairly broad, but the succeeding segments are slender, together exceeding the length of the second segment.

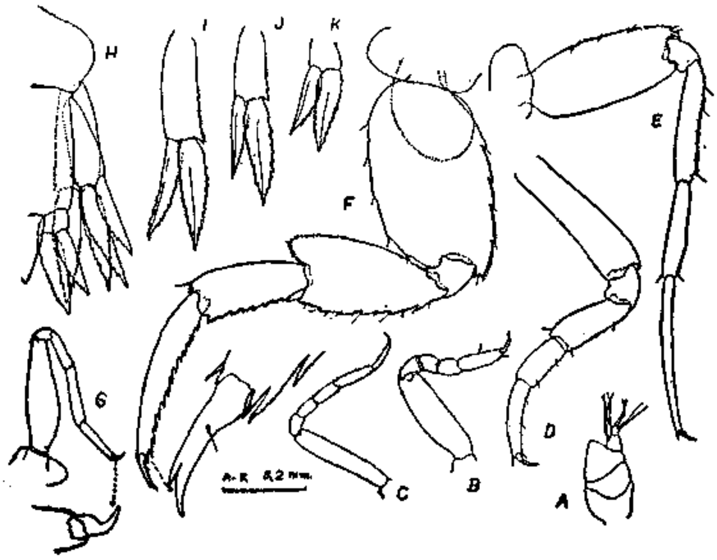

FIG. 13 *a*. *Lycaeopsis zamboangae* (Stebbing). Immature male. (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson; (I-K) uropods 1-3.

First uropod slightly overreaches the tip of the telson, its peduncle is slightly longer than the rami, latter have serrate border. Peduncle of the second uropod is shorter than the inner ramus, borders of inner ramus are serrate, outer ramus is comparatively small, its outer border is smooth. Third uropod is modified and considerably overreaches the telson. Peduncle is short but broad, outer ramus is prominently serrate along the inner border, inner ramus has its outer border smooth and part of the inner border serrate, distal part is bifid, outer lobe is blunt and ovate and the inner is prolonged into a long rod with slightly swollen tip.

Length 2·5 mm.

Remarks.—Pirlot has described in detail the variations within this species due to difference in age and sex. Judging from his illustrations all the specimens in the present collection are males. There are a few immature specimens which appear to resemble the juveniles described by Pirlot.

These specimens show conspicuous difference particularly in the shape of peraeopods five to seven and uropod three. I have illustrated a juvenile to emphasise these differences.

Lycaea pulex Marion

(Fig. 14)

Lycaea pulex Stebbing, 1888, p. 1567; Chevreux, 1900, p. 156; Chevreux and Fage, 1925, p. 429, fig. 419; Pirlot, 1930, p. 24; Shoemaker, 1945, p. 243.

Material.—(Number of specimens given in parentheses).—St. 953, (1); St. 1029, (1); St. 1278, (1); St. 1379, (1); St. 1379, (2); St. 1721, (1); St. 1722, (1); St. 1725, (4); St. 1736, (1); St. 1750, (1); St. 1807, (5); St. 1808, (1); St. 1808, (2); St. 1809, (2).

Specific characters.—Peraeopods one and two are subsimilar but the second is slightly more slender than the first and longer. Second segment of the first peraeopod is more swollen than that of the second and the inner part of the fifth segment is indistinctly spiny. Second segment of second peraeopod is somewhat cylindrical and the fifth segment only very indistinctly spiny, seventh segment of both peraeopods is slender and claw-like. Second segment of third and fourth peraeopods is narrow and long, hardly broader than the fourth segment. Second segment of fifth and sixth peraeopods is enlarged, that of fifth is longer but narrower than that of sixth, inner border of segments three to six of sixth peraeopod is prominently spiny. Seventh peraeopod is modified, with large flattened second segment, rest of the limb is comparatively very small, seventh segment has a basal inner spine-like process, the distal part is drawn out and spiny.

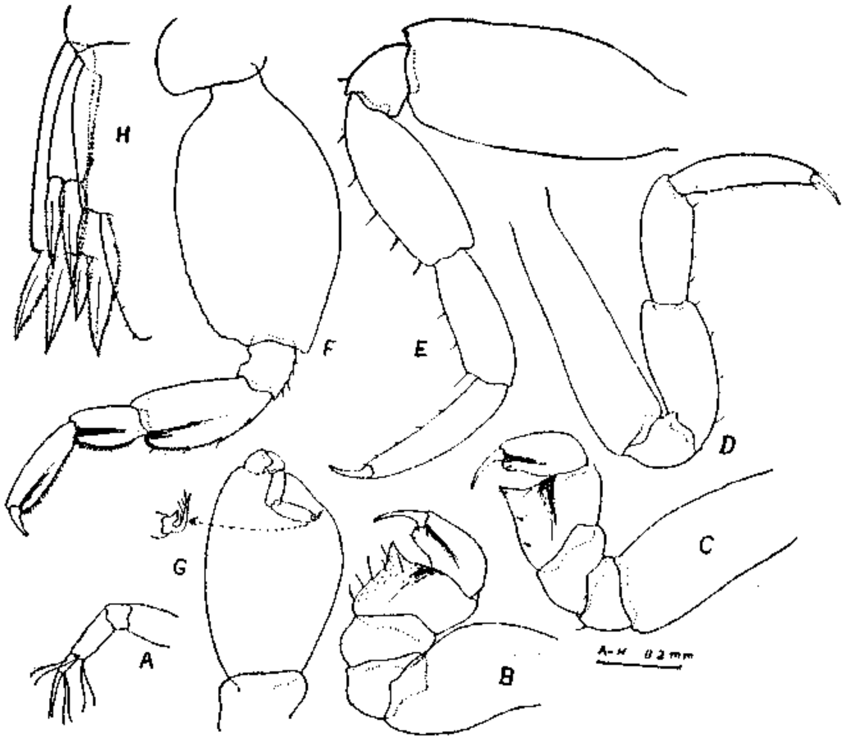

FIG. 14. *Lycaea pulex* Marion. (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson.

Telson is linguiform and only slightly shorter than the last urosome segment. Peduncle of the first uropod is long and stout, reaching the distal border of the peduncle of the third uropod, distal part of both borders is serrated, rami are short, nearly a third of the length of the peduncle, with serrate borders, and reaching the tip of the inner ramus of the third uropod. Peduncle of the second uropod stops short of the base of the peduncle of the third uropod, its inner border is serrated, inner ramus is longer than other, outer border of outer ramus is smooth. Peduncle of the third uropod is fused with the inner ramus, latter overreaches the telson, outer ramus is shorter and narrower than the inner ramus, latter is nearly straight and overreaches the telson.

Length 4 mm.

Brachyscelus crusculum **Spence Bate**

(Fig. 15)

Brachyscelus crusculum Stebbing, 1888, p. 1544, pl. 195 and 196; Chevreux and Fage, 1925, p. 427, fig. 418; Stephensen, 1925, p. 172; Schellenberg, 1927, p. 649, fig. 49; Spandl, 1927, p. 210; Pirlot, 1930, p. 25; Irie, 1948, p. 355, fig. 23.

Material (Number of specimens given in parentheses).—St. 745, (6); St. 941, (2); St. 945, (2); St. 976, (1); St. 977, (1); St. 1029, (1); St. 1032, (1); St. 1044, (1); St. 1118, (1); St. 1256, (1); St. 1292, (2); St. 1310, (1); St. 1329, (1); St. 1329, (4); St. 1329, (1); St. 1335, (2); St. 1353, (2); St. 1383, (1); St. 1385, (1); St. 1413, (1); St. 1415, (1); St. 1711, (1); St. 1719, (3); St. 1720, (1); St. 1721, (1); St. 1722, (1); St. 1723, (6); St. 1738, (7); St. 1739, (1); St. 1739, (1); St. 1748, (1); St. 1752, (1); St. 1752, (1); St. 1779, (3); St. 1805, (1).

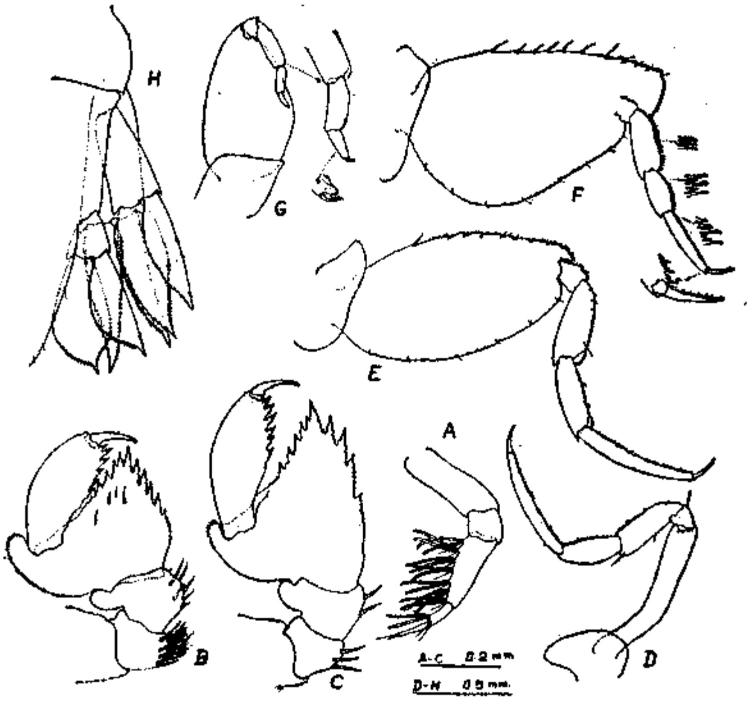

FIG. 15. ***Brachyscelus crusculum*** **Spence Bate.** **(A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson.**

Specific characters.—First two peraeopods are subsimilar, but the second is slightly longer and stouter. In the first peraeopod the inner distal part of the third segment has a bunch of stiff spine-setae but in the second there are only three setae. Likewise the fourth segment of the first peraeopod has a large number of setae. The fifth segment in both peraeopods is highly flattened and the outer distal part forms a large rounded lobe with serrate border, reaching beyond the base of the sixth segment, this lobe is more conspicuous in the second leg, sixth and seventh segments are similar in both peraeopods. Legs three and four are slender, with the inner border of the sixth segment serrated. Second segment of fifth peraeopod is elongate-ovate with its upper border cut into a series of broad teeth with pectinate margin, segments three to six have finely serrate inner border. Second segment of sixth peraeopod is broader than that of fifth and carries a row of spine-setae along the upper border, distal part is expanded into a thin lobe with broad teeth, inner border of segments four to six is strongly spiny. Second segment of seventh peraeopod is longer than broad, other segments are small.

Telson is as long as the urosome and elongate triangular, with blunt apex. Peduncle of the first uropod is shorter than the rami and reaches the base of the third uropod, outer ramus is slightly shorter and narrower than the inner and its outer border is smooth. Second uropod is similar to the first in construction but the rami are broader. Peduncle of the third uropod is very short, roughly equal in length and width, outer border of outer ramus is smooth and distal half of inner border is serrate, inner ramus is broader than the outer and the distal half of its borders is serrated, both rami are highly flattened.

Length 7·3 mm.

Euthamneus platyrhynchus **(Stebbing)**

(Fig. 16)

Thamneus platyrhynchus Stebbing, 1888, p. 1558, pl. 198; Schellenberg, 1927, p. 650, fig. 50.

Euthamneus recurvirostris Chevreux, 1900, p. 154, pl. 18, fig. 2.

Euthamneus platyrhynchus, Spandl, 1927, p. 210.

Material.—St. 1721, 2 females.

Specific characters.—Body is somewhat dorso-ventrally flattened, cephalon is comparatively small, with large lateral eyes, peraeon is nearly oval.

Second segment of first peraeopod is longer than the rest of the limb, its dorsal border carries a row of short setae, outer distal part of third and fourth segments carries several long stiff setae, fifth segment is expanded and its inner distal conical part is armed with five marginal spine-like prolongations, inner border of sixth segment has two teeth, seventh segment has two obsolete teeth on the inner border. In overall shape the second peraeopod is similar to the first but its second segment is comparatively short and the inner distal prolongation of the fifth segment has only five teeth, sixth segment has three to four teeth along the inner margin. Third and fourth peraeopods are subsimilar, second segment is as long as the combined length of the next three segments, fourth and fifth segments are prominently hirsute, sixth segment is as long as fifth, seventh is short. Second segment of fifth peraeopod is flattened and roughly oblong, with a dorsal marginal row of setae, fourth, fifth and sixth segments are prominently hirsute. Sixth peraeopod is very much similar to the fifth but the inner border of the fifth and sixth segments is denticulate, seventh segment has six blunt inner teeth. Seventh peraeopod is modified, second segment is roughly elliptic, with four dorsal setae, all the succeeding segments are present but small, seventh segment is a small curved claw, the inner distal angle of the sixth segment is produced into three blunt teeth working against the seventh segment.

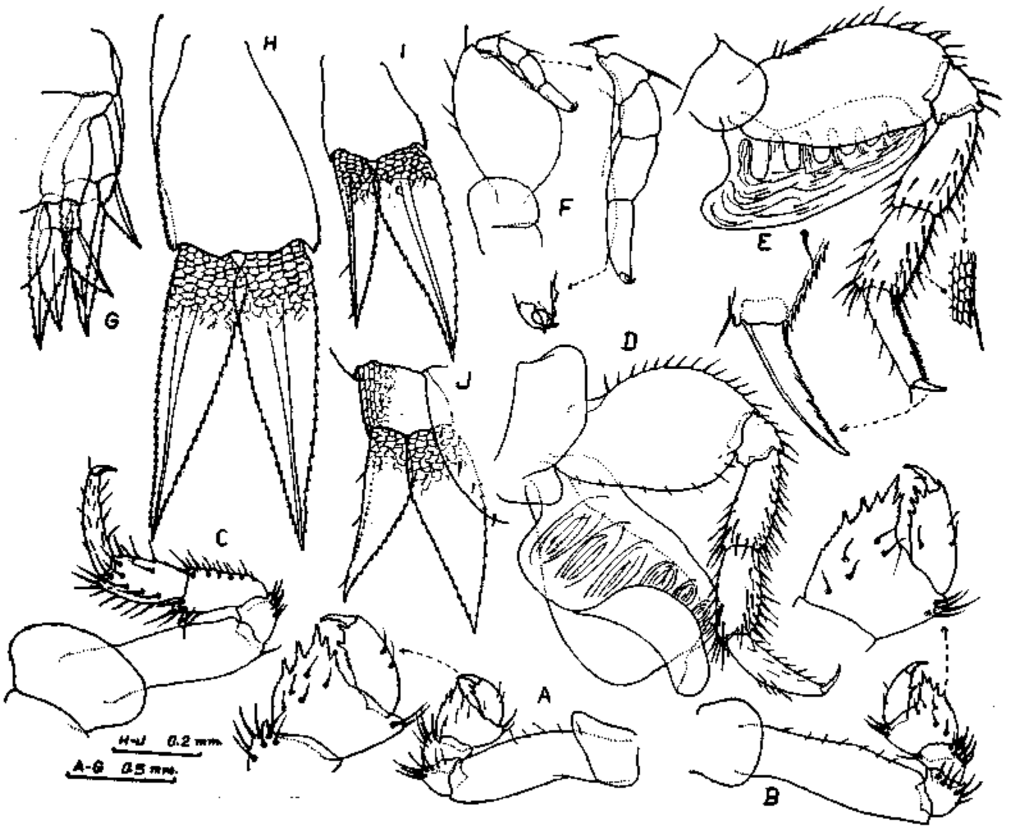

FIG. 16. *Euthamneus platyrhynchus* (Stebbing). (A) Peraeopod 1; (B) peraeopod 2; (C) peraeopod 4, (D) peraeopod 5; (E) peraeopod 6; (F) peraeopod 7; (G) uropods and telson; (H-J) uropods 1-3.

Peduncle of all the uropods is short but broad, rami of the first uropod are subsimilar with the endopod slightly longer, borders are serrate, outer border of the peduncle is also serrated. Outer ramus of the second uropod is much smaller than the inner, both borders of both rami are serrate. Third uropod is subsimilar to the second, but its peduncle is very short. Telson is roughly semicircular.

Length 8·1 mm.

Remarks.—The present collection includes only two females, both badly preserved. They show a few conspicuous differences from the description given by Stebbing. The most important among these is the prominently hirsute nature of the peraeopods. So also the surface of the appendages shows hexagonal markings. Probably these specimens will have to be assigned to a new species but I think it is more prudent to wait till additional material becomes available.

As observed by Spandl (1927) and Schellenberg (1927) *E. recurvirostris* Chevreux, (1900) is the same as *E. platyrhynchus.*

***Parascelus typhoides* Claus**

(Fig. 17)

Parascelus typhoides Chevreux and Fage, 1925, p. 424, fig. 416; Spandl, 1927, p. 262, fig. 55; Shoemaker, 1945, p. 260; Irie, 1948, p. 354, fig. 21; Hurley, 1955, p. 183, figs. 252–271.

Material (Number of specimens given in parentheses).—St. 745, (1); St. 748, (3); St. 960, (3); St. 1032, (3); St. 1045, (1); St. 1046, (3); St. 1118, (1); St. 1157, (3); St. 1161, (5); St. 1164, (5); St. 1167, (1); St. 1278, (2); St. 1278, (3); St. 1278, (3); St. 1278, (10); St. 1278, (2); St. 1351, (1); St. 1377, (3); St. 1385, (1); St. 1397, (2); St. 1399, (1); St. 1413, (1); St. 1413, (1); St. 1415, (1); St. 1415, (1); St. 1415, (5); St. 1704, (2); St. 1710, (1); St. 1721, (5); St. 1721, (4); St. 1722, (1); St. 1736, (1); St. 1737, (6); St. 1737, (6); St. 1737, (11); St. 1738, (6); St. 1738, (3); St. 1739, (1); St. 1746, (1); St. 1749, (4); St. 1752, (7); St. 1761, (1); St. 1763, (3); St. 1766 (1); St. 1773, (3); St. 1773, (1); St. 1775, (1); St. 1801, (3); St. 1802, (3); St. 1802, (4); St. 1802, (1); St. 1808, (5); St. 1808, (3); St. 1809, (3); St. 1811, (4).

Specific characters.—First antenna of female is comparatively stout and six-segmented. Second segment of first peraeopod is as long as or even slightly longer than the rest of the limb, succeeding segments are short and carry long setae. Second peraeopod is similar to the first but its second segment is more slender and longer and the succeeding segments carry a large number of setae. Third and fourth peraeopods are very long, with scattered long setae. Second segment of fifth peraeopod is expanded and oblong, with hairy border, succeeding part of the limb is reduced in size but longer than the second segment. Sixth peraeopod is highly modified, its second segment forms a very broad, irregularly shaped elytra with a few scattered marginal setae, succeeding part of the limb is considerably reduced in size and displaced to the ventral side of the second segment, third segment is small, fourth is comparatively stout and its inner border is serrated and with two setae, fifth segment is also armed along the inner border with a row of teeth and a seta, seventh segment is

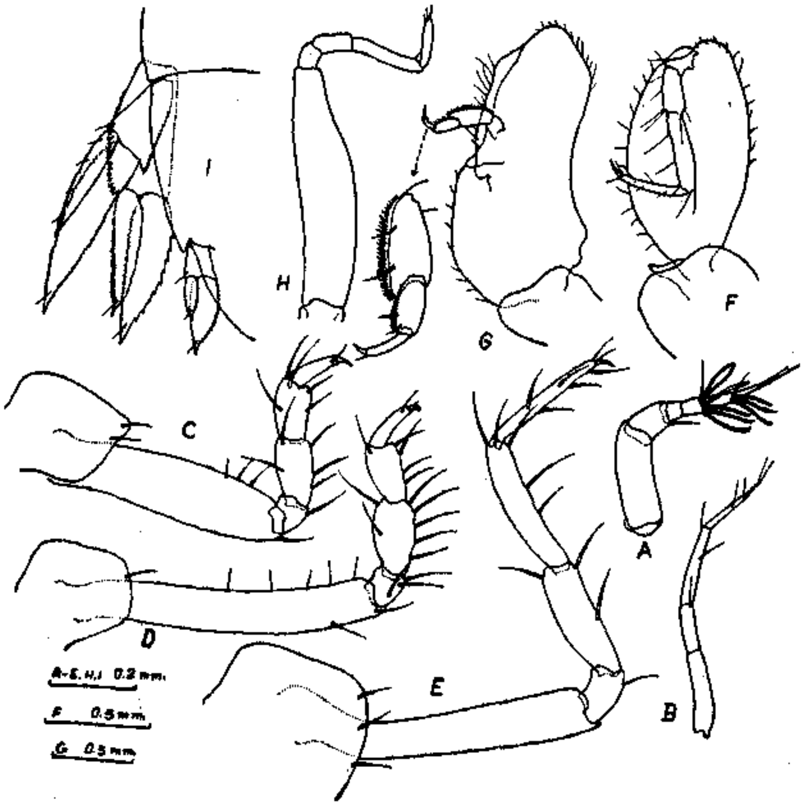

FIG. 17. *Parascelus typhoides* Claus. (A) Antenna 1; (B) antenna 2; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

very small. Seventh peraeopod is very small, its second segment is long, subequal in length to the rest of the limb, fifth segment carries one seta and the sixth three setae, seventh segment is apparently absent.

Telson is a broad-based triangle with rounded apex. First uropod reaches the tip of the third uropod, its peduncle is as long as the inner ramus, inner border of the latter carries well-spaced teeth, outer border is closely serrated, outer border of outer ramus is conspicuously serrated and the inner border feebly serrated, outer border of its peduncle carries prominent serrations. Second uropod reaches the tip of the first, its peduncle is short with serrated inner border, outer ramus is small and the inner very large, both borders of both rami are closely serrated. Third uropod is small, with dissimilar rami, overreaching the telson, borders of the rami are closely serrated.

Length 4·0 mm.

Platyscelus serratulus Stebbing

(Fig. 18)

Platyscelus serratulus Stebbing, 1888, p. 1470; Chevreux and Fage, 1925, p. 422, fig. 414; Shoemaker, 1925, p. 51, figs. 20–21; Stephensen, 1925, p. 215; Pirlot, 1930, p. 37; Barnard, 1930, p. 437; Shoemaker, 1945, p. 259.

Material (Number of specimens given in parentheses).—St. 1233, (2); St. 1245, (2); St. 1245, (4); St. 1256, (4); St. 1285, (1); St. 1310, (3); St. 1312, (3); St. 1329, (3); St. 1329, (1); St. 1333, (1); St. 1375, (3); St. 1381, (1); St. 1407, (7); St. 1411, (1); St. 1413, (2); St. 1704, (9); St. 1723, (9); St. 1737, (123); St. 1747, (2); St. 1748, (1); St. 1749, (5); St. 1752, (5); St. 1799, (1).

Specific characters.—Basal segment of the flagellum of the first antenna of the male is stout and is followed by three slender segments. Peraeopods one and two are subchelate and subsimilar, fourth segment of both is externally expanded, inner distal part of fifth segment is produced into a large conical process with prominently serrated border, that of first peraeopod fails to reach the tip of the sixth segment while that of the second peraeopod overreaches the sixth segment, inner border of the sixth segment of both legs is serrated. Third and fourth peraeopods are slender and long, with practically no kind of armature. Second segment of fifth peraeopod is roughly ovate and enlarged, rest of the limb is slender and feebly spiny along the inner border, second segment shows hexagonal markings especially near the periphery. Second segment of the sixth peraeopod is an irregular elytra with hexagonal markings, rest of the limb is short and displaced towards the ventral side of the second segment, inner border of the fourth and fifth segments is prominently spiny, seventh segment is apparently absent. Seventh peraeopod consists of a large elongate oblong curved lamina and two small segments, its coxal plate shows hexagonal sculpturing.

Telson is triangular, with rounded apex. Peduncle of the first uropod stops short of the base of the third uropod, its outer border is prominently serrated, rami are somewhat leaf-like, with feebly serrated border, inner ramus is longer and broader than the outer. Peduncle of the second uropod is very short, inner ramus is large, borders of the rami are feebly serrated. Inner ramus of third uropod is considerably larger than the outer and is fused with the peduncle and slightly overreaches the tip of the telson. The dorsal surface of the body shows scattered spinules.

Length 5·1 mm.

Remarks.—As pointed out by Barnard (1930) the figure of the seventh peraeopod given by Chevreux and Fage (1925) is quite unlike what is found in the present specimens. Their illustration of the uropods is also not very correct. The spinulation of the body and the sculpturing of the appendages do not appear to have been noticed before. From published literature it appears that this species shows some intraspecific variations. My illustrations are based on an adult male,

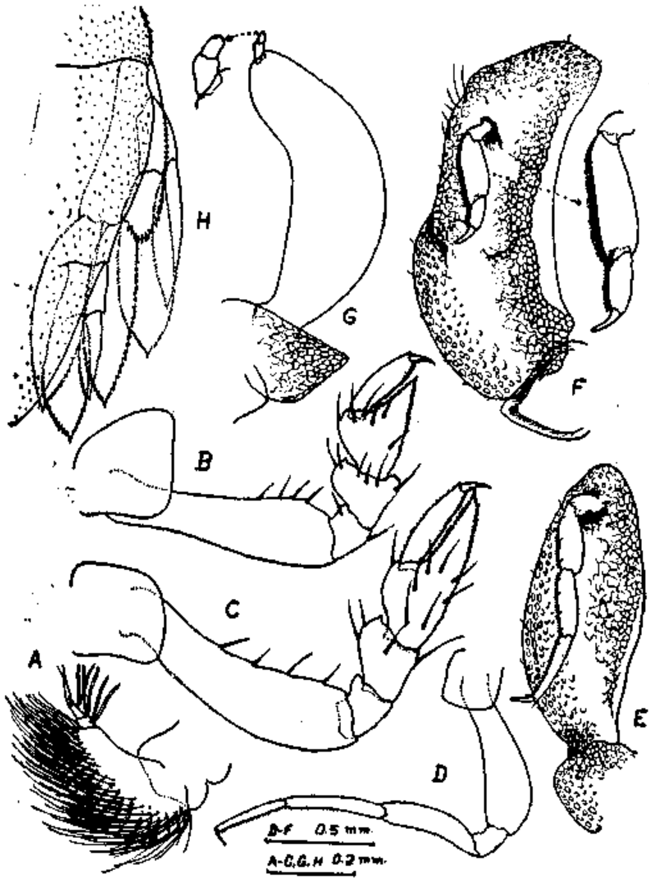

FIG. 18. *Platyscelus serratulus* Stebbing. (A) Antenna 1; (B) peraeopod 1; (C) peraeopod 2; (D) peraeopod 4; (E) peraeopod 5; (F) peraeopod 6; (G) peraeopod 7; (H) uropods and telson.

Tetrathyrus forcipatus Claus

(Fig. 19)

Tetrathyrus forcipatus Stebbing, 1888, p. 1484; Chevreux and Fage, 1925, p. 422, fig. 415; Stephensen, 1925, p. 224; Spandl, 1927, p. 240, fig. 48; Barnard, 1930, p. 439; Shoemaker, 1945, p. 259; Irie, 1948, p. 354, fig. 20.

Material (Number of specimens given in parantheses).—St. 745, (1); St. 976, (8); St. 1029, (1); St. 1055, (4); St. 1085, (3); St. 1118, (3); St. 1167, (2); St. 1256, (1); St. 1272, (3); St. 1290, (1); St. 1292, (9); St. 1294, (1); St. 1298, (1); St. 1329, (4); St. 1329, (4); St. 1335, (1); St. 1337, (1); St. 1355, (2); St. 1368, (1); St. 1373, (1); St. 1377, (1); St. 1383, (2); St. 1385, (1); St. 1397, (4); St. 1397, (12); St. 1407, (1); St. 1407, (2); St. 1413, (1); St. 1417, (1); St. 1688, (6); St. 1703, (16); St. 1711, (3); St. 1719, (6); St. 1720, (5); St. 1721, (1); St. 1721, (5); St. 1724, (14); St. 1725, (1); St. 1726, (1); St. 1727, (11); St. 1732, (8); St. 1737, (1); St. 1737, (25); St. 1738, (11); St. 1740, (2); St. 1746, (2); St. 1749, (5); St. 1750, (5); St. 1750, (5); St. 1752, (3); St. 1763, (3); St. 1807, (3); St. 1808, (1); St. 1808, (7); St. 1808, (7); St. 1813, (2).

Specific characters.—Basal flagellar segment of the first antenna of the male is only moderately enlarged, this is followed by four small segments. Second segment of first peraeopod is as long as the rest of the limb and has a dorsal distal bulge, segments four and five are somewhat broad, sixth segment is produced at its inner distal part into a small hollowed projection against which the seventh segment closes producing a chela. Second peraeopod is similar to the first but its second segment is longer and the inner border of the fourth and fifth segments carries more setae. Peraeopods three and four are very long and slender, second segment is the longest. Second segment of the fifth peraeopod is expanded into a large elongate-oblong lamina projecting as a rounded lobe beyond the insertion of the third segment, the rest of the limb is slender and long. Second segment of the sixth peraeopod is a large irregular elytra-like plate, the rest of the limb is very small and inserted near the distal two-thirds of its ventral side, fourth segment has its inner border strongly spiny and is distally produced into a lobe overlapping the fifth segment, inner border of the fifth and sixth segments also is spiny. Seventh peraeopod is an elongate-oblong lamina slightly curved dorsalwards, there is a small second segment.

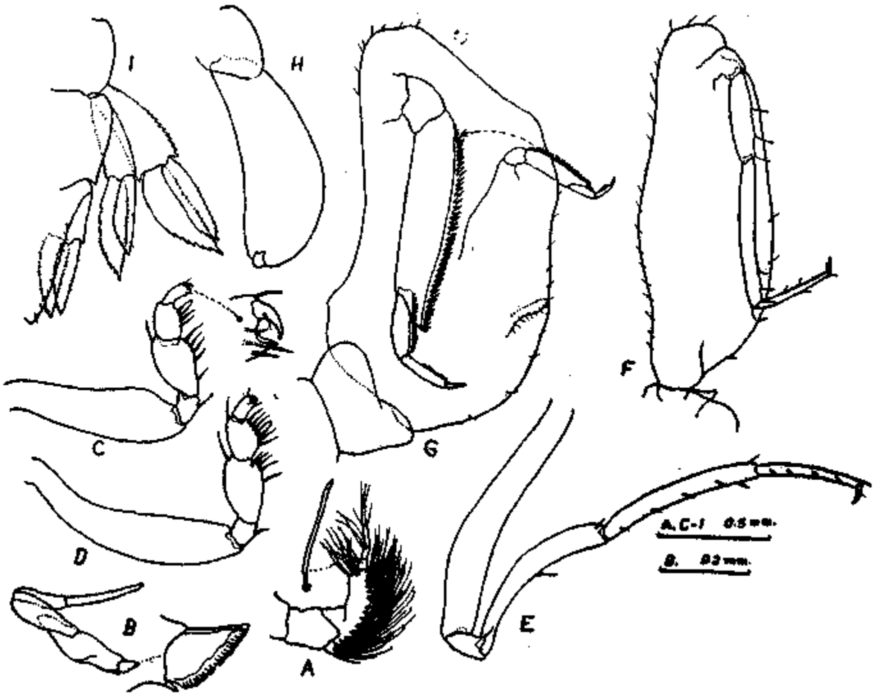

FIG. 19. *Tetrathyrus forcipatus* Claus. (A) Antenna 1; (B) mandible; (C) peraeopod 1; (D) peraeopod 2; (E) peraeopod 4; (F) peraeopod 5; (G) peraeopod 6; (H) peraeopod 7; (I) uropods and telson.

Telson is almost completely fused with the last urosome segment, nearly twice as long as the latter and steadily narrows towards the blunt apex. Peduncle of the first uropod reaches the tip of the peduncle of the second uropod, its outer distal part is serrated, rami are as long as the peduncle, with the distal half of their borders serrated, inner ramus is nearly twice as broad as the outer and also slightly longer than the latter. Inner distal part of the peduncle of the second uropod is indistinctly spiny, rami are dissimilar, outer border of outer ramus is smooth. Rami of the third uropod are subsimilar, stopping slightly short of the tip of the telson, inner ramus is fused with the peduncle.

Length 3·2 mm.

Remarks.—Both Chevreux and Fage (1925) and Spandl (1927) have shown the seventh peraeopod as a single segment which is apically drawn out and acute. But in the present specimens there is a small second segment. But for this character the present specimens are in accord with previous descriptions.

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EUPHAUSIACEA FROM INDIAN SEAS: SYSTEMATICS AND GENERAL CONSIDERATIONS*

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ABSTRACT

Taxonomic studies on the Euphausiacea collected from the Laccadive-Maldive and adjoining regions of the Indian Ocean are carried out. Twenty-three species of euphausiids are recorded from this locality with suitable remarks on their biology and keys for their identification.

The classification of this order is at present chiefly based on the male copulatory organ, the antennule and the elongated thoracic limbs which are easily broken off on collection and preservation. Hence the identification of female specimens is not quite easy. An attempt is made here to assess the systematic significance of the thelycum. The thelyca of the common forms are described and figured.

INTRODUCTION

THE importance of euphausiids in the dietary of oceanic fishes and baleen whales of the Boreal and Antarctic waters is quite well known. But todate we have very little precise information on their significance to the fisheries of the tropics. The present study, essentially taxonomic in nature, is intended as a preliminary to a more detailed investigation of the euphausiid fauna in relation to the fisheries of the Indian waters.

The Euphausiacea of the Indian Ocean is known mainly through the works of Tattersall (1906, 1911, 1925 and 1939), and Illig (1930). In addition, Euphausiacea have been studied from some restricted localities in the Indian Ocean and adjoining seas by Wood-Mason and Alcock (1891), Alcock and Anderson (1894), Anderson (1897), Hansen (1912), Colosi (1917), Torelli (1934), Pillai (1957), Boden (1954, in part) and Ponomareva *et al.* (1962).

In the systematics of Euphausiacea the nature of the male copulatory organ, the petasma, has come to stay as a very important taxonomic character following the works of Hansen (1910, 1911 and 1912). Thus, it is fairly easy to identify an adult male on the basis of the characteristics of the petasma; however, difficulty arises when females are to be identified where so many other morphological details have to be looked into. In a few instances species are erected on the basis of only small differences in the processes of the petasma with the result that their females are at present quite inseparable. In this connection, the taxonomic value of the female receptor organ, the spermatheca or thelycum, was stressed by Einarsson (1942 and 1945) but no subsequent worker seems to have paid attention to its study. During the present work the specific nature of the thelyca was again noticed and it was felt desirable to have them described and figured. The following report also provides a list of all the species hitherto recorded from the Indian Ocean, keys for their identification and short notes on the local species with suitable illustrations.

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AREA OF INVESTIGATION, MATERIAL AND METHOD

The material for the present study was obtained from the plankton samples collected on board *R. V. Varuna* and kept in the Central Marine Fisheries Research Institute. The plankton samples were collected from the seas off the west and south coasts of India, including the Laccadive-Maldive region (Fig. 1). The nets used in the collection of samples were made of different fabrics and were of different dimensions, but the majority of the collections were made with a half metre net with filtering cone of mosquito-netting. The maximum depth sampled by the net is 200 metres; however, on a few occasions when the author himself was on board the vessel, plankton samples from deeper waters were collected which yielded fully adult specimens of *Thysanopoda* and *Nematoscelis*. A few samples were collected with an Isaccs-Kidd midwater trawl also. Only qualitative work of a taxonomic nature is attempted in this study.

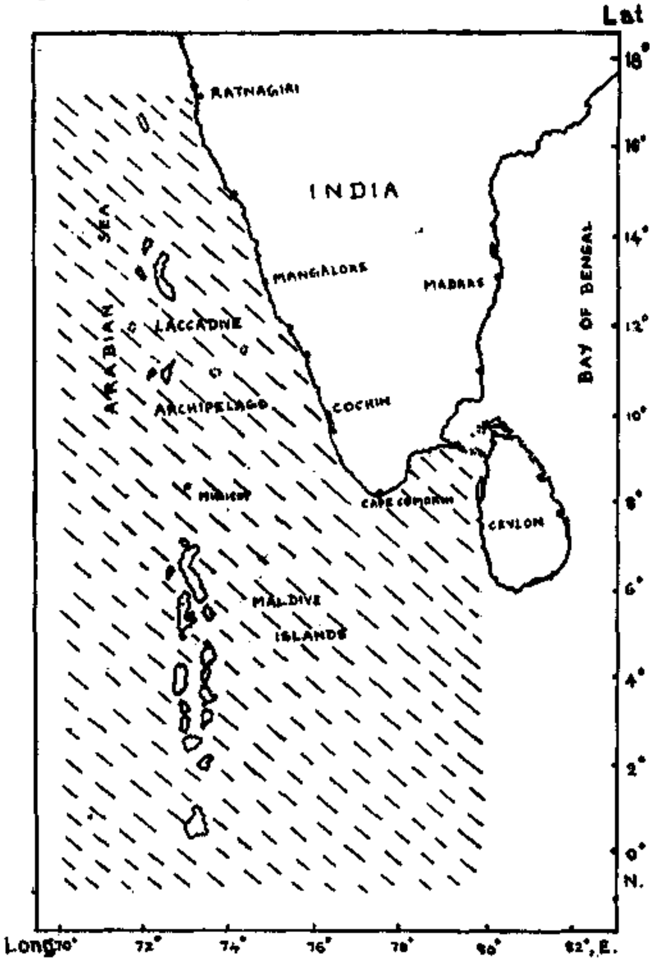

FIG. 1. Area investigated.

THE IMPORTANCE OF EXTERNAL SEXUAL CHARACTERS IN THE CLASSIFICATION OF EUPHAUSIACEA

1. *The petasma.*—Hansen (1910, 1911 and 1912) has clearly demonstrated the specific nature of the copulatory organ formed by the endopods of the first pair of pleopods of the male, and all subsequent workers duly recognised it as an important taxonomic character. Figure 2 *a* shows the

different parts of the petasma as they are referred to by Hansen (1910). The endopod of the first pair of pleopod is modified in the adult males of all the species except *Bentheuphausia amblyops* (G. O. Sars). Instead of the above modification *B. amblyops* shows the presence of a few spines on the basipodite (Einarsson, 1942). The specific nature of the petasma is easily understood from the fact that small differences in its structure is the only means of distinguishing closely related species like *Euphausia gibboides* Ortmann and *E. sanzoi* Torelli. Likewise, differences in the petasma provide the major distinguishing character among *Euphausia* spp. of the *gibba*-group and some species of *Nematoscelis.*

2. *The spermatheca or thelycum.*—As the petasma in the different species show specific differences and considerable diversity of form it is only natural that the thelycum should also show correspondingly specific structural modifications. Hence the author has made special efforts following Einarsson (1942 and 1945) to assess the systematic significance of the thelycum.

The thelycum is formed of parts of sternal as well as coxal origin (Fig. 2, *b.d.f.*). This view was held by Raab (1913), Ruud (1932), Bargmann (1937) and Einarsson (1942). In many cases extensive fusion of the sternal and coxal plates occur which makes recognition of their separate identity difficult. Even then the general configuration of the thelycum is quite specific. Small differences in the shape of the thelyca in virginal and fertilised females are noticed by Ruud (1936) who on this basis considers *Meganyctiphanes Calmani* Colosi synonymous with *M. norvegica* (M. Sars). Chiefly

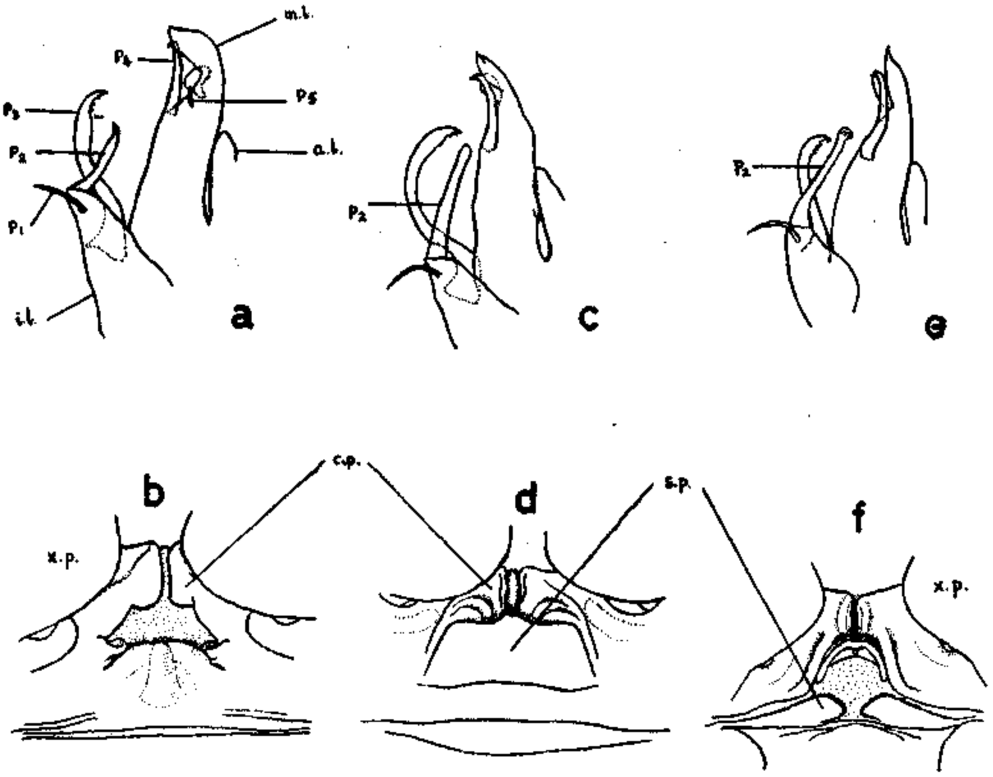

FIG. 2. Comparison of petasma and thelyca in three species. (*a*) *Thysanopoda acutifrons*: petasma; (*b*) same : thelycum; (*c*) *T. orientalis*: petasma; (*d*) same: thelycum; (*e*) *T. microphthalma*: petasma; (*f*) same: thelycum.

i.l., inner lobe; *m.l.*, median lobe; *a.l.*, auxiliary lobe; P1, spine-shaped process; P2, terminal process; P3, proximal process; P4, lateral process; P5, additional process; *c.p.*, coxal plate; *s.p.*, sternal plate; *x.p.*, coxopodite. [Figs. after Hansen (1910) and Einarsson (1942).]

on the basis of the identity of the thelyca in *Nematoscelis megalops* and *N. difficilis*, Einarsson (1942) considers the latter a synonym of the former. Einarsson (1945) found that a thelycum is absent in *Nyctiphanes couchii* (Bell). He has described the thelycum in the following eleven species (Einarsson, 1942 and 1945): *Thysanopoda orientalis* Hansen, *T. acutifrons* Holt and Tattersall, *T. microphthalma* G. O. Sars, *Nematoscelis megalops* G. O. Sars, *N. microps* G. O. Sars, *N. atlantica* Hansen, *N. gracilis* Hansen, *Meganyctiphanes norvegica* (M. Sars), *Thysanoessa longicaudata* (Kroyer), *T. inermis* (Kroyer), and *T. raschii* (M. Sars).

The present paper describes and figures the thelyca in the following twelve species of this locality: *Thysanopodat ricuspidata* Milne-Edwards, *T. monacantha* Ortmann, *T. aequalis* Hansen, *T. orientalis* Hansen, *Euphausia diomedeae* Ortmann, *E. distinguenda* Hansen, *Nematoscelis gracilis* Hansen, *N. microps* G. O. Sars, *N. tenella* G. O. Sars, *Nematobrachion boopis* (Calman), *N. flexipes* (Ortmann) Calman and *Stylocheiron longicorne* G. O. Sars.

It is seen that in taxonomy the thelycum is as important a character as the petasma. Figures 2 *a*, *c* and *e* show the petasma of three different species, *Thysanopoda acutifrons*, *T. orientalis* and *T. microphthalma*. The thelyca of the above species shown in Figs. 2 *b*, *d* and *f* provide equally conspicuous specific differences. Similarly, the thelyca are helpful in the indentification of the females of *Nematoscelis*, which are otherwise difficult for specific identification. Apart from their taxonomic value, a knowledge of the morphology of the thelyca will be helpful in any consideration of systematic affinity within the group.

EUPHAUSIACEA KNOWN FROM THE INDIAN OCEAN

Tattersall (1939) listed forty-two species; however, Illig's (1930) records from tropical Indian Ocean of *Thysanoessa gregaria* and *T. parva* (northernmost records from west of Sumatra) and *E. similis* var. *armata* (east of Ceylon) were not included. The species *Thysanoessa macrura* recorded from 34° 31·2′ south latitude (Illig, 1930), *Euphausia spinifera* from 34° 19′ s. latitude (John, 1936) and *E. lucens* from 35° 10′ s. latitude (John, *l.c.*) are included here though they are denizens of more southern waters. Illig (1930) has reported the occurrence of *E. superba*, *E. crystallorophias* and *E. triacantha* at one or two stations in southern Indian Ocean. However, literature on distribution shows that *E. crystallorophias* is reported to occur only along the coasts of the Antarctic continent, *E. superba* under the pack-ice, along its edge and in the colder waters of the Antarctic zone and *E. triacantha* in the Antarctic and in the coldest waters of the Sub-Antarctic zones (Rustad, 1934; John, 1936). As such, these species are not included here among the Indian Ocean forms. An important later addition to the list is the new species *Thysanopoda subaequalis* Boden (1954) reported from the Straits of Mozambique. *Nematobrachion sexspinosus* is added following the studies of Ponomareva *et al.* (1962).

The species are: *Bentheuphausia amblyops* (G. O. Sars), 1883; *Thysanopoda tricuspidata* Milne-Edwards, 1830; *T. monacantha* Ortmann, 1893; *T. aequalis* Hansen, 1905; *T. pectinata* Ortmann, 1893; *T. acutifrons* Holt and Tattersall, 1905; *T. orientalis* Hansen, 1910; *T. microphthalma* G. O. Sars, 1885; *T. obtusifrons* G. O. Sars, 1883; *T. cornuta* Illig, 1905; *T. subaequalis* Boden, 1954; *Pseudeuphausia latifrons* (G. O. Sars), 1883; **P. colosii* Torelli, 1934; **Euphausia eximia* Hansen, 1905; **E. messanensis* Colosi, 1916; **E. sanzoi* Torelli, 1934; *E. diomedeae* Ortmann, 1894; *E. mutica* Hansen, 1905; *E. recurva* Hansen, 1905; *E. brevis* Hansen, 1905; *E. similis* G. O. Sars, 1885; *E. tenera* Hansen, 1905; *E. hemigibba* Hansen, 1910; *E. pseudogibba* Ortmann, 1893; *E. paragibba* Hansen, 1910; *E. distinguenda* Hansen, 1911; *E. gibboides* Ortmann, 1893; *E. similis* var. *armata* Hansen, 1911; †*E. spinifera* G. O. Sars, 1885; †*E. lucens* Hansen, 1905; †*Thysanoessa macrura* G. O. Sars, 1883; *T. inermis* (Kroyer) 1846; *T. gregaria* G. O. Sars, 1883; *T. parva* Hansen,

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* The records are from the Red Sea. Tattersall's (1925) record of *Euphausia gibboides* from off the coast of Natal probably represents *E. sanzoi* Torelli (Tattersall, 1939; and Brinton, 1962).

† Southern boundary species.

1905; *Nematoscelis megalops* G. O. Sars, 1885; *N. microps* G. O. Sars, 1883; *N. gracilis* Hansen, 1910; *N. tenella* G. O. Sars, 1883; *Nematobrachion boopis* (Calman), 1896; *N. flexipes* (Ortmann), Calman, 1893; ‡*N. sexspinosus* Hansen, 1911; *Stylocheiron carinatum* G. O. Sars, 1883; **S. armatum* Colosi, 1917; *S. affine* Hansen, 1910; *S. suhmii* G. O. Sars, 1883; *S. microphthalma* Hansen, 1910; *S. longicorne* G. O. Sars, 1883; *S. elongatum* G. O. Sars, 1883; *S. maximum* Hansen, 1908; and *S. abbreviatum* G. O. Sars, 1883.

The salient features of taxonomic value regarding these species are to be found in the keys provided, which, however, do not include the Red Sea forms *Euphausia messanensis*, *Stylocheiron armatum* and *Pseudeuphausia colosii*. Thelycal characters have been taken into account in the key for the first time wherever found appropriate. In the preparation of the following keys liberal use has been made of the works of Hansen (1910, 1911 and 1912), Einarsson (1942), Sheard (1953) and Boden (1954).

KEY TO THE GENERA REPRESENTED IN THE INDIAN OCEAN

1 *a*. Eyes ill-developed; photophores absent; all the eight thoracic limbs fully developed, none much elongated; endopod of first pair of pleopod not transformed into copulatory organ in the male; exopod of uropod with a transverse suture. (Family Bentheuphausiidae Colosi, 1917)..*Bentheuphausia* Sars, 1885
[The only species known is *B. amblyops* (Sars), 1883.]

1 *b*. Eyes well developed; photophores present; eighth, or seventh and eighth pairs of thoracic endopods rudimentary; second or third pair sometimes elongated and modified into prehensile organs; exopod of uropod without transverse suture; endopod of first pair of pleopod modified into copulatory organ in male. (Family *Euphausiidae* Holt and Tattersall, 1905).

2 *a*. None of the thoracic endopods much elongated or modified as prehensile organs.

3 *a*. Only eighth thoracic endopod rudimentary; seventh though small is five-segmented. ....*Thysanopoda* Milne-Edwards, 1830

3 *b*. Seventh and eighth thoracic endopods rudimentary and unsegmented.

4 *a*. Exopod of seventh thoracic limb well developed; no ovisac in female...... ....*Thysanoessa* Brandt, 1851 (in part)

4 *b*. Exopod of seventh thoracic limb rudimentary; ovisac present or not.

5 *a*. Carapace produced into a truncate frontal plate; no rostrum; distal three segments of sixth thoracic limb greatly reduced; ovisac present in female.. ....*Pseudeuphausia* Hansen, 1910

5 *b*. Carapace not produced into a frontal plate; rostrum present; sixth thoracic limb similar to fifth; ovisac absent...............*Euphausia* Dana, 1850

2 *b*. Second or third thoracic endopods very much elongated and usually modified as prehensile organs.

6 *a*. Second thoracic endopod much elongated.

7 *a*. Second thoracic limb rather strong, the last two segments armed with spiniform bristles on both margins; ovisac absent.... ....*Thysanoessa* Brandt, 1851 (in part)

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‡ Included after its record by Ponomareva *et al.* (1962).

7 *b*. Second thoracic limb slender and almost naked except for an apical tuft of straight and stout bristles; ovisac present in female.. .... *Nematoscelis* Sars, 1883

6 *b*. Third thoracic endopod much elongated.

8 *b*. Third thoracic endopod with an apical tuft of straight and stout bristles; seventh thoracic endopod five-segmented; upper part of eye not narrowed or divided into big crystal cones; ovisac absent....... *Nematobrachion* Calman, 1905

8 *b*. Third thoracic endopod forming a true or false chela by the apposition of stiff, apically curved spiny setae arising from the ultimate and penultimate segments; seventh thoracic endopod only two-segmented; eyes usually with upper part narrowed and divided into big crystal cones; ovisac present in female................ *Stylocheiron* Sars, 1883

KEY TO THE SPECIES OF *Thysanopoda* KNOWN FROM THE INDIAN OCEAN

1 *a*. Carapace with deep cervical groove; sixth abdominal segment shorter than fifth; maxillula with pseudexopod not overreaching outer margin of third segment; bathypelagic; upto 79 mm... *T. cornuta* Illig, 1905

1 *b*. Carapace without distinct cervical groove; sixth abdominal segment longer than fifth; maxillula with pseudexopod overreaching outer margin of third segment.

2 *a*. Denticle(s) present on or near postero-lateral margin of adult carapace.

3 *a*. Abdominal segment(s) armed with dorsal spine(s).

4 *a*. Dorsal spine on third abdominal segment only; no spine at base of rostrum; single lateral denticle on carapace; 25–32 mm........................... .... *T. monacantha* Ortmann, 1893

4 *b*. Dorsal spine on third to sixth abdominal segments; spine present at base of rostrum; two lateral denticles on carapace; 15–26 mm................. .... *T. tricuspidata* Milne-Edwards, 1830

3 *b*. Abdominal segments unarmed.

5 *a*. Lobe from upper distal end of first antennular segment with several teeth on its outer, lateral margin; petasma without spine-shaped process; 15–20 mm................................ *T. aequalis* Hansen, 1905

5 *b*. Lobe from first antennular segment with a single tooth on its outer, lateral margin; petasma with spine-shaped process.

6 *a*. Lobe from first antennular segment covering more than half the second segment; 18 mm.................... *T. subaequalis* Boden, 1954

6 *b*. Lobe from first antennular segment covering less than half the second segment; 20 mm...................... *T. obtusifrons* Sars, 1883

2 *b*. Denticles absent on or near postero-lateral margin of adult and subadult carapace.

7 *a*. Lobe from first antennular segment with its distal margin pectinate; 29–44 mm................ *T. pectinata* Ortmann, 1893

7 *b*. Lobe from first antennular segment not pectinate.

8 *a*. Antennular lobe acutely spiniform in lateral view; terminal and proximal processes of petasma subequal with end of terminal process having a transverse row of saw-teeth just behind the flatly arched terminal surface; major sternal lobe of thelycum formed of two leaf-like outgrowths; 20–23 mm............*T. microphthalma* G. O. Sars, 1885

8 *b*. Atennular lobe not acutely spiniform in lateral view; proximal process of petasma about twice as long as terminal; major sternal lobe of thelycum formed of a single broad plate.

9 *a*. Dorsal hind margin of fourth and fifth abdominal segments slightly acuminate in the middle; terminal process of petasma with a broadly rounded, unarmed end; sternal lobe of thelycum without a conspicuous longitudinal ridge in the middle; 23–38 mm.....................................*T. orientalis* Hansen, 1910

9 *b*. Dorsal hind margin of fourth and fifth abdominal segments not acuminate; terminal process of petasma shorter with its distal fourth slightly curved and tapering; sternal lobe of thelycum with a conspicuous longitudinal ridge in the middle; 35–50 mm.....................*T. acutifrons* Holt and Tattersall, 1905

KEY TO THE SPECIES OF *Euphausia* KNOWN FROM THE INDIAN OCEAN

1 *a*. Two pairs of lateral denticles on carapace; no dorsal spines on third to fifth abdominal segments; proximal process of petasma with a secondary process or prominence near its distal end.

2 *a*. A small upper distal pectinate lobe with 9–10 spiniform processes on first antennular segment; 16–30 mm......................................*E. eximia* Hansen, 1905.

2 *b*. A large upward-pointing lobe (in female) or a recurved one (in male) on upper distal end of first antennular segment; a slender spiniform process at upper distal inner angle of second antennular segment; 16–20 mm................*E. recurva* Hansen, 1905

2 *c*. A small forward-pointing bifid lobe on upper distal end of first antennular segment; process at upper distal inner angle of second antennular segment absent or replaced by a triangular protuberance.

3 *a*. No process on second antennular segment; 8–13 mm.....*E. mutica* Hansen, 1905

3 *b*. A single process on second antennular segment; 8·5–10 mm...*E. brevis* Hansen, 1905

3 *c*. Two processes on second antennular segment; 12–19 mm...*E. diomedeae* Ortmann, 1894

1 *b*. Only a single pair of lateral denticles on carapace; no dorsal spine on third abdominal segment.

4 *a*. No conspicuous lobe on upper distal end of first antennular segment; a single process on second antennular segment; 8–9 mm..*E. tenera* Hansen, 1905.

4 *b*. A conspicuous lobe present on upper distal end of first antennular segment.

5 *a*. Lobe on first antennular segment bifid; two blunt upper distal projections on second antennular segment; 19–33 mm...*E. similis* G. O. Sars, 1885

5 *b*. Lobe on first antennular segment angular; no process on upper distal end of second antennular segment; 10–18 mm.......*E. lucens* Hansen, 1905

1 *c*. Only a single pair of lateral denticles on carapace; a dorsal spine or process present only on third abdominal segment.

6 *a*. No conspicuous lobe at upper distal end of first antennular segment ....*E. distinguenda* Hansen, 1911

6 *b*. A conspicuous lobe present at upper distal end of first antennular segment.

7 *a*. The above lobe bifid; 16–23 mm...*E. similis* v. *armata* Hansen, 1911

7 *b*. The above lobe angular.

8 *a*. Second antennular segment with short, broad, sub-rectangular lobe.

9 *a*. Distal part of terminal process of petasma simple; median lobe with a single triangular tubercle near base of lateral process; 22–30 mm...*E. gibboides* Ortmann, 1893

9 *b*. Distal part of terminal process of petasma bifid; median lobe with two triangular tubercles....................................*E. sanzoi* Torelli, 1934

8 *b*. Second antennular segment with a small, sharp tooth.

10 *a*. Dorsal spine on third abdominal segment about half as long as fourth segment; distal part of median lobe of petasma not much narrowed; 12–16·5 mm.........*E. hemigibba* Hansen, 1910

10 *b*. Dorsal spine on third abdominal segment less than half as long as fourth segment; distal part of median lobe of petasma narrowed to less than half the width of proximal part.

11 *a*. Dorsal keel on third antennular segment not reaching second segment and ending in an almost vertical border; lateral process of petasma without proximal dilation and additional teeth; 13–15 mm...........................*E. pseudogibba* Ortmann, 1893

11 *b*. Dorsal keel on third antennular segment decreasing in height backwards and almost reaching second segment; lateral process of petasma with proximal dilation carrying three acute teeth; 14–17 mm...........................*E. paragibba* Hansen, 1910

1 *d.* A single pair of lateral denticles on carapace; dorsal spine present on third to fifth abdominal segments; lobe from first antennular segment multi-digitate; spine on second segment strong and bifid; 21–29 mm............................*E. spinifera* G. O. Sars, 1885

KEY TO THE SPECIES OF *Thysanoessa* RECORDED FROM THE INDIAN OCEAN

1 *a.* Lateral margin of carapace without any denticle; sixth abdominal segment with a strong upper distal spine; 32 mm...*T. inermis* (Kroyer), 1846

1 *b.* Lateral margin of carapace with a denticle; sixth abdominal segment without upper distal spine.

2 *a.* Sixth abdominal segment shorter than the sum of the two preceding segments.

3 *a.* Setae along lower margin of fifth and sixth segments of second to fourth pairs of thoracic endopods slender, non-ciliated and much shorter than the terminal setae of seventh segment; 9–10 mm........................*T. parva* Hansen, 1905

3 *b.* Setae along lower margin of fifth and sixth segments of third to fifth pairs of thoracic endopods strong, conspicuously ciliated and as long as or longer than the terminal setae of seventh segment........................*T. gregaria* G. O. Sars, 1885

2 *b.* Sixth abdominal segment almost or fully as long as the sum of the two preceding segments ....*T. macrura* G. O. Sars, 1885

KEY TO THE SPECIES OF *Nematoscelis* KNOWN FROM THE INDIAN OCEAN

1 *a.* Maxillula with a pseudexopod; elongated pair of thoracic limbs with long bristles arising from the ultimate as well as penultimate segments; third to sixth pairs of thoracic endopods with three segments beyond the knee; terminal process of petasma longer and stouter than proximal process; sternal plate of thelycum with a finger-like process between and over coxal plates and with an anterior round margin; 20–26 mm........................ ....*N. megalops* G. O. Sars, 1885

1 *b.* Maxillula without pseudexopod; elongated pair of thoracic limbs with long bristles arising only from ultimate segment; third and fourth pairs of thoracic endopods with only two segments and fifth and sixth pairs with only one segment beyond the knee; terminal process of petasma much slender and shorter than proximal process; thelycum with coxal plates more or less angular.

2 *a.* Lower part of eye considerably larger than upper part; terminal and spine-shaped processes of petasma at least about half as long as proximal process, the distal outer margin of which is even, not serrated; coxal plates of thelycum angular with sides having deep notches at about midway; 15–20 mm...............*N. microps* G. O. Sars, 1883

2 *b.* Lower part of eye equal to or smaller than upper part; petasma with terminal and spine-shaped processes several times shorter than proximal process, the outer margin of which is serrated towards the end; coxal lobe of thelycum angular without any constriction of its sides.

3 *a.* Lower part of eyes not smaller than upper part; terminal process of petasma short, but yet longer than basal diameter of proximal process; coxal lobe of thelycum angular with straight sides........................*N. gracilis* Hansen, 1910.

3 *b.* Lower part of eyes smaller than upper part; terminal process of petasma very short, at the most as long as basal diameter of proximal process; coxal lobe of thelycum angular with sides arched; 15–21 mm.............*N. tenella* G. O. Sars, 1883

Key to the Species of *Nematobrachion* Known from the Indian Ocean

1 *a*. Abdominal segments without dorsal spines; frontal plate obtuse, without rostrum; eyes dark brownish, divided by a groove into an upper section more than twice as deep as lowerr; first antennular segment without any process from its distal outer angle; second antennular segment with a slightly produced acute angle at its upper distal outer angle; 19–21 mm... .... *N. boopis* (Calman), 1896

1 *b*. At least fourth and fifth abdominal segments with conspicuous dorsal spines; frontal plate terminating in a slender rostrum; eyes black, constricted into an upper section somewhat deeper than lower; first antennular segment with a long spiniform process from its distal outer angle; second antennular segment with a very conspicuous process from its upper distal outer angle.

2 *a*. Third to sixth abdominal segments each with single postero-dorsal spine, that on third segment much longer; maxillula without pseudexopod; process from second antennular segment with its proximal half plate-shaped and distal spiniform; 22–26 mm.................................... *N. flexipes* (Ortmann) Calman, 1893

2 *b*. Fourth and fifth abdominal segments each with a postero-dorsal row of three spines, none on other segments; maxillula with pseudexopod; process from second antennular segment is a large, oblong plate slightly acuminate at the acute end; 23 mm....... .... *N. sexspinosus* Hansen, 1911

Key to the Species of *Stylocheiron* Known from the Indian Ocean

1 *a*. Penultimate segment elongate, third pair of thoracic endopods with long setae arising laterally; a small spur on inferior distal margin of antepenultimate segment; 11–15 mm. .... *S. carinatum* G. O. Sars, 1885

1 *b*. Penultimate segment of third thoracic endopod with elongate setae arising more or less terminally, but no real chela is formed; ultimate segment very short with many elongate setae; no spur on distal margin of antepenultimate segment; adults usually below 14 mm.

2 *a*. Eyes oblong, upper part not divided into prominent crystal cones; sixth abdominal segment more than three times as long as deep; 13 mm....... *S. elongatum* G. O. Sars, 1885

2 *b*. Eyes with upper part divided into large crystal cones; sixth abdominal segment in adult less than three times as long as deep.

3 *a*. Two crystal cones in a transverse row in upper part of eye; 5·5–6·4 mm.......... .... *S. microphthalma* Hansen, 1911

3 *b*. Three crystal cones in a transverse row in upper part of eye; 8 mm............. .... *S. suhmii* G. O. Sars, 1885

3 *c*. Four to six crystal cones in a transverse row in upper part of eye; 6–8 mm.

A variant with 5–8 crystal cones is reported by Brinton (1962) from the Pacific. In it the length of the sixth abdominal segment is less than 1·6 times its depth..... .... *S. affine* Hansen, 1910.

3 *d*. Nine to nineteen crystal cones in a transverse row in upper part of eye; 6·4–9·5 mm., female upto 13 mm.

A variant with 7–8 crystal cones is noticed by Brinton (*l.c.*) in which the length of the sixth abdominal segment is more than 1·6 times its depth................. .... *S. longicorne* G. O. Sars, 1883

1 *c*. Penultimate segment of elongate thoracic endopod with setae arising terminally; one of the setae elongate, stiff and immovably fused against which closes a stout curved spine of ultimate segment so that a true chela is formed; ultimate segment elongated, carrying no long setae but a few short curved spines or teeth terminally; no spur on distal margin of antepenultimate segment; adults above 14 mm.

4 *a*. Upper part of eye much smaller than lower; fourth and fifth abdominal segments dorsally keeled and with posterior acute teeth; 15–16 mm...*S. abbreviatum* G. O. Sars, 1883

4 *b*. Upper part of eye at the most slightly smaller than lower; fourth and fifth abdominal segments dorsally unarmed; 23–24 mm..*S. maximum* Hansen, 1908

SPECIES OF EUPHAUSIACEA REPRESENTED IN THE *R. V. Varuna* COLLECTIONS

***Thysanopoda tricuspidata* Milne-Edwards**

Thysanopoda tricuspide M.-Edwards, 1830.

Thysanopoda tricuspidata M.-Edwards, 1837; G. O. Sars, 1885; Hansen, 1910, 1911 and 1912; Zimmer, 1914; Illig, 1930; Tattersall, 1936; Boden, 1954.

Represented by few numbers throughout the area covered by the survey. The Isaccs-Kidd mid-water trawl collected them in abundance along with *T. monacantha* from several places. The length of adult specimen is reported to be 10–20 mm. (Boden, 1954), but in the present collection almost all the adult specimens measured more than 20 mm., the maximum length being 26 mm. In a large collection from lat. 8° 10′ N. and long. 75° 55′ E., five males were present for every female. Probably a shoaling species. Has a very wide distribution in the tropical Indian Ocean.

Thelycum with a small triangular sternal lobe and with longitudinally folded coxal lobes. Only a single spermatophore with an elongated stem is carried (Figs. 15 and 16).

***Thysanopoda monacantha* Ortmann**

Thysanopoda monacantha Ortmann, 1893; Hansen, 1911 and 1912; Zimmer, 1914; Tattersall 1939; Boden, 1954.

T. agassizi Ortmann, 1893; Hansen, 1910.

T. lateralis Hansen, 1905 *a*.

T. ctenophora Illig, 1908.

More abundant in this region than *T. tricuspidata* and in an Isaccs-Kidd trawl from lat. 8° 10′ N. and long. 75° 55′ E., no less than 400 adult specimens were caught. They measured 25–29 mm. whereas the Siboga specimens measured only 23·5–25 mm. Males were few in number only, about three males per eighty females. Usually large specimens were found in plankton hauls from depths exceeding 200 metres.

Thelycum with a horse-shoe-shaped plate. Two distinct spermatophores borne on narrow stems. Widely distributed in tropical Indian Ocean.

***Thysanopoda aequalis* Hansen**

Thysanopoda aequalis Hansen 1905 (*b*), 1910 and 1912; Tattersall, 1911 and 1939; Zimmer, 1914; Illig, 1930; Boden, 1954.

Found in few numbers only; most of the specimens seen by me are males. Thelycum as shown in Fig. 17; somewhat similar to that in *T. tricuspidata*.

Thysanopoda orientalis Hansen

Thysanopoda orientalis Hansen, 1910, 1911 and 1912; Illig, 1930; Tattersall, 1939; Boden, 1954.

Found in few numbers, but more abundant in deeper hauls. The thelycum with a very broad sternal plate which almost covers up the spermathecal opening. Coxal plates are rounded lobes. Spermatophores, a pair.

Thysanopoda pectinata Ortmann

Thysanopoda pectinata Ortmann, 1893; Hansen, 1905 (*b*), 1910, 1911 and 1912; Illig, 1930; Tattersall, 1939.

T. ctenophora Illig, 1908.

Parathysanopoda foliifera Illig, 1909.

Rarely found. Only males were seen by me and hence the thelycum is not described.

Euphausia diomedeae Ortmann

Euphausia diomedeae Ortmann, 1894; Hansen, 1905 (*b*), 1910, 1911 and 1912; Illig, 1930; Torelli, 1934; Tattersall, 1939; Boden, 1954; Pillai, 1957.

The most abundant species. The setose lobe of the petasma with only seven setae; none was found with eight setae as reported by Pillai (1957).

The thelycum has an angular sternal lobe which becomes obtuse in larger specimens (Figs. 23, 24). Spermatophore single.

Euphausia distinguenda Hansen

Euphausia distinguenda Hansen, 1911 and 1912; Illig, 1930; Torelli, 1934; Tattersall, 1939.

This species is reported from the north-west parts of the Indian Ocean by Tattersall (1939) and Illig (1930) and from the Red Sea by Torelli (1934). According to Tattersall it is the most abundant euphausiid in the area explored by the John Murray Expedition.

Hansen described this species from the tropical East Pacific. According to him *E. distinguenda* is distinct from *E. pseudogibba*, *E. paragibba*, etc., in the absence of a conspicuous lobe from the first antennular segment and from *E. sibogae*, Hansen, 1908, in having the upper distal outer angle of second antennular segment raised as a short, oblique keel forming a nearly ear-like, rounded process directed upwards and somewhat forwards. The petasma shows striking similarity to that of *E. sibogae*. However, no further direct comparison of these two very closely related species has been made by Hansen. A close study of the descriptions of these two species brings out the following differences:—

	E. distinguenda	*E. sibogae*
1.	Median gastric keel seen from side rather high and even angular.	Keel somewhat high at the middle, but not really angular.
2.	Upper distal outer angle of second antennular joint with a rather short, high, oblique keel directed upwards and somewhat forwards, forming almost an ear-like, rounded process.	Second antennular joint without any distal protuberance or produced angle.
3.	Endopod of uropod slightly longer than the exopod and as long as or even a little longer than the telson.	Rami of uropods subequal in length and a little shorter than the telson.
4.	Terminal process of petasma with a rather long foot and a very long, curved heel.	Foot is not long and the heel moderately long, somewhat curved.
5.	Setiferous lobe with five setae from the triangularly produced terminal part and about four setae along the outer margin.	Terminal margin with five setae, besides two rather short setae on the outer margin.
6.	Length of both sexes from 10 to 14·5 mm.	8 to 8·5 mm.

Apart from this, a comparison of the figures of the petasma (Hansen, 1910 and 1912) shows that in *E. distinguenda* the tip of the proximal process reaches almost to the level of the tip of the terminal process, whereas, in *E. sibogae* the tip of the proximal process is much behind the level of the tip of the terminal process.

In the present material, the petasma showed resemblance to that of *E. sibogae*. The number of setae along the proximal outer margin of the setiferous lobe varied from 2 to 4. Rami of uropods are subequal in length and a little shorter than the telson. The upper distal outer angle of second antennular segment showed a low keel which is not prominent as an erect ear-like lobe. Adult males measured 10–12·5 mm. It is interesting to note that these specimens show some features characteristic of *E. sibogae*. No explanation could be found except to believe that the specimens represent a distinct population of *E. distinguenda*.

The species occurs mostly in swarms. A few stages in the development of the thelycum are shown in Figs. 20, 21 and 22.

Euphausia tenera **Hansen**

Euphausia tenera Hansen, 1905 (*b*), 1910, 1911 and 1912; Illig, 1930; Tattersall, 1939; Boden, 1954;

E. gracilis G. O. Sars, 1885. Represented in small numbers.

Euphausia brevis **Hansen**

E. brevis Hansen, 1905 (*b*), 1910, 1911 and 1912; Illig, 1930; Tattersall, 1939; Boden, 1954. Found very rarely.

Euphausia pseudogibba **Ortmann**

E. pseudogibba Ortmann, 1893; Hansen, 1905 (*a*), 1910, 1911 and 1912; Illig, 1930; Tattersall, 1939; Boden, 1954.

Found occasionally. Regarding its distribution, Boden (1954) remarks that it is apparently confined to the Atlantic. It has been recorded from the Indian Ocean by Illig (1930) and Tattersall (1939).

Pseudeuphausia latifrons (G. O. Sars)

Euphausia latifrons G. O. Sars, 1883 and 1885; Hansen, 1908; Tattersall, 1906.

Pseudeuphausia latifrons Hansen, 1910, 1911 and 1912; Illig, 1930; Tattersall, 1936 and 1939; Boden, 1954; Pillai, 1957.

A few specimens found in a collection from lat. 7° 48′ N. and long. 76° 28′ E.

Nematoscelis microps G. O. Sars

Nematoscelis microps G. O. Sars, 1883 and 1885; Hansen, 1908, 1910, 1911 and 1912; Illig, 1930; Ruud, 1936; Tattersall, 1939; Einarsson, 1942; Boden, 1954.

N. rostrata G. O. Sars, 1885; Ortmann, 1893.

The coxal lobe of the thelycum angular with the sides having deep constriction at about midway. Its tip is rounded. The females of *Nematoscelis* spp. were identified chiefly on the basis of the descriptions of thelyca by Einarsson (1942).

Nematoscelis gracilis Hansen

Nematoscelis gracilis Hansen, 1910, 1911 and 1912; Tattersall, 1911, 1939; Illig, 1930; Einarsson, 1942.

The coxal plate of thelycum angular with straight sides and almost pointed tip (Figs. 28 and 29).

Nematoscelis tenella G. O. Sars

Nematoscelis tenella G. O. Sars, 1883 and 1885; Hansen, 1905 (*b*), 1910, 1911 and 1912; Tattersall, 1911 and 1939; Illig, 1930; Boden, 1954.

N. mantis Chun, 1896.

N. sarsii Chun, 1896.

Ovigerous females occur in plankton hauls from depths exceeding 200 m. during the month of November.

The coxal lobe of thelycum angular with the sides arched (Fig. 33).

Nematobrachion boopis (Calman)

Nematodactylus boopis Calman, 1896.

Nematobrachion boopis Calman, 1905; Hansen, 1905 (*a*, *b*), 1910, 1911 and 1912; Tattersall, 1911 and 1939; Illig, 1930; Boden, 1954.

Occasional finds only in deeper plankton hauls. Thelycum as shown in Fig. 25; more complicated than that of *N. flexipes*, with the thelycal orifice partly covered by ventral and lateral plates.

Nematobrachion flexipes (Ortmann) Calman

Stylocheiron flexipes Ortmann, 1893.

Nematodactylus flexipes Calman, 1896.

Nematobrachion flexipes Calman, 1905; Hansen, 1905 (*b*), 1910, 1911 and 1912; Tattersall, 1911 and 1939; Illig, 1930; Boden, 1954.

More common than *N. boopis* (Calman). Boden (1954) remarks that this species has never been reported from the Indian Ocean. However, the species is already recorded from the Indian Ocean by Tattersall (1911 and 1939) and Illig (1930).

Thelycum more simple compared to that of *N. boopis*; the thelycal orifice is a more or less round opening.

Stylocheiron carinatum G. O. Sars

Stylocheiron carinatum G. O. Sars, 1883 and 1885; Hansen, 1910, 1911 and 1912; Tattersall, 1911 and 1939; Illig, 1930; Boden, 1954.

One of the common species of *Stylocheiron*. Exhibits shoaling habits at least during the breeding season. Ovigerous females with 4–6 heavily yolked eggs in the ovisac during February to April.

Stylocheiron affine Hansen

Stylocheiron affine Hansen, 1910, 1911 and 1912; Illig, 1930; Tattersall, 1939; Boden, 1954.

Only forms with the normal number of crystal cones of the eye were found. Fairly common.

Stylocheiron longicorne G. O. Sars

Stylocheiron longicorne G. O. Sars, 1883 and 1885; Hansen, 1910, 1911, and 1912; Tattersall, 1911 and 1939; Illig, 1930; Boden, 1954.

S. mastigophorum Chun, 1887 (*partim*).

Fairly common throughout the area explored; bigger specimens are caught by hauls from depths exceeding 200 m.

Thelycum formed of two prominent plates meeting in the middle and having an anterior Y-shaped cleft on the sides of which the paired spermatophores are attached.

Stylocheiron microphthalma Hansen

Stylocheiron microphthalma Hansen, 1910 and 1912; Tattersall, 1911; Illig, 1930.

This very small species is only occasionally found.

Stylocheiron elongatum G. O. Sars

Stylocheiron elongatum G. O. Sars, 1883 and 1885; Hansen, 1905, 1910, 1911 and 1912; Tattersall, 1911 and 1939; Illig, 1930; Boden, 1954.

A few subadults measuring 6·5–8 mm. were obtained from lat. 9° 03′ N. and long. 73° 20′ E., north of Minicoy island.

Boden (1954) remarks that this species is found only in Atlantic waters. The species has been reported from the Indian Ocean by Tattersall (1911 and 1939) and Illig (1930).

Stylocheiron abbreviatum G. O. Sars

Stylocheiron abbreviatum G. O. Sars, 1883 and 1885; Hansen, 1905 (*a*), 1910 and 1912; Tattersall, 1911 and 1939; Illig, 1930; Boden, 1954.

More common than *S. maximum*. Few specimens measuring 16 mm. were obtained but the majority were much smaller.

Stylocheiron maximum Hansen

Stylocheiron maximum Hansen, 1908, 1910, 1911 and 1912; Illig, 1930; Tattersall, 1939; Banner, 1949; Boden, 1954.

The species was found rarely; only subadults were seen.

A study of the euphausiid fauna of this region shows that among these many species encountered, judging from their size, abundance, shoaling habits, etc., the most important species are *Euphausia diomedeae* and *E. distinguenda*. Next in importance may come *Thysanopoda monacantha* and *T. tricuspidata* which, however, are ill-represented in the conventional plankton net collections. Further detailed study of the biology, development and distribution of the above species is desirable from the fisheries point of view.

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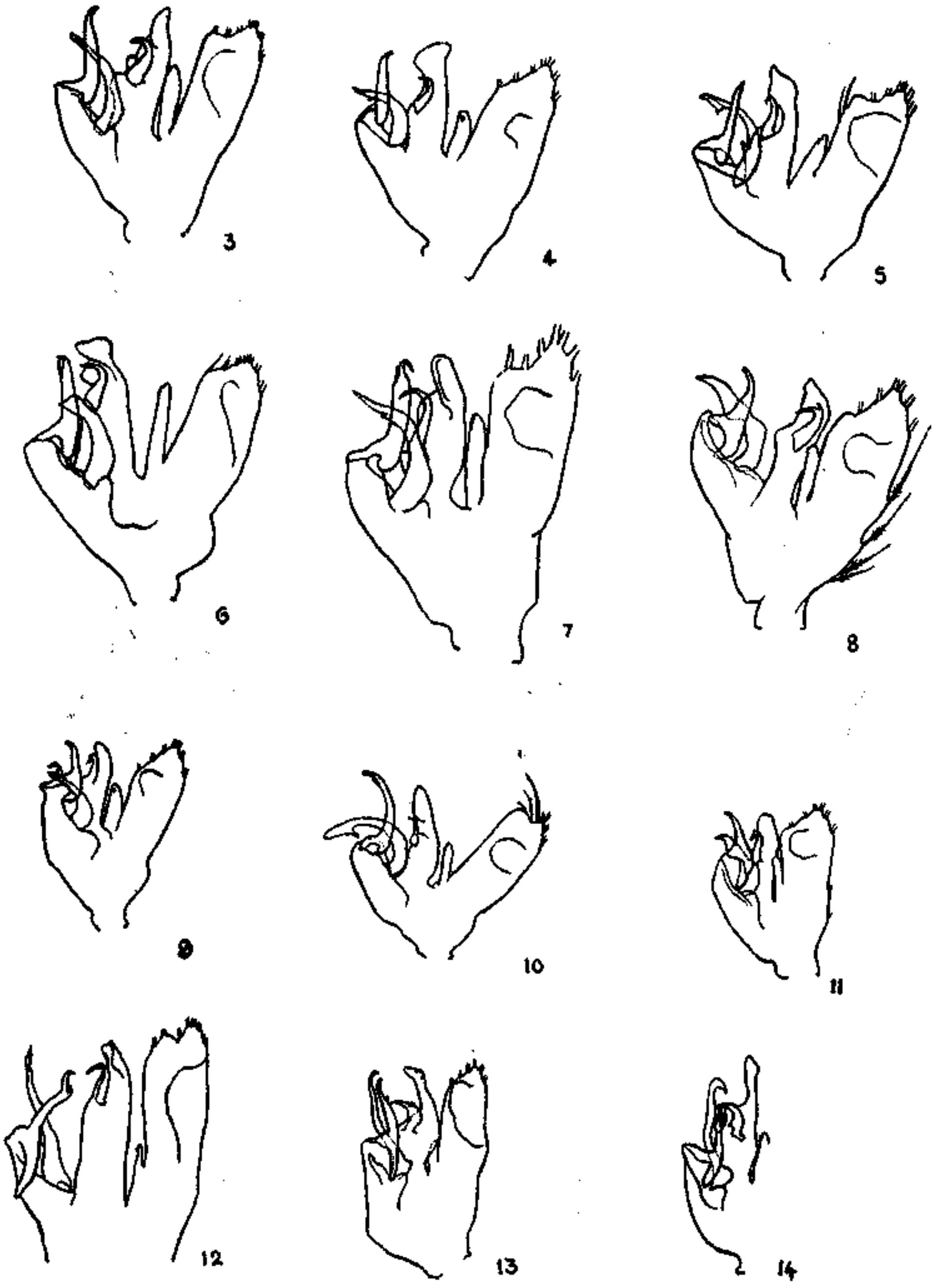
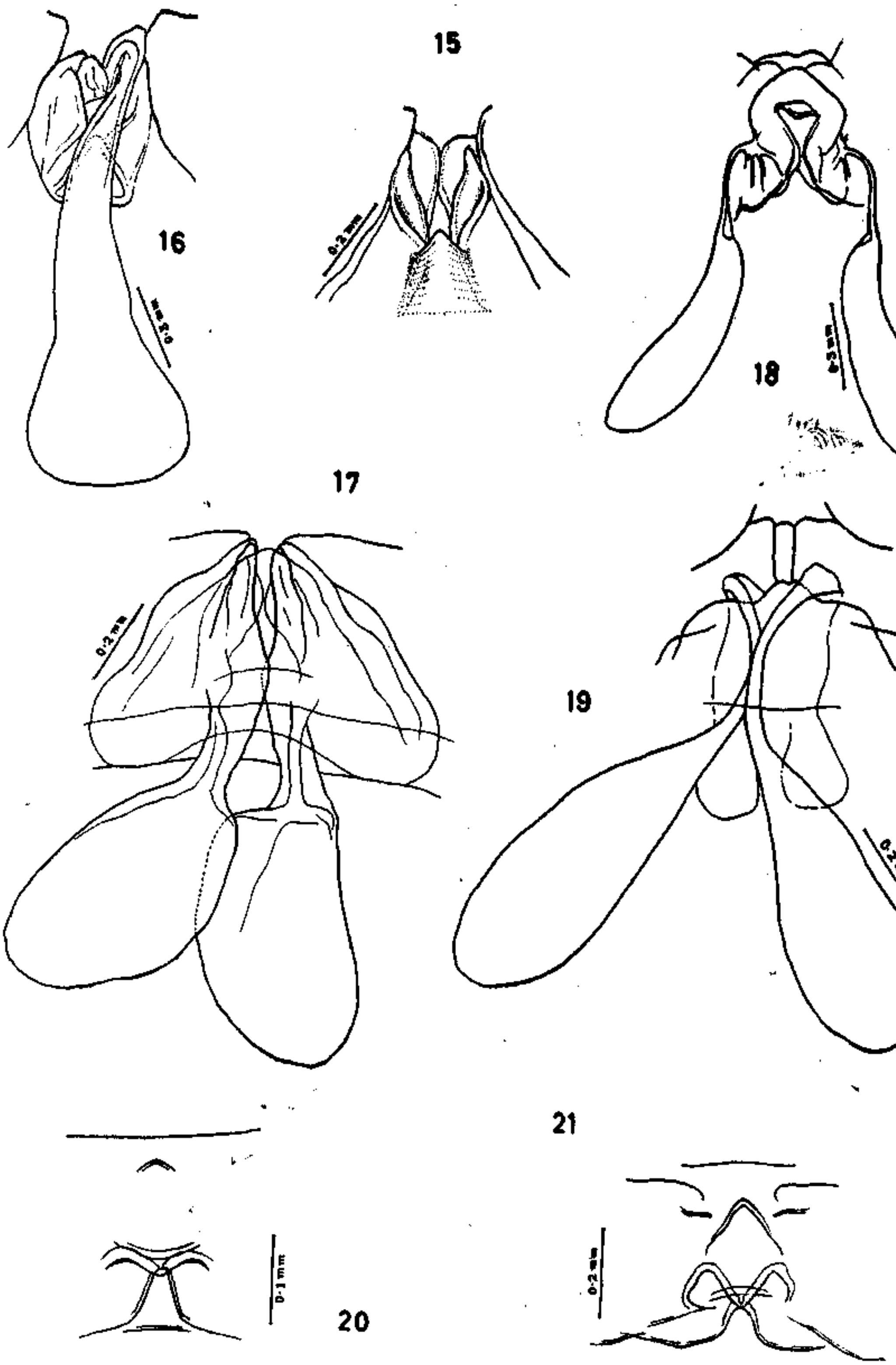
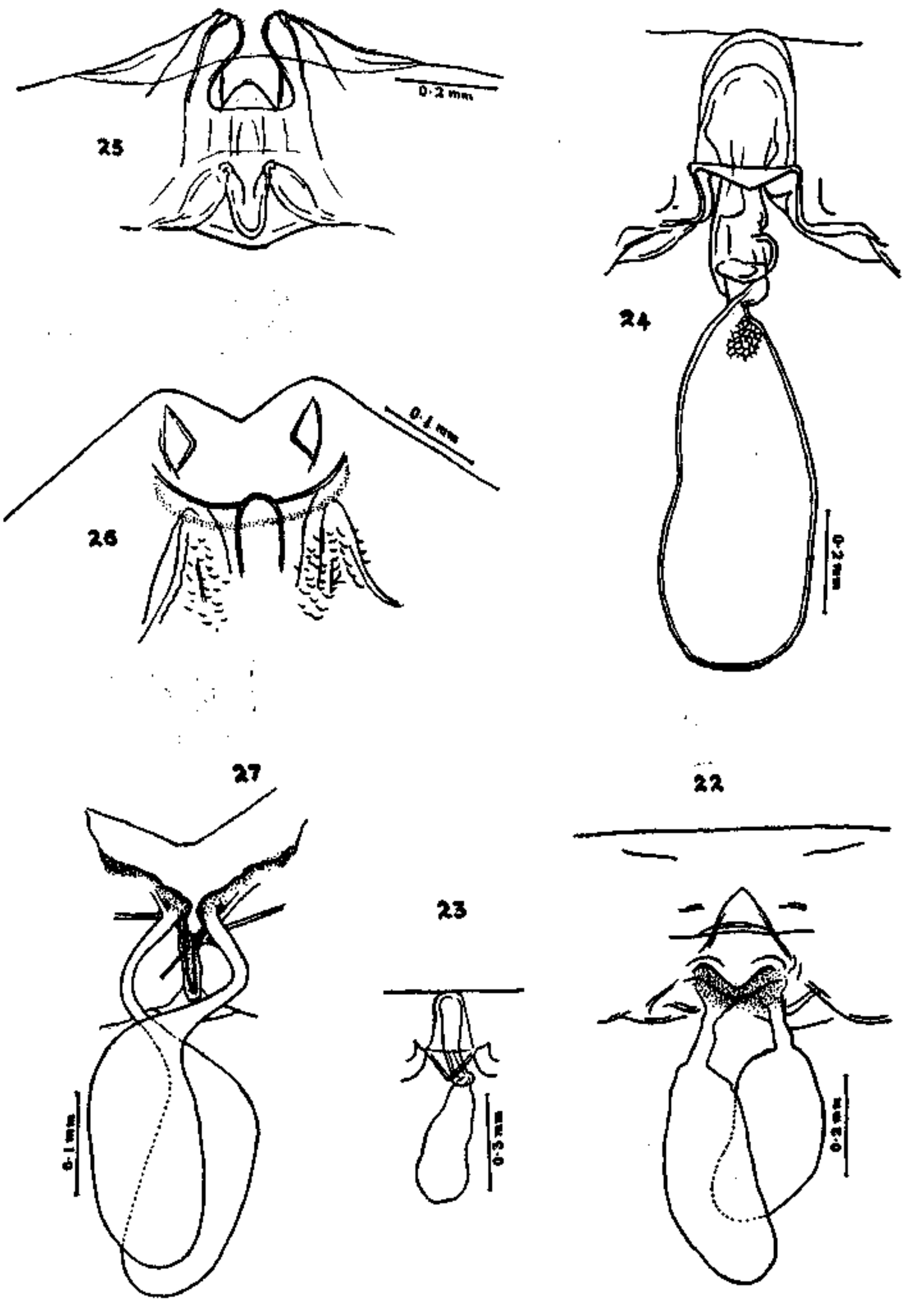


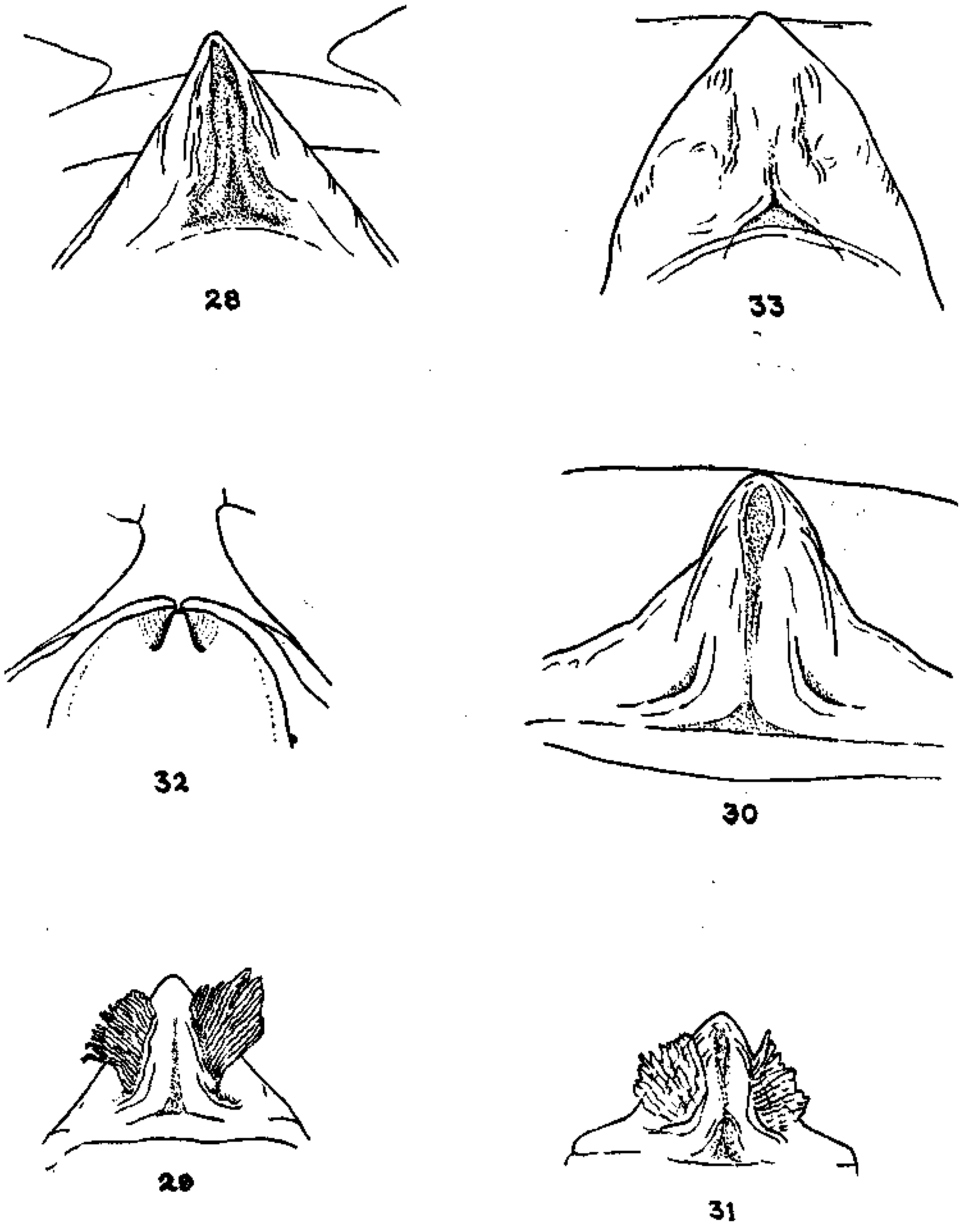
Figs. 3–14. Showing the specific nature of petasma in *Euphausia* spp. (Figs. mostly after Hansen, 1910 and 1912); (3) *E. eximia*; (4) *E. brevis*; (5) *E. gibboides*; (6) *E. recurva*; (7) *E. diomedeae*; (8) *E. distinguenda*; (9) *E. tenera*; (10) *E. mutica*; (11) *E. sibogae*; (12) *E. hemigibba*; (13) *E. paragibba*; (14) *E. pseudogibba*.



FIGS. 15–21. Thelyca in different species showing their specific nature. (15) *Thysanopoda tricuspidata*; (16) same, with spermatophore; (17) *T. aequalis*; (18) *T. monacantha*; (19) *T. orientalis*; (20) *Euphausia distinguenda* (young); (21) same, adult without spermatophore.



Figs. 22–27. Thelycum in different species. (22) *Euphausia distinguenda*, with spermatophore; (23) *E. diomedeae*; (24) same, large female measuring 20 mm.; (25) *Nematobrachion boopis*; (26) *N. flexipes*; (27) *Stylocheiron longicorne*.



FIGS. 28–33. Thelycum in *Nematoscelis* spp. (28) *N. gracilis*; (29) same, with spermatozoa; (30) *N. microp*: (31) same, with spermatozoa; (32) *N. megalops* (after Einarsson, 1942); (33) *N. tenella*.

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DISCUSSION

Dr. R. D. Turner: How did you identify the females? Is it by laboratory methods of allowing the females to copulate with identified males?

Mr. M. J. Sebastian: It is possible, though with some difficulty, to identify many female euphausiids on the basis of a number of structural details which they share in common with the males. In such cases the thelycum presents a single morphological character which enables easy identification. And in cases where the species are separated only on the basis of minute differences in the petasma, as in the case of *E. gibboides* and *E. sanzoi*, it is hoped that these studies on the thelyca may turn out to be useful.

Dr. V. Hansen: It is difficult to rear the euphausiids in the laboratory. Have you been able to identify their larvae ?

Mr. M. J. S.: No. Only the systematics of the adults are dealt with here. The larval development of many species of euphausiids of this region is yet to be studied.

Dr. J. H. Wickstead: Are there any different populations in your collections ?

Mr. M. J. S.: *Eupheasia distinguenda* obtained in those collection represent a population distinct from those described from elsewhere.

Dr. E. G. Silas: Is there any possibility of females escaping the sampling net, they being smaller than the males ?

Mr. M. J. S.: No. I do not think so.

Dr. V. Hansen: Have you examined collections from the guts of fishes ?

Mr. M. J. S.: No. I have not examined.

REMARKS ON EUPHAUSIACEAN PHYLOGENY*

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ABSTRACT

Some observations are made on the relationship of the Euphausiacea to the penaeid Decapoda. Remarkably similar adaptations to the pelagic environment have been made by the Euphausiidae and the Sergestidae, leading to the suggestion made by recent writers that the two groups are taxonomically at least co-ordinate.

THE interrelationships of the major groups of the higher Crustacea are not fully understood. Once allied with the Mysidacea in the old malacostracan order Schizopoda, the Euphausiacea were established as an independent order of the division Eucarida by Boas in 1883. Euphausiid gills are attached to the thoracic coxopodites and situated outside of the carapace. Though not modified as true maxillipeds in most genera, one or more of the first three pairs of thoracic legs are elongated or otherwise modified for feeding or for reproduction. Adult mysids and euphausiids retain thoracic exopods, while the adult Decapoda do not, except in Caridea.

As in the decapods, the euphausiid carapace is fused with all thoracic segments. Like the penaeideans *Penaeus* and *Sergestes*, many epipelagic euphausiids hatch from the egg as nauplii and pass through free zoea-like (calyptopis and furcilia) stages. Early life-histories of species belonging to the deep-living genera *Bentheuphausia* and *Thysanopoda*, which appear to be the primitive genera of Euphausiacea, and of species in the more specialized genus *Nematobrachion*, are not known.

Gurney (1942) was the first to definitely place the Euphausiacea in the Decapoda, making them co-ordinate with Eudecapoda. Isabella Gordon (1955) reviewed the basis for Gurney's decision to unite the two orders. She presented unpublished views of Kemp, who believed that the Euphausiacea are true Decapoda related to the Sergestidae, and of Calman, who suggested making Euphausiacea co-ordinate with Penaeidea, Caridea and so forth. Gurney favoured uniting the groups with free nauplius-protozoea development (Euphausiacea, Penaeidea) in one suborder, co-ordinate with the rest of the Decapoda.

Gordon summarized the evidence for placing the Euphausiacea in the lower Decapoda:

"Most Eucarida incubate their eggs, which are attached to the abdominal pleopods; but neither Euphausiacea nor Penaeidea do this—their eggs are either shed freely or adhere for a brief period to the posterior thoracic appendages. Moreover, Euphausiacea and Penaeidea are the only Malacostraca with free nauplius larvae. Penaeidea would appear to be more primitive than Euphausiacea; for example, there is no compression of the thoracic somites such as occurs in all other Eucarida, and the Penaeidae have elongated pear-shaped nauplii. In Euphausiacea there is extreme compression of the thorax and the appearance of the second and subsequent thoracic appendages is long delayed, except in *Euphausia superba*, which acquires precociously the swimming and feeding habits of the adult. Euphausiid development, though

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> gradual as in many Penaeidae, is remarkably close to that of the Sergestidae, where there is abrupt metamorphosis at the end of each phase. In Sergestidae also, there is the same tendency to reduction or loss of the last two pairs of thoracic appendages (post-larva *Lucifer*), and, in some species at least, to enlargement and modification of one pair of maxillipeds. Then there is general similarity of such adult structures as the male copulatory petasma and spermatophores, the female sperm receptacle (thelycum) and the photophores. The resemblances far outweigh the differences, chief of which is that in euphausiids the gills, which are specialized podobranchs, are exposed, not concealed by the carapace—but *Lucifer* has no gills at any stage."

The retention of various primitive characteristics has accompanied the development of highly specialized structures in almost all groups of Mysidacea, Euphausiacea, and Decapoda, obscuring the relationships. The evolutionary pathways are not clear, but the combination of primitive and specialized characters is emerging as a general principle.

Free shedding of eggs or attachment of eggs to thoracic legs.—Free shedding of eggs would appear to be of importance in adaptation to the upper pelagic zone of the open ocean, where broad dispersal is, obviously, a selective asset. Sergestids, alone among the decapods, and euphausiids have independently colonized these extensive regions.

In euphausiids, in which the pleopods are actively and continuously used for swimming, the eggs are attached to the posterior thoracic legs in five specialized genera. Such attachment may be indirectly related to the filtering mode of feeding of the epipelagic forms, inasmuch as there are no appendages which could effect the transfer of eggs to the under side of the abdomen. In *Pseudeuphausia, Meganyctiphanes, Nyctiphanes,* and possibly also *Nematoscelis,* as well as in near-shore penaeids, the early free shedding of eggs was eliminated in conjunction with colonization of coastal habitats. In *Stylocheiron* the attachment of eggs may be correlated with the greatly reduced number of eggs produced.

Free nauplius larvae.—The evidence is not conclusive that free naupliar-protozoea development is a primitive characteristic that bears weight at the ordinal level of crustacean calssification. It has not been determined whether or not the primitive euphausian genera, *Bentheuphausia* and *Thysanopoda,* have free naupliar stages. It is somewhat surprising that nauplii, commensurate in size with the large calyptopis larvae that have been recognized in a number of *Thysanapoda* species, have not been found. It is even more curious that no larval stages of *Bentheuphausia* have been found; individuals 6 mm. long, at which length *Thysanopoda acutifrons, T. monacantha,* and *T. pectinata* are in early furcilia stages, are post-larval. Similarly, prefurcilia of another deep-water genus, *Nematobrachion,* are still unknown.

There is a distinct possibility that some larval stages are passed within the egg as an adaptation of certain bathypelagic euphausiids, the eggs of which are not incubated in the warm, productive surface layers. In the same way that a variety of near-shore crustaceans have reduced the hazards of neritic larval life by passing early stages in berried eggs, the reduction of the early free-larval life would, in the bathypelagic zone, tend to reduce problems of larval feeding. At the same time, a long larval life would be of no obvious selective advantage from the standpoint of dispersal mechanisms in the monotonous environment of the deep sea, if the larvae occupy the same strata as the adult, and are not, therefore, differentially transported.

On the other hand, it might be that a pushing-back of the free-larval life to the nauplius stage has evolved secondarily in some neritic, epipelagic, or vertically migrating forms, as a means of promoting dispersal of populations by use of the vigorous current systems of the upper layers. Accompanying the adaptation of sergestid stocks to the upper pelagic zone and of penaeids to coastal waters, a long free-larval life could have this advantage. For the penaeids, the eggs of which are demersal according to Gurney, this would be of particular importance.

Compression of the thoracic somites.—It is difficult to assess what phylogenetic significance should be attached to the relative expansion of the thoracic somites in early protozoeal stages of some penaeids and sergestids. Uniformity of the thoracic segments is certainly an unspecialized character.

In the euphausiid calyptopis and caridean protozoea the thoracic somites are much compressed, as Gordon has pointed out, and remain relatively compressed throughout growth. The segments, here, appear to have been reduced in size (compressed) with the emergence of the mode of feeding of euphausiids: none are pure filter-feeders, but all appear to utilize anterior thoracic limbs for a measure of selective feeding. Euphausiids are among the largest of the zooplankters and much of the potential food of such plankters is large and active.

Penaeids, on the other hand, retain relative uniformity of the thoracic segments. This may be a consequence of the benthic and epibenthic habitat occupied by the group during most of its evolutionary history. Sergestids appear to be neotenic penaeid invaders of the pelagic environment.

Abrupt larval metamorphosis.—Euphausiids and, of the penaeids, sergestids undergo three separate periods of larval development. These are essentially defined upon the basis of the change or function of appendages or the presence or absence of appendages. Metamorphosis in sergestids (nauplius-elaphocaris-acanthosoma-mastigopus) is accomplished with less ontogenetic alacrity than the anamorphic nauplius-calyptopis-furcilia development in euphausiids. This difference suggests a more constant environment for euphausiids during their evolutionary history; penaeids have occupied benthic and pelagic zones. Similar sequences of development may be construed as evidence that the groups in which they occur are related. However, it must be emphasized that essentially the same epi-planktonic niche is occupied by the two groups. This fact would, in itself, be interpreted by some ecologists as evidence that the groups are probably not closely related.

It is alternatively proposed that larval metamorphosis is a specialized adaptation which serves to provide elements of large larval planktonic populations with a degree of ecological independence from each other. A calyptopis, newly equipped with three pairs of functional post-mandibular appendages, certainly occupies a different feeding niche from a furcilia which has acquired thoracic legs and pleopods that aid it in starting vertical migrations. The furcilia-adolescent metamorphosis entails loss of the natatory role of the antennae and increased pleopod function. The extent of vertical migration is increased and new food resources may be tapped at both extremes of the range.

Metamorphosis may be interpreted in another way as a specialized planktonic adaptation. Spawning and availability of food for larvae are, under optimal conditions, simultaneously initiated in a moving water mass. The events of growth, maturation, and decay of the food supply might be accompanied by successively distinct feeding habits (rather than intergrading habits) of the larval euphausiid (or sergestid) population, achieved through metamorphosis. When vertical migration is fully developed, the population will have attained, according to the postulate of Hardy (1956), nearly complete independence from a local water mass.

Modification and reduction of thoracic appendages.—Like mysids, euphausiids retain well-developed exopods, which are functional in swimming and in circulating water toward the gills and the thoracic basket. The bathypelagic oplophorids (carideans) have retained a somewhat reduced exopod, but the adult sergestid has entirely lost the exopod.

Thoracic legs are not modified as true maxillipeds in euphausiids. In accordance with partial reliance on filter-feeding, the anterior legs form a part of the complex screening basket, which is constructed (according to Barkeley, 1940, for *E. superba*) of superimposed screens: a superficial screen made up of coarse setae which prevents large material (30–40 μ) from clogging the fine (7 μ)

screen. However, in certain euphausiid genera one pair of anterior legs (two in *Tessarabrachion*) are greatly elongated.

Maxilliped development in mysids has been brought about by the reduction, rather than elongation, of the first pair of thoracic legs; in decapods the first three pairs are reduced and modified. In this respect, the more primitive euphausiid genera have retained a characteristic which is more unspecialized than the homologous condition in mysids.

The modification in decapods of three pairs of maxillipeds appears to have been correlated with the same bottom-dwelling habits that were related to the development of the five posterior thoracic legs as walking and grasping appendages.

The morphology of *Sergestes* suggests the subsequent modification toward filter-feeding of legs that in another habitat had served a variety of functions. The two anterior pairs are retained as maxillipeds, although the second pair is more than twice as long as the first. The third to sixth legs are coarsely setose, and differ greatly in length. The seventh and eighth legs bear rows of long, very closely spaced setae, probably used for fine filtering.

As in euphausiids, the modification of the two anterior pairs of pleopods for spermatophore transfer has accompanied the development of the filtering function of the thoracic legs.

Why *Lucifer* has entirely lost its posterior thoracic legs is not clear. In fact, it is difficult to understand why *Lucifer* looks the way it does, resembling the mastigopus larva of *Sergestes*. *Lucifer* subsists without gills, and probably does not need them because it has great surface area compared to volume. It has no use for the posterior thoracic legs, one of the main functions of which in euphausiids is the support of gills, and of exopods to push water past them.

If the reduction of the posterior thoracic legs in euphausiids and *Lucifer* suggests relationship, it is not accompanied by analogous modifications of the other legs. When the last pairs of thoracic legs of euphausiids are most reduced, this is accompanied by the appearance, anteriorly, of one or two pairs of very long legs, which may be used for selecting food particles. Here, the need for a large filtering basket is reduced, and the size of the thoracic legs progressively decreases posteriorly. Some *Stylocheiron* species have true chelae which, clearly, have evolved independently from those in decapods. Differing from what occurs in euphausiids, the fourth to sixth thoracic legs of *Lucifer* increase in length posteriorly, while the seventh and eighth legs are entirely lacking.

In general, then, the similarities of sergestids to euphausiids seem to be explicable in terms of their comparable habits. Barham (1956) has shown that the sonic scattering layer in the vicinity of Monterey, California, is made up mainly of sergestids and euphausiids. Euphausiids, compared with decapods, show a preponderance of unspecialized features. Of the two groups the euphausiids are most like the primitive mysids (Lophogastridae), although not even *Bentheuphausia* has the uncoalesced sixth and seventh abdominal segments shown by *Gnathophausia*.

Photophores characterise many mesopelagic crustaceans, particularly those associated with the sonic scattering layer. But the complex light organs of euphausiids are more like those of the caridean *Systellaspis* (*cf.* Dennell, 1940, for figures of *Systellaspis* photophores) than like the superficial ones of *Sergestes* (Welsh and Chace, 1938). Even the bathypelagic mysid *Gnathophausia* has maxillar photophores.

As Gordon has pointed out, degree of primitiveness cannot be judged entirely in terms of adult characteristics, nor in terms of larval characteristics alone. The features that are to be given significance in classification and in determining relationships must each be weighed in the light of the likely disguises of convergent evolution, hence, in the light of function.

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ON SPINY LOBSTERS OF THE GENERA *PALINURELLUS*, *LINUPARUS* AND *PUERULUS* (CRUSTACEA DECAPODA, PALINURIDAE)

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ABSTRACT

The two known species of *Palinurellus* are discussed and new locality records provided; the question of the presence or absence of pleopods on the first abdominal somite in the two sexes is considered but no satisfactory solution reached. The only known living species of *Linuparus*, *L. trigonus* (Von Siebold) is now reported for the first time from the Philippines. A lectotype is selected. The genus *Puerulus* is revised, and a key to the three species provided. *Puerulus angulatus* (Bate), the type of the genus is extensively described and its synonymy is discussed. The two other species, *P. sewelli* Ramadan and *P. velutinus* Holthuis are described and compared with *P. angulatus*. Of all the genera and species treated a complete synonymy is provided.

DURING a year's stay in Washington, D.C. (1959–60) the Decapoda Macrura Reptantia of the U.S. National Museum were studied by me and some interesting finds were made in the rich and well-kept collections. In the present paper part of the examined material is dealt with, while also specimens from other institutions are taken into account.

I wish to express here my sincere gratitude to Dr. Fenner A. Chace, Jr., at that time Curator of the Division of Marine Invertebrates of the U.S. National Museum, who made the arrangements enabling me to pay this visit to the United States, and who has continuously given me all the help that I needed to carry out my work. I am also very grateful to the other members of the staff of the division for their kindness and help. Furthermore I should like to express my indebtedness to Dr. Isabella Gordon of the British Museum (Nat. Hist.), London, Dr. Gilbert L. Voss and Dr. Frederick M. Bayer of the Institute of Marine Science, Miami, and Dr. J. H. Stock of the Zoological Museum, Amsterdam, for allowing me to study material of the collections of their institutions and for valuable help and advice.

Part of the material studied has been published upon elsewhere (*cf.* Holthuis, 1960, 1961; Holthuis and Villalobos, 1962; Holthuis, 1963, 1964), and part will be included in future publications. The present paper deals with three of the genera of Palinuridae, of which all the known species are listed here.

Palinurellus Von Martens, 1878

Palinurellus Von Martens, 1878, *S.B. Ges. naturf. Freunde Berlin*, 1878, p. 131. Type species, by monotypy: *Palinurellus gundlachi* Von Martens, 1878, *S.B. Ges. naturf. Freunde Berlin*, 1878, p. 131. Gender: masculine.

Synaxes Bate, March 1881, *Ann. Mag. nat. Hist.*, ser. 5, **7**: 220. Type species, by monotypy: *Synaxes hybridica* Bate, 1881, *Ann. Mag. nat. Hist.*, ser. 5, **7**: 220 (a junior subjective synonym of *Palinurellus gundlachi* Von Martens, 1878). Gender: feminine.

Araeosternus De Man, July 1881, *Notes Leyden Mus.*, **3**: 131. Type species, by monotypy: *Araeosternus wieneckii* De Man, 1881, *Notes Leyden Mus.*, **3**: 131. Gender: masculine.

Araeosterrus Bouvier, 1910, *Bull. Mus. Hist. nat. Paris*, **16:** 377. Erroneous spelling of *Araeosternus* De Man, 1881.

Palidurellus Torralbas, 1917, *Anal. Acad. Ci. med. fis. nat. Habana*, **53:** fig. 46. Erroneous spelling of *Palinurellus* Von Martens, 1878.

Palinurella F. G. W. Smith, 1948, *Fish. Ser. Caribb. Comm.*, No. 3, p. 12. Erroneous spelling of *Palinurellus* Von Martens, 1878.

The genus contains two species, one Atlantic, the other Indo-West Pacific.

Palinurellus wieneckii (De Man, 1881)

Araeosternus wieneckii De Man, 1881, p. 131.

Araeosternus wieneckei Winkler, 1881, p. 105, pl. 1, fig. 3; Winkler, 1882, p. 146.

Araeosternus wieneckei De Man, 1882, p. 1, pls. 1, 2.

Palinurellus wienecki De Man, 1882 *a*, p. 162.

Palinurellus Wieneckii Pfeffer, 1883, p. 103; Bouvier, 1915, p. 186, pl. 7, fig. 2; De Man, 1916, p. 34.

Palinurellus wieneckii Ortmann, 1891, p. 16.

Palinurellus Wienecki Bouvier, 1910, p. 376; Gruvel, 1911, p. 1350; Bouvier, 1914, p. 701; Belloc, 1959, p. 9.

Palinurellus Gunlachi Wieneckii Gruvel, 1911 *a*, p. 9, pl. 1, figs. 1, 2.

Palinurellus gundlachi wieneckei Holthuis, 1946, p. 114, pl. 11, fig. 9; Chace and Dumont, 1949, p. 11.

Material Examined

U.S. National Museum, Washington

Danawan Island near Darvel Bay, N. E. Borneo; in stomach of *Epinephelus fuscoguttatus* (Forskål); 27 September 1909; "Albatross" Philippine Expedition 1907-1909.—1 ♂, cl. 65 mm.

Lagoon reef at southern end of Falarik Island, opposite the Fannap (= men's house), Rauau village, Ifaluk Atoll, Caroline Islands; 14 September 1953; F. M. Bayer no. 334.—dry fragments, cl. 44 mm.

Rijksmuseum van Natuurlijke Historie, Leiden

Pulu Tikus (= Rat Island) near Benkulen, S. W. Coast of Sumatra; 1865; G. F. Wienecke; holotype.—1 ♂, cl. 80 mm. (reg. no. Crust. D. 965).

British Museum (Nat. Hist.), London

Mauritius.—1 specimen, cl. 72 mm. (dry).

The fragments from Ifaluk Atoll, which were described by the collector as "parts of a bright red, fuzzy lobster", were found in a coral head of the lagoon reef. They consist of the entire carapace to which the sternum is still attached, while it also carries the entire left antennal peduncle and the two basal segments of the right. Of all the other cephalic and thoracic appendages only one of the large first legs is present. The abdominal skeleton is fairly complete: it lacks all but the first pair of pleopods and one of the uropods. The Borneo specimen is 137 mm. long and in rather good shape. Both specimens agree well with De Man's (1881, 1882) descriptions and figures, only in both the rostrum is longer, reaching distinctly beyond the anterolateral angles of the carapace and almost attaining the middle of the second segment of the antennal peduncle. It is triangular and pointed, the lateral margin showing several small teeth, the proximal of which is the largest. In the shape of the rostrum the present specimens show a great resemblance to that figured by Bouvier (1915). A re-examination of De Man's type specimen, which is preserved in the Leiden Museum, showed the distal margin of the rostrum to be somewhat irregular so that it is quite well possible that its shape is abnormal, *e.g.*, through breaking and subsequent regeneration of the tip.

In the Ifaluk specimen the first pereiopod is somewhat more slender than that of the type, but this is evidently due to the fact that the specimen is much smaller; in the Bornean specimen the first pereiopods are as robust as in De Man's type.

The first abdominal somite of the Bornean male shows no sign of pleopods, and in this respect it is similar to the type, also a male. In the Ifaluk specimen, however, the first abdominal somite bears a pair of pleopods, each of which consists of two segments. Unfortunately, the specimen is too fragmentary to allow the determination of its sex. It would not be surprising, however, if it were a female. The question of the presence or absence of the first pleopods in specimens of this genus is quite interesting. Boas (1885, p. 183), who examined the type of *Palinurellus gundlachi* Von Martens, which is a female, remarked that the species has a pair of pleopods on the first abdominal somite; these pleopods consisting of a single branch. Such pleopods are figured also by Bate (1881, pl. 14, fig. 2) for the type of his *Synaxes hybridica* (= *Palinurellus gundlachi*), which likewise is a female. Bouvier (1915, p. 10) stated that Boas (1880) and Calman (1909) " ont justement observé que les *Palinurellus*, à l'encontre des autres Palinuridés, présentent encore des fausses pattes sur le premier segment abdominal". This statement seems to indicate that these first pleopods also are present in Bouvier's male specimen. However, this same specimen has been figured by Gruvel (1911 *a*, pl. 1, figs. 1, 2) and Gruvel's fig. 2, showing the ventral view of the animal, makes it clear that these pleopods actually are missing, at least at the time that the photograph was taken. In six males and four females of *Palinurellus gundlachi*, which I could examine, I found that in the males the first pleopods are invariably absent, while they are present in the females. There is thus a strong indication that the presence of first pleopods in females of this genus and their absence in males is a constant character. However, Calman (1909, p. 443) in a footnote emphatically stated: " I find that they [*i.e.*, the pleopods of the first abdominal somite] are also present in a male specimen belonging to this genus [= *Palinurellus*] in the British Museum collection". This specimen, the above-mentioned male from Mauritius, is still present in the British Museum. Dr. Isabella Gordon was so kind to examine this dry specimen again and remarked (in litt., 2 October 1964): " I can verify Calman's statement, for the genital ♂ openings are distinct on coxae p5 and there are indeed two small lash-like pleopods on the first abdominal sternum "...." I can see no trace of ♀ genital openings on coxae 3." The specimen might be abnormal, but as Dr. Gordon stated there are no clear indications for that. The problem of the presence or absence of the pleopods of the first abdominal somite therefore still remains unsolved.

The colour of the present species is not known. Dr. F. M. Bayer, when collecting the Ifaluk specimen noted it to be bright red, a colour still shown by the preserved animal. As at the time of collecting the lobster was already dead and broken up, it is not certain that this is the true colour in life.

Distribution.—So far, *Palinurellus wieneckii* was only known from Port Louis, Mauritius (Bouvier, 1910; Gruvel, 1911, 1911 *a*; Bouvier, 1914, 1915) and Pulu Tikus near Benkulen, Sumatra (De Man, 1881; Winkler, 1881, 1882; De Man, 1882, 1882 *a*; Pfeffer, 1883; Ortmann, 1891; Holthuis, 1946), so that the present records of the species from Borneo and the Caroline Islands greatly extend our knowledge of its range.

Type locality.—Pulu Tikus near Benkulen, Sumatra, Indonesia.

Palinurellus gundlachi Von Martens, 1878

Palinurellus Gundlachi Von Martens, 1878, p. 131; Pfeffer, 1881, p. 23; Boas, 1882, p. 112; Gruvel, 1911, p. 1350; Belloc, 1959, pp. 8, 9.

Palinurellus Boas, 1880, p. 92, figs. 2, 3.

Synaxes hybridica Bate, 1881, p. 220, pl. 14; Bate, 1888, p. 88, figs. 11, 12.

Palinurellus gundlachi Ortmann, 1891, p. 16; Stebbing, 1893, p. 197; Verrill, 1922, p. 179; Holthuis, 1946, p. 109; Smith, 1948, pp. 47, 79: Holthuis, 1956, p. 113; Hemming, 1958, p. 136; Morice, 1958, pp. 105, 106; Smith, 1958, p. 9; Smith, 1958 *a*, p. 8, 2 figs.; Morice, 1959, pp. 1, 3; Smith, 1959, p. 9.

Palinurellus Gunlachi Gruvel, 1911 *a*, p. 8, figs. 2, 3.

Palinurellus gundlachi gundlachi Chace and Dumont, 1949, p. 11; Smith, 1954, p. 463.

Palinurellus gundlachii Smith, 1958, p. 12; Smith, 1959, p. 12.

Material Examined

Institute of Marine Science, Miami

Isolated coral head off westernmost tip of N.W. Cay, Hogsty Reef, Bahama Islands; 29 May 1962; Chaplin Bahama Expedition Sta. 580.—1 ♀, cl. 50 mm.

Box Island, N. of Green Cay, Bahama Islands; 14 May 1959; Chaplin Bahama Expedition Sta. 496.—1 ♂, cl. 35 mm.

N. of Green Cay, Bahama Islands; 11 April 1959; Chaplin Bahama Expedition Sta. 513.—1 ♂, cl. 41 mm.

0·5 miles S.S.W. of Alligator Reef Light, Monroe Co., S.W. Florida; at ledge, 15–20 feet deep; 30 April 1961; Walter A. Starck II, Henry A. Feddern, and Terry Starck.—2 ♂♂, cl. 23 and 53 mm.; 1 ovigerous ♀, cl. 38 mm.; 1 juvenile, cl. 11 mm.

Bahia de Yegua, N.E. Puerto Rico; 12 November 1957; John E. Randall and D. S. Erdman.—1 ♂, cl. 48 mm.; 1 ♀, cl. 61 mm.

Yucatan; 22 June 1961; W. A. Starck II.—1 ♂, cl. 31 mm.

Zoological Museum, Amsterdam

Off Parguera Island, Tallaboa Bay near Guayanilla, Puerto Rico; near the margin of the shelf; depth 20–35 m.; collected with rotenone; 3 March 1963; J. H. Stock.—1 ♀, cl. 32 mm.

The present species was considered rare, and so far only four specimens have been reported upon. As shown by the above collections, the specimens of which were obtained by Scuba diving and with the use of rotenone, the species is not rare, but only lives in rather inaccessible places.

Distribution.—The species has been reported from the following localities: Bermuda (Verrill, 1922), West Indies (Bate, 1881, 1888; Boas, 1882), Camaricoia, E. of Matanzas, Cuba (Von Martens, 1878; Boas, 1882), Barbados (Pfeffer, 1881). The present records from the Bahamas, Florida, Puerto Rico, and Yucatan, thus more than double the number of known localities for the species.

Type locality.—Camaricoia, E. of Matanzas, Cuba.

Linuparus White, 1847

Linuparus White, 1847, *List Crust. Brit. Mus.*, p. 70, Type species, by monotypy: *Palinurus trigonus* Von Siebold, 1824, *Spicil. Fauna Japon*, p. 15. Gender: masculine.

Avus Ortmann, 1891, *Zool. Jb. Syst.*, **6**: 15, 21. Type species, by monotypy; *Palinurus trigonus* Von Siebold, 1824, *Spicil. Fauna Japon.*, p. 15. Gender: masculine.

Linuparis Ortmann, 1891, *Zool. Jb. Syst.*, **6**: 21. Erroneous spelling of *Linuparus* White, 1847.

Limparus Sclater, 1937, *Zool. Rec. Crust.*, **73** (for 1936): 37. Erroneous spelling of *Linuparus* White, 1847.

Liunparus Yoshida, 1941, *Bull. Fish. Exper. Sta. Tyosen*, no. 7, p. 32. Erroneous spelling of *Linuparus* White, 1847.

Several fossil species are assigned to the present genus. Some authors consider such fossil species as belonging to separate genera (*Podocratus* Geinitz, 1850, and *Thenops* Bell, 1858). Only one recent species is known so far.

Linuparus trigonus (Von Siebold, 1824)

Palinurus Trigonus Von Siebold, 1824, p. 15; Von Siebold, 1826, p. 20; Herklots, 1861, p. 143.

Palinurus trigonus De Haan, 1841, p. 157, pls. 39/40; De Haan, 1844, pls. L, M; Von Martens, 1876, p. 142; Heller, 1865, p. 94; Boas, 1880, p. 91; Fauvel, 1880, p. 196; Parker, 1883, p. 190; Parker, 1884, p. 304; Holthuis, 1956, p. 113; Hemming, 1958, p. 136.

Linuparus trigonus White, 1847, p. 70; Thompson, 1901, p. 18; Gruvel, 1911, p. 1351; Gruvel, 1911 *a*, p. 26, text-fig. 10, pl. 1, fig. 5; Balss, 1914, p. 76; Parisi, 1917, p. 8; Gee, 1925, p. 159; Komai, Akatsuka and Ikari, 1927, p. 294; *Fish. Soc. Japan*, 1935, pl. 58, fig. 1; Oo-U-Kijo, 1936, p. 385, figs. 1–3; Yoshida, 1941, p. 32, text-fig. 14, pl. 8, fig. 2; Holthuis, 1946, p. 121, pl. 11, figs. *i*, *j*; Chace and Dumont, 1949, p. 8, fig. 4; Barnard, 1950, p. 820; Okada, 1951, p. 85; McNeill, 1953, p. 89; Anonymus, 1954, p. 760, fig. 2190; McNeill, 1956, p. 53, fig.; Okada, Taki, Sakai and Abe, 1958, p. 143; fig. 258; Tung, Hu and Yu, 1958, p. 166; Kubo, 1960, p. 101, pl. 50, fig. 1; Liu, 1963, p. 232.

Avus trigonus Ortmann, 1891, p. 21; Bouvier, 1899, p. 175.

Linuparis trigonus Stebbing, 1893, p. 197; Doflein, 1902, p. 643; Doflein, 1906, pp. 198, 256; Komai and Ikari, 1929, p. 121.

Puerulus carinatus McNeill, 1949, p. 337, fig.

Material Examined

U.S. National Museum, Washington

Kururi District, Chiba Prefecture, Tokyo Bay, Honshu, Japan; April 1894; Mr. Sakumoto.—1 ♂, cl. 97 mm.

Tainan, Formosa; 20 April 1920; M. Ohshima.—1 ♀, cl. 153 mm.

Corregidor Light N. 26° E. 25·50 miles, Philippines, 14° N. 120° 22′ 30″ E.; mud, shells and coarse sand; 118 fms.; 14 July 1908; "Albatross" Sta. D. 5272.—3 ♂♂, cl. 95–128 mm.; 4 ♀♀, cl. 92–112 mm.

Louis Point Light N. 21° E. 5·5 miles, Philippines, 10° 09′15″ N. 123° 52′ E.; green mud; 162 fms.; 23 March 1909; "Albatross" Sta. D. 5412.—1 ♂, cl. 83 mm.

Baliscasay Island S. 22 miles, Philippines, 9° 52′ 30″ N. 123° 40′ 45″ E.; green mud; 174 fms.; 9 April 1908; "Albatross" Sta. D. 5197.—1 ♀, cl. 117 mm.

Rijksmuseum van Natuurlijke Historie, Leiden

Japan; 1823–1824; P. F. Von Siebold,; lectotype of *Palinurus trigonus* Von Siebold.—1 ♂, cl. 146 mm. (dry, reg. no. Crust. D. 5611).

Japan; 1823–1824; P. F. Von Siebold; paralectotypes of *Palinurus trigonus* Von Siebold.—2 ♂♂, cl. 99 and 120 mm.; 1 ♀, cl. 101 mm. (dry; reg. no. Crust. D. 5610).

Japan; 1823–1835; P. F. Von Siebold and H. Bürger.—7 ♂♂, cl. 104–138 mm.; 2 ♀♀, cl. 100 and 120 mm. (dry).

British Museum (Nat. Hist.), London

Japan; 1823–1835; P. F. Von Siebold and H. Bürger; from Leiden Museum.—1 ♂, cl. 124 mm. (dry).

In the collection of the Leiden Museum four syntypes of the present species are preserved. The largest of these, a male (cl. 146 mm.) is here selected the lectotype of the species. The specimen is dry, but in excellent condition.

Distribution.—Before 1949 this large and characteristic species was known only from Japanese and Chinese waters. In 1949 and 1956 McNeill reported the species from off the coast of New South Wales, Australia, while in 1950 Barnard listed a specimen caught off Portuguese East Africa. The present material from the Philippines partly fills the gap between the widely distant localities whence the species was so far known. The records in the literature are: Japan (Von Siebold, 1824, 1826; White, 1847; Herklots, 1861; Bouvier, 1899; Thompson, 1901; Gruvel, 1911, 1911 *a*; Parisi, 1917; *Fish. Soc. Japan*, 1935; Holthuis, 1946; Anonymus, 1954; Okada, Taki, Sakai and Abe, 1958; Kubo, 1960), Tokyo (= Yeddo) (Von Martens, 1876), Yokohama (Doflein, 1902; Parisi, 1917), Tokyo Bay (Ortmann, 1891), Sagami Bay (Doflein, 1906), Mie Prefecture (Okada, 1951), Seto near Wakayama, Honshu (Komai, Akatsuka and Ikari, 1927; Komai and Ikari, 1929), Kiushu (Balss, 1914), Omura and Shimabara Bays near Nagasaki, Kiushu, Japan (De Haan, 1841), Korea (Yoshida, 1941), Ningpo, Chekiang, China (Fauvel, 1880; Gee, 1925), Chushan, Chekiang (Tung, Hu and Yu, 1958), Formosa (Oo-U-Kijo, 1936), 16–18 miles East of Newcastle, New South Wales, Australia (McNeill, 1956), off Botany Bay, New South Wales (McNeill, 1949, 1953), off Inhambane, Portuguese E. Africa (Barnard, 1950).

Habitat.—The present Philippine material was collected at depths between 118 and 174 fms. The Australian specimens reported upon by McNeill (1949, 1953, 1956) were taken at depths of 50 and 65 fms., while Barnard's (1950) East African animal came from 180 fathoms. Of most of the material reported upon in the literature the depth of collecting is not given. The records in the literature which report on the bottom on which the animals were taken give it as rocky: "in locis saxonis" (De Haan, 1841), "on rocky ground" (Barnard, 1950). The "Albatross" Philippine specimens, however, were taken from muddy bottoms.

Type locality.—In the original publication no indication of the type locality is given, otherwise than that it is Japan. Von Siebold was stationed as a physician at the Dutch trading post of Decima, an island near Nagasaki, where he arrived 11 August 1823. He was allowed to enter Nagasaki, but was not permitted outside these two localities, until 1826 when he joined a Dutch delegation to Tokyo. The material that Von Siebold got together was either (1) acquired at the fish marketat Nagasaki, (2) collected by himself in the area or (3) obtained through his Japanese friends and puipls. Since Von Siebold's booklet containing the first description of *Palinurus trigonus* was published in 1824, he must have obtained the material very soon after his arrival in Japan. It is very likely therefore that it originated from the neighbourhood of Nagasaki. In the possession of the Leiden Museum is a collection of coloured plates of Japanese Crustacea sent to Holland by Von Siebold's assistant H. Bürger, who was in Nagasaki from 1825 to about 1835. Some of these plates are accompanied by a handwritten descriptive text. The text of the plate showing *Linuparus trigonus* ends with the following remarks; "Zeer schaarsch wordt somwijlen in het voor of najaar op rotsachtige gronden in de baaijen van Oomura en Simabara gevangen, en ook wel gegeten." (Very rare, is sometimes caught in the spring or autumn on rocky bottom in the bays of Omura and Shimabara; is also eaten). These remarks obviously were used by De Haan (1841) for his locality indication. It seems most likely that the type locality of the species should be one of these two just mentioned bays of the island of Kiushu not far from Nagasaki. The type locality is therefore restricted here to Omura Bay.

Colour.—Bürger in the above-mentioned manuscript text, gave the following account of the colour of the species: The shell of the body is pale red above with several white spots, below it is entirely white; the shell of the tail is also pale red above, with small blue dots and yellowish irregular spots; the swimming plates at the end of the tail (= tail fan) and under the tail (= pleopods) are yellowish with some white dots; the antennae are reddish and white; the legs white with numerous small bluish dots and a few red spots (translation of the Dutch text). Coloured figures of the species have been published by Fish. Soc. Japan (1935), Okada, Taki, Sakai and Abe (1958), and Kubo (1960).

***Puerulus* Ortmann, 1897**

Puer Ortmann, 1891, *Zool. Jb. Syst.*, **6:** 15, 37. Type species, selected by Calman, 1909, *Ann. Mag. nat. Hist.*, ser. 8, **3:** 442: *Panulirus angulatus* Bate, 1888, *Rep. Voy. Challenger, Zool.*, **24:** 81. An invalid junior homonym of *Puer* Lefebvre, 1842, *Mag. Zool.*, ser. 2, **4:** expl. pl. 92 (Neuroptera). Gender: masculine.

Puerulus Ortmann, 1897, *Amer. Journ. Sci.*, ser. 4, **4:** 290. Substitute name for *Puer* Ortmann, 1891. Gender: masculine.

Belloc's (1959, p. 7) suggestion to use the name *Puer* for the present genus and *Puerulus* for the natant stages of Palinuridae, cannot be followed. *Puerulus* is the valid name for the present genus (*Puer* being preoccupied). It might be much better to avoid using the name *Puerulus* for the young stages of other palinurids altogether.

In a list of Palinuridae known to him at that time the present author in 1946 enumerated 4 species of the genus *Puerulus*, viz., *P. angulatus* (Bate), *P. carinatus* Borradaile, *P. parkeri* (Stebbing), and *P. sewelli* Ramadan (*cf.* Holthuis, 1946, p. 110). Not included in that list was *Puerulus gracilis* Kubo, 1939, which at that time was not known to me.

Jasus parkeri Stebbing, 1902, which was brought by me in 1946 to the genus *Puerulus*, according to Barnard (1950, pp. 540, 541) does not possess a stridulating organ and therefore cannot be maintained in *Puerulus*. It certainly is not a *Jasus* either. The species at the moment is being studied by Dr. R. W. George of the Western Australian Museum, Perth, and Dr. J. R. Grindley, South African Museum, Capetown, who will soon publish their findings. The species is not further considered here.

A study of the material of *Puerulus* present in the U.S. National Museum made it possible for me to gain a better understanding of the status of the various species, so that a revision of the genus proved to be possible. In all I can recognize three distinct species in the genus, which may be identified with the help of the following key:

1. Post-orbital spine present. No teeth but 6 post-cervical and 6 intestinal tubercles on the median carina of the carapace. Tubercles on carapace low and largely obscured by the pubescence. Eyes large, much broader than long.................... *P. velutinus*

—Post-orbital spine absent. Median carina of carapace with 3 or 4 post-cervical and 2 or 3 intestinal teeth. Tubercles of carapace usually distinct and not obscured by the pubescence. Eyes smaller, longer than broad..2.

2. Median carina of carapace with 3 post-cervical and 2 intestinal teeth. Three teeth between the supra-orbital horns and the cervical groove...........*P. angulatus*

—Median carina of carapace with 5 post-cervical and 2 or 3 intestinal teeth. Two teeth between the supra-orbital horns and the cervical groove.................*P. sewelli.*

Puerulus angulatus (Bate, 1888)

Panulirus angulatus Bate, 1888, p. 81, pl. 11, figs. 2–4; Holthuis, 1956, p. 114; Hemming, 1958, p. 138.

Puer angulatus Ortmann, 1891, p. 37; Belloc, 1959, p. 9.

Puerulus angulatus Calman, 1909, p. 442 (pp.); Gruvel, 1911, p. 1350; Gruvel, 1911 *a*, p. 7, fig. 1; Bouvier, 1912, p. 78; Balss, 1925, p. 203; Holthuis, 1946, p. 110.

Puerulus carinatus Borradaile, 1910, p. 261, pl. 16, fig. 5; Ramadan, 1938, p. 133, figs. 6, 7; Holthuis, 1946, p. 110.

Puerulus gracilis Kubo, 1939, p. 316, figs. 1, 2.

not *Panulirus angulatus* Alcock and Anderson, 1894, p. 166; Alcock, 1899, p. 33; Alcock, 1901, p. 185; Sewell, 1913, p. 350.

not *Puerulus angulatus* De Man, 1916, p. 36, pl. 2, fig. 5.

Material Examined

U.S. National Museum, Washington

Malabrigo Light N. 46° W. 20·60 miles, Philippines, 13° 21′ 30″ N., 120° 30′ 33″ E.; 220 fms., green mud; 2 February 1908; "Albatross" Sta. D. 5122.—1 ♂, cl. 48 mm.

Jolo Light S. 46° W. 11·90 miles, Philippines, 6° 11′ 50″ N., 121° 08′ 20″ E.; 161 fms., fine coral sand; 7 February 1908; "Albatross" Sta. D. 5135.—1 ♂, cl. 41 mm., 1 ♀, cl. 45 mm.

Jolo Light N. 82° E. 6·75 miles, Philippines, 6° 02′ 55″ N., 120° 53′ E.; 186 fms., shells and coral; 5 March 1908; "Albatross" Sta. D. 5173.—3 ♂♂, cl. 23–29 mm.

Escarceo Light N. 59° W. 6 miles, Philippines, 13° 28′ 15″ N., 121° 04′ 30″ E.; 180 fms., fine black sand; 23 July 1908; "Albatross" Sta. D. 5293.—2 ♂♂, cl. 26 and 43 mm.

Cape Santiago Light S. 79° W. 4·5 miles, Philippines, 13° 47′ 20″ N., 120° 43′ 30″ E.; 180 fms.; 20 February 1909; "Albatross" Sta. D. 5363.—1 ♂, cl. 55 mm.

Cape Santiago Light N. 73° W. 6·7 miles, Philippines, 13° 44′ 24″ N., 120° 45′ 30″ E.; 214 fms.; 22 February 1909; "Albatross" Sta. D. 5365.—1 ♂, cl. 58 mm.

Malabrigo Light N. 81° E. 8 miles, Philippines, 13° 34′ 37″ N., 121° 07′ 30″ E.; 180 fms., sand; 22 February 1909; "Albatross" Sta. D. 5367.—2 ♂♂, cl. 36 and 36 mm., 2 ♀♀, cl. 39 and 41 mm.

Tayabas Light (outer) N. 9° E. 7·4 miles, Philippines, 13° 46′ 45″ N., 121° 35′ 08″ E.; 190 fms., grey mud; 2 March 1909; "Albatross" Sta. D. 5374.—1 ♀, cl. 43 mm.

Lauis Point Light N. 21° E. 5·5 miles, Philippines, 10° 09′ 15″ N., 123° 52′ E.; 162 fms., green mud; 23 March 1909; "Albatross" Sta. D. 5412.—2 ♂♂, cl. 40 and 47 mm., 1 ♀, cl. 46 mm.

Macabalan Point Light, S. 35° E. 8·2 miles, Mindanao, Philippines, 8° 37′ 37″ N., 124° 35′ E.; 214 fms., fine sand and grey mud; 4 August 1909; "Albatross" Sta. D. 5501 and 5502.—2 ♀♀, cl. 40 and 51 mm.

Macabalan Point Light S. 39° E. 6 miles and S. 31° E. 7·7 miles, Philippines, 8° 35′ 30″ N., 124° 36′ E. and 8° 37′ 15″ N., 124° 36′ E.; 200 and 220 fms., green mud; 5 August 1909; "Albatross" Sta. D. 5504 and D. 5505.—2 ♀♀, cl. 50 and 60 mm.

Camp Overton Light S. 6° E. 4·9 miles, Iligan Bay, Mindanao, Philippines, 8° 17′ 24″ N., 124° 11′ 42″ E.; 270 fms., green mud and fine sand; 5 August 1909; "Albatross" Sta. D. 5508.—1 ♂, cl. 52 mm., 1 ♀, cl. 50 mm.

Point Tagolo Light S. 64° W. 8·7 miles, Philippines, 8° 48′ N., 123° 31′ E.; 200 fms., grey mud, globigerina; 9 August 1909; "Albatross" Sta. D. 5518.—1 ♂, cl. 45 mm., 1 ♀, cl. 49 mm.

Point Tagolo Light S. 48° W. 6·7 miles, Philippines, 8° 48′ 44″ N., 123° 27′ 35″ E.; 10 August 1909; "Albatross" Sta. D. 5523.—1 ♂, cl. 50 mm., 1 ♀, cl. 48 mm.

Apo Island S. 26° W. 11·8 miles, Philippines, 9° 15′ 45″ N., 123° 22′ 00″ E.; 279 fms., green mud; 19 August 1909; "Albatross" Sta. D. 5536.—1 ♂, cl. 52 mm.

Mount Dromedario S. 22° W. 17·2 miles, Philippines, 5° 25′ 56″ N., 120° 03′ 39″ E.; 277 fms., sand; 23 September 1909; "Albatross" Sta. D. 5576.—1 juvenile, cl. 12 mm.

Description.—The supra-orbital horns are followed by three teeth, which decrease in size posteriorly. On the anterior margin of the carapace at the inner base of either supra-orbital horn one strong sharp tooth is present in all my specimens (sometimes this tooth is 2-, rarely 3-topped). Bate did not figure these teeth, but according to Ramadan (1938, p. 131) they are actually present in the type. The lower orbital tooth is strong, below it there is a single or 2-topped smaller tooth, behind it extends a longitudinal row of three smallish teeth, which decrease in size posteriorly. Between the supra-orbital and the infra-orbital rows of teeth there are two longitudinal rows of minute spinules; the upper of these rows is double and often curved, the lower is single, very short and consisting of 1 to 3 spinules, which sometimes are irregularly arranged. No post-orbital spine is present. In the anterior part of the median region before the cervical groove there are two anteriorly converging rows of 3 to 5 large and numerous small teeth (sometimes the two anterior median teeth are larger than the rest). There are a few scattered very small additional spinules in this area. Behind the cervical groove the carapace is evenly covered with small pointed tubercles and 3 rows (one median and 2 branchial) of teeth. The median of these rows consists of 3 post-cervical and 2 (rarely 3) intestinal teeth, which are well developed and pointed. The branchial row is formed of about 5 to 8 larger teeth and numerous small teeth, most of the latter cannot be distinguished from the pointed tubercles of the rest of the carapace. This branchial row extends practically in one line with the pre-cervical post-orbital row of spines.

The median carina of the first abdominal somite is short and interrupted in the middle. The segment shows a broad transverse groove, which is filled with a short pubescence. In the following four somites the exposed posterior half bears a median carina which is twice interrupted forming thereby three ridges, the second of which bears a posterior tooth in the fourth and fifth, and sometimes also in the third somite. In the second somite the posterior of the three ridges is more or less distinctly divided in two, in the fourth and fifth somites the first interruption may be obscure. Apart from the wide transverse groove, which separates the anterior part of the somite (namely the part which disappears under the previous somite when the abdomen is fully stretched) from the posterior part, there is a second transverse groove, which passes between the second and last of the median ridges. On each half of the dorsal surface of the abdominal somites II to V there are three oblique rows of tubercles, the inner of these becomes almost transverse in the fourth and fifth somites. The next extends from the posterior point of the base of the pleura forward and inward, while the third starts at the anterior point of the base of the pleura and runs posteriorly and outward. Sometimes the tubercles end in an acute tip. The pleura of somites II to V end in two sharply pointed teeth which are small and of about equal size in the male; in the female they are larger while the anterior usually is slightly longer than the posterior, especially so in the second somite. The anterior margin of the pleuron of somite II shows two denticles. The sixth somite bears 2 submedian rows of 4 to 6 posteriorly pointing denticles. The posterior margin of this somite bears a single small median tooth. An often irregular row of denticles extends over the base of the pleura and an oblique row may be seen on the pleura themselves. The pleura end in two posteriorly directed sharp teeth, the outer of which is the stronger. The lateral margins of the calcified portion of the telson each bear two spines: one in the middle and one at the end; on the dorsal surface there are two diverging rows of 2 to 6 spines, the last of which are strongest; furthermore there is a pair of submedian spines in the extreme anterior part of the telson. The abdomen is covered with a short pubescence which is most distinct in the grooves.

The eyes are longer than broad. The peduncle is constricted in the middle. The cornea is rounded, its breadth being less than the length of the eye.

The antennular plate bears one or two pairs of small spines which are somewhat curved outward at the top; these spines may be preceded by a row of 1 to 5 smaller spinules. In the juveniles these spines and spinules may be indistinct. The lateral ridges of the antennular plate form a stridulating organ with a process from the third antennal segment that slides over it.

The third (actually the fused second and third) segment of the antennal peduncle shows a strong tooth on the anterior margin just above the stridulating process; also the outer and lower parts of this margin are provided with teeth. Two, rarely three, teeth are placed on the outer margin and several smaller denticles on the lower surface. This surface also bears a rather large sub-distal tooth. The fourth segment bears four strong teeth on the outer margin, two oblique rows of 3 to 7 denticles on the upper surface, two longitudinal rows (one of 3 to 6 and one of 0 to 3 denticles) on the lower surface, and a strong inner antero-lateral tooth, which at its inner lower side bears a smaller tooth. The lateral margins of the fifth segment each bear three (seldom 2 on the outer or 4 on the inner margin) teeth, the anterior margin bears a dorsal and a ventral tooth, while some denticles are present on both upper and lower surface.

The epistome ends in a single strong median tooth.

The meri of the third maxilliped and the first two pereiopods bear distinct ventral teeth. The first two legs are far more heavy than the following. Their dactyli are more than half as long as the propodi, and about as long as the carpi; they bear scattered hairs. The last three legs are very slender and bear no ventral teeth on the merus. The dactylus of the third pereiopod is about 2/5 as long as the propodus and slightly shorter than the carpus, like in the following legs it bears two distinct longitudinal rows of hair dorsally. The following leg are much longer than the third; the fourth of both sexes and the fifth of the males reach with the dactylus and part of the propodus beyond the third. In the fourth the dactylus is distinctly less to somewhat more than $\frac{1}{3}$ as long as the propodus while this ratio in the fifth leg is somewhat less to slightly more than $\frac{1}{4}$, being somewhat more than $\frac{1}{2}$, and $\frac{1}{2}$ or somewhat more than $\frac{1}{2}$ as long as the carpus respectively. In the female the fifth leg is proportionally shorter and ends in a small but distinct chela, which is less than 1/5 as long as the propodus. In all the legs the merus bears an antero-dorsal spine.

The thoracic sternum bears a sharp median tooth on all somites; furthermore one sharp tooth is present at the bases of the second and third legs, while two or three such teeth are placed at the bases of the fourth and fifth legs.

In the males the vas deferens protrudes from the genital opening as a fleshy pointed organ.

The first abdominal sternite in both sexes bears two submedian and two lateral spines. In the second to fifth somites of the males only the submedian spines are present, while in the females even those are absent or most inconspicuous. In the sixth abdominal somite of the males there are three transverse rows of spines: the anterior consists of two submedian spines, the second of 6 spines and the third of 4 larger spines. In the females the first two rows are visible each as a pair of tubercles, the third row is as in the males. There are no pleopods on the first abdominal somites; in both sexes the pleopods of the second to fifth abdominal somites are very similar. In the males the endopod is absent, while the exopod is large and leaf-shaped. In the females the exopods of the pleopods also are large and leaf-shaped, but endopods are present here. The endopods are very similar to those of *Linuparus*: the endopod itself is very slender with a long and narrow protuberance in the basal part of the inner margin; on this protuberance a narrow and slender stylamblys is placed. The endopod proper and the stylamblys both are directed forward, they are of about the same length and width. The uropods in both sexes have the protopod ending in an outer tooth; the diaereses of the exo- and endopods are spinulose.

In the very young specimen from Sta. D. 5576 there are only two teeth behind the infra-orbital tooth, while the anterior margin of the carapace shows no teeth between the supra-orbital horns. The two submedian rows of spines in the anterior part of the carapace consist of three spines each, the rows are slightly diverging anteriorly and no spinules are present. There are three high post-cervical and two prominent intestinal teeth, which are relatively more conspicuous than in the adults. Also on the branchial ridges the teeth are relatively larger.

Each of the median ridges of the abdomen is visible in this specimen as a high and compressed pointed tooth; only the posterior ridge of the first somite is blunt. The tubercles of the abdomen are spinous and the two teeth at the end of the pleura are rather widely diverging.

The spinules on the antennular plate are hardly visible. On the antennal peduncle there are numerous small spines besides those found in the adults.

The epistome, instead of having a single median tooth which is directed forward, has two strong submedian spine-like teeth which are directed ventrally.

The propodi of the last three pereiopods are relatively shorter. The thoracic sternum shows no median spines and bears only one spine at the base of each leg. The uropods have very long and slender exo- and endopods.

The type specimen of *Panulirus angulatus* Bate is somewhat larger than the smallest specimen collected by the "Albatross". Ramadan (1938, p. 133) gave the carapace length of Bate's specimen as 16·5 mm. The spinulation of Bate's type agrees quite well with that of the present specimens, although in Bate's fig. 4 showing the animal in lateral view, the median teeth of the fourth and fifth abdominal somites and the pleuron of the third probably are not quite correctly represented. The epistome shows already the median spine, though traces of the submedian spines may also be seen. There cannot be any doubt that Bate's specimen and the present material belong to the same species.

Puerulus carinatus Borradaile has been very superficially described by its author. It is very difficult to decide from this description and the figure whether or not the species is distinct from *P. angulatus*. Borradaile's specimen is very large, its carapace length being about 70 mm. The differences from *P. angulatus* seem to be the following: (1) There are only two teeth behind the supra-orbital horns instead of three. (2) According to Borradaile's description two teeth are placed behind the infra-orbital teeth, but the figure shows three there. (3) The figure shows fewer dorsal median ridges on the abdomen than in *P. angulatus*, but this may be due to inaccuracy of the illustration; this feature is not discussed in the text. (4) The fourth antennal segment bears five outer teeth instead of four and the fifth segment is figured with four outer teeth, though the text indicates three there. The specimen which Ramadan (1938) assigned with some doubt to *P. carinatus* in all the just mentioned points agrees with *P. angulatus* and there can be little doubt that his specimen indeed belongs to the latter species. For the time being it seems safe to consider *P. carinatus* a synonym of *P. angulatus*.

The specimens collected by the Siboga Expedition and identified by De Man (1916) as *Puerulus angulatus* are different from that species and have recently been made the types of a separate species *P. velutinus*.

Balss (1925) described the specimen which he brought to *Puerulus angulatus* as having five teeth on the median carina of the carapace behind the cervical groove. This shows that that specimen indeed belongs to Bate's species and not to either of the other two species of this genus, which at times have been confused with *P. angulatus.*

Ramadan (1938) made it clear that the Indian specimens dealt with by Alcock and Sewell actually belong to a separate species which he named *P. sewelli.*

Kubo (1939) gave a good description and excellent illustration of a supposed new species, which he named *Puerulus gracilis.* His account clearly shows that his specimens belong to the present species, agreeing in all details with it. Kubo considered his species distinct as in *P. gracilis* a "longitudinal series of four teeth including supra-orbital spine" extends "backward almost to the cervical groove as in *P. carinatus*", but this is exactly the situation found in *P. angulatus* and correctly figured by Bate in his pl. 11, fig. 4. In Bate's fig. 3 the last of these teeth evidently is drawn too large. The other difference mentioned by Kubo is the absence of teeth on the frontal margin of the carapace between the supra-orbital horns in *P. angulatus*; as shown above these teeth have been erroneously omitted by Bate, while moreover they sometimes are absent in juvenile specimens. There can be little doubt therefore that *Puerulus gracilis* is nothing but the adult stage of *Puerulus angulatus* so that the two names should be synonymized.

Distribution.—The species has been reported from the following localities: E. of Zanzibar, 5° 34′ 24″ S., 39° 14′ 06″ E.–5° 37′ 00″ S., 39° 14′ 36″ E. (Ramadan, 1938) near Saya de Malha Bank, Western Indian Ocean (Borradaile, 1910), W. of Nicobar Islands, 7° 49′ N., 93° 10′ E. (Balss, 1925) N. of New Guinea, 1° 54′ S., 146° 39′ 40″ E. (Bate, 1888), off Kominato, Bôsyû province, Honshu, Japan (Kubo, 1939); the present material all originated from the Philippine Islands. The species was taken at depths between 150 and 293 fms. on a bottom of mud (green mud, grey mud, coral mud), or sand (fine coral sand, fine black sand, fine sand, sand), only once it was taken from a bottom of shells and coral.

Type locality.—N. of New Guinea, 1° 54′ S., 146° 39′ 40″ E., depth 150 fms.

Puerulus sewelli Ramadan, 1938

Panulirus angulatus, Alcock and Anderson, 1894, p. 166; Alcock, 1899, p. 33; Alcock, 1901, p. 185. (not *Panulirus angulatus* Bate, 1888).

Puerulus angulatus Calman, 1909, p. 442 (p.p.); Sewell, 1913, p. 350.

Puerulus sewelli Ramadan, 1938, p. 128, figs. 3–5; Holthuis, 1946, p. 110; Sewell, 1955, pp. 200, 201, 203.

Puer sewelli Belloc, 1959, pp. 7, 8, 9, fig. 6.

Material Examined

U.S. National Museum, Washington

13·5 miles N. 64° W. of Colombo Light, Ceylon; 142–400 fms.; brown mud; 4 December 1893; "Investigator" Sta. 151; don. Indian Museum.—1 juvenile paralectotype cl., 18 mm.

British Museum (Nat. Hist.), London

Gulf of Aden, 11° 53′ 42″ N., 51° 13′ 12″ E.; 73–220 m. deep; coarse sand and shells; 9 October 1933; John Murray Expedition Sta. 24.—1 ♀, paralectotype cl., 74 mm.

Gulf of Aden, 13° 16′ 00″ N., 46° 20′ 24″ E.–13° 16′ 36″ N., 46° 14′ 00″ E.; 220 m. deep; green mud; 7 May 1934; John Murray Expedition Sta. 194.—1 ♂ lectotype cl. 63 mm.

Ramadan (1938), when describing this species, did not distinguish between *P. angulatus* and *P. velutinus* and therefore some of his comparisons between *P. sewelli* and *P. angulatus* do not hold good. I found the following differences when comparing my material of *P. angulata* and *P. sewelli*:

1. The spines and teeth in *P. angulatus* are far sharper and more conspicuous than in specimens of *P. sewelli* of the same size.

2. The body of *P. sewelli* shows less pubescence.

3. Behind the supra-orbital horns there are two teeth in *P. sewelli* instead of three.

4. The abdomen (telson excluded) in *P. sewelli* is as long as or shorter than the carapace (the ratio abdomen/carapace being 0·9 to 1·0). In *P. angulatus* material measured by me the abdomen (without telson) is longer than the carapace (the ratio abdomen/carapace in this material being 1·1 to 1·3).

5. The region before the cervical groove is relatively shorter in *P. sewelli;* the ratio length post-cervical area/length pre-cervical area is 1·4 to 1·8 in *P. sewelli*, while in my material of *P. angulatus* it varies between 1·1 and 1·4.

6. Behind the lower orbital tooth there are two teeth in *P. sewelli*, three in *P. angulatus*.

7. The median carina behind the cervical groove in *P. sewelli* bears 5 post-cervical and 2 or 3 intestinal teeth. The second of the post-cervical teeth is double and smaller than the rest.

8. In the adults of *P. sewelli* the anterior of the two spines at the distal margin of the pleura of the abdominal somites II to V is far longer than the posterior; this is especially distinct in the female, where both spines are much longer than in the male; in the male the posterior spine is reduced to a mere tubercle. In the juvenile the two spines do not differ much in size.

9. No denticles are seen on the anterior margin of the pleura of the second abdominal somite in the adults of *P. sewelli*; in the juvenile they are present.

10. The spines on the antennal peduncle are smaller than in *P. angulatus*, and in the adults they are entirely lacking on the dorsal surface of the distal segment.

11. The pereiopods are less slender than in *P. angulatus* and in the adults they have no antero-dorsal spine on the merus; such a spine is present in the young.

12. The sternum of the male is much narrower and shows a median ridge which extends over the first 4 sternites and is produced into a low blunt tooth between the bases of the first to third legs, no other such teeth are present, except for a minute one at the end of the sternum. In the female these teeth are present on the first four sternites. In both sexes a transverse depression is visible on the sternum at the end of the fourth and fifth sternites.

13. In the adult there are no spines on the sternite of the sixth abdominal somite; they are present, however, in the juvenile.

Puerulus sewelli is closely related to *P. angulatus*, but the differences enumerated above in my opinion are sufficiently important and constant for the two forms to be considered good species.

Distribution.—The present species has been reported from the following localities: Gulf of Aden, 13° 16′ 00″ N., 46° 20′ 24″ E.–13° 16′ 36″ N., 46° 14′ 00″ E. and 11° 53′ 42″ N., 51° 13′ 12″ E. (Ramadan, 1938), Arabian Sea off Travancore, India (Alcock, 1901; Sewell, 1913), 13·5 miles N 64° W. of Colombo Light, Gulf of Mannar, Ceylon (Alcock, and Anderson, 1894; Alcock, 1899, 1901; Calman, 1909; Sewell, 1913). It was taken at depths between 73 and 1309 m. on bottoms of mud and coarse sand and shells.

Type locality.—Ramadan (1938), who based his new species both on his own material and that brought by Alcock (1901) to *Puerulus angulatus*, did not indicate a holotype so that all these specimens are syntypes. I now select the male specimen (cl. 63 mm.) from John Murray Expedition Sta. 194 listed above, as the lectotype of *Puerulus sewelli* Ramadan, 1938, the other specimens thus becoming paralectotypes. The type locality is restricted by this action to the Gulf of Aden, 13° 16′ 00″ N., 46° 20′ 24″ E.-13° 16′ 36″ N., 46° 14′ 00″ E., 220 m. deep. The lectotype is preserved in the collection of the British Museum (Nat. Hist.).

Puerulus velutinus Holthuis, 1963

Puerulus angulatus, De Man, 1916, p. 36, pl. 2, fig. 5. (not *Panulirus angulatus* Bate, 1888).

Puerulus velutinus Holthuis, 1963, p. 55.

Material Examined

U.S. National Museum, Washington

Point Tabonan S. 89° E. 33·5 miles, Palawan Passage, Philippines, 10° 57′ 45″ N., 118° 38′ 15″ E.; 375 fms., coral and sand; 27 December 1908; "Albatross" Sta. D. 5348.—1 ♀ paratype cl. 62 mm.

Makyan Island (S.) N. 67° W. 8·9 miles, northern Moluccas, 0° 12′ 15″ N., 127° 29′ 30″ E.; 288 fms., fine sand and mud; 29 November 1909; "Albatross" Sta. D. 5624.—1 ♂ paratype, cl. 65 mm.

Zoological Museum, Amsterdam

Bali Sea, Indonesia, 7° 35·4′ S., 117° 28·6′ E.; 521 m., coral; 1 April 1899; "Siboga" Sta. 38.—11 ♂ paratypes, cl. 31–47 mm., 12♀ paratypes, cl. 19–61 mm. (5 ovigerous ♀♀ cl. 47–61 mm.).

Between Roti and Timor, Lesser Sunda Islands, 10° 39′ S., 123° 40′ E.; 520 m., soft grey mud with brown upper layer; 27 January 1900; "Siboga" Sta. 297.—1 ♂ holotype cl. 53 mm., 2 ♂ paratypes cl. 43 and 50 mm., 2 female paratypes cl. 39 and 43 mm.

This species has been extensively described and figured by De Man (1916), who considered it to be identical with *Puerulus angulatus* (Bate). The differences between *Puerulus angulatus* and the present form, however, are so numerous and striking that there can be not the least doubt that De Man's specimens represent a distinct species. The most important features of *Puerulus velutinus* are:

The body is far less spinous than in *Puerulus angulatus*, most of the spines are reduced to mere spinules and are obscured by the dense pubescence of the carapace. The supra-orbital horns are more flattened, and in the large male do not have an additional spine on the anterior margin; in the female and the juvenile male three or four such spines are present, the outer being the larger. Behind the horns there are two teeth only, the last of these is extremely small. The lower orbital tooth is strong, behind it there are two very inconspicuous spinules. Below the lower orbital tooth there is a rounded lobe, which is unarmed in the large male, but carries two to four teeth in the female and young male. A strong post-orbital spine is placed behind the eye; this spine is entirely lacking in *Puerulus angulatus* and *P. sewelli*. Behind and slightly below this post-orbital spine a small additional spinule may be present. Above and behind it two rows of spinules similar to but far smaller than those of *P. angulatus* may be seen. In the anterior part of the median region before the cervical groove there are two almost parallel rows of about 5 small blunt spinules. There may be some other still smaller spinules, which, however, are usually obscured by the strong pubescence of the carapace. The median carina behind the cervical groove bears a longitudinal row of blunt tubercles. The line between the post-cervical and intestinal tubercles is very obscure. There are 4 to 7 post-cervical and 6 or 7 intestinal tubercles. An irregular row of about 18 tubercles extends over the branchial region.

The median carina of the first abdominal somite is inconspicuous and bears a small anterior tubercle. A transverse row of still smaller tubercles extends along the posterior margin. Similar transverse rows of tubercles also are found on the second and third somite, and are very inconspicuous on the fourth. The median carina is like in *P. angulatus*, only it is less distinct. Also the three rows of tubercles on each half of abdominal somites II to V are present here, but are less pronounced and may consist of more tubercles; the inner rows on the fourth and fifth somites are not transverse, but more longitudinal, while the second row as a rule is split into two more or less parallel rows. The pleura of abdominal somites II to V end in two teeth, the anterior of which is much longer than the posterior. In the male these teeth are far shorter than in the female, in the second somite they even are hardly discernible, becoming larger in the following somites. The sixth somite and the telson are like in *P. angulatus*, but with the spines much smaller. The abdomen is thickly covered with pubescence.

The eyes are far larger than those of *P. angulatus*. The breadth of the cornea far exceeds the entire length of the eye.

The antennular plate does not bear any spine, being only covered with pubescence.

There is no spine above the process of the third antennal segment which forms part of the stridulating organ. The fourth antennal segment is far broader than that of *P. angulatus*, its upper surface bears a few inconspicuous spinules. Its outer margin bears 5 teeth, the proximal of which is very small; the inner antero-lateral tooth is very strong in the female, less so in the male.

The meri of the legs often do not have an antero-dorsal spine. The propodus of the fifth leg possesses an antero-ventral process, which in the female forms a chela with a ventro-proximal process of the dactylus; in the male the dactylus does not possess any process. In *P. angulatus* the males do not show any process on the propodus.

The thoracic sternum in the males is more elongate than in *P. angulatus*. Its median line shows only low teeth, while also the lateral teeth are low. The last median tooth is flanked on each side by two tubercles which are placed in a transverse row.

The spines on the abdominal sternites are far smaller and less conspicuous than in *P. angulatus*. The pleopods of the smaller males (cl. about 35 mm. or less) show traces of the endopod and its stylamblys; these disappear in the adults. In the pleopod of the second abdominal somite of the female the stylamblys is distinctly more slender than the endopod, in the following pleopods this difference becomes gradually less distinct.

One of the males of " Siboga " Sta. 38 carried a lepadid on the dorsal surface of the telson.

In the relative length of the abdomen and the two parts of the carapace (*viz.*, that before and that behind the cervical groove) the present species agrees quite well with *P. angulatus*. It, probably, is the similarity in this character that made Ramadan decide that De Man's (1916) specimens indeed belong to *Puerulus angulatus*.

Distribution.—The species is only known from the specimens enumerated here. Its known range embraces the Lesser Sunda Islands, the Moluccas and S.W. Philippines. It is known from depths between 520 and 683 m., and has been found on bottoms of mud, sand and coral.

Type locality.—Lesser Sunda Islands, Indonesia, 10° 39′ S., 123° 40′ E., depth 520 m.

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ON THE OCCURRENCE OF *CALLIANASSA* (*CALLICHIRUS*) *AUDAX* DE MAN CRUSTACEA DECAPODA—CALLIANASSIDAE) ON THE SOUTHWEST COAST OF INDIA WITH A DESCRIPTION OF THE MALE*

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Abstract

The paper records the occurrence of *Callianassa* (*Callichirus*) *audax* de Man in Indian waters for the first time. Five specimens, four females and one male, were collected from Cannanore on the Malabar coast, at a depth of 2–3 meters. Since the male of the species has not so far been recorded or described, a full description of it is given in the paper.

The genus *Callianassa* enjoys a worldwide distribution, but many of the species are imperfectly known as the fossorial mode of life makes their capture difficult. Kemp (1915) described in detail *Callianassa* (*Callichirus*) *maxima* M. Edw., based on a specimen obtained from Madras and a large chela and two immature specimens from the Chilka lake. De Man (1928) recorded 14 species from the east coast of Africa and the Indian Ocean. Different stages of the larvae of callianassids obtained from the inshore plankton of the Madras coast have been described by Menon (1933 and 1940). Several new species belonging to the sub-genera *Calliactites*, *Cheramus* and *Callichirus* have been described by Edmondson (1944) from the Central Pacific. Recently Pillai (1954) reported the occurrence of *Callianassa* (*Callichirus*) *maxima* from the Kayamkulom lake (Central Travancore).

Callianassa (*Callichirus*) *audax* was created by de Man (1911) from two female specimens collected in 1892 in the Straits of Malacca. A full description of the species was subsequently published by de Man (1928). Apart from this record, this species has not been known from any part of the world.

The present collection consists of 5 specimens, four females and one male, obtained on 22-4-1963 from Cannanore on the Malabar coast. They were caught in the shore seines operated to catch fish at a depth of 2–3 meters. Since the male of this species has not so far been recorded or described a full description of the latter is given here.

Callianassa (*Callichirus*) *audax* de Man

Description of Male

Carapace with deep sutures; rostrum very short and depressed, frontal margin slightly concave and projecting between the eye stalk and the antennal peduncle; the whole frontal margin fringed with short hairs.

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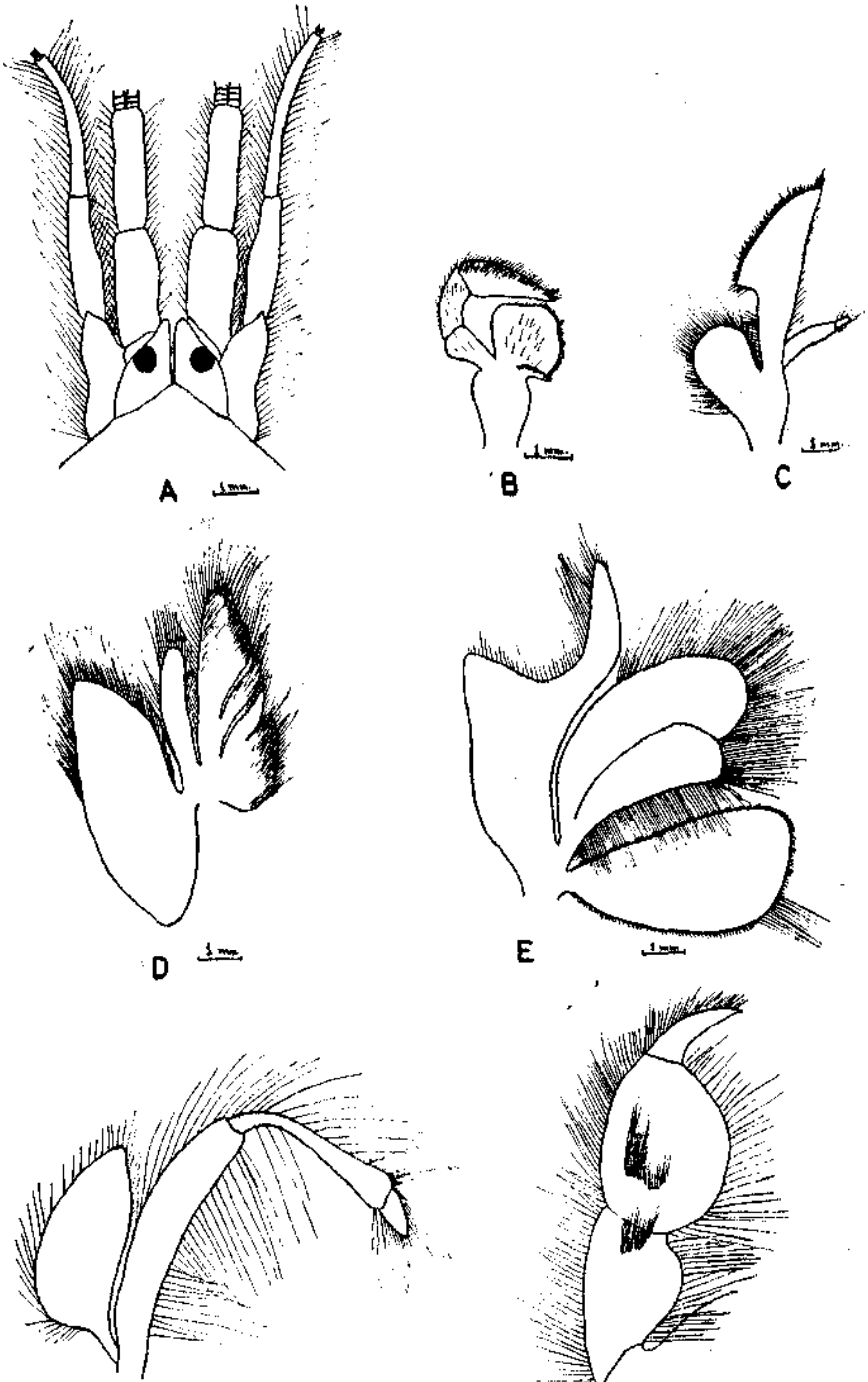

FIG. 1. Parts of ***Callianassa (Callichirus)*** *audax* de Man: A. Front border of carapace, eye stalks and peduncles of antennule and antenna, B. Mandible, C. Maxillule, D. Second Maxilla, E. First maxilliped, F. 2nd maxilliped, G. 3rd maxilliped.

Eye lobes (Fig. 1 A) nearly twice as long as broad, reaching the tip of the basal segment of the antennular peduncle, inner border straight, outer slanting, the eye lobe narrowing distalwards and terminating in a sub-acute apex. Cornea circular, placed in the middle more towards the outer border.

Of the three antennular segments the third is the longest and the second equal to or slightly shorter than the first, flagella equal.

First segment of antenna small; 2nd and 3rd almost equal, latter is much narrower than the preceding segments and the whole peduncle is longer than the peduncle of the antennule by ½ the length of its terminal segment.

Mandible (Fig. 1 B) quadrangular in outline, convex on the outer surface, cutting edge bearing a series of teeth; mandibular palp curved and three-jointed, third segment longest. There is a small transverse ridge placed at the proximal end of the cutting edge of the mandible.

Maxillule (Fig. 1 C) made up of three laciniae of unequal size; the outer lacina two-jointed and narrow; endopodite almost rounded and unjointed.

Maxilla (Fig. 1 D) foliaceous; endopodite unjointed and small; the gnathobasic lobes, endopodite and exopodite which is ear-shaped, fringed with setae along their entire margins.

First maxilliped (Fig. 1 E) flattened; exopodite unsegmented with a median ridge almost running its entire length; endopodite also unsegmented and expanded into a thin plate externally; epipodite thin and lamellar in the middle.

Endopodite of second maxilliped (Fig. 1 F) three-segmented terminal segment short, with a thick row of setae on the margin; exopodite broad and foliaceous.

Ischium of third maxilliped almost as broad as long; merus proximally broad and narrow distally; inner border of these segments carinate and armed with long hairs. Carpus as long as merus, narrowing towards both ends; propodus broader than carpus; dactylus slightly shorter than propodus (Fig. 1 G).

First pereiopods chelate and very dissimilar; left cheliped larger. The proximal end of ischium narrow and the distal end expanded, inner border finely serrated, except at the distal part. Merus a little shorter than ischium with lower margin expanded up to a little beyond the middle and armed with 13–14 small teeth and fringed with a few long hairs. A few granules present close to the lower margin. The narrow distal portion also serrated along its whole length. The upper border convex and feebly serrated. In the inner surface of the merus near the distal end there are 4 small tufts of setae placed one behind the other. Carpus as long as merus and as broad as long; both the inner as well as the outer sides slightly convex and smooth, the lower border carinated and fringed with long hairs, while the upper border has only a few short hairs. Palm (Fig. 2 A) as long as carpus and longer than broad, proximally as broad as carpus and slightly decreasing in width distally; the lower border serrated along its whole length to the tip of the fixed finger and fringed with hairs. The fingers overlap; the inner edge of dactylus granulated on the proximal portion and with a strong tooth in the middle. A number of granules present on the inner side of the palm near the articulation of the dactylus and at the base of the fingers.

Ischium of the smaller cheliped long and narrow with a slightly expanded distal portion. Merus shorter and 1½ times as long as wide; carpus almost as long as ischium and twice as long as its breadth. Fingers subequal and non-granulated except on the proximal inner edge and the fixed finger.

Ischium of the 2nd pereiopod small with a narrow base and expanded distal part. Merus which is the longest segment is as broad as the distal end of the ischium upto a little beyond the middle and then narrows; carpus proximally narrow and distally expanded; fingers equal and longer than plam.

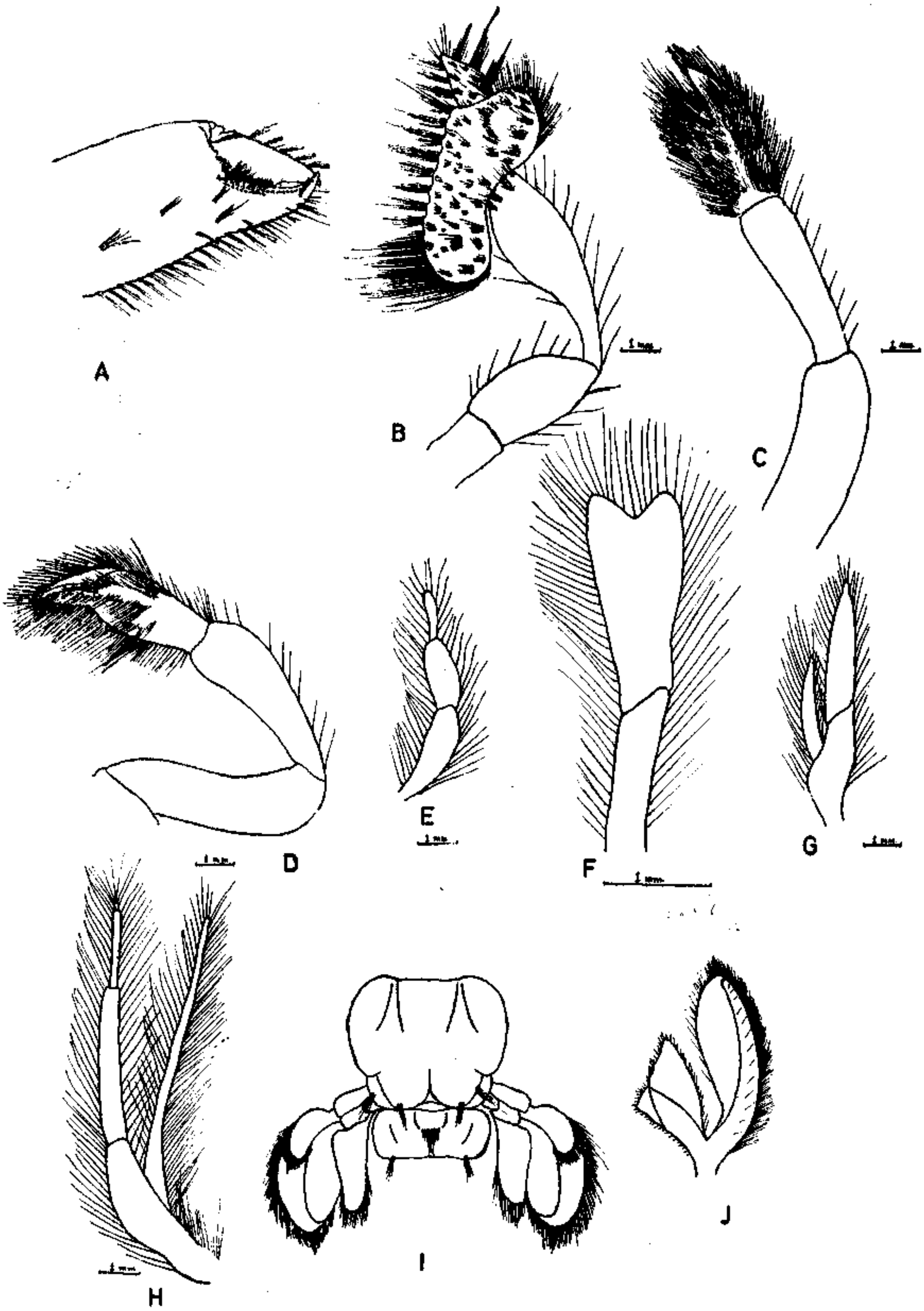

FIG. 2. *Callianassa* (*Callichirus*) *audax*: A. tip of large cheliped, B. 3rd leg, C. 4th leg, D. 5th leg, E. First pleopod, female, F. First pleopod, male, G. 2nd pleopod, male, H. 2nd pleopod, female, I. Telson and uropod, J. Third pleopod.

Third pereiopod (Fig. 2 B) is hammer-shaped; carpus slightly shorter than merus, proximally narrow gradually expanding ¾ its length and then narrowing. Sixth joint lobed, the anterior lobe small and the posterior lobe with a straight outer border. The dactylus broadly subtriangular, 6th segment and the dactylus covered with tufts of hairs.

Propodus of 4th pereiopod shorter, but broader than carpus, its lower apex produced as a short process, tip carries several short spines; dactylus somewhat ovate; both the 6th segment and the dactylus densely setose (Fig. 2 C).

Ischium of 5th pereiopod small less than ½ length of merus; carpus shorter than merus, former slightly expanded at the distal end. Propodus produced into a process at its distal end and densely setose. Dactylus placed very close to the base of this process and slightly longer with hairy tips (Fig. 2 D).

First abdominal segment triangular; second slightly narrower at the anterior part; third, fourth and fifth segments broader than long; sixth segment longer than the fifth and convex transversely. Behind the middle line a small furrow runs transversely inward from the lateral border. Three small furrows running forwards parallel to each other proceed from the posterior border of this region.

Telson (Fig. 2 I) broader than long and much shorter than the 6th segment; posterior margin slightly undulate; setae present near the lateral corner. Uropods extending well beyond the telson; outer ramus oval with the outer margin densely fringed with setae. In the middle there is a ridge running from the anterior end to the rounded posterior border. On the dorsal side, at the anterior region of the ramus is a superimposed raised portion, the outer margin of which is setose. Inner ramus somewhat triangular, longer than broad, with setose inner and distal borders.

First pleopod (Fig. 2 F) slender; two-segmented and covered with long setae, apex broad with a shallow depression.

Second pleopod (Fig. 2 G) biramous, and covered with short setae. Outer ramus very slender and shorter than the inner, latter is two-segmented with a small constriction near the tip.

Pleopods 3–5 large and foliaceous (Fig. 2 J), somewhat oval, outer margin more densely setose than the inner. In the outer ramus the arcuate ridge runs in the middle; the inner ramus is shorter and roughly triangular. In the proximal portion it is thickened and the outer margin slightly emarginate.

Length from tip of rostrum to extremity of telson ..	57 mm.
Length of carapace ...	17 „
Length of abdomen including telson ..	40 „
Length of 1st abdominal segment ..	8 „
Length of 2nd abdominal segment ..	8 „
Length of 3rd abdominal segment ..	6 „
Length of 4th abdominal segment ..	5 „
Length of 5th abdominal segment ..	6 „
Length of 6th abdominal segment ..	8 „

The female closely resembles the male except in the following characters: The first pleopod in female (Fig. 2 E) is stout and three-jointed, the third joint finger-shaped, a little shorter and less than half as wide as the second segment, the whole pleopod is covered with long setae. In the male it is slender and the apex of the terminal segment is broad with a shallow depression very much resembling that of *Callianassa* (*Cheramus*) *variabilis* Edmondson (1944). The second pleopod in the female (Fig. 2 H) is biramous with the outer ramus equal in length to the inner, but slender; the inner ramus is two-segmented with a minute knob, apparently a separate segment, at the tip of the second segment. In the male this pleopod is comparatively smaller in size, the outer ramus is very slender and shorter than the inner which is two-segmented.

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A REVIEW OF THE INDO-WEST PACIFIC SPECIES OF GENUS *PACHYCHELES* (PORCELLANIDAE, ANOMURA)*

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ABSTRACT

Pachycheles is a well-defined genus in the Porcellanidae, occurring world-wide and with approximately 40 species. To date the Indo-West Pacific members of the genus have not been reviewed as a whole. In this area there is a total of 11 species: of these, two have recently been described and two more have not previously been recognized as members of genus *Pachycheles*.

INTRODUCTION

PACHYCHELES Stimpson, 1858, is a well-defined genus in the Porcellanidae, occurring world-wide in tropical, warm-temperate, and cold-temperate regions and with approximately 40 species. Most of them live intertidally or in shallow water, although occasional individuals of a few species have been dredged in depths of 100 meters or more. Like most porcellanids they conceal themselves under stones, in the cavities of sponges, or among algae; in tropical regions they frequently live in corals.

Pachycheles belongs to that group of genera in which the basal antennal segment is short, not excluding the movable segments from the orbit. The carapace is usually about as broad as long in males and somewhat broader than long in females. The outer orbital angle is produced into a spine in some species but, except for spiniform tubercles which may be developed along the lateral margins (a condition occurring only in *P. spinipes*), there are no other spines on the carapace. The front is trilobate, but the anterior part of the frontal region is usually sharply deflexed so that the lobes are not visible in dorsal view. The lateral walls of the carapace (epimera) are incomplete, with the posterior (sub-branchial) portion consisting of one or more pieces separated by membranous interspaces from the anterior portion—a character shared by none of the other porcellanid genera which are represented in the Indo-West Pacific. The chelipeds are robust, and in males one is distinctly larger than the other; in females the difference between the two chelipeds is not always great. A strong lobe is developed on the anterior margin of the merus. The walking legs are usually hairy and the dactyl terminates in a single claw. There are either seven or five plates in the telson of the abdomen; five are present in all Indo-West Pacific species (the number of plates is unknown in *P. pectinicarpus*).

Certain characters, constant within a given species, are most useful in distinguishing members of genus *Pachycheles*. These include (1) presence or absence of a tuft of hair on the frontal region of the carapace; (2) structure of the hairs (whether plumose or not) on the carapace, chelipeds and walking legs; and (3) presence or absence of a pair of pleopods in males.

The present study grew out of routine attempts to identify specimens from various parts of the Indian and Pacific Oceans and to determine where each species might be expected to occur, during which it soon became apparent that a review of the Indo-West Pacific members of the genus was

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needed. In general, only the first of the three characters enumerated above has been mentioned in published discussions of the species, while too much reliance has been placed on certain other characters, such as the degree of tuberculation of the chelipeds, which are extremely variable within some forms. As a result there has been much confusion regarding the status of several species and their distribution.

Two recent studies (Haig, 1964; and 1965) dealt in part with *Pachycheles sculptus* and several species which have been confused with it. In the present paper, eleven Indo-West Pacific species of *Pachycheles* are recognized. Only published locality records which could be verified, or which seem reasonably certain, are cited. Locality records which have not appeared in the literature are marked with an asterisk (*).

KEY TO THE INDO-WEST PACIFIC SPECIES

1. Carapace devoid of hairs..........2
   Carapace distinctly hairy..........7
2. Males with a pair of pleopods..........3
   No pleopods in males..........4
3. Front narrow, rounded-triangular; walking legs with non-plumose hairs......*natalensis*
   Front broad, transverse, with a small median notch; walking legs thickly covered with plumose hairs..........*garciaensis*
4. Anterior portion of carapace covered with strong rugae and squamae; chelipeds and walking legs with strongly projecting, thorn-shaped tubercles..........*spinipes*
   No strong rugae or squamae across anterior portion of carapace; no thorn-shaped tubercles on chelipeds and walking legs..........5
5. Carpus and chela with longitudinal rows of well-separated tubercles, latter covered with short hairs..........*granti*
   Chelipeds devoid of hairs..........6
6. Anterior regions of carapace smooth; chelae smooth, tuberculate, or with four longitudinal ridges..........*sculptus*
   Anterior regions of carapace roughened by grooves; chelae with large, scalloped-edged tubercles..........*johnsoni*
7. Front without a distinct tuft of hairs; surface of carapace posterior to frontal region with scattered hairs..........*pisoides*
   Front with a distinct tuft of hairs; carapace otherwise hairless or nearly so..........8
8. Carpus and chela minutely hairy or devoid of hairs..........9
   Carpus and chela thickly covered with hairs..........10
9. Carpus of chelipeds sulcate, and with about three broad teeth on anterior margin..*stevensii*
   Carpus of chelipeds not sulcate, and with about eight small teeth on anterior margin..........*pectinicarpus*
10. Frontal tuft composed of plumose hairs only; carpus and chela covered with plumose hairs..........*balssi*
    Frontal tuft composed of short plumose hairs and long, scattered, non-plumose setae; carpus and chelae covered with short plumose hairs and long, scattered, non-plumose setae..........*tomentosus*

Pachycheles sculptus (H. Milne Edwards)

Porcellana sculpta H. Milne Edwards, 1837, p. 253 (type locality: Java; holotype in Paris Museum).

Porcellana pisum H. Milne Edwards, 1837, p. 254 (type locality: China; type not extant?).

Porcellana pulchella Haswell, 1882, p. 758 (type localities: Holborn Island and Port Molle, Australia; types in Australian Museum).

Pachycheles sculptus Ortmann, 1894, p. 29. Haig, 1964, p. 368.

Pachycheles sculptus var. *tuberculatus* Borradaile, 1900, p. 423 (type locality: Lifu, Loyalty Islands; types in Cambridge Museum).

Diagnosis.—Carapace devoid of hairs. Surface smooth except for faint rugosities on frontal region and series of grooves crossing posterolateral areas; carapace of some specimens very smooth, shining, strongly convex. Front in dorsal view broad, transverse.

Chelipeds devoid of hairs; extremely variable in ornamentation. Anterior margin of carpus with three or four broad teeth; dorsal surface entirely smooth, or with low, somewhat overlapping tubercles, or with irregular rows of strong, squamate tubercles, some of them transversely elongate. Chela entirely smooth, or with incipient smooth, longitudinal ridges, or with surface somewhat pitted, or with four smooth, narrow, longitudinal ridges, latter often crossed by slightly oblique grooves to form rows of close-set tubercles; the wide interspaces between these rows smooth, pitted, or with small, wide-set tubercles. Chelae similar in ornamentation, or minor more strongly ridged and tuberculate than major.

Walking legs completely hairless, or anterior margins with long, non-plumose setae.

No pleopods in males.

Distribution.—Indian Ocean: Mergui Archipelago and Western Australia. Pacific Ocean: Ryukyu Islands south to East Indian Archipelago and Queensland, Australia; *Caroline, *Gilbert, Loyalty, and *Tuamotu Islands. In the littoral, under stones and in coral head; dredged to about 1,800 metres.

Pachycheles johnsoni Haig

Pisosoma sculptum, Miyake, 1942, p. 374, text-figs. 33–35.

Pachycheles johnsoni Haig, 1966, p. 192, text-fig. 1 (type locality: Shark Bay, Western Australia; holotype in Western Australian Museum).

Diagnosis.—Carapace devoid of hairs. Surface smooth in median portion and with a series of transverse grooves along lateral margins, and distinctly roughened by grooves in anterolateral region. Front in dorsal view broad, transverse.

Chelipeds devoid of hairs. Anterior margin of carpus with three to five broad, strongly projecting teeth, their edges sometimes entire and sometimes scalloped or dentate; dorsal surface completely covered with large, close-set tubercles, either strongly convex or forming a smooth flat paving, and with their edges scalloped and sometimes free all the way around to form mushroom-shaped structures. Manus covered with tubercles of same size and structure as those of carpus, but generally arranged in more or less even longitudinal rows, spaces between the rows filled with smaller, less projecting tubercles.

Walking legs covered with long, stiff, non-plumose hairs.

No pleopods in males.

Distribution.—Indian Ocean: Western Australia. Pacific Ocean: Caroline Islands; Marshall Islands; Northern Territory, Australia. In the littoral, under stones and in coral heads; dredged to about 29 metres.

Pachycheles spinipes (A. Milne Edwards), n. comb.

Porcellana spinipes A. Milne Edwards, 1873, p. 262 (type locality: Upalu, Samoa; holotype in Hamburg Museum).

Porcellana sollasi Whitelegge, 1897, p. 144, pl. 7, figs. 3, 3 *a* (type locality: Funafuti Atoll, Ellice Islands; syntype in Australian Museum). Borradaile, 1900, p. 397.

Pachycheles sculptus, Calman, 1909, p. 706.

Diagnosis.—Carapace devoid of hairs. Frontal region with rounded tubercles, gastric, hepatic, and epibranchial regions with transversely elongate squamae, and hepatic and epibranchial margins with large spines or tubercles; this ornamentation is generally very strongly marked, but occasionally obsolescent. Cardiac and intestinal regions nearly smooth, meso- and post-branchial regions covered with series of strong, transverse ridges. Front in dorsal view transverse, with a deep median groove and sometimes appearing medially notched.

Chelipeds devoid of hairs or with faint setation, visible under magnification. Dorsal surface of carpus and chela covered with very strongly projecting, thorn-shaped tubercles, distally curved and pointed or truncate at their tips (in some specimens these tubercles more squamiform than thorn-shaped). Anterior margin of carpus with two or three narrow, pointed, strongly projecting, serrate-edged teeth.

Walking legs hairless or with a few fine, scattered setae; anterior margins of carpus and propodus with strong, thorn-shaped tubercles.

No pleopods in males.

Distribution.—Indian Ocean: Christmas Island. Pacific Ocean: *Caroline Islands; Loyalty Islands; Ellice Islands; Samoa. On coral reefs.

Pachycheles garciaensis (Ward)

Pisisoma garciaensis Ward, 1942, p. 64 (type locality: Diego Garcia, Chagos Archipelago; types in private collection of M. Ward).

Pachycheles graciaensis, Haig, 1965, p. 42.

Diagnosis.—Carapace devoid of hairs. Surface more or less smooth except for grooves crossing posterolateral areas and faint rugosities on frontal region. Front in dorsal view broad, transverse, and with a very small median notch.

Chelipeds devoid of hairs. Anterior margin of carpus with three large teeth proximally and one or two smaller ones distally, the largest teeth sometimes with serrate edges; dorsal surface covered with series of large, flattened, close-set tubercles, these usually taking the form of oblique rugae on anterior half of segment. Manus smooth or obliquely rugose; a longitudinal crest on outer margin and another near it on dorsal surface, these crests separated by a deep groove; a third, shorter crest sometimes present about midway on dorsal surface.

Anterior margins of carpus and propodus of walking legs thickly covered with long plumose hairs.

Males with a pair of pleopods.

Distribution.—Indian Ocean: Madagascar; Chagos Archipelago. Pacific Ocean: *Ryukyu Islands; Marianas Islands. On coral reefs and from coral heads.

Pachycheles granti Haig

Pachycheles sculptus, Grant and McCulloch, 1906, p. 40, pl. 2, fig. 1. McNeill and Ward, 1930, p. 364.

Pachycheles granti Haig, 1965, p. 104 (type locality: Yamba, New South Wales, Australia; holotype in Australian Museum).

Diagnosis.—Carapace devoid of hairs. Surface more or less smooth except on frontal region and near anterolateral margins, where it is roughened by grooves and flattened granules; a series of transverse grooves on posterolateral area. Front in dorsal view broad, transverse.

Carpus of chelipeds with three broad, strongly projecting teeth on anterior margin, these teeth smooth and with entire or minutely crenulate edges; dorsal surface (exclusive or marginal teeth) covered with five longitudinal rows of well-separated, strongly projecting tubercles, irregularly rounded or somewhat elongate, and covered except at their apices with very short, close-set hairs. Chela with five rows of tubercles similar in size, arrangement, and setation to those of carpus.

Carpus and propodus of walking legs with long, stiff, non-plumose setae.

No pleopods in males.

Distribution.—Pacific Ocean: Queensland and New South Wales, Australia. In the littoral, under stones and in sponges.

Pachycheles natalensis (Krauss)

Porcellana natalensis Krauss, 1843, p. 58, pl. 4, figs. 1, 1 *a–c* (type locality: coast of Natal, South Africa; location of type not known).

Pachycheles natalensis, Stimpson, 1858, p. 228. Barnard, 1950, p. 472, text-fig. 87. Haig, 1964, p. 371.

Pisosoma natalensis, Paulson, 1875 *a*, pl. 1, fig. 12; 1875 *b*, p. 88, pl. 11, fig. 5; 1961, p. 94, pl. 11, fig. 5.

Pachycheles sculptus, Ortmann, 1894, p. 29. Nobili, 1906 *a*, p. 67; 1906 *b*, p. 136. Riddell, 1911, p. 263. Balss, 1916, p. 8.

Pisosoma sculpta, Gravely, 1927, p. 140, pl. 20, fig. 8.

Diagnosis.—Carapace devoid of hairs. Surface with light transverse grooves along lateral margins and on frontal region. Front in dorsal view narrow, rounded-triangular.

Dorsal surface of chelipeds devoid of hairs. Anterior margin of carpus with a strong crest, cut into a large, truncate tooth at proximal end and two smaller teeth distally, these teeth often with serrate edges; dorsal surface with punctae, short, oblique rugosities, or small, flattened granules, and usually with two longitudinal grooves near posterior margin. Manus covered with granulations, more distinct than those on carpus; outer margin with a crest defined by a deep, broad groove, and surface with two broad crests, these not always well-defined. A long, thick tuft of fine plumose hairs sometimes present on ventral surface of major chela at base of fingers; in some specimens this tuft completely absent.

Walking legs densely or sparsely covered with long, non-plumose hairs.

Males with a pair of pleopods.

Distribution.—Indian Ocean: East African coast, Dar-es-Salaam to Natal; Red Sea; Gulf of Iran; Southern India. In the littoral and dredged to about 9 metres.

Pachycheles pisoides (Heller)

Porcellana pisoides Heller, 1865, p. 73, pl. 6, fig. 3 (type locality: Nicobar Islands; syntypes in Vienna Museum).

Pachycheles lifuensis Borradaile, 1900, p. 424 (type locality: Lifu, Loyalty Islands; syntypes in Cambridge Museum).

Pachycheles pisoides, Edmondson, 1925, p. 19. Haig, 1964, p. 371.

Pachycheles fronto Melin, 1939, p. 114, text-figs. 69–71 (type locality: Bonin Islands; syntypes in Stockholm Museum).

Diagnosis.—Carapace covered with scattered, non-plumose hairs, these more close-set on frontal region but very short and not forming a tuft. Surface more or less smooth except for grooves crossing postero-lateral area. Front in dorsal view broad, transverse.

Chelipeds covered with short and long non-plumose setae. Carpus with three or four strong, narrow teeth on anterior margin, most proximal one largest; posterior half of dorsal surface with elongate tubercles arranged in two more or less even, longitudinal rows, and a third row along posterior margin. Dorsal surface of manus covered with small, rounded, wide-set tubercles.

Walking legs with long, non-plumose setae.

Males with a pair of pleopods.

Distribution.—Indian Ocean: Seychelles; Nicobar Islands; Western Australia. Pacific Ocean: Ryukyu Islands; Bonin (Ogasawara) Islands; *Marianas Islands; *Carolina Islands; Loyalty Islands; Norfolk Island; Kermadec Islands; Hawaiian Islands; *Tuamotu Islands. On coral reefs and from coral heads.

Pachycheles stevensii Stimpson

Pachycheles stevensii Stimpson, 1858, pp. 228, 242 (type locality: Jesso, Japan; type not extant); 1907; p. 187, pl. 23, fig. 6. Makarov, 1938, pp. 111, 299, text-fig. 40; 1962, p. 107, text-fig. 40. Miyake, 1943, p. 103, text-figs. 32–33. Kobjakova, 1955, p. 152, pl. 38, fig. 1.

Diagnosis.—Carapace devoid of hairs except on frontal region, which bears a tuft of very short plumose hairs. Surface smooth or punctate, and with a series of transverse grooves in postero-lateral area. Front in dorsal view narrow, rounded-triangular.

Anterior margin of carpus of chelipeds with two or three large, irregularly shaped teeth on anterior margin, their edges serrate; dorsal surface, including teeth, covered with large, coarse granules or tubercles, their distal side fringed with hairs which are visible only under magnification; surface with three indistinct longitudinal crests defined by shallow sulci. Chelae covered with granules and minute hairs as in carpus; surface of manus with three broad, indistinct longitudinal crests, the median one somewhat produced distally to form a protuberance at base of pollex. On major chela, a thick tuft of plumose hairs on ventral surface at base of fingers.

All segments of walking legs with a thick fringe of plumose hairs along anterior margins; dorsal surface of carpus and propodus hairy.

Males with a pair of pleopods.

Distribution.—Pacific Ocean; Sea of Japan, south to Petra Velikogo Bay in U.S.S.R. and Hokkaido to Nagasaki in Japan; east coast of Japan south to Tokyo Bay. In the littoral, under stones.

Pachycheles pectinicarpus Stimpson

Pachycheles pectinicarpus Stimpson, 1858, pp. 228, 242 (type locality: Hong Kong: type not extant); 1907, p. 186, pl. 23, fig. 5.

Diagnosis.—Carapace hairless except for a tuft on frontal region. Surface smooth but postero-lateral area crossed by grooves. Front in dorsal view narrow, rounded, not prominent.

Chelipeds (apparently) not hairy. Anterior margin of carpus convex, armed with about eight small, subequal, spiniform teeth; dorsal surface covered with small granules, some of them a little larger and arranged in longitudinal rows. Chela covered with wide-set granules or small tubercles. Gape of fingers of major chela pubescent.

Remarks.—This species is known only from a single specimen (probably a female, to judge from the width of the carapace as shown in Stimpson's illustration). The brief description does not mention setation, except for its presence on the frontal region; and it is not known whether or not there are pleopods in the male.

Distribution.—" Found under stones on rocky ground in the third subregion of the littoral zone, on the shore of Ly-i-moon passage, near Hong Kong, China " (Stimpson, 1907).

Pachycheles balssi Miyake

Pachycheles pubescens, Balss, 1913, p. 32.

Pachycheles hertwigi Balss, 1913, p. 33, text-figs. 22, 23 *a–b*, 24 (corrected to *P. pubescens* Holmes in Balss, 1914, p. 98).

Pachycheles balssi Miyake, 1943, p. 106, text-figs. 34–36 (type locality: Okinosima Island, Japan; holotype in Zoological Laboratory, Kyushu University).

Diagnosis.—Carapace with a few very small, scattered hairs on anterior half, and with a tuft of short, plumose hairs on frontal region. Surface smooth or punctate, postero-lateral area crossed by grooves. Front in dorsal view narrow, rounded-triangular.

Chelipeds densely covered with long, plumose hairs. Proximal two-thirds of anterior margin of carpus occupied by two strongly projecting, serrate-edged teeth, distal third of margin unarmed or crenulate; dorsal surface with three widely separated longitudinal rows of small, pearly tubercles. Dorsal surface of manus completely covered with small, wide-set, rounded tubercles, which are rather strongly projecting but completely concealed by dense covering of hair. Pollex and distal third of dactyl paved with large, close-set, flattened tubercles; proximal two-thirds of dactyl with large tubercles in two longitudinal rows, area between these rows filled with hair which is otherwise nearly absent from dorsal surface of fingers. Lower surface of major chela with tuft of hair at base of fingers.

Anterior margin of walking legs, and dorsal surface of carpus and propodus, densely covered with plumose hairs.

Males with a pair of pleopods.

Distribution.—Pacific Ocean: east coast of Japan, from Tokyo Bay to Okinosima Island. In the littoral, under stones.

Pachycheles tomentosus Henderson

Pachycheles tomentosus Henderson, 1893, p. 428, pl. 39, figs. 16–18 (type locality: Karachi, Pakistan; syntypes in British Museum).

Diagnosis.—Carapace devoid of hairs except on frontal region, which bears a tuft of short plumose hairs and long, stiff, non-plumose setae. Surface nearly smooth except for grooves crossing posterolateral area. Front in dorsal view narrow, rounded-triangular.

Chelipeds densely covered with tufts of short plumose hairs; interspersed with these are long, stiff, scattered non-plumose setae. Carpus with two or three broad, shallow teeth on anterior margin; dorsal surface with three widely separated, longitudinal rows of small, pearly tubercles. Dorsal surface of chela with rows of tubercles like those on carpus. A short tuft of plumose hairs in gape of fingers of major chela.

Anterior margins of walking legs densely covered with plumose hairs.

Males with a pair of pleopods.

Distribution.—Known only from Karachi, Pakistan.

ACKNOWLEDGEMENTS

I have examined types of many of the nominal species, and re-examined considerable material on which published records were based. I have seen all the species (a long series of specimens in most cases) with the exception of *Pachycheles pectinicarpus*. None of this would have been possible without the generous help of many persons, for whose assistance I am very grateful.

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ON THE PORCELLANIDAE (CRUSTACEA-ANOMURA) OF RATNAGIRI ALONG THE WEST COAST OF INDIA

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Abstract

Very little work has been done in India on the porcellanid crabs, especially from the intertidal zones. The present paper deals with porcellanids of Ratnagiri District collected from the intertidal area. Nine species belonging to five genera are dealt with. Of these, *Porcellana gravelei* and *Polyonyx splendidus* were already described as new species by the author, *Petrolisthes lamarckii* (Leach), *Pisidia dehaani* (Krauss) and *P. spinulifrons* (Miers) are new records to Indian coasts, and *Petrolisthes boscii* (Audouin *Pachycheles natalensis* (Krauss), *Porcellana ornata* Stimpson and *Polyonyx hendersoni* Southwell are species already recorded.

Detailed taxonomic account of 5 species, excluding the four. *Porcellana gravelei, Polyonyx splendidus*, described earlier as new by the author, and *Petrolisthes boscii* and *Polyonyx hendersoni* for which detailed descriptions are available, along with illustrations and information on the ecology of all the species are given. Artificial keys have been formulated to enable identification of the Ratnagiri 'porcellanids.

Of the four families, *viz.*, Aeglaeidae, Chirostylidae, Galatheidae, and Porcellanidae of superfamily Galatheoidea of the section Anomura, family Porcellanidae has been the subject of much confusion with several carcinologists. Some of its genera are still being regrouped or revised, though today it is recognised as a distinct family in Galatheoidea.

Most of the works on the Indian fauna deal with deep water forms (Henderson, 1893; Miers, 1884; deMan, 1888–96; Alcock and Anderson, 1894; Anderson, 1896 and Alcock, 1901). Very little is known about the shallow water species, especially of the west coast of India. Southwell (1906) dealt with the porcellanids of Ceylon; Gravely (1927) described nine species from the Krusadai Island, three of which have been described up to the genera only; Jones (1959) described the association of a porcellanid crab with the sea pen *Pteroeides esperi* Herklots, from the Gulf of Mannar. The porcellanid was later identified and described by Sankarankutty (1961 *a*); Sankarankutty (1961) described a new genus from the Gulf of Mannar. While studying the fauna of Okhamandal, Southwell (1909) described nine porcellanids, of which one he could identify up to the genus only. Patil (1951) working on the marine fauna of Karwar and neighbouring islands mentioned the occurrence of the genus *Porcellana* there.

In Ratnagiri, the family Porcellanidae is represented by nine species belonging to five genera, *viz.*, *Petrolisthes, Pachycheles, Porcellana, Pisidia* and *Polyonyx*. Of these nine species, two were new to science, three are new records to Indian waters, and four are species already recorded.

The collection of the material was confined to the intertidal zones along the Ratnagiri coast, namely, Mirya Donghur, Mirya beach, Mirkarwada and Karla in Ratnagiri town, the Sindhudurg Fort area and North border of Kacheri in Malvan.

The identification of my porcellanid material was mainly based on the works of Miyake (1943) and Haig (1960) and as regards the genera *Porcellana, Pisidia* and *Pachycheles*, the changes suggested by Haig (*op. cit.*) have been accepted.

The length-width ratio of the various appendages was not found to be particularly useful from the taxonomic point of view and hence detailed proportional measurements are not taken. The length-width ratio of the carpus of the cheliped is useful, as already suggested by Haig (*op. cit.*) in the systematics of the species of the genera *Petrolisthes* and *Polyonyx*. In the present study, however, measurements have been taken of the carapace-length only and size-range has been given of the males, non-ovigerous and ovigerous females.

Only those works dealing with the forms of the Indian regions and a few others of general importance have been referred to in the present studies.

Family PORCELLANIDAE Dana, 1852

Key to the Ratnagiri genera of family Porcellanidae

1 *a*. First segment of antenna short, not strongly produced forward to meet anterior margin of carapace, movable segments with free access to orbit..............................2

1 *b*. First segment of antenna produced forward and broadly in contact with anterior margin of carapace, movable segments far removed from orbit..............................3

2 *a*. Posterior portion of epimera (side-walls) of carapace without separated pieces; chelipeds subequal, usually not robust; telson seven-jointed..................*Petrolisthes*.

2 *b*. Posterior portion of epimera consisting of one or more pieces separated by membranous interspaces; chelipeds thick, robust, distinctly unequal, telson five-jointed........ .... *Pachycheles*

3 *a*. Dactylus of walking legs with two or more large, strong, fixed spines; carapace markedly broader than long, front nearly transverse in dorsal view.... *Polyonyx*

3 *b*. Dactylus of walking legs with a single spine, usually with accessory movable spinules on posterior margin; front prominent, slightly tri-dentate or tri-lobed in dorsal view...4

4 *a*. Lateral margin of carapace posterior to epibranchial angle entire; fingers of chelipeds not twisted......................................*Porcellana*

4 *b*. Lateral margin of carapace posterior to epibranchial angle with spinules; fingers of one or both chelipeds twisted out of plane with palm............*Pisidia*

Genus *Petrolisthes* Stimpson, 1858

Key to the Ratnagiri species of Petrolisthes

Carapace and chelipeds with transverse rugae; carpus of cheliped with three to five teeth on anterior margin.. *boscii*

Carapace and chelipeds almost smooth, carpus of cheliped with three to seven teeth on anterior margin..*lamarckii*

Petrolisthes boscii (Audouin)

(Fig. 1)

Porcellana boscii Audouin, 1826, p. 89.

Porcellana (*Petrolisthes*) *boscii* DeMan, 1888, p. 217.

Petrolisthes boscii Henderson, 1893, p. 427; Southwell, 1909, p. 118; Gravely, 1927, p. 140; Miyake, 1937, p. 211; 1943, p. 90; Haig, 1964, p. 360, *Previous records*: Red Sea; Mergui Is.; North Australia; Nippon (Suruga Bay); India (Krusadai Island and Okhamandal).

Material examined: About 200 specimens were collected from various localities in Ratnagiri.

Measurements: Of the material examined, in connection with the present study, males were found to be ranging from 6 mm.–17 mm., non-ovigerous females from 5 mm.–13 mm., and ovigerous females from 7·5–15 mm.

Colour in live condition: Majority of the specimens were mottled maroon with the mosaic pattern of the rugae on the carapace and chelipeds and the rest were of mottled violet to blue in colour. In all the specimens examined so far, the ground colour of the ambulatory legs was blue with the rugae being either violet or pink or maroon depending upon the colour of the carapace and chelipeds. As observed by Southwell (1909) the colour does not undergo much change, in the preservative even after 1½ years.

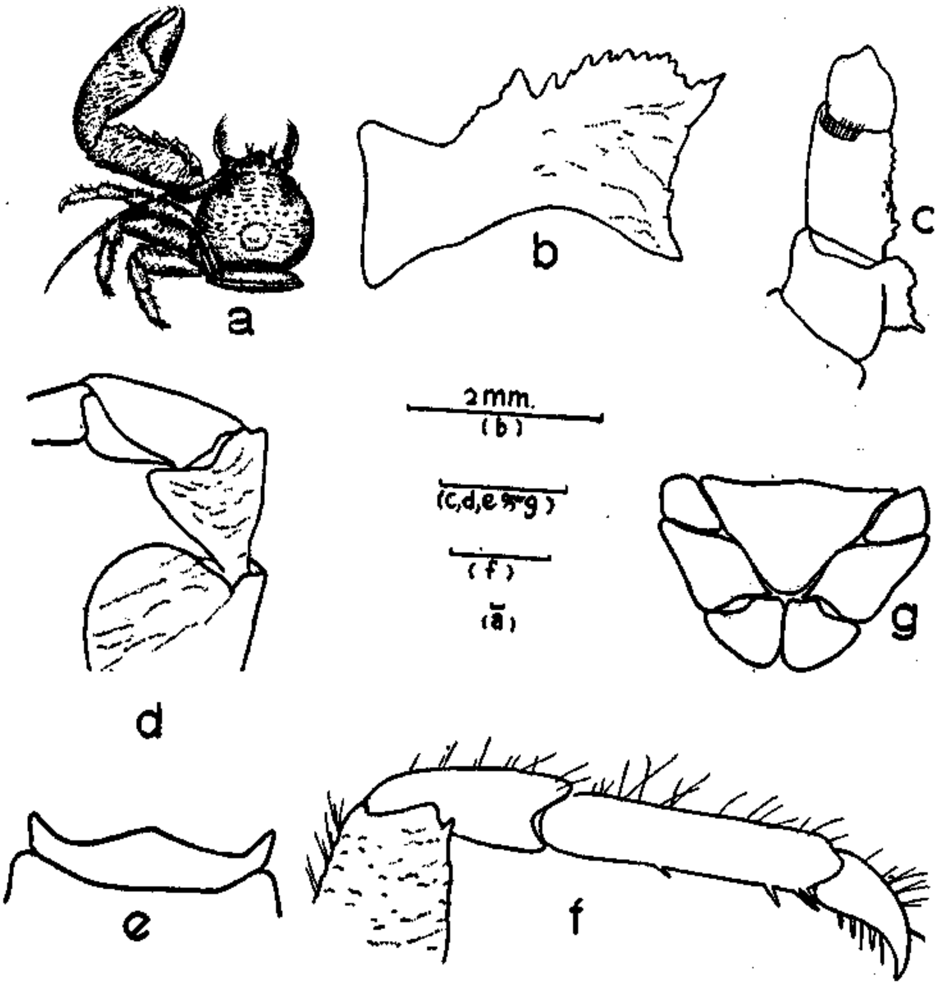

FIG. 1. *Petrolisthes boscii*. *a*, dorsal view; *b*, antennule; *c*, antenna; *d*, third maxilliped; *e*, sternum of third maxilliped; *f*, walking leg; *g*, telson; *h*, cheliped.

Ecology: It frequently occurs among and underneath stones and rocks in the intertidal zones of the rocky shores and many a time it has also been collected along with *P. lamarckii.* It always seems to prefer the upper zones of low tide level. As far as locomotion is concerned, *P. boscii* is very active.

Ovigerous females were available from August to May.

Remarks: In the Japanese specimens, as seen from the drawings of Miyake (1943) the outer margin of palm, is provided with about 11 spinules, whereas in the local forms, that too in smaller specimens, there are about 4 spinules on the outer margin and none so in larger specimens.

***Petrolisthes lamarckii* (Leach)**

(Fig. 2)

Pisidia lamarckii Leach, 1820, p. 54.

Petrolisthes dentatus Haswell, 1882, p. 146; Henderson, 1893, p. 426.

Porcellana (Petrolisthes) dentata DeMan, 1888, p. 216; DeMan, 1888 *b*, p. 409.

Petrolisthes dentatus DeMan, 1896, p. 374.

Petrolisthes obtusifrons Miyake, 1937, p. 155.

Petrolisthes larmarckii Borradaile, 1898, p. 464; Miyake, 1942, p. 342; Miyake, 1943, p. 98; Haig, 1964, p. 362.

Previous records: Indian Ocean, East Australia, East Indian Ocean, Polynesia, Micronesia, Sulu Sea, Hong Kong, Kagosima Bay.

Description (Fig. 2 *a*)*:* Length of carapace 12·5 mm., breadth of carapace 12·5 mm.

Carapace depressed, as long as broad, almost smooth except for minute elevated irregular ridges which are faintly visible in front of the gastric region or sides only; front triangular, apically rounded, slightly deflexed downwards with a distinct median furrow as in *P. boscii*; epibranchial spine generally present, occasionally inconspicuous and in some cases absent; rugae on the carapace more and more conspicuous along the sides from epibranchial spine to the postero-lateral part of carapace; epimera entire, slightly hairy with 4–5 minute or undeveloped rugae.

Antennule (Fig. 2 *b*)*:* First segment twice or less than twice as broad as long, its anterior margin undulated, roughly semicircular in outer half and with a single tooth on its outer extremity only; dorsally it bears one spine-like tooth on the inner side; the lower half of its ventral surface squamiform and granulated, upper half granular.

Antenna (Fig. 2 *c*): Anterior crest of second segment not distinctly undulated, its proximal end almost blunt and not drawn out into an acuminate spine as in *P. boscii*; a short joint between second and third segments present; third segment with small tubercles along ventro-lateral margin, microscopical hairs on sub-distal margin; fourth segment smooth.

Third maxilliped and its sternum (Fig. 2 *d* and 2 *e*) almost as in *P. boscii.*

Chelipeds (Fig. 2 *a*): Chelipeds subequal, upper surface ornamented with very minute rugae; merus armed with a long tooth at the inner extremity and a smaller tooth on the mid-ventral line of its distal margin; anterior margin of carpus lobed, provided with 3–7 teeth, its posterior margin generally with 3 distinct teeth, 3–4 indistinct teeth also present on a rudimentary crest, arising from the proximal part, these teeth increase in size distally; upper surface of carpus and propodus ornamented with minute rugae, these rugae tend to become somewhat large and semicircular towards the posterior margin and less prominent towards the base of the fixed finger and dactylus.

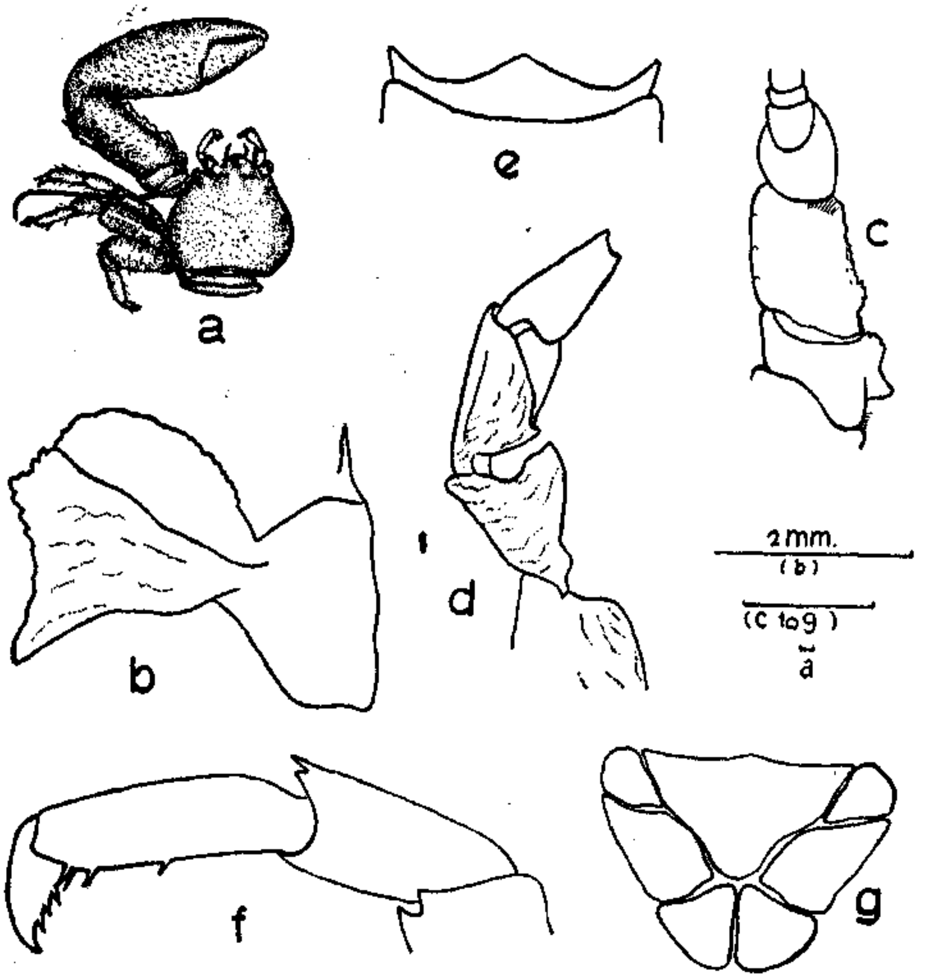

FIG. 2. *Petrolisthes lamarckii.* Lettering as in Fig. 1.

Walking legs (Fig. 2*f*): Merus of first three ambulatory legs provided with rows of small, oblique granular ridges with microscopic hairs anteriorly, less distinct than in *P. boscii*; merus of first two legs with a spine at distal end of posterior margin; carpus of first pair with a spine at antero-distal end; propodus with four spinules on its posterior margin; dactylus with 3 spinules.

Telson (Fig. 2*g*): 7-jointed, middle piece very broad.

Material examined: Several specimens of various sizes were collected from several localities in Ratnagiri.

Measurements: The minimum and maximum size of males were 6 mm. and 17 mm., of non-ovigerous females 5 mm. and 9 mm. and of ovigerous females 7 mm. and 12 mm.

Colour in live condition : Most of the specimens were dark violet, mottled with violet-pink. On preservation majority of the specimens lost their colour, changing from dark violet to various degrees of light red, the mottled spots becoming bright red and often persisting for about one to one and one-half years.

Ecology : *P. lamarckii* is generally found underneath and between stones along rocky shores; it occurs usually at a slightly higher level in the intertidal zone, than that occupied by *P. boscii.*
Berried females were observed from August to May.

Remarks : The number of teeth on the anterior margin of the carpus of the chelipeds was found to vary from 3–7, though 4–6 was the usual number. So also the number of teeth on its posterior margin was found to be 3, at times 2 only, but in addition to the 3 distinct ones, 3–4 indistinctly formed teeth were also present.

In the present specimens the epibranchial spine was generally present, though very inconspicuous in most of the specimens, in some cases it was altogether absent. By studying specimens of different sizes it was observed that the presence or absence of the epibranchial spine was not a character of any taxonomic value.

This is the first record of the species for India.

Genus *Pachycheles* Stimpson, 1858

***Pachycheles natalensis* (Krauss)**

(Fig. 3)

Porcellana natalensis Krauss, 1843, p. 58.

Pachycheles natalensis Stimpson, 1858, p. 228; Barnard, 1950, p. 472.

Pisosoma natalensis Paulson, 1875, p. 88.

Pisosoma sculpta Gravely, 1927, p. 140.

Pachycheles natalensis Haig, 1964, p. 371.

Previous records: Persian Gulf, Red Sea, Dar-es-Salaam, Durban, Gulf of Mannar (India).

Description (Fig. 3, *a*): Length of carapace 4·50 mm., breadth of carapace 4·75 mm.

Carapace broader than long in males, more or less convex, with no hairs on dorsal surface but with minute plications or rugae and with minute hairs arranged in lines on the epimeral regions, the rugae on the frontal region are broken and crowded, in the remaining area they are small and scattered, urogastric and cardiac regions almost smooth; front almost straight or slightly convex in dorsal view, rostrum bent downwards so that in frontal view, the front appears to be trilobed; outer orbital angle produced into a small but distinct tooth; epimera composed of two pieces, one large and the other small.

Antennule (Fig. 3, *b*): Basal segment a little broader than long, ventral surface with a granulated ridge, its anterior margin with 3 or 4 minute teeth on the inner side, 2 such teeth on the outer angle, rest of margin minutely undulated.

Antenna (Fig. 3, *c*); First segment much broader than long with acuminate edge on upper margin; second segment with a single tubercle on upper margin; upper margin of third segment almost smooth except for a few granules; fourth segment short and smooth, *Third maxilliped* (Fig. 3 *d*): Ventral surface rugose; merus with short transverse rugae, its free margin somewhat undulated; sternum of third maxilliped shorter than thoracic sternum, central process more produced than the lateral ones with its apex pointed (Fig. 3, *e*).

Chelipeds (Fig. 3 *a*): Unequal, right or left being larger; merus rugose with its sub-triangular lobe projecting on anterior margin, ventral surface smooth; carpus almost as broad as long, covered with small crowded striations or rugae which become somewhat larger than those on the lobe, less crowded and slightly imbricate in the middle, a shallow ridge near the outer margin, the ridge fading at both extremities, outer margin with a spine-like tooth at its distal end; propodus covered with rounded granular tubercles provided with hairs in the front, the granules are more prominent on the dorsal than on the ventral side and become smaller on both the fingers, a longitudinal ridge runs along and almost parallel to the outer margin from the carpal articulation to the base of the fixed finger from where it almost continues to the distal one-thirds of the finger, another small ridge, less distinct near the finger cleft; finger tips calcareous white, overlapping; dactylus curved, in length more than one-half the propodus and covered with minute granular tubercles and rugae; ventrally a group of matted hairs in the cleft near the articulation of the dactylus; fingers gaping.

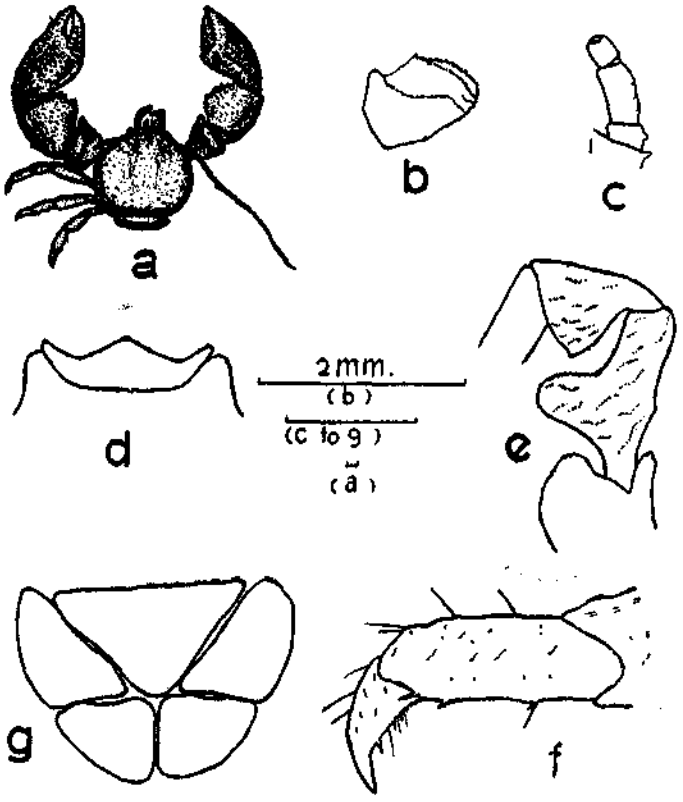

FIG. 3. ***Pachycheles natalensis*****. Lettering as in Fig. 1.**

Small cheliped almost similar to the large, except in size, fingers straight, leaving almost no gap between them and group of matted hairs absent in the cleft of the fingers.

Walking legs (Fig. 3, *f*): Slightly striated and with a few scattered hairs; propodus with 4 movable spinules of which 2 are on the posterior margin and the other two at the distal end of the margin, but one on either surface; dactylus with 3 movable spinules which increase in size distally, tip a claw-like simple spine.

Telson (Fig., 3 *g*): 5-plated, central piece being fairly large and broad.

Material examined: About 200 specimens were collected from Ratnagiri.

Measurements: Of the material examined, males ranged from 3–4·75 mm.; non-ovigerous females from 2·5–2·75 mm. and ovigerous females from 3·5–5 mm.

Colour in live condition: General colouration is various shades of greenish-brown.

Ecology: This species occupies the same habitat as *Polyonyx hendersoni* in the intertidal zone and is generally found in the crevices of stones covered with weeds and *Zoanthus* colonies and occasionally inside the sponge colonies.

Remarks: In a few specimens, the cutting edge of the dactylus of the chelipeds has near its base a large blunt tooth followed by 4–5 smaller rounded tubercles which decrease in size distally.

The four teeth on the inner marginal lobe of the carpus often tend to divide along their edges, followed distally by 2 smaller teeth.

Haig (1960) has shown that the two genera *Pisosoma* and *Pachycheles* cannot be maintained separate and therefore combined them under the name *Pachycheles* Stimpson.

The species is recorded for the first time from the West Coast of India.

Genus *Porcellana* Lamarck, 1801

Key to the Ratnagiri species of Porcellana

Carapace not smooth, regions distinctly accentuated; chelipeds rather flat, upper surface sculptured with ridges and tubercles..*ornata*

Carapace almost smooth except for mats of hairs on some areas, regions not prominently accentuated; chelipeds rather hairy, upper surface not sculptured with ridges and tubercles but with distinct rugae..*gravelei*

Porcellana ornata **Stimpson**

(Fig. 4)

Porcellana ornata Stimpson, 1858, p. 242; 1907, p. 188.

Porcellana sp. Gravely, 1927, p. 141.

Porcellana ornata Gordon, 1931, p. 529; Miyake, 1943, pp. 118–121.

Previous records: Hong Kong, Japan, Shingle and Krusadai Islands (Gulf of Mannar).

Description (Fig. 4, *a*): Carapace as broad as long, sub-ovate, upper surface almost convex, regions well defined, those on anterior half of carapace especially, protogastric and hepatic regions demarcated by deep grooves, epigastric region slightly elevated, protogastric region divided into two lobes, inner lobe larger than outer; mesogastric and urogastric regions fused, cardiac region not distinctly differentiated; front when viewed from the dorsal side appears biconvex but in the frontal view it is trilobed, the median lobe being strongly grooved and slightly deflexed; frontal and antennal margins minutely serrated, supra-orbital margin not provided with a median tooth above the eye; lateral border armed with about 4–7 denticles and some minute serrations on the branchial region, no small tooth in front of outer protogastric lobe.

Antennule (Fig. 4, *b*): Frist segment much longer than broad, with 3–4 prominent teeth on each angle of the dorsal plate, either side of the ventral tooth minutely serrated and so also the inner side of the tooth at the upper inner angle.

Antenna (Fig. 4, *c*): Second segment broader than long, distally narrowed, upper distal end of third segment produced into a lobe; fourth segment short.

Third maxilliped (Fig. 4, *d*): Crest of merus almost subquadrate with its anterior margin serrated and surface striated; sternum of third maxilliped (Fig. 4 *e*) quite high, its central process almost as high as the lateral ones, margins more or less straight, lateral process slender; anterior margin of sternum convex.

Chelipeds (Fig. 4, *a*): Chelipeds sub-equal or almost equal, rather flat, dorsal surface provided with ridges and tubercles; merus with a large lobe bearing about 6 minute teeth; carpus oblong quadrate, with two pronounced longitudinal ridges on dorsal surface, anterior margin almost straight, armed with 2–4 small teeth on the proximal lobe, rest of the margin being minutely serrated, posterior margin dentate; propodus much broader than one-half its length, provided with a rather prominent median ridge, on the outer side of which are round, large but flat tubercles, a few tubercles also present on the inner side near the articulation of the dactylus; outer margin with delicate hairs.

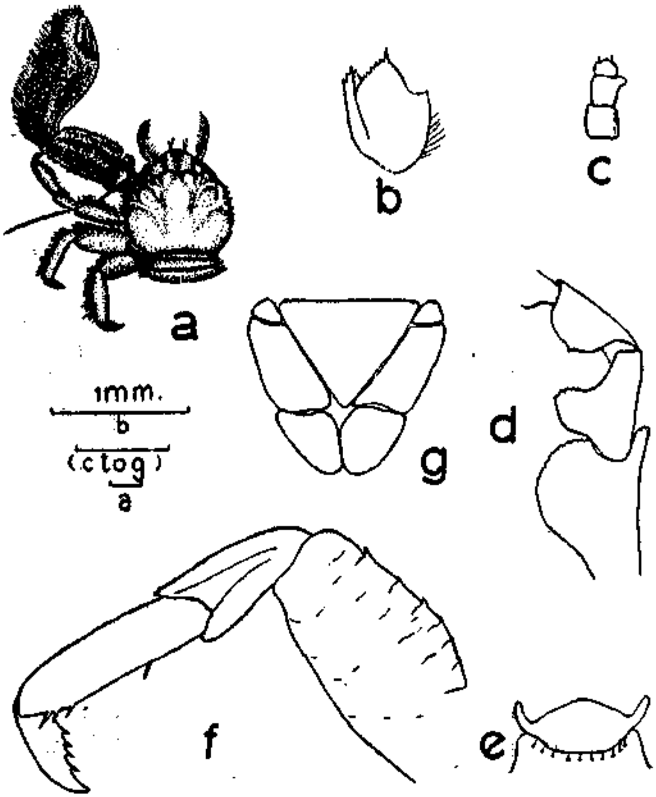

Fig. 4. *Porcellana ornata.* Lettering as in Fig. 1.

Ambulatory legs (Fig. 4, *f*): Hairy; merus rather stout, spinules on the outer margin more prominent than those on the posterior margin; carpus similarly but less distinctly spinulose, the distalmost spinules being large; propodus armed with 4 spinules on the posterior margin, 2 at the distal end and 2 on the border; dactylus with 4 spinules.

Telson (Fig. 4, *g*) : 7-jointed, antero-lateral plates very small, central one fairly large, medio-laterals narrowing posteriorly, postero-lateral ones rather longer than broad.

Material examined: 80 specimens of various sizes were collected from Ratnagiri.

Measurements: Males were 2–4 mm. long, non-ovigerous females 2·25–2·75 mm. and ovigerous females from 2·75–3·75 mm.

Ecology: Though not so abundant, as the previous three species it is generally found underneath the loose stones encrusted with seaweeds, mostly in the same level as *Pisidia spinulifrons* in the intertidal zones; when disturbed the crab at once folds its chelipeds along the carapace and remains still for a while.

Remarks: What Gravely (1927) figures as *Porcellana* species (pl. XX, fig. 14) appears to be *P. ornata* in all essential features.

This is the first record of the species along the West Coast of India.

***Porcellana gravelei* Sankolli**

(Fig. 5 *a*)

Pachycheles sp. Gravely, 1927, p. 140.

Porcellana gravelei, Sankolli, 1963, pp. 280–283.

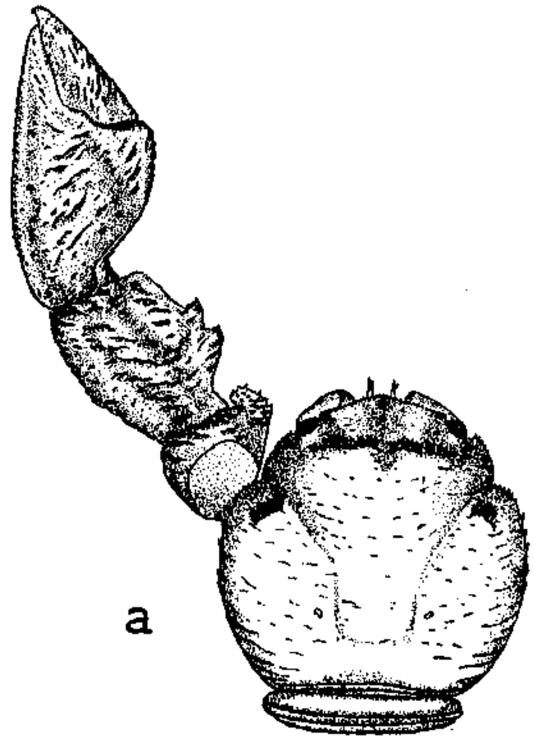

FIG. 5. *Porcellana gravelei* (dorsal view).

Genus *Pisidia* Leach, 1820

Key to the Ratnagiri species of the genus Pisidia

Carpus of chelipeds with two dorsal ridges and a proximal tooth on the inner lower margin; dactylus alone twisted; propodus and dactylus of walking legs with 2 and 3 spinules respectively on the posterior margin .... *dehaani*

Carpus of chelipeds without dorsal ridges or proximal tooth on the inner lower margin; both fingers twisted; propodus and dactylus of walking legs with 3 and 5 spinules respectively on the posterior margin.. *spinulifrons*

Pisidia dehaani (Krauss)

(Fig. 6)

Porcellana dehaani Krauss, 1843, p. 59; Henderson, 1888, p. 110; Barnard, 1947, p. 378; Barnard, 1950, p. 476.

Previous records: Natal, Durban and Delagoa Bay.

Description (Fig. 6 *a*)*:* Carapace slightly convex, a little broader than long, glabrous with tufts of hairs near the epigastric region; minute squamiform granules arranged as horizontal striae especially prominent on the postero-lateral regions of the carapace, gastric and hepatic regions distinctly elevated; distal part with two teeth and these are followed anteriorly by two smaller ones at the distalmost end of the lateral margin, the lateral notch takes a smooth curve bearing at its beginning 2 or 3 spinules which are then followed by 3 or 4 tubercles; 4 minute teeth on the antennal angle; front distinctly trilobed with margins minutely serrated, the middle lobe being the largest and extending a little beyond the lateral ones; epimera provided with 3–4 distinct longitudinal striations and about 5 small teeth in the anterior margin just adjoining the first segment of the antenna.

Antennule (Fig. 6 *b*)*:* First segment longer than broad, its lateral margins more or less straight, inner margin distally serrated, upper plate strongly concave with a few tubercles, its margin armed with 5–6 distinct teeth, the teeth on the dorsal side of upper plate larger than the rest.

Antenna (Fig. 6 *c*)*:* First segment very broad, upper surface slightly concave, its anterior margin minutely serrated with a prominent tooth at the extremity whereas in Barnard's (1950) specimens the anterior margin is entire, though sometimes very minutely and feebly denticulate distally; second segment short with a stumpy blunt tooth at the distal end of the anterior margin; third segment comparatively longer and provided with about 4 teeth; 4th segment short and smooth.

Third maxilliped (Fig. 6 *d*) ; Merus with undulations on the outer upper projection; sternum of third maxilliped high, as wide as the first thoracic sternum (Fig. 6 *e*), central process with its margin quite triangular, projecting well beyond the lateral ones, lateral processes fairly long, separated by a large rounded sinus; anterior margin of thoracic sternmum with a deep notch at its middle.

Chelipeds (Fig. 6 *a*)*:* Rounded with minute squamiform granules as on carapace, subequal or almost unequal in the 8 specimens (females) examined so far; angle at extremity of meral lobe prominent, minutely dentate with about 8 denticles; in the S. African specimens, it appears that the meral lobe is entire as per Barnard's figure and description; carpus with two median, wide obtuse but not so well developed ridges, one towards the anterior and the other towards the posterior margins, a prominent tooth, which is generally not seen or partly seen from above, in the proximal part of the inner lower margin, this tooth seems to be almost absent in the S. African specimens (*see* remarks); propodus armed with a median obtuse ridge, which fades away towards the finger cleft the depression on the inner side of its ridge being more prominent than the one on the outer; dactylus longer than the fixed finger but as long as the palm from the base to the finger gap, twisted at the tip with a slight groove proximally, when closed fingers leave no gap and the hairs are absent.

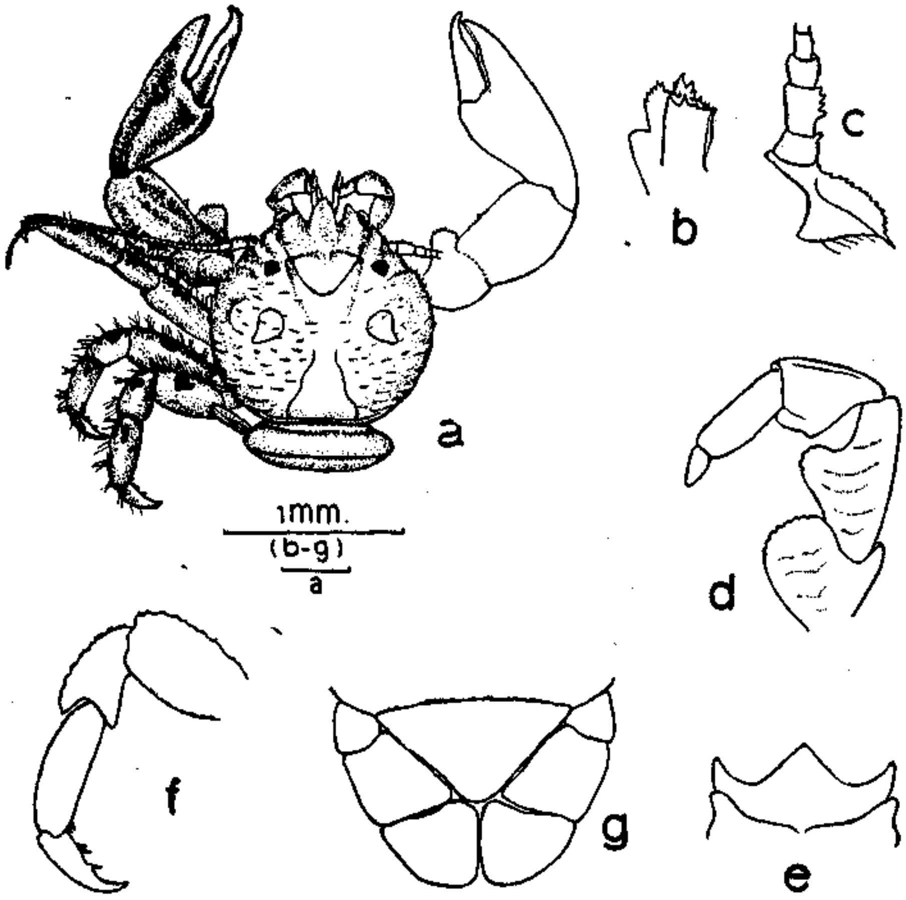

FIG. 6. *Pisidia dehaani.* Lettering as in Fig. 1.

Walking legs (Fig. 6*f*): Rather stout, sparsely hairy; anterior margin of merus and carpus not smooth but irregularly serrated or undulated; carpus less than one-half the length of propodus; propodus with 2 spinules distally and dactylus with 3 spinules on the posterior margin.

Telson: 7-jointed, middle piece broader (Fig. 6*g*).

Material examined: During the course of the present study only 8 females could be collected.

Measurements: Of the specimens examined, the ovigerous specimens were ranging from 2–4·2 mm.

Colour in live condition: The ground colour of this porcellanid is pale reddish-brown. On the carapace are a few whitish patches, one roughly triangular patch on either side on the proto-gastric region, one much larger patch on the mid-longitudinal line extending from the posterior margin to almost the urogastric region and the other being more or less a triangular patch from the front to almost the mesogastric region. Of these the frontal triangular patch was found to remain constant in the 8 specimens examined, although the other patches were observed to change from the general pattern as shown in the figure. There is also a dark brown blotch on either side on the hepatic region. The chelipeds have only one small dark brown patch on each of their fingers. Each segment of the walking legs has one patch of irregular shape on its upper surface.

Ecology : *P. dehaani* was found underneath the loose stones and rocks covered with seaweeds; frequently encountered with *P. spinulifrons* and *Porcellana ornata.* The species appears to inhabit the same level as that of the two species mentioned above.

So far berried specimens could be collected from April to June.

P. dehaani is not as active as *Porcellana ornata* and is much slower than *P. spinulifrons.*

Remarks : Barnard (1950) has given a brief account of the species, comparing it with *P. streptocheles* and this species is not reported, in literature, outside South Africa. There are certain differences in the morphology of the basal segment of the antenna and the chelipeds of the South African and the local specimens. These differences, cited in the text of the present account, may, however, be due to the age or size of the specimens. The carapace of Barnard's specimens ranged upto 8 mm., though in the local specimens the carapace varied from 2-4·2 mm., though all of them were berried. Dr. (Miss) Janet Haig of California has many specimens of this species in her collection from the Indian Ocean and she informed me that all her specimens have the tooth at the proximal part of the inner lower margin of the carpus of the cheliped, but in larger specimens this tooth becomes reduced to a blunt but distinct tubercle (personal communication). It, therefore, appears that Barnard's specimens do not have this tooth even in smaller specimens, since otherwise he would have made a mention of it in his description of the species.

Pisidia spinulifrons (Miers)

(Fig. 7)

Porcellana spinulifrons Miers, 1879, p. 46; Gordon, 1931, p. 530.

Previous records : Strait of Tyosen and Hongkong.

Description (Fig. 7 *a*) *:* Carapace slightly convex, nearly smooth except for small striations with squamiform granules posteriorly on sides, glabrous with tufts of hairs here and there, anteriorly contracted and posteriorly rounded; lateral margin takes a little but sharp turn inwards at the lateral notch of carapace; 3–4 minute tubercles on the lateral notch, one or two slightly larger spinules on the inner side; 3 small sharp teeth on the lateral margin, of these one situated near about its middle, another near the tip of antero-lateral margin and the last (3rd) between these two; two small spines on the insertion of antenna and an additional one just behind the external angle of the orbit; front distinctly trilobed, triangular, margins minutely serrated; middle lobe largest, but not produced more than the others and a little deflexed and rounded downwards; epimeral regions slightly striated.

Antennule (Fig. 7 *b*) *:* First segment longer than broad, lateral margins nearly straight, almost parallel to each other, inner margin serrated at its distal portion, outer margin with hairs on the anterior half; upper plate strongly concave, its margin armed with 1–3 teeth on each of the four angles; 4–5 smaller teeth on the inner angle of the ventral surface.

Antenna (Fig. 7 *c*) *:* First segment much broader than high, upper surface depressed and its tip provided with three teeth, ventral margin minutely serrulated; second segment short with a small acuminate tooth at the distal end of upper margin; third segment with two comparatively smaller teeth on upper margin; fourth segment short.

Third maxilliped (Fig. 7 *d*); Laminate crest of merus almost rounded, except for a small tooth; carpus divergent distally, its smooth distal margin strongly produced, rounded but with a small angular projection. Sternum of third maxilliped (Fig. 7 *e*) very high, central process projecting upwards, with its margin rounded, lateral processes fairly large, separated by a rounded sinus.

Chelipeds (Fig. 7 *a*): Unequal in both sexes; angle at extremity of merus prominent, sometimes minutely dentate with 2 large and 2 or 3 smaller teeth; anterior margin of carpus armed with 2 larger and 5 or 6 smaller teeth, distal angle of anterior margin not produced into an acute tooth, posterior margin armed with one tooth near its middle; palm with a median angular ridge, more or less prominent and obtuse; fingers twisted and pilose within.

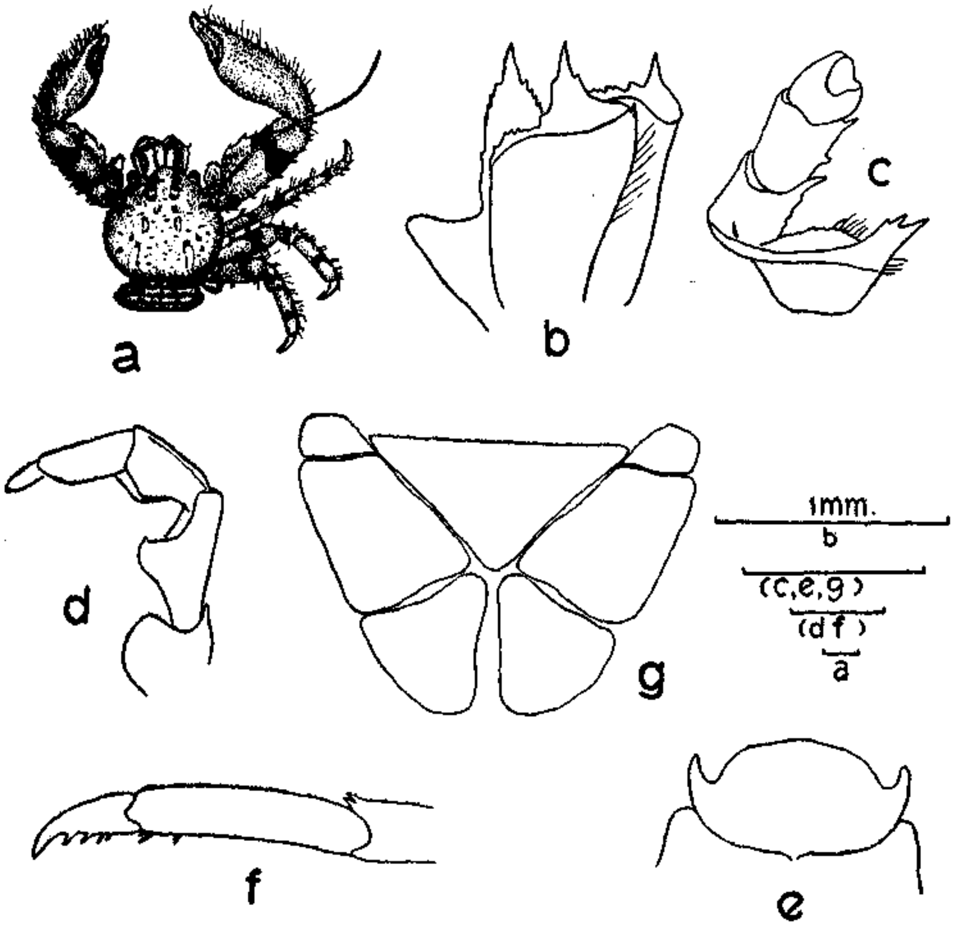

FIG. 7. *Pisidia spinulifrons.* Lettering as in Fig. 1.

Palm of female and smaller male specimens pubescent on outer margin and with its median ridge tuberculated or spinulated.

Walking legs (Fig. 7 *f*): Rather slender, sparsely hairy; carpus less than one-fourth the length of propodus; propodus armed with 3 spinules on the posterior margin; dactylus with 5 spinules on posterior margin.

Telson (Fig. 7 g): Seven-jointed; much broader in the female than in male; distal joint of abdominal appendages spoon-shaped.

Material examined: Numerous specimens of varying sizes were collected from Mirkarwada only.

Measurements: Of the material examined, for the present study, the minimum and maximum sizes of males were 3·75 mm. and 5 mm., of non-ovigerous females 2 mm. and 2·5 mm. and of ovigerous females 3·5 mm. and 4·75 mm.

Colour in live condition: In most of the specimens the general colouration was light brown with dark brown patches on carpus, merus and propodus of the walking legs. On the carapace there were a few whitish longitudinal patches of more or less regular shape. In others and especially in smaller specimens instead of light brown the general colouration was blue.

Ecology: The species is generally found underneath the loose stones and rocks encrusted with seaweeds in the intertidal zones much lower than that of *Polyonyx hendersoni* and *Pachycheles natalensis*. While killing in freshwater this species was found to die much earlier than *P. hendersoni* and *P. natalensis*. *P. spinulifrons* is quite agile in its locomotion and is well camouflaged to its brownish surroundings of the underside of the stones where it generally inhabits.

Remarks: *P. spinulifrons* is most closely related to *P. serratifrons* (Stimpson, 1907). Gordon (1931) briefly discussed the differences between these two forms and observed that "It is possible that transitional forms may yet be found. It is just possible that *P. spinulifrons* is a young, though sexually mature (larger females ovigerous), form of *P. serratifrons* previously recorded from Korea and Japan."

I had no opportunity to critically study the type specimens of *P. serratifrons* to see whether there is a transition between the two forms, but by studying the brief discussion and several illustrations given by Gordon (*op. cit.*) I am inclined to think they are separate species. Till the two are critically examined, I think it is sufficiently safe to assign the local species to *P. spinulifrons* (Personal communication with Dr. Janet Haig of Allan Hancock Foundation, California).

This is the first record of the species from the Indian waters.

Genus *Polyonyx* Stimpson, 1858

Key to the Ratnagiri species of the genus Polyonyx

Only smaller cheliped hairy that too on the upper part of propodus, otherwise chelipeds with blunt tubercles and tubercular ridges on all segments............................*hendersoni*

Both chelipeds extremely hairy with sharp tubercles and tubercular ridges especially on propodus and carpus..*splendidus*

Polyonyx hendersoni Southwell

(Fig. 8)

Polyonyx tuberculosus Henderson, 1893, p. 430; Gravely, 1927, p. 141.

Polyonyx hendersoni Southwell, 1909, pp. 117–118; Johnson, 1958, pp. 112–113; Haig, 1964, pp. 380–381.

Previous records: Adam's Bridge, Pamban, Ceylon and Okha.

Material examined: About 200 specimens of varying sizes were collected from Mirkarwada (Ratnagiri) and Sindhudurg fort area (Malvan).

Measurements: Males 4–6·5 mm.; non-ovigerous females 3·5–4·00 mm.; ovigerous females, 5·75–8·00 mm.

Colour: Majority of the specimens had varying shades of dark red colour, though specimens of light brown to greenish-brown colouration were also present.

Ecology: *P. hendersoni* was found in the interstices of the stones and rocks encrusted with *Zoanthus* colonies and in the cavities of sponges; often found along with *Pachycheles natalensis.* It was also observed that this species generally inhabits a level slightly lower than that inhabited by *Petrolisthes boscii* in the intertidal zones. Southwell (1909) recorded this species as occurring associated with *Polyonyx obesulus* and so far, it was once taken from 8½ fathoms—Adam's Bridge—Ceylon.

Several berried females were taken from April to July.

P. hendersoni was observed to be very sluggish in locomotion when compared with *P. boscii* and *P. lamarckii.*

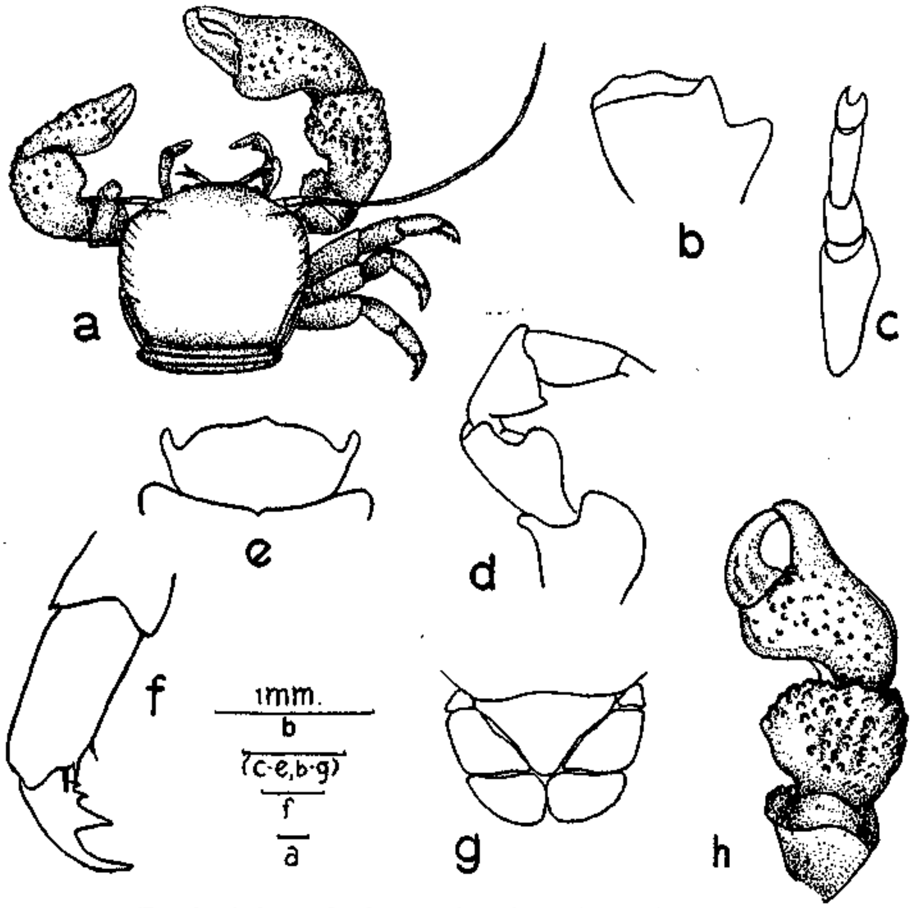

FIG. 8. *Polyonyx hendersoni.* Lettering as in Fig. 1.

Affinity: As Johnson (1958) observes, *P. hendersoni* is a distinct species, its nearest affinity being apparently to *P. obesulus,* considering the general form of carapace and cheliped. And hence he places it in his *P. biunguiculatus* group, though it differs widely in some of the important characters of the members of that group.

Remarks: From his examination of Henderson's material, Johnson (1958) confirmed Southwell's (1909) opinion that the species doubtfully referred by Henderson as *P. tuberculosus* was quite distinct from the true *P. tuberculosus* de Man; my observations are also in accordance with Johnson's confirmation.

In the local specimens examined so far, the form of large cheliped does not appreciably change with age and sex, as observed by Johnson (1958). Only the lower part of palm of the small cheliped of all sizes of males and females, is matted with hairs and not the distal ventral portion of plam of large cheliped as observed by Johnson in Henderson's specimens.

It appears that the species is well established as far as the West Coast of India is concerned, since Southwell records it from Okha also.

Polyonyx splendidus **Sankolli**

(Fig. 9 *a*)

Polyonyx splendidus Sankolli, 1963.

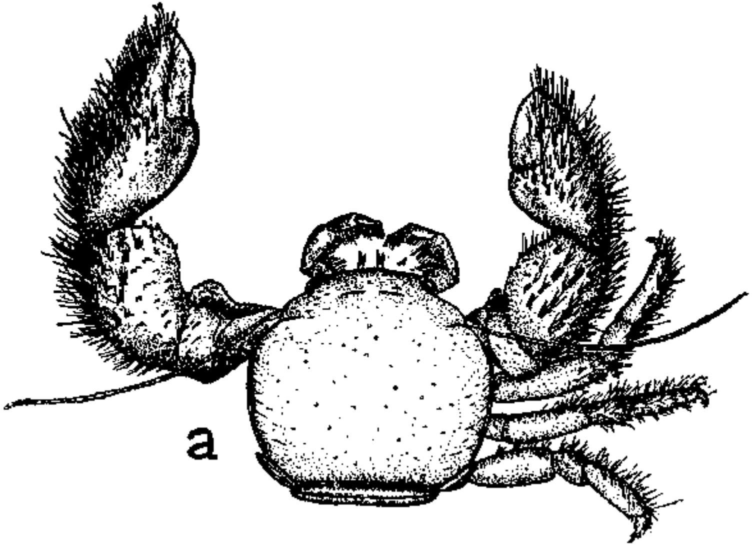

FIG. 9. *Polyonyx splendidus* (Dorsal view).

ACKNOWLEDGEMENTS

I am grateful to Dr. C. V. Kulkarni, Director of Fisheries, Maharashtra, for constructive criticism of the paper and to Dr. H. G. Kewalramani, Senior Scientific Officer, for the personal guidance during the course of the studies. Special thanks are also due to Dr. L. B. Holthuis of the Rijksmuseum van Natuurlijke Historie, Leiden, and Dr. (Miss) Janet Haig of the Allan Hancock Foundation, California, for the valuable suggestions and advice in the confirmation of the species. I am also obliged to Dr. M. P. Ranade, Research Officer, Marine Biological Research Station, Ratnagiri, for affording the necessary facilities as and when necessary, at his station.

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DISCUSSION

Dr. H. G. Stubbings: I would suggest that the paratypes of the materials are sent to one of the western museums so as to benefit those working in that region.

Dr. S. Jones: I think it would be better if, in course of time, the holotypes of the materials are deposited in the National Museum and the other types, when available, are sent to one of the western museums as suggested by Dr. Stubbings so that at one stage when the material is required for examination it will be available in one place or the other.

COMMENTS ON PHYLOGENY OF SECTION CARIDEA (DECAPODA NATANTIA) AND THE PHYLOGENETIC IMPORTANCE OF THE OPLOPHOROIDEA

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ABSTRACT

Considerable doubt has been voiced from time to time concerning whether or not section Caridea is a natural unit. Searches for common factors have not been outstandingly successful in the past. This paper presents the thesis that the Section is a natural assemblage. It proceeds from the view-point that the oplophoroid shrimps are nearest to the hypothetical ancestral form, with members of family Oplophoridae being probably the closest of modern shrimps. A hypothetical ancestral form is visualized as having (*a*) mandibles with fused incisor and molar elements and a palp of 3 segments, (*b*) exopods on all pereiopods, (*c*) chelae ending in interdigitating terminal pegs or spines, (*d*) full branchial formulae, (*e*) second carpus either solid or segmented and (*f*) telson with terminal and lateral spines. A phylogenetic chart is shown, which speculatively shows the Crangonoidea and Pasiphaeoidea as departing early from the common stem, with the remaining superfamilies passing through an oplophoroid-like phase. Two main branches are visualized: one proceeding through the Bresilioidea to the Pandalioidea; the other through a newly erected superfamily, Heterocarpodoidea to the Palaemonoidea and Alpheoidea. The Heterocarpodoidea is construed as containing families Heterocarpodidae (new), Rhynchocinetidae, and Campylonotidae.

INTRODUCTION

SECTION Caridea presents a definite challenge to students of phylogeny inasmuch as current schemes of classification are based primarily on convenience rather than on knowledge of relationships. Above family in the Caridean heirarchy, groupings become exceedingly vague. As many as seven and as few as three families, for instance, have been assigned to Superfamily Oplophoroidea at various times. Because of the vagueness of definition, Kemp (1906) and Barnard (1950), have stated that superfamilial groupings should be avoided until more is known of the characteristics of the families. This, however, represents an ultraconservative view, which, if put into practice, would be a deterrent to further study.

Much of this confusion and vagueness of definition stems from the inadequate nature of the fossil record and of data on larval comparative morphology. According to Gurney (1942), existing information on larval development confuses rather than aids interpretation of phylogenetic courses.

The principal basis today for phylogenetic studies of Section Caridea is adult morphological comparison. However, conclusions drawn on this basis must be viewed with caution and can be tentative only. It is to be hoped that biochemical studies can soon be carried out on the carideans to support or negate conclusions drawn.

THE MORPHOLOGICAL BASES OF COMPARISON

The following structures or groups of structures appear to offer the most value in tracing phylogenetic courses through morphology: (1) branchial complements; (2) mandibles and first and second maxillipeds; (3) pereiopodal exopods; (4) chelipeds and chelae; and (5) armature of the telson. The general characteristics displayed by the major caridean families in regard to these structures and a few others of lesser significance are listed in Table I,

TABLE I

Characteristics of major caridean families that are considered of particular phylogenetic importance (where variability within families is marked ranges are given)

Family	Benthic or Pelagic	Branchial Formula								Exopods on Pereiopods	Mandible			Lash on 1st Maxilliped	Chelae Adaptations	Position of Telson Spines	Nature of Carpus of 2nd Pereiopod
		1	2	3	1	2	3	4	5		Incisor	Molar	Palp				
Oplophoridae	Primarily P	2	3	4	4	4	4	4	3 4	5	Y	Y	Y	N	Spines on fingers	Lateral and terminal	Entire
Eugonatonotidae	B	2	3	4	4	4	4	4	4	5	Y (R)	Y	Y	Y	Spines on fingers	Dorsal and terminal	Entire
Atyidae	B	1 2	1 2	4	1 4	1 3	1 3	1 2	1	0 5	Y	Y	Y	Y	Long terminal hairs on fingers	Dorsal and terminal	Entire
Bresiliidae	P	2	2	0	1	1	1	1	1	0	Y	Y	Y	Y	?	?	Entire
Nematocarcinidae	B	2	3	4	4	4	3	3	1	3 4	Y	Y	Y	Y	Terminal hairs on fingers	Lateral and terminal	Entire
Palaemonidae	B	2	3	3 4	1	1	1	1	1	0	Variable, generally molar only			Y	Variable, specialized	Dorsal and terminal	Entire
Alpheidae	B	2	2	3	2	2	2	2	1	0	Variable			Y	Variable, specialized	Dorsal and terminal	Entire or segmented
Hippolytidae	B	2	2 3	4	2 3	2 3	2 3	2	1	0	Variable			Y	Variable	Dorsal or lateral, terminal	Entire or segmented
Pandalidae	B	2	3	3 4	2 3	2 3	2 3	2 3	1	0	Y	Y	Y	Y	Terminal hairs or inconspicuous spines	Lateral and terminal	Segmented
Heterocarpodidae	B	2	3	4	3	3	3	3	1	0	Y	Y	Y	Y	Spines on fingers	Lateral and terminal	Segmented
Rhynchocinetidae	B	2	3	4	2	2	2	2	1	0	Y	Y	Y	Y	Spines on fingers	Lateral and terminal	Entire
Pasiphaeidae	P	0	0	1	3	3	3	2	2	5	Y	N	Y N	Y N	Crossed and serrated fingers	Lateral and terminal	Entire
Crangonidae	B	2	2	1 4	1	1	1	1	1	0	N	Y	N	Y	Subchelae	Lateral and terminal	Entire
Glyphocrangonidae	B	2	2	3	2	2	2	2	1	0	N	Y	N	Y	Subchelae	Unarmed	Segmented
Psalidopodidae	B	2	3	4	2	2	2	2	1	0	Y	Y	Y	Y	Both fingers movable on 1; brushes on 2	Terminal	Entire

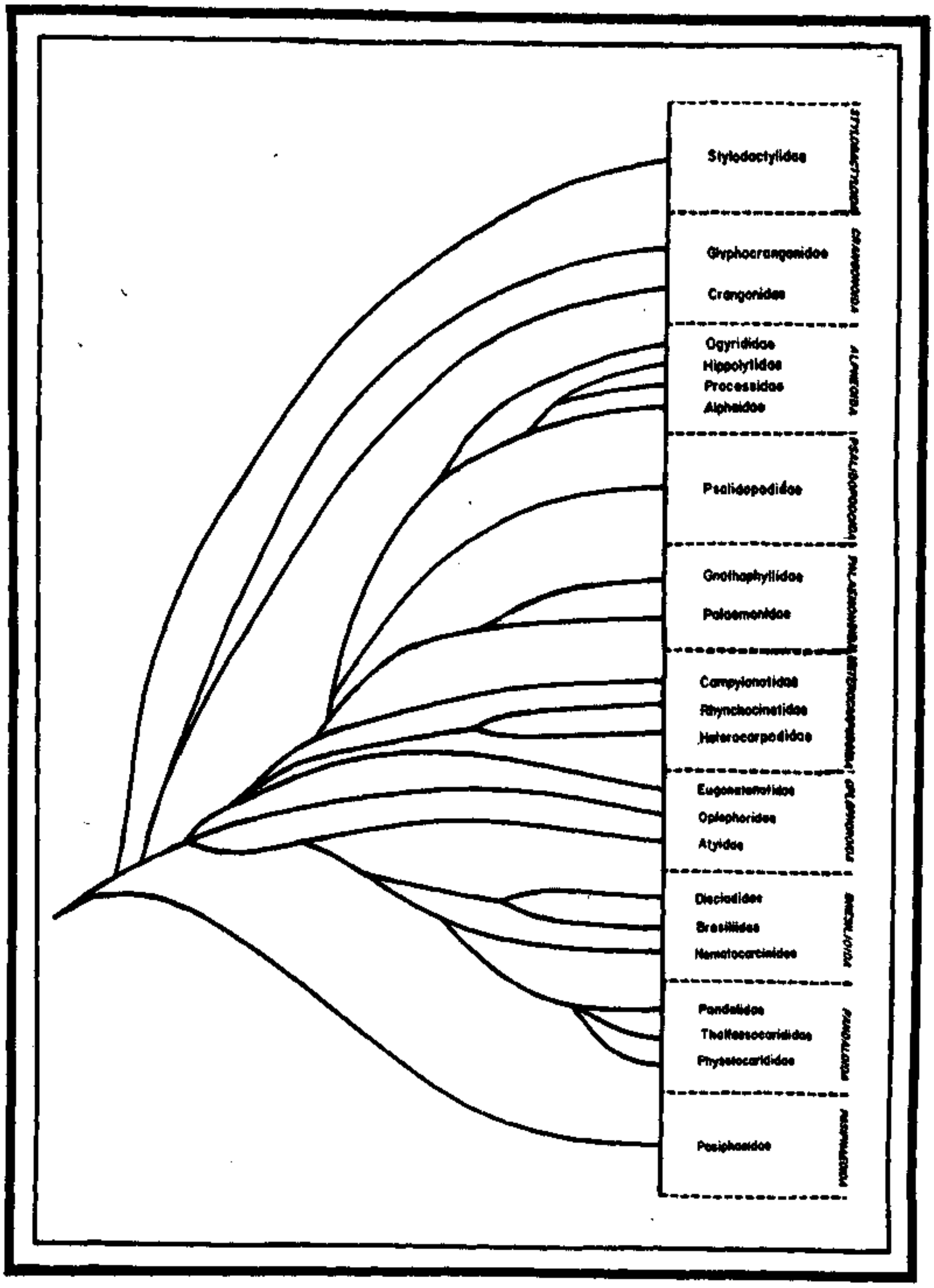

FIG. 1. Diagram of the probable phylogenetic relationships within Section Caridea based on morphological criteria.

Working knowledge of the groups concerned and analysis of the data in the table indicate that the families included in Superfamilies Oplophoroidea, Bresilioidea, Palaemonoidea, Alpheoidea, and Pandaloidea are all closely related and are members of what appears to be a natural monophyletic unit. The relations borne by the remaining Superfamilies—Pasiphaeoidea, Stylodactyloidea, Psalidopodoidea, and Crangonoidea—to the others are not so readily seen. It is entirely possible that Section Caridea, as it is usually viewed, is a polyphyletic group, with Superfamilies Pasiphaeoidea and Crangonoidea at least originating from different and separate stems. Stylodactyloidea may have branched from an oplophoraceous stem, and the Psalidopodoidea bear some resemblance to the Palaemonoidea and Alpheoidea, from which they may have been derived.

However, assuming that Section Caridea is a natural, monophyletic grouping, the most logical deduction is that Superfamily Crangonoidea left the main carid stem at some early stage in carid evolution and evolved from that point along a relatively straight branch that split only to form the two families Crangonidae and Glyphocrangonidae. Superfamily Pasiphaeoidea must also have left the main stem early in the evolution of the section (Fig. 1).

Superfamilies Pasiphaeoidea, Stylodactyloidea, Psalidopodoidea, and Crangonoidea are all highly specialized groups; the first is adapted for pelagic existence, the second for an epifaunal existence, and the last two for benthic mud bottom life.

Superfamily **Pasiphaeoidea**

The Pasiphaeoidea depart more radically from the "typical" caridean form than the others do. The mandible of members of this group consists of either an incisor portion alone or an incisor and palp. The first and second maxillipeds depart from the typical pattern and are markedly more pediform than those of other carideans. The chelae have slender fingers that cross at the tips and bear serrations on their inner edges. Presumably this would aid them in holding onto prey in the pelagic environment. The branchial formula (Table II), though varying from genus to genus, is strikingly reduced, and the telson of many species is sulcate on its posterior border like the telson of many larval but few adult carideans. The pereiopods bear strong exopods.

TABLE II

Arrangement of branchiae and exopods for species of Pasiphaea

Structure	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	0	0	0	1	1	1	1	1
Arthrobranchs	0	0	0	1	1	1	0	0
Podobranchs	0	0	0	0	0	0	0	0
Epipods	0	0	0	0	0	0	0	0
Exopods	0	0	1	1	1	1	1	1
TOTALS	0	0	1	3	3	3	2	2

Though definitely caridean, as carideans are presently defined, the Pasiphaeoidea have no obvious near relatives. Holthuis (1955) and Gurney (1942) have shown that the bresiloid genus *Bresilia* is not, as previously supposed, closely related. If the Pasiphaeoidea arose from the same stem as the remaining carideans, the intermediate stages in the development of present-day forms are missing, though they seem to have been carried on within the pasiphaeoid lineage and not to have involved offshoots entailing any other fossil or now-living group.

Superfamily **Stylodactyloidea**

Stylodactyloidea, too, must have left the main evolutionary stem at an early stage, though perhaps not as early a stage as the pasiphaeoids. They seem to be more closely related to the oplophoroids than the pasiphaeoids are to any living group, though the relationship is not close. Members of family Stylodactylidae and genus *Stylodactylus*, the sole representative of the superfamily, have fused molars and incisors similar to those of the oplophoroids and the second maxillipeds, though strangely different from those of any other caridean group in that the two terminal segments of the exopod are placed side by side on the tip of the antepenultimate, can be vaguely traced to an oplophoroid ancestry. Their branchial formula is only slightly reduced; they have lost the exopods from the pereiopods; the chelae are long and slender, being as long or longer than the carpus in most species; and the telson bears lateral as well as terminal spines, resembling the oplophoroid condition in this also. In the accompanying diagrammatic chart (Fig. 1), they are placed off by themselves owing to the differences displayed in the morphology of their second maxillipeds and in their chelae, and because more study is needed before their position can be fixed definitely. There is little doubt that, wherever they are placed, they are on an evolutionary "sideshoot".

Superfamily Psalidopodoidea is considered in a later paragraph, along with the Alpheoidea and the Palaemonoidea. Its position, however, is far from fixed.

Superfamily **Crangonoidea**

The Crangonoidea left the main stem later than either the Pasiphaeoidea or the Stylodactyloidea, judging by characters held in common with modern caridean families of other groupings. The mandible, like those of some alpheoids and many palaemonoids, consists solely of a molar process. The second maxilliped bears the terminal segment stripwise along the penultimate segment, much as do those of several other caridean groups including the pandalids. The chelae demarcate the group most readily. The first pereiopods are fitted with subchelae rather than with chelae proper. This adaptation to rapid digging is found among several reptant groups (*e.g.*, the Raninidae), but is not found elsewhere in present-day carideans. The branchial formula is markedly reduced (Tables III and IV), and the telson varies in armature. In *Glyphocrangon* it is devoid of armature,

TABLE III

Arrangement of branchiae and exopods for species of genus Pontophilus, *a crangonid*

Structure	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs ..	0	0	1	1	1	1	1	1
Arthrobranchs ..	0	0	1–0	0	0	0	0	0
Podobranchs ..	0	1	0	0	0	0	0	0
Epipods ..	1	1	1–0	0	0	0	0	0
Exopods ..	1	1	1	0	0	0	0	0
TOTALS ..	2	3	4–2	1	1	1	1	1

TABLE IV

Arrangement of branchiae and exopods for members of genus Glyphocrangon, *subgenus* Glyphocrangon

Structure	Maxillipeds 1	2	3	Pereiopods 1	2	3	4	5
Pleurobranchs ..	0	0	0	1	1	1	1	1
Arthrobranchs ..	0	0	2	1	1	1	1	0
Podobranchs ..	0	0	0	0	0	0	0	0
Epipods ..	1	1	0	0	0	0	0	0
Exopods ..	1	1	1	0	0	0	0	0
TOTALS ..	2	2	3	2	2	2	2	1

whereas in the crangonids, it is always furnished with terminal spines and usually bears dorsolateral or lateral spines.

Apparently carideans ancestral to the Crangonoidea existed with both segmented and entire carpuses on the second pereiopods, as the Glyphocrangonidae are separated from the Crangonidae by their segmented second carpus. Though relationships are sometimes conjectured between the Crangonidae and Glyphocrangonidae and the pandalids, these seem based on such convergent factors as reduction in branchial formula (which seems to be indicative of specialization, but not necessarily of relationship) and the presence in *Glyphocrangon* of the segmented second carpus. Since segmented second carpuses are found in several groups in addition to Pandaloidea, this is no particular indication of close relationship. The conclusion is that the Crangonoidea are not closely related to any living group of Caridea, and certain features, such as the subchelae of the first pereiopods, seem to bind them to reptant groupings more than is the instance in other caridean groups.

THE HOMOGENEOUS SUPERFAMILIES

The remaining carideans, as stated previously, are more homogeneous, and the problem is not one of ascertaining the point of departure of the groups from a distant main stem, but of deciding which groups are more basically primitive than others and of unravelling an apparent anastamosis of interrelationships.

Analysis of phylogenetic relationships in this more homogeneous group demands consideration of: (1) significance of neritic-pelagic and benthonic modes of life to phylogeny; and (2) adaptational differences between neritic-pelagic and benthonic shrimps that might either aid in interpretation or obscure phylogenetic patterns.

Students of carideans have been of two minds regarding the origin of the section. Some (*e.g.*, Borradaile, 1907; Calman, 1909) have attempted to derive the caridean from a natant penaeid or penaeid-like stock. Others, chief among them K. Beurlen and M. F. Glaessner, have pointed to a possible origin among the reptant decapod groups, principally the axiids. Russell (1962) and Gordon (1964) have reviewed Beurlen's ideas.

The similarities between penaeid and caridean shrimps are obvious and include marked superficial similarities, general agreement in life modes, and general conformance to a similar body plan. On the other hand, there are striking differences. Carideans have phyllobranchiate gills rather than dendrobranchiate gills and bear chelae on only the first two pereiopods rather than the first three. The shape and structure of the mouthparts are also quite different, those of the carideans being generally less pediform and more nearly akin to those of the reptant decapods. Finally, strong superficial resemblances have been noted between present-day benthonic carideans and reptant fossils (such as *Pemphix*, a Triassic member of the now extinct Pemphicoidea and members of the also extinct Jurassic group Glypheoidea and the present-day Crangonoidea).

It is impossible, on anatomical evidence alone, to evaluate the two views thoroughly, and exhaustive treatment of them is outside the limits of this paper. In passing, however, it should be noted that homologies among the gill structures of adult decapods are by no means concisely fixed and that further studies of these structures might show that the axiids are derived from carid-like ancestors rather than the carideans being derived from axiid-like ancestors. A clue to this has been provided by Burkenroad (1939), who shows that pleurobranchs appear before arthrobranchs and that the position of pleurobranchs relative to arthrobranchs is different in the Caridea from the situation in the Penaeidea where arthrobranchs appear before pleurobranchs. If it can be shown that the "pleurobranchs" of Caridea are "arthrobranchs" in reality, then it would be possible to derive the axiids from the carideans rather than the carideans from the axiids. This bynote does not warrant further development here. It is noticed for future use only. Biochemical studies of the relationships of the carideans to the penaeids on one hand and axiids on the other have high potential usefulness, also in settling phylogenetic problems.

From the foregoing, it can be seen that derivation of Caridea cannot be assigned definitely at this time to either a natant or a reptant group. Moreover, specialization within the Caridea proceeds in two directions—towards species adapted for strict pelagic existence (*i.e.*, many Pasiphaeoidea) and towards species adapted for strict benthonic existence (*i.e.*, the Crangonoidea). Backward reasoning would thus tend to suggest an ancestral form somewhere between the strictly pelagic and the strictly benthonic—a shrimp capable of swimming and of burrowing, somewhat after the fashion of the present-day inshore penaeids, *Penaeus aztecus*, *P. duorarum*, *P. setiferus*, and others.

MAJOR PELAGIC-BENTHONIC ADAPTATIONS

If a series of carideans could be found showing all gradations in mode of life from neritic-pelagic to fossorial, what trends in morphological adaptations would be found? To answer this, extensive series of all available carideans, both pelagic and benthonic, were examined. In Family Oplophoridae, a largely pelagic family, the most complete gradation was found. Members of genus *Acanthephyra* occupy niches extending from diurnally epipelagic to benthic. The only consistent trend in a progression from pelagic to benthic within this group that can be determined is one toward reduction in size of the exopods of the pereiopods.

Extending comparisons of pelagic and benthic shrimps to other and diverse groups indicate that there is a marked reduction and loss of exopods with benthic adaptation. The pelagic shrimp species generally bear strong spines on the tips of the fingers of the chelae, and possess mandibles capable of both crushing (molar processes) and cutting (incisor processes) in contrast to benthic shrimps with chelae which often bear only minute terminal spines or lack spines altogether. Reduced mandibles are also prevalent among benthic species.

Other features examined and found without distinct trends from pelagic to benthic were: (1) absolute size; (2) comparative bulk; (3) thickness and rigidity of integument; (4) relative size of pleopods and pereiopods; (5) presence of floatation devices; (6) general body shape; (7) egg size; and (8) degree of development of eyes.

The marked clarity of the trend toward reduction and loss of pereiopodal exopods with a benthic mode of life weakens the theory that the carideans were derived from reptant stocks, since it is difficult to see how pelagic species with exopods could be derived from benthic species which had lost their exopods. The possibility does exist, however, that the loss of exopods is a more recent development.

The relationships among the Superfamilies Oplophoroidea, Bresilioidea, Palaemonoidea, Alpheoidea, and Pandaloidea must now be explained.

Superfamily **Palaemonoidea**

Superfamily Palaemonoidea has been suggested as the group nearest to a primordial common stock. It has been found in large numbers in Upper Jurassic formations and is today a prominent and highly diversified group in warm shallow seas the world over. But members of the family are highly specialized (Table I). Their gill formulae are reduced markedly (Table V); in many genera the mandibles lack incisors or palps, or both; chelae and chelipeds show a wide degree of specialization and diversification; exopods are missing from the pereiopods; the armature of the telson of most representatives of the superfamily are specialized in that the spines along its length are placed dorsally rather than dorsolaterally; and the group as a whole seems to be generally confined narrowly to freshwater, estuarine, and coastal marine waters. There are no offshore representatives and most of those species that are fully marine are commensal and hence have a highly modified environment. Fossil evidence plus evidence afforded by the number and variety of free-living and commensal species combine to show that the group is ancient; the evidence does not, however, indicate great importance in the evolution of the Section Caridea.

TABLE V

Arrangement of branchiae and exopods for species of the palaemonoid genera Leander *and* Palaemonetes
(According to Gurney, 1942, *pp.* 148–149)

Structure	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs ..	0	0	1*	1	1	1	1	1
Arthrobranchs ..	0	0	1	0	0	0	0	0
Podobranchs ..	0	1	0	0	0	0	0	0
Epipods ..	1	1	1	0	0	0	0	0
Exopods ..	1	1	1	0	0	0	0	0
TOTALS ..	2	3	4*	1	1	1	1	1

* Pleurobranch missing from third maxilliped of *Leander.*

Superfamily **Oplophoroidea**

I suggest that members of Superfamily Oplophoroidea, particularly members of Family Oplophoridae, are closest to the main evolutionary stem for the following reasons: (1) they possess the fullest branchial formula known for the Caridea, allowing the formulae of all other carideans to be derived from this one by reduction or loss of branchiae; (2) member species usually possess exopods on all 5 pereiopods, again allowing derivation of reduced exopod conditions in other groups; (3) not only is the mandible composed of palp, molar, and incisor, but the molar and incisor are fused allowing derivation of those other carideans with cleft molars and incisors through separation of the fused parts (presaged in some atyids) or of those with only molars or incisors through a continued process of fusion (indicated in *Eugonatonotus*) or loss; (4) they possess conspicuous interlocking spines on the ends of the fingers in addition to fine hairs, which, through reduction, could develop into the fine spines of some pandalids or through loss into the spineless condition shown by the fingers of members of other groups; (5) both large-egged and small-egged species are included in the group; and (6) the armature of the telson of Oplophoridae may be considered "primitive" in that the terminal spines are strong and numerous and dorsolateral spines are present, which seem to move dorsally with specialization in other groups.

The discussion that follows is based on the premise that the oplophorids are nearest a common stem and that they are derived most directly from an oplophorid-like stage in evolution that was common to six or eight of the ten caridean superfamilies considered herein (but not necessarily to Superfamilies Pasiphaeoidea or Crangonoidea). The general course of evolution visualized is shown diagrammatically in Fig. 1. In the figure, Superfamily Oplophoroidea separates Superfamilies Bresilioidea and Pandaloidea from Superfamilies Heterocarpodoidea, Palaemonoidea, Psalidopodoidea, and Alpheoidea. The first two superfamilies are referred to for convenience as the "pandalid lineage"; the other four will be termed the "palaemonid lineage". Superfamilies Stylodactyloidea, Pasiphaeoidea, and Crangonoidea are shown as having branched off before the common oplophoroid stage. The separation of Pasiphaeoidea from the other two disappears if the diagram is visualized as a three-dimensional structure rather than a two-dimensional one.

THE PANDALID LINEAGE

A firm connection between Superfamilies Oplophoroidea and Pandaloidea has long been recognized in broad features. Details of the connection have not been clearly set forth, and an apparent anastamosis of interconnecting relationships seemed present. This can be corrected by removal of genus *Heterocarpus* from the Pandalidae. Such removal is accomplished by erecting a new family, Heterocarpodidae, and new Superfamily Heterocarpodoidea, as described in a later paragraph.

The pandalids differ from oplophorids in the following principal particulars: (1) Pandalidae lack exopods on pereiopods; (2) the first chelipeds either lack chelae or possess minute chelae only; (3) the chelae of the second pereiopods have tufts of fine hairs at the fingertips, but terminal spines, if present, are not conspicuous as they are in the Oplophoridae; (4) the carpus of the second pereiopod is multisegmented; (5) the branchial formulae of member species are reduced; (6) the first maxilliped bears a distinct lash; and (7) usually some of the teeth of the rostrum or rostral crest are movable.

One intermediate between Oplophoridae and Pandalidae is Family Nematocarcinidae, which has been defined (Thompson, in press[1]) as consisting of genera *Nematocarcinus* and *Lipkius* and which is assigned to Superfamily Bresilioidea. Members of Nematocarcinidae resemble oplophorids in: (1) possessing exopods on some pereiopods, though those of *Lipkius* are rudimentary; (2) having an entire (non-segmented) second carpus and chelae on all four chelipeds; and (3) the branchial formula, which is the same as that of the oplophorids (exclusive of the exopods). The nematocarcinids resemble the pandalids in that: (1) the exopods, though present, are reduced in number and rudimentary in *Lipkius*; (2) the fingers of the chelae are equipped with terminal hairs rather than with strong spines; (3) the first maxilliped bears a lash; (4) some of the teeth of the rostrum and crest are movable; and (5) the molar and incisor processes of the mandible are cleft.

Another group intermediate in some respects between Oplophoridae and Pandalidae is Family Atyidae (Oplophoroidea). This is a group of freshwater shrimps of variable morphology. According to Gurney (1942) they are to be considered primitive with respect to the remainder of the Oplophoroidea, a view that is not consistent with present views and that is not explained by Gurney.

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[1] The Caridean Family Bresilioidea (Decapoda Natantia): A Revision and a Discussion of its Validity and Affinities. Submitted to *Crustaceana*.

Burkenroad (1939) gives a full account of possible derivation of the *Nematocarcinus* and *Discias* (also placed in Bresilioidea) from *Atya*. The derivation involved the formation of a cleft between incisor and molar presaged in *Atya* by the disappearance of teeth along a strip where the cleft appears in other atyids and in *Nematocarcinus* and the Pandalidae; certain resemblances between larval *Nematocarcinus* and adult *Atya*; and reductions of epipods and arthrobranchs in *Atya* presaging further reductions in *Discias*.

The pandalid lineage thus involves a common oplophorid-like stem from which gave rise to the Oplophoridae and the Atyidae of Superfamily Oplophoroidea. Along the line leading to the Atyidae, another branch evolved leading to the Bresilioidea. From the line leading to Nematocarcinidae of the Bresilioidea, which according to Holthuis (1955) is more distantly removed from Disciadidae and Bresiliidae than either is to the other, a branch leading to present-day pandalids split off.

THE PALAEMONID LINEAGE

Connections between the palaemonids and the oplophorids have also been observed many times in the past. Morever, at least one family, Campylonotidae, has been shifted back and forth between the two groups, and the Rhynchocinetidae has been suggested by Burkenroad (1939) as a candidate for the Oplophoroidea rather than the Palaemonoidea.

Just as the oplophoroid-pandaloid linkage has been explained as passing through an intermediate superfamily, Bresilioidea, the oplophoroid-palaemonoid linkage is here visualized as proceeding through an intermediate, Heterocarpodoidea.

Superfamily **Heterocarpodoidea** (nova)

This taxon is erected to contain a new family Heterocarpodidae, constituting genus *Heterocarpus* (formerly Pandaloidea Pandalidae); family Rhynchocinetidae, formerly variously assigned to the Palaemonoidea, Oplophoroidea, or Bresilioidea and consisting of the single genus *Rhynchocinetes*; and Campylonotidae, formerly combined with either the Oplophoroidea or Palaemonoidea and consisting of the two genera *Campylonotus* and *Bathypalaemonella*. The constituent families display characteristics midway between those of the Oplophoroidea and Palaemonoidea. All have characteristically heavily carinated bodies with thick, rigid integuments; chelae without long terminal hairs but instead with terminal spines, pegs, or acicules; and telsons with the usual lateral armature situated medially on the dorsal surface.

Within the superfamily, the families may be separated as follows:

1. Rostrum movably articulated with carapace; chelae on first two pairs of pereiopods; carpus of second pereiopods solid.......................................RHYNCHOCINETIDAE

1′. Rostrum not movably articulated with carapace; chelae present or absent on first pereiopods; carpus of second pereiopods solid or segmented..................................2

2 (1′). Chelae on all four pereiopods of first two pairs; carpus of second pereiopods solid ....CAMPYLONOTIDAE

2′ (1′). No chelae on first pereiopods; carpus of second pereiopods multiarticulate ....HETEROCARPODIDAE

Family Campylonotidae has not been recorded from the western North Atlantic, the region with which I am personally familiar. Yaldwyn (1960), however, has reviewed the major features of the genus *Campylonotus* in his paper on the Chatham Rise Decapoda, in which he also discusses *Rhynchocinetes*.

Family **Heterocarpodidae** (nova)

At present only genus *Heterocarpus* can be assigned to this newly created family. *Heterocarpus* has been considered a pandalid genus since Smith (1882) assigned his *Pandalus carinatus* (= *Heterocarpus ensifer*) to family Pandalidae, stating that, whereas A. Milne-Edwards (1881) found close similarity between his *Heterocarpus* and *Oplophorus*, he (Smith) was certain that the true relationship of *Heterocarpus* would fall with the pandalids. (Smith recognized the generic validity of *Heterocarpus* in 1884.)

Smith's chief bases for placing *Heterocarpus* in Pandalidae are those that have been used by all workers since. Family Pandalidae, by common definition, has contained those shrimps that lack chelae on the first pereiopods and have segmented carpuses on the second. I do not believe that these criteria, alone or in combination, are sufficient to set off taxa at the family level. I feel that the *shape* and *structure* of chelae are vastly more important, taxonomically, than their presence or absence (chelae are missing on the second pereiopods of some of the crangonids—indeed the entire second pair of pereiopods is missing from genus *Paracrangon*—without family Crangonidae being split for that reason, and they are missing from one or both of a pair of some Palaemonidae and Alpheidae). Segmented carpal joints are found in many caridean families in a seemingly indiscriminant pattern (genus *Glyphocrangon*, genus *Processa*, and others).

The mouthparts of *Heterocarpus* resemble those of the pandalids closely, and the branchial formula of *Heterocarpus* is the same as that of some members of genus *Plesionika*. But so are the mouthparts and branchiae of *Nematocarcinus* like those of *Plesionika*, the presence of exopods serving to separate *Nematocarcinus* from the pandalids. I, therefore, have no compunction over removing the genus from Pandalidae.

There is, however, a second and more positive reason for the separation. It is possible to derive the pandalid genera *Pandalus*, *Plesionika*, and *Parapandalus* at least, from the Atyidae and the Oplophoridae through the Nematocarcinidae. If *Heterocarpus* is considered a pandalid genus, it is also possible to derive the Pandalidae (*Heterocarpus*) from the Oplophoridae by way of Eugonatonotidae. Thus, the Pandalidae would seem to have a diphyletic origin, an undesirable situation at best.

If *Heterocarpus* is removed from the Pandalidae, as it has been here, it must be raised to familial rank, for it is sufficiently distinct from other familial groups that it stands alone. I consider it entirely possible (even probable) that critical examination of some of the less well-known pandalid genera remaining will show that they may well be joined with genus *Heterocarpus* in the Heterocarpodidae. Joined with Rhynchocinetidae and Campylonotidae into the Heterocarpodoida, *Heterocarpus* creates a taxonomic niche between the Oplophoroidea and the Palaemonoidea akin to that created between Oplophoroida and Pandaloida by rearranging Bresilioidea and placing Nematocarcinidae therein.

The branchial formula for the Western Atlantic species of Hetercarpodidae is given in Table VI.

Within superfamily Oplophoroidea, families Oplophoridae and Eugonatonotidae are closely related. The principal differences between the two families lie in the presence of a lash on the first maxilliped of *Eugonatonotus* and a complete fusion of molar and incisor in *Eugonatonotus*, causing a disappearance of the incisor. The exopods of *Eugonatonotus*, which have been referred to as " rudimentary " are short relative to the endopod portions of the pereiopods, but are no shorter than those of the benthic and near-benthic oplophorids *Acanthephyra eximia* and *A. armata*. With its heavy integument and marked abdominal crests and spines, *Eugonatonotus* bears a very strong superficial resemblance to *Oplophorus* (Oplophoridae), a resemblance made more striking by the presence in both genera as well as in *Acanthephyra* of heavily pigmented interlocking terminal spines or pegs on the fingers of the chelae.

TABLE VI

Arrangement of branchiae and exopods determined for members of genus Heterocarpus *in the South-Western North Atlantic*

Structure	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	0	0	0	1	1	1	1	1
Arthrobranchs	0	0	2	1	1	1	1	0
Podobranchs	0	1	0	0	0	0	0	0
Epipods	1	1	1	1	1	1	1	0
Exopods	1	1	1	0	0	0	0	0
TOTALS	2	3	4	3	3	3	3	1

From *Eugonatonotus* to *Heterocarpus* is a step involving few changes. *Heterocarpus* possesses a cleft mandible and a segmented carpus on its second pereiopod. It lacks exopods and there is no chela on the first pereiopod. In all these respects it fits the Pandalidae and differs from the Oplophoridae. But, as seen, the pandalid lineage is established rather clearly through the oplophorid-atyid-nematocarcinid lineage, which logically leads to such genera as *Plesionika*, *Parapandalus*, and *Pandalus*—genera closely similar in all respects to *Nematocarcinus* rather than to *Heterocarpus*.

If an additional line leading to the Pandalidae were postulated, leading from Oplophoridae through Eugonatonotidae to Pandalidae (*Heterocarpus*), a bilineal descent would need to be explained. Removal of *Heterocarpus* from Pandalidae eliminates the paradox and can be justified on the basis of its similarities with *Eugonatonotus*, *Rhynchocinetes*, *Campylonotus*, and the palaemonids and alpheids.

Aside from a strong superficial resemblance to *Eugonatonotus*, *Heterocarpus* resembles *Eugonatonotus* and the oplophorids in possessing, at the tips of the fingers of the single pair of chelae, darkly pigmented, interlocking terminal spines. These are found also in *Rhynchocinetes*. Further, *Heterocarpus* has the spines on its telson situated dorsolaterally, not laterally. In this it resembles the palaemonids more than it does the pandalids. These evidences of new affinity are admittedly slight, but no more so than the evidence binding *Heterocarpus* to the pandalids. Segmented carpuses are found in the Alpheidae in several not closely related groups and in the Glyphocrangonidae. In view of the wide differences existing among chelae in caridean groups, absence of chelae from the first pereiopods is not astounding. It is more astounding when a particular morphological likeness in chelae can be traced through several genera. The absence of chelae from the first pereiopods combined with the segmented carpuses of the second is the only criterion binding *Heterocarpus* to the Pandalidae. This combination, in fact, is the principal criterion holding the family together, and though a convenient criterion, its phylogenetic validity seems doubtful. Other members of the family (especially *Pantomus*, the only caridean other than *Rhynchocinetes* with a jointed or movable rostrum) should be critically examined to determine the closeness of fit.

Families Rhynchocinetidae and Campylonotidae have been combined with Heterocarpodidae in the Heterocarpodoidea. This may or may not be a valid grouping; however, all have in common a number of palaemonid and oplophorid qualities and seem to be intermediate between those two groups. *Campylonotus* occurs only in the Southern Hemisphere and I have not examined specimens. Its mandible is fused, indicating relationship to Oplophoridae from which it is excluded by lack of exopods on the pereiopods and the presence of a lash on the first maxilliped. The branchial formula (excluding exopods) is the same as for oplophorids and the chelae are similar; according to Yaldwyn (1960), however, there is only one strong tooth at the end of each finger rather than two on one and one on the other as in the oplophorids, *Eugonatonotus*, and *Heterocarpus* or three on one and one on the other as in *Rhynchocinetes*. In general appearance *Campylonotus* strongly resembles *Eugonatonotus*, *Oplophorus*, and *Heterocarpus*, and *Rhynchocinetes*. Moreover, Burkenroad (1939) calls attention to a marked similarity between the shape of the first pleopods of males of *Campylonotus* and *Rhynchocinetes*. The armature of the telson is dorsally placed as it is in the palaemonids.

Rhynchocinetes, as mentioned, resembles closely both *Eugonatonotus* (from which it differs by its cleft mandible and lack of exopods on the pereiopods) and *Heterocarpus* (from which it differs by its undivided second carpus and possession of chelae on all four of the first two pairs of pereiopods). It further differs from both in that its rostrum is articulated with the carapace through a joint. Gurney (1942) has shown that *Rhynchocinetes* is close to the oplophorids in details of larval development.

The Palaemonidae can be derived from *Campylonotus* principally through loss of arthrobranchs and epipods from the pereiopods and through the cleft mandible or the missing incisor process.

In summary, the palaemonid lineage proceeds from an oplophorid-like common ancestor to the Oplophoridae and Eugonatonotidae. From the Eugonatonotidae line a branch is visualized leading to Heterocarpodidae and Rhynchocinetidae and somewhat farther apart to the Campylonotidae. An evolutionary sideshoot from the base of the Heterocarpodoidea line led to the Palaemonoidea.

The relation of Psalidopodoidea and Alpheoidea to Palaemonoida is by no means clear or settled. Superfamily Alpheoidea is in many respects a catch-all category containing a number of diverse forms. It needs more critical study. In the meantime, I have left it as Holthuis (1955) has indicated. The same has been done for *Psalidopus*, though in general structure and shape of mouthparts, this shrimp is apparently truly near the Palaemonidae.

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ON SOME DECAPOD CRUSTACEANS FROM THE SOUTH-WEST COAST OF INDIA*

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ABSTRACT

Fourteen species of decapod crustaceans, 10 belonging to Natantia (7 Caridea and 3 Penaeidea) and 1 each belonging to Palinura, Astacura, Anomura and Brachyura, collected during the exploratory and research cruises of the vessels of the Indo-Norwegian Project from the waters off the Kerala coast are reported in this paper. Out of these, 5 species are recorded for the first time from these waters.

THE collections on which the following report is based were made during the exploratory and research cruises of the vessels of the Indo-Norwegian Project, *M. V. Kalava* and *R. V. Varuna* in 1962–64 from the waters off the Southwest Coast of India. The macruran shrimps of the families Penaeidae, Sergestidae, Pasiphaeidae, Oplophoridae and Pandalidae, and one species each from the suborders Palinura, Astacura, Anomura and Brachyura collected from varying depths upto 380 fathoms are included here. Out of these five species are recorded for the first time from these waters.

Suborder MACRURA

Supersection *NATANTIA*

Section PENAEIDEA

Family PENAEIDAE

***Gennadas propinquus* Rathbun**

Gennadas propinquus Rathbun, 1906, p. 908.

Gennadas alcocki Kemp, 1910, pp. 174–75 (Male).

Gennadas propinquus Burkenroad, 1936, p. 66 (in key).

Material: One female, 26 mm.

Locality: Station 2299, Arabian Sea, off Alleppey (Lat. 9° 31′ N.; Long. 75° 33′ E.), 380 fathoms.

Distribution: Hawaiin Islands, Indo-Pacific. Kemp's record of the species is from the Bay of Bengal and off Cape Comorin, 1043 fathoms. The present record extends the distribution of the species further north in shallower waters.

Remarks: Antennal and infra-antennal angles pointed; branchiostegal spine very small, but distinct. Distance between cervical and post-cervical grooves dorsally about 1/5 distance of latter from hind margin of carapace. Antennal scale 4 times as long as wide, with the terminal spine present. In the 3rd leg, 5th joint slender and longer than 4th joint. Sixth abdominal somite dorsally carinate. Thelycum very much as described by Kemp (1910).

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Gennadas scutatus Bouv.

Gennadas scutatus Barnard, 1950, p. 634 (with synonymy).

Material: Three males, length 22 mm., 21 mm. and 21 mm.

Locality: Station 2299, Arabian Sea, off Alleppey (Lat. 9° 31′ N.; Long. 75° 33′ E.), 380 fathoms.

Distribution: North and South Atlantic, Indo-Pacific. Kemp (1910) recorded the species off Cape-Comorin at 1053 fathoms. The present collection indicates the further northerly distribution of the species in the Arabian Sea.

Remarks: Infra-antennal angle acute; branchiostegal spine quite distinct. Distance between cervical and post-cervical grooves dorsally slightly more than 1/5 distance of the latter from the hind margin of carapace. According to Calman (1925), the 4th joint of the 3rd leg is slightly shorter than 5th joint, but in Bouvier's (1908) original description of the species, he has described the 4th joint as longer than the 5th joint. The present specimens agree with Calman's description. The petasma agrees with the previous descriptions in most respects except that the external lobe is more elongated and pointed.

Family SERGESTIDAE

Sergestes seminudus Hansen

Sergestes seminudus Hansen, 1919, pp. 18–22.

Material: Several specimens, both male and female; 24–40 mm.

Locality: Station 2299, Arabian Sea, off Alleppey (Lat. 9° 31′ N.; Long. 75° 33′ E.), 380 fathoms.

Distribution: Hansen's (1919) collections are from the Indo-Pacific from an area Lat. 0–7° S. and Long. 126–130° E. This is the first record of the species from Indian waters.

Remarks: Rostrum short and acute; hepatic spine present. Cornea wider than stalk, no protuberance on the latter. Telson apically acute, with a pair of minute lateral spinules near the apex and a pair of denticles on postero-lateral margin. In petasma, lamina externa of pars externa shorter than processus uncifer which is slender. Processus ventralis long with a broad base and acute process distally. Lobus armatus does not project beyond processus ventralis as observed by Hansen, but falls a little short of the latter, its whole inner margin has a row of about 10 hooks. Lobus inermis as broad as lobus terminalis at the base, but tapering to a sub-acute tip and without hooks. Two small sharp teeth present on the third coxa of female.

Section CARIDEA

Family PASIPHAEIDAE

Pasiphaea alcocki Wood-Mason

Pasiphaea alcocki Wood-Mason, 1891, p. 190.

Pasiphaea alcocki de Man, 1920, p. 6.

Pasiphaea alcocki Chace, 1940, p. 123.

Material: One female, 63 mm.

Locality: Arabian Sea, Southwest of Cochin, off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 185 fathoms.

Distribution: Bay of Bengal, Gulf of Mannar and Arabian Sea off the Sind Coast—406–947 fathoms. Wood-Mason's record of the species from the Arabian Sea is from the northern region and in 947 fathoms. This is the first record of the species from the southern region of the Arabian Sea and in lesser depths.

Remarks: Carapace not carinate dorsally; abdomen without dorsal carination or armature on any somite. Telson sub-acute on the dorsal surface and not conspicuously forked. First pereiopod with 4–6 spines on the merus and 1 spine on the carpus. Second pereiopod with 13–16 spines on the merus and 1 spine on the carpus. The fingers of the first chelae slightly more than half the length of the palm, while the fingers of the second chelae almost of the same length as the palm.

Family OPLOPHORIDAE

Oplophorus gracilirostris **A. M. Edw.**

Hoplophorus gracilirostris Alcock, 1901, p. 73.

Hoplophorus gracilirostris Kemp and Sewell, 1912, p. 20.

Hoplophorus gracilirostris de Man, 1920, p. 48 (in key).

Material: Several specimens, male and female, varying from 48 to 55 mm.

Locality: Arabian Sea, Southwest of Cochin, off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 180–205 fathoms.

Distribution: Off St. Domingo Islands, Dominica, St. Vincent, etc.—118 F. (A. Milne Edwards); Arabian Sea, Bay of Bengal, Andaman Sea—145–1439 F. (Alcock), and Hawaiin Islands.

Remarks: Carapace with dorsal carina extending to the posterior margin. Rostrum very long, almost equal in length to the carapace. Branchiostegal spine quite distinct, with a well-defined keel. Spine on the 3rd abdominal tergum very much longer than those on the 4th and 5th. In the male the anterior border of the first abdominal somite is bilobed with the posterior lobe more pronounced and angular.

Acanthephyra sanguinea **Wood-Mason**

Acanthephyra sanguinea Wood-Mason, 1892, p. 358.

Acanthephyra kempi Balss, 1925, p. 256.

Acanthephyra sanguinea Calman, 1939, p. 193 (with synonymy).

Material: Three females, 115 mm., 116 mm. and 119 mm.

Locality: Arabian Sea, South-West of Cochin, off Alleppey, (Lat. 9° 25′ N.; Long. 75° 40′ E.), 180–205 fathoms.

Distribution: Indo-Pacific, from the Gulf of Aden and East African coast to 138° E. and 18° N. to 12° S.

Remarks: Rostrum longer than carapace with 7 dorsal and 5 ventral teeth, extending much beyond the tip of the antennal scale. Branchiostegal spine small, forming a small projection on frontal border of carapace and without a carina. Surface of carapace finely pitted as in all the species of the *purpurea* group. Dorsal carinae of 3rd to 6th abdominal somites ending in pointed spines, that of 3rd somite the longest and of 4th and 5th of equal size and smallest. Four pairs of dorsolateral spines present on the telson.

Family PANDALIDAE

Plesionika martia (A. M. Edw.)

Plesionika martia var. *semilaevis* de Man, 1920, p. 116 (with synonymy).

Plesionika martia Balss, 1925, p. 278.

Plesionika martia Schmitt, 1926, p. 377.

Plesionika martia Calman, 1939, p. 197.

Plesionika martia Chace, 1940, p. 190.

Plesionika martia Barnard, 1950, p. 679.

Material: Several specimens, male and female, varying from 86 mm. to 106 mm.

Locality: Arabian Sea, Southwest of Cochin, off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 150–200 fathoms.

Distribution: Eastern Atlantic and Mediterranean, Indian Seas, Hawaiin Islands, Zanzibar area, off South Africa, Japan and Australia. Alcock's (1901) initial record of the species from Indian waters is from the Andaman Sea, Bay of Bengal and the Arabian Sea.

Remarks: The squamose nature of the whole integument caused by numerous short transverse series of setiferous pits as described by Barnard (1950) is easily noticed in the present specimens under low magnification. The specimens on hand agree quite well with the descriptions of Barnard and others.

Parapandalus spinipes Bate

Parapandalus spinipes de Man, 1920, p. 142.

Parapandalus spinipes Calman, 1939, p. 201.

Material: Several specimens, male and female, measuring 90–129 mm.

Locality: Arabian Sea, Southwest of Cochin, off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 180–200 fathoms.

Distribution: Malay Archepelago, North of New Guinea, Japan, Kermadec Islands, off Cape Comorin, Red Sea, Gulf of Aden and Zanzibar area. The present record extends the distribution of the species further north in the Arabian Sea.

Remarks: In a specimen measuring 91 mm. in total length, the rostrum is armed with 46 teeth on the dorsal surface and 31 teeth on the ventral. In the same specimen, the minimum width of the 6th abdominal somite is 3·0 mm. and the length and height of the same segment 9·2 mm. and 5·2 mm. respectively. The telson which is 11·1 mm. in length is almost double the length of the 5th abdominal somite which is slightly more than that of de Man's specimens. The minute tubercle on the dorsal surface of the carapace at about 1/6 of its length from the hinder edge which corresponds in position to the small blunt median spine recorded by Rathbun (1906) in *P. longicauda* and noticed by Calman (1939) is present in almost all the specimens of the present collection.

Heterocarpus wood-masoni Alcock

Heterocarpus wood-masoni Calman, 1939, p. 204 (with synonymy).

Material: One male, 103 mm.

Locality: Arabian Sea, Southwest of Cochin, off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 180 fathoms.

Distribution: East African Coast, Andaman Sea to Kei Islands. This is the first record of the species from the Arabian Sea.

Remarks: The single specimen on hand agrees closely with the detailed descriptions of Alcock and de Man, except that the telson bears 5 pairs of dorsolateral spinules besides those at the tip, as against 4 pairs described by de Man and 2 pairs by Calman.

Heterocarpus gibbosus Bate

Heterocarpus gibbosus de Man, 1920, p. 163 (with synonymy).

Material: 3 males, 100 mm., 127 mm. and 130 mm. and 3 females, 134 mm., 133 mm. and 138 mm., all ovigerous.

Locality: Arabian Sea, Southwest of Cochin, off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 185–200 fathoms.

Distribution: Off Tables Island, Andaman Sea, Bay of Bengal, Arabian Sea off the Travancore Coast to Kei Islands.

Remarks: The teeth on the dorsal crest and the rostrum together vary from 8 to 10 in the 6 specimens, the teeth on the rostrum proper varying from 2 to 4. The dactyli of the 3 posterior legs short, agreeing more with the description of Alcock (1901) rather than that of de Man (1920). The median carination of the 3rd abdominal tergum is quite prominent.

Supersection *REPTANTIA*

Section PALINURIDEA

Family PALINURIDAE

Panulirus homarus (Linnaeus)

Panulirus dasypus Gravely, 1927, pp. 138–139; Miyamoto and Shariff, 1961, p. 255; Balasubramanian *et al.*, 1961, p. 275; De Bruin, 1962, p. 9.

Panulirus burgeri Prasad and Tampi, 1959, p. 397; Miyamoto and Shariff, 1961, p. 255; Balasubramanian *et al.*, 1961, p. 275.

Panulirus homarus, George, 1963, p. 3; Kubo, 1963, p. 68 (with synonymy); George, 1964, pp. 1–6.

Material: Several specimens, male and female, measuring 95–315 mm.

Locality: Arabian Sea, Southwest of India off south of Trivandrum (Lat. 8° 10′ N.; Long. 77° 11′ E.), 3–10 fathoms.

Distribution: East Indies, South Africa, South Coast of Arabia, Indian Ocean and Indo-West Pacific.

Remarks: So far the records of this species in Indian waters have been under the names *Panulirus dasypus* and *P. burgeri*, although Holthuis (1946) has proposed synonymising the two as *P. homarus* which has been followed by later authors. Hence this species is recorded here as *P. homarus*.

In the specimens of the present collection, there is considerable variation in the nature of the flagellum of the exopod of the 2nd maxilliped as observed by De Bruin (1962), Gordon (1953) and George (1964). The number of joints in the flagellum when present is shown in Table I which shows that there may be no joints at all or as many as 6.

TABLE I

Number of joints of the flagellum of the exopod of the 2nd maxilliped	Number of lobsters	
	Right	Left
0	8	8
1	7	7
2	..	..
3	1	..
4	..	1
5	..	1
6	1	..

In the number of abdominal segments with interrupted grooves also there is considerable variation noticed by different authors. The variability of this feature in the present specimens is shown in Table II.

TABLE II

Segmental groove interrupted medially	Number of lobsters
2nd only	1
3rd only	3
4th only	Nil
5th only	,,
6th only	,,
2nd and 3rd	4
2nd and 4th	Nil
2nd and 5th	,,
3rd and 4th	,,
3rd and 5th	,,
4th and 5th	,,
2nd, 3rd and 4th	2
2nd, 3rd and 5th	Nil
2nd, 3rd, 4th and 5th	,,
3rd, 4th and 5th	1
2nd, 4th and 5th	Nil
All grooves 1, 2, 3, 4, 5 and 6 uninterrupted	3
2nd, 3rd, 4th and 6th	1
2nd, 3rd and 6th	2

In the nature of these variations these specimens are more or less similar to De Bruin's (1962) specimens from Ceylon, but differ from the samples of George (1963) from East Aden. From the above it appears that the Ceylon and South-West Indian population are more or less the same, but sufficiently distinct from the East Aden population.

Section ASTACIDEA

Family ASTACIDAE

Nephropsis carpenteri **Wood-Mason**

Nephropsis carpenteri Wood-Mason, 1885, p. 70.

Material: One male, 90 mm., 2 females (one ovigerous), 88 mm. and 113 mm.

Locality: Arabian Sea, Southwest of Cochin off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 185 fathoms.

Distribution: Bay of Bengal and Jodomi, Japan. This species is now for the first time recorded from the Arabian Sea.

Remarks: Rostrum extends upto the anterior margin of the antennular peduncles in which character it differs from the closely allied species *N. stewarti* which has a slightly longer rostrum. Dorsally the distance of the cervical groove from the posterior margin of the carapace is half the length of the carapace. Carapace and abdomen granulated and finely pilose. Chelipeds are densely clothed with hairs and like the carapace and abdomen finely granulated. Faint median dorsal carinae are present in the last four abdominal segments. Pleopod 1 in male comparatively short, reaching coxa of 4th leg, channelled on its median side and set dorsoventrally parallel with its fellow. The distal half is cultrate and without hairs. Pleopod 1 in female is slender and feeble. Pleopod 2 in male with a conspicuous appendix masculina, the tip of which bears granulated spines.

Suborder **ANOMURA**

Section GALATHEIDEA

Family CHIROSTYLIDAE

Eumunida funambulus **Gordon**

? *Eumunida smithii* Parisi, 1917, p. 6.

Eumunida funambulus Gordon, 1929, p. 746.

Eumunida funambulus Van Dam, 1933, p. 7.

Material: One male, 66 mm. in carapace length and 1 female, 56 mm.

Locality: Arabian Sea, Southwest of Cochin, off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 185 fathoms.

Distribution: Timor, Philippines (Parisi); Gulf of Aden, from cable off Philippine Islands, Sakul Bank south of Timor, Sacotra channel, from sub-marine cables between Aden and Bombay and Madura Strait, Java, 70–400 fathoms (Gordon); and Pulu We near Sumatra—111–752 m. (Van Dam). This is the first record of the species from the southern region of the Arabian Sea.

Remarks: The specimens agree well with Miss Gordon's description except for the comparative length in the dactylus and the palm of the cheliped.

Length of dactylus of right cheliped of male	.. 35 mm.
Length of palm of right cheliped of male	.. 40 „
Length of dactylus of left cheliped of male	.. 50 „
Length of palm of left cheliped of male	.. 60 „
Length of dactylus of right cheliped of female	.. 31 „
Length of palm of right cheliped of female	.. 33 „
Length of dactylus of left cheliped of female	.. 32 „
Length of palm of left cheliped of female	.. 35 „

Gordon (*op. cit.*) observed that the palm of the cheliped is shorter than the finger except in old males with atypical chelipeds, in which, palm is equal to or slightly longer than the finger. Van Dam (1933) recorded a female specimen with palm longer than dactylus. In the present specimens also the palm is longer than dactylus. The two spines on the merus of the external maxilliped are prominent. Spines present on the propodite of the walking legs, but more in numbers than recorded by Gordon (*op. cit.*).

Suborder **BRACHYURA**

Section DROMIACEA

Family THELXIOPEIDAE

Thelxiope megalops **(Alcock)**

Homola (Homalax) megalops Alcock, 1901, p. 62.

Homola megalops Kemp and Sewell, 1912, p. 27.

Thelxiope megalops Gordon, 1950, p. 222 (with synonymy).

Material: 2 males, carapace length 46 mm. and 50 mm., one female, 31 mm. (ovigerous).

Locality: Arabian Sea, Southwest of Cochin off Alleppey (Lat. 9° 25′ N.; Long. 75° 40′ E.), 180 fathoms.

Distribution: Indian Ocean, Arabian Sea, Andaman Sea, 188–200 fathoms and 379–419 fathoms; off Madras Coast, 145–250 fathoms; off Colombo (Gulf of Mannar), 142–400 fathoms.

Remarks: The specimens listed above agree in general with Alcock's description of the species. The noteworthy variations are (*a*) cheliped more slender in female than in male, (*b*) in male the chelipeds reach a little beyond half-way along the propodus of the first pair of legs, whereas in the female, they reach the tip of the carpus, (*c*) the movable finger is proximally provided with a conspicuous denticle on the inner edge and about ¾ as long as the rest of the hand, (*d*) the 2nd and 3rd pairs of legs are nearly 2½ times as long as carapace. Pleopod 1 in male short, with the distal end having a depression towards the inner side and a short projection at the outer side. Terminally along the outer border are a few simple and long setae. The second pleopod of male is short, extending to the middle of the length of the 1st pleopod, with the distal end truncate.

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DISCUSSION

Dr. R. Serene: I would like to suggest that the materials on which descriptions of new species are based, are deposited and registered in a central institution because it would be otherwise very difficult or at times impossible to trace the material when required for examination.

Mr. M. J. George: The specimens described here are being deposited in the Reference Collection Museum of the Central Marine Fisheries Research Institute at Mandapam Camp.

Dr. R. S.: What I want to say is that proper registration numbers be given and cited in the accounts published.

Dr. S. Jones: I wish to state here that this is being done in the Central Marine Fisheries Research Institute. In fact no paper is allowed to be published unless the material is deposited in the Reference Collections Museum. I would incidentally mention here that the Central Marine Fisheries Research Institute is not intended to do elaborate taxonomic work and whatever has been done in this line was carried out by the workers during their spare time.

Dr. R. S.: I understand the situation. I would only like to stress that more importance is given to registering and maintenance of the collections.

ON A COLLECTION OF PENAEID PRAWNS FROM THE OFFSHORE WATERS OF THE SOUTH-WEST COAST OF INDIA*

M. J. GEORGE**

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ABSTRACT

13 species of penaeid prawns collected during the exploratory and research cruises of *M. V. Kalava* and *R. V. Varuna* respectively in 1962 and 1963 from the offshore waters of south-west coast of India are recorded. Of these, 8 are recorded for the first time from this region.

EXPLORATORY trawl fishing conducted by the vessels of the Indo-Norwegian Project *M. V. Kalava* and the Research Vessel *Varuna* during 1962 and 1963 in the offshore waters of Cochin and Alleppey upto 205 fathoms caught a large number of prawns. Some of these proved to be new records for this area and are reported here. Trawl operations of *M. V. Kalava* were conducted during these cruises mostly in the 160-200 fathom depths off South-West of Cochin. But *Varuna* operated in shallow waters upto 50 fathoms off North-West of Cochin. One or two species caught in the trawl nets of the small mechanised fishing vessels operating in the 5 to 10 fathom area off Cochin are also included.

Tribe **PENAEIDEA**

Family PENAEIDAE Bate

Subfamily SOLENOCERINAE Wood Mason and Alcock

Solenocera pectinata **(Bate)**

Philonicus pectinatus Bate 1888, p. 279.

Philonicus cervicalis Zehntner 1894, p. 210.

Solenocera pectinata de Man, 1911, pp. 45–47.

Solenocera pectinata Anderson and Lindner, 1943, p. 286.

Solenocera pectinata Nataraj, 1945, p. 96.

Solenocera pectinulata Kubo, 1949, pp. 251–255.

Solenocera pectinata Hall, 1961, p. 80; 1962, p. 13.

Material: Seven males, 24–32 mm. and 7 females, 26–36 mm.

Locality: Arabian Sea, off Cochin (Lat. 9° 55′ N. and Long. 75° 50′ E.) and N.W. of Cochin off Ponnani (Lat. 10° 35′ N. and Long. 75° 20′ E.)—25–50 fathoms.

Distribution: Arafura Sea, south of Papua (Bate), Flores Sea, Ceram Sea and Buton Strait—32–95 m. (de Man), Kumanonada off Owase, Japan—350 m. (Kubo), Arabian Sea (Nataraj) and South China Sea (Hall).

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** Present Address: Central Marine Fisheries Research Substation, Ernakulam.

Remarks: The post-rostral carina does not extend beyond the cervical groove and interrupts the same at 0·55 length of carapace. The vertical groove connecting the hepatic spine and the post-orbital spine is very distinct. The antennular peduncles are 0·55 of the length of the carapace. The outer distal margin of the exopod of the uropod is without spine. The petasma is very much as described by Kubo (1949) for *Solenocera pectinulata*, with the distal third of the lateral margin fringed with fine setae regularly increasing in length distalwards.

Solenocera koelbeli de Man

Solenocera distincta Koelbel, 1884, p. 314.

Solenocera koelbeli de Man, 1911, p. 48.

Solenocera distincta Balss, 1914, pp. 5–6.

Solenocera koelbeli Anderson and Lindner, 1943, p. 286.

Material: One male, 66 mm. and 5 females, 60–79 mm.

Locality: Arabian Sea, N.W. of Cochin off Ponnani (Lat. 10° 35′ N., and Long. 75° 20′ E.)—35–40 fathoms.

Distribution: Koelbel recorded the species from Japan and this is the first record of the species from Indian waters.

Remarks: Rostrum rather short and armed with 7–8 teeth on upper border, anterior three teeth on the rostrum proper. Pterygostomian spine absent. Cervical groove not interrupted by the post-rostral carina. Antennal peduncle almost reaching apex of antennal scale. De Man has observed that the third maxilliped extends only to the apex of the antennal scale, but in the present specimens the third maxillipeds overreach the distal ends of the antennal scale by the length of the dactylus as in *S. brevipes* (Kubo, 1949). The fifth pereiopod reaches beyond the tip of the antennal scale by about ½ of the length of the propodus and dactylus.

As mentioned by Burkenroad (1934 *a*), in synonymising *S. koelbeli* with *S. distincta* (De Haan, 1850), Balss (1914) apparently overlooked the fact that de Man (1911) had confirmed the occurrence of a pterygostomian spine in the type of the latter.

Solenocera hextii Wood Mason

Solenocera hextii Wood Mason, 1891, p. 275.

Solenocera hextii Alcock, 1901, pp. 20–21.

Solenocera hextii de Man, 1911, p. 7.

Solenocera hextii Ramadan, 1938, p. 56.

Solenocera hextii Anderson and Lindner, 1943, p. 286.

Material: One male, 55 mm. and 2 females, 138 and 109 mm.

Locality: Arabian Sea, S.W. Cochin off Alleppey (Lat. 9° 25′ N. and Long. 75° 40′ E.)—185–200 fathoms.

Distribution: Bay of Bengal—65–276 fathoms and Arabian Sea from Indus delta to the Malabar Coast—108–124 fathoms (Wood Mason and also Alcock), Gulf of Aden—186 m. and South Arabian Coast—201–274 m. (Ramadan). The present report extends the distribution of the species further south on the S.W. coast of India.

Remarks: Rostrum is ascendant and dorsally armed with 7–8 teeth, extending to the end of the basal joint of the antennular peduncle. Antennular flagella ⅔ the length of carapace. The 'L' shaped groove on the branchiostegal region of the carapace is conspicuous. The characteristic spine on the cervical groove ventral to the posteriormost spine of the rostral series is present. Telson is trifurcate and almost as long as the exopod of the uropod. Anderson and Lindner (1943) included this species in the group with tooth or spine absent on the outer distal margin of the exopod of the uropod. But in the present specimens these spines are present. The thelycum is quite similar to that of *S. alticarinata* described by Kubo (1949).

Hymenopenaeus aequalis **(Bate)**

Haliporus equalis Spence Bate, 1888, pp. 285–286.

Haliporus aequalis de Man, 1911, pp. 32–33.

Hymenopenaeus aequalis Kubo, 1949, pp. 219–222 (with synonymy).

Material: One female, 71 mm.

Locality: Arabian Sea, S.W. of Cochin off Alleppey (Lat. 9° 25′ N. and Long. 75° 40′ E.), 185 fathoms.

Distribution: Between Philippine Islands and Borneo—250 fathoms (Bate), Andaman Sea and off Ceylon (Alcock), near Kei Islands and Bali Sea—538–560 m. (de Man), S.W. coast of India—237 fathoms (Kemp), East Coast of Africa—628–1362 m. (Balss) and Kumanonada and Heta in Japan—200–450 m. (Kubo).

Remarks: Except in minor variations the descriptions of de Man (1911) and Kubo (1949) clearly apply to the present specimen. In de Man's specimens the rostrum reaches the distal end of the 2nd segment or the middle of the terminal joint of the antennular peduncle. But in the specimens described by Kubo (*op. cit.*) it extends to about ⅓ the length of the 2nd segment of the peduncle. In the present specimen the rostrum extends to the middle of the terminal joint. The fact that the 'Siboga' specimens as well as the present one are females whereas Kubo's specimens were males might explain this difference in this feature. Unlike as described by de Man and Kubo, in the present specimen the rostral teeth formula is 8 + 2 as against 7 + 2. The abdominal segments 4–6 are dorsally carinated.

Subfamily ARISTAEINAE Alcock

Aristeus semidentatus **(Bate)**

Hemipenaeus semidentatus Bate, 1888, p. 305.

Aristeus semidentatus de Man, 1911, pp. 29–31.

Aristeus semidentatus Ramadan, 1938, p. 40.

Not *Aristeus semidentatus* Alcock, 1901, and Kemp and Sewell, 1912 (*Aristeus alcocki* Ramadan, 1938) and *Aristeus semidentatus* Balss, 1925 (*Aristeus mabahissae* Ramadan, 1938).

Material: Three males, 86, 82 and 90 mm. and several females varying in lengths from 100 to 178 mm.

Locality: Arabian Sea, S.W. Cochin off Alleppey (Lat. 9° 25′ N. and Long. 75° 40′ E.)—180–205 fathoms.

Distribution: Near Kermadec Islands and off Banda (Bate), and near Kei Islands—560 m. (de Man). This species is reported for the first time from Indian waters.

Remarks: The specimens on hand tally well with the descriptions of the 'Challenger' and 'Siboga' material. They differ from *A. semidentatus* Alcock (*A. alcocki* Ramadan, 1938) in the nature of the pleurobranchiae on segments X–XIII. These branchiae in the present specimens are not mere papillae but distinct filaments provided with pinnules. However, the buttress of the pterygostomian spine is not so very long. The chelae of the first three pairs of pereiopods are shorter in proportion to the carpus than in *A. alcocki*. In the male the inner edge of the merus of the first leg is concave which is a distinctive feature of *A. semidentatus* according to Ramadan (*op. cit.*). There is no median spine on the posterior edge of the third abdominal segment and in this character as well as in the comparative lengths of the chelae of the legs it differs from *A. mabahissae*. Movable spines are present on the meri of the first and second legs. The females of this species were present in varying numbers in several of the hauls made during the cruises of *M. V. Kalava*. The numbers varied from few to 50 or 60 per haul. In the catches of these cruises this species comes second in the order of abundance. The possibility of catching this on a commercial basis is worth exploring.

Aristeus alcocki Ramadan

Aristeus semidentatus Alcock, 1901, p. 31.

Aristeus semidentatus Kemp and Sewell, 1912, p. 19.

Aristeus alcocki Ramadan, 1938, pp. 40–42.

Material: One female, 141 mm. (with spermatophore in tact).

Locality: Arabian Sea, S.W. of Cochin off Alleppey (Lat. 9° 25′ N. and Long. 75° 40′ E.)—185 fathoms.

Distribution: Bay of Bengal—193–594 fathoms and Arabian Sea near the Laccadives and Cape Comorin—224–487 fathoms (Kemp and Sewell, and Alcock), and Gulf of Aden—270–1051 m. (Ramadan). The present report extends the distribution of the species slightly north in the Arabian Sea in lesser depths.

Remarks: The single specimen obtained agrees well with the description of Alcock and Ramadan especially in the nature of the minute pleurobranchiae on segments X–XIII, the position of the branchio-hepatic groove, the glabrous integument, etc. However, Ramadan (*op. cit.*) observed mobile spinules on the meri of the first and second legs only. But the specimen on hand posseses these spinules on the meri of all the three legs. In the length of the pereiopods also there is slight difference from Ramadan's descriptions. The third pereiopod slightly overreaches the tip of the antennal scale, and the fourth and the fifth legs reach beyond the scaphocerite by the length of the dactylus.

Aristaeomorpha wood-masoni Calman

Aristeomorpha wood-masoni Calman, 1925, p. 8 (with synonymy).

Aristeomorpha wood-masoni Burkenroad, 1936, p. 85.

Aristeomorpha wood-masoni Ramadan, 1938, p. 53.

Aristaeomorpha rostridentata Kubo, 1949, p. 206.

Aristaeomorpha wood-masoni Barnard, 1950, p. 627.

Material: One male, 107 mm. and 1 female, 112 mm.

Locality: Arabian Sea, S.W. of Cochin off Alleppey (Lat. 9° 25′ N. and Long. 75° 40′ E.)—180–205 fathoms.

Distribution: Bay of Bengal and Andaman Sea—271 fathoms (Kemp and Sewell, and Alcock), and South-East Australia (Calman). This is the first report of the species from the Arabian Sea.

Remarks: The most important character which distinguishes this species from *A. foliacea* is the nature of the pterygostomian region (*cf.* Kemp and Sewell, 1912; Calman, 1925; and Kubo, 1949). In both the specimens on hand the length of the pterygostomian area is only a little over twice its greatest breadth, whereas in *A. foliacea* the length of this region is from 3 to 4·5 times its breadth. The specimens agree well with the descriptions of Alcock and Calman. The telson reaches the tip of the endopodite of the uropod. Rostrum of the male is armed with 10 teeth. In the female obtained the rostrum is broken. The tips of the fourth and fifth pairs of pereiopods of both specimens are missing. Petasma is subtrapezoid in outline with the outer margin straight and longer than the inner. The thelycum consists of shield-shaped plates on the sternites between fourth and fifth pereiopods. Sternites of abdominal segments 1–3 with apically sharp median elevation successively decreasing in length.

Subfamily PENAEINAE Burkenroad

Parapenaeus investigatoris **Alcock and Anderson**

Parapenaeus investigatoris Ramadan, 1938, p. 73.

Parapenaeus investigatoris Kubo, 1949, pp. 406–408 (with synonymy).

Parapenaeus investigatoris Barnard, 1947, p. 382.

Parapenaeus investigatoris Barnard, 1950, pp. 602–604.

Material: Four males, 76, 70, 73 and 73 mm. and 1 female, 79 mm.

Locality: Arabian Sea, S.W. of Cochin off Alleppey (Lat. 9° 25′ N. and Long. 75° 40′ E.)—175–185 fathoms.

Distribution: Off Pulicat, Gulf of Mannar and Andaman Sea N.E. and North of North Island—133–419 fathoms (Alcock), near Kei Islands—310 m. (de Man), Gulf of Aden—220 m. (Ramadan), off Maisaku, Japan—300 m. (Kubo), and off Cape Natal, Durban—185 fathoms (Barnard). This is the first record of the species from the Arabian Sea.

Remarks: The specimens on hand quite agree with the descriptions and figures given by previous authors. Rostrum slightly tilted upward but showing a distinct concavity dorsally and armed with 6–7 teeth in addition to the epigastric tooth placed at ⅓ the length of the carapace from the anterior, overreaching the eye in the female but a little shorter in male. Epipodites absent on the last three pereiopods. The 5th pereiopod extends to ¾ the length of the scaphocerite. The 6th pleon segment is a little over twice the length of the 5th segment and longer than the telson by ⅓ of its length. The telson is much shorter than the endopodites of the uropod.

Parapenaeus longipes **Alcock**

Parapenaeus longipes Alcock, 1905, p. 525.

Parapenaeus longipes Alcock, 1906, p. 33.

Parapenaeus longipes de Man, 1911, pp. 81–82.

Parapenaeus longipes Kubo, 1951, pp. 259–263; Racek & Dall, 1965, pp. 52–53.

Material: Two males, 53 and 55 mm.

Locality: Arabian Sea, S.W. of Cochin (Lat. 9° 55′ N. and Long. 76° 10′ E)—10 fathoms.

Distribution: Off Ganjam Coast, Vizagapatam, Mangalore (Malabar Coast) and Sand Heads—7–35 fathoms (Alcock), Madura Strait, Bay of Bima, Timor Sea and Java Sea—55–88 m. (de Man), Kii Channel, Japan—60 m. (Kubo) and New Guinea (Racek & Dall). The present report extends the distribution of the species further south on the South-West coast of India.

Remarks: Rostrum reaching just beyond the eyes with a concavity dorsally and armed with 6 + 1 teeth in both specimens. As described by de Man (1911) and Kubo (1951) the second segment of the antennal peduncle is twice as long as the third instead of 1·5 times as figured by Alcock (1905). The third maxilliped reaches the tip of the antennal scale according to the description of both Alcock and Kubo. In one of the present two specimens the pediform external maxilliped reaches the tip of the antennal scale, but in the other it is slightly shorter. The fifth pair of legs reaches almost the end of the antennal scale according to de Man. But both Alcock and Kubo describe the fifth leg as reaching a dactylus length beyond the antennal scale, which is the case in the present specimens also. The petasma is typically as described by Kubo with the process on the dorsal lateral border of the median lobe directed backwards.

Penaeopsis rectacuta (Bate)

Penaeopsis rectacutus Ramadan, 1938, pp. 67–68.

Penaeopsis rectactus Kubo, 1949, pp. 322–326 (with synonymy).

Penaeopsis rectacuta Hall, 1962, p. 18.

Penaeopsis rectacutus Kurien, 1964, p. 216.

Material: This species is present in almost all the hauls made during the cruises of *M. V. Kalava* operating trawls in depths 160–205 fathoms in varying numbers, sometimes amounting to 10–15 kg. per haul. The males ranged from 70–105 mm. in size and females which outnumbered the males on all occasions ranged from 75 to 115 mm.

Locality: Arabian Sea, S.W. (Lat. 9° 25′ N. and Long. 75° 40′ E.) and N.W. (Lat. 10° 40′ N. and Long. 74° 50′ E) off Cochin—160–205 fathoms.

Distribution: Fiji Islands and Philippines (Bate), off Pulicat, Madras, South of Port Blair, Andaman and North of North Andaman Island—145–419 fathoms (Alcock), Bali Sea and Makassar Strait—289–521 m. (de Man), Nicobar Islands (Balss), off Owase and Tenryugawa, Japan (Yokoya), Gulf of Aden—186 m. (Ramadan), Kumanonada off Owase, Japan—400 m. (Kubo) and South China Sea (Hall). Recently Kurien (1964) reported this species from the Arabian Sea off Kerala coast. He gives the distribution of this species in the area as from North of Cochin to Calicut. But in the present collection it was obtained from south of Cochin also.

Remarks: Kubo (1949) has spelt the specific name of this species as *rectactus*. In quoting the other authors also he gave the same spelling whereas in the references quoted by him the spelling is actually *rectacutus*. Evidently Kubo's *rectactus* appears to be a spelling mistake. The present specimens argee well with the descriptions of previous authors.

Among the prawns present in the catches of all these exploratory cruises this species is perhaps the only one which is caught in comparatively large numbers. The catches of this species varied from ½ to 15 kg. per haul of 1 hour duration. But the size of the prawn as shown above is quite small and not very suitable for the freezing industry. Nevertheless, the possibility of exploiting this species for commercial purposes is worth considering. But factors like the depth from which it is caught and the consequent increased expenses involved in the fishing operations at such depths and the smaller size of the prawn point to its unsuitability for commercial exploitation. However, further exploratory fishing in slightly lesser depths may prove to be useful in determining their presence in larger quantities at such depths.

Metapenaeopsis andamanensis (Wood Mason)

Metapenaeus philippinensis var. *andamanensis* Wood Mason, 1891, p. 271.

Penaeus (*Metapeneus*) *coniger* var. *andamanensis* Alcock, 1901, p. 17.

Metapeneus coniger var. *andamanensis* Alcock, 1906, p. 27.

Penaeopsis coniger var. *andamanensis* de Man, 1911, pp. 61–62.

Metapenaeopsis coniger Kubo, 1949, pp. 432–434.

Metapenaeopsis andamanensis Hall, 1961, pp. 109–110; 1962, pp. 35–36.

Material: Fifteen specimens, 6 males, 89–100 mm. and 9 females, 90–111 mm.

Locality: Arabian Sea, S.W. of Cochin (Lat. 9° 25′ N. and Long. 75° 40′ E.)—150–200 fathoms.

Distribution: East of North Andaman Island, off Port Blair, off Cape Comorin and Andaman Sea—100–244 fathoms (Alcock), Bali Sea, Madura Bay and Kei Islands—54–310 m. (de Man), Japan 150–230 m. (Kubo) and Northern Malacca Straits—87 fathoms (Hall). The present record extends the distribution of the species further north in the Arabian Sea.

Remarks: As observed by Hall (*op. cit.*) the rostrum armed with 6 — 7 + 1 teeth is more or less horizontally straight and not uptilted as described by Alcock (*op. cit.*). The subcarinae of fourth to sixth abdominal terga are indistinct. Like the Malayan species the branchiostegal spines are well developed and telson is shorter than the exopods of the uropod. Sharply pointed spine is also present on the outer distal margin of the basicerite. The small basial spines reported to be present on the second legs of the 'Siboga' and Malayan specimens are not found in the present specimens.

Trachypenaeus curvirostris (Stimpson)

Trachypenaeus curvirostris Ramadan, 1938, p. 63.

Trachypenaeus curvirostris Dall, 1957, pp. 203–206.

Trachypenaeus curvirostris Kunju, 1960, p. 83; Racek and Dall, 1965, p. 89.

Trachypenaeus curvirostris Hall, 1961, pp. 98–100 (with synonymy); 1962, p.29.

Material: Eighteen males, 42–70 mm. and 35 females, 54–92 mm.

Locality: Arabian Sea, S.W. of Cochin (Lat. 9° 55′ N. and Long. 75° 50′ E)—22–25 fathoms and N.W. of Cochin off Ponnani (Lat. 10° 35′ N. and Long. 75° 20′ E.)—35–40 fathoms.

Distribution: Detailed distribution of the species is given by Kubo (1949). Later Racek (1955) and Dall (1957) reported this species from Australia, the former from New South Wales and Moreton Bay and the latter from off Point Lookout, Queensland—20–30 fathoms. Kunju (1960) recorded the same from northern part of the Arabian Sea off Sassoon Docks, Bombay—6–7 fathoms. Recently Hall (1961) reported it from Singapore—17–45 fathoms. The present record extends the distribution of this species to southern coast of the Arabian Sea.

Remarks: In general there is very close agreement between the present specimens and the various descriptions published previously. Minute ischial spines of the first pereiopods overlooked by de Man (1911) are said to be present in Kubo's specimens. Ramadan (*op. cit.*) did not find these ischial spines on the first leg of his specimens and observed that no great importance should be given to this character in separating the section as done by Burkenroad (1936). However, in the present specimens these spines are present even though they are very minute and visible only under very high magnification. Dall (*op. cit.*) also observes the presence of small ischial spine on first leg of his specimen. There is no spine on the basis of the third maxilliped. Unlike Kubo's specimens fifth legs of the present specimens extend to the tip of the antennal scale. Third legs also extend to the same length as the fifth.

Subfamily SICYONINAE Ortmann

***Sicyonia lancifer* (Olivier)**

Sicyonia lancifer de Man, 1911, pp. 123–124 (with synonymy).

Eusicyonia lancifer Kubo, 1949, pp. 439–444.

Eusicyonia lancifer Kurien, 1953, p. 761.

Sicyonia lancifer Hall, 1961, p. 112; 1962, p. 37.

Material: One male, 36 mm.

Locality: Arabian Sea, off Cochin (Lat. 9° 55′ N. and Long. 75° 55′ E.)—17 fathoms.

Distribution: " Mer des Indes ", Arafura Sea, Kagoshima, Japan, Penang and Pearl banks, Gulf of Mannar, Ceylon. Kurien (1953) recorded the species from Arabian Sea off Trivandrum from 12 to 15 fathoms. The present record extends the distribution of the species further north in the Arabian Sea.

Remarks: Rostrum reaches the end of the third segment of the antennular peduncle. The postrostral carina is armed with 5 teeth. The hepatic spine is quite strong. The abdominal pleura of first and second segments are unispinose, while the third, fourth and fifth are armed with three spines. In the ' Siboga ' specimens in all the chelate legs the fingers are one and half times as long as the palm. But in the present specimen this feature is more in agreement with the figures of Bate in that in one or two pairs at least the fingers are not much longer than palm. The first pair of thoracic legs extends to the middle of the scaphocerite whereas the third pair reaches with their fingers beyond the tip of the latter.

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ON DECAPODA BRACHYURA FROM THE GULF OF MANNAR AND PALK BAY*

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ABSTRACT

Materials forming the basis of the present investigation are 88 species of Brachyura representing the families Dromiidae, Dorippidae, Calappidae, Leucosiidae, Hymenosomidae, Maiidae, Parthenopidae, Pinnotheridae, Gonoplacidae, Portunidae, Grapsidae, Ocypodidae and Xanthidae collected from the Indian coast of the Gulf of Mannar and Palk Bay. Of the total of 88 species, *Zalasius indica* is new to science, *Portunus samoensis* (Ward) is perhaps known only from the type locality and *Rhabdonotus pictus* A. Milne Edwards has so far been reported only by A. Milne Edwards (1878) and De Man (1888); the additional records for the Indian region are *Dromidiopsis cranioides* (De Man), *Dorippe polita* Alcock and Anderson, *Elamena sindensis* Alcock, *Halimus aries* (Latreille), *Metopograpsus frontalis* Miers, *M. thukuar* (Owen), *Thalamita spinifera* Borradaile, *T. parvidens* Rathbun, *Charybdis* (*Charybdis*) *anisodon* (De Haan), *Portunus pubescens* (Dana) and *P. samoensis*. *Xenophthalmus pinnotheroides* White, *Philyra verrucosa* Henderson and *Aethra scruposa* (Linnaeus) are species of interest.

A brief outline on the species of Brachyura associated with the various habitats of this area has been given, in so doing only species typical of the particular habitat is included.

THE Gulf of Mannar and Palk Bay along the Indian coast are well known for their faunistic richness and variety. Henderson (1893) has aptly remarked " No collection ground in the Indian seas can show greater profusion of animal life than the Gulf of Mannar between India and Ceylon, famous for its pearl fisheries." Of those who have contributed towards the knowledge of the brachyuran fauna of these areas, mention must be made of Henderson (*loc. cit.*), Alcock (1895–1900), Laurie (1906), Southwell (1911), Kemp (1919), Gravely (1927), Chopra (1931), and Balss (1935).

A perusal of the literature on the collections from this area reveals that the species of *Metopograpsus* commonly encountered is *M. messor* (Forskål). Banerjee (1960), in his studies on the genera *Grapsus, Geograpsus* and *Metopograpsus*, has indicated that the species identified and recorded as *M. messor* by earlier workers, may be either of the two closely related species of *Metopograpsus*, *viz.*, *M. messor* and *M. frontalis* Miers (refer Sankarankutty, 1961, for figure of the first male pleopod of latter). A careful study of a large series of the species collected from this area showed that they belong to *M. frontalis*; and it is presumed that *M. messor* recorded by earlier workers may all be *M. frontalis* since the intensive survey during the present investigation failed to show the occurrence of *M. messor* in this area.

Materials forming the basis of the present investigation are 88 species of Brachyura representing the families Dromiidae, Dorippidae, Calappidae, Leucosiidae, Hymenosomidae, Maidae, Parthenopidae, Pinnotheridae, Gonoplacidae, Portunidae, Grapsidae, Ocypodidae and Xanthidae. Of these, *Zalasius indica* is new to science; *Portunus samoensis* (Ward) and *Rhabdonotus pictus* A. Milne Edwards are known only from their type localities; *Dromidiopsis cranioides* (de Man), *Dorippe polita* Alcock and Anderson, *Elamena sindensis* Alcock, *Halimus aries* (Latreille), *Metopograpsus frontalis, M. thukuar* (Owen), *Thalamita spinifera* Borradaile, *T. parvidens* Rathbun, *Charybdis* (*Charybdis*) *anisodon* (De Haan) and *Portunus pubescens* (Dana) are additional records for the Indian region; *Xenophthalmus pinnotheroides* White, *Philyra verrucosa* Henderson and *Aethra scruposa* (Linnaeus) are species of interest.

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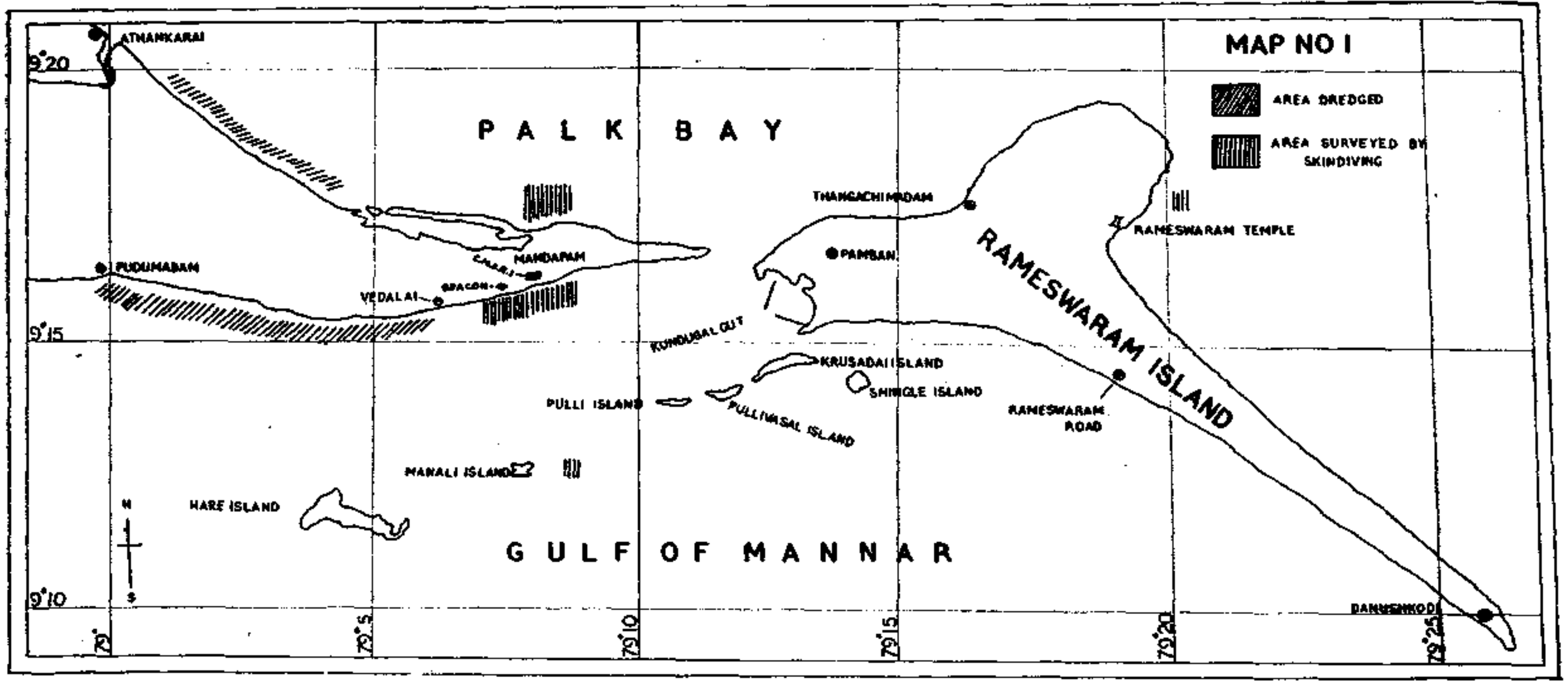


Map 1. Showing the Mandapam area with localities of collection.

Collections were made from the intertidal zone representing the various habitats during the extensive shore collection trips. Fish traps and shore seines operated from the various fish landing places were also examined frequently, often providing good representatives of crabs. *Portunus pelagicus* (Linnaeus) were obtainable in good numbers from the crab nets operated along this coast. Extensive skin-diving around this area enabled me to collect and observe good number of species of crabs, especially those which are commensals. Dredging in the Gulf of Mannar and Palk Bay also contributed a number of species of crabs. Two species (*Dromidiopsis cranioides* and *Rhabdonotus pictus*) were collected from a depth of 25 metres off Tuticorin, using Aqualung.

As good descriptive accounts on most of the species of the present collection already exist, only *Zalasius indica, Rhabdonotus pictus, Harrovia albolineata* Adams and White, *Thalamita parvidens, Charybdis* (*Charybdis*) *anisodon, Portunus pubescens* and *P. samoensis* are described here. First male pleopod and male abdomen of *Achaeus lacertosus* Stimpson (Text-Figs. 8 and 27), *Elamena sindensis* (Text-Figs. 12 and 33), *Paratymolus hastatus* Alcock (Text-Figs. 24 and 26), *Thalamita spinifera* (Text-Figs. 21 and 32) and *Pinnotheres ridgewayi* Southwell (Text-Figs. 23 and 28) are illustrated along with the first male pleopods of *Dorippe granulata* de Haan (Text-Fig. 15), *D. polita* (Text-Fig. 16), *Philyra adamsia* Bell (Text-Fig. 25), *Halimus aries* (Text-Fig. 11), *Micippa thalia* Herbst (Text-Fig. 9), *M. philyra* (Herbst) (Text-Fig. 10), *Metopograpsus thukuar* (Text-Fig. 17), *Scopimera pilula* Kemp (Text-Fig. 13) and *S. proxima* Kemp (Text-Fig. 14).

All the species reported here have been deposited in the Reference Collections of the Central Marine Fisheries Research Institute, Mandapam Camp.

LIST OF SPECIES

Species	Material examined	Locality
1. *Dromia dromia* (Linn.)	A male	Rameswaram
2. *Dromidiopsis cranioides* (de Man)	A female	Tuticorin
3. *Dromidia unidentata* (Rüp.)	A male and a female	Vedalai
4. *Pseudodromia integrifrons* Hend.	Two females	Mandapam in Gulf of Mannar
5. *Dorippe frascone* (Hbst.)	3 ovigerous and 2 non-ovigerous females and 7 males	Pudumadam
6. *D. granulata* de Haan	A male	Pudumadam
7. *D. polita* Alc. and And.	2 males and a female	Pudumadam
8. *Calappa hepatica* (Linn.)	A female	Hare Island
9. *C. philargius* (Linn.)	A male	Palk Bay
10. *Matuta lunaris* (Forskål)	2 males, 2 females and a juvenile	Hare Island, Mandapam in Palk Bay
11. *M. planipes* Fabr.	2 females and a male	Mandapam in Palk Bay
12. *Philyra scabriuscula* (Fabr.)	10 males and 5 females	Mandapam in Palk Bay
13. *P. verrucosa* Hend.	A male	Pudumadam
14. *P. adamsia* Bell	17 ovigerous and 9 non-ovigerous females and 15 males	Pudumadam
15. *Elamena cristatipes* Grvly.	An ovigerous female	Madras Harbour
16. *E. sindensis* Alc.	A male, 3 females and a juvenile	Mandapam in Gulf of Mannar
17. *Achaeus lacertosus* Stmpn.	2 ovigerous and 2 non-ovigerous females and a male	Pudumadam
18. *Paratymolus hastatus* Alc.	3 males, one ovigerous and 3 non-ovigerous females	Athankarai
19. *Acanthonyx macleayi* Krauss	A male and a female	Vedalai
20. *Menaethius monoceros* (Latr.)	2 males, 4 ovigerous and 11 non-ovigerous females	Vedalai
21. *Halimus aries* (Latr.)	2 males	Kilakarai
22. *H. pleione* (Hbst.)	2 males and 3 females	Kilakarai
23. *Schizophrys aspera* (H. M. Edws.)	A female and 2 males	Pamban, Manoli Island
24. *Micippa thalia* Hbst.	A male	Hare Island
25. *M. philyra* (Hbst.)	2 females and 2 males	Hare Island
26. *Rhabdonotus pictus* A. M. Edws.	A female	Tuticorin

Species	Material examined	Locality
27. *Harrovia albolineata* Adams and White	2 females	Vedalai
28. *Aulacolambrus hoplonotus* (Adams and White)	2 males, one ovigerous and 3 non-ovigerous females	Hare Island
29. *Aethra scruposa* (Linn.)	A female	Rameswaram
30. *Zalasius indica* Sp. nov.	A female	Devipatnam
31. *Grapsus albolineatus* Lmck.	An immature male, one ovigerous and one non-ovigerous female	Mandapam in Gulf of Mannar
32. *Metopograpsus frontalis* Miers	Numerous specimens of both sexes	Pamban, Mandapam in Palk Bay
33. *M. thukuar* (Owen)	A male, one ovigerous and one non-ovigerous female	Kundugal point
34. *Sesarma plicata* Latr.	2 males, one ovigerous and one non-ovigerous female	Pullivasal Island
35. *Metaplax distincta* H. M. Edws.	A female	Athankarai
36. *Percnon planissimum* (Hbst.)	2 males	Shingle Island
37. *Plagusia depressa* var. *tuberculata* Lmck.	2 males and a female	Mandapam in Gulf of Mannar
38. *Thalamita crenata* (Latr.)	4 males, one ovigerous and 5 non-ovigerous females	Mandapam in Palk Bay, Shingle Island
39. *T. prymna* (Hbst.)	7 males and 6 females	Mandapam in Palk Bay, Manoli Island, Tuticorin
40. *T. spinifera* Borr.	A male, 3 ovigerous and 2 non-ovigerous females	Vedalai
41. *T. integra* Dana	Numerous specimens of both sexes	Mandapam in Palk Bay, Vedalai
42. *T. parvidens* Rath.	4 males and 2 ovigerous females	Vedalai
43. *Charybdis* (*Charybdis*) *annulata* (Fabr.)	A male	Krusadai Island
44. *C.* (*Charybdis*) *helleri* (A. M. Edws.)	7 males, 3 females and 3 juveniles	Krusadai Island, Mandapam in Palk Bay
45. *C.* (*Charybdis*) *feriata* (Linn.)	A male and a female	Vedalai, Pudumadam
46. *C.* (*Charybdis*) *natator* (Hbst.)	3 females and 5 males	Vedalai, Mandapam in Palk Bay
47. *C.* (*Charybdis*) *anisodon* (de Haan)	A male	Vedalai
48. *Portunus pelagicus* (Linn.)	A male, a female, many juveniles and 6 with *Sacculina*	Pamban, Vedalai, Devipatnam
49. *P. sanguinolentus* (Hbst.)	4 males	Vedalai, Dhanushkodi
50. *P. pubescens* (Dana)	4 ovigerous and one non-ovigerous females, an immature male	Vedalai
51. *P. hastatoides* Fabr.	18 males, one ovigerous and 2 non-ovigerous females	Athankarai, Panaikulam
52. *P. samoensis* (Ward)	A male	Hare Island
53. *Scylla serrata* (Forsk.)	A male	Mandapam in Palk Bay
54. *Eucrate crenata* var. *dentata* Alc.	2 females	Vaighai estuary
55. *Xenophthalmus pinnotheroides* White	A female	Devipatnam
56. *Pinnotheres deccanensis* Chopra	7 ovigerous and 7 non-ovigerous females	Mandapam in Gulf of Mannar
57. *P. ridgewayi* Southwell	Numerous specimens of both sexes	Mandapam in Palk Bay and Gulf of Mannar
58. *Ocypode ceratophthalma* (Pallas)	11 males and 19 females	Mandapam in Gulf of Mannar, Kundugal point
59. *O. macrocera* H. M. Edws.	5 males and 2 females	Mandapam in Palk Bay, Kundugal point
60. *O. cordimana* Desmarest	3 males and 2 females	Mandapam in Gulf of Mannar, Kundugal point
61. *O. platytarsis* (H. M. Edws.)	A male	Rameswaram Road
62. *Uca annulipes* (H. M. Edws.)	Numerous specimens of both sexes	Kundugal point, Vaighai estuary
63. *U. marionis* var. *nitidus* Dana	6 males and a female	Manoli Island
64. *Dotilla myctiroides* (H. M. Edws.)	6 males and 4 females	Vedalai, Kundugal point
65. *Scopimera pilula* Kemp.	14 males, one ovigerous and 9 non-ovigerous females	Kundugal point
66. *S. proxima* Kemp.	2 males and 4 females	Mandapam in Gulf of Mannar
67. *Macrophthalmus depressus* Rüpp.	19 males, 2 ovigerous and 7 non-ovigerous females	Palk Bay lagoon, Kundugal point Manoli Island

Species	Material examined	Locality
68. *M. convexus kempi* Grvly.	A male	Manoli Island
69. *Carpilius maculatus* (Linn.)	A female	Kilakarai
70. *Chlorodiella nigra* (Forsk.)	A male, 4 females and 2 juveniles	Manoli Island
71. *Phymodius monticulosus* (Dana)	A male	Pulli Island
72. *Etisus (Etisus) laevimanus* Randall	2 males	Kilakarai
73. *E. (Etisodes) electra* (Hbst.)	A male	Hare Island
74. *Xanthias lamarcki* (H. M. Edws.)	A male	Shingle Island
75. *Cymo melanodactylus* de Haan	9 males, 15 ovigerous and one non-ovigerous females and 4 juveniles	Mandapam in Gulf of Mannar, Manoli Island
76. *C. andreossyi* (Audouin)	A female	Manoli Island
77. *Ategratis intergerrimus* (Lmck.)	3 males, a female and an immature male	Kilakarai, Manoli Island
78. *Actaea ruppelli* (Krauss)	2 females	Mandapam in Gulf of Mannar
79. *A. granulata* (Audouin)	A male	Pudumadam
80. *Leptodius exaratus* (H. M. Edws.)	Numerous specimens of both sexes	Shingle Island, Pulli Island, Krusadai Island, Mandapam in Palk Bay
81. *L. crassimanus* A. M. Edws.	A female	Shingle Island
82. *Menippe rumphii* Fabr.	3 males and a female	Mandapam in Palk Bay
83. *Heteropanope laevis* (Dana)	A male	Pudumadam
84. *Eurycarcinus grandieri* A. M. Edws.	A male	Pamban
85. *Pilumnus vespertilio* (Fabr.)	A female	Mandapam in Palk Bay
86. *Eriphia sebana* (Shaw and Nodder)	A male, one ovigerous and 4 non-ovigerous females	Pullivasal Island
87. *Trapezia areolata* Dana	An ovigerous female	Rameswaram reef
88. *Tetralia glaberrima* (Hbst.)	4 males, one ovigerous and 6 non-ovigerous females	Mandapam in Gulf of Mannar, Rameswaram reef

Genus *Zalasius* Rathbun

(Plate I)

The genus includes only four species, *viz.*, *Z. dromiaeformis* (de Haan) (McNeill and Ward, 1930), *Z. horii* Miyake (Miyake, 1940), *Z. sakaii* Balss (Balss, 1938) and the present new species *Z. indica*. The genus is recorded for the first time from Indian waters.

***Zalasius indica* sp. nov.**

(Plate I, Fig. 4)

Holotype: A female measuring 37·0 mm. in breadth and 33·0 mm. in length.

Type locality: Devipatnam in Palk Bay.

Description: Carapace highly tomentose like *Dromia dromia*, conspicuously convex in either directions, regions indicated by deep grooves and postero-lateral region with few miliary granules. Front narrow but broader than orbit, bilobed with median part deflexed and almost touching the epistome thereby separating antennulary fossa of either side; frontal lobes not separated from inner angle of orbit. Orbit complete with its upper border divided into three regions by two deep fissures of which inner being more prominent. Outer angle of orbit not pronounced and not forming any tooth or lobe. Antero-lateral border immediately outside orbit forming a concave zone followed by uniformly convex tuberculated border, the line of tubercles curving inwards and ending on either sides of cardiac region. Postero-lateral border short and more or less straight.

Antennules fold obliquely; antenna separated from the orbit by the fusion of basal antennal joint to the inner side of orbit, antennal flagellum reduced. Pterygostomian, sub-hepatic and sub-branchial regions tomentose; pterygostomian region granulated.

External maxilliped not closing the buccal cavern completely, its exposed surface completely clothed in plumose hairs. Ischium narrow and elongated, widening distally, merus longer than broad with concave inner and outer borders and rounded distal border. Palp short, attached to the middle of the distal end of merus and partly concealed in a groove at the inner distal end of merus; exopod with short flagellum.

Chelipeds sub-equal and like the walking legs completely covered with hairs excepting the inner side of propodus and fingers. Merus short and high, being higher than long, its borders tuberculate, similar tubercles found on upper surface of the outer side also. Ventral hinge of merus elongated (length of merus along ventral border including the ventral hinge considerably more than length along the upper border but slightly less than height of merus) and almost coming in contact with the proximal hinge of propodus. Carpus with a line of tubercles on the inner side in the proximal half and at about the middle of the segment drooping down on the inner side. Propodus higher than long (length measured along the upper border) and shorter than movable finger, upper border slightly on the inner side with three rows of tubercles reducing in size distally. Outer surface of propodus tuberculated, a group of tubercles on the inner side of propodus at the proximal end. Ventral border of propodus with a longitudinal row of about eight tubercles. Fingers sharp, pointed with serrated cutting edges and leaving a wide gap at the proximal end between them.

First two pairs of walking legs sub-equal and longer than lost two pairs, fourth pair shortest. Dactylus of all legs thin and long ending in sharp hook-like claw, its length more than the length of merus in the last two legs but about as long as merus in first two legs.

Sternal segment of cheliped with three enlarged tubercles arranged in a triangle—two on the outer and one on the inner side; a deep groove between inner tubercles of either side through which project out the long pleopods. Each of the following sternal segments with one such tubercle reducing in size posteriorly (those on last two segments being indistinct); another transverse tubercle between two sternal segments and closer to the base of legs, being prominent only on the last two segments.

Abdomen in female of seven separate segments with a median broad convex ridge along the entire length of abdomen except in the last segment. Third segment broadest from where abdomen narrowing distally, end segment conical and broader than long.

The species can be easily separated from other three known species by the conspicuous absence of the coarse granulation on the carapace.

Genus *Rhabdonotus* A. Milne Edwards

***Rhabdonotus pictus* A. Milne Edwards**

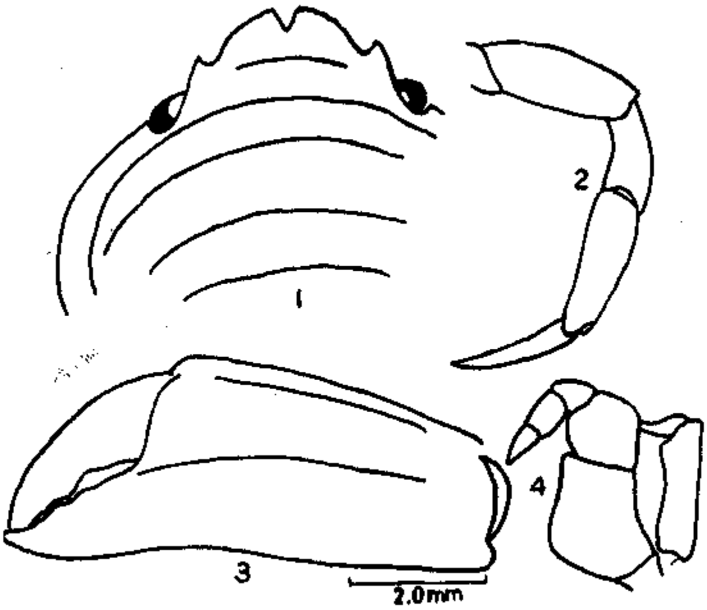
(Figs. 1–4)

Rhobdonotus pictus, A. Milne Edwards, 1878, p. 6: Viet-Nam; R. Serene and K. Romimohtarto, 1963, p. 9: Singapore.

Material: A female.

Locality: Tuticorin in the Gulf of Mannar.

Description: Carapace nearly as long as broad, perfectly smooth and polished, convex in either direction, glabrous and without any indication of regions. Front prominent and quadrilobate, all the lobes lying in the same plane and with serrated border; inner frontal lobe broader than outer and separated by a deep median cleft, its inner end more prominent than outer and its border oblique and straight; outer frontal lobe conical and small, separated from inner lobe by a concavity and not projecting to the extent of inner lobes. Outer border of outer frontal lobes oblique and forming partly the upper border of orbit. Outer angle of orbit not distinct as a tooth and at a lower level. A minute fissure on the supra-orbital border towards the outer angle. Antero-lateral border together with the postero-lateral border forming a smooth, convex, sharp and entire border. Posterior border of carapace broad and concave. Antennules fold obliquely. Basal antennal joint broad closing the inner gap of orbit, antennal flagellum consisting of few segments. Infra-orbital border slightly concave and entire.



TEXT-FIGS. 1-4. *Rhabdonotus pictus.* (1) Part of carapace; (2) walking leg; (3) outer surface of the propodus of the cheliped; (4) external maxilliped.

Cheliped sub-equal, smooth to the naked eye but granulated microscopically, segments nearly cylindrical. Inner angle of carpus not prominent. Propodus stout, sub-cylindrical and its upper border longer than dactylus. Fingers toothed and pointed, dactylus closing inside the tip of fixed finger.

Legs reducing in size posteriorly, segments smooth and glabrous, dactylus nearly as long as propodus.

Female abdomen consisting of seven separate segments.

Carapace in live condition slightly brownish in colour with transverse red lines. A short narrow line between orbits immediately followed by three or four short tranverse lines equally spaced and parallel to each other. An oval or circular ring in the gastro-cardiac region, posterior part of carapace with irregularly disposed lines. Propodus of cheliped on the outer side with two longitudinal lines.

The species was observed to be commensalic on *Virgularia* sp. and was collected from the pearl banks off Tuticorin in the Gulf of Mannar from a depth of 25 metres.

Genus *Harrovia* Adams and White

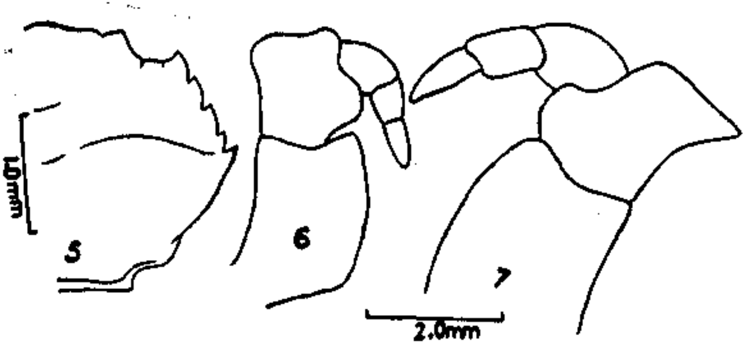
***Harrovia albolineata* Adams and White**

Harrovia albolineata, Laurie, 1906, p. 393: Ceylon; Serene, Tran Van Duc and Nguyen van Loum, 1958, p. 200: Viet-Nam; Jones and Sankarankutty, 1960, p. 194: Gulf of Mannar (refer for figure and photographs).

Material: Two females.

Locality: Vedalai.

Description: Carapace flattish, broader than long, smooth and hexagonal, regions not very markedly distinguishable, a faint transverse groove representing the posterior boundary of gastric region. Front quadrilobate and minutely spiny and granulate; median lobe broader than lateral having more or less straight or slightly convex border, inner end of median frontal lobes slightly deflexed; lateral lobes narrow and conical in shape and a little more pronounced than median lobes. Supra-orbital border a semicircular concavity without any division. Antero-lateral border divided into four lobes of unequal size; first lobe with nearly straight border forming the outer orbital angle; second similar to the first; third and fourth conical in shape and spiny, third lobe variable in size (refer Jones and Sankarankutty, Figs. 3 and 4). Posterior border of carapace nearly straight. Antennaules fold obliquely; antenna at the inner end of orbit, basal antennal joint not touching front. Infra-orbital border coarsely granulate and cut into two lobes, inner larger and outer smaller. Inner border of ischium of external maxilliped uniformly serrated.



TEXT-FIGS. 5–7. (5) Carapace of *Thalamita parvidens*; (6) external maxilliped of *Portunus pubescens*; (7) external maxilliped of *P. samoensis*.

Chelipeds sub-equal and decidedly more than the length of carapace; merus and propodus sub-cylindrical long segments, propodus longer than merus and compressed from side to side with slightly bulging middle part. All segments of cheliped covered with minute granules. Dactylus shorter than upper border of propodus, much curved and covered with granules on the dorsal surface. Fingers pointed and toothed on the cutting edge.

Legs reducing in size posteriorly, merus of all legs minutely spiny on the dorsal surface. Dactylus of all legs nearly as long as propodus.

Carapace in live specimen with a circular broad black ring running parallel to the borders of the carapace; two transverse bands join this ring in the anterior half; cardiac region with a shorter spindle-shaped black band not connected to the ring. Cheliped with median longitudinal whitish portion bordered on either side by broad black border.

Genus *Thalamita* Latreille

Thalamita parvidens **Rathbun**

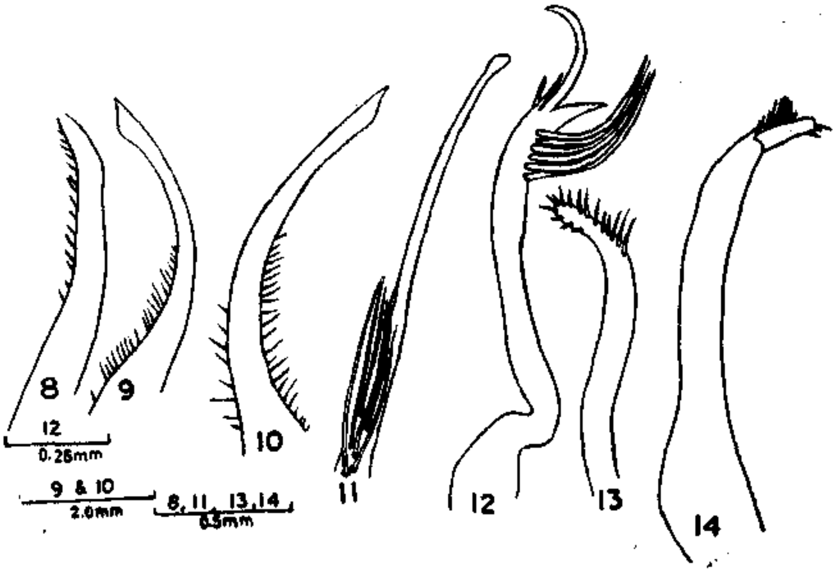
(Text-Figs. 18, 19 and 30)

Thalamita parvidens, Stephenson, 1961, p. 122: Western Australia.

Material: Four males and two ovigerous females.

Locality: Dredged from the Gulf of Mannar off Vedalai.

Description: Carapace almost glabrous and with the following faintly distinguishable ridges—epibranchial interrupted only by the cervical groove, lateral cardiac, mesogastric and frontal. Front bilobed with a fairly distinct median notch, inner orbital lobe oblique and narrower than frontal lobe. Antero-lateral border of carapace with five sub-equal teeth, or fourth slightly smaller than rest, first or first three blunt. Basal part of all teeth granulated. Breadth of basal antennal joint more than diameter of orbit (1·16–1·33). Crest of basal antennal joint minutely serrated.



Text-Figs. 8–14. First male pleopod of: (8) *Achaeus lacertosus*; (9) *Micippa thalia*; (10) *M. philyra*; (11) *Halimus aries*; (12) *Elamena sindensis*; (13) *Scopimera pilula*; (14) *S. proxima*.

Cheliped unequal; anterior border of merus with three blunt teeth and few granules preceding them, upper surface of merus also granulated. Inner angle of carpus with a spine and outer side with blunt projections, ridges join spines, upper surface of carpus minutely granulated. Upper surface of propodus with two longitudinal ridges, inner one alone with a spine in the middle, spine on the proximal dorsal hinge in the form of a blunt projection. Upper surface of propodus including carina granulated, a single faint ridge on the outer surface of propodus entering fixed finger. Ventral proximal end of propodus minutely granulated. Fingers long, toothed; dactylus carrying a recurved tooth at its base.

Male abdomen consisting of five separate pieces with segments 3–5 fused together. Penultimate segment broader than long and with nearly parallel sides. End segment triangular in shape and distinctly broader than long.

Remarks: The examination of the first male pleopod of the specimen of the present collection showed a marked difference in the curvature and armature of the tip compared to the figure provided by Stephenson.

Genus *Charybdis* de Haan

Charybdis (Charybdis) anisodon **(de Haan)**

(Text-Figs. 22 and 31; Plate II, Fig. 1)

Charybdis anisodon, Sakai, 1939, p. 405: Japan.

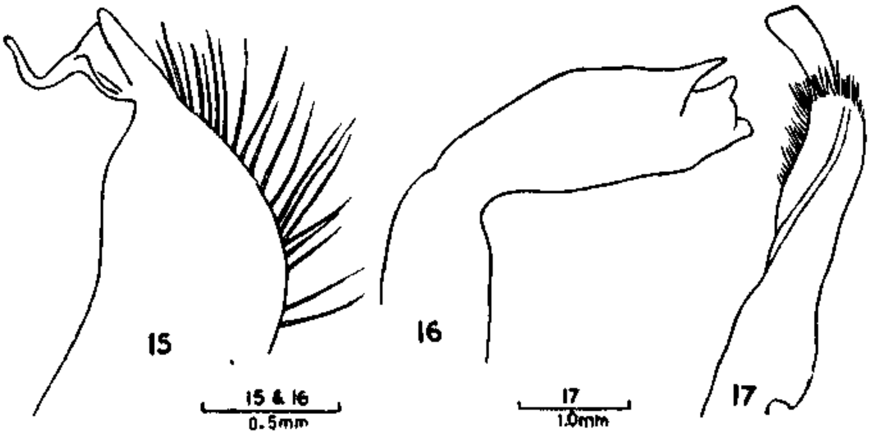
Charybdis (Goniosoma) anisodon, Gordon, 1931, p. 527: Coast of China; Shen, 1937, p. 117: Singapore.

Charybdis (Charybdis) anisodon, Leene, 1938, p. 64: Gier and Kleiweg de Zwaan collection, off the river mouth near Tello, Celebes, Makassar; Stephenson, Hudson and Campbell, 1957, p. 493: Australia.

Material: A male.

Locality: Vedalai.

Description: Carapace convex, smooth and naked; regions ill-defined, following transverse ridges noticeable—protogastric, mesogastric interrupted and epibranchial interrupted in the middle of gastric region and by the cervical groove. Front cut into six teeth, median tooth a little more prominent than sub-median and with an almost straight border, sub-median similar in shape as median and at a higher plane, lateral as prominent as sub-median but narrow. Supra-orbital border with two distinct clefts. Antero-lateral border of carapace divided into six teeth, first two smaller than rest with rounded tips, second smallest, third and fourth sub-equal and broader than fifth, sixth a long spine almost pointing laterally and much more than twice the length of fifth.

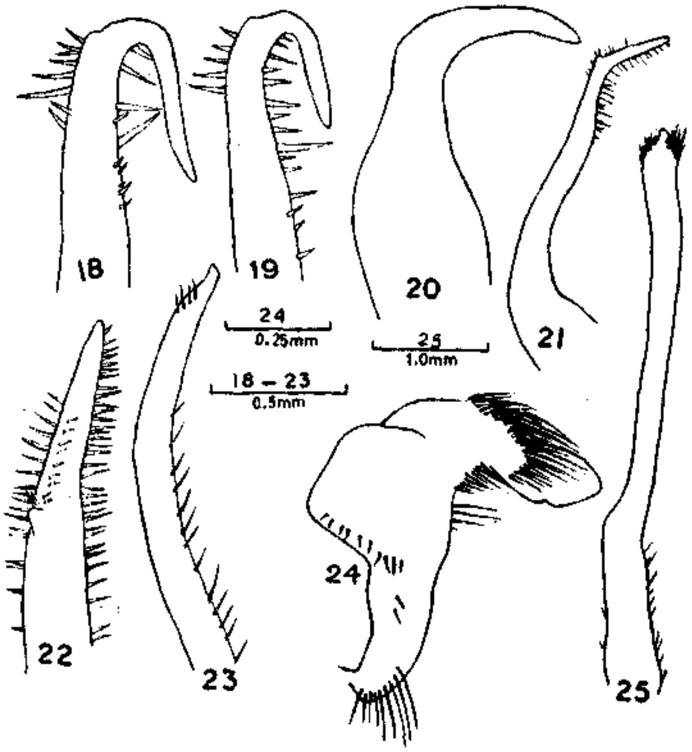


TEXT-FIGS. 15–17. First male pleopod of: (15) *Dorippe granulata*; (16) *D. polita*; (17) *Metopograpsus thukuar*.

Chelipeds slightly dissimilar in size. Anterior border of merus armed with two spines, posterior border unarmed. Carpus with the usual large spine on the inner side but three spines on the outer side represented by tubercles. Upper surface of propodus provided with two spines, but spine on the proximal hinge remaining as tubercle, second spine in the middle on the inner side of propodus. Dactylus longer than upper border of propodus.

Posterior border of propodus of natatory leg unarmed.

Male abdomen with transverse carinae on second and third segments; sixth segment broader than long and with convex borders.



TEXT-FIGS. 18-25. First male pleopod of: (18 and 19) *Thalamita parvidens*; (20) *Portunus samoensis*; (21) *Thalamita spinifera*; (22) *Charybdis* (*Charybdis*) *anisodon*; (23) *Pinnotheres ridgewayi*; (24) *Paratymolus hastatus*; (25) *Philyra adamsia*.

Genus *Portunus* Weber

***Portunus pubescens* (Dana)**

(Text-Fig. 6; Plate II, Fig. 2)

Neptunus pubescens, Sakai, 1934, p. 303: Japan.

Neptunus (*Achelous*) *pubescens*, Doflein, 1904, p. 98: Sandwich Island.

Neptunus (*Neptunus*) *pubescens*, Sakai, 1939, p. 338: Japan.

Portunus pubescens, Edmondson, 1954, p. 237: Hawaiian Islands; Stephenson and Campbell, 1959, p. 99: Australia.

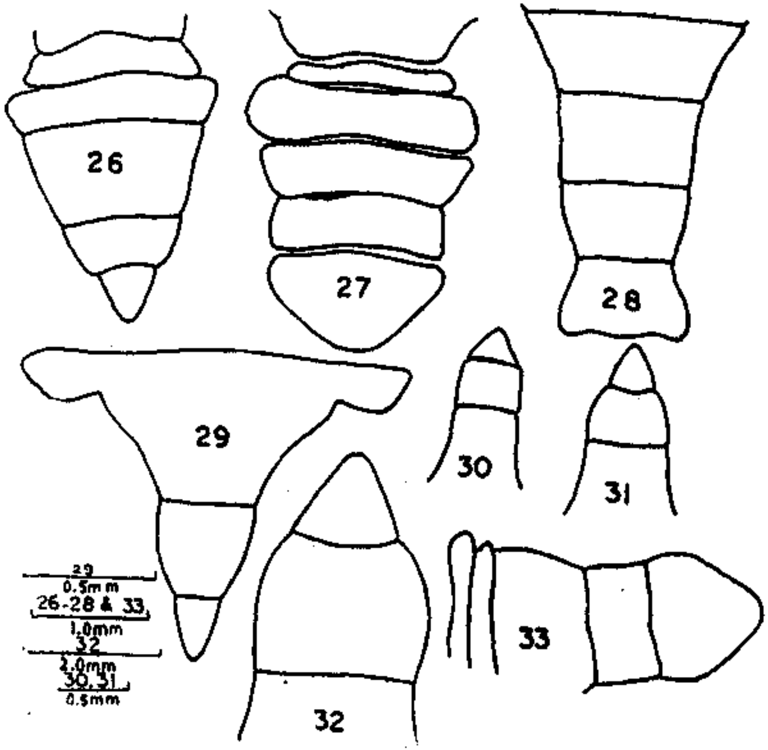
Material: Four ovigerous and one non-ovigerous females, and one immature male.

Locality: Vedalai.

Description : Carapace convex, covered with a coating of hairs concealing the granulated ridges, following ridges recognisable—curved mesogastric and epibranchial. Front cut into four lobes with squarish or rounded tips, inner frontal lobe a little smaller than outer. All frontal lobes project beyond the inner orbital lobe. Supra-orbital border with two distinct clefts. Antero-lateral border provided with nine teeth, first being a little larger than the rest, last largest and spiny projecting laterally.

Chelipeds sub-equal and short. Merus armed with three spines along the anterior border and unarmed along the posterior. Carpus with four distinct carinae all of which terminate in spines; inner and outer carinae reach up to the distal end of the segment, inner ending in the usual large spine of carpus; two carinae in the middle being short and not reaching the distal end of the segment; a short oblique carina confined to the distal half of the segment joining the dorsal hinge of carpus. Upper surface of propodus with three carinae of which inner two terminate in spines. Inner and outer surfaces of propodus provided with a carina each.

Antero-external angle of merus of third maxilliped not produced laterally.



Text-Figs. 26–33. Male abdomen of: (26) *Paratymolus hastatus*; (27) *Achaeus lacertosus*; (28) *Pinnotheres ridgewayi*; (29) *Portunus samoensis*; (30) *Thalamita parvidens*; (31) *Charybdis (Charybdis) anisodon*; (32) *Thalamita spinifera*; (33) *Elamena sindensis*.

Portunus samoensis **(Ward)**

(Text-Figs. 7, 20 and 29)

Monomia samoensis, Ward, 1939, p. 4: Samoa.

Portunus samoensis, Stephenson and Campbell, 1959, p. 60.

Material: A male.

Locality: Dredged from the Gulf of Mannar near Hare Island.

Description: Carapace fairly convex, covered with sparse hairs not concealing the granulated area, its breadth about 1·66 times its length. A faint metagastric ridge recognisable in the present specimen. Following regions well defined—cardiac, lateral cardiac and branchial. Front cut into four teeth, median pair minute and its inner end deflexed; lateral tooth more prominent than median frontal and inner supra-orbital lobes. Supra-orbital border with two distinct clefts. Anterolateral border divided into nine teeth, last being largest and spiny. First tooth blunt tipped and larger than following seven acute subequal teeth. Lower border of orbit with ' V '-shaped cleft at the outer angle.

Chelipeds sub-equal, anterior border of merus with four and posterior border with two spines, both borders fringed with hairs. Upper surface of merus more or less granulated, a terminal spine on the ventral side of merus. Carpus with the usual spine to which joins a carina arising from the proximal end of the segment, another shorter carina arising from the proximal end of carpus but not reaching the distal end of the segment and not terminating in a spine. Propodus with seven distinct ridges, three on dorsal surface of which the innermost being granular, strongest and with a fringe of hairs along the inner side and terminating in a spine. Two ridges on the outer side of propodus, the lower entering the fixed finger. Two ridges on the inner side of propodus less distinct than those on the outer side. Dactylus longer than upper border of propodus.

Antero-external angle of merus of external maxilliped produced laterally.

Penultimate segment of male abdomen longer than broad with its sides converging distally.

Remarks: The lone specimen in the present collection is provisionally identified as *P. samoensis* since it shows the following differences from *P. argentatus* (A. Milne Edwards): (1) absence of a spot on dactylus of natatory leg, (2) presence of fringes of hairs on antero-lateral border of carapace and chelipeds, (3) relatively longer terminal segment of male abdomen and (4) shape of first male pleopod (refer Edmondson, 1954 for figures of male pleopod and male abdomen and photograph of *P. argentatus*).

DISTRIBUTION OF BRACHYURA IN THE MANDAPAM AREA

The Gulf of Mannar and Palk Bay around Mandapam, termed here as Mandapam area (refer Map 1), present diverse ecological habitats (refer Plate II, Figs. 3–5) including the luxuriant growth of corals, each with a distinct fauna of its own. During the present investigation, an attempt was made to study the branchyuran fauna in its natural environment. In this part of the study, the term sub-terrestrial is used to indicate those forms which are exposed at least during the ebb tide, and aquatic, those which are always confined to the area below the low tide mark. Mention must also be made that only typical and conspicuous species are dealt with here; the rare, and forms of doubtful distribution are omitted.

AQUATIC

Sandy:

Matuta lunaris, M. planipes, Philyra scabriuscula, Portunus pelagicus, P. sanguinolentus and *P. hastatoides.*

Beneath and among Rocks:

Schizophrys aspera, Micippa thalia, M. philyra, Thalamita crenata, T. prymna, Charybdis (Charybdis) helleri and *C. (Charybdis) natator,* Among Sea Weeds:

Menaethius monoceros, *Aulacolambrus hoplonotus* and *Thalamita integra.*

SUBTERRESTRIAL

Rocky Coast:

Grapsus albolineatus and *Plagusia depressa* var. *tuberculata.*

Sandy:

Ocypode ceratophthalma, O. macrocera, O. cordimana, O. platytarsis, Dotilla myctiroides and *Scopimera proxima.*

Broken Coral Rocks:

Metopograpsus frontalis, Percnon planissimum, Leptodius exaratus, Atergatis intergerrimus, Etisus (Etisus) laevimanus, Eriphia sebana, Pilumnus vespertilio and *Menippe rumphii.*

Marshy:

Uca annulipes, U. marionis var. *nitidus, Macrophthalmus depressus, Scopimera pilula, Metopograpsus thukuar* and *Sesarma plicata.*

Commensal on Corals:

Trapezia areolata, Tetralia glaberrima, Chlorodiella nigra, Cymo melanodactylus, C. andreossyi and *Phymodius monticulosus.*

Other Commensals:

Pseudodromia integrifrons within ascidian.
Harrovia albolineata on crinoid.
Pinnotheres ridgewayi inside *Pinna* sp.
P. deccanensis within *Holothuria scabra* Jäger.

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DISCUSSION

Dr. R. Serene: How do you consider your collections as rich since you have described only 88 species in your account ?

Dr. C. Sankarankutty: I only mentioned that the area is rich in fauna. It may be noted here that earlier works in this area have revealed a large number of species; as for example in 1906 Laurie has recorded 208 species of Brachyura from the Gulf of Mannar.

EXPLANATION TO PLATES I AND II

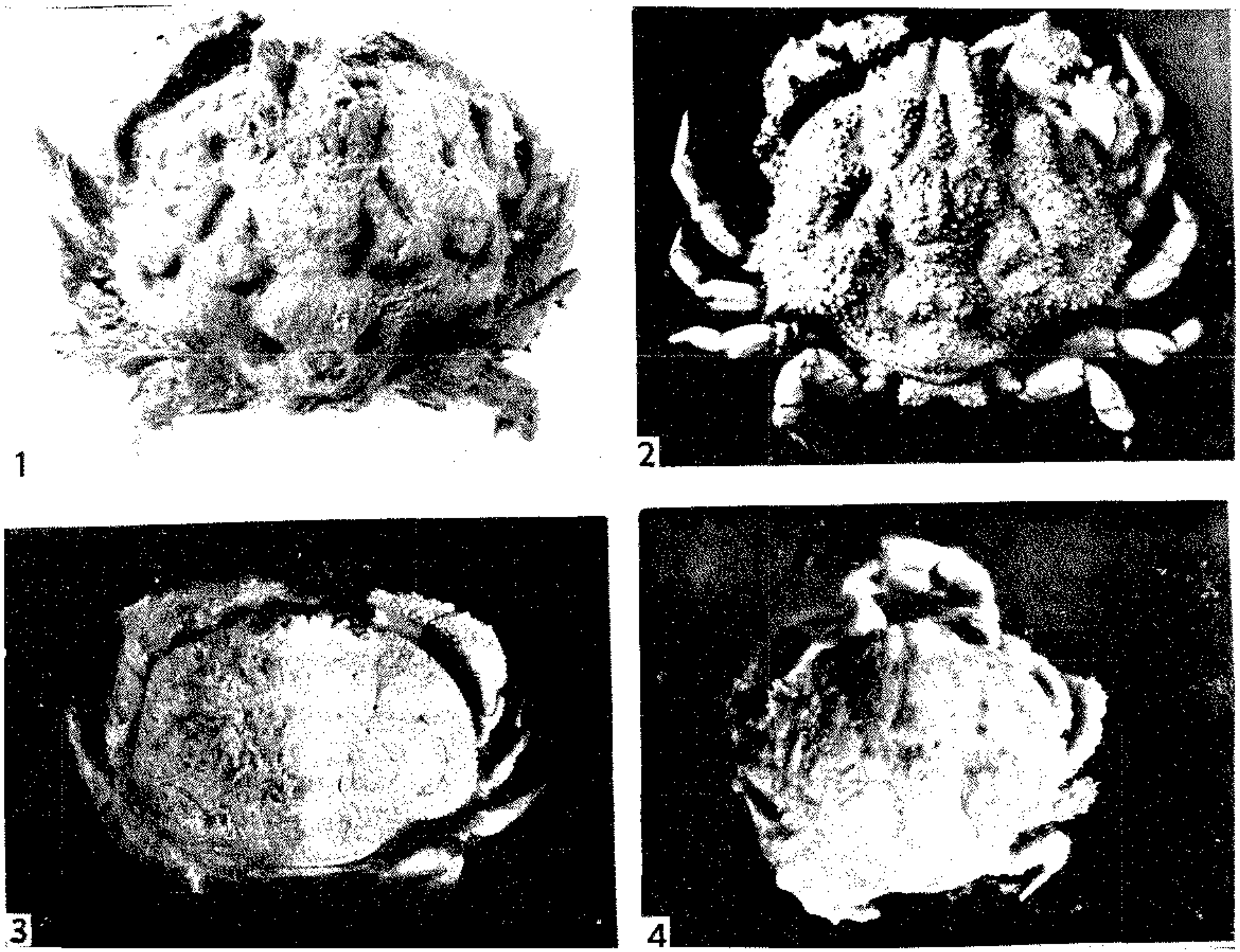
PLATE I

FIGS. 1–4. Figs. 1 and 2. *Zalasius dromiaeformis* (de Haan). Fig. 3. *Z. horii* Miyake. Fig. 4. *Z. indica* new species.

PLATE II

FIGS. 1–5. Fig. 1. *Charybdis* (*Charybdis*) *anisodon*. Fig. 2. *Portunus pubescens*. Fig. 3. Large expanse of marshy area at Kundugal Point exposed during ebb tide. Fig. 4. Sand-stone rock formations inhabitated by *Grapsus albolineatus* and *Plagusia depressa* var. *tuberculata*. Fig. 5. Dilapidated granite pier in the Gulf of Mannar close to the C.M.F.R. Institute colonised by *Grapsus albolineatus* and *Plagusia depressa*.

C. Sankarankutty



FIGS. 1-4

PL. I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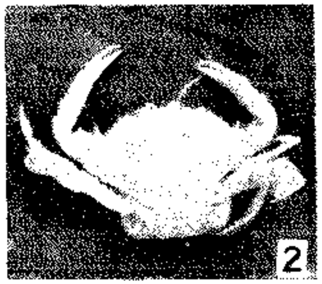
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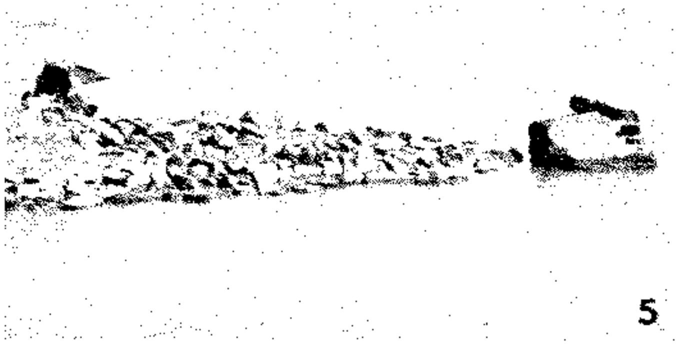
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Figs 1-5

A MORPHOMETRIC ANALYSIS OF CERTAIN WESTERN AMERICAN SWIMMING CRABS OF THE GENUS *PORTUNUS* WEBER, 1795

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ABSTRACT

Extensive series of western American species of *Portunus* have been examined by both classical and biometrical techniques. In the *P. xantusii* " complex " there are three intergrading forms linked by clines, these meriting subspecific status as follows: *P. xantusii xantusii, P. xantusii minimus, P. xantusii affinis.* A fourth form *P. pichilinquei* is a synonym of *P. xantusii minimus.*

In the *P. acuminatus* " complex " *P. panamensis* is a synonym of *P. asper* and *P. acuminatus* is confirmed as being a separate species.

The existence of male dimorphism in the *P. xantusii* complex is noted, and also an insignificantly small correlation coefficient between the lengths of ultimate and penultimate segments of the male abdomen.

I. INTRODUCTION

Two tentatively identified collections of portunid crabs from Western America have recently been examined by the author. The first and most comprehensive is contained in the Allan Hancock Foundation and had been tentatively identified by Dr. John S. Garth. The second is from the collections of the Smithsonian Institution which have accumulated since Rathbun's time, and which were identified by the author and Miss May Rees.

When the collections were compared side by side, it was evident that two groups within the genus *Portunus* had caused difficulty:—

(*a*) The *Portunus xantusii* " complex ". This comprises four closely related species whose distributions partly overlap:

- (i) *P.* (*Portunus*) *xantusii* (Stimpson, 1860); previously known from Southern California (Santa Barbara), *via* the Pacific coast of Lower California, to the south eastern portion of the Gulf of California (*see* Map).
- (ii) *P.* (*Achelous*) *pichilinquei* Rathbun, 1930; previously known from Magdalena Bay (Lower California) *via* Cape San Lucas to the head of the Gulf of California.
- (iii) *P.* (*A.*) *minimus* Rathbun, 1898; previously known from within the Gulf of California and from Tres Marias Islands just to the South.
- (iv) *P.* (*A.*) *affinis* (Faxon, 1893); previously known from off Cape San Lucas and Isabel Island (Gulf of California) to off Ecuador and including the Galapagos Islands.

(*b*) The *Portunus acuminatus* " complex ". This comprises three closely related roughly sympatric species:

- (i) *P.* (*P.*) *acuminatus* (Stimpson, 1871); previously known from Isabel Island (Gulf of California) to Ecuador,

Map showing areas and localities mentioned in the text.

(ii) *P.* (*P.*) *asper* (A. Milne Edwards, 1861); previously known from Pta Piaxtla, Gulf of California to Chile.

(iii) *P.* (*P.*) *panamensis* (Stimpson, 1871); previously known from Magdalena Bay (Lower California) and the Gulf of California to Chile.

Within each complex the supposed interspecific differences were obvious in some cases, obviously non-existent in others, and of doubtful validity in the remainder. Measurements were made upon doubtful features and data analysed statistically.

II. MEASUREMENTS

Carapace lengths and breadths were measured with dial calipers to the nearest 0·1 mm. as follows: length—from most protruding frontal tooth to centre of posterior margin of carapace; breadth—between notch separating eighth and ninth anterolateral teeth on one side and corresponding notch on the other. This measurement excludes the ninth anterolateral teeth.

The following were measured with calibrated eyepiece micrometer to the nearest 0·01 mm.: length and breadth of median frontal teeth, length of ninth anterolateral teeth, length and breadth of male abdominal segments, and length and breadth of merus of fifth legs. Bilateral structures were measured on the right side except in cases of damage or loss. Lengths of abdominal segments were measured in the midline; breadths were the maxima of the respective segments. Lengths of ninth anterolateral teeth were measured from the notch separating eighth and ninth teeth to the tip of the ninth, and at right angles to the anteroposterior axis of the carapace, rather than attempting to follow curvatures in horizontal and vertical planes. Because species distinctions are more obvious in males than females, only males were measured unless otherwise stated. As the statistical methods which were employed are scattered variously in the literature, and not always fully given, they are detailed in the appendices.

III. THE *P. XANTUSII* COMPLEX

1. Systematic Discussion

(*a*) *P. minimus* and *P. pichilinquei*

(For figures *see* Rathbun, 1930, text-fig. 13, pl. 36; and pl. 37 respectively.)

Specific differences, given by Rathbun (1930, pp. 36, 76, 78) are discussed below on the basis of examination of over 600 specimens in the Hancock collections, together with Rathbun's types in the Smithsonian Institution.

(1) Ninth anterolateral tooth short in *P. minimus* (twice length of eighth tooth), long in *P. pichilinquei* (width of next three teeth). In one specimen (second largest male, '*Velero*' Sta. 717-37) one side has a *minimus*-like tooth, and the other a *pichilinquei*-like tooth. Using 50 specimens of more or less the same size, but otherwise chosen at random, lengths of the ninth tooth were measured in terms of widths of preceding teeth (to nearest ½ tooth). Data gave a unimodal frequency distribution curve; range *ca.* 1½–4, mode *ca.* 2. (The modal value lies on the boundary of a supposed distinction between *P. minimus* and *P. affinis*.)

(2) Remaining anterolateral teeth more robust and closely spaced in *P. minimus*, more slender and sharp in *P. pichilinquei*. Intergradation is complete in the collections examined. It should be noted that the eighth tooth on the left side of the holotype of *P. pichilinquei* is little more than a rudiment.

(3) Front less advanced in *P. minimus* than in *P. pichilinquei*. There are no differences in advancement of the basis of the front, such differences as do exist are in length and sharpness of frontal teeth. Intergradation is complete. Length/breadth ratios of median frontal teeth of the 50 chosen specimens gave a unimodal frequency distribution curve; range *ca.* 0·4–1·0, mode *ca.* 0·5.

None of the described differences have diagnostic value. Minute examination failed to reveal further differences of diagnostic importance. It is concluded that *P. pichilinquei* is a synonym of *P. minimus*. Garth (private communication) states that Dr. G. P. Ashcroft who had previously examined the Hancock collections came to the same conclusion. Garth himself states (1960, p. 113): "......the exhaustive series in the Hancock collections suggest that these [*P. minimus* and *P. pichilinquei*] may represent but a single species."

(*b*) *P. pichlinlquei* and *P. xantusii*

(For figures *see* Rathbun, 1930, pl. 37 and pl. 18)

Interspecific differences are given by Rathbun (1930, pp. 36, 50, 78). These are discussed below on the basis of comparison of about 400 "*pichilinquei*-like" specimens of *P. minimus* with over 500 *P. xantusii*.

(1) Front more prominent and frontal teeth flatter and blunter in *P. pichilinquei*. No differences could be found in advancement of the basis of the front, but rather those with more advanced fronts had longer sharper frontal teeth. Therefore if Rathbun is followed *P. pichilinquei* is presumably distinguished from *P. xantusii* by having both longer and sharper, and in simultaneous contradiction flatter and blunter frontal teeth. At all events, no differences other than those due to random variation could be detected.

(2) Anterolateral margin straighter and less arched in *P. pichilinquei*. This diagnostic feature is also confusing. While the carapace of *P. pichilinquei* has straighter margins, it was placed by Rathbun in the subgenus *Achelous*, which is distinguished from the subgenus *Portunus* (containing *P. xantusii*) by the sharper convex curvature of its borders. Actually many species of *Portunus* in both subgenera have slightly *concave* borders and the carapace of an "average" *P. pichilinquei* (including the type) is slightly less concave than an average *P. xantusii*. There is considerable intergradation, possibly complete intergradation, through intermediate forms.

(3) Anterolateral teeth more slender, unequal, spiniform and outstanding in *P. pichilinque*. No constant differences were detectable in specimens examined.

(4) Ninth anterolateral tooth of good length in *P. pichilinquei*. In *P. xantusii* the tooth was generally longer than in *P. pichilinquei*, with uncertainty regarding the completeness of intergradation.

(5) Male abdomen more broadly triangular in *P. pichilinquei*. Broader abdomens occurred in some specimens (only) of *P. pichilinquei* and also in some *P. xantusii*.

No further differences of diagnostic importance were apparent and it was concluded that only about half of the supposed differences merited further study. These comprised carapace shapes, male abdomens, and lengths of last anterolateral teeth.

(*c*) *P. minimus* and *P. affinis*

(For figures *see* Rathbun, 1930, text-fig.13, pl. 36, and pls. 38, 39 respectively.)

Specific differences are given by Rathbun (1930, pp. 36, 80, 82). They are discussed below on the basis of comparison of about 400 "*minimus*-like" (as distinct from "*pichilinquei*-like") specimens of *P. minimus* with over 1,000 *P. affinis*.

(1) Shorter ninth anterolateral tooth in *P. affinis*. This tooth described as less than twice the length of the preceding tooth in *P. affinis* as against twice or more in *P. minimus*. It has already been shown that the modal value for tooth length in a randomly selected population of *P. minimus* lies exactly on this supposed boundary [*see* (*a*) (1) above].

(2) First eight anterolateral teeth less unequal in *P. affinis*. No constant differences were apparent.

(3) Carapace very convex in *P. affinis*. In specimens from widely spaced localities this difference was apparent, but differences were much more doubtful when specimens from adjacent localities were compared.

A minute comparison between the large series in the Hancock collections gave the impression that *P. affinis* might be distinct from *P. minimus* but in almost undefinable ways. The merus of the fifth leg appeared broader in *P. affinis* than in *P. minimus* and this was further investigated, together with studies of carapace shape, male abdomens, and lengths of last anterolateral teeth.

2. MORPHOMETRIC ANALYSES

These concern features of doubtful diagnostic value: carapace shape, length of last anterolateral teeth, shape of segments of male abdomen, and shape of merus of fifth leg.

(*a*) *Preliminary Analyses of Carapace Shape*

This is possibly the most important of the features listed because it governs placement of species in subgenera. It is also the most difficult to study, because descriptions refer to curvatures of anterolateral borders, and analyses of curvature present problems. In the present work linear measurements of length and breadth were made. General methods of handling data were developed by preliminary work upon carapace shape as reported below.

(*i*) *Representative selected specimens*: 60 *P. xantusii* and 60 *P. minimus* were selected from a large number of collections so as to give reasonably even cover of available size ranges. To avoid possible misidentifications all *P. xantusii* were from open Pacific coasts of California and Baja California, while all *P. minimus* were from the Gulf of California.

Individual data were plotted as "scatter diagrams" using a variety of functions of length and of breadth and it was visually apparent that log./log. plots closely approximated to rectilinear. Assuming they are rectilinear, variables are related by a formula of the type:—

$y = ax + c$ where y is $\log_{10}$ carapace length, x is $\log_{10}$ carapace breadth, a regression coefficient, and c intercept on y-axis. a and c are constants characterising the group under discussion. (For details of computing a and c, *see* Appendix I.) Present data gave: *P. xantusii* $a = 1{\cdot}0345$, $c = 0{\cdot}1404$; *P. minimus* $a = 1{\cdot}0614$, $c = 0{\cdot}0852$; combined data $a = 1{\cdot}0600$, $c = 0{\cdot}0985$.

There are two methods of determining whether the specimens came from a single variable population or from two. The first is a significance test upon a and c, and involves considerable computation; the second involves consideration of deviations of y values from regression. These are easily computed (*see* Appendix II) and when plotted as a frequency distribution diagram give visual indications of an homogeneous population (unimodal curve) or of an heterogeneous population (multimodal curve). In the present case combined data gave a bimodal curve, reflecting unimodal curves for each species (Fig. 1). A t test of differences between mean deviations from regression gave a significant difference ($P = 0{\cdot}001$).

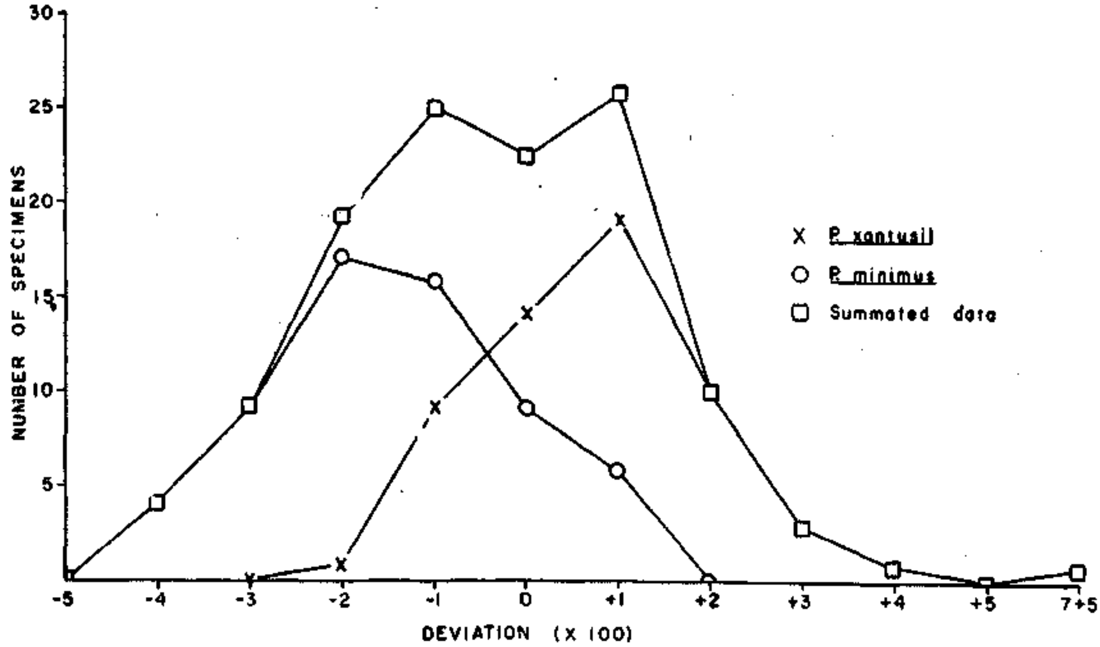

FIG. 1. Frequency distribution of deviations from the mean regression relating carapace length and carapace breadth based upon 60 specimens of *P. xantusii* and 60 of *P. minimus*.

(ii) *Specimens from different localities*: Because of the possibility of clines, data were obtained upon latitudinal groupings of localities of each species. Mean deviations from regression for combined data are given in Table I.

TABLE I

Species	Mean latitude N	Relation to known distribution range	Mean deviation from regression	Number of specimens
P. xantusii	33° 29′	near N. extremity; Pacific Ocean	+1·75	13
	28° 38′	near centre of range	+0·90	10
	24° 36′	near S. extremity; Pacific Ocean	+0·67	36
P. minimus	30° 26′	most northern collections; Gulf of California	−1·11	19
	29° 41′	near N. extremity; Head Gulf of California	−1·36	11
	27° 54′	Gulf of California	−1·25	8
	26° 02′	Gulf of California (centre)	−1·90	10
	24° 24′	Gulf of California	−1·09	7
	23° 05′	S.W. extremity; Cape San Lucas	−1·04	25
	21° 52′	Isabel Islands, S. of Gulf of California	+0·33	15

Clines are apparent in the *P. xantusii* data, and the *P. minimus* values on Isabel Island material fit this cline. In the remaining *P. minimus* material general variability, no doubt influenced by small sample sizes, obscures clear indications of a cline.

In further analyses all available males from a series of latitudinal groupings were considered.

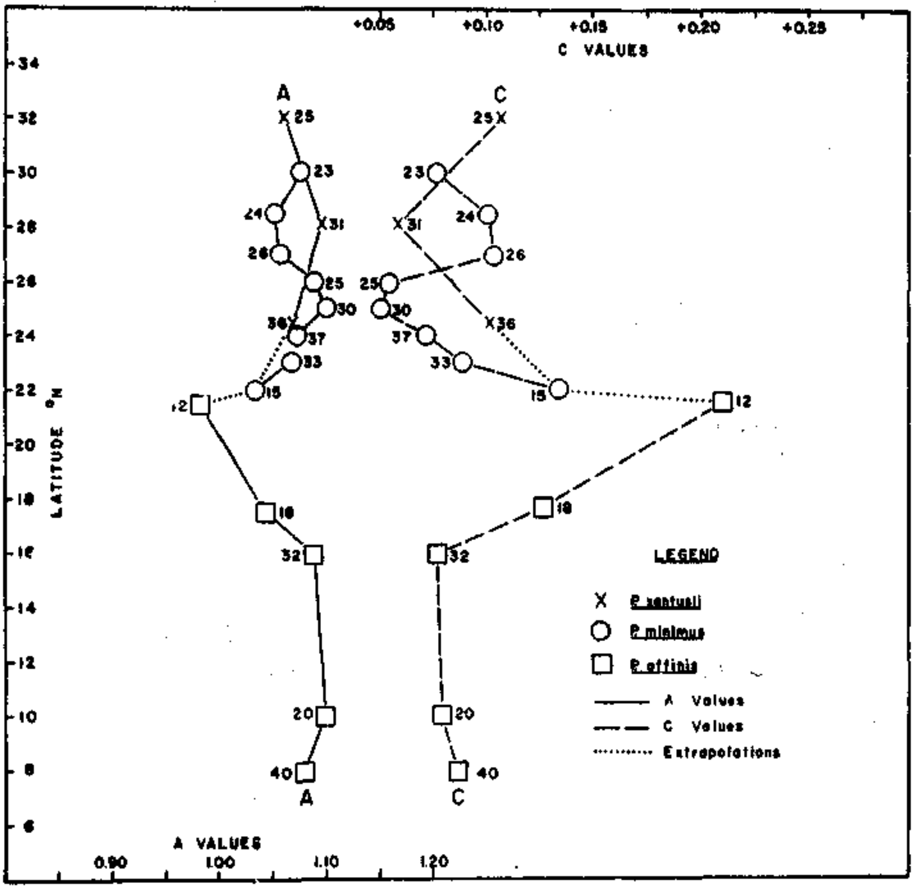

FIG. 2. Values of a and c in the formulae:—log. carapace length = a (log. carapace breadth) = c for different latitudinal collections of *P. xantusii*, *P. minimus* and *P. affinis*. Numerals adjacent to the plotted points indicate the numbers of specimens measured.

(*b*) *Final Analysis of Carapace Shape*

Regression analysis data upon *P. xantusii*, *P. minimus* (including *P. pichilinquei*) and *P. affinis* are given in Fig. 2. These data show:—

(i) that low a values accompany high c values and *vice versa*. Since this applies to most analyses, a general interpretation is attempted. The differences between c values are larger than those between a values, showing that differences between groups are most evident with smaller specimens. As specimens become larger, distinctions tend to disappear, those with shortest carapaces (lowest c values) tending to lengthen fastest (highest a values). This " growth homeostasis " possibly supports the concept that all specimens belong to one species (*see* Discussion);

(ii) values of *a* and *c* change with latitude indicating the existence of clines. In *P. xantusii* and *P. affinis* clines are bow-shaped, and in *P. minimus* sigmoid;

(iii) in *P. xantusii* and *P. minimus* both *a* and *c* values intersect at c. 30° N. and c. 26½° N. Here the species are indistinguishable by present criteria:

(iv) curves for all species converge at c. 22° N. Here none of the species are mutually distinguishable;

(v) over the range of latitudes from 8° N. to 16° N., *a* and *c* values of *P. affinis* are close to the mean values of *P. xantusii* and *P. minimus*.

It is concluded that differences in the measured proportions of the carapace are valueless as specific criteria, and hence that *P. xantusii* cannot belong to a different subgenus from the remainder.

(*c*) *Length of Ninth Anterolateral Tooth*

Lengths of the tooth and carapace breadths were measured initially upon *P. xantusii* and *P. minimus* collections, and it appeared that the variables constituted a rectilinear regression in a

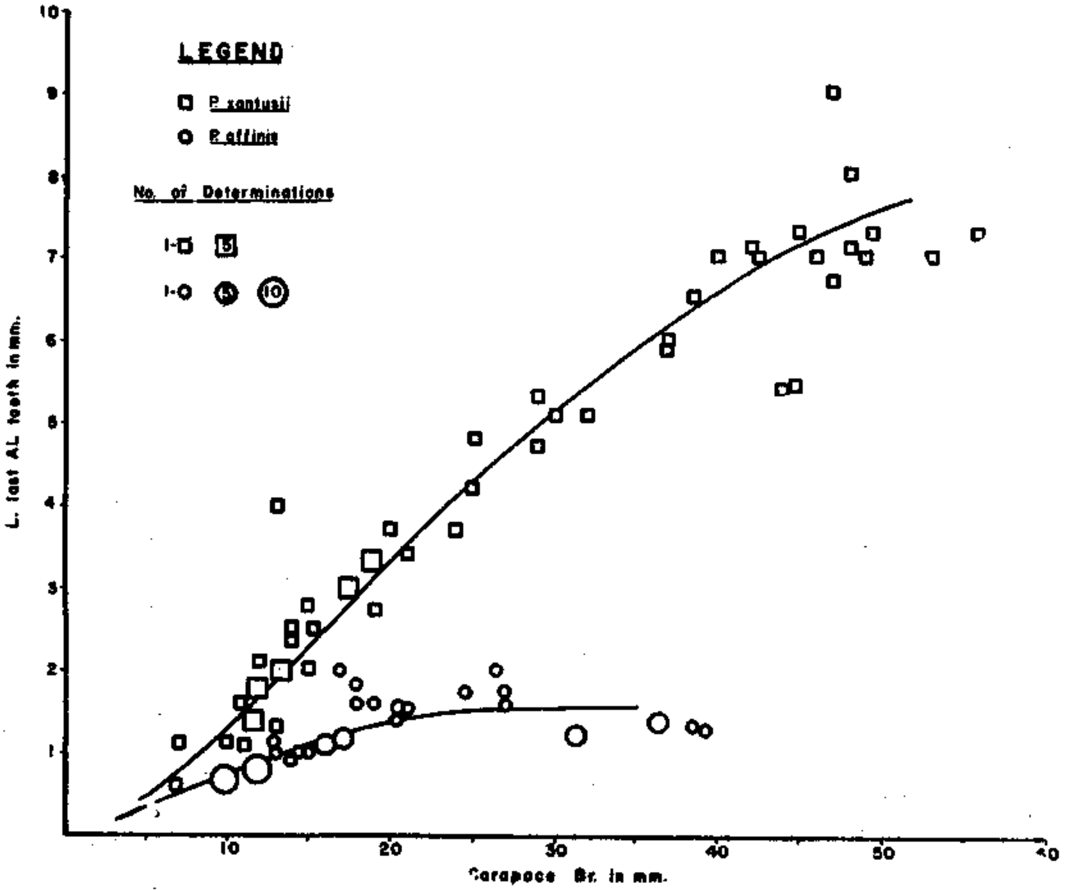

FIG. 3. Length of the last anterolateral tooth against carapace breadth in randomly selected specimens of *P. xantusii* and *P. affinis* respectively. "Scatter" diagrams with visually smoothed curves.

log./log. plot apart from minor divergences in the smallest specimens. Data upon *P. affinis* were obtained later, and here the relationship between the variables is more complex with an approximation to a straight line log./log. plot only up to a carapace breadth of c. 20 mm., where a growth inflection causes a levelling off (*see* Fig. 3). Meanwhile equivalent data upon other species (see Figs. 11 and 12) showed even more involved relationships, in which it seemed desirable to apply rectilinear arithmetic regressions to a series of growth phases.

Finally three analyses were applied to present data:—

(1) log./log. regressions to: *P. xantusii* apart from smallest specimens, *P. minimus* apart from smallest specimens, and to *P. affinis* apart from larger (breadth < 20 mm.);

(2) arithmetic regressions to all species apart from largest specimens (breadth > 20 mm).

(3) graphical analysis of larger specimens of all species;

(1) *Logarithmic Analysis on Selected Size Ranges*

Results are given in Fig. 4; conclusions parallel those of the previous section, but with differences in details:—

(i) *a* and *c* values show a roughly inverse relationship. (Note this applies to the size ranges indicated and not to larger specimens);

(ii) *a* and *c* values indicate bow-shaped clines for all three species.

(iii) clines for *P. xantusii* and *P. minimus* approach each other closely or intersect at c. 28–30° N.;

(iv) Isabel Island material conforms least to the general pattern, but is possibly linked to *P. minimus via* the middle of the Gulf of California;

(v) clines for all species tend to converge at c. 22° N.;

(vi) *a* and *c* values for *P. affinis* at latitudes from 8° N. to 10° N. are very similar to those of the bulk of *P. xantusii* and *P. minimus* collections.

(2) *Arithmetic Analysis Excluding Larger Specimens*

Results are given in Fig. 5, and while conclusions are similar to those above, there are differences. Thus, considering *a* values, the Cape San Lucas collection of *P. minimus* apparently conforms least to the general pattern, although possibly representing southern extensions of both *P. xantusii* and *P. minimus* clines. *a* values of *P. affinis* link to those of *P. xantusii via* the Isabel Island collection.

Considering *c* values indicate convergence of *P. xantusii* and *P. minimus* clines to the Cape San Lucas material. The *P. affinis* cline evidently extrapolates to the Isabel Island material, but at a latitude of 22–23° N., there is a morphological gap between *P. xantusii* plus *P. minimus* on the one hand and *P. affinis plus* the Isabel Island material upon the other.

(3) *Graphical Analysis of Larger Specimens*

Data from all available specimens broader than 20 mm. irrespective of latitude of collection are plotted as a "scatter diagram" in Fig. 6, where values from *P. xantusii* and *P. affinis* respectively are joined by visually smoothed curves. Data upon *P. minimus*, as far as it is available, appears completely to bridge the difference between the two curves.

Summarising results upon relative length of last anterolateral teeth (1) logarithmic analyses upon certain size ranges, and graphical analyses of data from the larger specimens suggests that

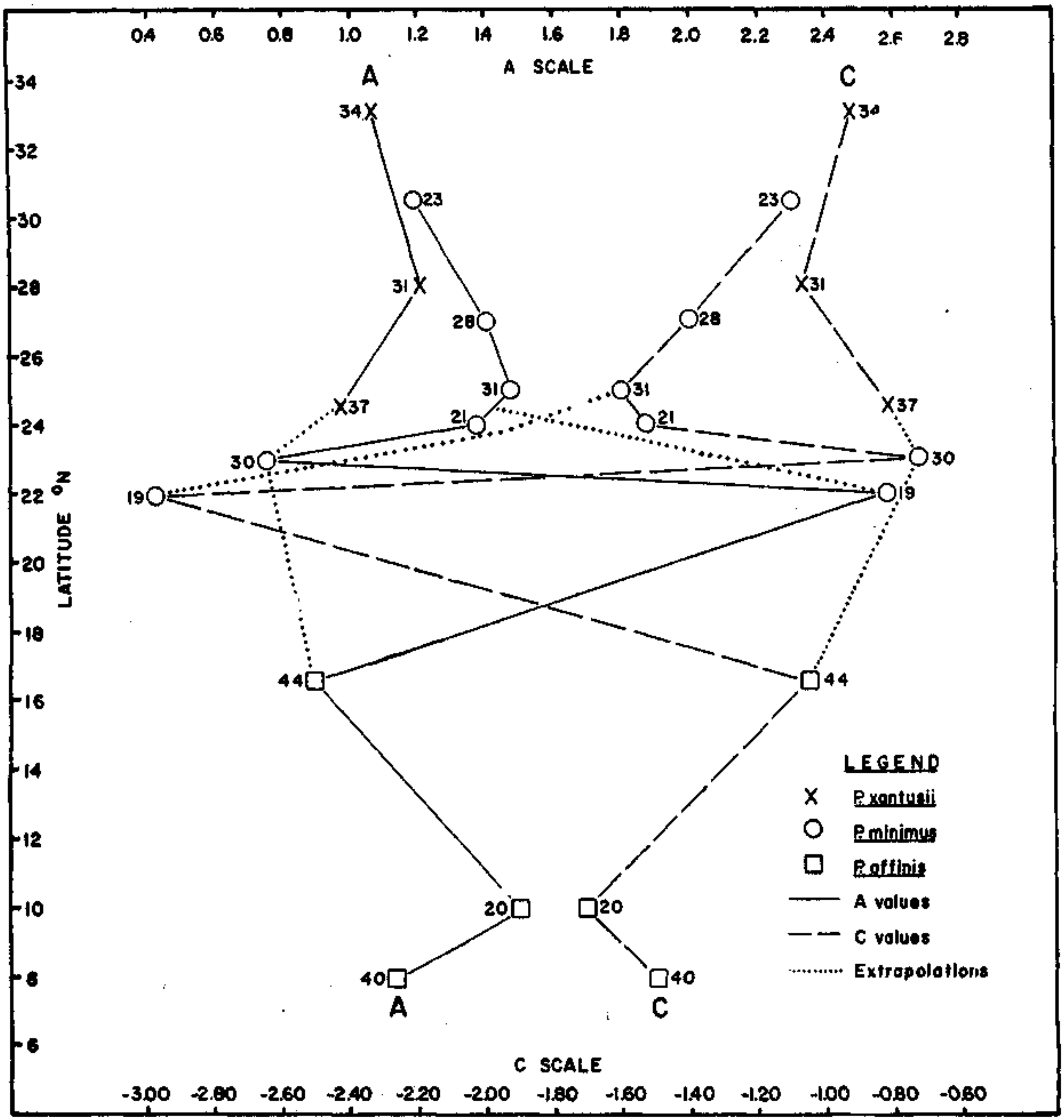

FIG. 4. Value of *a* and *c* in the formulae:—log. length last anterolateral tooth = *a* (log. carapace breadth) + *c* for different latitudinal collections of *P. xantusii*, *P. minimus* and *P. affinis*. Numerals adjacent to the plotted points indicate the numbers of specimens measured.

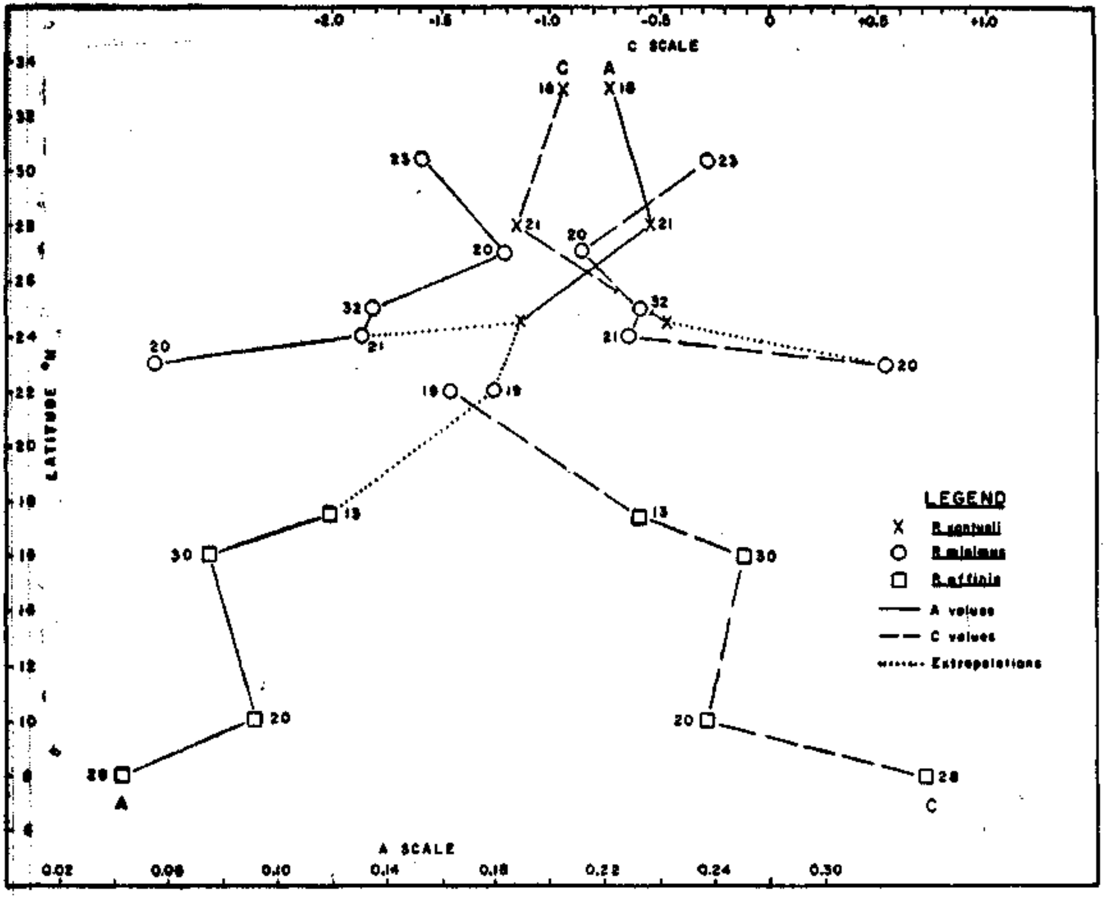

FIG. 5. Values of a and c in the formulae:—length last anterolateral tooth = a (carapace breadth) + c for different latitudinal collections of *P. xantusii*, *P. minimus* and *P. affinis*. Numerals adjacent to the plotted points indicate the numbers of specimens measured.

P. xantusii is completely linked to *P. affinis* via *P. minimus* and (2) arithmetic analyses of data from small and medium-sized specimens suggests that two populations are present a northern one comprising *P. xantusii* and *P. minimus*, and a southern one comprising *P. affinis* with the Isabella Island specimens. It should be stressed that sample sizes, in the critical range of latitudes (20–23° N.) are inadequate.

(*d*) *Shape of Male Abdomen*

(1) *Ultimate Segment*

Lengths and breadths were measured, log./log. plots suggested a rectilinear regression, and relevant data are given in Fig. 7. These are discussed under two headings:—

(i) P. xantusii *and* P. minimus : a and c values show a roughly inverse relationship, and there are apparently clines which link the species. Deviations of y from each of the regression lines are

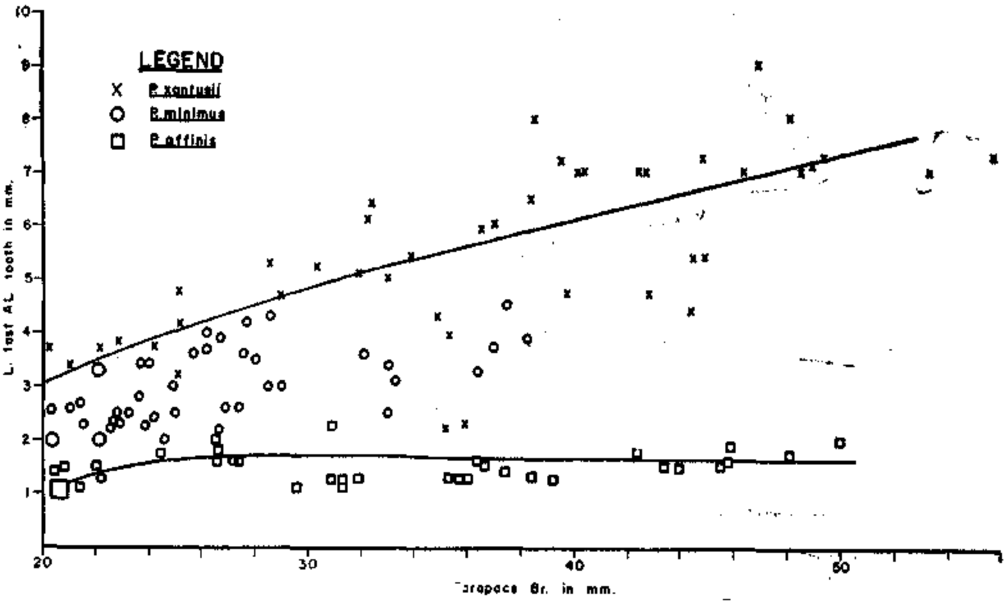

FIG. 6. Length of the last anterolateral tooth against carapace breadth in larger specimens of *P. xantusii*, *P. minimus* and *P. affinis*. "Scatter diagrams with visually smoothed curves for *P. xantusii* and *P. affinis* only. The larger symbols indicate measurements upon five specimens.

plotted in Fig. 8 as frequency distribution diagrams. Combined data give a bimodal curve, with distinct indications of bimodality within *P. xantusii* and indistinct indications within *P. minimus*. In both species there is apparently a smaller group with narrow abdomens, and a larger group with broad abdomens.

(ii) P. affinis *in relation to foregoing species* : Again there are suggestions of clines, with the *a* values linking with the clines for the above species. However the *c* cline diverges considerably.

(2) *Penultimate Segment*

Treatment was as for the ultimate segment, with results in Fig. 9.

(i) P. xantusii *and* P. minimus : Inferences are similar to those above. Deviations from regre sions again gave a bimodal curve, but indications of bimodality within each species were doubtfull detectable.

(i) P. affinis : Data link to those of the foregoing species.

(3) *Relationships between Shapes of Ultimate and Penultimate Segments*

From data upon lengths and breadths of the two segments, numerous relationships could be investigated. First confirmation was sought of a high positive correlation between the lengths of the two segments. The analysis was restricted to *P. xantusii* and *P. minimus*, and for 77 specimens of the former the correlation coefficient was + 0·064, while for 116 specimens of the latter, —0·035. Apparently lengths of the two segments are not closely related,

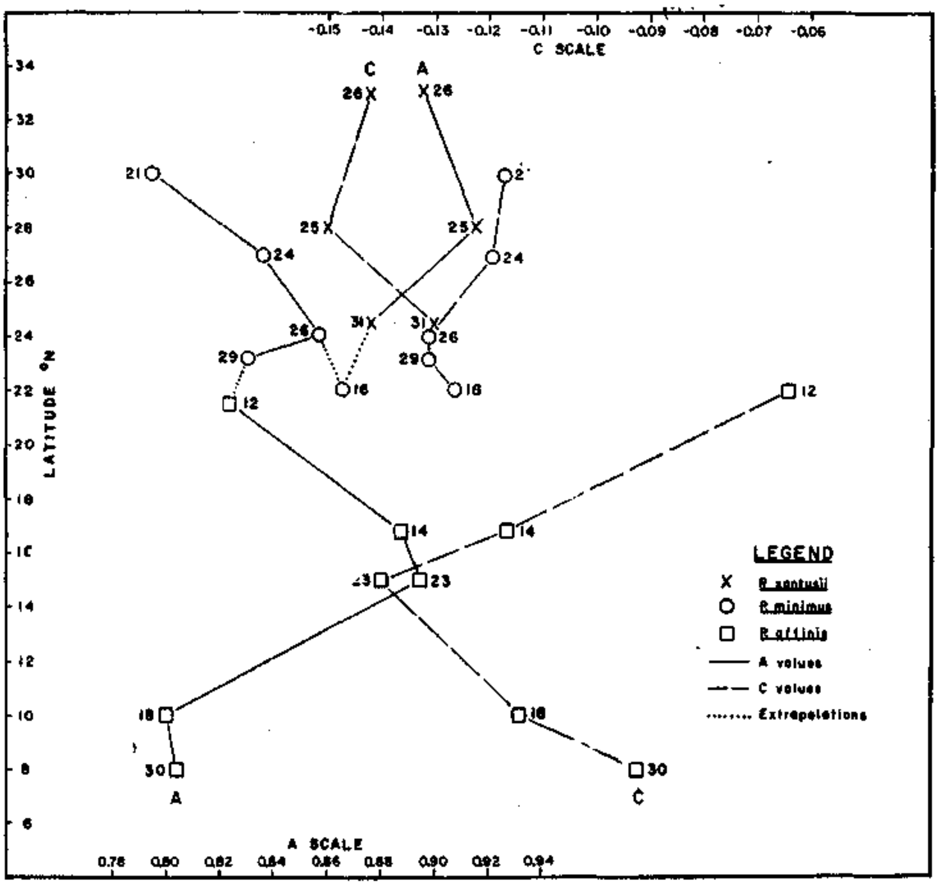

FIG. 7. Values of *a* and *c* in the formula log. breadth ultimate segment of male abdomen = *a* (log. length) +*c* for different latitudinal collections of *P. xantusii, P. minimus,* and *P. affinis.* Numerals adjacent to the plotted points indicate numbers of specimens measured.

(*e*) *Shape of Merus of Fifth Leg*

Lengths and breadths were measured in material from a variety of size ranges and localities, comprising both sexes of *P. xantusii*, of *P. minimus* and of *P. affinis*. In each set of results log./log. plots indicated approximately rectilinear regressions. Data upon males of *P. xantusii* and *P. minimus* appeared completely to intergrade, as did data upon females, but the two sexes appeared to differ. Values for *a* and *c* in the formula log B = *a* log L + *c* were as follows:

Males *P. xantusii* + *P. minimus*	$a = 1 \cdot 0544$,	$c = -0 \cdot 2042$ ($n = 36$)
Males *P. affinis*	$a = 1 \cdot 1961$,	$c = -0 \cdot 2266$ ($n = 39$)
All males	$a = 1 \cdot 1065$,	$c = -0 \cdot 2032$ ($n = 75$)
Females *P. xantusii*+*P. minimus*	$a = 1 \cdot 1153$,	$c = -0 \cdot 2242$ ($n = 43$)
Females *P. affinis*	$a = 1 \cdot 1941$,	$c = -0 \cdot 2106$ ($n = 38$)
All females	$a = 1 \cdot 1043$,	$c = -0 \cdot 1926$ ($n = 81$)

Individual deviations from the combined male data and combined female data respectively, were computed. These gave a bimodal frequency distribution curve but with overlap covering about 50% of the material (*see* Fig. 10). A *t*-test of significance showed 90% probability that the groups were separate.

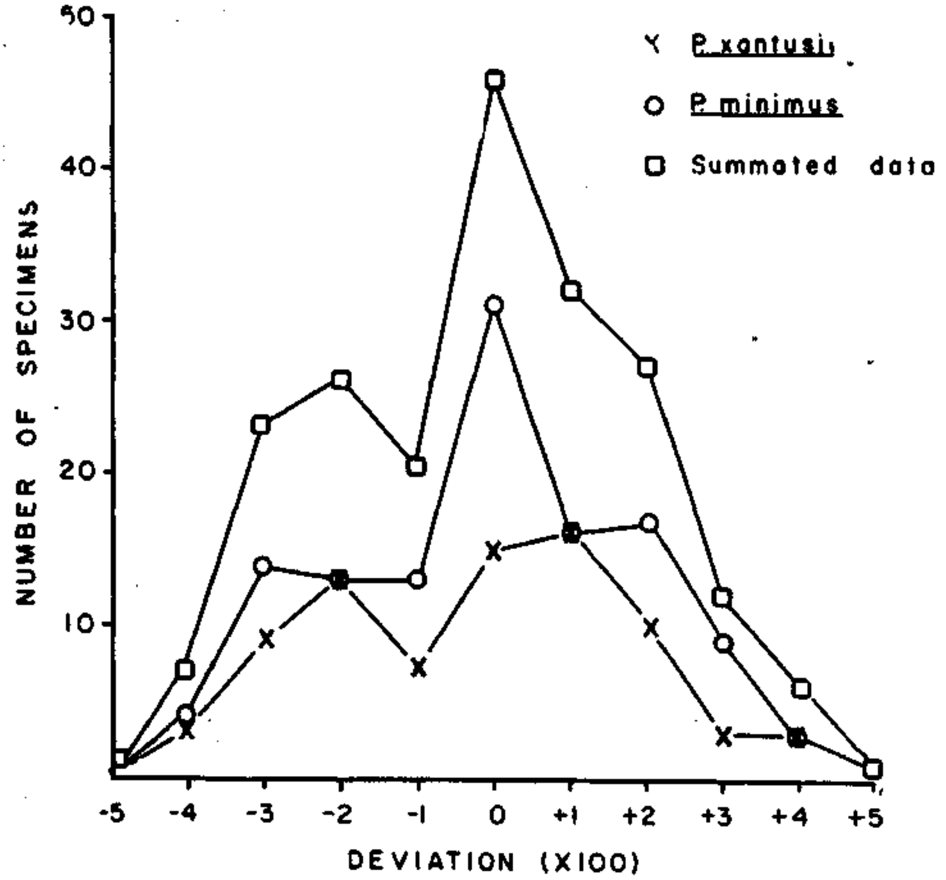

FIG. 8. Frequency distributions of deviations from the different latitudinal regression lines relating log. breadth and log. length of ultimate segment of male abdomen.

Specimens from Isabel Island ('Velero' Sta. No. 277-36) which lies in the region of distributional overlap of *P. minimus* and *P. affinis*, were then measured. Deviations from the above regressions showed wide and continuous variation from one extreme to another.

3. CONCLUSIONS

(*a*) *P. pichilinquei* is a synonym of *P. minimus*. While most species of *Portunus* can be diagnosed by the relative width of the carapace and length of last anterolateral tooth, these are variable features in the present instances. There is completely continuous variation from one facies to another within the collections from the Gulf of California.

(*b*) The "*pichilinquei*" form of *P. minimus* shows a similar intergradation with *P. xantusii*, the three nominal species being linked by complex clines.

(*c*) *P. affinis* appears inseparable from the "*minimus*" form of *P. minimus* on most features previously supposed to be of diagnostic value. Morphometrical study did not lead to any firmer conclusion than general examination in which it was felt that in some almost indefinable way the forms might be separate. While in most measured features clines link *P. affinis* to *P. minimus* there are three possible exceptions:—

(1) in arithmetic analyses of lengths of last anterolateral teeth in relation to carapace breadth, in medium and small-sized specimens the *c* values of *P. affinis* at the north of its range differed from the southern material and from the remainder of the complex. On this basis, *P. affinis* would include material from Isabel Island which in other respects resembled the rest of the complex;

(2) in logarithmic analyses of lengths and breadths of the ultimate segment of the male abdomen, *c* values of *P. affinis* at the north of its range differed from southern material and the rest of the complex;

(3) logarithmic analyses showed that the merus of the fifth leg upon "randomly selected" *P. affinis* is broader than in the remainder of the complex, at a 90% probability level. The Isabel Island material was very heterogeneous in this respect.

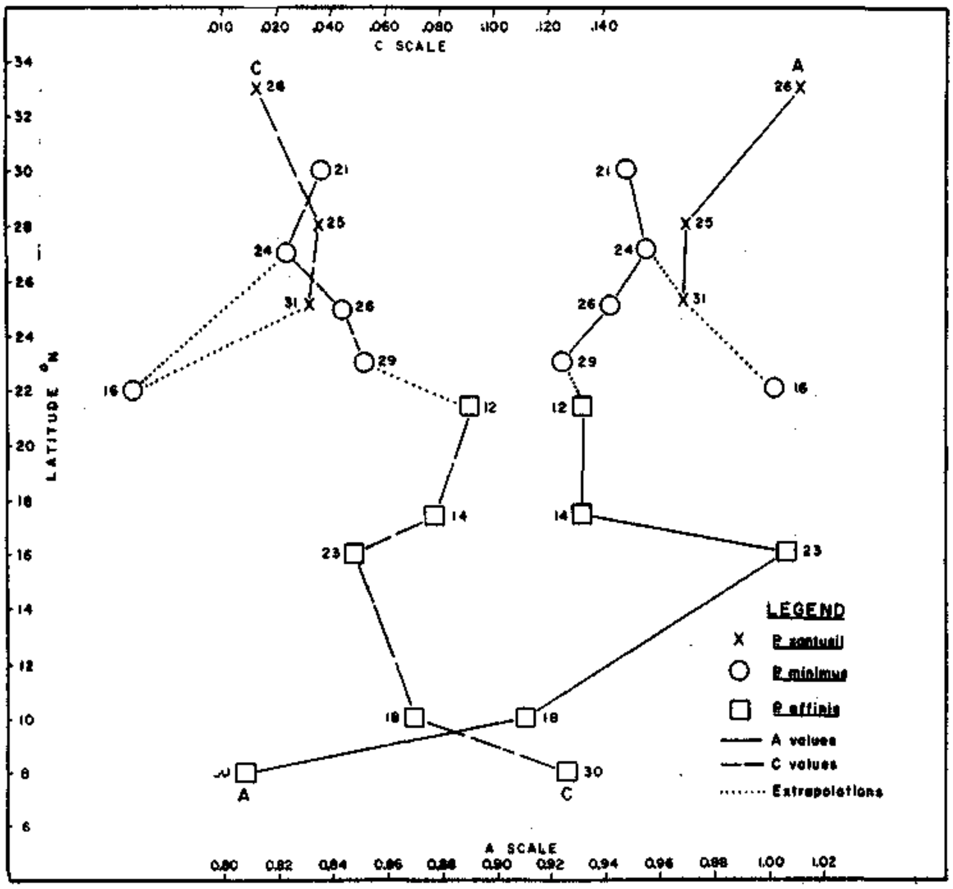

FIG. 9. Values of *a* and *c* in the formula log. breadth penultimate segment of male abdomen = *a* (log. length) + *c* for different latitudinal collections of *P. xantusii*, *P. minimus* and *P. affinis*. Numerals adjacent to the plotted points indicate numbers of specimens measured.

In the unmeasured features a possibility remains of separation by the more convex carapace of *P. affinis*, and there are further possibilities, as yet not examined, in the colouration and behaviour of living material. Until an abundance of live material collected between the latitudes of 21° and 24° N. has been examined, it seems desirable to keep *P. affinis* separate, but only at the subspecific level.

IV. THE *P. ACUMINATUS* COMPLEX

1. TAXONOMIC DISCUSSION

(*a*) *Past Descriptions*

Rathbun (1930, p. 53) recognised that the three species in this complex presented problems and stated that they have so much in common and vary so much within a species that it is difficult to determine whether they are forms of a single species or three distinct species.

Meanwhile Garth (1940, pp. 73–76) has shown that Rathbun's *P. acuminatus* does not belong to *Achelus acuminatus* Stimpson, but probably to *P. asper*. Garth selected a neotype and redescribed Stimpson's species. He considered the three forms as having equal and specific rank, and diagnosed them (p. 76) as follows:—

"(1) *P. asper:* Anterolateral arc broad, teeth showing little reduction; lateral spine equal to width of 4 or 5 adjacent teeth; cheliped heavy, 2½ times carapace length.

(2) *P. panamensis:* Anterolateral arc narrow (*Achelous*-like), teeth 2, 4 and 6 showing reduction; lateral spine equal to width of 2½–3 adjacent teeth; cheliped heavy, 3 times carapace length in male, 2½ in female.

(3) *P. acuminatus :* Anterolateral arc broader than *panamensis* though not as broad as in *asper*, teeth 2, 4 and 6 showing reduction; lateral spine equal to width of 6 or 7 adjacent teeth; cheliped fragile, length 3–3½ times carapace in male, height of manus 1/6 or 1/7 times length of chela."

(*b*) P. acuminatus *and* P. asper

(For figures *see* Garth, 1940, pl. 19; and Rathbun, 1930, pl. 20, figs. 2, 3, pl. 21, pl. 22, figs. 1, 2)

Examination of nearly 250 specimens from the Hancock Foundation collections, which include the neotype, left no doubt that *P. acuminatus* is distinctly separate from the remainder. It can be recognised immediately by "the extreme fragility of the carpus and manus (of the cheliped)" (Garth, 1940, p. 75). Large specimens can also be recognised by the "extreme attenuation of the lateral spine" (Garth, 1940, p. 75). In adult males the species are also distinguished by the first male pleopods, which are sinuously curved in *P. acuminatus* but smoothly curved in *P. asper*. However small specimens are most difficult to separate and sole reliance has to be placed upon cheliped fragility.

(*c*) P. asper *and* P. panamensis

(For figures *see* Rathbun, 1930, pl. 20, figs. 2, 3; pl. 21, pl. 22, figs. 1, 2; and pl. 20, fig. 1, pl. 22, fig. 3, pls. 23, 24)

Over 1,200 specimens in the Hancock collections were examined and of these the larger specimens (apart from three which the author felt incapable of assigining firmly to either species) all fit the description of *P. asper*. The smaller specimens are predominantly *P. panamensis*, but amongst them were many intermediates. In specimens from the Smithsonian Museum collections, which were predominantly medium-sized, about half appeared to be intergrades.

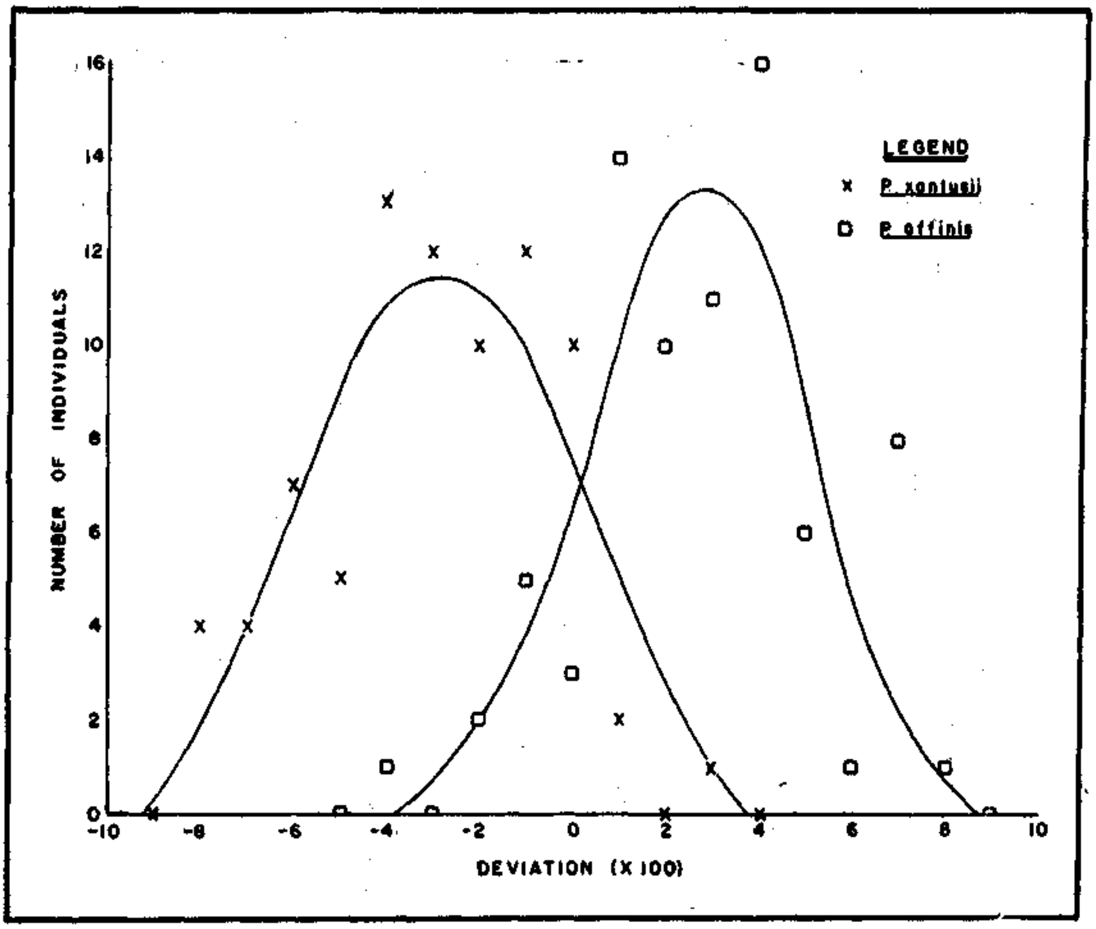

FIG. 10. Deviations from regression of log. B against log. L of merus of fifth leg for *P. xantusii* and *P. affinis*

Examination of *P. asper* and *P. panamensis* followed study of the *P. xantusii* complex, and was influenced by the conclusions obtained. Thus little reliance was placed upon such potentially variable features as relative breadth of anterolateral arc—in smaller specimens it would certainly be narrower than in larger (*e.g.*, *P. panamensis* cf. *P. asper*). The last anterolateral tooth can also be expected to be shorter in smaller specimens. The degree of reduction of anterolateral spines 2, 4 and 6 is also greater in smaller specimens.

In these respects, and also as regards relative length of the chelipeds, no firm line of demarkation could be found. No other features of diagnostic importance could be discovered and Rathbun's doubts whether these two species at last were forms of a single species appeared to be well founded.

Uncertainty regarding intergradation appeared strongest in the case of relative length of the last anterolateral teeth. The validity of separating the species appeared to depend upon this feature, which was analysed biometrically.

2. Morphometric Analysis

(*a*) *Length of Last Anterolateral Tooth in* P. asper *and* P. panamensis

Measurements of length of tooth and carapace breadth were made upon males and females, using specimens previously identified to species level and others unidentified beyond the level of the complex. Arithmetic and logarithmic plots showed that the relationships of the variables over the entire range of data are complex, and data were treated as follows:—

(i) arithmetic data were plotted and curves smoothed visually (Figs. 11 and 12);

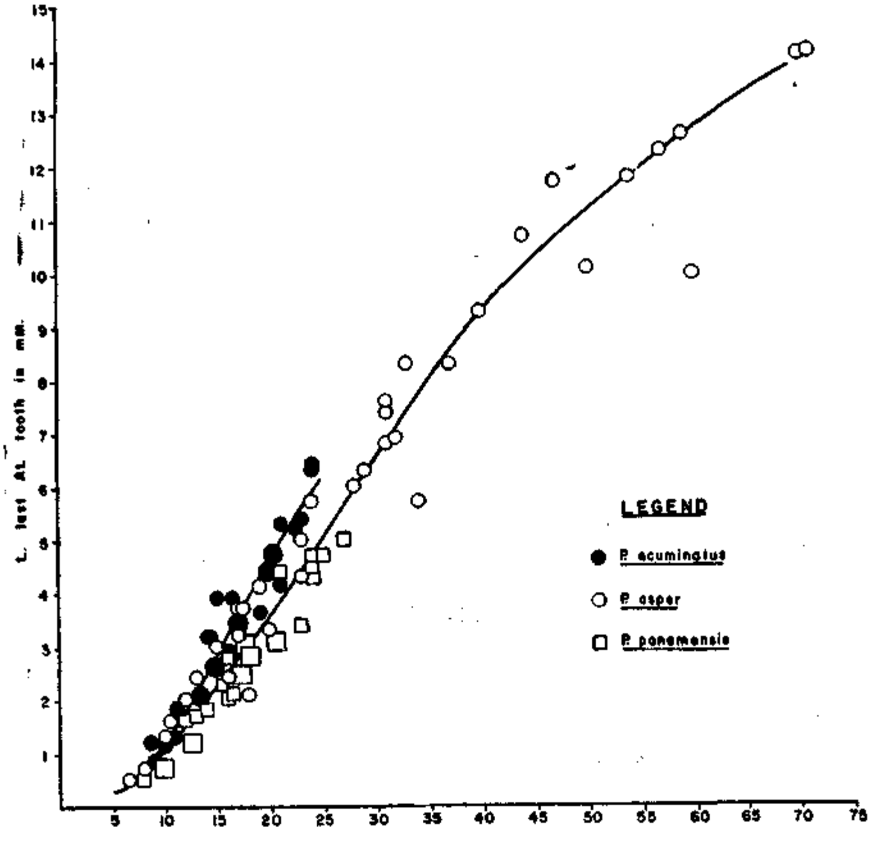

Fig. 11. Length of the last anterolateral tooth against carapace breadth in males, of *P. acuminatus*, *P. asper* and *P. panamensis*. Larger symbols indicate measurements upon five specimens. Curves smoothed visually, with a single curve for data upon *P. asper* plus *P. panamensis*.

(ii) deviations of each point from the curve were obtained graphically.

(iii) each was expressed as a percentage of the "tendency" value as indicated by the level of the smoothed curve at that point;

(iv) these percentage deviations were plotted as frequency distribution diagrams for each sex (Figs. 13 *a*, and 13 *b*) and examined for bimodality. None was apparent. It is concluded *P. panamensis* is a synonym of *P. asper*.

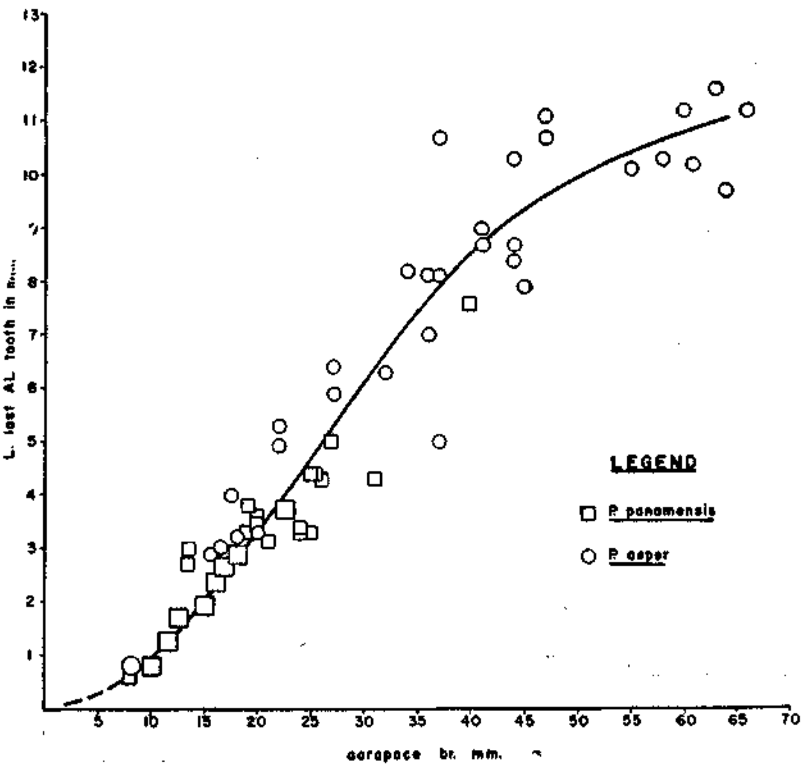

FIG. 12. Length of the last anterolateral tooth against carapace breadth in female of *P. asper* and *P. panamensis*. Larger symbols indicate measurements upon five specimens. Curve smoothed visually.

(*b*) *Length of Last Anterolateral Tooth in* P. acuminatus *and P.* asper

Measurements upon males of *P. acuminatus* are also shown on Figure 11. The visually smoothed curve diverges from that for *P. asper*, and by inspection one would expect distinctions to be possible with a slight margin of error at carapace widths of over 20 mm., very doubtful for those of 15–20 mm. breadth, and impossible for specimens narrower than 15 mm.

Over the range 10–35 mm. carapace breadths, the smoothed curves of arithmetic data for both species approximate to straight lines. Their formulae are:—

P. acuminatus .. $L = 0{\cdot}3357\,B - 2{\cdot}2133$ $(n = 52)$

P. asper .. $L = 0{\cdot}2483\,B - 1{\cdot}3739$ $(n = 75)$

A *t*-test on the regression coefficiens showed the difference was not significant even at the 0·90 level.

3. CONCLUSIONS

(*a*) *P. panamensis* is a synonym of *P. asper*. There had been a past tendency to refer to *P. panamensis* firstly small specimens and secondly specimens with relatively short anterolateral teeth.

(*b*) *P. acuminatus* is distinct from *P. asper* as regards the form of its chelipeds and first male pleopods. Consideration of last anterolateral teeth, in isolation from other structures, only gives a 70% probability that the species are distinct and separation of small specimens by this feature alone is virtually impossible.

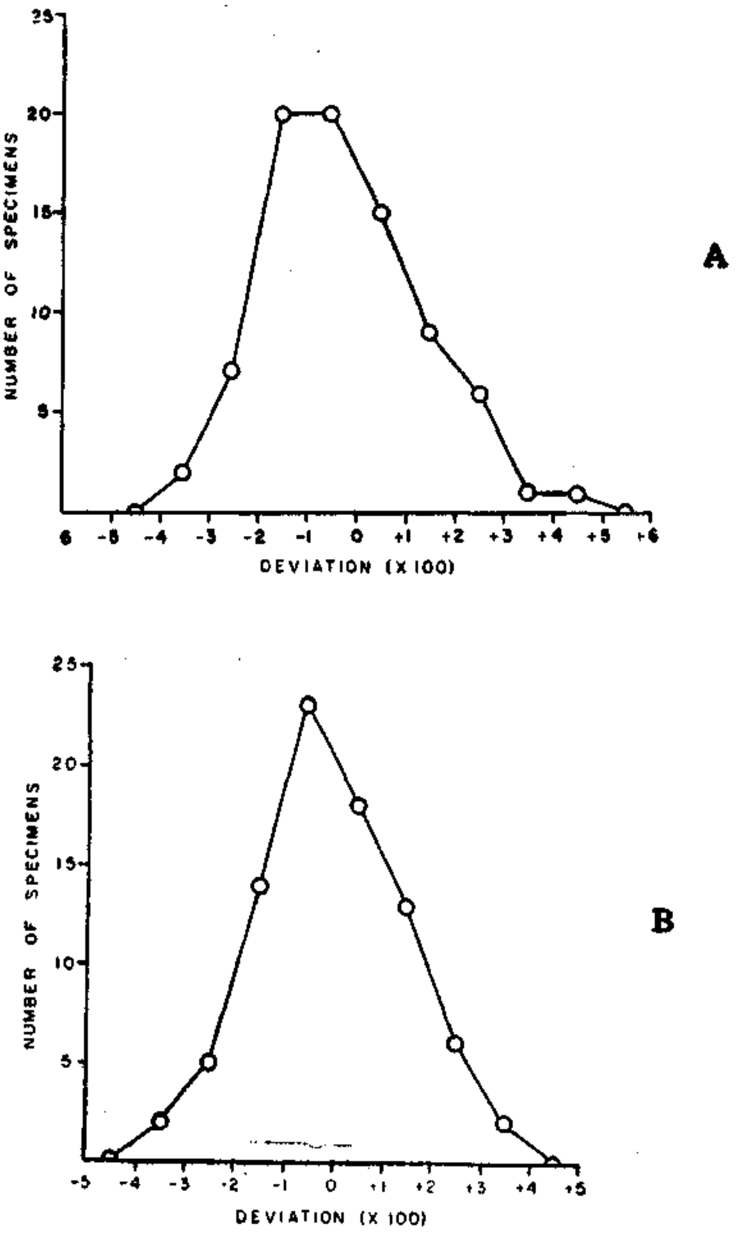

FIG. 13. Frequency distribution of deviations from visually smoothed curve relating length of last anterolateral tooth to carapace breadth in *P. asper* plus *p. panamensis*. Fig. 13 *a*—males; Fig. 13 *b*—females.

V. DISCUSSION

Western American species of the genus *Portunus* include the most difficult species of this difficult genus so far encountered by the author (Stephenson and Campbell, 1959; Stephenson, 1961; Stephenson and Rees in MS). Whereas in most cases of species comparisons a few diagnostic differences can be supported by a multiplicity of less obvious and less definable differences, in the present group some species can only be distinguished by of the order of 3–5 features. The problems are made more difficult because some features of expected constancy vary widely in Western American species, for example relative breadth of carapace and relative length of last anterolateral teeth. Because of variation of this nature, *P. panamensis* must be regarded as a synonym of *P. asper* which closely approaches, but is still separate from *P. acuminatus*.

Study of the *P. xantusii* complex showed intergradations which follow a clinar pattern. *P. pichilinquei* is clearly a synonym of *P. minimus*, which in turn appears to be a synonym of *P. xantusii*. *P. minimus* had been placed in the subgenus *Achelous*, and *P. xantusii* in the subgenus *Portunus*. If these species are not separable at the specific level, and very doubtfully at even subspecific level, they cannot be placed in two different subgenera. The only justification would be the knowledge that a ‘ good ’ character was breaking down in a limited part of the group, as happens in some portunids at generic level (*see* Stephenson and Hudson, 1957, p. 371; for other examples *see* Michener, 1963). This does not apply in the present case, and the use of subgeneric names throughout the whole of the genus *Portunus* is best avoided at the present stage (Stephenson and Campbell, 1959, p. 88).

The fact that members of the complex were previousy described as nominal species is because extensive collections had not been examined, and the possibility of intraspecific clinal variation had not been considered. In analysing such variation a basic conflict arises between the taxonomic and statistical approaches. In the former species should not be synonymised until they are proven identical; in the latter where there is no demonstrably significant difference between groups these ought to be fused. A somewhat intermediate course is here taken.

Throughout the morphometric analyses of this complex, differences between groups (*i.e.*, locality groups and subspecific groups) were more evident in smaller specimens, and intergroup distinctions tended to disappear in larger specimens. This is the reverse of what happens in most animal groups, and for this phenomenon the term “ growth homeostasis ” is used; it implies essentially the same as “ developmental homeostasis ” (Waddington, 1957 and earlier papers; Mayr, 1963, pp. 220, 263–96). An alternative explanation is that there is incipient or actual speciation in the younger stages (*see* de Beer, 1958, pp. 45–51). Until this possibility has been investigated at the larval levels it seems desirable to “ lump ’ species cautiously as suggested above.

During the morphometric analysis it soon became apparent that ratios of lengths of parts could not be used effectively for comparative purposes, because they varied with size of the specimens. Within the *P. xantusii* complex, in which most of the work was done, several pairs of measurements could be related in a simple fashion by formulae of the type:—

$$\log_{10} \text{length} = a \log_{10} \text{breadth} + c.$$

This applied to lengths and breadths of carapace, and to lengths and breadths of both ultimate and penultimate segments of the male abdomen. A relationship of this type might be expected on the basis of allometric growth (*see* Teissier, 1948; Simpson, Roe and Lewontin, 1960, pp. 406–15). No doubt the descriptions of many decapod crustacea could be improved by replacing ratios by log./log. regressions.

However the relationships between two of the variables are of a much more complex nature, *i.e.*, between lengths of last anterolateral teeth and carapace breadths. Consideration of data within both complexes (Figs. 3, 11, 12) suggested that they could be expressed by a common family of curves, but if so these constituted complex second order regressions. There are two ways to handle data of this type. The first, which has been pioneered in the field of ichthyology by Parr (1960), is to determine the equations which best fit the data, however complex they eventually become. This method would stand little chance of present acceptance into general carcinological practice. The second method is to plot simple functions of the variables, to divide the curves into intervals between " growth inflections " and to apply linear functions to each growth " stanza ". Teissier (1948) has used a succession of log./log. functions with the crustacean *Maia squinado*, Ebeling (1962) a succession of ratios to the bathypelagic fish genus *Melamphes*, and Ahlstrom and Counts (1958) a succession of simple linear regressions of arithmetic data in the fish *Vinciguerria lucetia*. In the present work log./log. regressions have largely been used and arithmetic regressions occasionally. In some cases deductions were made, in effect, by inspection of arithmetic plottings.

Study of the ultimate segment of the male abdomen by means of deviations from log./log. regressions showed that in both *P. xantusii* and *P. minimus* there is a smaller group of specimens with a narrow segment, and a larger group with a broad segment. This is an example of male dimorphism which is more obviously exemplified in some of the Indo-West-Pacific portunids where it is described by Stephenson and Rees (MS). It is either a case of balanced dimorphism or alternatively of incipient speciation. If the latter, it is not following the lines of the nominal species, but running across them.

Analyses of lengths and breadths of penultimate and ultimate segments of the male abdomen in *P. xantusii* and *P. minimus* led to an unexpected conclusion. There is negligible correlation between greater or less length in one segment and greater or less (respectively) in the other. Where distinctions between male abdomens in portunid species are slight, it is wisest to consider the two segments as completely independent entities.

Finally the suggested status to be given to the members of the two complexes are:—

P. xantusii becomes *P. xantusii xantusii.*

P. pichilinquei becomes *P. xantusii minimus.*

P. minimus becomes *P. xantusii minimus.*

P. affinis becomes *P. xantusii affinis.*

P. acuminatus remains unchanged.

P. asper remains unchanged. And

P. panamensis becomes *P. asper.*

VI. ACKNOWLEDGEMENTS

Thanks are due to Drs. J. S. Garth, F. J. Little and J. C. Yaldwyn for helpful comments and to the National Science Foundation whose Fellowship made the work possible. Dr. A. W. Ebeling gave invaluable assistance in detailed discussions of an early draft.

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APPENDIX

I. Computations required in relationship $y = ax + c$

n = number of specimens measured.

Σx = algebraic sum of x values.

$\bar{x}$ = mean value of x.

Σy = algebraic sum of y values.

$\bar{y}$ = mean value of y.

Σx^2 = squares of x values, summed.

Σy^2 = squares of y values, summed (only required for tests of significance).

Σxy = products of x and y values, summed.

$(\Sigma x)^2$ = square of algebraic sum of x values.

$(\Sigma y)^2$ = square of algebraic sum of y values (only required for tests of significance).

$\Sigma x \, \Sigma y$ = product of sum of x values times sum of y values.

The following derivations are conveniently computed separately:—

$n \, \Sigma x^2 - (\Sigma x)^2$.

$n \, \Sigma xy - (\Sigma x)(\Sigma y)$.

$n \, \Sigma y^2 - (\Sigma y)^2$ (only required for tests of significance).

Then,

$$\mathrm{A} = \frac{n \, \Sigma xy - (\Sigma x)(\Sigma y)}{n \, \Sigma x^2 - (\Sigma x)^2}.$$

$$\mathrm{C} = \bar{y} - a\bar{x}.$$

II. Computations to determine Individual Deviations of y *from Curve* y = ax + c.

For a given value of x, determine y from above formula; *i.e.*, y calculated. Then deviation is y as measured less y calculated.

III. Determination of Correlation Coefficient of Deviations from Two Regression Curves (From Lacey, 1953, pp. 155 *et. seq.*)

(*a*) Compute individual deviations as in II above giving two series of values, *e.g.*, u values for ultimate segment and p values for penultimate segment.

(*b*) For each pair compute product (up) and squares (u^2 and p^2).

(*c*) Sum each of these, *i.e.*, $\Sigma\, up$, $\Sigma\, u^2$, $\Sigma\, p^2$ respectively.

(*d*) Correlation coefficient $r = \dfrac{\Sigma up}{\sqrt{(\Sigma u^2)(\Sigma p^2)}}$.

IV. t-test of significance of differences in regression coefficients (derived from Stimpson, Roe and Lewontin, 1960, p. 229)

$$t = \frac{(a_1 - a_2)\sqrt{\dfrac{\left(\dfrac{n_1\Sigma x_1{}^2 + (\Sigma x_1)^2}{n_1}\right)\left(\dfrac{n_2\Sigma x_2{}^2 + (\Sigma x_2)^2}{n_2}\right)}{\left(\dfrac{n\Sigma x_1{}^2 + (\Sigma x_1)^2}{n_1}\right) + \left(\dfrac{n_2\Sigma x^2 + (\Sigma x_2)^2}{n_2}\right)}}}{\sqrt{\dfrac{\dfrac{n_1\Sigma y_1{}^2 + (\Sigma y_1)^2 - a_1{}^2\left(n_1\Sigma x_1{}^2 + (\Sigma x_1)^2\right)}{n_1} + \dfrac{n^2\Sigma y_2{}^2 - (\Sigma y_2)^2 - a_2{}^2\left(n_2\Sigma x_2{}^2 - (\Sigma x_2)^2\right)}{n_2}}{n_1 + n_2 - 4}}}.$$

where the symbols are those used previously.

Apply t-test with $n_1 + n_2 - 4$ degrees of freedom.

ÜBER PHYLOGENETISCHE EIGENSCHAFTEN VON *BALANUS IMPROVISUS* DARWIN

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Ich habe zusammen 5000 Exemplaren gesamt mit rezenten und fossilen *Balanus improvisus* Darwin studiert. Ich konnte fest-stellen, dass die fossilen Exemplaren fast vollkommen nur auf *Ostraea* angeheftet waren—die rezenten hatten dagegen sehr verschiedene Anheftungsoberflächen.

Balanus improvisus Darwin ist zur Zeit eine euryhalyne Art—ob sie in Miozänzeiten auch ebenfalls eine euryhalyne war, kann ich bezweifeln, da ich fand sie als fossile nur mit *Ostraea* in Assoziation.

Mein Material stammt von Tortonien d.USSR (Ukraine, Suskovci); Burdigalien d.USSR (Karakum, Turkmenistan); Aquitanien v.Ungarn (Bükk, Pannonien); Nord-Meere (Deutschland); Baltisches Meer (Poland); Schwarzes Meer (Asowische See, Romanien, Bulgarien); Kaspisches Meer (USSR).

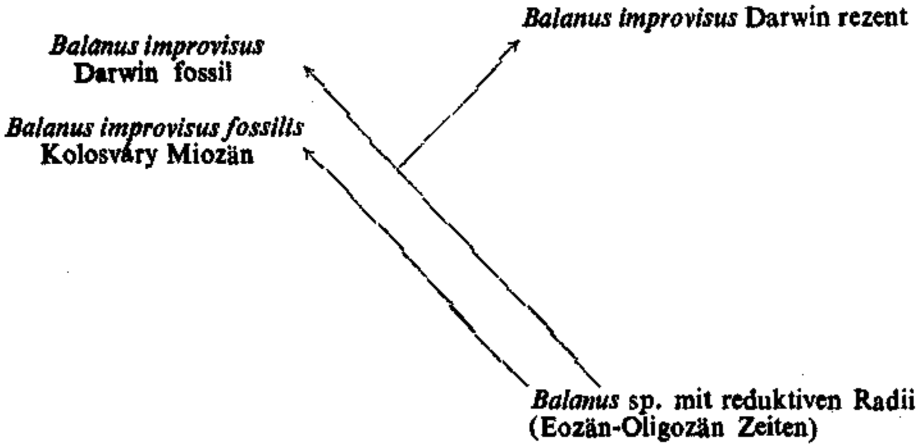
Die Populations-Variabilität der Art ist sehr konstant. Unterarten gibt es nicht. Eine Stenohalynie in Miozänzeiten ist wahrscheinlich.—In der Nachpliozänzeiten tritt eine Elastizität auf und die Art wird euryhalyn sein ohne ihre grundsätzliche Morphologie aufzugeben.—Die Verbreitung im Weltmeere wird schon als eine progressive Erscheinung aufzufassen, só dass eine euryhalyne Anpassung zu eine Weltubiquismus führte.—Eine alte Regression hat die Art in eine besondere Rudimentation der Radii bewahrt.

Also eine Tabellarische Zuzammenstellung der phylogenetischen Eigenschaften der art ist wie folgt:

Konservative Eigenschaften	Elastische Eigenschaften	Progressive Eigenschaften	Regressive Eigenschaften
Variabilität Klein und Konstant. Stenohalynie in Miozän.	Euryhalyne Einpassungen	Ubiquistische Verbreitung	Regression der Radii und eine Dünnheit der Mauerkrone

Es ist interessant zu erwähnen, dass "ein auffallender Unterschied zwischen fossilen und rezenten Formen ist die Färbung der Mauerkrone. Die rezenten sind im allgemeinen eintönig gelbweiss, die fossilen" bei Budafok-Promontor in Ungarn zeigen aber eine lila Färbung mit einem weissen Querstreif überhaupt. Es ist also wahrscheinlich, dass eine Färbungreduktion auch zu der Kategorie "Regressive Eigenschaften" zugehört.(S.lit.: "Über tertiäre Balaniden Ungarns" von G. Kolosváry, ersch. in: *Paleont Zeitschr.* 23.1/2. p. 203–205, 1942.)

STAMMBAUM


Balanus improvisus Darwin rezent
Balanus improvisus Darwin fossil
Balanus improvisus fossilis Kolosváry Miozän
Balanus sp. mit reduktiven Radii (Eozän-Oligozän Zeiten)

ÜBER BIOKIBERNETISCHE CHARAKTERISTIKEN IN DER PHYLOGENESE DER CIRRIPEDIER

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Es nimmt man im allgemeinen an,dass die Entwicklung der Cirripedier von der Protostraken ausgegangen geworden war. L. chitinosa, Brachilepadomorphen, Acrothoracica, Rhizocephala und Ascothoracica sind Seitenäste der Cirripedier, der Hauptast ist Thoracica. Von hierher entwickelten sich Verrucomorphen, Lepadomorphen und Balanomorphen.

Eine Kontrollvergleichung nach meiner Meinungen kann folgenderweise rechtfertigen zu können auf Grund des ökologischen Freilebens, Synoekose und Parasitismus der Cirripedier.

Eine ursprüngliche, einpassungsartige und progressive Thoracica sind diejenige, die freilebend und synoekotisch sind. Regressive sind diejenige, die bohren, einen engeren synoekotischen Verbindung aufzeigen mit Monostomaten und Echinodermen, sowie dann die parasitisch sind.

Eine kleine tabellarische Zusammenstellung ist wie folgt:

Wirtstiere	Alte Lebensweise	Adaptationen oder Einpassungen	Progressiven	Regressiven
Vertebrata			Thoracica	
Evertebrata deuterostomier		Thoracica		Asco-und Acrothoracica
Evertebrata protostomier		Thoracica		Asco-und Acrothoracica und Rhizocephala
	Thoracica und Acrothoracica freilebend			

Die folgende Serie zeigt einen biokibernetischen d.h. regulierten System zwischen Wirtstiere und synoekotische Tiere wie folgt:

Wirtstiere	Urtypen	Adaptiven Typen	Progressive Typen	Regressiven
Teleostei Lepidosteus	Platylepas			
Ophiurae Lapemis und Distria	Platylepas			
Mammalia Manati	Platylepas	Chelonibia		
Testudinaria Thalassochelys und Chelone	Platylepas	Chelonibia	Stephanolepas, Cylindrolepas, Stomatolepas	
Mammalia Cetacea			Coronula (Conchoderma), Cryptolepas, Tubicinella, Xenobalanus	
Aves Branta leucopsis				Lepadidae Lepas anatifera

Die Vertebraten, die mit Cirripedier in Synoekose leben, geben einen speziellen, regulativen d.h. biokibernetischen Signifikation in die Phylogenese der Cirripedier überhaupt, so, dass es mit den Formel.

Cetacea × Coronula × Conchoderma

Trio aufzufassen ist.

Die allgemein bekannte phylogenetische Grundprinzipien der Cirripedier werden unter Kontroll der Vergleichung des Freilebens, Synoekose und Parasitismus untersucht. Freileben ist die ursprüngliche Lebensweise; die Synoekose ist die elastische Lebenserscheinung und Progression die höchste Formel dieses Lebensweise. Als Regression kann die bohrende, sowie die parasitische Lebensweise aufzufassen.

Für eine gerichtete Progression sind die Vertebraten als Wirtstiere eigen; für Elastizismus sind die Evertebraten als Wirtstiere eigen und freilebend sind nur alten Thoracica und Acrothoracica bekannt geworden.

Eine biokibernetische Regulierung und Richtungsgabe spiegelt sich innerhalb der Vertebraten auch in die Teleostei-Ophiurae-Testudinaria-Cetacea-Aves Serie wider, d.h. das bedeutet eine Serie für Gasttiere: Platylepas-Chelonibia-Coronula-Lepadida—im allgemeinen.

Als akmischer zustand werde das Trio Cetacea × Coronula × Conchoderma Regulation für ein Beispiel zur Biokibernetik der Cirripedier aufzufassen.

NEUE ANGABEN ZUR WELTVERBREITUNG EINIGER CIRRIPEDIER

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Taxonomisches

1. *Balanomorpha*

Acasta spongites (Poli) Gower Glamorgoshire coll. T. Moyse, 1960.

Armatobalanus (*Balanus*) *dolosus* (Darwin) Suffolk England Pleistozän coll. Collins; Beggard Hollow England Pliozän, coll. Collins.

Armatobalanus (*Balanus*) *inclusus* (Darwin) Sutton England Pliozän coll. Collins.

Balanus amphitrite amphitrite Darwin Tunis S. Plage de la Pondriére coll. B. Bedö; Split-Dalmatien 1960 coll. A. Horváth; Aral-See W. Helvetien coll. 1962 L. V. Mironova; Mittelmeer coll. L. Körmendy; Schiffsbewuchses des Schiffes "Hazám" (Ungarn) coll. 1965 Kolosváry & Vida & Csizmazia; Turkmenistan Karakum Burdigalien USSR 1959 coll. Merklin.

Balanus amphitrite albicostatus Pilsbry Turkmenistan Karakum Burdigalien 1959 coll. Merklin.

Balanus amphitrite formosanus Hiro Turkmenistan Karakum Burdigalien 1959 coll. Merklin.

Balanus amphitrite helenae Kolosváry Turkmenistan Karakum Burdigalien coll. 1959 Marklin.

Balanus amphitrite inexpectatus Pilsbry Florida, Caloosahotchee Ufer USA.

Balanus amphitrite karakumiensis Kolosváry Turkmenistan Karakum Burdigalien 1959 coll. Merklin.

Balanus amphitrite merklini Kolosváry Turkmenistan Karakum Burdigalien 1959 coll. Merklin.

Balanus amphitrite tongaensis Kolosváry Tongatabu Nukulofa, pazifisches Ozean in Korallsediment.

Balanus balanus (Linné) Uddewalla Schweden; Suffolk England Pleistozän coll. Collins.

Balanus calidus Pilsbry Opanetz Bulgarien Tortonien 1962 coll. Kojumdgiova.

Balanus cariosus (Pallas) Paramuschir Kuril Inseln coll. 1964 Vialov (Endemismus).

Balanus concavus Bronn Budafok Ungarn Burdigalien 1958 coll. T. Báldi; Gyöngyöspata Ungarn Tortonien 1951 coll. F. Legányi; Nekézseny Ungarn untere Miozän 1951 coll. F. Legányi; Abod Ungarn Miozän 1958 coll. A. Jámbor; Dédes-Dezsövölgy Ungarn Helvetien coll. F. Legányi und G. Kolosváry; Cesnjica Jugoslavien Oligozän 1964 coll. R. Pavlovec; Uzbekistan USSR untere Miozän 1959 coll. Merklin; Turkmenistan Karakum Burdigalien USSR coll. Merklin 1959; Florida USA Miozän.

Balanus concavus oligoseptatus Kolosváry Kizil-Kum USSR obere Oligozän coll. 1960, Vialov, *Balanus crenatus* Bruguiére Uddewalla Schweden; Suffolk England Pleistozän coll. Collins; Jassen Bulgarien Tortonien 1962 coll. E. Kojumdgiova; Usz-Urt Plateau mittlere Oligozän USSR coll. 1962, L. V. Mironova; Cosnjica Jugoslavien Oligozän 1964 coll. R. Pavlovec; Weisses Meer Osorov USSR coll. Vialov; Dissewitza Bulgarien Tortonien 1962 coll. Kojumdgiova; Csobánka Ungarn Helvetien 1959 coll. B. Bolkay; Riss-würm interglaziale Schichten in Poland Baltik, 1965, coll. Brodniewicz; Atlantik 1965 coll. Mikulszka.

Balanus dentifer Broch Tongatabu Nukulofa Pazifik in Korallen Sand Sediment.

Balanus eburneus Gould Split Dalmatien 1960 coll. A. Horváth.

Balanus gizellae Kolosváry Tongatabu Nukulofa in Pazifik Korallen-Sand Sediment.

Balanus hameri (Ascanius) Uddewalla Schweden.

Balanus improvisus Darwin Uddewalla Schweden; Schwarzes Meer 1960–61, coll. K. Bába; Turkmenistan Karakum Burdigalein 1959 coll. Merklin; Africa auf Mahagoni-Holz 1963 coll. G Kolosváry jun.; Helgoland 1963 coll. G. Uherkovich; Cesnjica Jugoslavien *Oligozän* 1964 coll. R. Pavlovec; Suskowci Ukraine USSR Tortonien coll. 1962 Vialov; Schwarzes Meer 1956–57, coll. M. Ferencz-Székely, sowie K. Bába und der Expedition der Zoologischen Garten zu Budapest; Usz-Urt Plateau USSR Oligozän coll. L. V. Mironova; aus Schiffsbewuchs von "Hazám" in Hafen Szeged-Tápé coll. 1965, Kolosváry & Vida & Csizmazia; Kolobrzeg Baltikum 1965 coll. Kolosváry-Vida-Csizmazia; Nord Meere 1965 coll. G. Uherkovich.

Balanus laevis fossilis Kolosváry Gyöngyöspata Ungarn, Tortonien 1951 coll. F. Legányi.

Balanus perforatus perforatus Bruguiére Tunis S., Plage de la Pondriére coll. B. Bedö; Bakonygyepes Ungarn Tortonien 1955 coll. F. Legányi; Rovinj Istria Jugoslavia 1937 coll. Kolosváry; Atlantisches Meer 1965 coll. E. Mikulszka.

Balanus polyporus Pilsbry Aral See Kuza Ufer untere Miozän 1959 coll. Merklin; Jackson Bluff Florida USA Miozän.

Balanus provisoricus Kolosváry Turkmenistan Karakum Burdigalien 1959 coll. Merklin.

Balanus rostratus Hoek Kizil-Kos Uszurt Plateau USSR Miozän, 1959 coll. Merklin.

Balanus stellaris Brocchi Asnjica Jugoslavien Oligozän 1964 coll. R. Pavlovec.

Balanus trigonus Darwin Tunis S. Plage de la Pondriére coll. B. Bedö; Tongatabu Nukulofa Pazifik in Korallensand Sediment; Jalmouth coll. J. P. Harding (Von British Museum).

Balanus tuboperforatus Kolosváry Tongatabu Nukulofa im Korallensand Sediment.

Balanus tumorifer Kolosváry Tongatabu Nukulofa im Korallen-Sand Sediment.

Balanus variegatus cirratus Darwin Turkmenistan Karakum Burdigalien 1959 coll. Merklin.

Balanus venustus venustus Darwin Aden coll. 1965, Scartecci.

Balanus venustus niveus Darwin Turkmenistan Karakum Burdigalien 1959 coll. Merklin; Florida USA Caloosachotsche Ufer.

Balanus vialovi Kolosváry Fergana USSR obere Eozän 1962 coll. Vialov und 1961 coll. L. V. Mironova.

Chelonibia testudinaria (Linné) Mittelmeer aus Thalassochelys imbricata.

Chirona (*Balanus*) *unguiformis* (Sowerby) Komanovo Bulgarien Priabonien 1962 coll. E. Kojumdgiova.

Chthamalus stellatus stellatus f. typica Kolosváry Split Dalmatien 1960 coll. A. Horváth; Sardona Adriatisches Meer in Albanien 1960 coll. J. Megyeri; Rovinj-Istria Jugoslavien 1937 coll. G. Kolosváry; Helgoland, 1963 coll. G. Uherkovich.

Conopea (*Balanus*) *stultus morycowae* Kolosváry Kuba Antillen in Millepora sp. 1965 coll. E. Morycowa.

Coronula diadema (Linné) Cape Brett Neu Seeland von "Terra Nova" Expedition gesammelt aus Megaptera nodosa coll. J. P. Harding.

Coronula reginae Darwin South Shetlands coll. J. P. Harding (vom British Museum).

Creusia rangi (Desmoulins) Bivolare Bulgarien Tortonien 1962 coll. E. Kojumdgiova.

Creusia spinulosa Leach—formae inde. Stratopatitza Bulgarien, Opanetz Bulgarien, Bivolare Bulgarien, in Tarbellastraea sp. Korallen alle von E. Kojumdgiova 1962 gesammelt.—Fedémes in Ungarn ebenfalls wie in Bulgarien aus Tortonien coll. 1962 A. Jámbor.

Creusia spinulosa forma *cladangiae* Kolosváry Opanetz Bulgarien, Jassen Bulgarien, Bivolare Bulgarien coll. 1962 E. Kojumdgiova-Tortonien.

Creusia spinulosa forma *kojumdgiovae* Kolosváry Bivolare Bulgarien Tortonien, 1962 coll. E. Kojumdgiova.

Creusia spinulosa forma *praespinulosa* Kolosváry Jassen Bulgarien, Bivolare Bulgarien Tortonien, 1962 coll. E. Kojumdgiova.

Elminius modestus Darwin ohne Fundortsangaben vom J. P. Harding aus dem British Museum im Tausch.

Megabalanus (*Balanus*) *psittacus* (Molina) Süd-Amerika Pazifik; Commodoro Rivadiva Argentina 1962 coll. A. Kovács.

Megabalanus (*Balanus*) *tintinnabulum* (Linné) Adriatisches Meer von d. ungarischen Adria "Najade"-Expedition im 1913–14 Station B.22. aufgesammelt.—Nekézseny Ungarn untere Miozän coll. F. Legányi; Almárvölgy Ungarn Miozän, coll. F. Legányi; Kizil Kum USSR obere Oligozän 1960 coll. Vialov; Cesnjica Jugoslavien Oligozän coll. R. Pavlovec; Csobánka Ungarn Helvetien 1959 coll. B. Bolkay; Jalmouth coll. J. P. Harding (British Museum).

Schréteriella cenomanica Kolosváry Padezelu Mic in Siebenbürgen Cenomanien 1911 coll. Z. Schréter.

Tetraclita cf. *pacifica* Pilsbry Tongatabu Nukulofa in Korallensand Sediment.

Tetraclita squamosa (Bruguiére) mit Hybriden-Eigenschaften rufotincta und stalactifera Rotes Meer Eliath 1961 coll. M. Szlep (Jerusalem); Tunis S. Plage de la Pondriére coll. B. Bedö und einige Exemplaren von J. P. Harding (British Museum).

Verruca strömia (O. F. Müller) Bergen, 1904 coll. G. Entz jun.-Uddewalla Schweden.

2. *Lepadomorpha*

Acroscalpellum sp. indet. Sümeg Ungarn Senonien 1963 coll. L. Czabalay-Benkö.

Acroscalpellum longicostalis Kolosváry Sümeg Ungarn coll. 1963, Senonien, L. Czabalay-Benkö.

Aporolepas reflexa (Sowerby) Wight Inseln England Oligozän coll. Collins.

Calantica sp. indet. (Syn. *Titanolepas* sp. indet.) Sümeg Ungarn Senonien, coll. 1963, L. Czabalay-Benkö.

Conchoderma auritum (Linné) Cape Brett Neu Seeland von d. Exped. "Terra Nova" gesammlet aus Coronula von Megaptera nodosa. Coll. J. P. Harding (British Museum).

Cretiscalpellum sp. indet. I. Armenien USSR, Maesstrichtien coll. V. T. Akopjan, *Cretaiscalpellum* sp. indet.II. Kuztanaj USSR obere Kretazeische Schichten, 1958, coll. V. G. Nikityin.

Cretiscalpellum unguis (Sowerby) Kent England Gault-Albien coll. Collins.

Virgiscalpellum cf. *darwinianum* (Bosquet) Sümeg Ungarn Senonien 1963, coll. L. Czabalay-Benkö.

KLASSIFIKATIONEN

Es wurde möglich einige Arten phylogenetisch zu klassifizieren nach ihren phylogenetischen Eigenschaften wie folgt:

Immobile Arten	Variabile und mobile Arten	Arten mit vielen ssp. und excell. Tubes	Regressive Arten
B. cariosus, dentifer, hameri, improvisus ; C. reginae, diadema, C. testudinaria ; E. modestus ; M. psittacus ; V. strömia ; T. pacifica.	*A. spongites ; B. eburneus, balanus, crenatus, perforatus, trigonus ; M. tintinnabulum ; T. squamosa.*	*B. gizellae, amphitrite, tuboperfor ; C. stultus, spinulosa, stellatus.*	*Alle ausgestorbene* Arten

NOTE SUR LA TAXONOMIE ET LA DISTRIBUTION GEOGRAPHIQUE DES HAPALOCARCINIDAE (DECAPODA-BRACHYURA)

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Abstract

The description of 3 new genera, 4 subgenera and 16 new species by Fize *et* Serène (1957) has given a new extension to the family of Hapalocarcinidae. As a result, the actual taxonomy seems to need a general revision. A partial revision, limited to the genus *Troglocarcinus*, is presented in the paper. The actual data on the geographical distribution of the genera and species are recorded and completed.

Cette note présente une modification partielle de l'actuelle classification des Hapalocarcinidae et des remarques sur la répartition géographique des espèces.

Fize et Serène (1957) décrivent et figurent 22 des 25 espèces indo-pacifiques, dont 16 nouvelles qu'ils ajoutent aux 6 antérieurement décrites. Serène (1962) étudie 2 des 3 espèces non examinées par ces auteurs. J'ai récolté depuis deux nouvelles espèces à décrire, qui s'ajoutent aux deux nouvelles non décrites mais signalées dans le journal des récoltes de Fize et Serène (1957, page 173). L'extention donnée à la famille par la description de nombreuses formes nouvelles fait souhaiter comme Fize et Serène (1957, page 182) le notent, une révision de l'ensemble du cadre actuel de la classification se réferrant à un plus important matériel d'étude. Ces auteurs n'ont travaillé que dans une seule localité et il semble qu'on devrait récolter des Hapalocarcinidae partout où existe le récif de corail.

La récolte des Hapalocarcinidae nécessite une certaine expérience de la classification des Hexacoralliaires et de leur identification in situ au moins au niveau générique. La connaissance de la forme d'habitat des différents genres d'Hapalocarcinidae sur les colonies d'Hexacoralliaires est également utile. C'est l'observation en plongée (au masque ou en scaphandre) in situ des loges des Hapalocarcinidae qui permet de choisir les blocs d'Hexacoralliaire, les fragments de colonie, à détacher et à ramener au laboratoire. Après quelques erreurs au début, on apprend assez vite à distinguer, in situ (en plongée) et à la surface des coraux, les orifices des mollusques perforants, des annelides, des cirripèdes de ceux des Hapalocarcinidae.

Les Hapalocarcinidae renferment à ce jour 27 espèces, réparties en 5 genres, dont l'un est subdivisé en 4 sous-genres. La modification à ce cadre présentée ci-dessous répartit les 27 espèces en 8 genres.

Elle se limite à la révision du genre *Troglocarcinus* Verrill 1908, qui est le plus hétérogène. Sans modifier le cadre systématique de Fize et Serène (1957), les sous genres de ces auteurs sont portés au niveau générique. Les changements de nom découlent de l'application des règles de nomenclature.

Le genre *Troglocarcinus* Verrill 1908 renferme 14 espèces, réparties par Fize et Serène (1957) en 4 sous-genres: *Troglocarcinus*, *Favicola*, *Fungicola*, *Mussicola*, par référence aux familles ou sous-familles des Hexacoralliaires hôtes. Si les 14 espèces possèdent le caractère générique du premier pléopode femelle biramé, certaines diffèrent grandement d'autres par des caractères morphologiques, plus ou moins en relation avec la forme de la loge qu'ils habitent et la structure de l'Hexacoralliaire hôte.

Le genre au sens large est modifié comme ci-dessous:

1. *Troglocarcinus* Verrill 1908 (avec pour espèce type *T. corallicola* Verrill 1908 hôte d'un Mussidae) est restreint aux espèces hôtes de cette famille; *Troglocarcinus* (*Mussicola*) Fize et Serène 1957 devient synonyme.

2. *Pseudocryptochirus* Hiro 1938, (avec pour espèce type *Ps. viridis* Hiro 1938, hôte d'un *Turbinaria*) est rétabli pour grouper les espèces du sous-genre *Troglocarcinus* (*Troglocarcinus*) Fize et Serène 1957. Le genre reste hétérogène. Les espèces sont hôtes de différents genres d'Hexacoralliaires: *Turbinaria, Pavona, Merulina, Hydnophora, Pectinia, Oxypora, Echinophyllia.* Si *viridis* et *crescentus* ont une morphologie de la carapace et une loge d'habitat de forme voisine, les 3 autres espèces sont très différentes aussi bien par la forme de la carapace que par la loge d'habitat et devront sans doute être séparées du genre. Le relatif aplatissement dorso-ventral de la carapace sur *boissoni*, plus accentué sur *krempfi* n'est pas sans relation avec celui de *Fungicola*. La position de *sheni* est différente. La remarque de Monod (1956, page 466) au sujet de la priorité du nom *Troglocarcinus* Verrill 1908 sur *Pseudocryptochirus* Hiro 1938 n'était valable que parce qu'Utinomi (1944) considerait les deux genres comme identiques, synonymes.

3. *Favicola* Fize et Serène 1957, (avec pour espèce type *F. rugosus* (Edmonson, 1933) hôte d'un Faviidae) correspond au sous-genre homogène de Fize et Serène (1957) porté au niveau générique. Les espèces sont toutes hôtes de divers genres des Faviidae et Monstrastraeidae.

4. *Fungicola* Fize et Serène 1957, avec pour espèce type *F. utinomii* (Fize et Serène), correspond au sous-genre homogène de Fize et Serène (1957). Les espèces sont toutes hôtes de genre des Fungiidae.

Les espèces indo-pacifiques d'Hapalocarcinidae sont:

Cryptochirus Heller, 1861.
1. *C. coralliodytes* Heller, 1861.
2. *C. bani* Fize et Serène, 1957.
3. *C. nami* Fize et Serène, 1957.
4. *C. tri* Fize et Serène, 1955.
5. *C. dimorphus* Henderson, 1906.
6. *C. edmonsoni* Fize et Serène, 1955.
7. *C. pacificus* Edmonson, 1933.

Hapalocarcinus Stimpson, 1858.
8. *H. marsupialis* Stimpson, 1858.

Pseudohapalocarcinus Fize et Serène, 1955.
9. *Ps. ransoni* Fize et Serène, 1955.

Pseudocryptochirus Hiro, 1933.
10. *Ps. viridis* Hiro, 1933.
11. *Ps. crescentus* (Edmonson, 1925).
12. *Ps. sheni* (Fize et Serène, 1955).
13. *Ps. boissoni* (Fize et Serène, 1955).
14. *Ps. krempfi* (Fize et Serène, 1955).

Troglocarcinus Verrill, 1908.
15. *T. heimi* Fize et Serène, 1955.
16. *T. stimpsoni* Fize et Serène, 1955.

Fungicola (Fize et Serène, 1957).
17. *F. utinomi* (Fize et Serène, 1955).
18. *F. fagei* (Fize et Serène, 1955).

Favicola (Fize et Serène, 1957).
19. *F. rugosus* (Edmonson, 1933).
20. *F. helleri* (Fize et Serène, 1957).
21. *F. verrilli* (Fize et Serène, 1957).
22. *F. minutus* (Edmonson, 1933).
23. *F. pyriformis* (Edmonson, 1933).

Neotroglocarcinus (Fize et Serène, 1955).
24. *N. monodi* (Fize et Serène, 1955).
25. *N. dawydoffi* (Fize et Serène, 1955).

Les deux espèces atlantiques sont:
Troglocarcinus corallicola Verrill, 1908.
Neotroglocarcinus balssi (Monod, 1956).

Les 27 espèces d'Hapalocarcinidae sont toutes de la zone tropicale ou subtropicale; la distribution géographque de la famille étant celle des récifs de coraux. On connait 25 espèces de la région indo-pacifique et 2 de la région atlantique. Sur ces deux dernières, l'une du genre *Troglocarcinus* est de la côte américaine, l'autre du genre *Neotroglocarcinus* de la côte africaine, ces deux genres de l'Atlantique étant aussi représentés dans la région indo-pacifique. La remarque et rectification de Monod (1956, page 466) au sujet de la répartition géographique des genres d'Hapalocarcinidae donnée par S. Eckmann (*Zoogeography of the Sea*, 1953, page 51) reste valable; le genre *Cryptochirus* est exclusivement indo-pacifique et le genre *Troglocarcinus* aussi bien atlantique qu' indo-pacifique. Toutefois ce dernier genre est limité à la côte américaine dans l'Atlantique l'espèce de la côte africaine étant maintenant rapportée à *Neotroglocarcinus*. La rareté des formes atlantiques résulte davantage, à mon avis, d'une insuffisante prospection du récif de corail que de conditions biogéographiques. Il est étonnant en particulier qu'on ne connaisse qu'une espèce d'Hapalocarcinidae de la côte atlantique américaine où les récifs de coraux sont bien développés.

Si les Hapalocarcinidae de l'Indo-Pacifique (8 genres et 25 espèces) sont beaucoup mieux connus, on sait très peu encore sur la distribution géographique des espèces.

Deux espèces, les plus signalées, sont largement indo-pacifique de l'Afrique du Sud à la Mer Rouge et de l'Australie au Japon et Hawaii; ce sont: *Hapalocarcinus marsupialis* et *Cryptochirus coralliodytes*.

Cinq espèces sont signalées de quelques localités seulement: *Pseudocryptochirus viridis*, de Hong-Kong (Shen, 1936); des Iles Palao (Hiro, 1938 et Utinomi, 1944); de Nhatrang, Vietnam (Fize et Serène, 1957).

Pseudocryptochirus crescentus, des Iles Hawaii (Edmonson, 1925, 1933), de Hong-Kong (Shen, 1936); des Iles Palao (Hiro, 1937, 1938 et Utinomi, 1944); de Nhatrang, Vietnam (Fize et Serène, 1957).

Favicola rugosus, des Iles Hawaii (Edmonson, 1933 et Serène, 1962), de Nhatrang, Vietnam (Fize et Serène, 1957);

Favicola helleri, de Nhatrang, Vietnam (Fize et Serène, 1957) et des Iles Hawaii (Serène, 1962).

Favicola minutus, des Iles Hawaii (Edmonson, 1933 et Serène, 1962) et de Nhatrang, Vietnam (Fize et Serène, 1957).

Les 18 autres espèces ne sont connues à ce jour que d'une seule localité:

Cryptochirus dimorphus, Henderson 1906 des Iles Andamans.

Cryptochirus pacificus et *Favicola pyriformis*, des Iles Hawaii (Edmonson, 1933 et Serène, 1962).

Cryptochirus bani, *C. nami*, *C. tri*, *C. edmonsoni*; *Pseudohapalocarcinus ransoni*; *Pseudocryptochirus sheni*, *Ps. boissoni*, *Ps. krempfi*; *Troglocarcinus heimi*, *T. stimpsoni*; *Fungicola utinomii*, *F. fagei*; *Favicola verrilli*; *Neotroglocarcinus monodi*, *N. dawydoffi* de la baie de Nhatrang, Vietnam (Fize et Serène, 1957).

Quelques récoltes récentes montrent que les données actuelles reflètent davantage la distribution des récoltes que la distribution réelle des espèces.

Le Dr. Garth m'a adressé, en 1961 pour identification, des spécimens de l'Ile Clipperton; il s'agissait de *Troglocarcinus crescentus*, c'est-à-dire *Pseudocryptochirus crescentus* de la nouvelle nomenclature de cette note. J'ai récolté en 1963 à Padang, sur la côte Sud de Sumatra (Indonésie), des spécimens de cette espèce. Sa distribution géographique, considérablement agrandie, s'étend donc au Sud jusqu'à l'Océan Indien et à l'Est jusqu'au voisinage des côtes américaines.

A Padang, côte Sud de Sumatra (Indonésie), j'ai récolté en 1963, sur le même site que le *Ps. crescentus* signalé ci-dessus, des spécimens de *Favicola helleri*, et de *Pseudocryptochirus sheni*. La distribution de la première de ces espèces, connue seulement du Vietnam et des Iles Hawaii, s'étend donc jusqu'à l'Océan Indien; la distribution de la seconde, connue seulement du Vietnam, également.

J'ai récolté de même, *Pseudohapalocarcinus ransoni* à Quezon, dans le Sud de la côte Ouest de Palawan (Philippines) en 1963 et *Neotroglocarcinus monodi* à Poulo Paway, au large de Singapour en 1964; les deux espèces n'étant encore connues que du Vietnam.

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FIZE, A. AND R. SERÈNE 1957. Les Hapalocarcinides du Vietnam. *Arch. Mus. Hist. Nat., Paris*, 7è s., 5: 200 p. XV Pl. Ce travail comporte une bibliographie des Hapalocarcinides.

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THE GENERAL DISTRIBUTION OF SPECIES OF THE CALANOID COPEPOD FAMILY CANDACIIDAE IN THE INDIAN OCEAN WITH NEW RECORDS

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ABSTRACT

As manifested in the distribution of species of the copepod family Candaciidae, the western Indian Ocean can be divided into three main plankton communities. North of about latitude 20° South, equatorial species predominate. In the extreme western limits, those species are carried southward by the Agulhas Stream.

From latitude 20° South to about 38° South, species characteristicof the southern Central Water are found.

In the Arabian Sea and the Bay of Bengal, neritic or intermediate forms are found. These are apparently associated with the chemical or physical influence of land and the outflow of rivers.

New records include *Candacia samassae* reported for the first time from the Arabian Sea and the Bay of Bengal. This species was originally described from the Red Sea and has not until now been found elsewhere. Another new record is that of *C. guggenheimi* Grice and Jones reported here from the western Indian Ocean and previously known only from the Central Pacific.

THE calanoid copepod family Candaciidae contains 2 genera and 27 described species, according to Grice (1963). With the exception of the extreme polar waters, one or more of the species appear to be endemic to each of the major circulation patterns of the oceans. A few tropical and temperate species usually are found in neritic waters. With such a relatively large number of species so widely distributed, the members of this family appear to have considerable potential value as indicator organisms.

Sewell (1932 and 1947) summarized most of the reports of the occurrences of Candaciidae in the Indian Ocean. Since then Tanaka (1960), Vinogradov and Voronina (1962), Krishnaswamy (1953), and Chiba and Tsuruta (1955) have added to Sewell's records. Vinogradov and Voronina (1962) presented a map of the distribution of *Paracandacia bispinosa* (Claus), and their data were incorporated into the general distribution map of that species in this report.

The purpose of this paper is to present, in a very preliminary manner, the general distribution of several species of the family Candaciidae in the Indian Ocean. The results are based, for the most part, on samples collected during cruises 1 and 2 of the *ANTON BRUUN*.[1] In addition, two new records from the Indian Ocean are presented. In a later publication, more quantitative data will be included. Furthermore, a study also will be made of the changes in the distribution of species with those in the environment. The following are the results of this preliminary study.

Candacia samassae Pesta

New record for the Indian Ocean. The only previous record of this species known to me is the original description (Pesta, 1941) in which the female was found in the Red Sea. In the present

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[1] The operation of the *ANTON BRUUN* was supported by the National Science Foundation as a part of the U.S. Program in Biology, International Indian Ocean Expedition.

study, both sexes of *C. samassae* were found in abundance in the zooplankton hauls made in the Bay of Bengal (*ANTON BRUUN* Cruise 1) and the Arabian Sea (*ANTON BRUUN* Cruise 2). The general distribution of this species is given in Fig. 1. In the Arabian Sea, *C. samassae* appeared most frequently in the day hauls made between the depths of 125 and 250 meters, while in the Bay of Bengal this species was collected in the nets towed obliquely from the surface to 100 or 200 meters. None was found in the night surface samples.

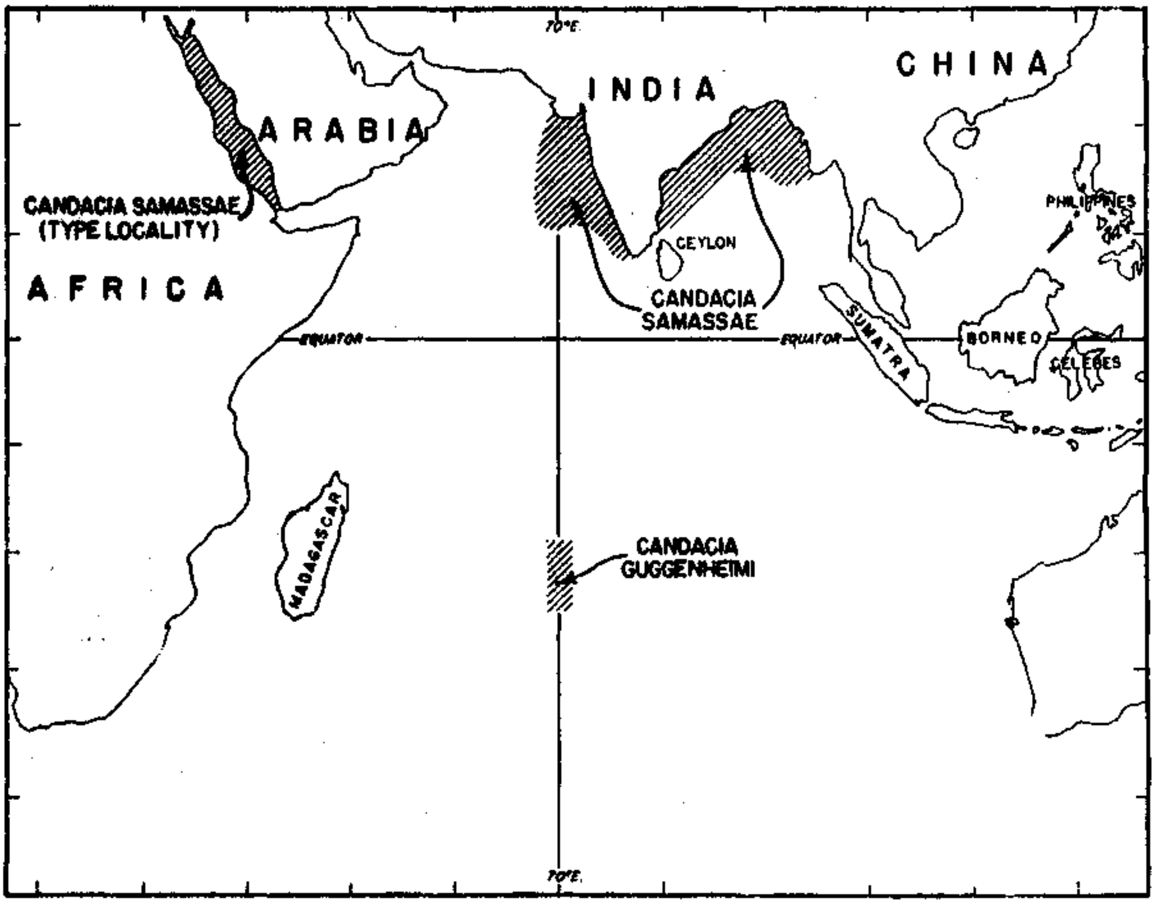

FIG. 1. New records of Candaciidae from the Indian Ocean.

Considering the thorough sampling in those waters as reported by Sewell (1932 and 1947), his failure to find this species presents somewhat of a mystery. The sampling pattern of the two *ANTON BRUUN* cruises did not permit a conclusion regarding the degree of contiguity of the distribution of *C. samassae* from the Red Sea to the Bay of Bengal, but the observed distribution does suggest exchange among those bodies of water.

***Candacia guggenheimi* Grice and Jones**

New record for the Indian Ocean. This species has been reported only from the area of its original discovery in the central North Pacific between the Equator and latitude 35° N. (Grice and

Jones, 1960). In the *ANTON BRUUN* samples, *C. guggenheimi* was collected in small numbers along longitude 70° E., between latitudes 19° and 26° S. (Fig. 1). For the most part, it was found between 125 and 250 metre depths and only in day hauls. It was not found in any of the night surface hauls.

Candacia norvegica (Boeck)

Second record from the Indian Ocean. This species was first described from specimens collected off the Norwegian coast; since then it has been reported as being prevalent in the cold, North Atlantic. Grice (1963) reported *C. norvegica* as occurring in the area of the Benguela Current off the west coast of southern Africa between latitudes 8° and 15° S. Wilson (1942 and 1950) recorded it from many stations in the tropical and temperate Pacific. Fleminger and Bowman (1956), however, believed that all of Wilson's records of the species were in error. Tanaka (1953) included *C. norvegica* in his list of copepods from the Izu region off Japan and Grice and Jones (1960) reported it as from the central North Pacific. Sewell (1932) described a variety *tropica* from *Investigator* station 682, collected in April 1925 at latitude 10° 26′ N., longitude 74° 32′ E., in the Arabian Sea from a haul made from the surface to 700 fathoms. In this sample he found two females.

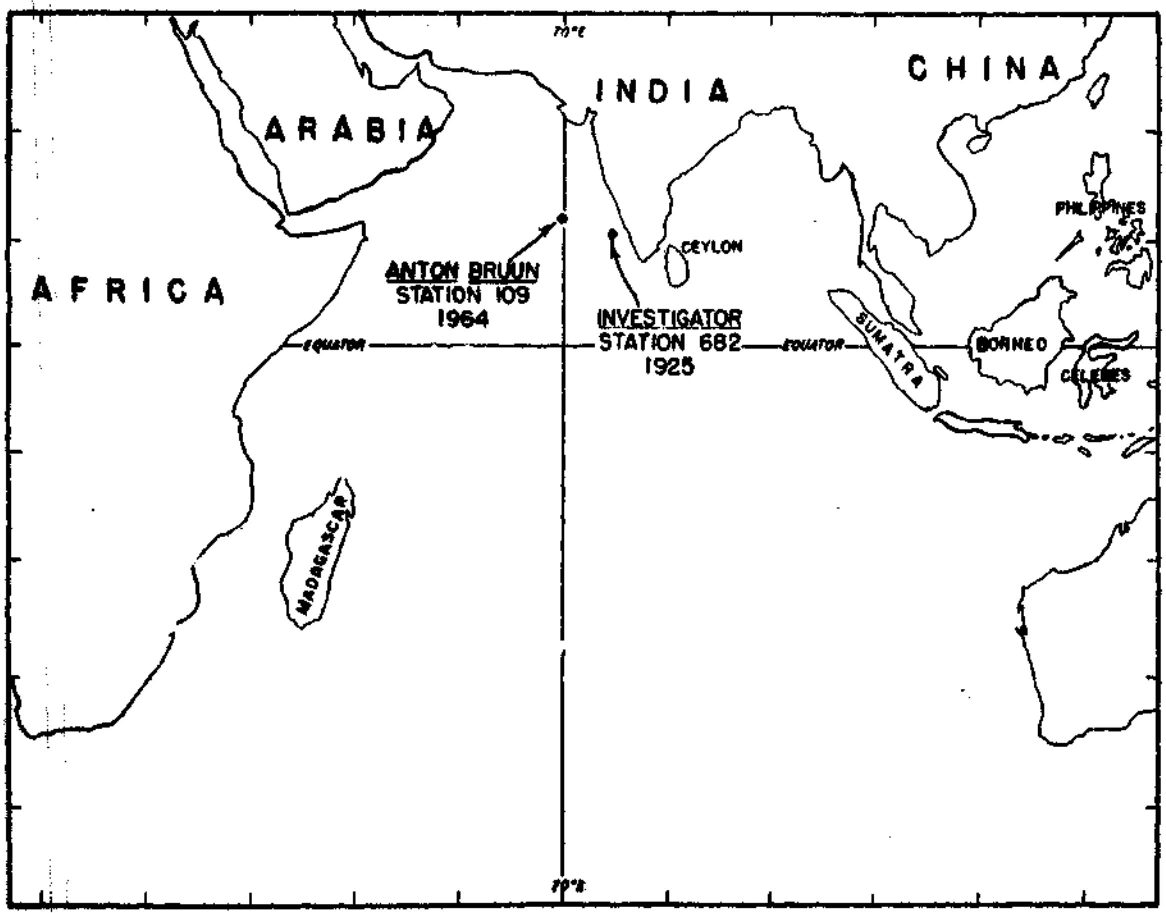

FIG. 2. Records of *Candacia norveica* (Bloeck) from the Indian Ocean

Thirty-eight years later, one female was found in a sample collected during cruise 2 of the *ANTON BRUUN* at station 109, latitude 11° 59′ N., longitude 69° 55′ E., less than 300 miles from Sewell's locality (Fig. 2). The terminal spines of the fifth feet of the *ANTON BRUUN* specimen are unequal with the outer spine being longer. In this respect it differs from Sewell's *tropica* and agrees with Pacific and Atlantic specimens as reported by Grice and Jones (1960). This suggests that *tropica* is not a valid variety, but only a manifestation of morphological variation within the species.

Candacia longimana (Claus)

Grice (1963) reported this species as being present in the Indian Ocean only north of latitude 20° S. However, in samples collected along longitude 70° E. during cruise 2 of the *ANTON BRUUN*, *C. longimana* was found, for the most part, south of that position. *C. longimana* was present in one night surface haul and in six night oblique hauls made to the top of the thermocline. This species was absent from all of the day hauls collected on the same dates and at nearby locations (Fig. 3).

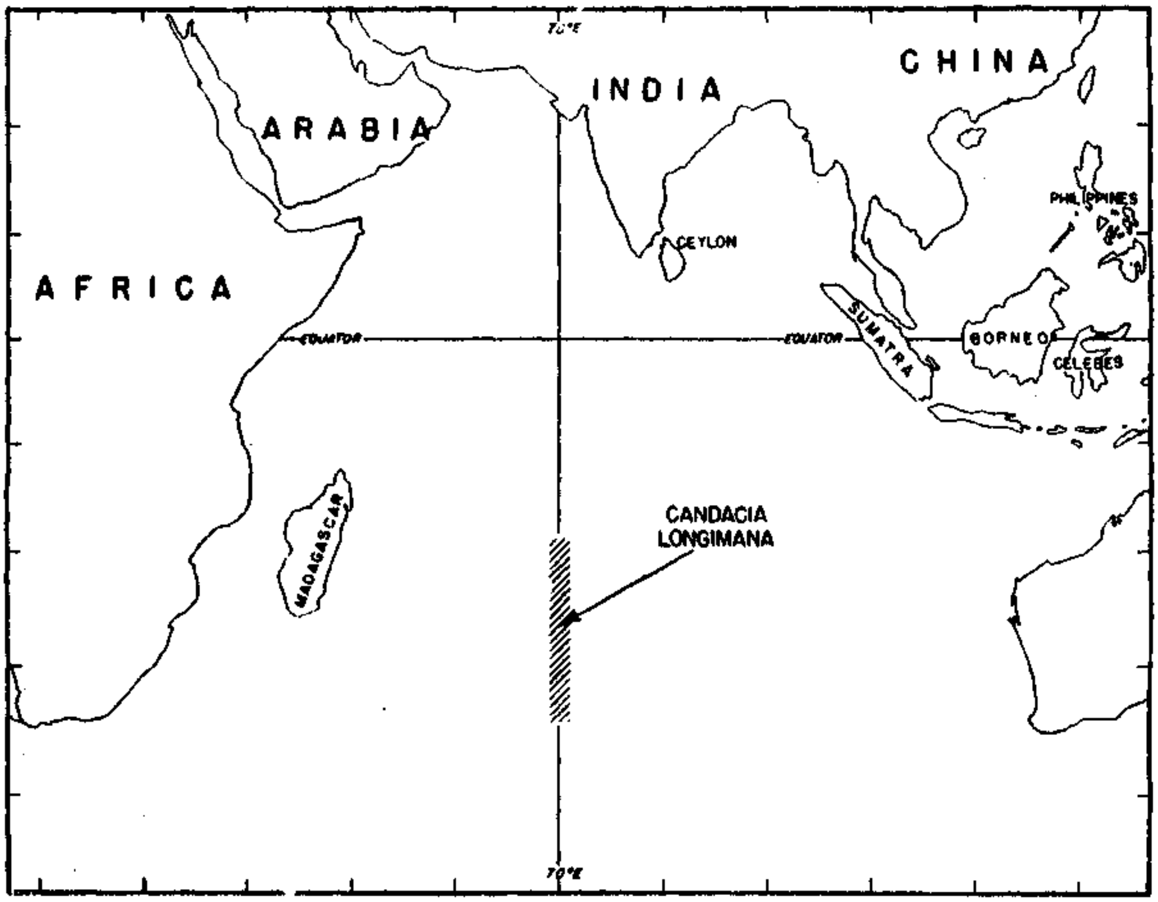

FIG. 3. Location of *Anton Bruun* cruise 2 records of *Candacia longimana* (Claus) in the Indian Ocean.

These day hauls were made with closing nets down to 2,000 meters. It is difficult to explain the circumstances which resulted in such observed distribution. Diel movement does not appear to be as plausible an explanation as does net dodging.

Candacia pachydactyla (Dana), *C. catula* (Giesbrecht) and *Paracandacia truncata* (Dana)

These three species inhabit equatorial waters in the Indian Ocean, for the most part, north of latitude 20° S. (Fig. 4). In *ANTON BRUUN* samples, they usually were found in the upper 250 metres of water and were most abundant in night surface samples. In the extreme western regions of the Indian Ocean, they are carried southward by the Agulhas Stream to the southern extreme of Africa, but apparently do not enter the Atlantic. They were not found in southern central waters of the Indian Ocean nor in the coastal neritic waters of the Arabian Sea and the Bay of Bengal.

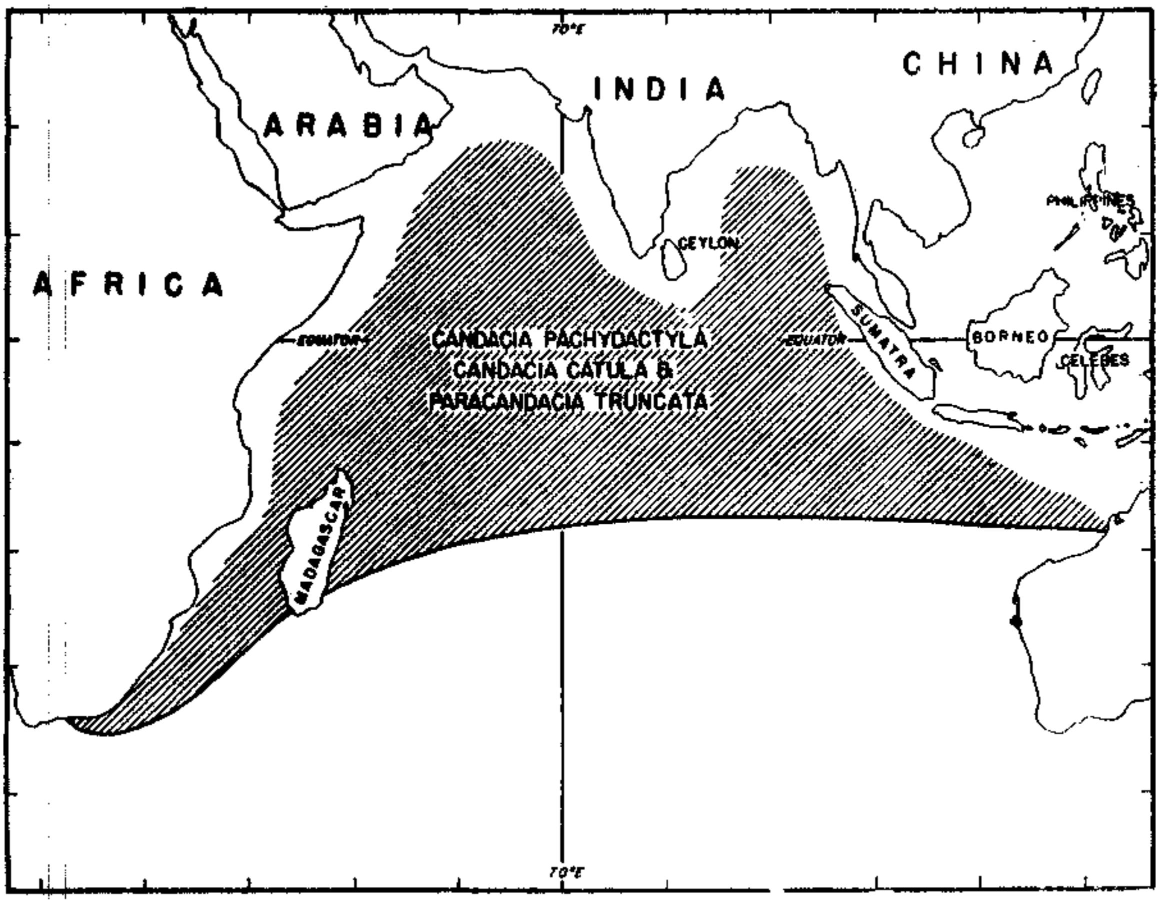

FIG. 4. General distribution of equatorial species of Candaciidae in the Indian Ocean.

Candacia ethiopica (Dana) and *Paracandacia bispinosa* (Claus)

These two species are most abundant in the southern central waters of the Indian Ocean, but they also occur in smaller numbers in equatorial waters. In samples collected during cruise 2 of the *ANTON BRUUN*, these species were most abundant between latitudes 20° and 30° S. (Fig. 5). *C. ethiopica* appeared in small numbers as far south as lattitude 38° S. where its limits coincided with the surface isotherm of 15° C.

In addition to the species discussed, the following species were collected in such small numbers that their distribution patterns cannot yet be determined: *C. varicans* (Giesbrecht), *C. bipinatta* (Giesbrecht), *C. tenuimana* (Giesbrecht), *C. curta* (Giesbrecht). Two of these, *C. bradyi* and *C. discaudata*, were found most often in neritic waters and may be considered indicators of such waters.

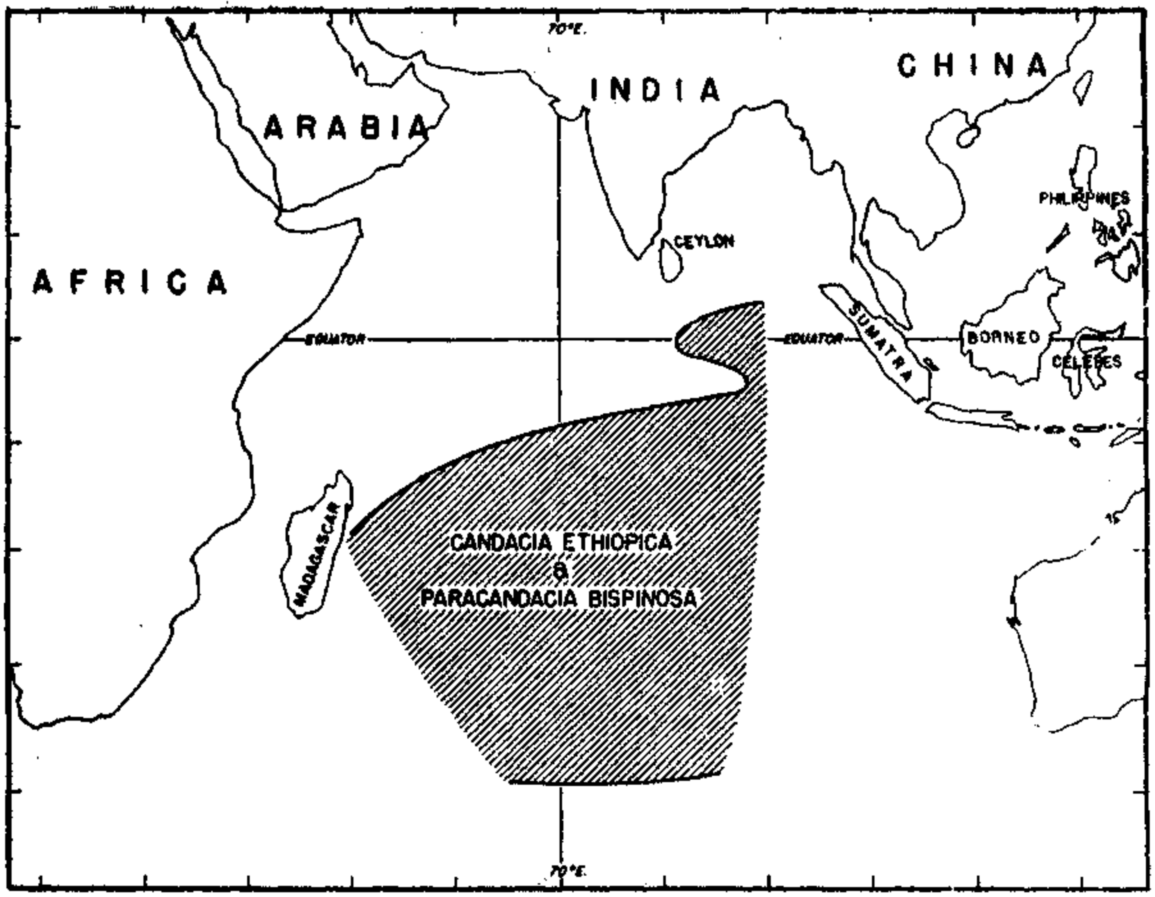

FIG. 5. General distribution of *Candacia ethiopica* (Dana) and *Paracandacia bispinosa* (Claus) in the Indian Ocean.

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EVIDENCE OF ISOLATION BETWEEN POPULATIONS OF *CANDACIA PACHYDACTYLA* (DANA) (COPEPODA: CALANOIDA) IN THE ATLANTIC AND THE INDO-PACIFIC OCEANS

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ABSTRACT

Atlantic and Indo-Pacific samples of *Candacia pachydactyla*, a calanoid copepod inhabiting equatorial waters, were examined for differences in morphological characteristics. Such differences were found between samples from the two oceans and are believed to be evidence of genetic isolation of two populations.

Distribution data indicated that the Indo-Pacific population is not carried around the tip of Southern Africa into the Atlantic by the Agulhas Stream. About 2000 miles of water appeared to separate the two populations.

SEWELL (1948) summarized the investigations on the effect of the southern portion of the continent of Africa as a barrier to the mixing of warm water Atlantic and Indo-Pacific pelagic copepods. Two questions seemed to have been considered: (1) Does warm, tropical water from the Agulhas Stream of the south-western Indian Ocean enter the Atlantic after rounding the Cape of Good Hope, and (2) if this takes place, do the tropical copepods from the Indian Ocean survive and enter the gene pool of their Atlantic counterparts ? Sewell listed 138 species of warm water copepods he considered to be " Indo-Pacific species ", which also are found in the Atlantic; from this he concluded that the African continent does not form an effective barrier to the mixing of populations of the two oceans.

Steuer (1928) concluded it is likely that Africa forms an effective barrier most of the time but occasionally, under certain circumstances, this barrier is broken down. He believed that Indian Ocean populations carried to the Atlantic generally did not survive there. DeDecker (1964) stated that Indo-Pacific copepods carried by the Agulhas Stream disappeared over the Agulhas Bank and were seldom if ever carried further west.

The problem originally was defined because the passage of Agulhas water represents the only possible source of mixing of warm water populations of animals from the two oceans. The probability of such mixing increases with the length of time and the number of species considered. That is, if given sufficient time and if all existing warm water species and fluctuating marginal conditions are considered, mixing between the Atlantic and Indo-Pacific populations is virtually certain to occur at some time at least among some of the species. Because the frequency of such occurrences is not known, it appears to be inappropriate to reach general conclusions which imply that warm water species are never transported around the Cape, or that the Cape does not, in any sense, form a barrier to such transport. Such general conclusions cannot gain merit until the frequency of mixing can be estimated from the analysis of large amounts of data on the distribution of restricted and *well-defined* taxons within the areas under consideration.

This investigation was narrowed to concern a single species inhabiting the equatorial waters of both oceans rather than the broader " warm waters " which include the central water masses of middle latitudes. Because the southern central water masses of the two oceans are separated by less distance than are the equatorial waters, and because the range of environmental conditions of the former are greater, the frequency of mixing between central water mass populations would appear to be greater than between equatorial populations. The results of a study of the distribution of *Candacia pachydactyla* (Dana) are presented along with evidence of morphological differences between the Atlantic and the Indo-Pacific populations. The presence of such morphological differences suggests a high degree of isolation between those populations.

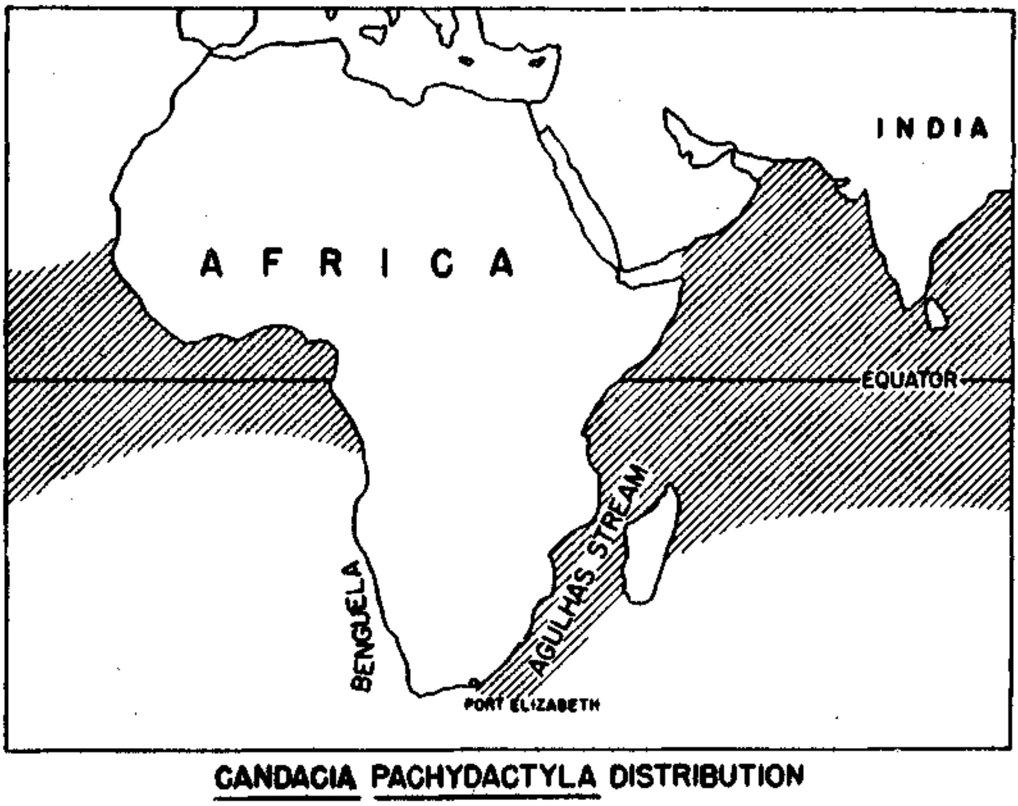

FIG. 1. The general distribution of *Candacia pachydactyla* (hatched area).

A series of plankton samples collected on cruises of the *R. V. Vema* of the Lamont Geological Observatory of Columbia University was examined for the presence of *C. pachydactyla*. This series was collected from stations along the eastern coast of Africa from the Arabian Sea to the Cape of Good Hope, around the Cape, through the area of the Benguela Current and into equatorial waters just south of the Gulf of Guinea. Additional samples from the Gulf of Guinea were made available by the Bureau of Commercial Fisheries Biological Laboratory in Washington, D.C. From this material, it was determined that *C. pachydactyla* was carried by the Agulhas Stream southward and eastward to a point just offshore from Port Elizabeth, South Africa. This species was not encountered in the Atlantic samples south of latitude 8° S. in the vicinity of longitude 10° E. Thus, the Atlantic and Indo-Pacific populations were separed by about 2,000 miles of ocean which included the cold Benguela Current. Unpublished data from the *Vema* cruises indicated that during the period of sampling, this cold, neritic, coastal water extended at least 300 miles off shore from south-west Africa. The Benguela Current therefore appears to constitute an additional barrier to Indo-Pacific individuals mixng with their counterparts in the Atlantic.

Figure 1, based on the samples described and also upon published records, presents the general distribution of *C. pachydactyla* in the areas under consideration.

Samples of *C. pachydactyla*, both males and females, from the central equatorial Pacific Ocean, the Indian Ocean, the Gulf of Guinea in the eastern Atlantic Ocean, and the Straits of Florida in the western Atlantic Ocean were examined in detail for morphological differences among or between populations.

No consistent differences were found between samples from the Indian Ocean and the central Pacific; likewise, none were found between the two Atlantic samples. However, the following differences between Atlantic and Indo-Pacific populations were consistent:

(1) In the females from the Atlantic, a low rounded process is sometimes present between the middle and internal terminal spines of the fifth feet; when present, however, this is never strong or pointed (Fig. 2 *a*). In the Indo-Pacific females, this process is prominent and often pointed (Fig. 2 *b*).

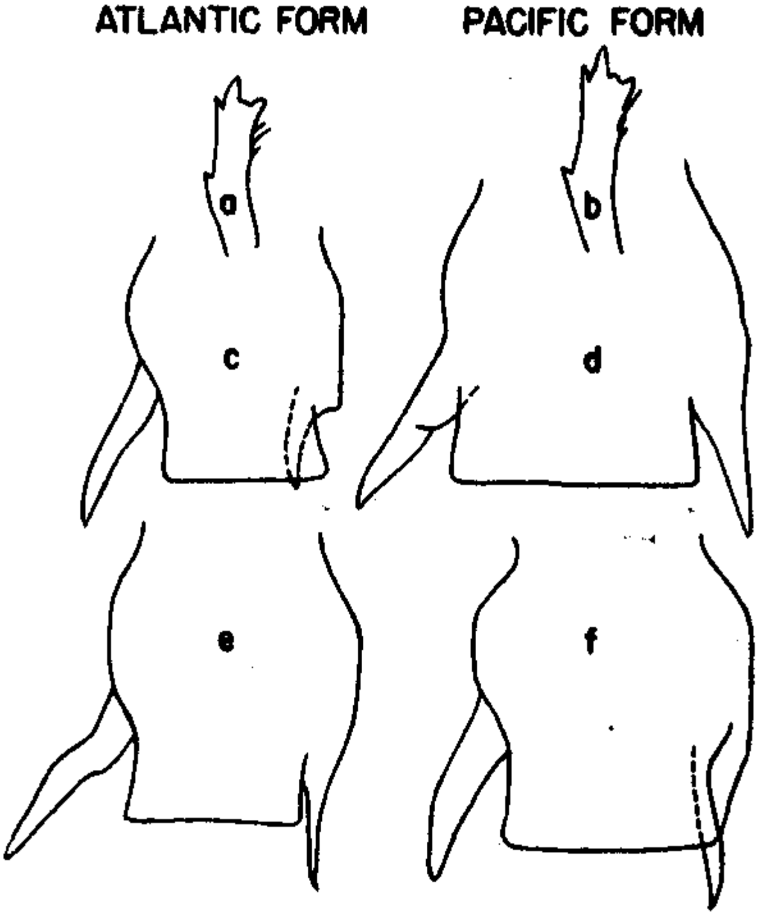

FIG. 2. (*a*) Female fifth foot, Atlantic form; (*b*) female fifth foot, Pacific form; (*c*) female genital segment, Atlantic form; (*d*) female genital segment, Pacific form; (*e* and *f*) female genital segments showing intermediate forms of right spine.

(2) In the Atlantic females, the caudally directed spine on the right margin of the genital segment (in dorsal view) usually points slightly mediad and is usually partially hidden from view (Fig. 2 *c*). The external margin of this spine is usually concave. In most Indo-Pacific females, the right spine points straight caudad or slightly laterad and the tip is not usually hidden in dorsal view (Fig. 2 *d*). Extremes of these two forms appear to be peculiar to the Atlantic or the Indo-Pacific, but intermediacy occurs (Figs. 2 *e,f*) so that this characteristic is not, by itself, enough to distinguish the two populations.

(3) In the males from the Atlantic samples, the posterior margin of the dextral genital process is indented or concave (Fig. 3 *a*). In the Indo-Pacific males, that margin is straight or slightly convex (Fig. 3 *b*).

(4) In all males of this species, the elongated process on the right corner of the fifth thoracic segment has, when viewed laterally, the superficial form of a foot with a pointed " toe " and a smaller " heel ". In the Atlantic males, the " heel " is weak or nearly absent and slightly rounded (Fig. 3 *c*). In the Indo-Pacific specimens, the " heel " is stronger, pointed and there is a definite indentation in the " arch " of the " foot " (Fig. 3 *d*).

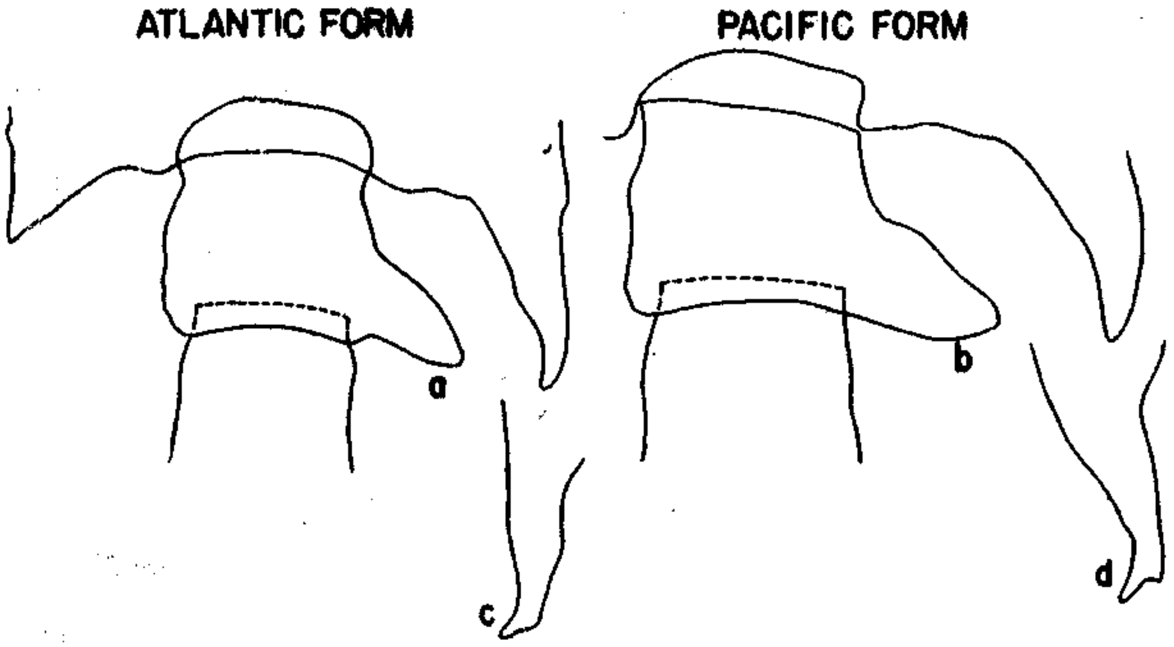

FIG. 3. (*a*) Male genital segment, Atlantic form; (*b*) male genital segment, Pacific form; (*c*) male thoracic process, lateral view, Atlantic form; (*d*) male thoracic process, lateral view, Pacific form.

Other parts of the appendages and body of many individuals from both oceans were examined for differences and while some were found, none appeared to be constant enough to be useful as distinguishing marks.

As a test of the integrity and objectivity of the observed differences, 20 specimens, drawn at random from the two Indo-Pacific and the two Atlantic samples and stained to remove possible color differences, were presented to the author. These were examined and on the basis of the criteria described above, the author was able to correctly relate 19 out of 20 to the proper ocean. He was unable, however, to consistently disinguish beween the two Atlantic samples or the two Indo-

Pacific samples. No elaboration or statistical tests seemed necessary to support this 95 per cent. success in separation.

The conclusion that populations of *C. pachydactyla* in the Atlantic and the Indo-Pacific are separated by the barrier of southern Africa and by associated oceanographic conditions is supported by distribution records of certain other species within the family Candaciidae. Two other Pacific equatorial species, *C. catula* (Giesbrecht) and *Paracandacia truncata* (Dana), are not found in the Atlantic (Grice, 1963). Except for the Atlantic form of *C. pachydactyla*, the Atlantic Ocean appears not to contain any species peculiar to equatorial waters.

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BIOGEOGRAPHIE DER BATHYNELLACEA (SYNCARIDA)

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ABSTRACT

Eine Revision der Bathynellacea hat ergeben, daß diese Gruppe 3 unäbhangige Stämme enthält, die als eigene Familien aufgefaßt werden (Bathynellidae, Parabathynellidae, Leptobathynellidae).

Die Bathynellidae sind im Wesentlichen plesiomorph und auf die gemäßigten Zonen der Palaearktis (vermutlich auch Holarktis sowie der Neotropis (Patagonia) beschränkt.

Die Parabathynellidae scheinen dagegen circumtropisch die Tropen und Subtropen vermutlich der ganzen Welt zu bewohnen. Sie enthalten eine plesiomorphe Restgruppe (*Allobathynella*) neben stärker—abgeleiteten, apomorphen Arten (*Parabathynella*).

Die stark abgeleiteten Leptobathynellidae scheinen bisher in der tropisch-subtropischen Zone der Neotropis endemisch zu sein.

Auf die obligatorische Bindung der Bathynellacea an das limnisch-mesopsammale Interstitium wird hingewiesen. Bislang sind als Ausnahmen nur 2 sekundär freilebende Arten aus der Tiefe des Baikal-Sees bekannt geworden.

Die Gruppe ist heute deutlich salzfeindlich. Aus ökologischen und morphologischen Gründem sowie nach palaeontologischen Befunden wird auf ihr sehr hohes Existenzalter im speziellen Biotop geschlossen.

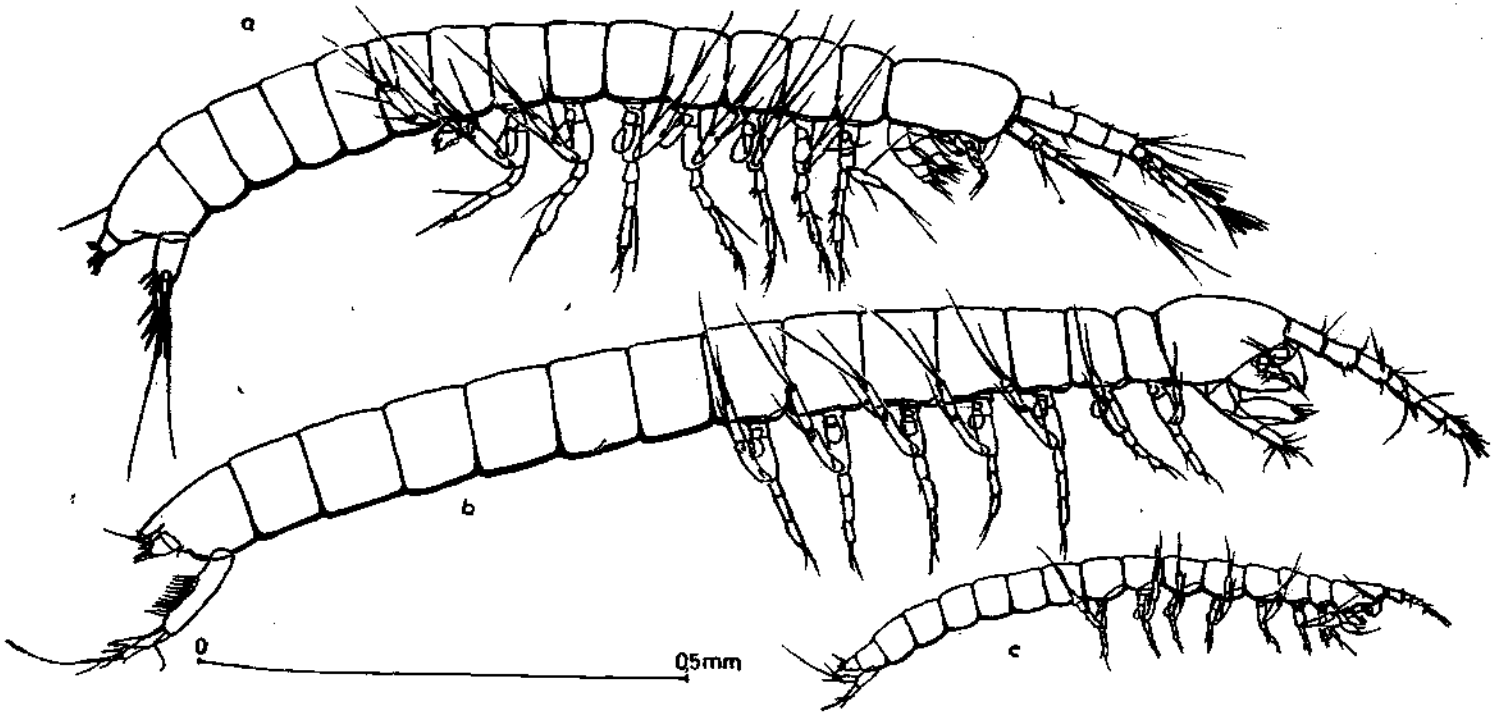
Demnach ist ihr rezentes Verbreitungsbild biogeographisch signifikant und wird als Hinweis auf die frühere Existenz zusammenhängender Kontinentalblöcke (wenigstens Gondwana) gedeutet.

STICHHALTIGE biogeographische Analysen haben exakte Vorstellungen über die wirklichen Verwandtschaftsverhältnisse, also über das natürliche System der betreffenden Organismengruppe, zur unbedingten Voraussetzung. In vielen Taxa des Tierreichs ist diese Voraussetzung jedoch bekanntlich durchaus noch nicht erfüllt, wie die anhaltende Diskussion um die "richtige" Stammbaumkonstruktion selbst wesentlicher Tierstämme (Arthropoda, Mollusca, Echinodermata, Chordata usw.) zeigt.

Hierin ist u.a. die mißliche Situation begründet, in der sich der Zoogeograph auch heute noch befindet. Fast alle zusammenfassenden Darstellungen über die Geschichte der Verbreitung des Lebens auf der Erde kranken immernoch an der relativen Unzuverlässigkeit der herangezogenen Fakten und kommen dadurch zu zum Teil wesentlich divergenten Ergebnissen (vgl. z.B. die unterschiedlichen Beurteilungen des Verbreitungsbildes der Marsupialia und der großen Laufvögel!)

In einigen Fällen haben dagegen modernere Revisionen nach den Methoden einer phylogenetischen Systematik verblüffende Einsichten in die Verbreitungsgeschichte einiger Gruppen eröffnet (z.B. Plecoptera, Illies). Der Verfasser hofft, mit einer systematischen Revision der Bathynellacea zugleich einen Beitrag zur Erklärung des Verbreitungsbildes dieser interessanten, fast rein subterranen Crustaceengruppe zu liefern.

Vor wenigen Jahren noch bot das scheinbar völlig disjunkte Areal der wenigen bis dahin bekannten Arten der Bathynellacea keine Möglichkeit einer Erklärung. Man erblickte in ihnen



G. 1. Habitusformen typischer Vertreter der 3 Familien der Bathynellacea (nach NOODT, 1965 *a*). (*a*) *Bathynella cautinensis* Noodt (Bathynellidae); (*b*) *Parabathynella neotropica* Noodt (Parabathynellidae); (c) *Leptobathynella riegelorum* Noodt (Leptobathynellidae).

verstreute Reste einer archaischen Fauna im ökologischen Refugium des Grundwassers (Chappuis Thienemann u.a.).

Im Rahmen der in jüngster Zeit in fast allen Erdteilen intensiv begonnenen Psammon- und Grundwasseruntersuchungen wurde und wird nun jedoch eine solche Vielzahl von Arten beschrieben, daß eine verbreitungsgeschichtliche Analyse der Gruppe nicht nur möglich, sondern auch geboten erscheint (derzeit hat der Verfasser von 66 Species, Subspecies, Rassen usw. Kenntnis).

Die dafür zunächst erforderliche systematische Revision führte zu einer Neueinteilung der Gruppe in 3 selbständige Familien (Noodt, 1965 *a*). Danach sind zu unterscheiden (vgl. die Zusammenstellung der Taxa mit Diagnosen am Ende dieser Arbeit):

Fam. Bathynellidae Grobben mit im Wesentlichen plesiomorphen (phylogenetisch erstarrten?) Formen (Fig. 1 *a*).

Fam. Parabathynellidae Noodt mit einigen deutlich plesiomorphen (*Allobathynella*), einer Anzahl intermediärer (*Parabathynella* partim, *Chilibathynella, Thermobathynella*) und zahlreichen m.o.w. apomorphen Formen (*Parabathynella*, Fig. 1 *b*).

Fam. Leptobathynellidae Noodt mit im Wesentlichen stark apomorphen Formen (Fig. 1 *c*).

Eidonomische Indizien sprechen dafür, daß diese 3 Linien sich offenbar schon seit erheblichen Zeiträumen konvergent entwickelt haben. Ein relativ engerer Zusammenhang zwischen Bathynellidae und Leptobathynellidae wird vermutet, denen gegenüber eine Anzahl von Merkmalen auf eine bereits ältere Selbständigkeit der Parabathynellidae zu deuten scheint (Noodt, 1965 *a*).

Die Bathynellacea sind praktisch ganz auf das interstitielle Grundwasser beschränkt. Als einzige Ausnahmen wurden bislang 2 offenbar sekundär "freilebende" Arten aus der Tiefe des Baikalsees bekannt (Bazikalova, Kozhov). Die zahlreichen Reduktionsmerkmale der Gruppe deuten auf einen schon sehr lange währenden Aufenthalt im speziellen Biotop, in dem diese Tiere ein charakteristisches Element darstellen.

Hinzu kommt eine ausgesprochene Salzfeindlichkeit der Gruppe. Sie dokumentiert sich darin, daß die Bathynellen ausnahmslos bereits vor der oligohalinen, landwärtigen Zone des Küstengrundwassers (Remane) Halt machen und im Meere ganz fehlen.

Da die Entstehung der Gruppe noch im Paläozoikum wahrscheinlich ist (Funde von Palaeocaridacea, Brooks), Fossilfunde jedoch völlig fehlen, scheinen auch hier Indizien für ein hohes Existenzalter in ein und demselben Milieu vorhanden zu sein. Demnach hätte es sich schon sehr lange um zarte Kleinformen gehandelt, für die keine Chance einer Erhaltung als Fossil bestand.

Das Fehlen von leicht verbreitungsfähigen Dauerstadien spricht für die Annahme einer nur sehr geringen Ausbreitungsfähigkeit der Bathynellen. Da sie jedoch fast kosmopolitisch verbreitet sind, lassen sich auch hieraus Hinweise auf ihr hohes Existenzalter ableiten.

Diese Fakten, die alle auf ein hohes Alter der Bathynellacea im Sandlückensystem deuten, sind nun überraschend gut in Einklang zu bringen mit dem Verbreitungsbild der 3 Familien, soweit es uns heute bereits bekannt ist (Fig. 2):

Die Bathynellidae besiedeln ein auffällig disjunktes Areal. Die Masse der Arten findet sich offenbar in der Zone gemäßigter Temperaturen der Palaearktis, wahrscheinlich der gesamten Holarktis. Gegen Norden scheint die Grenze von der diluvialen Vereisung geprägt, im Süden besteht eine ziemlich geringe Überlappung mit dem Areal der Parabathynellidae. Erst in jüngster Zeit fand man Angehörige dieser Familie außerdem auch in der Südhemisphäre, und zwar in der südlichen Neotropis (Patagonia) (Delamare-Deboutteville, Noodt).

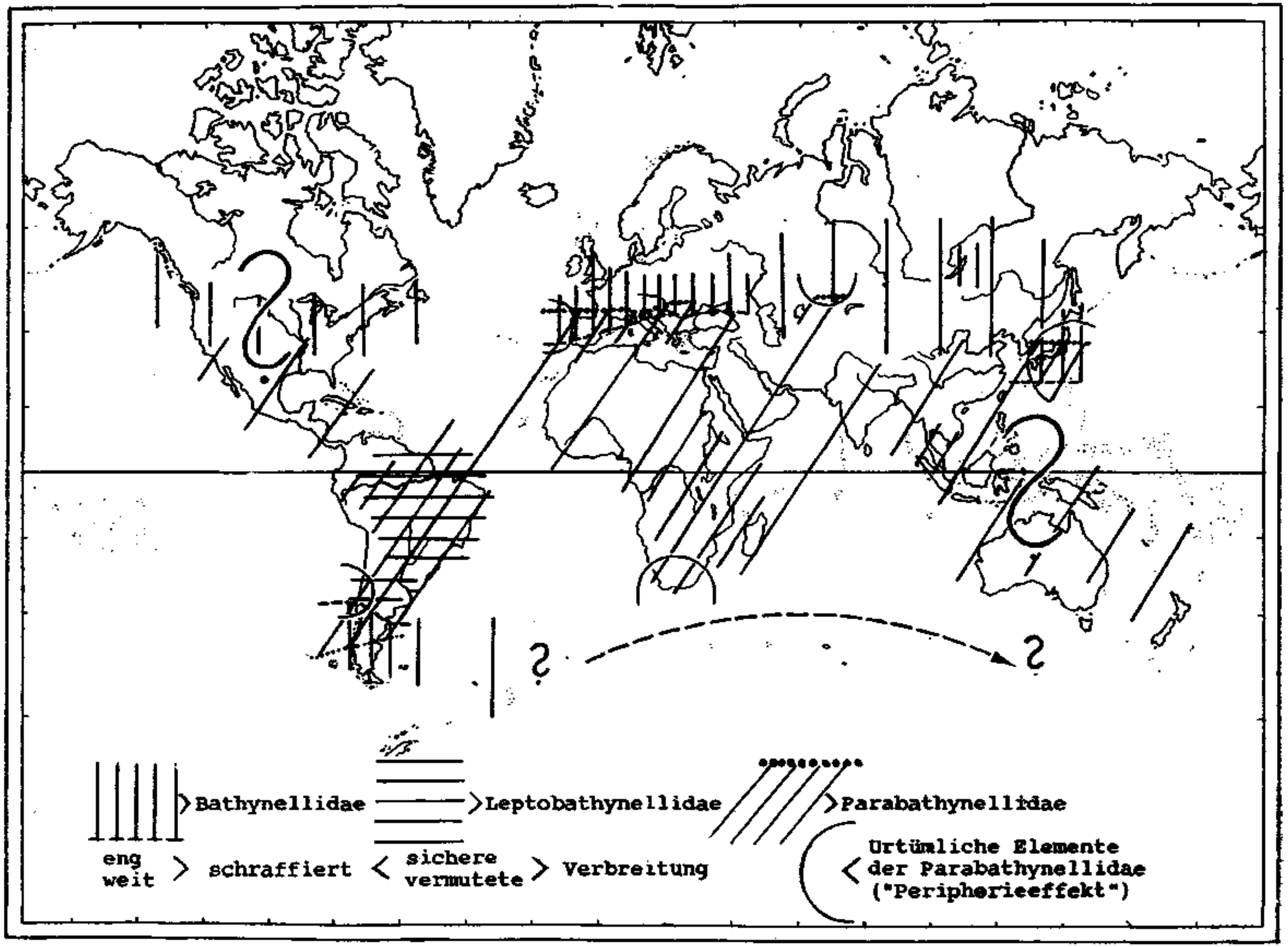


FIG. 2. Das Verbreitungsbild der Bathynellacea (nach Noodt, 1965 *a*, verändert).

Gegenüber den möglicherweise älteren, plesiomorphen Bathynellidae besiedeln die in ihrer Masse stärker abgeleiteten Parabathynellidae das Grundwasser der tropischen bis subtropischen Zonen wahrscheinlich der ganzen Welt (Fig. 2). In Patagonia ist die Überlappung mit dem Areal der Bathynellidae relativ breit.

Die Leptobathynellidae scheinen bislang neotropisch-endemisch und kommen in ihrem gesamten Areal mit Parabathynellidae gemeinsam vor. Sie dringen jedoch nicht soweit wie diese im Süden in die gemäßigte Zone vor (Noodt, 1963, 1965, 1965 *b*).

Eine Erklärung dieses Verbreitungsbildes ist nach Ansicht des Verfassers am einfachsten unter folgenden, noch theoretischen Voraussetzungen möglich:

1. In der Verbreitung der Bathynellidae und Parabathynellidae über mehrere Kontinente wird ein Hinweis auf das hohe Alter beider Gruppen gesehen. Mit der Vorstellung eines bis ins ausgehende Palaeozoikum bestehenden Zusammenhanges der Urkontinente (zumindest Gondwana) mit darauf einsetzender Trennung durch Epeirophorese scheint uns eine vergleichsweise zwanglose Erklärungsmöglichkeit dieses Phänomens an die Hand gegeben zu sein.

2. Das ursprünglich sicher kontinuierliche Areal der (altertümlicheren) Bathynellidae könnte durch Zurückdrängen dieser Gruppe durch die (höher entwickelten) Parabathynellidae auf die klimatisch weniger begünstigten hohen Breiten gespalten worden sein. Konkurrenzeffekte zwischen beiden Gruppen sind jedenfalls wahrscheinlich. Angehörige beider Gruppen wurden bislang fast nie gemeinsam angetroffen (Noodt, 1965 *a*).

3. Falls die unter (1) und (2) gemachten Voraussetzungen zutreffen, wäre auf eine jüngere Entstehung der Leptobathynellidae (aus einem noch evolutionsfähigen tropischen Stamm der Bathynellidae?) erst nach der Isolierung Südamerikas zu schließen. Die Leptobathynellidae haben der Konkurrenz der Parabathynellidae erfolgreich begegnen können. Aus anatomischen Gründen müssen sie sogar als die am stärksten abgeleiteten (= angepaßten) Bathynellen überhaupt gelten.

Die Frage, ob und in welchem Umfange die Bathynellen evtl. noch als primäre Meeresbewohner durch Ausbreitung im Meere die verschiedenen Kontinente erreicht und besiedelt haben, muß derzeit noch offen bleiben. Im Sinne der oben entwickelten Ansichten ist die Annahme einer Ausbreitung im Meere nicht erforderlich (vgl. jedoch hierzu die Ansichten von Birstein and Ljovuschkin sowie von Jakobi). Der Nachweis von rezenten Syncarida im Meere war bis jetzt noch nicht möglich.

Für die Zukunft sind in diesen Zusammenhängen vor allem Untersuchungen in zweierlei Richtung erforderlich:

1. Erforschung der Bathynellenfauna der in dieser Hinsicht noch nicht untersuchten Regionen (z.B. Nordamerika, Arabien-Indien, China, Australien). Falls die oben entwickelten Anschauungen zutreffen, wäre z.B. damit zu rechnen, daß auch im südlichen Afrika und auf Australien-Tasmanien-Neuseeland noch Restbestände der Bathynellidae—" Altschicht " anzutreffen sind, wie es in der südlichen Neotropis der Fall ist. Beachtung verdient ferner das Phänomen der offenbaren Häufung plesiomorpher Merkmale an der Peripherie des Areal der Parabathynellidae (vgl. Fig. 2).

2. Bemühungen um eine genauere Untergliederung der Parabathynellidae, speziell der sicher noch inhomogenen Gattung *Parabathynella*. Aus offenbarem Mangel an Spezialhomologien läßt sich bisher noch kein präziser Einblick in die feineren Verwandtschaftszusammenhänge dieser weltweit verbreiteten Gruppe gewinnen, wie er als Voraussetzung einer feineren biogeographischen Analyse erforderlich ist (Noodt, 1965 *a*).

In jedem Falle verspricht jede Vertiefung unserer Kenntnisse über Verbreitung und natürliche Gliederung dieser interessanten Crustaceen-Ordnung wertvolle Aufschlüsse in biogeographischer wie palaeogeographischer Hinsicht.

DIE GLIEDERUNG DER ORDNUNG BATHYNELLACEA CHAPPUIS (NACH NOODT, 1965 *a*)

Syncarida mit freiem 1. Thorakalsegment, nur 5 freien Pleomeren (Pleotelson!) und Furca; ohne Antennen-Statocysten, Augen und Petasma; Pleopoden stark reduziert oder fehlend.

Fam. BATHYNELLIDAE Grobben

Bathynellacea mit Paragnathen und Exopoditen an Antenne II; Labrum glattrandig, Mandibularpalpus 3-gliedrig und prähensil; Exopoditen der Thorakopoden 1-gliedrig; 1–2 Paar stets 2-gliedriger Pleopoden.

Gattung *Bathynella* Vejdovsky.

Fam. PARABATHYNELLIDAE Noodt

Bathynellacea ohne Paragnathen und ohne Exopodit an Antenne II; Labrum gezähnelt, Mandibularpalpus 1-gliedrig, nicht prähensil; Exopoditen der Thorakopoden 1-oder mehrgliedrig; 0–1 Paar 1-gliedriger Pleopoden.

Gattungen *Allobathynella* Morimoto and Miura, *Parabathynella* Chappuis, *Chilibathynella* Noodt, *Thermobathynella* Capart.

Fam. LEPTOBATHYNELLIDAE Noodt

Bathynellacea mit Paragnathen und rudimentärem Exopodit an der 5-gliedrigen Antenne II; Labrum glattrandig, zuweilen fein beborstet, Mandibularpalpus 1-bis 2-gliedrig, nicht prähensil; Maxille II prähensil, Exopoditen der Thorakopoden 2-gliedrig; Pleopoden fehlen.

Gattungen *Brasilibathynella* Jakobi, *Leptobathynella* Noodt.

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SOME FACTORS INFLUENCING THE DISTRIBUTION OF FRESHWATER PRAWNS IN MALAYA

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ABSTRACT

A single alpheid, 12 palaemonid, and 10 atyid prawns occur in Malayan freshwaters. Some are widespread, others local. Distribution of certain species are in part determined by the presence of brackish water or marine phases in their life-cycles. Others have been affected by human activity. An attempt has been made to determine the ranges of pH, 4·5 alkalinity, temperature, oxygen, calcium, etc., in which the species occur and to consider possible connections with known distributions. It is noted that two species occur in acid waters with no detectable calcium.

ONE of the features characterizing Malayan freshwaters is the abundance and variety of their freshwater prawns. Prawns are absent from a few high mountain areas, from some isolated ponds and lakelets, from certain very shallow, especially temporary waters, and from highly polluted waters. They are otherwise generally distributed and sometimes they are the dominant organisms in a habitat.

Dana (1852) described *Palaemon equidens* (= *Macrobrachium equidens*) from Singapore. This species is not a true freshwater species but the record is the first of a non-marine prawn from Malaya. Lanchester (1901, 1906) reported and described a number of species from the most northern parts of Malaya and from peninsular Thailand. Nobili (1903) reported several brackish water species from Singapore. Kemp (1918) reported some species from northern Malaya and peninsular Thailand and described *Caridina brachydactyla peninsularis* (= *C. simoni peninsularis*) from Penang. Roux (1935) described *Palaemon* (*Macrobrachium*) *malayanum* (= *M. malayanum*). In 1936 he further described *Palaemon* (*Parapalaemon*) *trompi armatus* which is synonymous with *M. trompii* (de Man). Johnson (1960 *a* and *b*; 1961; 1962 *a* and *b*) has published a series of papers on Malayan freshwater prawns and associated taxonomic and distributional problems.

As a result of these investigations and of others as yet unpublished we now know about 25 species of prawns from Malayan freshwaters. Eleven of these belong to the Atyidae, 1 to the Alpheidae, and the remainder to the Palaemonidae.

Some of these species have very localized distributions within Malaya. For example, *Caridina typus* M. Milne Edwards is only known from the Langkawi islands though abundant there,* *C. excavatoides* Johnson is only known from Kedah, whilst *Macrobrachium latidactylus* (Thallwitz) and *M. palawanense* are each confined to a few localities in eastern Malaya, so far as we at present know. By contrast such forms as *Caridina simoni peninsularis*, *Macrobrachium rosenbergii* (de Man) and *M. pilimanus* (de Man) appear to be present in suitable habitats throughout the country. We are far from understanding the reasons for the detailed distributions of the various species; but investigations carried out by us in Singapore, by defining the problems more clearly, go some way towards a solution, at least for some of the species.

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* Since this was written *C. typus* has been found in two farther groups of offshore islands.

Forms with Saline Water Phases

I have previously (Johnson, 1960 *a*) drawn attention to the different distributional patterns shown by prawns with a marine phase, or which are known to be tolerant of saline water, from the patterns shown by fully freshwater species. The overall distribution of these species resembles that of fully marine organisms. In this paper I have noted several of these species which have wide Indo-West Pacific ranges but are absent or rare in areas within the Asian continental shelf. It seems probable that they are excluded from these areas by biotic factors, that is they are unable to establish themselves in the presence of the rich and well-integrated freshwater faunas of Asia. One of these species, *Caridina typus*, occurs in Malaya. It is abundant in fast streams in the Langkawi islands to the north-west of Kedah; but we have not found it anywhere on the mainland, though we have collected habitats which appear very similar to those in which it lives in Langkawi. The distribution of this species in Malaya appears thus to be a special instance of the phenomenon of continental exclusion.

On the basis of their distribution within Malaya one can divide the majority of those species which can tolerate brackish waters into two principal groups. The first and largest group comprises those forms which are essentially inhabitants of low salinity brackish waters and only penetrate marginally into fully freshwaters. These species have a coastal distribution and are never found far from the tidal zone. Some of the freshwater populations appear to be well established but the absence of these forms from more inland localities suggests that over a long period of time these freshwater populations would die out unless there were at least intermittent immigration from neighbouring brackish water localities. Species falling into this group include *Alpheus paludosus* Kemp and several species of *Caridina* (*C. gracilirostris* de Man, *C. propinqua* de Man, *C. tonkinensis* Bouvier, and *C. thambipillaii* Johnson). It is possible that *Macrobrachium palawanense* should also be included here but its distribution is still insufficiently known.

A second group comprises those species which as adults are fully freshwater species often living far from the sea, but whose larvae are found in saline waters. Good examples are *M. rosenbergii* and *A. spinipes* Newport, both of which have been taken in rivers over 100 miles from the mouth. Neither of these species occurs in habitats which are isolated from the sea unless transported by man, though adults of *M. rosenbergii* may thrive in such habitats when introduced into them. The work of Ling and Merican (1961) has shown conclusively that the larvae of *M. rosenbergii* will only develop if the water is somewhat saline. I intend to discuss the biology and distribution of the genus *Atya* more fully elsewhere. Here it may be noted that the distribution of *A. spinipes* both within Malaya and elsewhere is consonant with the limitations imposed by the need of the adult for a torrent environment and by the presence of a marine larval phase.

There are two Malayan species which are known to show some salt-water tolerance but which do not easily fit into either of the above groups. *Caridina simoni* Bouvier is a wide-ranging species extending from Ceylon to Melanesia and Australia. This distribution would suggest some capacity for marine dispersal. However the species is not constant throughout this range but is split up into a number of subspecies, suggesting that its distribution through the seas is less efficient than that of many other species. This is consonant with the fact that though we have taken this species in low salinity waters in Malaya it is infrequent there, although it is a common species of inland freshwaters. *Macrobrachium javanicum* (Heller) has the appearance of a true freshwater species. Breeding individuals can be collected in freshwater. However I have seen an adult from almost pure sea-water at Singapore, associated with *M. equidens*. Its general distribution is sundanian as with other fully freshwater forms but it extends to the Mergui archipelago and there is a subspecies in southern Celebes. These extensions are consonant with a limited amount of dispersal (by adults ?) through the sea.

There is no evidence for marine dispersal in our remaining freshwater species and some of these certainly breed in freshwater and have no or limited salt tolerance. These include *M. lanchesteri* (de Man), *M. sintangense* (de Man), *M. trompii* (de Man), *M. pilimanus* (de Man), *M. malayanum* (J. Roux), and *M. geron* (Holthuis).

WATER-FLOW

Atya spinipes when adult and the closely related pair of species *M. pilimanus* and *M. malayanum* are confined to fast-flowing habitats. *Atya spinipes* is confined to rocky bottoms but the *Macrobrachium* species have been taken on sandy bottoms as well. *Caridina typus* also appears to be limited to fast streams; but its localized occurrence in a remote and rather inaccessible part of Malaya has prevented full investigation. Other species which can occur in fast, though seldom in torrential waters, but are not confined to these include, *Caridina weberi sumatrensis* de Man, *C.* cf. *babaulti* Bouvier, *M. geron*, *M. trompii*, and *M. rosenbergii*. Most species of *Caridina* are characteristic of slow-flowing or still waters and this is true also of such species of *Macrobrachium* as *M. lanchesteri*, *M. idae*, and *M. sintangense*. The only species commonly taken in freshwater ponds are *Caridina simoni peninsularis* and *M. lanchesteri*; but both *M. idae* and *M. sintangense* have occurred in such habitats and *M. rosenbergii* flourishes without reproducing itself if artificially introduced.

Just how far these restrictions reflect direct influence of water-flow it is impossible to say. The absence of *M. rosenbergii* from fully stagnant waters is certainly fortuitous, being a consequence of the need of the larva for saline water. It is at least possible that the absence of other species from pond habitats may be likewise due to similarly fortuitous factors. The inability of the torrent species to establish themselves in slow waters is more probably due to a combination of such factors as oxygen content, temperature, and other animals rather than to any direct effect of water movement or its lack. On the other hand it is significant that those species of *Caridina* which are not found in fast waters are all small forms with delicate build, whereas those species which occur in fast waters tend to be larger and more robustly built. Thus it may well be that the slow-water species are physically incapable of withstanding a considerable water-flow.

ALTITUDE

At high levels in Malaya (approximately above 4,000 ft.) prawns are absent as are almost all freshwater fish. This exclusion does not seem to be the result of any simple environmental factor. The temperatures are not too low at least for certain species, as we will see below. In other features many habitats above 4,000 ft. seem well suited for both prawns and fish. Freshwater prawns have often been found at high levels in the greater Sunda islands. One cannot avoid the conclusion that the absence of prawns from these levels is a consequence of inaccessibility of the habitats. Streams at these higher levels are almost all cut off from the lower levels by extensive series of very steep rapids and commonly at least by high waterfalls.

Still-water species in Malaya are only known from very low levels. We have no records from above 500 ft. Once again inaccessibility of the habitats is most probably the deciding factor. By contrast the torrent species are found in hilly areas and are rare at low altitudes. The restricting factor here is the availability of suitable habitats not altitude as such. Holthuis (1950) listed 250 metres as the lower limit for *M. pilimanus* but we have found it in fast streams almost down to sea-level and it is common in Malaya at heights of about 300 ft. (100 ms.). Given torrent streams in tree country these torrent prawns can flourish in generally low-lying areas.

HUMAN ACTIVITY

The indirect effects of human activity have undoubtedly been important in determining the distribution of prawns within Malaya. Some species have suffered; others have been favoured.

M. lanchesteri is one of the species which has been favoured; within Malaya its distribution is closely correlated with areas of riceland and fish ponds. *M. lanchesteri* appears to have originated in the monsoonal countries to the north of Malaya. It is still abundant in the lowlands of Thailand and I have seen specimens from the lowlands of Burma. The extension of rice-cultivation has allowed it to spread southwards until now it is the most abundant prawn in the developed areas of western Malaya as far south as Malacca State. It has also established itself in Johore Bahru and Singapore island in circumstances which strongly suggest accidental introduction from the north. Another species of *Macrobrachium* which may have benefited by rice-cultivation is *M. sintangense*. This species is certainly more abundant in open country than it is in tree-country. However it is more restricted to hard waters than are many of our prawns and this may also contribute to its distributional pattern.

Where felled forests have been replaced by rubber estates or other tree cultivation this seems to have little long-term effect on the prawn population. Where however, the tree cover is permanently removed this can result in the disappearance of many species, especially of forms such as *M. trompii* and *M. geron* which live in leaf-beds. In general the Atyidae are much less restricted to tree country than are the Palaemoninae and all Malayan species of *Caridina* have been found in open country, with the exception of *C. typus*, though *C. weberi sumatrensis* appears to be somewhat more frequent in tree country.

OTHER CHEMICAL AND PHYSICAL FACTORS

In an attempt to give greater precision to our knowledge of the factors governing the distribution of freshwater prawns within Malaya I have collected together my field records of prawns together with records of the pH, 4·5 alkalinity, oxygen saturation, calcium, sodium and potassium contents of the water at the time of collection and also the temperature of the water. Data for all factors except the metallic ion contents are based on over 100 habitats spread throughout Malaya, though with some preponderance of southern habitats. Owing to technical limitations it has only been possible to carry out determinations of the metallic ions in a comparatively small number of localities in southern Malaya and it is hoped to extend this aspect of the work in future. The ranges determined for the different species are given in the tables and graphs and the factors are discussed individually below. The greatest value of such results is in providing evidence of conditions which the species concerned can definitely withstand under natural conditions. They also are useful in delimiting the natural ranges of species with respect to the factors. Thus one can say with confidence that *M. trompii* is an acid-water species if one means by that statement that in nature its occurrence is closely correlated with waters of low pH. What one cannot say from such results is that the species cannot survive in waters of high pH. This may be so but it is not established from the results. Comparative physiological experiments would be needed to give strength to such a statement and even then there would be doubts because of the inevitable differences between a laboratory and a natural environment. Similar considerations apply to other species and other factors. Again it does not follow that because a correlation has been established between the distribution of a species and any given physical and chemical factor that that factor is itself crucial in limiting the distribution of the species. The true limiting factors may be unmeasured factors closely correlated with the factor being measured. Again it is most probable that the distribution of any species is determined by factors acting in combination rather than in isolation. In other words interactions between factors will be important and it will be the total environment rather than its parts to which the organism reacts. Many of these points have already been put cogently by Macan (1963) who has pointed out that there is probably only one freshwater species about which we can point with absolute certainty to the real limiting factors. With these limitations borne in mind it is hoped that the tables and graphs have validity as descriptive rather than explanatory summaries. The time is not yet ripe for the latter and possibly never will be in this field.

TEMPERATURE

Recorded ranges for temperature are shown in Table I and Fig. 1. The range of records obtained by the Deutschen Limnologishen Sunda-Expedition in Sumatra, Java and Bali (abstracted from J. Roux, 1933) are included in the figure for comparison. The comparatively small ranges for all species reflect the small range of temperature variation found in lowland freshwaters in Malaya. This is especially true of the lower limits which almost certainly do not represent the lowest temperatures at which any species can survive in the wild. This is clearly brought out when the Malayan figures for *Macrobrachium pilimanus* are compared with the range abstracted from Roux's report. The lower temperatures given in that report reflect the greater altitudes at which the species has been found in Java and Sumatra. Two other species *M. trompii* and *M. geron* have been kept alive for considerable periods in our laboratory at temperatures around 21° C., though without reproducing. These considerations are of importance in assessing the absence of prawns at high altitudes in Malaya (see above). *M. pilimanus* could certainly stand the temperature conditions at these heights and *M. trompii* and *M. geron*, and possibly other species also could probably do so.

TABLE I

Temperature ranges for freshwater prawns in natural habitats in Malaya

Species	Number of records	Temperature ° C.	
		Range	Mean
C. gracilirostris	4	26·5–30·0	28·3
C. simoni peninsularis	11	24·5–35·5	28·3
C. propinqua	4	26·5–35·5	30·8
C. tonkinensis	5	26·5–30·0	28·4
*C. weberi sumatrensis**	8	23·5–28·0	25·7
C. typus	4	25·0–27·0	26·1
A. paludosus	3	24·8–25·0	24·9
M. rosenbergii	6	24·5–25·5	25·1
M. lanchesteri	34	25·5–33·5	29·3
M. idae	3	24·8–29·5	26·9
M. sintangense	9	24·8–32·3	27·5
M. javanicum neglectum	8	24·5–30·5	26·2
M. trompii	36	24·5–35·5	26·4
M. pilimanus	17	22·5–29·0	25·7
M. geron	14	24·5–27·8	26·0

* Includes records made by Nicholl and Floyd at Kuala Lumpur.

There is a general correlation between type of habitat in which the species most frequently occurs and its temperature range. Forest and tree-country species are in general known from a narrower range of temperatures than are those forms found in open country. This reflects the very constant temperature conditions of forest streams in the Malayan climate. *M. trompii* forms an interesting exception to this generalization and one which would act as a warning against the facile acceptance of high temperatures as limiting factors for forest species. *M. trompii* is commonest in streams in tree-clad country and hence, as the position of the mean shows is most frequently encountered in waters with rather low temperatures (for Malaya). It also occurs, however, in open-country blackwater streams with bottoms consisting in part or entirely of peaty detritus and thus comparable to the leaf-beds in which it is commonly found in forest streams. Some of these blackwater streams can reach very high temperatures and, as the records show, *M. trompii* is not excluded by these.

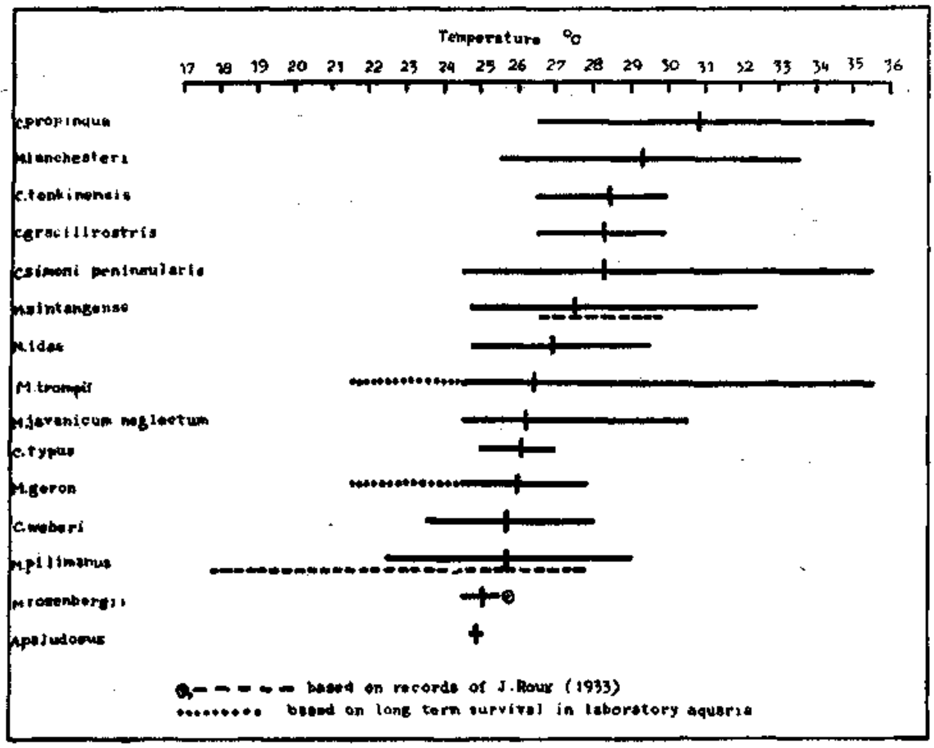

FIG. 1. **Temperature ranges of some Malayan freshwater prawns in natural habitats in Malaya.**

Most Malayan freshwaters, even in open-country, have water temperatures which seldom or never exceed 33° C. Exceptions include some of the blackwaters just mentioned, a few shallow ponds and ditches, and hot springs. Apart from *M. trompii* only three species have been demonstrated as occurring in such waters. All three are common in open-country. *Caridina simoni peninsularis* and *Macrobrachium lanchesteri* are common in still and almost still waters. *C. propinqua* is probably the commonest prawn of our low-salinity brackish waters. The difference in temperature range for this species and for the other two species of *Caridina* with similar habitat may be a result of sampling accidents but it is in good general agreement with the greater frequency of *C. propinqua* in small, shallow habitats.

OXYGEN CONTENT

Data on oxygen ranges are given in Table II. The determinations are daytime determinations. In many of the habitats the night-time oxygen content will be distinctly lower. It is of considerable interest that several species can survive in habitats where the oxygen content can fall to very low levels. None of these species are air-breathers and none show any striking modifications for life in low oxygen concentrations. It must be admitted, however, that increased concentration of haemocyanin would be much less obvious in the absence of special investigation than increased concentration of say haemoglobin.

TABLE II

Oxygen saturations of waters containing freshwater prawns in Malaya

Species	Number of records	Range %	Number below 25%
C. gracilirostris	1	20	1
C. simoni peninsularis	7	25·5–87·0	0
C. propinqua	1	20	1
*C. weberi sumatrensis**	8	30·0– 94·7	0
M. rosenbergii	2	56·0– 87·0	0
M. lanchesteri	17	1·0–145·0	5
M. sintangense	5	32·0– 87·0	0
M. javanicum neglectum	3	56·0– 87·0	0
M. trompii	12	10·2– 84·0	4
M. pilimanus	10	32·0–160·0	0
M. geron	6	16.2– 87·0	2

* *See* footnote to Table I.

Macrobrachium lanchesteri is revealed as a remarkably eurytropic species with respect to oxygen as to other factors. It has been found in waters with oxygen saturations ranging from 1% to 88% saturation as determined by standard Winkler technique. This is the only palaemonid prawn which has been found in habitats with oxygen saturations of less than 10%. Even so it is much more frequently encountered in somewhat higher oxygen concentrations and only two out of seventeen records are for habitats with saturations of less than 15% (1% and 10·5%). Amongst the atyids *Caridina tonkinensis* has been recorded from a habitat with oxygen saturation of 9%.

The leaf-bed prawns, *Macrobrachium trompii* and *M. geron* can also occur in places with fairly low oxygen content. *M. trompii* has twice been found in a saturation of 10·2% and twice in a saturation of 18%. Two determinations in leaf-beds populated by *M. geron* were of 16·2 and 18·0%.

No other species has been recorded from waters with oxygen saturation less than 20%. It is worthy of note that there seems to be very little correlation between the occurrence of species in low oxygen habitats and their general nature as tree-country or open-country forms. Low and high oxygen habitats occur in both general environments but only certain species in each environment are able to penetrate into low oxygen environments. It is also worthy of note that no species has been found in habitats with undetectable oxygen. As a group the freshwater prawns seem to be less tolerant of low oxygen than such groups as the freshwater fish.

pH

Data for pH are given in Table III and Fig. 2. In interpreting these it must be remembered that most freshwaters in southern Malaya are slightly to distinctly acid. Thus there is a slight sampling bias in favour of acid habitats and this may well be reflected in a shortening of the alkaline end of the range of some species. Roux's records from Sumatra and Java where alkaline waters are frequent form a useful supplement at this point and these ranges have been included in the figure for comparison.

Taking the two sets of results together it will be noted that four species, *Caridina propinqua*, *C. simoni peninsularis*, *Macrobrachium sintangense*, and *M. pilimanus*, have been found in highly alkaline habitats with pH above 8·0. All species extend into slightly acid waters and all save

TABLE III

pH ranges of freshwater prawns in natural habitats in Malaya

Species		Number of records	Range	Mean
C. gracilirostris	..	4	5·4–7·0	6·2
C. simoni peninsularis	..	9	5·9–8·2	6·5
C. propinqua	..	3	5·4–8·2	6·8
*C. weberi sumatrensis**	..	9	5·6–7·5	6·8
C. typus	..	4	6·0–7·3	6·6
M. rosenbergii	..	4	5·2–6·2	5·8
M. lanchesteri	..	27	4·9–7·6	6·4
M. idae	..	3	5·0–7·4	6·0
M. sintangense	..	7	5·5–7·4	6·5
M. javanicum neglectum	..	7	5·8–6·5	6·1
M. trompii	..	27	4·4–7·4	5·7
M. pilimanus	..	10	5·0–7·4	6·2
M. geron	..	14	5·7–7·4	6·1
A. paludosus	..	3	5·0–6·2	5·7

* *See* footnote to Table I.

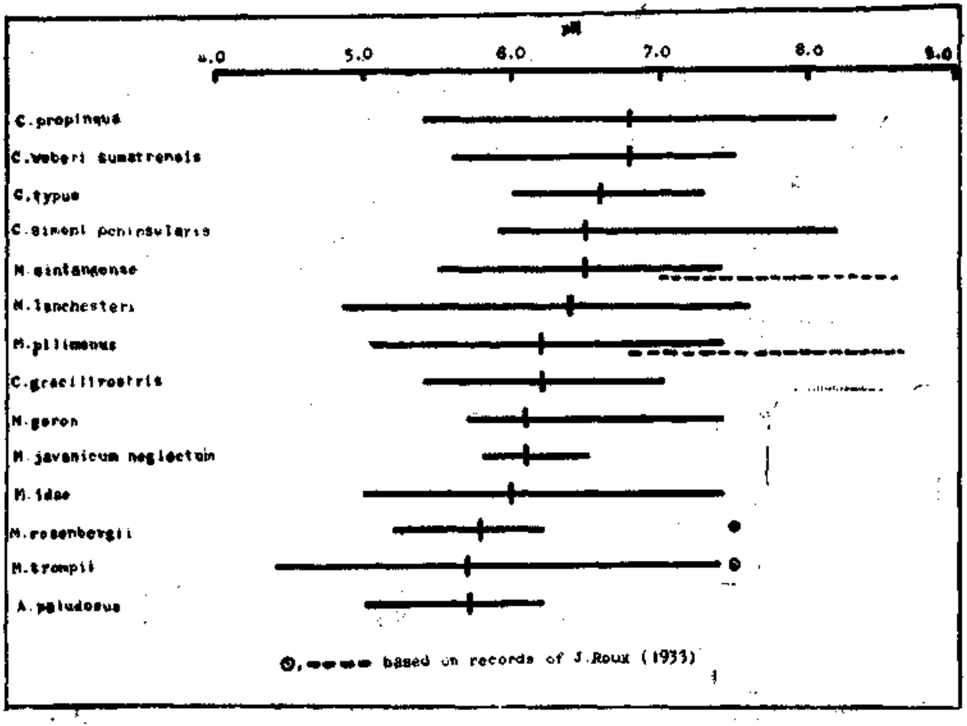

FIG. 2. pH ranges of some Malayan freshwater prawns in natural habitats in Malaya.

Caridina typus have been found in distinctly acid waters with pH of less than 6·0. Four species, *Macrobrachium lanchesteri*, *M. pilimanus*, *M. trompii* and *Alpheus paludosus*, extend into very acid waters with pH of less than 5·0. Only *M. trompii* has so far been reported from waters of pH less than 4·5, that is with zero alkalinity.

Most of the species can tolerate a wide range of pH values. The very wide total range of *M. pilimanus* is especially noteworthy. In general the species of *Caridina* are found in higher pH values than are the Palaemonidae but there is a wide overlap. The success of so many species in acid habitats is noteworthy in view of the importance of calcium carbonate for skeletal hardening in prawns.

4·5 ALKALINITY

4·5 alkalinity was determined by titrating with N/50 HCl using B.D.H. 4·5 indicator. Results of such tritrations are commonly expressed in terms of calcium carbonate equivalent. We have good evidence that in many Malayan freshwaters, certainly in most of the softer freshwaters, calcium carbonate contributes only an inappreciable fraction to the alkalinity. It seems best therefore to express the results in terms of volume of HCl used. In order to facilitate comparison with other results the standard chosen is the volume of N/10 HCl needed to bring the pH of a 100 ml. sample to 4·5. The results are given in Table IV and Fig. 3. In the figure results abstracted from Roux's paper have been included for comparison. The figure is plotted on a logarithmic scale in order to bring out more clearly the varying limits of the species at very low alkalinities. 1 ml. N/10 HCl 100 is equivalent to the alkalinity of a solution of 50 parts per million $CaCO_3$.

TABLE IV

4·5 alkalinity ranges of freshwater prawns in natural habitats in Malaya

Species	Number of records	ml. N_{10}HCl per 100 ml.	
		Range	Mean
C. gracilirostris	1	0·420	..
C. simoni peninsularis	7	0·080–0·800	0·291
C. propinqua	5	0·114–3·552	1·397
C. tonkinensis	3	0·420–0·920	0·620
C. thambipillaii	1	0·100	..
C. cf. *babaulti*	3	0·080–0·600	0·267
C. weberi sumatrensis	2	0·360–0·456	0·408
C. typus	3	0·400–2·076	1·345
A. paludosus	3	0·080–0·100	0·090
M. rosenbergii	5	0·080–1·560	0·616
M. lanchesteri	31	0·120–2·800	0·511
M. idae	2	0·090–0·530	0·310
M. sintangense	7	0.080–0·570	0·387
M. javanicum neglectum	4	0·080–0·320	0·180
M. trompii	26	0·000–0·760	0·153
M. pilimanus	17	0·080–3·320	0·570
M. geron	8	0·060–0·200	0·110

Any alkalinity of less than ·10 corresponds to a very poorly buffered water and, on the assumption of correlation with calcium carbonate content to very soft waters. With the exception of

M. lanchesteri all the treated species of *Macrobrachium* have been found in such waters at least once; but only two species of *Caridina* have been found in them. Only two species have been taken in waters with alkalinities of less than ·08. These are *M. trompii* and *M. geron* the two commonest species in acid water forest streams in southern Malaya. *M. trompii* alone occurs in waters with zero alkalinity and it has on several occasions been taken in waters with less than ·05 alkalinity.

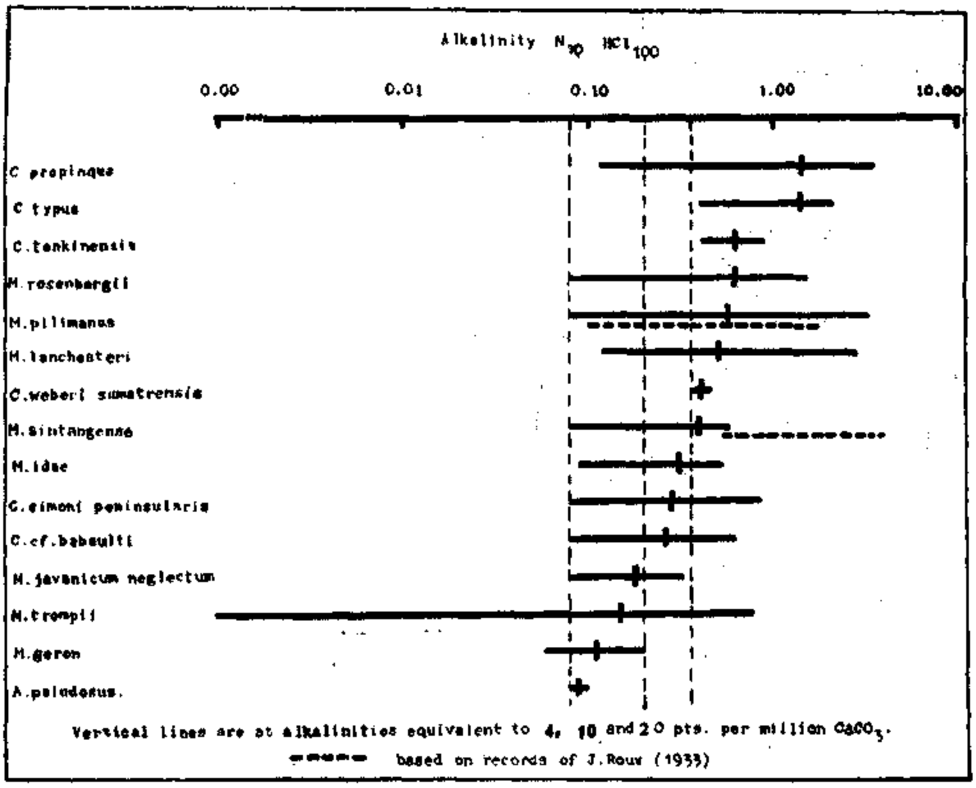

FIG. 3. 4·5 **alkalinity ranges of some Malayan freshwater prawns in natural habitats in Malaya.**

Taking an alkalinity of ·40 as corresponding to a well-buffered reasonably hard water we find that all the species have been recorded at least once from such waters with the exception of *M. geron*, *M. javanicum neglectum* and *Alpheus paludosus*. The absence of records for the last two species is almost certainly the result of sampling error but the general pattern of occurrence of *M. geron* justifies the tentative conclusion that it is a soft water species. The same conclusion can be made for *M. trompii* for which species only 2 out of 27 determinations exceed ·40. On the other hand the records for *Caridina typus, C. tonkinensis, C. gracilirostris*, and *C. weberi sumatrensis*, indicate that these species are characteristic of high alkalinity waters. In the genus *Macrobrachium* one may note that 17 out of 31 determinations for *M. lanchesteri* and 4 out of 7 for *M. sintangense* are from waters with alkalinity of more than ·40. These figures are the more significant in the light of the bias in collecting towards low alkalinity habitats. Both these species appear to be characteristic of high alkalinity waters. The records of Roux for *M. sintangense* support this conclusion.

CATIONS

We have only recently been able to determine with accuracy any of the cations in our freshwaters so that our records are very incomplete. Those available are given in Table V. The ability

TABLE V

Malayan freshwater prawns and associated concentrations of calcium (Ca), sodium (Na) and potassium (K), in southern Malayan habitats

(Concentrations are given in parts per million)

Species	Ca	Na	K
C. gracilirostris	0·25	1·65	1·98
C. simoni peninsularis	..	1·40	1·04
C. weberi sumatrensis	..	1·30	0·45
C. propinqua	0·25	1·65	1·98
M. rosenbergii	1·40	..	..
M. lanchesteri	3·20	0·26	1·68
M. sintangense	..	1·40	1·04
	..	1·30	0·45
	3·20	0·26	1·68
M. trompii	..	1·40	1·04
	..	1·30	0·45
	0·00	1·45	0·41
	0·00	1·65	1·98
	0·00	4·00	0·40
	0·00	6·00	0·30
	0·80	..	..
	1·00	..	..
	1·20	..	..
	1·25	1·60	0·23
	1·40	..	..
	2·50	28·10	2·00
M. pilimanus	..	1·40	1·04
	..	1·30	0·45
M. geron	..	1·40	1·04
	0·00	4·00	0·40
	0·00	6·00	0·30
	1·00	..	..
	1·40	..	..
	1·50	1·50	0·45

of *M. geron* and *M. trompii* to survive in waters with no detectable calcium is especially noteworthy. With the apparatus used this corresponds with a concentration of less than about ·02 parts per million. One may also note the very ill-balanced ratios of calcium to sodium and potassium even in some of the calcium-containing waters in which *M. trompii* has been found.

GENERAL DISCUSSION

The connection between distribution and tolerance of high salinities, at least at some stage in the life-history, is very clear for Malayan freshwater prawns. The interpretation of other factors is less evident. Species can be divided into two groups of torrenticolous and non-torrenticolous prawns. Whilst it is probable that fast water-flow prevents some forms becoming established in torrents there is no evidence that those forms which are limited to fast waters demand considerable water movement as such. The limitation, whatever its cause, does result in the restriction of such species as *Caridina typus*, *Atya spinipes*, and *Macrobrachium pillimanus* to hilly and mountainous areas. There is no evidence that altitude as such (within the Malayan range) is important in limiting the distribution of any Malayan species. Apparent altitude restrictions such as that cited by Holthuis (1950) for *M. pilimanus* are most probably the result of other factors. However low level country has few torrents so that torrent prawns are rare there. Conversely forms of slow waters are only found at low levels since they have not been able to scale the torrents of hilly country. The complete absence of prawns at altitudes above 4,000 ft. in Malaya is a reflection of the barriers to dispersion imposed by torrents and waterfalls at lower levels.

There is no clear-cut evidence that temperature is an important factor in limiting the distribution of Malayan freshwater prawns. However, work needs to be done on such aspects as the long-term effects on reproduction before temperature can be dismissed as a limiting factor. The ability of *M. trompii* which is usually a forest form to withstand temperatures of 36·5° C. is noteworthy.

Contrary to expectation it has not proved possible to demonstrate any correlation between ability to survive in low oxygen habitats and forest or open-country dwelling habits. In view of the absence of air-breathing adaptations and of obvious adaptations the ability of certain species to withstand very low oxygen concentrations is noteworthy.

The ability of many species, especially of the genus *Macrobrachium* to survive in very acid waters with low alkalinity and very low calcium content is of considerable interest, especially in view of the importance of calcium carbonate as a material for hardening the skeleton. The species *M. trompii* is especially noteworthy in this respect. Most work on tropical freshwater prawns has been done in hard-water areas so that it is difficult to find data on which to assess how general is the ability to live in such soft, acid waters amongst tropical prawns. The only comparable data available to me are those given by Holthuis (1959) for Surinam. It is clear that several species penetrate into acid waters in Surinam and the species *Euryrhynchus wrzesniowskii* Miers appears to be closely comparable to *M. trompii*, in this respect.

There is a good correlation within Malaya between the ability of a species to survive in acid, soft waters and its general distribution. Harder water species such as *M. lanchesteri* and *M. sintangense* are rare in southern Malaya, especially in tree country. On the other hand the species *M. trompii* and *M. geron* which are characteristic of acid, soft waters, are abundant in southern Malaya but have not yet been found in the most northern parts of the country. *M. geron* is only known from Banka outside Malaya and both are unrecorded from the hard water areas of southern Sumatra and from Java. In the absence of knowledge of their ecological requirements it would be tempting to interpret the central Sundanian distributions of these two species as resulting from historical factors. The ecological factors render such historical hypotheses unnecessary. It is noteworthy that many Malayan freshwater fish, especially in the genus *Rasbora*, which have likewise been considered as southern species, are really limited to acid, soft-water areas (Johnson and Tan, unpublished results).

One striking feature of these results is the ability of several species characteristic of low salinity brackish waters to survive in soft, acid waters near the sea, even though they have not been able to penetrate far inland. *Alpheus paludosus* is a good example of such species.

Prawns are influenced by the total environment rather than by any single factor in isolation. Thus where other conditions are suitable a species may occur outside its normal range with respect to any given factor. Thus *M. trompii* has as its central niche: soft, acid, peaty, forest streams, slow-flowing to moderately fast and containing plenty of leaf-beds. In the Kuala Tahan area it survives in streams which are only slightly acid and which contain hard water. These streams are however in forest country; they have voluminous leaf-beds; and they are slightly peaty. In the other direction *M. trompii* extends into open-country habitats where these are very acid, very peaty and where they possess stretches of bottom with peaty detritus.

Competition between species may also be of some importance in determining their distribution. Unfortunately it is very difficult to prove exclusion by competition. It probably plays a part in the distribution of such species as *Caridina typus*. *M. geron* is normally found in slow to moderately fast streams, especially in leaf-beds; but I have encountered it filling the niche of *M. pilimanus* in a stream on Gunong Pulai from which the latter species was absent.

SUMMARY BY SPECIES

Alpheus paludosus

This is really a species of low salinity waters which only marginally penetrates into freshwater. Somewhat surprisingly it occurs in acid waters with low alkalinity. There is no clue as to why it does not succeed in penetrating into inland freshwaters.

Caridina gracilirostris

This is a euryhaline species which only marginally penetrates into freshwater. It extends into distinctly acid waters but has not so far been reported from waters with very low alkalinity. It has not so far been collected in temperatures above 30° C. It seems to be less frequent in small shallow habitats than *C. propinqua*.

C. simoni peninsularis

This form is widely distributed in lowland freshwaters both slow-flowing and stagnant. It is especially frequent in weedy waters and is in consequence very local in tree-country. It has not been reported from saline waters but we have collected it from non-saline tidal waters and it may well extend into brackish waters on occasion. It appears to be more strictly restricted to higher pH values than any other investigated species except *C. typus* but is nonetheless frequent in slightly acid waters. It does penetrate into waters with distinctly low alkalinity but is more frequent in waters of higher alkalinity. It penetrates into waters with temperatures above 35° C. It has not been found in waters with low daytime oxygen content.

C. propinqua

This is another low-salinity species which penetrates marginally into freshwaters. It is found in a wide range of waters from distinctly acid to highly alkaline but has not been recorded from low-alkalinity waters and appears to be rather frequent in waters with high alkalinity. This is another species which can survive in high temperature habitats. The only available oxygen record is from a rather low oxygen habitat. All these features are in agreement with its common occurrence in small, shallow, water-bodies.

C. tonkinensis

This is another brackish water species which extends marginally into freshwaters. Though it extends into distinctly acid waters it has not yet been reported from waters of low alkalinity. The three available oxygen determinations are all from waters with low oxygen content.

C. thambipillaii

Data for this species are inadequate. It appears to be a species of low salinity waters extending into freshwaters. It has been found in peaty waters and in the single brackish habitat from which alkalinity data are available the alkalinity is low.

C. cf. *babaulti*

This species has only been collected away from the sea in habitats with noticeable water-flow. It extends into waters with low alkalinity. It has not been reported from low oxygen habitats.

C. weberi sumatrensis

This is an inland species which occurs in slow to moderately fast streams. It has not been reported from brackish waters in Malaya. It has not been found in low-alkalinity waters and appears to be relatively infrequent in distinctly acid waters. It does not occur in low-oxygen habitats and it has not been reported from high temperatures.

C. typus

This is a species of fast flowing streams which is so far only known from P. Langkawi in Malaya.* Its general distribution suggests a marine dispersal phase and restricted ability to survive in the presence of a fully-developed, 'continental', freshwater fauna. Its Malayan habitats are hard waters with high alkalinity. It has not been found in very acid waters, nor in those of high temperature.

Atya spinipes

As an adult this is an inhabitant of torrent stretches of rivers and large streams. The eggs are very small and post-larvae have been collected in marine habitats. Its general distribution can be explained in terms of marine dispersal and the need of the adult for torrent habitats.

Macrobrachium rosenbergii

M. rosenbergii is widely distributed in rivers and large streams. The adults can survive in still-waters but the larvae cannot survive in pure freshwater so that the species only occurs in those habitats which can be reached by spreading upstream from brackish areas. Within these limits it occurs throughout the lowland area of Malaya, extending as far as the beginnings of the torrent zone, and occurring up to over 100 miles from the sea. It occurs in both low and high alkalinity habitats. The only available Malayan records for pH are from distinctly acid waters but it is recorded from pH 7·5 by Roux and undoubtedly occurs in waters of high pH in Malaya. It has not been recorded from high temperature or low-oxygen habitats.

M. lanchesteri

This species is especially common in riceland and other open-country areas and it is not normally found in tree-country. It most probably entered Malaya from the north, and with the extension of open-country habitats it has become the most common species in many parts of western Malaya. It has not been found in habitats with very low alkalinities but it has sometimes occurred in distinctly acid waters. It has a wide temperature tolerance and can occur in habitats with very low oxygen content. *M. lanchesteri* commonly occurs in abundance and despite its small size it might well be worthy of commercial exploitation.

M. idae

Though widely distributed this species is nowhere very abundant. It has been taken in brackish water. It has not been found in waters with very low alkalinity and it has not yet been reported from very high temperatures.

M. sintangense

This species appears to be most frequently encountered in open-country habitats with at least moderately hard waters. It is however sometimes taken in distinctly acid waters. It extends into high temperature waters but it has not been found in waters with very low daytime oxygen content. Its ecological requirements probably account for its comparative rarity in southern Malaya as compared with its abundance in western Java and in parts of northern and central western Malaya.

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* See footnote on page 418.

M. javanicum neglectum

This species appears to be rather common in large and small rivers. Individuals have occasionally been taken in marine or near-marine habitats but in general the species appears to be a freshwater form. It can be found in low-alkalinity habitats but is absent from very acid waters. It has not been found in low-oxygen habitats. It has been found in moderately but not very high temperatures.

M. trompii

This is one of the two commonest prawns in forest streams in southern Malaya. It extends into fast waters but it is not found in true torrential habitats and is not normally found in ponds. It is most commonly found in or about leaf-beds or peaty detritus. *M. trompii* is characteristic of soft, acid, low-alkalinity waters and is only rarely found in harder waters. It is remarkable in being able to survive in waters with pH less than 4·5 and hence with no alkalinity and in waters with no detectable calcium. It is very common in peaty waters. Though commonest in tree-country it does occur in open-country in acid, peaty waters. It can survive at very high temperatures and is often found in low-oxygen habitats. It has a southern distribution in Malaya but this probably reflects its normal habitat requirements. These may well also account for its apparent rarity in southern Sumatra and Java.

M. pilimanus

This species is an inhabitant of fast or torrential streams and is generally distributed in both lowlands and hill country where such habitats are available. It has been reported from lower temperatures than other Malayan species and does not extend into high temperature waters. It is not found in low-oxygen habitats. It has been found over a wide range of pH from very acid to very alkaline and occurs in both low-alkalinity and high-alkalinity habitats.

M. geron

Previously considered to be a rare species this form is one of the two most abundant prawns in forest streams in southern Malaya. It is found in both slow-flowing and torrential habitats. It is especially frequent in leaf-beds and rarely extends into open-country even in peaty habitats. It is not known from high alkalinity habitats. Like *M. trompii* it has been found in waters with no detectable calcium but it does not extend into the very acid, very low alkalinity habitats in which that species is sometimes found. *M. geron* occurs in low-oxygen habitats but it has not been found in high-temperature habitats. The absence of this species from well-collected areas of Java and southern Sumatra may be as much the result of ecological as of historical factors.

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DISCUSSION

Dr. S. Jones: You mentioned about the species which is washed down to the sea. What is the size of the adults? Can the young ones ascend the waterfalls and how the larvae are captured?

Dr. D. S. Johnson: The species is *Atya spinipes*. The adults can reach a size of 85 mm. and are mature at just over 40 mm. The eggs are less than 0·5 mm. in diameter. Larvae have not been collected in streams which are uncollectable at times of flood, but post-larvae have been entering streams from the sea. The young can ascend waterfalls when the slope is about 45° but may not be able to climb sheer drops.

Dr. D. G. Frey: What sort of correlations exist between species which can occur in waters that are acidic and their morphology?

Dr. D. S. J.: Only two species are regularly found in these waters. They show no obvious unusual features. However in the rare *M. payawanense* which man be such a species the skeleton is unusually soft and flexible.

ASPECTS OF THE BIOGEOGRAPHY OF MALAYSIAN MARINE DECAPODA

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ABSTRACT

The region centred on Singapore has a rather typical but somewhat depauperate decapod fauna. Several species regarded as common elsewhere are absent or rare. Such species have oceanic distributions. Other species, especially euryhaline forms, are exceptionally well represented. Claims have been made of the presence of a major faunal boundary in the Straits of Malacca. These are discussed. Comment is also made on the group of species which extends westwards to India but not beyond. The suggestion is made that, in so far as concerns their decapod fauna the Mergui and Andaman islands and the Gulf of Thailand belong to the same sub-region as the sundanian area.

THE study of Malaysian* decapod crustacea can be said to have begun in 1852 when Dana reported a number of species from Singapore and off northern Borneo. Early reports on Malaysian crustacea include those of Walker (1887), de Man (1895–98), Lanchester (1900 *a* and *b*, 1901, 1902, 1906) and Nobili (1901, 1903 *a* and *b*). Alcock (1895–1900, 1906), Rathbun (1910), and Kemp (1916, 1918) also reported species from Malayan waters. Intensive and continuing study began in the thirties with the work of Tweedie (1935–1954) especially on grapsid and ocypodid crabs, and papers by Gordon (1936, 1938 *a* and *b*), Balss (1938) and Shen (1934). Such study has continued since the war. Buitendijk (1947, 1950) wrote two short reports on Pt. Dickson and Singapore material. During its few years of existence the Singapore Regional Fisheries Research Station made extensive collections in the waters around Malaya and Malaysian Borneo. Especial attention was paid to the Penaeidae. Work on these is reported in various papers, principally Hall (1962) where reference is also made to earlier work by Tham (1955) and others on Malayan penaeideans. Wickstead (1958) gives some information on forms taken in plankton hauls. The general collections of decapod crustaceans made by this station were kindly handed over to me by Dr. Ommanney and are being studied together with continuing collections made by the Department of Zoology of the University of Singapore. Ow-Yang (M.Sc. Thesis) has made a comprehensive study of the families Portunidae and Maiidae and a more general study of the other brachyuran groups. Johnson (1958; in press) has reported on the Galatheidea, on the Scyllaridae (in press), and, in summary, on the non-penaeid prawns (1961). In addition to studying these Malayan collections grants of study leave have made it possible for me to study collections in various European museums. We have now reached the stage where it is possible to prepare a first listing of Malayan crustacea which will have some meaning. This list is at present being compiled by Johnson and Ow-Yang. In the course of this task we have encountered certain distributional problems which may be of general interest.

DIFFICULTIES

There are two basic requirements for any distributional study: a sufficiency of collections with accurate locality labels which can be taken as reasonably representative of the faunas of the areas collected, and the accurate taxonomic treatment of these collections. Inadequacies in both collecting and taxonomy pose especial difficulties for the student of the very rich but comparatively poorly studied crustacean fauna of the Indo-West Pacific.

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* This word is used in its current political sense.

When Johnson (1961) wished to compare the fauna of Singapore, in so far as concerned caridean prawns, with that of other Indo-West Pacific areas, he found that there was no other area of comparable size which had been adequately studied. Though there was some evidence that the Singapore fauna was impoverished, yet there were more species in the Singapore list than in any published list for an area of comparable size; in consequence a valid comparison was only possible with the much larger areas of the Andamans and the Moluccas. Similar difficulties are often encountered in attempts to define the distribution of individual species. Some of these are mentioned below. Especially important are the results of the limited collecting from certain habitats which tend to be overlooked by major expeditions and often also by general collectors. A good example is provided by the prawns of littoral weed beds. These have been well studied by Kemp in the Andaman islands and have recently been intensively collected by Johnson at Singapore. In other areas they have been less intensively studied. Thus the abundance of such a species as *Periclimenes aesopius* (Bate) in the Andamans and at Singapore and its apparent rarity elsewhere or the presence of *Latreutes porcinus* Kemp in the Andamans and at Singapore and its apparent absence elsewhere are merely reflections of varying collecting intensity and are devoid of zoogeographical significance. Other groups to which similar considerations apply include the gall-crabs (Hapalocarcinidae) and the commensals of bivalves and crinoids. Absence or rarity of a species in any area means little unless one can be sure that its possible habitats have been adequately sampled.

Difficulties resulting from inadequate taxonomy must be only too familiar to workers on Indo-West Pacific crustaceans. These difficulties are especially pronounced in certain families such as the Alpheidae, the Xanthidae, and the Grapsidae, but there are very few groups where the taxonomy of the Indo-West Pacific forms has been fully established. Especially when dealing with older papers it is seldom safe to accept uncritically the writer's records and often the true identity of the specimens reported can only be established after a careful re-examination of the specimens. Such re-examination is not always possible so that doubts must remain as to the exact distribution of many species. There is still a great need for adequate studies of the faunas of different parts of the Indo-West Pacific and for more publications of the type of Barnard (1950) and Sakai (1936–39) which include sufficient information about most species to enable other workers to assess the reliability of the identifications. In view of the small number of workers in the field and the lack of available funds it is a need which is likely to remain for many years to come.

In recent years our knowledge of the distribution of Indo-West Pacific decapod Crustacea has increased greatly. A considerable number of species which were formerly thought to have restricted distributions are now known to be widespread in suitable habitats. A striking instance is that of *Linuparus trigonus* (van Siebold) reviewed by Holthuis (1965) in another paper in this symposium. In addition to the localities mentioned by Holthuis this species has also been taken to the west of Penang. As another such example *Polyonyx suluensis* (Dana) was formerly only known from the Philippine islands and immediately proximal areas. Haig (1964) has shown that it is identical with *P. denticulatus* Paulson and the species is now shown to range at least from the Red Sea to Japan, the eastern part of Indonesia and western Australia.

In view of these difficulties it might seem premature to treat the group zoogeographically. It is true that any conclusions must be to some extent tentative and speculative; but they may nonetheless have value in stimulating further investigation. This paper is intended and should be treated as such an interim report drawing attention to problems and possible future lines of advance.

THE DECAPOD FAUNA OF SINGAPORE

Combining published and unpublished records we have found that there are over 500 species known from Singapore waters. This is a very large total, greater than that for any other area of comparable size in the central portion of the Indo-West Pacific. Nonetheless there are good reasons for believing that other localities have even greater total numbers of species. As is to be expected the fauna shows a generalized Indo-West Pacific facies. Ekman (1953) and others have pointed out that within the Indo-West Pacific the greatest diversity of species occurs in the Indo-Australian archipelago the total numbers falling off to east and west and to north and south of this area. In conformity with this pattern the Singapore fauna contains in addition to many wide-ranging species other species which are dominantly western and do not appear to reach Polynesia, some which are eastern and do not reach the westernmost parts of the Indian ocean, and a few with restricted distributions centering around Singapore. Noteworthy amongst these are such forms as *Mimocaris heterocarpoides* Nobili which are so far only known from the shallow seas of the Sundaland area.

Comparison with other areas reveals that a considerable number of species which are regarded as being common and widely distributed in the Indo-West Pacific are either absent or very rare in the well-worked waters around Singapore. Many of these species are similarly rare or absent in the whole area of shallow seas extending from Siam to Sumatra, Java, and Borneo. Amongst these there are several which are recorded from the western coast of Sumatra, the southern coast of Java, and the eastern and northern coasts of Borneo. Johnson (1961) has already commented on this phenomenon in connection with the caridean prawns and shown that the group contains several well-known species of the family Hippolytidae, the families Rhynchocinetidae, and Gnathophyllidae, and several freshwater prawns, which have or are presumed to have marine phases. Despite our somewhat inadequate knowledge a similar pattern is suggested by the distribution of commensal species (Johnson, 1963). Of all the many species of *Callianassa* known from the Indo-Australian archipelago only one has been found in Singapore waters and that is a species which is normally considered to be rather rare and associated with brackish waters. Coral reef hermit-crabs of the genera *Calcinus* and *Aniculus** have not so far been found on Malayan coral reefs. The very common, reef-dwelling porcelain-crab *Petrolisthes lamarckii* (Leach) referred to by Haig (1964) as ranging 'throughout the Indo-West Pacific where it is the most abundant littoral porcellanid' is very rare at Singapore even on its favoured habitat of coral reefs. The mole-crab *Emerita emerita* is abundant throughout the Indo-West Pacific and occurs in abundance on the beaches of the oceanic side of Penang island but has never been found at Singapore. Species of *Hippa* are also still unrecorded from southern Malaya. No member of the Raninidae has been reported from Malayan waters though *Ranina ranina* (Linnaeus) occurs in the South China Sea. Amongst the Portunidae an intensive search has failed to reveal any specimens of the holothurian commensal *Lissocarcinus orbicularis* Dana though this species has been found in numbers in other areas in the Pacific and Indian Oceans. Several other members of this family are unrepresented in the very extensive collections which have been examined from Singapore though well known elsewhere in the Indo-West Pacific. Amongst these *Catoptrus nitidus* A. Milne-Edwards and *Thalamita admete* (Herbst) were found by Tweedie (1950) in the course of a very brief collecting trip to the offshore island of P. Aor in the South China Sea. Amongst the Xanthidae one may note such absentees as *Carpilodes tristis* Dana, *Zosimus aeneus* (Linnaeus), *Lophozozymus dodone* (Herbst), which Buitendijk (1960) states is 'common throughout the Indo-Pacific', and probably *Xantho gracilis* (Dana).† Other species could be added to this list.

In the light of these records one can hardly avoid the conclusion that the Singapore fauna is impoverished. As I have previously noted (Johnson, 1961) this depauperation is most clearly marked amongst the reef-dwelling forms and it is not confined to the decapod crustacea. Published records would indicate a similar depauperation in other parts of the central area of sundanian shallow seas, though it is perhaps unsafe to stress this too strongly in the absence of the sort of intensive collecting which has occurred at Singapore. As I have previously noted (Johnson, 1961) those species which are absent or rare tend to be species which have pronouncedly oceanic general distributions. To offset this impoverishment of the coral-reef fauna Singapore and western Malaya have an exceptionally rich fauna of species characteristic of high salinity brackish waters. Such genera as *Sesarma* (Tweedie, 1940), *Penaeus* and *Metapenaeus* (Hall, 1962) are exceptionally well represented and many of their species are very abundant. Other genera which are well repre-

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* The report made by Lanchester was based on an erroneous identification.

† Lanchester's record is based on an erroneous identification of specimens of *X. exaratus* (H. Milne-Edwards).

sented include those characteristic of shallow, sandy to muddy bottoms, such as *Parapenaeopsis* and *Metapenaeopsis* (Hall, 1962) and the spider-crab genera *Hyastenus* and *Doclea*. The burrowing nut-crabs, Leucosiidae, are also common and diversified with over 40 species. It is amongst such species that one finds those such as *Mimocaris heterocarpodes* and *Hippolysmata ensirostris* Kemp which have restricted 'continental' distributions.

It is fairly clear that the impoverishment of the Singapore decapod fauna is a reflection of its pronouncedly non-oceanic position. This is borne out by records from Penang and P. Aor of species not found in the much better collected Singapore area but common in the more oceanic parts of the Indo-West Pacific. Just which features of the Singapore environment are important is less clear. Singapore is one of the largest ports in the world and it is an oil transhipment and storage centre. These activities have undoubtedly led to changes in many Singapore habitats, changes which are deteriorations for much of the fauna. Thus one finds that species which are now rare, or which have not been collected in recent years, are represented in the comparatively small collections made by Archer (Walker, 1887), and by Bedford and Lanchester (partly reported in Lanchester, 1900). Amongst such forms one may note the porcelain-crabs *Petrolisthes lamarckii* and *Polyonyx triunguiculatus* Zehntner, and the xanthid *Halimede ochtodes* (Herbst).

The salinity of Singapore waters is possibly a more important contributory factor. Even at the centre of the Straits of Singapore the water is distinctly less saline than in offshore areas of the South China Sea and its salinity is more variable (Hall, 1962; Ommanney, 1961). In inshore waters the salinity may become very low especially after prolonged wet weather. Thus at Bedok on the southern coast of Singapore island facing the open straits and well away from any major estuary the salinity of the surface water sometimes drops below 20 parts per thousand and brackish water species such as *Macrobrachium equidens* (Dana) and *Callianassa maxima* occur alongside more marine species. Temperature may also be involved. In the north-east monsoon period the Singapore area is reached by a tongue of comparatively cool water from the South China Sea. Though the resulting annual variation in temperature is small it is still much more than occurs in most more oceanic areas of the equatorial tropics. Small salinity changes which might be unimportant in themselves could become more important when reinforced by this slight temperature instability.

THE STRAITS OF MALACCA—A FAUNAL BOUNDARY?

A somewhat different sort of problem is posed by the question as to whether Malayan waters are to be treated as part of a single zoogeographical area, presumably also including the non-oceanic parts of Sumatra, Java, and Borneo, or whether they are better treated as a boundary area between eastern (Pacific) and western (Indian Ocean) faunas. Tweedie (1954) on the basis of his studies of grapsid and ocypodid crabs suggested that the region could be divided into two areas, an eastern comprising the east coast of Malaya, the north-west coast of Borneo, and the region around Singapore, and a western comprising most of the west coast of Malaya. He noted several species which appeared to be limited to one of these two areas some of them forming vicarious pairs. He also claimed that the portunid crab *Thalamita prymna* (Herbst) occurred in two forms one characteristic of eastern and one characteristic of western Malaya. Ow-Yang however has found it impossible to maintain the separation of these two varieties. Hall (1958) reported that *Metapenaeus monoceros* of authors consisted of two species, *M. monoceros* (Fabricius) and *M. ensis* (de Haan) distributed respectively to the west and to the east of the landmass formed by the Malay Peninsula and Sumatra. With the discovery of specimens of *M. ensis* in the waters of north-western Malaya, Hall (1960) somewhat modified his position. He still maintained, however, his general view that the Straits of Malacca formed a barrier to the dispersal of the Penaeidae, explaining the difference in pattern between his penaeids and Tweedie's grapsoids in terms of the more off-shore breeding grounds and larval habitats of the Penaeidae. In this paper he also noted the occurrence of the shallow-water, Indian species, *Metapenaeus dobsoni* (Miers) and *Parapeneopsis coromandelica* Alcock, in the waters of north-western Malaya but not at more southerly localities on the Malayan west coast, nor in the northern Java Sea-South China Sea area. It should perhaps be noted that Hall's collections from this north-west Malayan area contained no less than 38 specimens of *M. ensis* but not a single specimen of the western *M. monoceros* which would have been expected in the area if the Malaya-Sumatra landmass were truly important in separating these two species. More recently *M. ensis* has been obtained in several other collections from the area; but so far *M. monoceros* has not been found. Hall further drew attention to the very shallow one-fathom bank between Malaya and Sumatra and suggested that a former land connection there could have contributed to the separation of eastern and western faunas. He noted that its position agrees very well with the pulative boundary between Tweedie's eastern and western grapsoid faunas.

Our work has brought to light a few other examples of apparently similarly restricted distributions. The brackish-water palaemonid prawn *Leptocarpus potamiscus* (Kemp) ranges from India to western Sumatra and Malaya and is common in the Straits of Malacca as far south as Port Swettenham; it is not found at Singapore or farther to the east. The freshwater prawn *Macrobrachium scabriculum* (Heller), widely distributed in the Indian Ocean, appears to reach its eastern limits at the west coast of Sumatra, though specimens in the Bedford-Lanchester collection show that it formerly reached Singapore. The hippolytid prawn *Tozeuma lanceolatum* Stimpson is a Sino-Japanese species which occurs at Singapore. Records from other parts of the Indo-Australian archipelago and from the Indian Ocean are of the allied *T. armatum* Kemp. However there are discrepancies in the descriptions given by various authors of the latter prawn. The leucosiids *Arcania erinaceus* (Fabricius) and *A. globata* Stimpson are a possible vicarious pair. The Singapore species is *A. globata* which also occurs in the Sino-Japanese area. *A. erinaceus* is found in the Indian Ocean but has not been taken at Singapore. However the available evidence is too scanty to justify a definite conclusion on this point. There are several other Sino-Japanese porcellanids, xanthids, and leucosiids which on present evidence reach Singapore but do not extend into the Indian Ocean but our distributional knowledge of these forms is still inadequate and their apparent absence from the Indian Ocean may well be fortuitous. In this connection it is worth noting that the xanthid *Lophozozymus pictor* (Fabricius) which is abundant in the Indo-Australian archipelago but has not been reported from India or farther west does occur on the Indian Ocean coast of Sumatra. Thus this species is not one for which the Malaya-Sumatra landmass has formed a barrier.

The case for a barrier in the vicinity of the Straits of Malacca thus rests on the known distributions of a very small number of species and several of the suggested examples are for one reason or another of rather doubtful value. The vast majority of species are found equally to the east and to the west of Malaya so that there is no indication for these that dispersal has been restricted in the area.

Amongst those forms whose ranges are limited at or near to the Straits of Malacca a high proportion inhabit brackish waters for at least a part of their life-cycle. Any postulated factor limiting dispersal must thus be particularly effective against these brackish water forms. It may be noted that the mountainous west coast of Sumatra and south coast of Java would be especially unfavourable for the spread of brackish water species, which might thus be unable to spread along these coasts from the Indian into the Pacific area and *vice versa*. Since this area is and has been for a considerable geological period a region of uplift conditions were probably equally unfavourable in the past. Any barrier in the Straits of Malacca area would thus be especially effective in preventing the spread of these forms since they could less easily circumvent it.

This solution is not completely satisfactory since it ignores the considerable numbers of brackish water species which are found on both coasts of Malaya. Certain of these such as *Alpheus paludosus* Kemp and *Callianassa maxima* have 'Indian' distributions and appear to have reached the east coast of Malaya by transpeninsular water-connections for the existence of which in comparatively recent geological times there is considerable evidence. *Macrobrachium mirabile* (Kemp) known from areas around the Bay of Bengal and from western Borneo is another brackish water form whose distribution suggests that it has crossed the Malay Peninsula in this fashion. In the present state of our knowledge it is not possible to put forward a fully satisfactory explanation of the failure of other brackish water species to avail themselves of this route.

It is also not immediately evident why the Straits of Malacca should be a barrier to dispersal rather than an avenue of dispersal. Hall (1962) invokes a former land-connection in the vicinity of the one-fathom bank; but it is not easy to see why species which had been barred by such a connection did not spread beyond it when it was breached. The waters of the southern portion of the Straits of Malacca are of rather low salinity and appear to be unsuitable for coral growth. They thus form an effective barrier to the dispersal of many species; but these have spread into the Indian Ocean *via* the coast of Sumatra. Low-salinity water could hardly explain the non-dispersion of brackish-water species.

A suggestion that has not previously been made is that the climatic gradient along the Straits of Malacca might be the limiting factor. At the northern ends of these straits the climate is slightly but definitely seasonal whilst at the southern end seasonal differences are scarcely detectable. This might well have adverse effects on the reproductive capacity of seasonally breeding species such as many penaeids appear to be. In this connection it is noteworthy that some of the species involved appear to be at the extreme limits of their known ecological range at the ends of these straits. In my view it is ecological factors of this sort rather than former land barriers which have been the true limiting factors.

There seems from the above argument to be no justification for dividing the seas around Malaya into two areas with 'Indian' and 'Pacific' affinities. Rather the whole area of shallow seas of central Sundaland can be regarded as a single province. Comparison of the Malayan fauna with published lists from the Mergui region (*e.g.*, de Man, 1888) and the Gulf of Thailand (*e.g.*, Rathbun, 1910) shows many similarities. Almost all the species found in those areas, even the rarer species, have also been found at Singapore. This is not true of other areas of the Indo-West Pacific such as Ceylon or the eastern part of Indonesia. Thus, in so far as concerns the decapod crustacea, it seems reasonable to include the sundanian seas, the shallow seas of the eastern coast of the Bay of Bengal northwards to the Irrawaddy delta, and the Gulf of Thailand in a single zoogeographical area.

AN INDIAN BARRIER?

Most Malaysian species are widely distributed in the Indian Ocean but there are a number of species which extend to the region of Ceylon and southern India but not, so far as is at present known, farther west. Such species include amongst others: *Metapenaeus dobsoni* (Miers); *Penaeus latisulcatus* Kishinouye; *Parapeneopsis coromandelica* Alcock; *Hippolysmata ensirostris* Kemp; *Macrobrachium equidens* (Dana)*; *Alpheus paludosus* Kemp; *Atergatis dilatatus* de Haan; *Euxanthus exsculptus* (Herbst); and *Porcellana spinulifrons* Auct.† There are also some species which extend up to the west coast of the Indian peninsula as far as Karachi but are not recorded from further west. Examples are *Penaeus penicillatus* Alcock; *P. merguiensis* de Man; *Metapenaeus brevicornis* (H. Milne-Edwards); and *M. mutatus* (Lanchester).

On the other hand there are several species which appear to be common in the western Indian Ocean but have never been found in the sundanian area. Most of these are known from the eastern side of the Arabian Sea, several occur in Ceylonese waters but they have not been reported from more northerly localities in the Bay of Bengal. It may be that some of these may yet be discovered further east, for instance *Petrolisthes rufescens* (Heller) which Haig (1964) lists as endemic to the western Indian Ocean seems to be present in collections in the British Museum said to have come from Borneo; but there are too many of them for the facile explanation of accidents of collection

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* Records from the east coast of Africa are based on erroneous identifications.

† To be renamed by Johnson (in press).

to be easily accepted. Amongst others the group includes: *Macrobrachium rude* (Heller), a brackish water species; *Pachycheles natalensis* (Krauss); *Petrolisthes ornatus* Paulson; *Dehaanius dentatus* (H. Milne-Edwards); and others. In addition to these there are a few species which are common in this transition zone of southern India-Ceylon but have not been found elsewhere. A good example is *Polyonyx hendersoni* Southwell.

Combining these lines of evidence we get an indication of a sub-regional boundary between the western Indian Ocean and the central Indo-West Pacific with the west coast of India forming a transition zone between the two. It is not easy to postulate why there should be dispersal difficulties in the absence of a more thorough knowledge of water movements than we at present possess. It is also necessary that many more collections should be made along the western coast of India and westwards to the Persian Gulf if we are to verify the existence of a boundary in this region. A sub-regional boundary which affected decapod crustaceans alone would be rather incredible. However there is evidence for a similar distributional boundary in other groups, for instance in the copepod family Pseudodiaptomidae (Grindley, personal communication).

SUBDIVISION OF THE INDO-WEST PACIFIC REGION

It is tempting to subdivide the Indo-West Pacific into Indian Ocean and West Pacific divisions. This would imply the existence of a major faunal boundary in the region of the Malay Peninsula. As we have seen there is no good evidence for this. On the contrary there is good evidence that the region of the Malay Peninsula and the Indo-Australian archipelago represents a central area for the Indo-West Pacific fauna. This apparent anomaly becomes intelligible when we realize that shallow-water forms are distributed along the coastlines of the ocean basins. The many peninsulas and islands of the Indo-Australian ensure continuity of the coastal faunas of the two oceans. Major divisions of the coastal fauna must be quite different if they exist. We have seen that, in the present state of our knowledge, there is a case for regarding the western Indian Ocean as a major subdivision. There is a much stronger case for recognising an eastern or polynesian subdivision. A glance through almost any extensive paper giving full distributions of species suffices to show the impoverished nature of the fauna of that area. For example not a single species out of the 53 species of Penaeidae treated by Hall (1962) is listed as extending to Polynesia. Of 16 Xanthidae occurring in the Indo-Australian archipelago for which Buitendijk (1960) records distributions extending from the western Indian Ocean to Japan and/or Australia five do not appear to reach Polynesia and a sixth is only noted from the western border of the area at Fiji. There is thus reason in the present state of our knowledge to recognize three major subdivisions within the Indo-West Pacific, at least with respect to littoral decapod Crustacea; a western region comprising the western Indian ocean merging by a transition zone in the area of western India and Ceylon into a central region comprising the coasts of the Bay of Bengal, the seas and coasts of eastern Asia, the Indo-Australian archipelago, the northern coasts of Australia, the Palau islands, and Melanesia, and an eastern region comprising Hawaii and Polynesia.

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ON THE OCEANIC TRANSPORT OF CRAB LARVAL STAGES*

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ABSTRACT

Evidence from the disciplines of oceanography, marine geology, crustacean physiology, life-history and faunistic studies is marshalled in an attempt to demonstrate the probable manner in which fragile-bodied and short-lived crab zoeae and megalopa have been able to span ocean barriers, following major ocean currents as highways and using remote islands as stepping-stones to continental shores. While the concept has been developed in connection with distribution studies of crabs of western America and its offshore islands in the eastern Pacific, it is believed applicable with suitable refinement to other continents and their outlying islands in other seas.

INTRODUCTION

IT is nearly 20 years since the writer postulated, in connection with studies on Galapagos Brachyura, that "the system of oceanic circulation observed in the Galapagos Islands, *plus* that known to exist in the greater Pacific area, are together capable of accounting for the recognized distribution of brachyuran species within the archipelago on the basis of oceanic transportation of larval stages alone" (Garth, 1946, p. 617). In that study the California, Niño, Peru, and Equatorial Counter currents were designated, either singly or in combination, as the agencies responsible for the transporting of larval stages to the archipelago from the Baja California-Gulf of California region, the Bay of Panama, the South American west coast, and trans-Pacific islands. As a corollary the role of intervening islands as way-stations was recognized : "The fact that other Galapagos species are common to the intermediate outposts of Clarion and Socorro....suggests that these islands, along with those of Cocos and perhaps Clipperton, may have served as stepping-stones for current-borne larval stages" (*Ibid.*, p. 609).

As stated by Hamilton (1956, p. 51), "The chief objection to over-water migrations of shallow-water animals has been the tremendous distances these animals must travel over deep water before finding shallow water of the right temperature in which to find lodgment". In the past twenty years, and particularly within the last ten, considerable progress has been made toward overcoming this objection, and the once unanswerable question of how a fragile and short-lived crab zoea or megalopa can be transported by powerful but torpid ocean currents over distances seemingly too great to be encompassed within its assumed life-span and at their known speeds is well on the way toward solution. The answers are partial and come from six different disciplines, three physical and three biological: oceanography, marine geology, glaciology, crustacean physiology, life-history studies, and faunistic studies. Together they present a more convincing argument, if not an actual proof, in support of the type of transportation postulated than could be given when evidence was largely conjectural and factual information was scanty.

EVIDENCE FROM OCEANOGRAPHY

The nature of ocean currents is better understood now than a few years ago. The late H. U. Sverdrup in a personal interview likened the North and South Equatorial currents to massive

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Mississippis, westwardly directed, piling up water against the Asiatic coast to a height of eight feet, then turning to the north and south to begin their gigantic gyrals, clockwise in the North Pacific and counter-clockwise in the South Pacific, while between them the narrow but swift Equatorial Counter Current flowed eastward, downhill, all the way to the American coast. While there is nothing basically wrong with this concept, it fails to account for the presence in the Galapagos Islands of crabs of Indo-west Pacific origin, for this narrow current passes hundreds of miles north of the Galapagos, and in order for the larval crabs to get there it is necessary that they be carried back from the Bay of Panama by the Niño Current, a southwesterly directed current that periodically or intermittently bathes Galapagan shores.

To clarify his understanding of the situation the writer addressed the following letter to the Woods Hole Oceanographic Institution (May 19, 1948):

"In my research, which is concerned with the distribution of brachyuran Crustacea in the eastern tropical Pacific, it is necessary to account for the presence of identical intertidal forms on islands separated by hundreds of miles and sometimes by thousands of miles of open ocean. To do this I have postulated the transport of larvae by ocean currents; but to attain these distances at the known speed of the currents involved, it is necessary to assume a lower metabolic rate and a longer life-span than occurs when the creatures are reared under optimum laboratory conditions."

In replying, Dr. C. O'D. Iselin, the Director, wrote as follows (May 25, 1948): "I believe it is safe to say that the velocity of ocean currents is about twice that shown on current charts. Evidence is rapidly accumulating that the currents are not broad and gradual as all charts showing average conditions indicate. The flow is narrow, streaky, and fluctuating. Especially the more powerful currents meander widely and throw off large, powerful eddies on either side.

"The current charts have been constructed by averaging a large number of observations from ships which were sometimes in the strong part of the current and sometimes not. Thus this type of statistical information is bound to end up with weak, diffuse currents.

"Some of the evidence on which these ideas are based is given in an unpublished report available at Scripps. This is entitled: "Technical Report No. 9 on the Hydrography of the western Atlantic: Meanders and Velocities of the Gulf Stream," by Frederick C. Fuglister and Valentine Worthington, October, 1947. Fuglister and I have also prepared a paper on the same subject which will appear before the end of the year in the *Journal of Marine Research* (*see* Iselin and Fuglister, 1948, p. 324, in which velocities of four and five knots for the Gulf Stream and of three knots for its eddies are given).

"My picture of your crabs is that from time to time they can get a fast ride from one island to the next, the current being something like a snake on the floor."

This newer "snake-on-the-floor" concept explains how offshoot currents from the main Equatorial Counter Current, if directed to the south-east, might transport larval crab stages from Palmyra directly to the Galapagos without the necessity of return by the Niño Current, while if directed to the north-east, might transport them directly to Clipperton. The increased speed, in the case of the Equatorial Counter Current from 2 to 4 knots, or from 48 to 96 nautical miles per day, if maintained would halve the time required in transit from Palmyra to Galapagos, bringing the 2,000-mile journey within the four-week period required by most crabs to reach the first adult stage. That this period may, under unfavourable conditions, be extended will be considered later on.

The currents heretofore mentioned are superficial currents, at most a few hundred feet deep. In 1952 a submerged current was discovered flowing in an easterly direction beneath the westerly directed South Equatorial Current (Cromwell *et al.*, 1954). Named the Cromwell Current for its discoverer, it has since been traced for 3,500 miles from the longitude of the Marquesas, where its core is at 100 meters, to the Galapagos, where it ascends to 40 meters. Its volume equals that of the Florida Current and its speed is three knots, as compared to the one-knot speed of the opposite surface stream. At the equator the depth of the change from west to east flow is at about 20 meters (Knauss, 1960). While little is known of the vertical migration of crab larvae in the mid-Pacific, it is reasonable to suppose that not all individuals remain at the surface in view of the marked turbulence that exists, particularly at the edges of currents moving in opposite directions. It is therefore apparent that any plankter descending below this comparatively shallow depth (of 20 meters) would be captured by the Cromwell Current and be carried hundreds or thousands of miles eastward at speeds up to 72 nautical miles per day.

EVIDENCE FROM MARINE GEOLOGY

With the perfection of echo-sounding has come the practicability of mapping the ocean floor with an exactitude never envisioned by those who used the older method. A byproduct of echo-sounding has been the discovery, within the last 20-year period, of hundreds of submerged mountain tops, the so-called *guyots* of the central Pacific (Hess, 1946). These submarine features exhibit a remarkable uniformity in that all rise to about the same height with respect to the sea surface, and all are flat-topped or planed off at that level. They are thought to represent truncated volcanoes with flat platforms eroded by wave action (Hamilton, 1956). While reef-building corals were at one time established upon them, these failed to maintain sufficient growth to keep above water as the block on which they were situated slowly sank, so that they never became fully developed atolls. At their present level of from 700 to 900 fathoms they support a fauna not unlike that of the shelf surrounding the Hawaiian Islands, but separated from it, and from the continental shelves, by oceanic depths. When at sea-level or above, they formed island groups as extensive as existing ones, thereby providing additional stepping-stones for land-bound animals of all sorts, including marine forms restricted to the littoral.

While flat-topped seamounts, although not uncommon in the Gulf of Alaska (Menard, 1955), are of rare occurrence in the eastern Pacific at mid-latitudes, several are known between Hawaii and the North American mainland. Of these may be mentioned Erben and Fieberling guyots, located 800 and 600 miles west of San Diego, and with tops at 400 and 280 fathoms, respectively (Carsola and Dietz, 1952). Two shallow banks also deserve mention: Ranger Bank, located 6 miles north of East San Benito Island, with a minimum depth of 67 fathoms (Emery, 1948), and Stranger Bank, also known as Hurricane Bank, located 200 miles south-west of Clarion Island, with a minimum depth of only 15 fathoms (Hubbs, 1959). The question of how long ago these may have been at the surface, and thus available for larval crab dispersal, is best left until after the next paragraph.

EVIDENCE FROM GLACIOLOGY

It is a well-known fact that much of the earth's water is tied up in its continental glaciers, and that as glaciers wax and wane, so fluctuates the level of the sea. The 7 million cubic miles of Antarctic ice, if melted, would raise the sea-level throughout the world by 200 feet or more, while the abrupt melting of both the Greenland and Antarctic icecaps would raise the present world-wide sea-level by as much as 300 feet (Haag, 1962, p. 115). One of the periods of greatest glacial advance and retreat, and hence of the greatest rise and fall in sea-level, was the Pleistocene; indeed, it is by no means certain that we are not still in one of its interglacial phases. Should severe glaciation ensue, the sea-level might drop to the point that the shallower banks, those under 100 fathoms, would again be exposed, serving once more, as in the past, as island havens. Since it is only about 18,000 years since the last severe glaciation, the Wisconsin, left the northern tier of states, and since at its maximum about 36,000 years ago the sea-level was lowered by as much as 460 feet (*Ibid.*, p. 120), it can be seen that as many as three times within the last 200,000 years islands now hundreds of feet below the surface may have been exposed as Clipperton and other Pacific atolls are today. And 200,000 years is but a fraction of the time that has been available to existing species for trans-Pacific migration.

It is by now apparent that the shallow banks on the one hand and the submerged seamounts or guyots on the other are phenomena of different magnitudes and ages. The shallow banks, being less than 100 fathoms deep, have been exposed repeatedly by inter-glacial fluctuations in sea-level occurring as recently as late Pleistocene. The guyots are the result of subsidence that has been continuous since Cretaceous times and has reached a depth of several hundred fathoms. They are too deep by far to have been exposed by the comparatively superficial changes in sea-level of the late Tertiary and early Quaternary periods. If stepping-stones are sought for recent migrations responsible for species now common to western and eastern Pacific localities, the search must be restricted to existing islands and banks of less than 100 fathoms. If, however, stepping-stones are sought for past migrations responsible for genera now common to the two areas, their common genera being more numerous than common species, it may be assumed that the guyots, as exposed islands or submerged banks of an earlier era, played an important, if not a predominant role.

EVIDENCE FROM LIFE-HISTORY STUDIES

The rearing of a crab through all its life stages from egg to adult has been accomplished numerous times in the laboratory: for *Lophopanopeus bellus bellus*, *Pinnotheres taylori*, *Hemigrapsus nudus*, and *H. oregonensis* by Hart (1935); for *Pinnotheres ostreum* by Sandoz and Hopkins (1947); for *Neopanope texana sayi* by Chamberlin (1957); for *Pagurus samuelis* by Coffin (1958, 1960); for *Lophopanopeus leucomanus*, *L. bellus diegensis*, and *Paraxanthias taylori* by Knudsen (1958, 1959 *a*, 1959 *b*); and for *Sesarma cinereum* by Costlow and Bookhout (1960). Length of larval life has been shown to be for *Pinnotheres taylori* 4 weeks; for *Hemigrapsus oregonensis* 4–5 weeks; for *Pinnotheres ostreum* 25 days (at 23° C.); for *Neopanope texana sayi* from 20–25 days (at 24° C.); for *Pagurus samuelis* from 23–32 days (at temperatures ranging from 28–17° C.); for *Lophopanopeus leucomanus* from 5–7 weeks; for *L. bellus diegensis* about 5 weeks; for *Paraxanthias taylori* from 5–6 weeks; and for *Sesarma cinereum* from 20–39 days (at temperatures ranging from 30–20° C.). Thus it may be seen that the pre-adult life of a number of anomuran and brachyuran crabs is from 25–50 per cent. longer than the usual four weeks expected, and that cooler temperatures prolong the larval period.

EVIDENCE FROM CRUSTACEAN PHYSIOLOGY

These averages were achieved with abundant food present. It is well known that starvation retards ecdysis (inhibits molting, Passano, 1960, p. 583). It is therefore possible that the life-span of an emaciated zoea or megalops might be extended until such time as sufficient food could be procured with which to fuel the next metamorphosis. The observations of Hahn (1948, p. 103) regarding the semi-starved condition of the pelagic population of the Sargasso Sea during an investigation by the *Atlantis* are pertinent in this connection. Wilson (1952, p. 120) found that the larvae of *Ophelia bicornis* have a period of at least several days during which they are able to metamorphose, and concluded (*op. cit.*, p. 56) that the ability to postpone metamorphosis until a suitable environment for adult life is reached is undoubtedly widespread.

EVIDENCE FROM FAUNISTIC STUDIES

As long as knowledge of the littoral marine faunas of remote islands and island groups was based upon incomplete collections, randomly made, and often by persons not overly familiar with the animals collected, it was difficult to discern patterns of distribution. Now that the Galapagos Islands have been investigated by the Hancock Expeditions and Clipperton Island by the Scripps Oceanographic Institution Expeditions, each with a staff of scientists, and with faunal lists reasonably complete, it can be seen that the occurrence of Indo-west Pacific species in the eastern Pacific is not an isolated phenomenon, but one that occurs regularly and predictably in all groups having larvae suited to transport by ocean currents. (This is independent of, but not unrelated to, the occurrence at these same islands of western Pacific species of *Plagusia*, *Planes*, and *Pachygrapsus*, whose members are habitually transported on drifting logs or on sea turtles as adults.) It has been reported for mollusks by Hertlein (1937), and by Hertlein and Emerson (1953, 1957), and for fishes by Briggs (1961), and by Rosenblatt and Walker (1963). In fact, it is so prevalent that the Central Pacific Oceanic Barrier may either no longer be considered the absolute obstacle to east-west distribution that it once was (Ekman, 1953), or its line of demarcation must be moved eastward to include Clipperton Island at least (Garth, 1965). The new point for conjecture is no longer how western Pacific littoral species may have reached the outliers of the American continent; it is why, having reached Clarion, Clipperton, or Culpepper (an outpost of the Galapagos group), they have not made it to the mainland coast.

SUMMARY

Thus, while no one has followed the passage of a larval brachyuran or anomuran crab from one Pacific island to another by radioactive tracer or otherwise, it is almost a foregone conclusion that this is the way in which their dispersal occurs, following the highways of the seas, the ocean currents. Factors unknown or only surmised twenty years ago that increase this certainty are (1) a new concept of ocean currents as faster, narrower, and more highly irregular than was formerly believed; (2) the discovery of flat-topped seamounts or guyots representing submerged truncated volcanoes that as islands provided additional resting places in the distant past, and of shallow banks that similarly served more recently; (3) the knowledge that sea-levels have fluctuated widely in response to advances and retreats of continental glaciers, and will continue to do so, making islands where none presently exist, as well as obliterating existing islands; (4) the fact that crustaceans control, within limits, the time of molting, and hence, presumably, of metamorphosis, waiting until conditions are propitious before advancing to the next life stage; and finally (5), that crabs reared under laboratory conditions, and with an abundant food supply, require from a month to six weeks to reach adulthood, while in the absence of food or of a suitable substrate this period may be indefinitely extended. In the absence of evidence to the contrary, it may be assumed that random dispersal of ocean current-borne larval stages operating over long periods of time and great distances is responsible for the present assemblage of species of brachyuran and anomuran crustaceans found at Clarion, Socorro, San Benedicto, Clipperton, Cocos, Malpelo, and the Galapagos Islands. And, with the possible exception of the guyots, which until recently have been regarded as an exclusively mid-Pacific phenomenon, the same factors that have assured the distribution of crustacean species in the eastern Pacific would appear to have operated in similar manner in other oceans and their seas.

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PRELIMINARY NOTE ON THE GEOGRAPHIC DISTRIBUTION OF THE DECAPOD CRUSTACEANS OF THE MARINE WATERS OF ARGENTINA (SOUTH-WEST ATLANTIC OCEAN)

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ABSTRACT

A brief description of the characteristics of the waters of the Argentine continental shelf is given, and two types of waters are distinguished: Cold waters of sub-antarctic origin, and temperate waters from the North. The crustacean decapods of the Argentina littoral waters are separated into the two groups according to type of waters from which they originate: (*a*) warm temperate decapods which come from the North following the coastline of the Province of Buenos Aires and reach a latitude of 42–43° S. and (*b*) cold temperate Patagonian decapods from South which travel close to the coastline up to 45° S, where they separate from the coast, becoming deeper water forms at the latitude of the Province of Buenos Aires and remaining always associated with sub-antarctic waters. The species investigated by the author include decapods Caridea, Penaeidea, Brachyura, Anomura and Macrura.

INTRODUCTION

THE taxonomic and zoogeographical knowledge of the South American decapod Crustacea is still rather fragmentary. Information is available on certain groups of Brachyura and the commercially important penaeids, whilst for others very few data are available. Notwithstanding the present state of the information on the marine Decapoda of Argentina, it is possible to delimit, although provisionally, the geographic distribution of the principal known species to date and to establish the biogeographical region to which they belong. The data herein presented permit a comparison with the geographic range of other marine organisms of the South Atlantic, and a definition of the biogeographical units of the Argentine continental shelf waters. Many species of Caridea, Callianassidae and Pinnotheridae have not yet been studied, and other material which is at present under investigation will not be included in this first attempt to clarify the geographical distribution of the Argentine marine Decapoda. It is hoped that further information on the subject will be gathered in the future.

GENERAL HYDROGRAPHY OF THE ARGENTINE CONTINENTAL SHELF WATER

The Argentine continental shelf is extensive covering a surface of 960,000 km.^{2}, with a distance of 4,000 km. from the continental shore. The shelf has in general a gentle slope, its width varying between 300–1,000 km. the latter extension being found in the Patagonian region where the isobath of 200 m depth is situated far from the coast. Towards the north on the coast of the Province of Buenos Aires the shelf is narrower (Map 1).

In this extensive sea are to be found waters of different origin, varying with the season of the year, but in general it may be stated that all Argentine shelf is affected by cold waters of sub-antarctic

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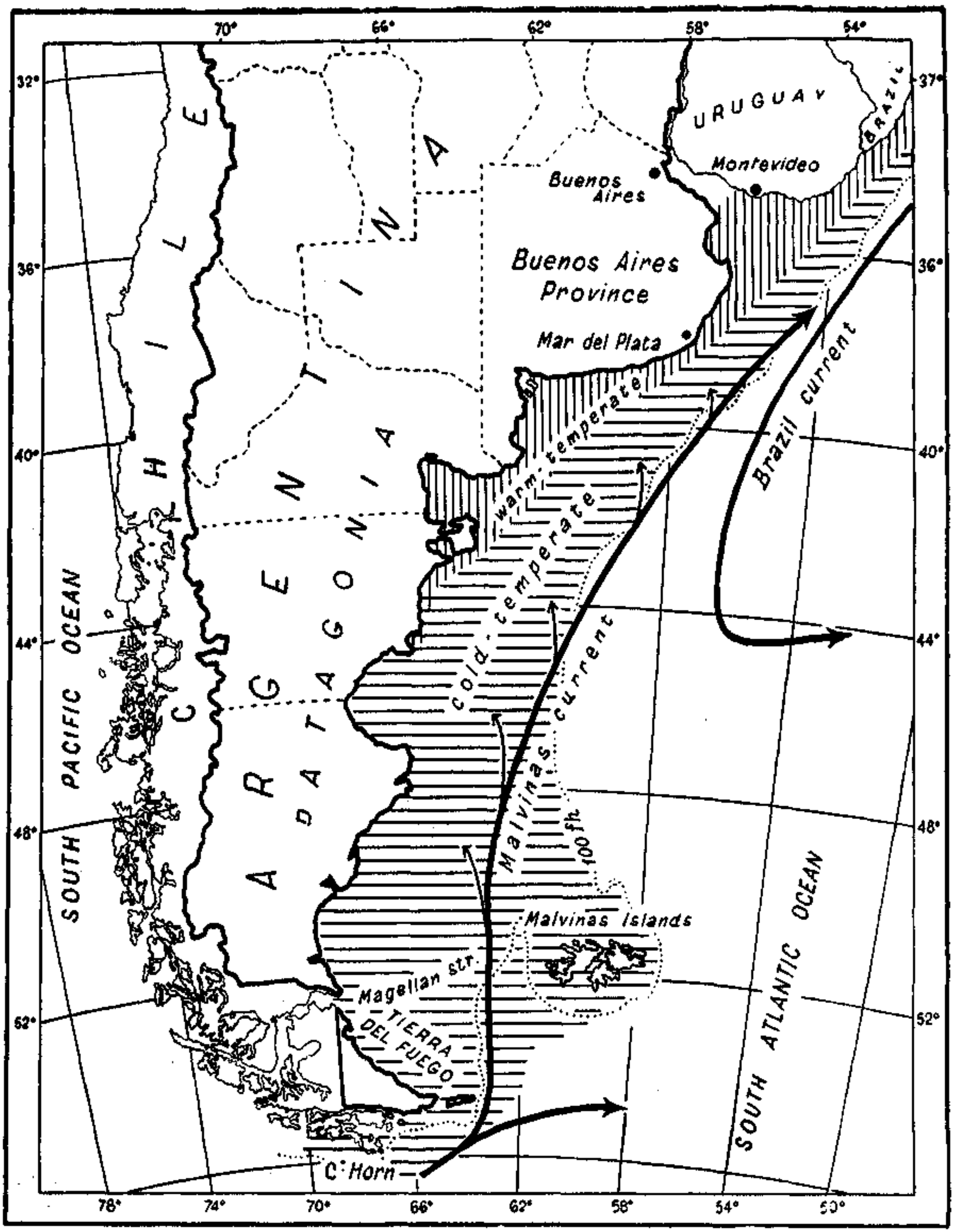

Map 1. Biogeographic regions of the Argentinian Continental shelf. Horizontal strie indicates cold-temperate region; vertical stripe indicates warm-temperate region. Strong arrow to north indicates the cold Malvinas current with deflections to inshore water. Downward arrow indicates offshore warm Brazil current.

origin forming the Malvinas current (Falkland current) which comes from the south as a northern arm of the Cape Horn current. The waters of the Malvinas current diverge somewhat from the coast at the latitude of Cape Blanco (47° S.) and continue northwards, narrowing somewhat at the surface to pass the latitude of the Province of Buenos Aires. These waters have temperatures varying between 6° and 13° C. with a salinity 33·56–34·07‰. Some stretches of this current move towards the coast and others return warmed from the north and mix with the waters from the rivers of the Province of Buenos Aires and the Patagonia, which reach the sea constituting masses of coastal waters having peculiar characteristics, which Hart (1946) denominated "old shelf waters", of higher temperature, more pronounced thermic changes and generally of lower salinity than the sub-antarctic waters. These waters cover the coastal region of the Province of Buenos Aires and northern Patagonia, with accentuated seasonal changes in the southern limit. The temperature of these waters varies during the year between 8–22° C. Another important current is that of Brazil with warmed tropical waters, almost reaching the shelf of the Province of Buenos Aires and northern Patagonia, turning away towards the West (Map 1).

Between the warm northern current of Brazil and the cold waters of the Malvinas current from the south there exists a variable region, denominated the subtropical convergence zone. Along the edge of the Buenos Aires shelf are to be found various centres of upwelling with waters of lower temperature and rich in nutrients, permitting a rich growth of phytoplankton.

The general characteristics of the climate in this latitude and the hydrology of the water masses of the Argentine continental shelf permit two great biogeographical regions to be recognized, which are characterised by the distribution of the marine organisms.

BIOGEOGRAPHICAL REGIONS IN THE ARGENTINA CONTINENTAL SHELF

1. *Warm-temperate region.*—This extends from the coastal waters of the Province of Buenos Aires to Northern Patagonia, Lat. 43–44° S., with a depth varying in the external limit between 20 and 30 fathoms. The southern limit of this region fluctuates in accordance with the seasonal hydrographical and climatic variations, advancing somewhat towards the south in the warm season. This region is continued northwards up to the subtropical coast of Brazil (Cabo Frio, Lat. 23° S.). Some workers call this biogeographical sector "Argentine Province" (Balech, 1964; Bernasconi, 1964; López, 1964; Stuardo, 1964) corresponding approximately to the South American sector of the region called by Ekman (1953) and Pérès (1961) as "warm-temperate" (Map 1).

The number of species of decapod crustaceans classified to date from this region is 37 (Table I belonging to the following familes: Penaeidae, Alpheidae, Scyllaridae, Porcellanidae, Sergestidæ, Callianassidae, Paguridae, Albuneidae, Majidae, Portunidae, Xanthidae, Pinnotheridae, Grapsidae, Atelecyclidae and Ocypodidae. Stray representatives of other families not typical to this region have not been included in this table as Nephropsidae (*Nephrops rubellus*). It is also possible that the total number of species will be increased as the present research programme on Crustacea is continued, with particular reference to the Caridea, which have been little studied so far.

The decapod Crustacea of this warm-temperate region show subtropical characteristics since many genera have their greatest development in that region and only few species, generally one or two, reach the Buenos Aires coastal waters. The diversity of species increases towards the extreme north of this region, particularly on the Brazilian coasts (Boschi, 1964 *a*, 1964 *b*).

2. *Cold-temperate region.*—Influenced by waters of sub-antarctic origin, this comprises the coast of Tierra del Fuego and adjoining areas, the vicinity of the Malvinas Islands (Falkland), Patagonian waters and deep regions off the Province of Buenos Aires. This region remains very near the coast up to latitude of 44–45° S., later diverges in an eastern direction towards deeper waters and joins the Malvinas current. At the latitude of the Province of Buenos Aires it is approximately 60–120 miles, away from the coast depending on the seasonal changes and local hydrology. Some workers

TABLE I

Marine Decapod Crustacea in different regions of the Argentinian Continental Shelf

Species	Coastal region of Buenos Aires Province and Northern Patagonia, Lat. 36–41° S. (Warm-temperate)	Deep region of Buenos Aires Province, Lat. 36–41° S. (Cold-temperate)	Southern Patagonia, Lat. 41–52° S. (Cold-temperate)	Region of Tierra del Fuego, Str. Magellan and Malvinas Islands, Lat. 51–56° S. (Cold-temperate)
NATANTIA				
Penaeidea				
Fam. Penaeidae				
Hymenopenaeus muelleri (Bate)	×	—	—	—
Artemesia longinaris Bate	×	—	—	—
Fam. Sergestidae				
Pelsos petrunkevitchi Burkenroad	×	—	—	—
Sergestes articus Krøyer	—	—	—	×
Caridea				
Fam. Hippolytidae				
Nauticaris magellanica (A. M. Edwards)	—	—	—	×
Fam. Alpheidae				
Betaeus truncatus Dana	—	—	—	×
Betaeus lilianae Boschi	×	—	—	—
Alpheus sp.	×	—	—	—
Fam. Campylonotidae				
Campylonotus vagans Bate	—	×	×	×
Campylonotus semistriatus Bate	—	—	—	×
Fam. Pandalidae				
Austropandalus grayi (Cunningham)	×[1]	×	×	×
REPTANTIA				
Macrura				
Fam. Scyllaridae				
Scyllarides deceptor Holthuis	×	—	—	—
Fam. Callianassidae				
Callianasa spp.	×	—	×	—
Anomura				
Fam. Galatheidae				
Munida subrugosa (White)	—	×	×	×
Munida gregaria (Fabricius)	—	×	×	×
Fam. Porcellanidae				
Pachycheles haigae Rodrigues	×	—	—	—
Pachycheles chubutensis Boschi	×	—	—	—
Fam. Lithodidae				
Lithodes antarticus (Jacquinot)	—	×	×	×
Paralomis granulosa (Jacquinot)	—	—	—	×
Fam. Albuneidae				
Blepharipoda doelloi Schmitt	×	—	—	—
Fam. Paguridae				
Loxopagurus laxochelis (Moreira)	×	—	—	—
Pagurus exilis Benedict	×	—	—	—
Pagurus gaudichaudi H. M. Edwards	—	×	×	×
Pagurus forceps H. M. Edwards	—	—	—	×
Brachyura				
Fam. Leucosidae				
Leucosia planata (Fabricius)	—	—	—	×
Ebalia rotundata (A. M. Edwards)	—	—	×	—
Fam. Hymenosomidae				
Halicarcinus planatus (Fabricius)	—	—	×	×
Fam. Majidae				
Eurypodius latreillei Guérin	—	×	×	×
Collodes rostratus A. M. Edwards	×	—	—	—

TABLE I (*Contd.*)

Species	Coastal region of Buenos Aires Province and Northern Patagonia, Lat, 36-41°S. (Warm-temperate)	Deep region of Buenos Aires Province, Lat. 36–41°S. (Cold-temperate)	Southern Patagonia, Lat 41–52°S.[1] (Cold-temperate)	Region of Tierra del Fuego, Str. Magellan and Malvinas Islands, Lat. 51–56°S. (Cold-temperate)
Leurocyclus tuberculosus M. Edwards and Lucas	×	–	–	–
Libinia spinosa M. Edwards	×	–	×	–
Rochinia gracilipes M. Edwards	×	–	–	–
Libidoclaea granaria M. Edwards	–	×	–	–
Pelia rotunda M. Edwards	×	–	–	–
Leucippa pentagona M. Edwards	×	–	–	–
Fam. Portunidae				
Ovalipes punctatus (de Hann)	×	–	–	–
Callinectes acutidens Rathbun	×	–	–	–
Coenophtalmus tridentatus A. M. Edwards	×	–	–	–
Fam. Xanthidae				
Platyxanthus crenulatus A. M. Edwards	×	–	–	–
Platyxanthus patagonicus M. Edwards	×	–	–	–
Pilumnoides hassleri A. M. Edwards	×	–	–	–
Pilumnus reticulatus Stimpson	×	–	–	–
Fam. Pinnotheridae				
Pinnixa patagoniensis Rathbum	×	–	–	–
Pinnaxodes chilensis (M. Edwards)	–	–	–	×
Fabia sp.	×	–	–	–
Pinnotheres sp.	×	–	–	–
Fam. Grapsidae				
Cyrtograpsus affinis (Dana)	×	–	–	–
Cyrtograpsus angulatus Dana	×	–	×	–
Cyrtograpsus altimanus Rathbum	×	–	–	–
Chasmagnathus granulata Dana	×	–	–	–
Metasesarma rubripes Rathbum	×	–	–	–
Fam. Atelecyclidae				
Peltarion spinosulum (White)	–	×	×	×
Corystoides chilensis M. Edwards and Lucas	×	–	–	–
Acanthocyclus albatrosis Rathbum	–	–	–	×
Fam. Ocypodidae				
Uca uruguayensis Nobili	×	–	–	–

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[1] only for 43° 40′ S.–65° 05′ W.

call this region, including the Southern Chile "Magellan Province" (Balech, Bernasconi, López, Stuardo, *op. cit.*). In reality it corresponds to the South American sector of the region termed "Antiboreal" by Ekman (1953), "Austral-temperate" by Pérès (1961) or "Notal" by Boschi (1964 *a*). The number of decapod Crustacea recorded to date is 22 (Table I), and comprises the following families: Sergestidae, Hyppolitidae, Alpheidae, Campylonotidae, Pandalidae, Callianassidae, Galatheidae, Lithodidae, Paguridae, Leucosidae, Hymenosomidae, Majidae and Atelecyclidae. This region has a lesser number of species than the warm-temperate one and practically all of them are derived from the Southern Chilean fauna, which demonstrates the biogeographical unity between the South Atlantic and the South Pacific Ocean. It is possible at all events to establish several subregions on the basis of species from Patagonia and Tierra del Fuego. Many species have been found in the region of Magellan Strait, but it is possible that they exist also in the region of Tierra del Fuego (Map 1).

CONSIDERATIONS ABOUT THE SPECIES DIVERSITY OF DECAPOD CRUSTACEA ON THE CONTINENTAL SHELF OF ARGENTINA

The study of the distribution of the decapod crustaceans in the Argentine Epicontinental Sea revealed many important facts. These are the reduction in the number of species compared to the faunistic complexes of the Northern South America and the Caribbean, the low number of endemic species, and the existence of certain special intertidal communities such as the "cangrejal" formed by semi-aquatic crabs. The distribution of the Decapoda permits the establishment of two great biogeographical regions in the waters of the Argentina Continental shelf, quite in agreement with the geographical distributions of other marine organisms.

In a few other papers some of the above observations have been discussed (Boschi, 1964 *a*, 1964 *b*) but for the present it only remains to formulate certain considerations upon the species diversity of the marine Decapoda in Argentina. The most relevant of these is the reduced number of species of the higher Crustacea to be found in a region as extensive as the Argentine continental shelf with a surface of approximately 960,000 km.[2] Fisher (1960), among others, has recently brought together interesting comparative material, particularly marine invertebrates, and arrived at the conclusion that the diversity of species is greater in tropical climes and decreases progressively in the regions of cold and temperate climes of higher latitudes, with certain exceptions observed by Thorson (1957) in the marine infauna. This numerical difference is clearly observed in the South American marine decapods. The Caribbean and North South American communities are very numerous with regard to the species of higher Crustacea, as for example is the case of the Brachyura of the Caribbean which reach almost 290 species. In Surinam approximately 100 species of marine decapods are known (Holthuis, 1960); in Puerto Rico and the Virgin Islands the number reaches 330 (Schmitt, 1935; Rathbun, 1933), whilst in the Argentina coast the number of species reaches only 60, a number much lower than that of the tropical regions (Table II). Also in the interesting paper by Forest and Guinot (1962) which concerns a study of the distribution of species of Brachyura in different regions of the Atlantic and Indian Oceans, a greater concentration of these crustaceans was observed in the tropical and warm-temperate regions.

TABLE II

Species density of Marine Decapod Crustacea in different regions of Central and South America

Region	Brachyura	Anomura	Macrura	Caridea	Penaeidea	Stenopodidea
Puerto Rico and Virgin Islands, Lat. 18° N.	200	60	11	63	9	..
Surinam, 7° N.	58	13	7	11	14	2
Northern Brazil, Lat. 2–6° S.	60	?	?	?	8	?
Uruguay, 34–35° S.	30	?	?	?	5	..
Coastal water Province Buenos Aires, Argentina, Lat. 35–41° S.	23	5	2	4	3	..
Patagonia, Argentina, Lat. 45–52° S.	6	4	..	2	..	..
Tierra del Fuego and Magellan region, Argentina, Lat. 53–55° S.	6	6	..	5	1	..

Note.—All these numbers are approximate. In the Patagonian region a larger number of Decapods is to be expected, at least similar to that found in the Magellan region.

The causes of this reduced number of species of the marine decapod in South America, both Atlantic and the Pacific coasts, appear to be due to a generalized factor which has arisen from a lesser stability and maturity of the ecosystems of the cold and temperate regions throughout the evolution of the earth and in particular the littoral of Argentina is included in the temperate region. The climatic variations and the massive extensions produced in South America by the paleographic occurrences on the Pleistocene show at present faunistic communities in a clear process of adaptations and evolution, with many ecological niches free. According to Margalef (1960) all ecosystems which do not support more or less catastrophic alterations pass through a series of successive stages until they reach a phase of relative stability, which means to say that the maturity increases with time in an undisturbed ecosystem (Margalef, 1963). This permits a qualification of a determinated community as young or mature, and for these reasons the tropical ecosystems are mature as a result of the stability maintained throughout millions of years, which has permitted a high degree of evolution and adaptation of the species with the resulting occupations of a greater number of ecological niches and an accentuated specializations of their form of life. Margalef (1961) has singled out the coral reef as the actual ecosystem most mature of the sea.

It is natural, therefore, that the distribution and density of the marine organisms should be controlled by the characteristics of the medium and in a special way the availability of food is an important factor. The number of Decapoda in Argentina is reduced, and with the exception of the commercial penaeids they do not form great concentrations, which suggest the existence of some limiting factor controlling their abundance. It is possible that this may be due to certain trophic deficiencies in the food chain among the communities which limit the number of Decapoda of the Argentina Sea.

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ECOLOGIC DISTRIBUTION OF RECENT OSTRACODA*

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ABSTRACT

Ostracods are known to live in equilibrium with their environment. Their widespread geologic and geographic distribution, sensitivity to environment, comparatively large size (± 1 mm.), excellent preservation and easy identification have increased their usefulness in stratigraphy, paleoecology and ecology.

Physical factors that control the distribution of ostracods are temperature, bottom topography, depth, transparency and bottom currents. Of the chemical factors, salinity, hydrogen-ion concentration (pH), alkalinity, total phosphate and dissolved oxygen (O_2) are those that appear to have some effect on their distribution. Biological elements like food supply and gross relationships with other life also effect total populations. Striking relationships have been observed between faunal distribution patterns and mean-grain size and organic carbon content of sediments and temperature. Salinity is the most important chemical factor which affects ostracods. Of the biological factors, food supply and nature of the substrate (algae, sea grasses, sponges, etc.) seem to have a limiting effect on the distribution of various ostracod communities.

Ostracods inhabit purely terrestrial environment like spalean (*Mesocypris terrestris* Harding), fluvial (*Candona, Limnocythere, Darwinula*), paludal (Cypridinae, Cyclocypridinae), and lacustrine (several genera). Marginal marine environments like marsh rivers, coastal lagoons, deltas, estuaries, mangrove islands, salt marshes and fluvial marine assemblages are characterized by several species which are peculiar to these environments. Environmental factors which control the distribution of shallow water ostracods seem to be salinity, temperature, sediments and organic carbon.

Detailed studies in the Gulf of Naples, Italy, where eight major ostracod assemblages are recognized in a purely marine environment, the limiting factors that control total populations are thought to be depth, substrate, and possibly salinity. Certain species show definite association with the type of substrate (*Posidonia*, calcareous algae, seaweeds, *Phyllochaetopterus socialis*, sponges, etc.), and some species are restricted to these environments.

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FACTORS INFLUENCING DISTRIBUTION

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INTRODUCTION

OSTRACODS are known to live in equilibrium with their environment. Their widespread geologic and geographic distribution, sensitivity to environment, comparatively large size (± 1 mm.), excellent preservation and easy identification have increased their usefulness in stratigraphy, paleoecology and ecology.

FACTORS INFLUENCING DISTRIBUTION

Physical factors that control the distribution of ostracods are temperature, bottom topography, depth, transparency and bottom currents. Of the chemical factors, salinity, hydrogen-ion concentration (pH), alkalinity, total phosphate and dissolved oxygen (O_2) are those that appear to have some effect on their distribution. Biological elements like food supply and gross relationships with other life also effect total populations. Striking relationships have been observed between faunal distribution patterns and mean-grain size and organic carbon content of sediments and temperature. Salinity is the most important chemical factor which affects ostracods. Of the biological factors, food supply and nature of the substrate (algae, sea grasses, sponges, etc.) seem to have limiting effect on the distribution of various ostracod communities. Other factors that play an important role in zoo-geography are paleogeography, dispersal ability, reproduction, evolution, morphologic adaptation to suitable habitats, population structure of the communities and effectiveness of the barriers.

SALINITY

Salinity has a profound effect on the distribution of ostracods. This effect is most significant in mixohaline (salinity 0·5 ± 30‰) waters as is amply shown in classic studies by Elofson (1941) in the Baltic Sea and the Skagerrak, by Wagner (1957) in the North Sea and by Swain (1955) in the San Antonio Bay area in the Gulf of Mexico. In the North Sea, five distinct assemblages can be recognized from the work of Wagner (1957):

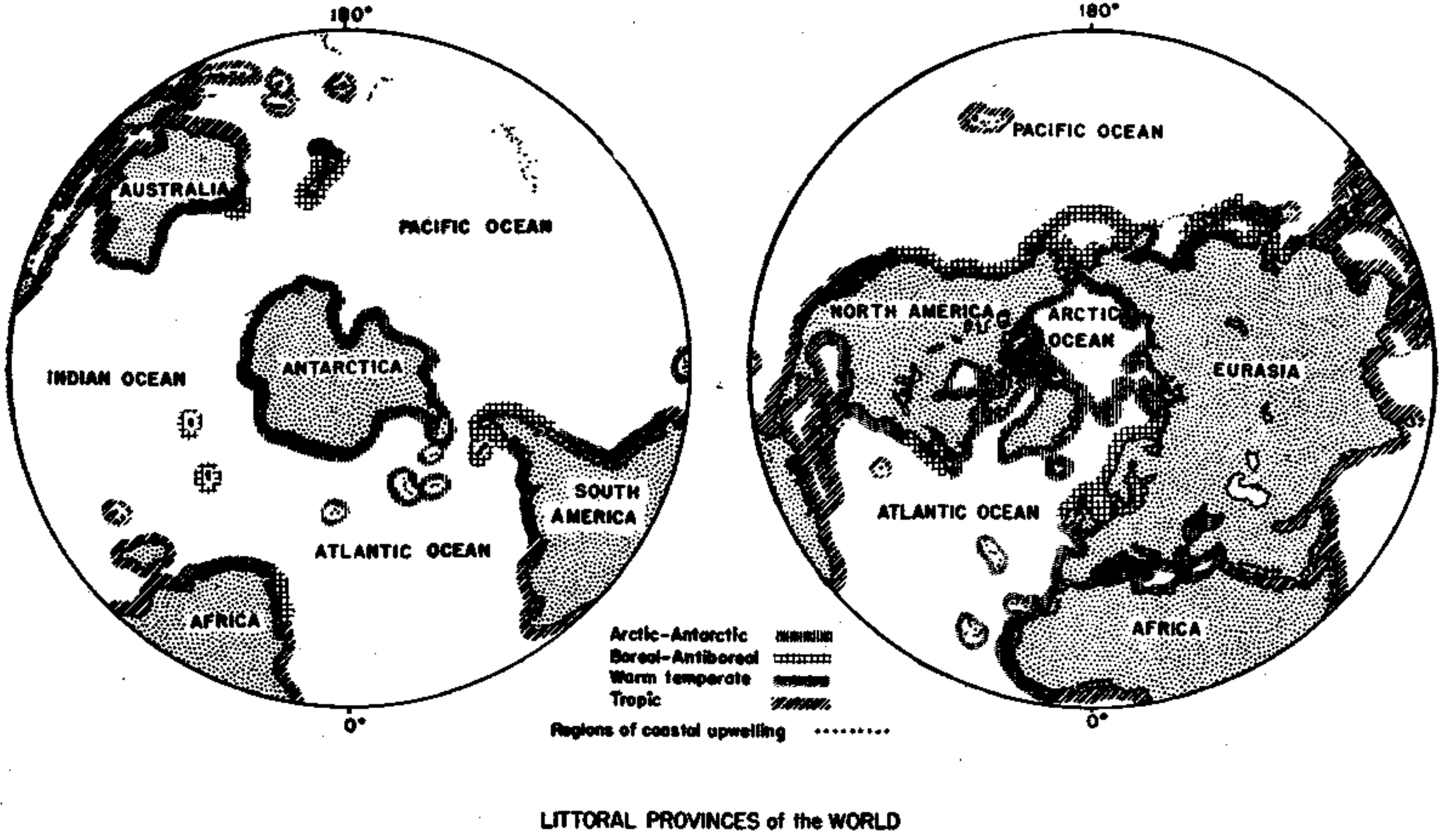


FIG. 1. Littoral Provinces of the World (after Hedgepeth, 1957).

1. Limnetic (freshwater salinity range 0·2–0·5‰)

Candona insculpta Müller, *C. pratensis* Hartwig, *C. acuminata* Fischer, *C. welteri* Hartwig, *C. hyalina* Brady and Robertson, *C. fabaeformis* Fischer, *C. marchica* Hartwing, *Candonopsis kinsleyi* Brady and Robertson, *Eucypris lutaria* Koch, *E. virens* Jurine, *Cypricercus affinis* Daday, *C. fuscatus* Jurine and *Erpetocypris reptans* (Baird).

2. (Mixo-) oligohaline (salinity range 0·2–0·5‰; 2–3‰)

Candona compressa (Koch), *C. neglecta* Sars, *C. hartwigi* Müller, *Cyclocypris laevis* (Müller), *Darwinula stevensoni* (Brady and Robertson), *Iyocypris decipiens* Masi, *I. gibba* Ramdohr, *Limnocythere inopinata* (Baird), *Cypridopsis vidua* Müller, *Potamocypris* sp., *Cypria opthalmica* (Jurine) and *Erpetocypris chevreuxi* Sars.

3. (Mixo-) mesohaline A (salinity range 2–10‰)

Candona angulata Müller, *Cyprideis torosa* (Jones), *Cypridopsis aculeata* (Lilljeborg), *Cytheromorpha fuscata* (Brady), *Cytherura gibba* (O. F. Müller), *Cyprinotus salinus* (Brady) and *Loxoconcha elliptica* Brady.

(Mixo-) mesohaline B (salinity range >10‰).

Semicytherura nigrescens (Baird), *Loxoconcha rhomboidea* Fischer, *Xestoleberis aurantia* (Baird), *Cytherois pusilla* Sars, *Paradoxostoma variabile* (Baird), *Paradoxostoma pulchellum* Sars, *Paradoxostoma abbreviatum* Sars, *Hemicytherura cellulosa* (Norman), *Hirschmannia viridis* (O. F. Müller), *Xestoleberis pusilla*, *Hemicythere villosa* (Sars), *Semicytherura undata* (Sars), *Paradoxostoma normani* (Brady), *Paracytherois arcuata* (? Brady), *Cythere lutea* O. F. Müller, *Heterocythereis albomaculata* (Baird), *Leptocythere pellucida* (Baird), *Semicytherura angulata* (Brady), *Semicytherura acuticostata* (Sars), *Loxoconcha fragilis* Sars, *Paradoxostoma ensiformis* Brady, *Sclerochilus contortus* Norman, *Paracytherois flexuosa* (Brady), *Leptocythere crispata* (Brady), *Xestoleberis depressa* Sars, *Semicytherura striata* (Sars), *Leptocythere baltica* (Hirschmann), *Xenocythere cuneiformis* (Brady), *Hemicytherinae* (?) *angulata* (Sars), *Eucythereis emarginata* (Sars), *Leptocythere castanea* (Sars) and *Cytherois fischeri* Sars.

4. (Mixo-) polyhaline (salinity range >17‰)

Paracypris polita Sars, *Trachyleberis tuberculata* (Sars), *Pterygocythereis jonesi* (Baird), *Loxoconcha tamarindus* Jones, *Cytheridea papillosa* Bosquet, *Elofsonella concinna* (Jones), *Loxoconcha granulata* Sars, "*Cythereis*" *dunelmensis* (Norman), *Clithrocytheridea sorbyana*, *Cytheropteron latissimum* (Norman), *Macrocythere simplex* (Norman), *Krithe bartonensis* Jones, *Philomedes globosus* Lilljeborg, *Eucythere argus* Sars, *Polycope orbicularis* Sars, *Cytheropteron alatum* Sars, *Cytheridea punctillata* Brady and *Cythereis crenulata* Sars.

5. Euhaline (salinity range >32‰)

Argilloecia conoidea Sars, *Cytherella abyssorum* Sars, *Polycope sublaevis* Sars, *Erythrocypris hispida* Sars, *Echinocythereis echinata* (Sars), *Cythereis latimarginata* (Speyer), *Macrocypris minna* Baird, *Polycope clathrata* Sars, *Cytheropteron testudo* Sars, *Philomedes lilljeborgi* Sars, *Bythocythere constricta* Sars, *Cypridina norvegica* Baird, *Polycope punctata* Sars, *Bythocythere dromedaria* Sars, *Macrocypria angusta* Sars, *Argilloecia cylindrica* Sars and *Asterope snorvegica* Sars.

Salinity has a direct effect on the number of species in marine and marginal environments. Generally, the number of species increases with increasing salinity as is shown by Elofson (1941). The greatest increase in the Baltic Sea and Skagerrak occurs at salinity range between 2–10‰ (18 species) to 10–17‰ (42 species) and the number of species gradually rises to 78 with the increase in salinity to euhaline (33‰). With the decrease in the number of species from euhaline to mixohaline waters, the number of individuals progressively increases. This phenomenon is worldwide.

TEMPERATURE

Water temperature varies from place to place depending on the latitude and the climate. The climate also effects the vertical temperature of the water mass. A "sensitive phase" of temperature requirement during reproduction of ostracods may effect sex ratios (*see* Reproduction p. 463). The occurrence of Boreal species in the Arctic region could be attributed to the warmer temperature of the Gulf Stream. Effects of temperature are shown on several ostracod assemblages which in deeper water are stenothermal. Temperature tolerances of individual species under controlled conditions are needed.

SUBSTRATE

The nature of bottom sediments, grain size, and the presence or absence of bottom vegetation have a considerable effect on the distribution of ostracods. Remane (1933) used the term " phytal " and divided the fauna into species that showed preference for sand, mud and the phytal. This procedure was followed by Elofson (1941), who greatly refined Remane's classification and grouped the species according to burrowers, clawers or creepers between sand grains. A direct correlation exists between the form and sculpture of the carapace, and the nature of the substrate. This correlation is shown for the first time by Elofson (1941), who observed that smooth-shelled forms burrow either in the mud or were phytals and coarsely sculptured animals were inhabitants of a sandy substrate. This is generally true as has been shown by recent studies by Hulings and Puri (1964) in the Gulf of Mexico and Marinov (1964) in the Black Sea. On the west coast of Florida, Hulings and Puri (1964) showed that in clastic sediments, clean sands support fewer number of species and the greatest number occurs in the varying mixtures of sand and mud. Out of 42 species of marine assemblages, 30 showed a distinct preference for sand and mud mixture, 5 a preference for clean sand and 7 exhibited no preference at all. At least 15 species were found associated with marine grasses. Marinov (1964) has similarly grouped the Black Sea marine ostracods into three natural assemblages: Psammophile (sand); Phytophile (vegetation) and Pelophile (clay or mud). In a typically estuarine environment, however, there does not seem to be any clear-cut correlation between substrate and ostracod assemblages except for vegetation.

One of the factors that controls distribution of phytals is transparency. In transparent waters in the Gulf of Naples, sessile algae obtain sufficient light to live at a depth greater than 100 m. (Harvey, 1945). The zone of photosynthesis can be considered to extend to below 100 m., which is of importance in the distribution of marine plants. From our studies in the Gulf of Naples, marine plants are restricted to a depth of 100 m. However, detritus of marine plants, like *Posidonia*, sometimes occurs at a depth greater than 100 m. The ostracod fauna supported by such a detritus consists of a distinct assemblage.

DEPTH

There appears to be no definite relationship between depth and ostracod distribution, except for bathyal assemblages. Many factors, such as temperature, salinity and substrate, are closely related with depth. In a marine environment, progressive increase in depth is also accompanied by an increase in salinity, and fine-grained sediments, and a decrease in bottom temperature. Thus in an ideal situation, a slight depth (0–30 m.) assemblage will coincide with a (mixo-) mesohaline (salinity range $> 10‰$) assemblage which will also be very eurythermal.

There is an instance of such a coincidence in the Skagerrak (*see* Wagner, 1957, Fig. 3) where 10–125 m. assemblage is restricted to a substrate which consists of a mixture of sand-mud and coarse sand in a (mixo-) polyhaline (salinity range $> 17‰$) water, which is also eurythermal. Another depth assemblage (125–700 m.) lives on a substrate of mud and (mixture of mud and slight sand) in a stenohaline (salinity $> 32‰$) which is also stenothermal.

Since, increase in depth of water also represents an increase in the pressure, it can be a limiting factor ecologically because species that are accustomed to live under slight pressure may not survive under an increased pressure with increased depth. However, there are certain species which are vertically cosmopolitan.

ORGANIC CARBON

Sand-mud mixtures usually contain a higher organic carbon than clean sands. Offshore areas composed of a clean sand substrate show paucity of ostracods and are generally regions characterized by low productivity. Sand-mud mixtures, however, support a greater majority of benthonic ostracods in the west coast of Florida; this coincides with an increased amount of organic carbon and it is considered to be a primary controlling factor (Hulings and Puri, 1964). This also holds true for the Gulf of Naples.

PALEOGEOGRAPHY AND EVOLUTION

In order to have a clear concept of the distribution of modern ostracods, it is necessary to understand paleogeography. The nature and location of ancient seas have affected the distribution of the modern fauna in as much as hundred per cent. of the modern species are descendents of the Miocene, Pliocene and Pleistocene faunas. Relict faunas have been reported from the Caspian Sea, the Sea of Azov and the Black Sea, where euhaline ancient species have acclimatized themselves to live in either ultrahaline or mixohaline waters. In the Mediterranean, colder Boreal species have adapted themselves in waters of the Gulf of Naples.

In the Gulf of Mexico, over fifty per cent. of the Miocene, Pliocene and Pleistocene species persist into the Recent. Such a close relationship with ancient faunas makes it necessary to understand the evolution of these long-range species, their paleoecology and distribution. As for example, the Tamiami (Upper Miocene) and Caloosahatchee (Pleistocene) faunas south of lake Okeechobee in Florida are more closely related to the modern Caribbean fauna while the fauna from sediments of similar ages in western Florida and the western Gulf are closely related to the Gulf of Mexico. Such a relationship becomes clearer when it is realized that during the Miocene Gulf of Mexico waters communicated with the North Atlantic through the Suwannee Straits. This fact also explains the occurrence of a cosmopolitan deep-water North Atlantic fauna in the Gulf of Mexico.

DISPERSAL AND MIGRATION

The distribution of marine ostracod is accomplished by two means of dispersal. Active dispersal is carried out by planktonic forms as most of them are either swimmers or floaters. Since benthonic ostracods can either creep or crawl and are not equipped with active means of locomotion, their distribution is carried by passive dispersal. In freshwater and oligohaline ostracods passive distribution of eggs and larvae can be carried out by wind, drifting vegetation, birds, tides, storms, other marine animals which eat ostracods, and any free floating object. Freshwater ostracod species owe their cosmopolitan distribution to such a passive dispersal. The wide distribution of marginal marine ostracods can be attributed to tides, strong winds, storms and currents. Tide has a sigficant effect in estuaries, lagoons which have an open connection with the sea, and tidal streams. Rising tide acts as wedge of high salinity water which moves slowly and gently upstream for scores of miles. This high salinity wedge carries with it euhaline species which sooner or later adapt themselves to a mixohaline environment. The boundaries of such a mixohaline environment are in a constant state of flux and adjustment. The fauna which lives under such rigorous circumstances is morphologically better equipped to expand its environment to nearby estuaries, lagoons, tidal rivers and bays. This perhaps accounts for a very wide distribution of relatively uniform mixohaline and oligohaline assemblages.

Birds are mentioned by Klie (1926) as agents of passive dispersal and introduction of *Cyprideis torosa* into Lake Rudolf in Kenya is attributed by Klie (1939) to migratory birds. A very wide distribution of certain species of *Cyprideis* in the Americas coincides with the paths of migratory waterfowl and shorebirds and birds are considered to be significant agents of passive distribution (Sandberg, 1964).

In freshwater ostracods, the egg is encased in a very resistant membrane and can withstand years of drought and desiccation. Consequently a certain species could be successfully introduced in a new environment. In mesohaline ostracods, Sandberg (1964) suggests that in the case of *Cyprideis*, the animal may tolerate condition approaching desiccation.

Bottom and ocean currents play an important role in the distribution of ostracods. In the Gulf of Naples, near-shore shallow water ostracods are believed to have been drifted by currents in the deeper offshore environment. In the North Atlantic, the distribution of *Krithe barthonensis* of authors (which is represented by at least 2 closely related species) coincides with the course of the Gulf Stream and the North Atlantic Drift (Neale, 1964). Similarly occurrence of a boreal fauna by Akatoba, 1957 (*Philomedes brenda* Baird, *Heterocyprideis sorbyana* (Jones), *Eucytheridea papillosa* (Bosquet), *Echinocythereis ? septentrionalis* (Brady), and "*Cythereis*" *dunelmensis* (Norman) in the Arctic Bay of Onega of the White Sea could be attributed to the effect of the eastern branch of the Gulf Stream. Similarly both the Jutland and Baltic currents affect the coastal fauna of the Skagerrak region, where a branch of the high salinity (30–34‰) Jutland Current enters the Baltic and meets a low salinity (10–15‰) Baltic Current. This causes extensive layering and considerable fluctuations in the water. In the Baltic Current, the fauna is mixohaline and eurythermal and the fauna in the deeper parts of the Skagerrak region is euhaline and stenothermal (Ekman, 1953, p. 106; Elofson, 1941).

Reproduction and Sex Ratios

Most freshwater ostracods are parthenogenetic and the male is very seldom found. Most marine and marginal marine species are amphigonic, the males are, however, much scarcer than the females.

There is no published record of a truly marine parthenogenetic population in modern ostracods, although it is known that a large number of species have been described only from the female populations. Consequently computation of male-female ratios in modern marine ostracods is meaningless. However, in recent studies by Pokorny (1961, 1964) evidence has been presented which favours this in the Trachyleberididae during the Cretaceous. This poses some very difficult problems in population analysis in modern ostracods.

Factors that control sex ratios and sex determination are unknown in ostracods. Studies on other Crustaceans have established that there exists an environmental control which determines sex and sex ratios. It is attributed to a large degree to temperature and to a lesser extent to salinity and perhaps to other environmental factors in the case of *Gammarus duebeni* by Kinne (1961). There is a "sensitive phase" (number of days before oviposition) during which temperature seems to control sex. In the case of *G. duebeni*, "females kept at a constant salinity of 10 ± 0.4‰ and under normal annual temperature fluctuation.... produced males if the temperature during 'sensitive phase' happened to be below 5° C.; they produced females if the temperature happened to be above 6° C. and mixed broods if the temperature happened to be between 5° and 6° C." (Kinne, 1961).

Unless some experimental work is done under controlled conditions to determine the factors that control sex in ostracods, the sex ratios cannot be applied to modern marine populations with any degree of accuracy.

Adaptive Morphology

There is a relationship between particle size of the substrate and the ornamentation of the ostracod carapace. Coarsely ornamented forms usually live among large sand grains. Thick, heavy, highly ornamented, large carapaces of genera like *Carinocythereis, Costa, Mutilus, Quadracythere, Cytheridea* and *Urocythereis* characterize near-shore coarse-grained sediments. Ventral flattenning of the carapace in *Microcythere* is attributed to an easier climbing on the sand grains. In areas effected by strong currents, the animal has a tendency to develop a stronger and more reticulate carapace.

Several genera such as *Bosquetina*, *Pterygocythereis*, *Cytherura* and *Cytheropteron* have lateral spines which aid in supporting the carapace on soft, fine-grained sediments. Ostracods with smooth or subdued ornamentation are generally found living on a fine sediment bottom.

Most of the species which live in mud have feather-like bristles on the limbs as well as the antennae in order to assist the animal towards an easier forward motion on the surface of a soft bottom.

Genera like *Polycope* and *Parvocythere* live in small cavities in interstitial water and they have adapted themselves morphologically to such a habitat. Such an adaptation for *Parvocythere* seems to be independent of salinity since two species of this genus live in two different hemispheres, one in a salinity of 1–20‰ and the other (*P. hartmanni*) in 17–18‰ (Marinov, 1964, p. 86). Both the species of *Parvocythere* have adapted themselves to interstitial environment by the reduction of the third pair of walking legs (p. 11).

Genera like *Paradoxostoma*, *Cytherois*, *Paracytherois* and *Sclerochilus* have developed lips with a sucking disc in order to feed on vegetation. Planktonic forms, as species of *Conchoecia* and *Archi-.conchoecia*, have thin carapaces and some of the appendages are furnished with long natatory bristles.

POPULATION STRUCTURE

Density of population at the sediment-water interface has been studied in detail in some areas. Distribution of total ostracod populations generally shows some correlation with the relative size of the individual. Lowest populations of ostracods (1–50) in the Gulf of Naples, are composed of individuals with large carapaces which inhabit a coarse-grained substrate. Largest populations (500–1000) are generally composed of individuals of much smaller size and their distribution pattern coincides with areas of either fine-grained substrate or increased vegetation; this effect may well be due to an increased food supply.

FOOD SUPPLY

Supply of food is one of most important factors in the distribution of ostracods. However, very little is known about food habits in marine benthonic ostracods. Genera like *Paradoxostoma* feed on *Posidonia* and have sucking discs in their lips; *Cytherella* are filter feeders and some genera like *Cypridina* are parasitic and live on the gills of fishes. Elofson (1941) mentioned that algae and diatoms were common in the intestines of 45 species; some of them dug in the mud showed some Foraminifera and bristle of polychaetes in their intestines. But detailed studies in other areas are lacking. The effect of the availability of the nature and amount of food in the sediment-water interface and its relationship to the productivity of benthonic ostracods is essential to a clearer understanding of the distribution patterns. In the San Antonio Bay, Swain (1955) thought that the variations of ostracod populations were effects of food supply. This is also true in Gulf of Naples, where largest total populations are associated with calcareous algae, *Posidonia* and other forms of vegetation.

BARRIERS AND SUITABLE HABITATS

Physical or chemical barriers obviously effect the distribution of ostracods to suitable habitats. Of the chemical barriers, salinity is perhaps the most effective in the prevention of an expanding environment. Both the climate and the temperature are also limiting factors in the distribution of ostracods. Submarine topography plays an important role in determining the paths of migration of the benthonic ostracods. The amount of food supply, or the lack of it, is an important factor which determines the survival in suitable habitats.

OSTRACODA ENVIRONMENTS

Ostracods inhabit purely terrestrial environment like spalean (*Mesocypris terrestris* Harding), fluvial (*Candona, Limnocythere, Darwinula*), paludal (Cypridinae, Cyclocypridinae), and lacustrine (several genera). Marginal marine environments include areas close to the land mass which is usually included in the littoral environment. These areas are from the coast-line to the edge of the continental shelf and include estuaries, lagoons, bays, beaches, and deltas. These areas are most affected by surface run-off, food, terrigenous sediments, a marked degree of variation in temperature and salinity. Generally speaking, these areas are considered to be in the " turbulent zone " of water. The composition of marginal marine environments varies from one area to another depending on local hydrographic and climatic conditions. The succession of ostracods assemblages from fluvial terrestrial to outer neritic are well illustrated in the Gulf of Mexico and the Gulf of Naples. The littoral provinces of the world are shown on Fig. 1.

THE NORTH ATLANTIC BOREAL FAUNA

THE CELTIC PROVINCE

This biogeographic unit includes the area around the British Isles, the North Sea, and the Scandenavian Coast, perhaps as far north as North Cape. The northern boundary with the Arctic faunas is not well defined because of a transition zone in which the Boreal fauna of the Celtic is mixed with northern Arctic species. The southern boundary of this province is placed differently by various authors but it is generally agreed that it runs south-west of the British Channel.

The ostracod fauna has been studied, among others, by Baird (1850), Brady (1868, 1880, 1910), Brady and Norman (1889, 1896), Brady and Robertson (1870), Sars (1899, 1922–28), Klie (1926, 1938), Elofson (1941), Wagner (1957) and Vos (1957). In a recent paper, Neale (1964) has ably summarized the research work done in the past 200 years in this province. The ostracod fauna consists of almost 400 species and some of the more characteristic forms are listed under salinity (*see* p. 458) and the reader is referred to Neale's paper for finer details.

THE BALTIC SEA

The Baltic Sea is characterized by low salinity (10–20%) and is the largest brackish-water sea. The salinity of the water progressively decreases towards the interior. The ostracod fauna consists of truly oligohaline and mixohaline species a great number of which came from the neighbouring North Sea. The ostracod fauna of this region has been studied by Hirschmann (1909, 1912, 1916), Sars (1922–1928) and has been the subject of an excellent study on ecology by Elofson (1941). A list of some of these species which characterize the Baltic Sea is given under salinity (*see* p. 458) and is not repeated here. For further details, the reader is referred to the classic work of Elofson (1941).

THE MAURETANIAN REGION

The areas generally included in the Mauretanian region consist of the Islands of Cape Verde, Canaries, Madeira and the Azores. The ostracod fauna consists of a mixture of both Mediterranean and European boreal species.

Ostracods of Madeira have been studied by Fischer (1855) who described the type species of *Paradoxostoma* (*P. dispar*) from near-shore material. In a later study Brady (1911) reported the following two assemblages:

(*a*) *Littoral Zone*

Aurila convexa (Baird), *Hemicythere albomaculata* (Baird), *Xestoleberis depressa* Sars, *X. nigromaculata* Brady, *Loxoconcha impressa* Baird, *Cytherura maculata* Brady, *Hemicytherura cellulosa* (Norman), *Sclerochilus laevis* ? Müller *Paradoxostoma hibernicum* Brady and *P. arcuatum* Brady.

(*b*) *Dredged in* 30–70 *fathoms*

Bythocypris reniformis Brady, *Macrocypris decora* Brady, *Pontocypris succinea* Müller, *P. dispar* Müller, *Bairdia amygdaloides* Brady, *B. obtusalata* Sars, *B. dubia* Brady, *B. mediterranea* Muller, *B. acanthigera* Brady, *Argilloecia affinis* Brady, *Leptocythere crispata* (Brady), *L.*? *cingulata* (Brady), *Trachyleberis*? *tuberculata* (Sars), "*Cythere*" *emaciata* Brady, *Carinocythereis runcinata* (Baird), *C. antiquata* (Baird), *Occultocythereis deformis* (Brady), *Pterygocythereis jonesi* (Baird), *Cushmanidea elongata* (Brady), *Eucythere prava* Brady and Robertson, *Loxoconcha obesa* Brady, *L. decipiens* Müller, *L. impressa* Baird, *L. subalata* Brady, *Xestoleberis latissima* Brady, *Cytherura striata* Sars, *C. cribrosa* Brady, *C. cribriformis* Müller, *C. fossulata* Brady, *Neocytherideis subulata crenulata* (Brady), *Sclerochilus contortus* Norman, *S. laevis* Müller, *Paradoxostoma gracile* Brady, *P. flexuosum* Brady, *P. cylindricum* Müller, *Sarsiella capsula* Norman and *Cytherella*? *ovalis* Brady.

From the Mauretanian Sahara Coast, Klie (1943) reported *Cyclasterope lobiancoi* Müller and off Morocco, in a depth 55 m. *Philomedes folini* Brady.

THE NORTH AMERICAN BOREAL PROVINCE

On the western side of the North Atlantic along the North American coast, in addition to several endemic species in this biogeographic region, at least 32 species which are common between two sides of the North Atlantic, have been reported by Cushman (1916) in the Vineyard Sound, by Blake (1933) from Maine, Tressler and Smith (1948) from Maryland and Tressler (1940) from North Carolina. The faunas on the North American coast are not as well known as in the eastern side of the Atlantic, but one cannot escape the fact that there is strong evidence to support the existence of an American Boreal Province north of Beaufort, N.C. The following are common between the sides of the Atlantic:

Heterocythereis albomaculata (Baird), *Asterope abyssicola* Sars, *Cylindroleberis muelleri* (Skogsberg), *Asterope elliptica* Phillippi, *Asterope mariae* (Baird), *Cythere lutea* O. F. Müller, *Hirschmannia viridis* (O. F. Müller), "*Cythereis*" *clavata* Sars, *Bradleya*? *dawsoni* (Brady), "*Cythereis*" *dunelmensis* Norman, *Normanocythere leioderma* (Norman), *Trachyleberis tuberculata* (Sars), *Hemicythere villosa* (Sars), *Eucytheridea papillosa*, *Cytheridea punctillata* (Brady), *Cushmanidea rubra* (Müller), *Cytherois pusilla* Sars, *Cytheromorpha fuscata* (Brady), *Neocytherideis fasciata* (Brady), *Cytheropteron pyramidale* Brady, *Cytherura gibba* (O. F. Muller), *Semicytherura striata* (G. O. Sars), *S. undata* (Sars), *Hemicythere concinna* (Jones), *Leptocythere castanea* (Sars), *L. macallana* (Brady and Robertson), *Loxoconcha guttata* (Norman, *L. impressa* (Baird), *Philomedes globosus* (Lilljeborg), *Sclerochilus contortus* Norman, *Xestoleberis aurantia* (Baird) *X. depressa* (Sars).

THE MEDITERRANEAN-ATLANTIC FAUNAS

THE MEDITERRANEAN SEA

The Mediterranean Sea is treated here as a unit although it is realized that the boreal North Atlantic fauna intruded into the Mediterranean through Gibraltar.

The surface temperature of the water during summer in the Western Mediterranean is 20–25° C. (subtropical) with a greater change in seasonal temperature than the eastern part which is tropical (summer temperature 25–27° C.). Salinity in the western part is + 38‰ while in the eastern tropical part it is 40‰. Mediterranean Sea has a much lower fertility than the neighbouring Atlantic. The bottom sediments consist of sands, clays, muds and shell sands. Vegetation of the coastal areas in depths upto 100 m. consists of *Posidonia*, calcareous algae and fibrous algae. This uniformity in bottom conditions has resulted in a remarkably similar fauna from the Balearic Sea in the west to the Levantine Coast in the east. Ecologically the ostracod fauna has been studied in much greater detail than anywhere in the world. This region has provided classic works, such as G. W. Müller (1894), Rome (1939, 1942, 1964), Reys (1961, 1963) and Hartmann (1963).

THE WESTERN MEDITERRANEAN

Phytal.—The fauna associated with bottom vegetation, east of Balearis Islands, consists predominantly of species of *Paradoxostoma*, *Xestoleberis*, *Cytherois*, *Sclerochilus* and *Paracytherois* The following species commonly occur from Marseille in the west (Reys, 1961, 1963), through

Monaco (Rome, 1939, 1942, 1964) to the Naples region (Puri, Bonaduce and Malloy, 1964) in the east:

Paradoxostoma intermedium Müller, *P. taeniatum* Müller, *P. caecum* Müller, *P. rarum* Müller, *P. breve* Müller, *P. incongruens* Müller, *Xestoleberis parva* Müller, *X. fuscomaculata* Müller, *X. communis* Müller, *X. labiata* Brady and Robertson, *X. margaritea* Brady, *X. decipiens* Müller, *Cytherois frequens* Müller, *Sclerochilus abbreviatus* Brady and Robertson, *S. aequus* Müller, and *Paracytherois striata* Müller.

Calcareous Algae.—The following fauna associated with the Coralline Algae in the Marseille area also occur as far east as the Gulf of Naples:

Aurila aff. *A. convexa* (Baird), *Hemicytherura videns* Müller, *Loxoconcha rhomboidea* (Fischer), *Xestoleberis parva* Müller, *X. pellucida* Müller, *Paradoxostoma intermedium* Müller, *P. rarum* Müller, and *Cytherois frequens* Müller.

The faunal uniformity of the Western Mediterranean is shown by the following species which commonly occur in Marseille, Monaco and Gulf of Naples:

Aurila aff. *A. convexa* (Baird), *Hemicytherura videns* Müller, *Xestoleberis parva* Müller, *X. margaritea* Brady, *X. decipiens* Müller, *X. fuscomaculata* Müller, *X. communis* Müller, *Paradoxostoma intermedium* Müller, *P. taeniatum* Müller, *P. caecum* Müller, *P. rarum* Müller, *P. breve* Müller, *P. incongruens* Müller, *Cytherois frequens* Müller, *Sclerochilus abbreviatus* Brady and Robertson, *S. aequus* Müller and *Paracytherois striata* Müller.

For discussion in this paper, the Western Mediterranean is divided into Balearic Sea, Tyrrhenian Sea, Ionian Sea and Adriatic Sea.

Balearic Sea

In the French Riviera, Rome (1939, 1942, 1964) studied the ostracod fauna near Monaco and discovered a marked similarity between the fauna of that area and that of the Gulf of Naples. Eighty-six species, representing twenty-six genera, were found to be common to the areas. Rome's samples were collected at various depths to below 400 meters. The majority of these samples, however, were collected from shallow waters of less than 30 m. depth. Bottom conditions in the Monaco area are similar to those of the Gulf of Naples, with sands and plants giving way to clays with increasing depth.

In a recent study (Reys, 1961, 1963) in the vicinity of Marseille in the Golfe du Lion, based on 37 samples from 5 biocoenose, 85 species, distributed over 22 genera, were reported.

There is remarkable similarity between faunas around Baleares, Banyuls, Monaco, Marseille and the Gulf of Naples. The association of ostracods with certain types of vegetation and substrate is well established from studies by G. W. Müller (1894), De Buen (1916), Rome (1939, 1942, 1964), Reys (1961), Hartmann (1953) and Puri, Bonaduce and Malloy (1964). The following species occur in all the five areas (Baleares, Banyuls, Monaco, Gulf of Naples and Marseille):

Loxoconcha rhomboidea (Fischer), *Xestoleberis labiata* Brady and Robertson, *X. margaritea* Brady, *X. communis* Müller.

The following species occur in the above four areas except Banyuls:

Xestoleberis decipiens Müller, *Paradoxostoma incongruens* Müller, *Cytherois frequens* Müller and *Paracytherois striata* Müller.

Xestoleberis parva Müller, *X. fuscomaculata* Müller, *X. communis* Müller, *Paradoxostoma intermedium* Müller, *P. caecum* Müller and *P. rarum* Müller.

The following 20 species occur in Monaco, Gulf of Naples and Marseille:

Aurila convexa (Baird), *Hemicytherura videns* (Müller), *Xestoleberis prava* Müller, *X. labiata* Brady and Robertson, *X. margaritea* Brady, *X. decipiens* Müller, *X. fuscomaculata* Müller, *X. communis* Müller, *Paradoxostoma intermedium* Müller, *P. teaniatum* Müller, *P. caecum* Müller, *P. rarum* Müller, *P. breve* Müller, *P. incongruens* Müller, *Cytherois frequens* Müller, *Sclerochilus abbreviatus* Brady and Robertson [= *S.* (?) *levis* Müller], *S. aequus* Müller and *Paracytherois striata* Müller.

The following species are associated with Coralline algae in the Marseille area:

Bairdia raripila Müller, *Aurila convexa* (Baird), *Hemicytherura videns* (Müller), *Loxoconcha rhomboidea* (Fischer), *Xestoleberis parva* Müller, *X. labiata* Brady and Robertson, *X. pellucida* Müller, *X. margaritea* Brady, *X. fuscomaculata* Müller, *Paradoxostoma intermedium* Müller, *P. parallelum* Müller, *P. fuscum* Müller, *P. taeniatum* Müller, *P. caecum* Müller, *P. rarum* Müller, *P. atrum* Müller, *P. breve*, Müller, *Cytherois frequens* Müller.

Tyrrhenian Sea

The Gulf of Naples (Fig. 2) has been studied in detail by Müller (1894); and Puri, Bonaduce and Malloy (1964). Because of very little rainfall in this region, surface run-off has very little

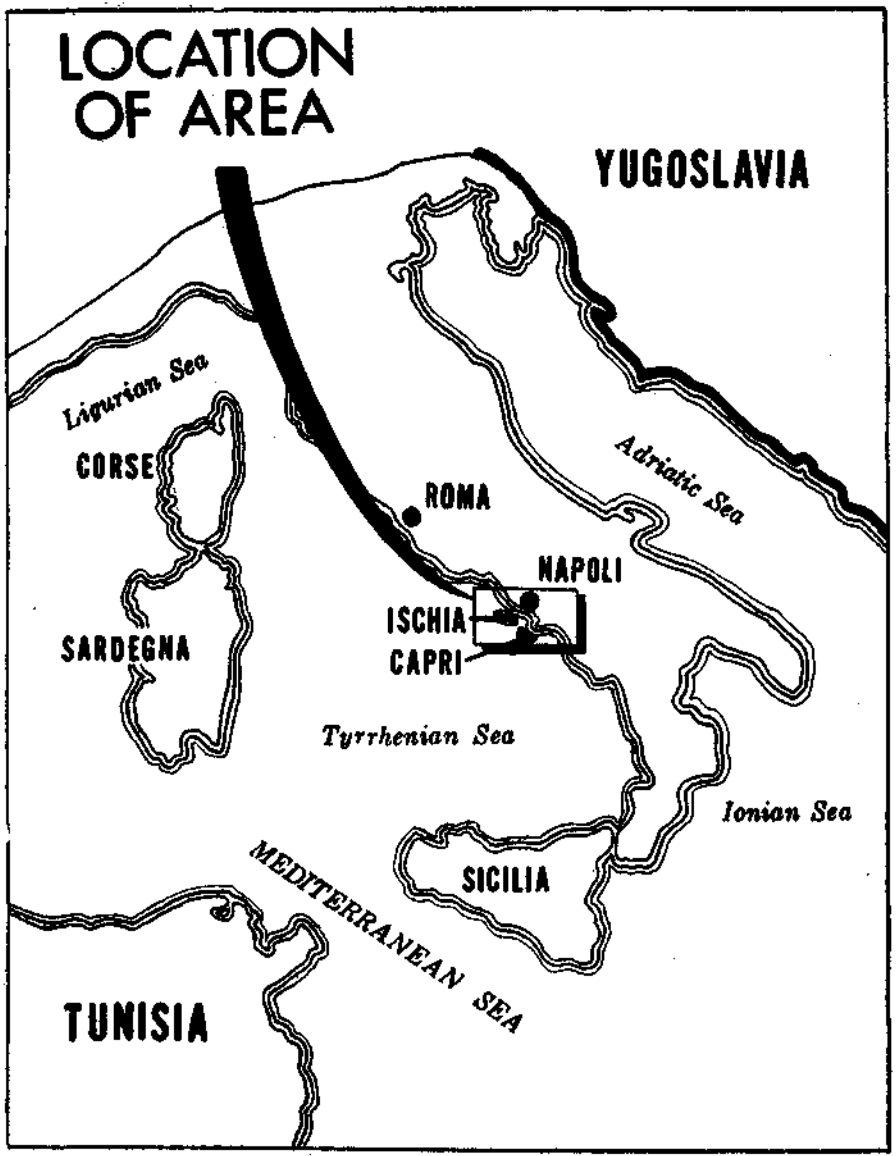


FIG. 2. Location map showing Gulf of Naples and its vicinity.

influence on the water of the Gulf. Consequently the open-sea character due to the connection with the Mediterranean is even more pronounced (Fig. 3). The bottom sediments are derived mostly from volcanic tuft except in the Sorrentine Peninsula and Capri, where erosion of sedimentary rocks provides some clastic material. The bottom temperature at depths greater than 50 m. is uniform (14–15° C.). Hydrogen-ion concentration (pH) is between 7·7 and 8·20. Bottom salinity varies between 37‰ around to coast and 38·50‰ at the connection with the Mediterranean. Transparency of the water is as high as 37 m. below surface in the middle of the Gulf.

Lagoons.—Lago di Patria is a shallow water (average depth 2 meters) littoral lagoon: salinity seldom exceeds 13–14‰, minimum temperature is 7–8° C. and maximum temperature is 30° C. (Sacchi, 1961). Distribution of ostracods from this area consists of 16 species of a typical brackish-assemblage which is shown on Fig. 4 (data from Mackenzie, 1963).

Shelf.—Three shallow shelf (depth up to 100 metres) inner neritic assemblages are recognized (Puri, Bonaduce and Malloy, 1964); these consist of: *Aurila* aff. *convexa* (Baird), *Buntonia sublatissima* (Neviani), *Carinocythereis carinata* (Roemer), *C. antiquata* (Baird), *C. quadridentata* (Baird), *Costa runcinata* (Brady), *Cuneocythere* n. sp. A., *Cytheridea neapolitana* Kollmann, "*Cythereis*" *polygonata* Rome, *Cytheridea* n. sp. A., *Eucythere declivis* (Norman), *Hemicytherura videns* (Müller), *Krithe similis* Müller, *Leptocythere bacescoi* (Rome), *L.* n. sp. C., *Mutilus speyeri* (Brady), *Neocytherideis foveolata* (Brady), *Quadracythere* (?) *p rava* (Baird) and *Urocythereis margaritifera* (Müller). The following five species are restricted to depths up to 50 metres or attain their maximum development in these depths and may represent a distinct assemblage: *Costa batei* (Brady), *Cushmanidea elongata* (Brady), *C. turbida* (Müller), *Krithe reniformis* (Brady), and *Semicytherura incongruens* (Müller).

Ostracods associated with bottom vegetation like *Posidonia*, calcareous algae, algae, seaweeds, *Phyllochaetopterus socialis*, and bottom animals, like sponges, are here considered as separate assemblages although it is realized that these assemblages are confined to depths less than 100 metres. In most cases *Posidonia* occurs on shallow banks around Ischia, Procida, Naples and Sorrento Peninsula; while calcareous algae are confined to Ischia bank, Gulf of Pozzuoli, south of Naples, north of Castellammare and Bocca Piccola (Fig. 3). In some places, however, *Posidonia* and calcareous algae occur together and it is impossible to delineate their boundaries either by bottom vegetation or by their ostracod assemblage. The boundaries of *Posidonia*, calcareous algae and fibrous algae ostracod assemblages coincide with the limits of their vegetation pattern.

The following species are associated with *Posidonia*:

Philomedes aspera Müller, ? *Sarsiella capsula* Norman, *Cylindroleberis mariae* Baird, *C. teres* Norman, *Polycope dentata* Brady, *P. tuberosa* Müller, *P. reticulata* Müller, *P. striata* Müller, *P. fragilis* Müller, *P. dispar* Müller, *P. serrata* Müller, *Macrocypris succinea* Müller, *Paracypris complanata* (Brady and Robertson), *Pontocypria spinosa* Müller, *Pontocypris subfusca* Müller, *P. succinea* Müller, *P. setosa* Müller, *P. declivis* Müller, *P. levis* Müller, *P. mediterranea* Müller, *Bassleriтes teres* (Brady), *Neocytherideis foveolata* (Brady), *Cytheretta rubra* Müller, and *Cytherelloidea sordida* (Müller).

The following species are associated with calcareous algae:

Cypridina mediterranea Costa, *Philomedes interpuncta* Baird, *P. levis* Müller, *Pseudophilomedes foveolata* Müller, *P. angulata* Müller, ? *Sarsiella capsula* Norman, *Cylindroleberis mariae* (Baird), *C. teres* Norman, *Polycope rostrata* Müller, *P. tuberosa* Müller, *P. maculata* Müller, *P. striata* Müller, *Polycopsis compressa* Müller and *Macrocypris succinea* Muller.

Offshore assemblage and depth zonation.—Offshore inner neritic assemblages (depth over 100 m.) can be distinguished into three depth zones: 100–200 m.; 200–300 m.; and over 300 m.

The following are indicative of 100–200 m. depth zone:

Buntonia giesbrechti (Müller), *B. sublatissima dertonensis* (Ruggieri), *Cytherella* n. sp., *Cytheropteron* ? *crassipinnatum* Brady and Norman, *C. latum* Müller, *C.* n. sp. H., *Cytherura acuticostata* Sars, *C. dispar* Müller, *Cuneocythere* n. sp. C., *Loxoconcha decipiens* Müller, *L. napoliana* Puri, and *L.* n. sp. D., *L. versicolor* Müller, *L.* n. sp. A., *Pterygocythereis jonesi* (Baird) and subspecies *ceratoptera* and *fimbriata*, *Semicytherura acuminata* Müller and *Tetracytherura angulosa* (Seguenza).

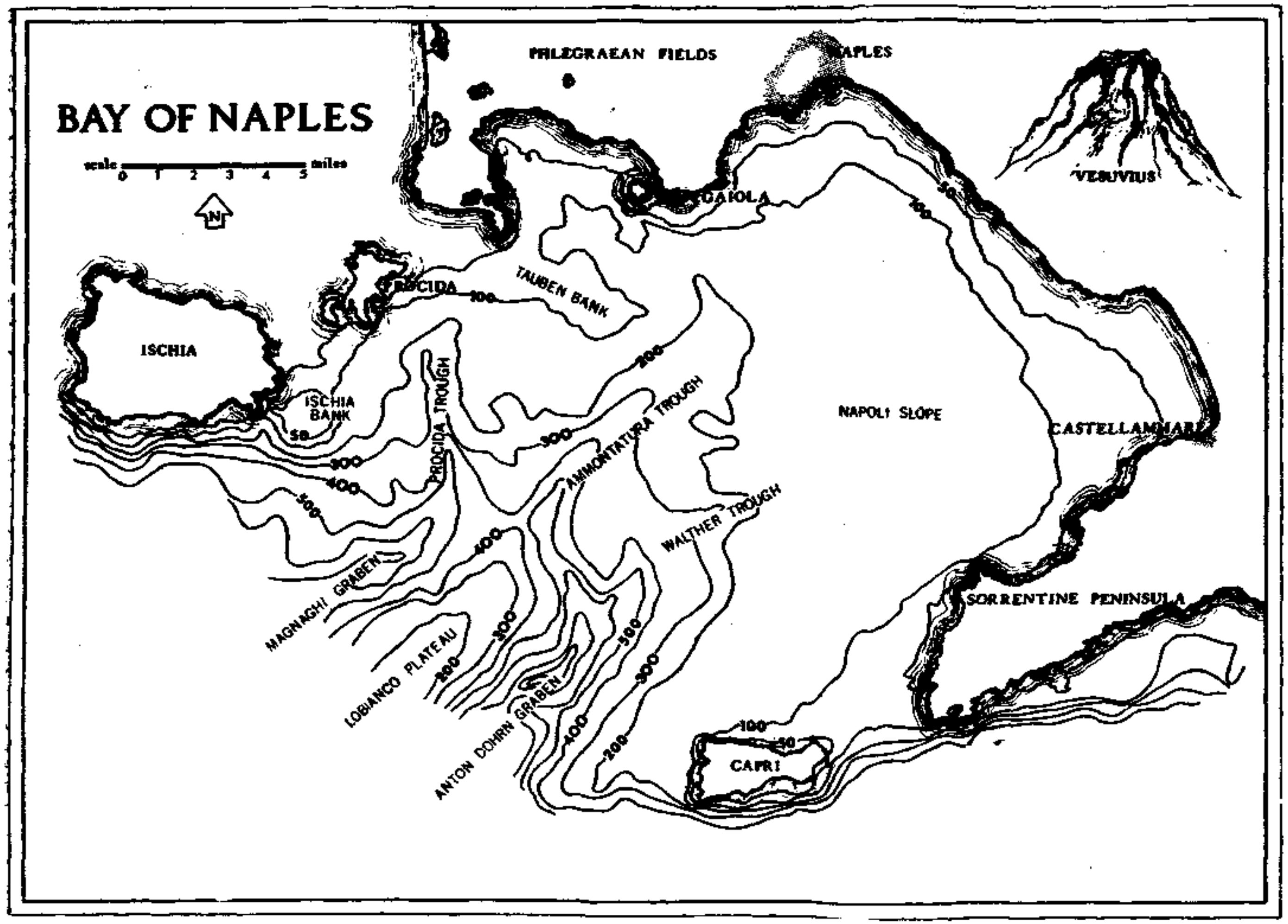


FIG. 3. Gulf of Naples showing bottom topography (contour interval in metres below water surface).

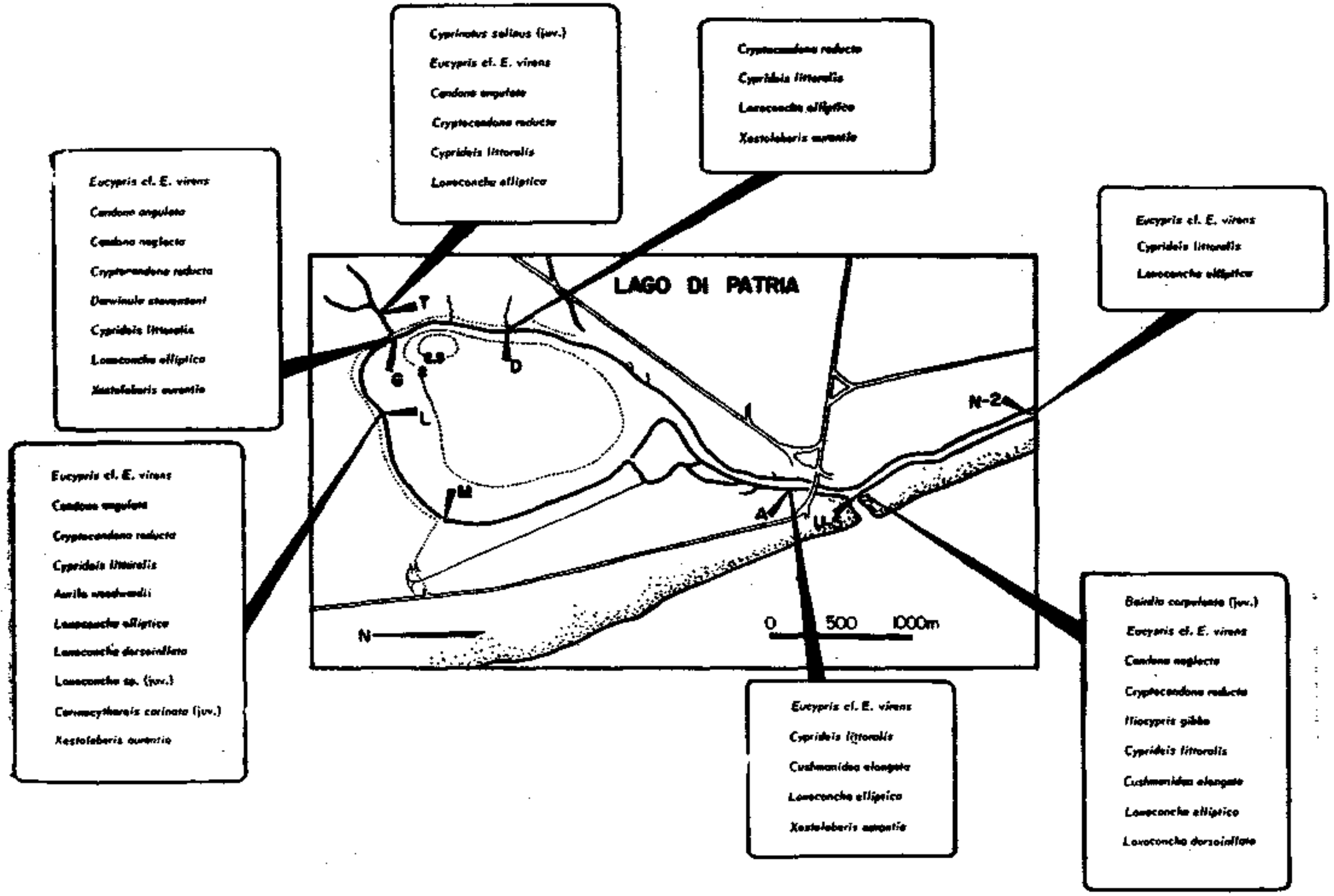


FIG. 4. Distribution of brackish-water assemblage in the Lago di Patria (Data from Mackenzie, 1963).

The following species are indicative of 200–300 m. depth zone:

Bosquetina carinella (Reuss), *Cytheropteron latum* Sars, *Henryhowella sarsi* (Müller), *Krithe* n. sp. B., *Pseudocythere caudata* Sars, *Semicytherura paradoxa* (Müller) and *Trachyleberid* n. gen. D. n. sp. 1.

The following species occur in depths over 300 m.:

Cytheropteron rotundatum Müller, *Cytherura rara* Müller, *Kangarina abyssicola* (Müller).

From beach sand at Forte dei Marmi, Tuscany, Ruggieri (1955) described *Tyrrhenocythere pignattii* Ruggieri.

The Adriatic Sea

The Adriatic borders on the east by Yugoslavia and Albania and the west by the Italian coast; in the south it connects with the Ionian Sea. In the northern part, shallow depths (upto 80 m.) are encountered, the middle is moderately deep (80–200 m.); greatest depths (upto 1,200 m.) are encountered in the southern part. There is very little drainage into the sea except for the Po River, which flows into the sea south of Venice. Surface and salinity are normal open sea (35–38‰) and are fairly uniform. Bottom sediments in the northern part are variable and consist of mostly sand and argillaceous sands and clay. Central part shows a predominantly muddy bottom with occasional sand and clay; the southern part is mostly clay except in the southernmost part which exhibits a mixture of sand, mud and clay (Ascoli, 1964). Ostracods of the Adriatic has been studied by Klie (1942), Ruggieri (1952) and Ascoli (1964).

Data from bottom cores throughout the Adriatic have enabled Ascoli (1964) to recognize the following 4 depth Zones: (1) "*Inner Sublittoral*" (31–42 m.) is a shallow inner neritic assemblage which is dominated by *Cytheridea neapolitana* Kollmann, *Cushmanidea elongata* (Brady) and *Semicytherura incongruens* (Müller). This assemblage inhabits a predominantly sandy bottom, with clay and mud. (2) "*Transitional*" (42–74 m.) zone consists of species which are common in 31–42 m. assemblage and an increase in the population of *Pterygocythereis*, *Callistocythere diffusa* (Müller) and *Henryhowella*. This assemblage does not show a preference for a definite sediment type. (3) "*Outer Sublittoral*" (74–243 m.) is characterized by *Bairdia*, *Loxocythere* and *Loxoconcha tamarinda* (Baird). *Bosquetina dentata* (Müller), *Henryhowella* and *Cytherella* are frequent. (4) "*Bathyal*" (243–1,192 m.) is characterized by species of *Macrocypris*, *Argilloecia*, and *Krithe*.

The following species are common between the Adriatic, Gulf of Naples, Monaco, and Marseille:

Hemicytherura videns (Müller), *Loxoconcha rhomboidea* (Fischer), *Xestoleberis labiata* Brady and Robertson, *Xestoleberis pellucida* Müller, *Xestoleberis decipiens* Müller, *Xestoleberis communis* Müller, *Paradoxostoma intermedium* Müller, *Paradoxostoma fuscum* Müller, *Paradoxostoma rotundatum* Müller, *Paradoxostoma atrum* Müller, and *Sclerochilus abbreviatus* Brady and Robertson, *Pontocypris pirifera* Müller, *Callistocythere lobiancoi* Müller, *Neocytherideis foveolata* (Brady).

THE EASTERN MEDITERRANEAN

The Ionian Sea and Greece

The fauna of Korfu and Greece ostracods have been studied by Klie (1938) and Stephanides (1937, 1948). Klie (1938) described a brackish-water species, *Cytherois stephanidesi* Klie from Korfu living in a minimum salinity of 2·6‰. This is the first time that a species of a truly marine euryhaline genus, *Cytherois*, was recorded from such a low salinity. Stephanides (1948, p. 93) later on found another specimen of this interesting form from a ditch in Ragusa in low brackish-water (salinity 4–6‰). The other marine forms reported by him is a species of *Leptocythere*, tentatively identified as *L. ilyophila* Hirschmann, a boreal form recorded from Germany and Finland. Other brackish-water forms recorded by Stephanides are *Cyprideis littoralis* Brady (NaCl 2–3‰ and

20–25‰), *Loxoconcha gauthieri* Klie (NaCl 2–25‰) and *Leucocythere mirabilis* Kaufman (2–3‰ NaCl) largely cosmopolitan.

The following freshwater assemblage is reported by Stephanides (1948) from Korfu:

**Iliocypris gibba* Ramdohr, *I. biplicata* "(Koch)"), *I. bradyi* Sars, *I. getica* Masi, **I. australiensis* Sars, *Notodromus persica* Gurney, **Cypris pubera* O. F. Müller, *C. bispinosa* Lucas, *Eucypris virens* Jurine, *E. kerkyrensis*, *E. elongata* Stephanides, **Herpetocypris reptans* Baird, **H. chevreuxi* Sars, *H. strigata* O. F. Müller, *Ilyodromus olivaceus* Brady and Norman, **Cyprinotus incongruens* Ramdohr, **C. salina* Brady, **C. fretensis* Brady, **C. inaequivalvis* Bronstein, **Cypridopsis vidua* O. F. Müller, **C. parva* Muller, *C. aculeata* Costa, *C. hartwigi* Müller, *C. newtoni* Brady and Robertson, *Potamocypris fulva* Brady, **P. maculata* Alm , *Cyclocypris ovum* Jurine, **Physocypris kerkyrensis* Klie, **Candona neglecta* Sars, *C. fabaeformis* Fischer and *Candonopsis kingsleii* Brady and Robertson.

(Forms preceded by * are also recorded by Stephanides from Macedonia, Epirus and Central Greece, together with *Herpetocypris brevicaudata* Kaufman, *Potamocypris variegata* Brady and *Cyprideis littoralis* Brady).

Malta Area

A sample of clay dredges from a depth of 100 fathoms south of the Island of Malta by Prof. U. Moncharmont of the Zoological Station of Naples (Italy) has yielded an assemblage in which the following species are common:

Pterygocythereis jonesi (Baird), *P. fimbriata* (Munster), *Bosquetina carinella* (Reuss), *Henryhowella sarsi* (Müller) *Mutilus* (?) *speyeri* (Brady), *Loxoconcha decipiens* Müller, *L. pellucida* Müller, *Semicytherura acuticostata* (Sars), *S. paradoxa* (Müller), *S. mediterranea* (Müller), *S. punctata* (Müller), *Cytherura dispar* Müller, *Eucytherura gibbera* Müller, *Hemicytherura videns* (Müller), *Cytheropteron rotundatum* Müller, *C. alatum* Sars, *Polycope reticulata* Müller, *P. dispar* Müller, *P. striata* Müller, *P. rostrata* Müller, *P.* cf. *P. dentata* Brady.

Cyprus

Marine ostracods of the Cyprus area are largely unknown but the following list includes freshwater fauna reported by Stephanides from the Island of Cyprus:

Ilyocypris divisa Klie, *Eucypris virens* Jurine, *Herpetocypris reptans* Baird, *Cyprinotus* (Heterocypris) *incongruens* Ramdohr, (*H.*) *salina* Brady, ? *C.* (*H.*) *fretensis* Brady and *Cypridopsis* sp.

The Levantine Coast

The ostracods of the Levantine Coast have been studied by Klie (1935), who reported two species from Alexandria. Later on Ruggieri (1953) reported the following assemblage from Port Said:

Cyprideis sp., "*Cythereis*" *emaciata* Brady, *Carinocythereis turbida* Müller, *C. runcinata* (Baird), *C. scutigera* (Brady), *Hemicythere* sp., *Bassleriites teres* (Brady), *Neocytherideis* cf. *N. subulata* (Brady), *Cushmanidea elongata* (Brady), *Caudites* sp., *Paijenborchella* (*Neomonoceratina*) *mediterranea* Ruggieri.

In a more recent study by Lerner-seggev (1964), ostracod fauna from the Coast of Israel (from Haifa in the north and Vadi Rubin in the south), nine species are recorded from the eulittoral zone to a depth of 158 m.

This assemblage consists of:

Cytherella pori Lerner-Seggev, *Bairdia incognita* Lerner-Seggev, *Krithe bartonensis levantina* Lerner-Seggev, *Neocytherideis foveolata* (Brady), *Cytheridea neopolitana* Kollmann, *Buntonia giesbrechti* (Müller), *Loxoconcha stellifera* Müller and *Paradoxostoma intermedium* Müller.

Except for the new forms reported by Lerner-Seggev, the remaining of the fauna is of western Mediterranean nature.

The Lebanon Sea

Five samples were collected in the Beirut area at depths up to 135 fathoms. The following 19 species are common:

Loxoconcha impressa Baird, *L. napoliana* Puri, *L. pellucida* Müller, "*Cythereis*" *polygonata* Rome, *Cytheridea neapolitana* Kollmann, *Semicytherura acuticostata* (Sars), *S. alifera* Ruggieri, *S. inversa* (Seguenza), *Hemicytherura videns* (Müller), *Cytheropteron latum* Müller, *Kangarina abyssicola* (Müller), *Aurila* aff. *A. convexa* (Baird), *Bosquetina carinella* (Reuss), *Costa batei* (Brady), *Bairdia formosa* Brady, *Callistocythere diffusa* (Müller), *Xestoleberis communis* Müller, *Polycope reticulata* Müller.

THE BLACK SEA

The modern Black Sea communicates with the Mediterranean through Bosporus; in the past, however, it was joined with the Caspian Sea through Sea of Azov. Consequently the ostracod fauna of the Black Sea has both Mediterranean and Sarmatic elements.

The salinity of the Black Sea is very low (15–18‰ on the surface) as compared with the rest of Mediterranean (+ 38‰). The bottom sediments consist of coarse to fine sands, detrital sands and silt and clays. The ostracod fauna has been studied by Klie (1937, 1942), Dubowsky (1939), Caraion (1958, 1959, 1960, 1962, 1963) and Marinov (1962, 1963, 1964) and by Cvetkov (1959). The hollowing three biotopes are recognized in the Bulgarian coast by Marinov (1964):

1. *Phytals.*—The fauna commonly encountered among algal vegetation along the coast consists of *Loxoconcha pontica* Klie, *Eucytherura bulgarica* Klie, *Paradoxostoma intermedium* Müller, *Xestoleberis aurantia* (Baird) and *X. decipiens* Müller. Comparatively rare are *Paradoxostoma abbreviatum* Sars, *P. bradyi* (Sars), *Cytheroma karadagiensis* Dubowsky, and *Sclerochilus gewemuelleri dubowskyi* Marinov.

2. *Pelophile biotope* which inhabits a clayey bottom consists of *Carinocythereis rubra pontica* Dubowsky, *C. antiquata* (Baird), *Pterygocythereis jonesi* (Jones), *Loxoconcha granulata* Sars and *Callistocythere diffusa* (Müller).

3. *Psammophile biotope* which prefers a sandy bottom consists typically of a large assemblage of *Parvocythere hartmanni* Marinov, *Microcythere varnensis* Marinov, *M. longiantennata* Marinov, *Loxoconcha nana* Marinov, *L. bulgarica* Klie, *L. aestuarii* Marinov, *Cytherois pontica* Marinov, *C. pseudovitrea messambriensis* Marinov, *C. pseudovitrea carcinitica* Marinov, *Semicytherura pontica* (Marinov), *S. remanei* Marinov, *Pontacytheroma arenaria* Marinov, *Cushmanidea bacescoi* Caraion, *Pseudocytherura pontica* Dubowsky, *Paracytheridea pauli* Dubowsky, *Cytherois cepa* Klie. *Microcytherura* sp. and *Leptocyhtere pellucida* (Baird).

Certain species, such as *Loxoconcha minima* Müller and *L. impressa* (Baird), also inhabit algal vegetation while *Carinocythereis rubra pontica* Dubowsky lives also in muddy bottom. *Cushmanidea chernjawskyi* (Dubowsky) inhabits argilleaceous sand. Some of the psammophile species are interstitial forms, like *Microcythere varnensis* Marinov and *Parvocythere hartmanni* Marinov which live at a depth of 2–5 m., in a salinity of 1–2‰ to 17–18‰ (Marinov, 1964, p. 86).

The fauna in the Bosporus region consists of forms like *Loxoconcha granulata* Sars, *Carinocythereis antiquata* (Baird), *C. rubra pontica* Dubowsky, etc., which have a large distribution in the Black Sea together with such stenohaline species such as *Philomedes intermedia* (Baird), *Pterygocythereis jonesi* (Baird), *Costa hamata* (Müller), *Cytheropteron rotundatum* Müller, *Cytheretta rubra* (?) Müller, *Bythocythere* sp. and some species of Bairdiidae. These typically Mediterranean stenohaline forms have adapted themselves in lower salinity and lower winter temperature of the water.

The distribution of ostracods in the brackish-water Black Sea estuaries and ultrahaline lakes is divided into four categories according to their origin, as follows (Marinov, 1964, p. 83):

1. Freshwater species which have also been found in the brackish-water basins. The most common forms are represented by *Ilyocypris biplicata* (Baird), *Candona neglecta* Sars, *C. levanderi* Hirschmann, *Limnocythere inopinata* (Baird), *Darwinula stevensoni* (Brady and Robertson).

2. *Typical brackish-water species.*—Most abundant and common forms are represented by *Cyprideis littoralis* Brady, *C. torosa* Jones, *Hemicythere sicula* (Brady) and *Potamocypris steueri* Klie.

3. Ultrahaline species is represented by *Eucypris inflata* (Sars) which occurs along the Bulgarian coast and in lakes near Schabla, Baltschik, Pomorie and Burgas. Salinity in these lakes and basins during summer months is up to 80‰.

4. Sea-euryhaline species which are open-sea forms that have adapted themselves in mesohaline waters. These are represented by *Cytheridea neapolitana* Kollmann, *Callistocythere diffusa* (Müller), *Leptocythere pellucida* (Baird), *Callistocythere mediterranea* (Müller), *Eucythere declivis* (Norman), *Carinocythereis antiquata* (Baird), *Pterygocythereis jonesi* (Baird), *Costa hamata* (Müller), *Hemicytherura cellulosa* (Norman), *Cytheropteron rotundatum* Müller, *Cytheroma variabile* Müller, *Loxoconcha granulata* Sars, *L. impressa* (Baird), *L. minima* Müller, *L. littoralis* Müller, *Xestoleberis decipiens* Müller, *X. aurantia* (Baird), *Paradoxostoma intermedium* Müller, *P. simile* Müller, *P. variabile* (Baird), *P. abbreviatum* Sars and *P. bradyi* Sars.

The above assemblage is typically Mediterranean mixed with some European boreal species.

THE SEA OF AZOV

The Sea of Azov is shallow (13 m.) and temperature range of the water is 30° C. and 0·6° C. (mean 25° C.) and is very variable. During the Quaternary period, the Mediterranean invaded the Black Sea through Bosphorus and in the open part of the Black Sea a large percentage of the brackish-water Sarmatic fauna was destroyed but in the Sea of Azov, survivors of the Sarmatic fauna are still living (Ekman, 1953, p. 96). This is also true of ostracods. In the delta parts of rivers in the Azov Sea basin, Schornikov (1964) reported 8 species of Caspian origin which are still alive. Five of these species *Candona schweyeri* Schornikov (*nom. nov.* pro *Candona elongata* Schweyer, 1949 *non C. elongata* Herrick, 1879 *non C. elongata* Vavra, 1891), *Leptocythere striatocostata* (Schweyer), *L. quinquetuberculata* (Schweyer), *L. longa* (Negadaev) and *Loxoconcha lepida* Stepanaitys, were originally described from the upper Pliocene and post-Pliocene of the South of U.S.S.R. The other three species include *Leptocythere lopatici* Schornikov, *L. relicta* Schornikov and *L. gracilloides* Schornikov.

THE CASPIAN SEA

The Caspian Sea is marked by a very high salinity (up to 170‰). The ostracod fauna was described by Sars (1927) from the littoral region and the two species *Heterocythereis amnicola* (Sars) and *Loxoconcha umbonata* (Sars) were described by Elofson (1945). Sars (1887) reported *Heterocythereis amnicola* from the coast of Sicily in the Mediterranean.

THE RED SEA

From material collected by the expedition of the S.M.S. " Pola " in the Red Sea, Graf (1931) described the Cypridinidae. Recently, Hartmann (1964) has described the following fauna consisting of 49 species from the eulittoral and supralittoral zones:

Philomedes grafi Hartmann, *Rudiderma compressa* Brady and Norman, *Sarsiella crispata* Scott, *Asterope mariae* Baird, *Polycope microdispar* Hartmann, *P. elongata* Hartmann, *Ghardaglaia triebeli* Hartmann, *Bairdia schulzi* (Hartmann), *Cyprideis littoralis* (Brady), *Leptocythere* cf. *L. littoralis* (Müller), *Callistocythere arenicola* Hartmann, *Hemicytherura videns aegyptica* Hartmann, *Loxoconcha ghardaquensis* Hartmann, *L. idkui* Hartmann, *L. ornatovalvae* Hartmann, *Loxoconchella dorsobullata* Hartmann, *Paracytheridea remanei* Hartmann, *Xestoleberis rotunda* Hartmann, *X. multiporosa* Hartmann, *X. ghardaque* Hartmann, *X. capillata* Hartmann, *X. rhomboidea* Hartmann, *X. rubrimaris*

Hartmann, *X. simplex* Hartmann, *Paradoxostoma breve* (Müller), *P. arcuatum* Hartmann, *P. parabreve* Hartmann. *P. longum* Hartmann, *P. punctatum* Hartmann, *Cytherois glacialis* Hartmann, *Sclerochilus rectomarginata* Hartmann, *Cytheroma dimorpha* Hartmann, *Adbitocythere subterranea* Hartmann, *Bradleya reticulata* Hartmann, *Moosella striata* Hartmann, *Cythereis? rubrimaris* Hartmann, *Caudites laevis* Hartmann, *Hemicythere? borcheri* Hartmann.

The fauna of the Red Sea is most distinct and only two species (*Leptocythere* cf. *L. littoralis* and *Paradoxostoma breve*) are common with Mediterranean.

TROPICAL AND SUB-TROPICAL FAUNAS OF AMERICAS

The warm water fauna could conveniently be divided into two natural provinces, the Caribbean and the Gulf of Mexico.

THE CARIBBEAN PROVINCE

The "West Indian" or the Caribbean biogeographic division stretches from South Florida and Bahama to Venezuela. The fauna between Cape Kennedy and Cape Hattaras can best be termed temperate rather than subtropical. The warm water fauna of the Caribbean has several endemic species and the fauna as a unit is distinctive enough to be treated as a separate biogeographic province. The ostracods on this area have been described by Brady (1868–71, 1880), Tressler (1949), Puri (1960), Kornicker (1959, 1961, 1963, 1964) and Van den Bold (1946, 1950, 1957, 1958, 1964). The following is a list of some of the more distinctive species reported from this region:

Macrocypris africana G. W. Müller, *Macrocypris schmitti* Tressler, *Macrocypris tenuicauda* Brady, *Bairdia longisetosa* (Brady), *Bairdia subdeltoidea* (Sars), *Orionina bermudae* (Brady), *Paracytherois pulchella* (Brady), *Bythocypris reniformis* Brady, "*Cythere*" *compacta* Brady, "*Cythere*" *dupperei* Brady, "*Cythere*" *oblonga* Brady, *Orionina bahamensis* (Brady), "*Cythereis*" *pumicosa* (Brady), "*Cythereis*" *ramdohri* (Müller), *Trachyleberis tuberculata* (Sars), *Cytherella pulchra* Brady, *Cytheridea curta* Brady, *Cytheridea setipunctata* Brady, *Cytheridea subquadraregularis* (Brady), *Bairdia crosskeyana* Brady, *Bairdia* cf. *B. tuberculata* Brady, *Kangarina bradyi* Puri, *Leptocythere cranekeyensis* Puri, *Leptocythere yoni* Puri, *Orionina bermudae* (Brady), *Orionina serrulata* (Brady), *Orionina bradyi* Van den Bold, *Platetlla muelli* Puri, *Pontocypris intermedia* Brady, *Triebelina bradyi* Tiebel, *Triebelina coronata* (Brady), *Triebelina indopacifica* Van den Bold, *Triebelina sertata* Triebel, *Xestoleberis punctata* Tressler, *Bairdia rostrata* Kornicker, *Bairdia shulerae* Puri, *Bairdia bradyi* Van den Bold, *Bairdia dinochelata* Kornicker, *Bairdia gigacantha* Kornicker, *Bairdia harpago* Kornicker, *Bradleya hornibrooki* Puri, *Caudites angulata* Puri, *Caudites howei* Puri, *Cytherelloidea sarsi* Puri, *Cytherella arostrata* Kornicker, *Cytherella harpago* Kornicker, and *Cytherella pandora* Kornicker.

The Caribbean could be divided into three subprovinces, the Bahaman, South Floridan and Venezuelan.

The Bahaman biogeographic subdivision has been studied extensively by Kornicker. The climate is subtropical; average temperature in the summer is 28° C. as compared with 22° C. in the winter. The Bahamas are separated from Florida by the Florida Straits and the Florida Current moves through these straits. This area has an endemic fauna which consists of many species of Myodocopa and because of a natural barrier (the Florida Straits) some of the benthonomic ostracods which occur in Florida are not present in the Bahamas (Kornicker, 1964). The following biotic zones are recognized by Kornicker (1964) in order of increasing abundance of ostracod in the Bahamas: Outer Shelf, Restricted Shelf, Restricted Lagoon and Hypersaline Lagoon.

The South Florida subprovince is marked with a carbonate substrate and reef. The ostracod fauna is distinctive and has many endemic species (*Macrocypris schmitti* Tressler, *Orionina bermudae* Brady, *Kangarina bradyi* Puri, *Leptocythere cranekeyensis* Puri, *L. yoni* Puri, *Tribelina coronata* Brady, *Xestoleberis punctata* Tressler, *Caudites angulata* Puri, etc.). It is hoped that current studies by Van den Bold and Hulings in Caribbean will help to clarify the southern boundary of this biogeographic unit.

The Venezuela subprovince, although has many species common with the rest of the Caribbean, the fauna is tropical rather than subtropical. The following species, reported by Van den Bold (1964) from the north coast of Venezuela, seem to be endemic to this area: *Bythocypris keiyi* Van den Bold, *Gangamocytheridea dictycon* Van den Bold, *G. sandbergi* Van den Bold, *Caudites nipeensis* Van den Bold, *C. obliquecostatus* Van den Bold, *Quadracythere pannosa* (Brady), *Campylocythere*? *perrensis*, (Brady) *Costa variabilcostata* Van den Bold, *Basslerites minutus* Van den Bold and *Loxoconcha rugosa* Van den Bold.

Gulf of Mexico

Coastal Lagoons of Texas

The major geographic features and shoreline together with location of the area discussed here is shown on Fig. 5. The nature of the bottom sediments appears on Fig. 6. A comprehensive study was made by Swain (1955) on the ostracod ecology in the vicinity of San Antonio Bay. The major geographic features and ostracod facies recognized in this classic area is shown on Fig. 7. This Bay is shallow (average depth 5 feet), turbid for most of the year, with a clayey substrate. It exhibits a very wide range of chlorinity (1–20%). Average temperature in nearby Aransas and Copano Bays varies between 13° C. and 31° C. Variable values in pH are recorded, lowest pH (2·5) values are obtained from fluvial part of Bay, but higher values (5·5) are reported from the Lower Bay. The Lower Bay also has lowest carbonate values (4·1%) and lower total nitrogen (·07%) than the Upper Bay (·17%) (Swain, 1955).

Movement of the water in the Bay occurs in two masses; the first mass enters the Upper Bay as fluvial run-off, and moves into the Lower Bay and then westward into Mesquite Bay and the Gulf of Mexico. The movement of the water eastward is prevented by a second mass that enters the Espirtu Santo Bay from the Gulf of Mexico through Pass Callavo. Since these water masses are of two distinct types, its effect on the Bay is reflected in very variable hydrographic and environmental conditions through the entire Bay. The following biofacies are recognized in San Antonio Bay and vicinity, and their diagnostic assemblages are illustrated on Fig. 7 (data from Swain, 1955).

River and prodelta facies	River subfacies Prodelta subfacies
Bay facies	Midbay subfacies Lower bay subfacies Marginal subfacies
Open gulf facies	Nearshore subfacies Offshore subfacies

The three subfacies of the Bay facies are recognized by the following assemblages (after Swain, 1955):

Midbay subfacies

Limnocythere sanctipatricii Brady and Robertson (most abundant in Upper Bay), *Cyprideis torosa* Jones, *Cyprideis litteralis* Brady, *Cyprideis locketti* (Stephenson), *Paracytheridea troglodyta* Swain, *Perissocytheridea brachyforma* Swain (also occurs in several of the Matagorda Island samples and rarely in the open Gulf), *Cytherura elongata* Edwards (also from Matagorda Island lakes and marshes), *Cytherura swaini* Van den Bold (also in open ocean), *Cytherura johnsoni* Mincher (also from Matagorda Island and open Gulf), *Cytherura forulata* Edwards, *Cytheromorpha paracastanea* (Swain) (also open Gulf), *Monoceratina*? sp., *Paradoxostoma atrum* Müller and *Cytheromorpha curta* Edwards (most common in Upper Bay).

Marginal subfacies

Perissocytheridea bicelliforma Swain, *Perissocytheridea rugata* Swain, *Paradoxostoma ensiforme* Brady and *Cytherura johnsoni* Mincher (is relatively more abundant in the marginal parts of the Bay than in the middle where it is entirely absent at many stations).

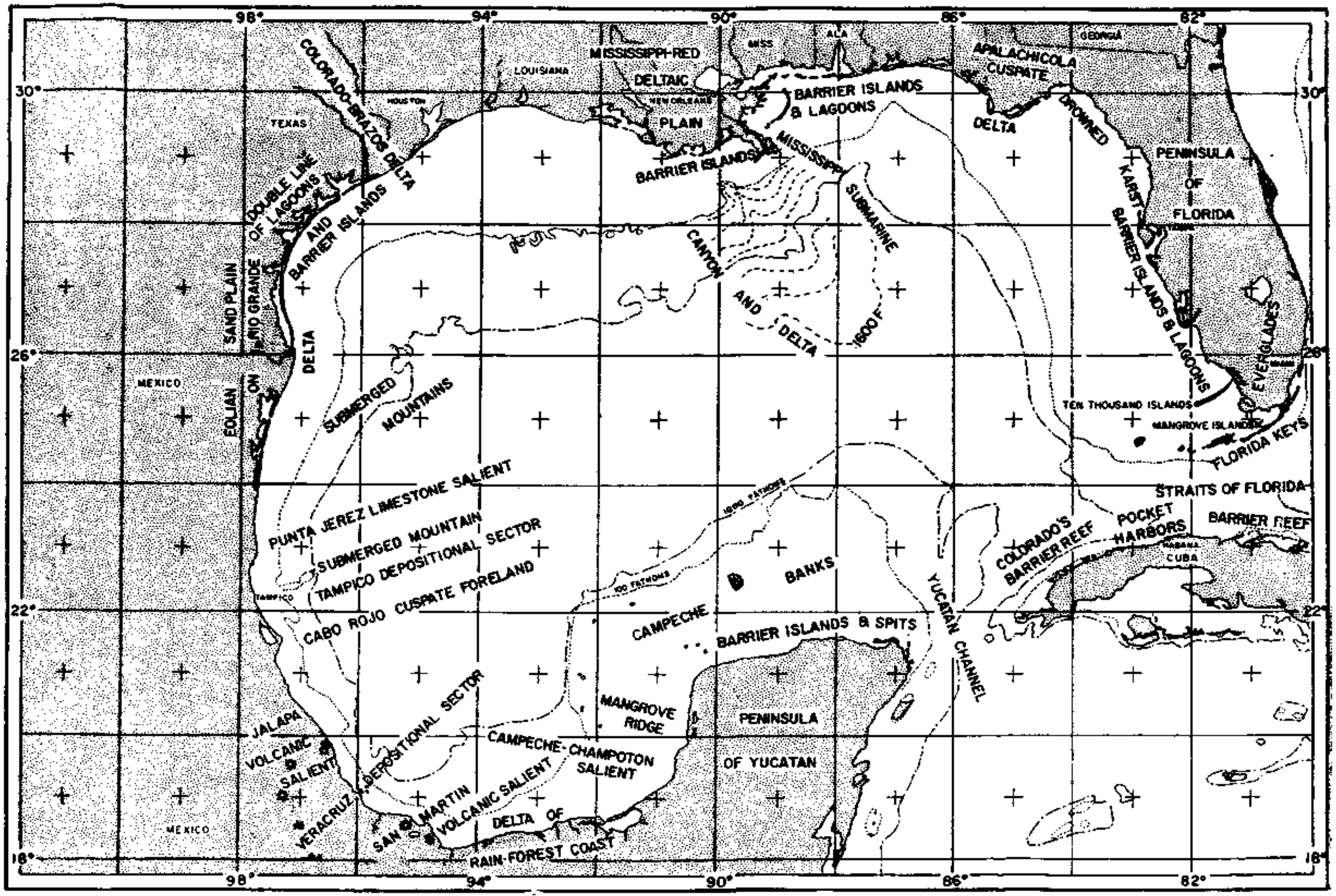


FIG. 5. Gulf of Mexico showing the shorelines and major geographic features (after Price, 1954).

Lower Bay subfacies

Haplocytheridea bradyi Stephenson (also rare in Upper Bay), *Haplocytheridea bassleri* Stephenson, *Perissocytheridea brachyforma excavata* Swain (also rare from Matagorda Island and open Gulf), *Paracytheridea vandenboldi* Puri, *Cytheromorpha* sp. (also Matagorda Island), *Cytherura gibba* Müller, *Cytherura costata* Müller, *Loxoconcha matagordensis* Swain (also rare in open Gulf and from Matagorda Island), *Campylocythere concinnoidea* Swain (also rare in open Gulf and from Matagorda Island), *Cushmanidea* aff. *C. mayeri* (Howe and Johnson), *Cushmanidea* (also from Matagorda Island), *Actinocythereis* aff. *A. exanthemata* (Ulrich and Bassler) (also is in open Gulf and is rare in Upper Bay and from Matagorda Island), *Paracytheroma johnsoni* (Mincher) and *Hemicythere conradi* Howe and McGuirt (rare in Upper Bay and from Matagorda Island).

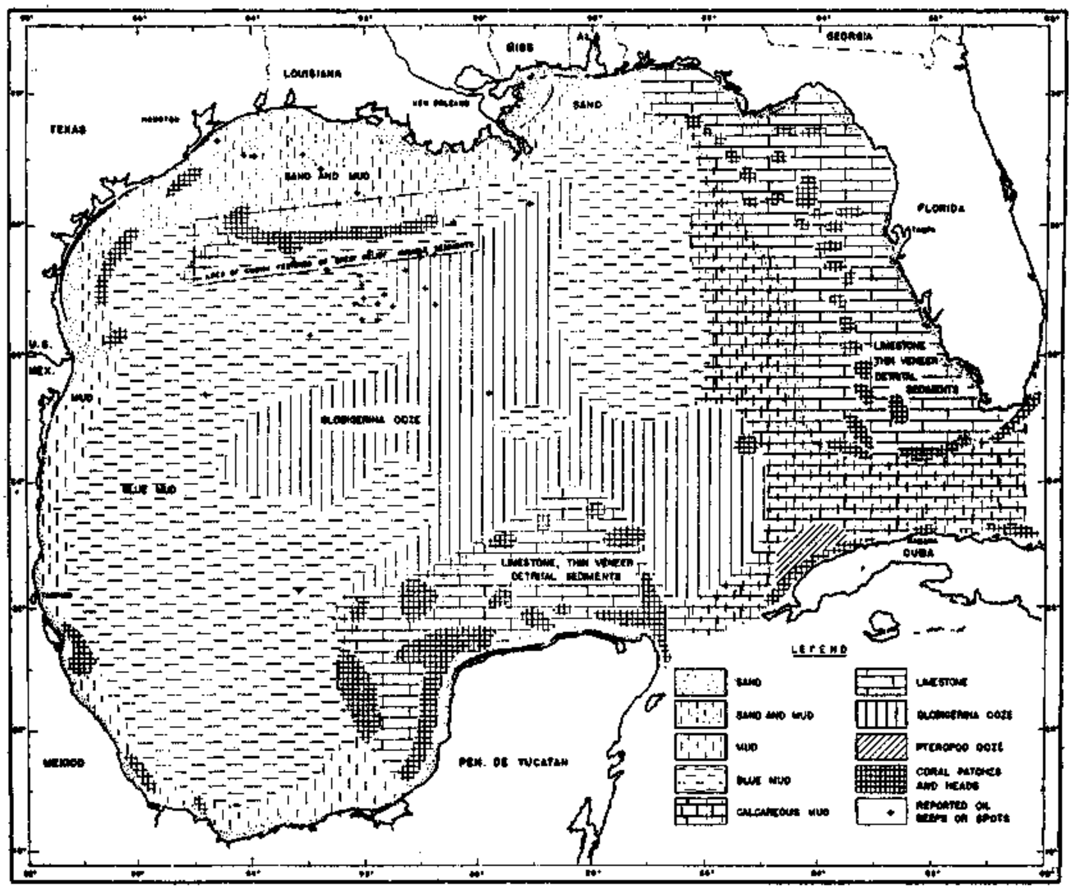


FIG. 6. Sedimentary Provinces of the Gulf of Mexico (after Lynch, 1954).

The ostracod biofacies of the open Gulf are based on a meager fauna consisting of a few specimens of *Cushmanidea*, *Protocytheretta danaiana*, *Puriana* sp. and *Neomonoceratina* sp. Species belonging to *Pontocythere* also occur in the San Antonio Bay.

Seasonal study of ostracods has been conducted in the Redfish Bay, about 25 miles south-west of San Antonio Bay (Kornicker, 1964). Like the latter, Redfish Bay is shallow (average depth 6 ft.), with temperature range of approximately 0–40° C. and salinity from 16–37‰. The composition of the ostracod fauna in this Bay is similar to the Lower Bay facies in the San Antonio Bay and this could be attributed to higher salinity in the Redfish Bay. The total seasonal populations of the ostracod fauna are dominated by *Aurila floridana* Benson and Coleman and *Loxoconcha*

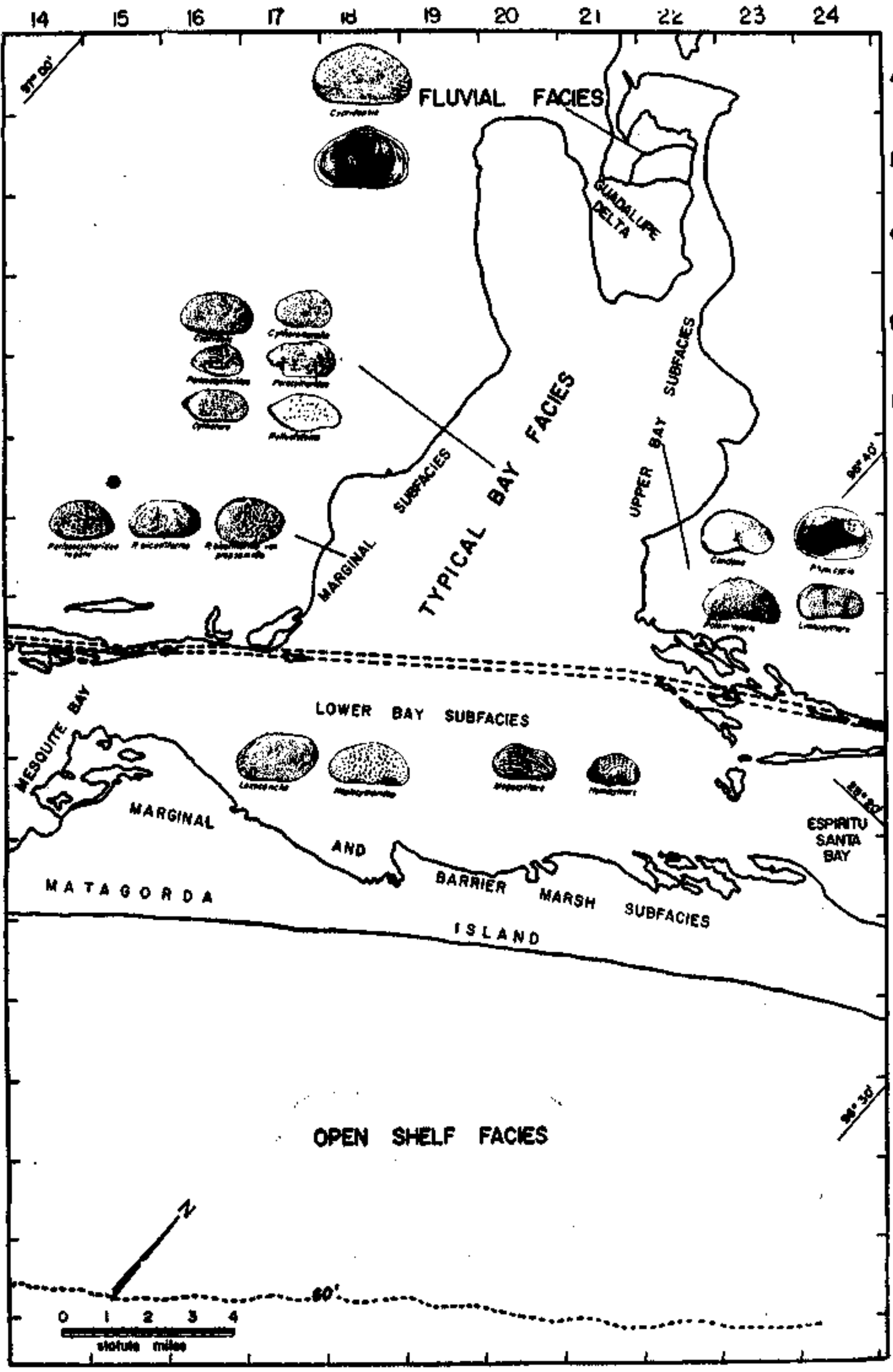


Fig. 7. Ostracod assemblages in the San Antonio Bay Area, Texas (Data from Swain, 1955).

purisubrhomboidea Edwards. Kornicker (1964) observes that living ostracods are more abundant in the summer months when the salinity is normal marine, higher temperature and carbon content. This is perhaps an area of slow deposition of sediments as Kornicker's comparison of average annual living and dead populations at one station are quite similar.

Results of experimental laboratory work by Kornicker and Wise (1960) show that *Aurila floridana* has a very wide salinity (6–65%) and temperature tolerance (6–36° C.).

Florida Lagoons and Bays

Coastal lagoons and bays in Florida have been studied by Hulings (1958), Waller (1961), Benda and Puri (1963), Benson and Coleman (1964), Puri and Benda (1965) and the following summary is based on a synthesis by Hulings and Puri (1964): The St. Andrew Bay system is a complex of estuaries (North Bay, West Bay and East Bay) opening into a central St. Andrew Bay. The discharge into the estuaries is relatively small, North Bay receiving the greatest discharge as indicated by the average salinity, 20‰ (range 3–32). The remaining estuaries of the complex have higher mean salinities, West Bay, 26‰ (range 16–34) and East Bay 26‰ (range 10–31). St. Andrew Bay proper is in direct connection with the Gulf of Mexico and the salinities of the Bay especially near the Gulf are essentially the same as those of the Gulf (mean 29·5, range 23–24). The predominant sediments of the bay are sands and mixtures of silt and clay. Grass flats are rather extensive in the shallower portions of the complex. On the basis of average monthly temperatures for all stations in the complex, the temperature range was 10–30° C. (Waller, 1961).

Another bay which has been studied in great detail is the Apalachee Bay. The inshore waters of Apalachee Bay are under the direct influence of two factors: estuarine discharge and proximity of Gulf water. Two large estuaries and numerous spring-fed creeks empty into Apalachee Bay thereby exerting an influence primarily on the salinity and sediments.

The bottom salinity range for Apalachee Bay was 20–35%, the lower values occurring near the mouths of the estuaries. The lower values were noted at ebb tide. The higher salinities were obtained toward the south-eastern end of the area investigated and indicate the influence of Gulf water.

The bottom temperature range during the investigation was 14 –30° C. The annual temperature range in the area is around 15° C. The currents of Apalachee Bay appear to be tidal in nature. Permanent currents in Apalachee Bay appear to be absent.

The sediments of Apalachee Bay are clastic in the form of fine to medium-grained quartz sand. The influence of the estuaries can be seen because of the presence of considerable quantities of silt throughout the area. Clean sands are predominant in the southern part of the Bay. Grass flats are frequent in the shallower portions of the area (Hulings, 1958).

Ochlockonee Bay is a positive estuary, according to the classification of Pritchard (1952), that is, a coastal indenture in which there is a measurable dilution of sea-water by land drainage. The Bay is about 5 miles long and about 1½ miles wide. The Ochlockonee River system discharge averages 4,000 cubic feet per second. The mouth of the estuary permits relatively free exchange with the open Gulf.

The salinity ranges from 0–15‰ in the upper part of the bay and 16–30‰ in the lower part, depending of course on the tide. Because of the predominant semi-diurnal tides, there is almost continual flushing of the estuary.

The annual temperature range is on the order of 10–30° C. The sediments are predominantly mud with mixtures of shell, sand and mud in the lower part of the Bay. Fairly clean sands occur along the shores (Hulings, 1958; Zehiye *et al.*, 1961).

Boca Ciega Bay is a northerly extension of Greater Tampa Bay. The Bay is separated from the Gulf of Mexico by a chain of barrier islands with numerous tidal channels. The study in Boca Ciega Bay was restricted to the lower portion.

The average depth of lower Boca Ciega Bay is about 6 feet and extensive grass flats are numerous. The salinity distribution is relatively uniform and ranges from 18–34%. There is no direct river discharge into lower Boca Ciega Bay. The temperature range reported for the Bay is 10–32° C. The sediments generally consist of gray, clayey to silt, quartz sand. Boca Ciega Bay is considered near-marine environment (Puri and Benda, 1965).

The Cape Romano area was divided into four environments by Benda and Puri (1962). The environmental factors of three of these will be briefly discussed.

Lagoonal environment consists of a network of interconnected lagoons. The lagoons are very shallow, averaging about 4 feet in depth. The observed salinity range for this environment is in the vicinity of 13–43‰. The seasonal temperature range is 20–33° C. The sediments consist predominantly of highly organic ooze, in some cases reducing. Appreciable quantities of sand and silt occur.

Mangrove environment consists of a myriad of mangrove islands, restricted baylets, shallow waterways and relatively deep channels. Water depths rarely exceed 4 feet except in channels where the depths may exceed 6 feet. The salinity range for this environment is in the vicinity of 23–40‰. Bottom temperatures range from 20–32° C. The sediments are essentially the same as those of the lagoonal environment.

Dominant and diagnostic assemblages in the Cape Romano area are shown on Fig. 8.

The following is a typical estuarine assemblage:

Aurila conradi var. Howe and Mc Guirt, *Cyprideis* cf. *C. littoralis* (Brady), *Cytheromorpha pascagoulensis* Mincher, *Hulingsina sandersi* Puri, *Megacythere johnsoni* (Mincher), *Perissocytheridea bicelliforma* Swain, *Perissocytheridea brachyforma* Swain, *Perissocytheridea rugata* Swain, and *Reticulocythereis multicarinata* (Swain).

Two marginal assemblages are recognized by Hulings and Puri (1964) since they range into lower salinity areas. The following assemblage shows absolute preference for sand-mud mixture and is found in all four areas:

Actinocythereis exanthemata (Ulrich and Bassler), *Actinocythereis subquadrata* Puri, *Cushmanidea elongata* (Brady), *Cytheromorpha warneri* Howe and Brown, *Cytherura forulata* Edwards. *Cytherura johnsoni* Mincher, *Cytherura wardensis* Howe and Brown, *Haplocytheridea setipunctata* (Brady), *Hemicythere amygdala* Stephenson and *Hulingsina sulcata* Puri.

The following assemblage is restricted to three of the four areas investigated:

Cytherura elongata Edwards, *Cytherura* sp. C, *Loxoconcha australis* Brady, *Loxoconcha matagordensis* Swain and *Neocaudites nevianii* Puri.

Florida Shelf

In the Panama City offshore area, the topography of the bottom is fairly uniform with no large channels or sounds in the area. The sediments are predominantly medium to fine-grained, well-sorted quartz sands. Minor amounts of finer sediments occur sporadically.

The currents in the area are predominantly longshore (N.W.S.E.) and low velocity (0·25) knots. These currents appear to be tidal in origin.

The bottom seasonal temperature range in the Panama City area is from 14–30° C., the mean being about 24° C.

The bottom salinity range is from 33–36‰, the mean being 35‰. The marine environment off Panama City Beach is unique in many respects. There are no major rivers emptying into the area

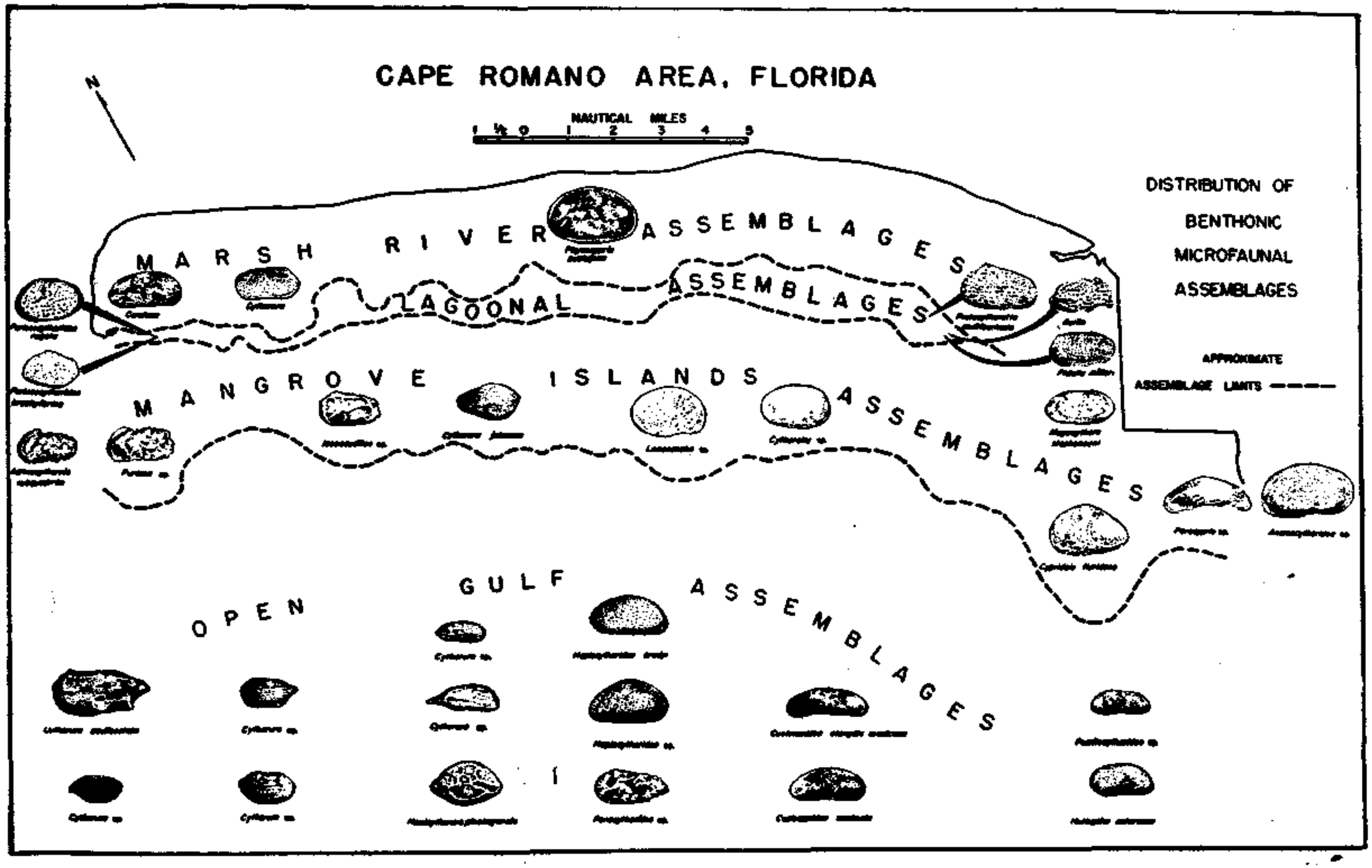


FIG. 8. Ostracod assemblages in the Cape Romano Area, Florida (Data from Benda and Puri, 1962).

and as a result conditions are essentially those of a normal marine environment (Puri and Hulings, 1957).

In the Cape Romano area, the shallow shelf is characterized by a gently sloping bottom, about 2 feet per mile. The bottom salinity range for this environment is 36–40‰, the temperature range 20–31° C. The bottom sediments consist of mainly fine, slightly shelly quartz sand. The organic content is greatest near the mangrove islands and decreases seaward (Benda and Puri, 1963).

The following two assemblages are recognized by Hulings and Puri (1964):

A high (30‰) salinity shallow water (less than 65 feet) assemblage which does not show any preference for sediment type consisting of:

Acticythereis laevissima Edwards, *Aurila conradi* (Howe and McGuirt), *Bairdia shulerae* Puri, *Bythocypris laeva* Puri, *Campylocythere concinnoidea* Swain, *Campylocythere laeva* Edwards, *Cytherelloidea* cf. *C. leonensis* Howe, *Cytheretta sahnii* Puri, *Haplocytheridea bradyi* Stephenson, *Hemicytherura cranekeyensis* Puri, *Hulingsina ashermani* (Ulrich and Bassler, *Megacythere robusta* Puri, *Neocytheridinae* sp., *Pellucistoma mangniventra* Edwards, *Puriana floridana* Puri and *Puriana rugipunctata* (Ulrich and Bassler), and *Xestoleberis* spp. (1–4).

A shallow water and high salinity assemblage found in only three of the four areas consisting of:

Cushmanidea sp. A., *Cyprideis floridana* Puri, *Loxoconcha postdorsolata* Puri, *Paracytheridea washingtoniensis* Puri, *Paradoxostoma ensiforme* Brady, *Paradoxostoma* sp. and *Protocytheretta danaiana* (Brady).

Deep water faunas have been reported from the Gulf of Mexico by Tressler (1954) and Hulings (1959). This faunal assemblage is very closely related to the South Atlantic Coast of the United States. The following is a list of species reported from depths up to 3,630 m. by Tressler (1954):

Argilloecia cylindrica Sars, *Asterope elliptica* Phillippi, *Bythocythere turgida* Sars, *Bythocythere bosquetina* Brady, *Bythocypris complessa* Brady, *Echinocythereis echinata* (Sars), *E. erica* (Brady), *Bradleya dictyon* (Brady), *Cushmanidea silicula* (Brady), *Cytheropteron alatum* Sars, *C. macronatum* (Brady), *Cytherura lineata* Brady, *Echinocythereis echinata* (Sars), *Eucytherura complexa* (Brady), *Eucytherura declivis* Norman, ?? *Krithe bartonensis* Jones, *Krithe tumida* Brady, *Loxoconcha avellana* (Brady), *Loxoconcha dorsotuberculata* (Brady), *Loxoconcha elegans* (Brady), *Macrocypris decora* (Brady), *Macrocypris maculata* Brady, *Macrocypris similis* (Brady). *Macrocypris tumida* Brady, *Bairdia amygdaloides* (Brady), *Bairdia ovata* (Bosquet), *Bairdia victrix* (Brady), *Paracytherois flexuosa* (Brady), *Paradoxostoma ensiforme* Brady, *Polycope orbicularis* Sars, *Pontocypris intermedia* Brady, *Pontocypris subreniformis* Brady, *Pontocypris trigonella* Sars, *Pseudocythere caudata* Sars, *Xestoleberis curta* (Brady), *Xestoleberis expansa* Brady and *Xestoleberis minima* Brady.

THE SOUTH ATLANTIC OCEAN

The South Atlantic ostracods are relatively poorly known except on the south-west coast of Africa. Müller (1908) described six species of benthonic ostracods from Simontown (*Macrocypris africana* Müller, *M. dispar* Müller, *Pontocypris gaussi* Müller, *P. flava* Müller, *Xestoleberis capensis* Müller and *X. ramosa* Müller). In a recent study Benson and Maddocks (1964) have described the ostracod fauna of Knysna estuary, Cape Town, South Africa. The following four assemblages are recognized in the Knysna estuary (Benson and Maddocks, 1964): (1) Road Bridge Assemblage (*Paracypris westfordensis* Benson and Maddocks). (2) Ashyord Assemblage (*Paracypris westfordensis* Benson and Maddocks and *Perissocytheridea estuaria* Benson and Maddocks). (3) Rail Bridge Assemblage (*Aglaiella railbridgensis* Benson and Maddocks, *Sulcostocythere knysnaensis* Benson and Maddocks, *Loxoconcha parameridionalis* Benson and Maddocks, *Perissocytheridea estuaria* Benson and Maddocks). (4) Leisure Isle Assemblage (*Aurila dayii* Benson and Maddocks and *Cytheretta knysnaensis* Benson and Maddocks).

COAST OF SOUTH-WEST AFRICA

The ostracod fauna of this area has been studied by Klie (1940) who reported the following species in this area:

Cypridina dorsoserrata Müller, *Rutiderma africana* Müller, *Philomedes [illegible]fricana* Klie, *Asterope grimaldi* Skogsberg, *A. muelleri* Skogsberg, *Pontocypris flava* Müller, *Cyprideis remanei* Klie, *Eucythereis mirabilis* Klie, *E. levetzovi* Klie, *Procythereis serrata* Klie, *P. major* Klie, *P. minor* Klie, *Xestoleberis ramosa* Müller, *X. crenulata* Klie, *X. ferax* Klie, *X. baja* Klie, *X. humilis* Klie, *Sclerochilus meridionalis* Müller, *S. incurvatus* Klie, *Cytherois minor* Müller, *Paradoxostoma caeruleum* Klie, *P. griseum* Klie, *P. angustissimum* Klie, *P. reflexum* Klie and *P. semilunare* Klie.

Brady (1880) examined the ostracod fauna collected during the " Challenger " expedition. The following is a list of the species reported by Brady from the South Atlantic:

Aglaia meridionalis G. S. Brady, *Pontocypris simplex* G. S. Brady, *P. subreniformis* G. S. Brady, *Paracypris eburnea* (G. S. Brady), *Macrocypris maculata* G. S. Brady, *M. similis* G. S. Brady, *Bythocypris elongata* G. S. Brady, *B. reniformis* G. S. Brady, *Bairdia formosa* G. S. Brady, *B. victrix* G. S. Brady, *B. villosa* G. S. Brady, *Murrayina* (?) *audei* (G. S. Brady), *Orionina craticula* (G. S. Brady), *Bosquetina cytheropteroides* (G. S. Brady), *Echinocythereis dasyderma* (G. S. Brady), *Bradleya dictyon* (G. S. Brady), *Cativella dorsoserrata* (G. S. Brady), *Echinocythereis ericea* (G. S. Brady), *Orionina exilis* (G. S. Brady), *Leptocythere falklandi* (G. S. Brady), *Climacoidea* (?) *flabellicostata* (G. S. Brady), *Hemicythere fulvotincta* (G. S. Brady), *H. impluta* (G. S. Brady), *Echinocythereis irpex* (G. S. Brady), "*Cythereis*" *lepralioides* G. S. Brady, *Echinocytheres melobesioide* (G. S. Brady), *Callistocythere moseleyi* (G. S. Brady), *Quasibuntonia pyriformis* (G. S. Brandy), *Occultocythereis reussi* (G. S. Brady), *Cushmanidea scintillulata* (G. S. Brady), *Orionina serratula* G. S. Brady, *Aurila speyeri* (G. S. Brady), " *Cythereis*" *squalidentata* G. S. Brady, *Krithe producta* G. S. Brady, *K. tumida* G. S. Brady, *Loxoconcha subrhomboidea* G. S. Brady, *Xestoleberis africana* G. S. Brady, *X. expansa* G. S. Brady, *X. polita* G. S. Brady, *Semicytherura clausi* (G. S. Brady), *Cytherura clavata* G. S. Brady, *C. mucronata* G. S. Brady, *C. rudis* (?) G. S. Brady, *Bosquetina fenestratum* (G. S. Brady), *Bythocythere exigua* G. S. Brady, *Halocypris inflata* Dana, *Conchoecia atlantica* (Lubbock), *C. imbricata* (G. S. Brady), *Polycope orbicularis* G. O. Sars, *Cytherelloidea dromedaria* (G. S. Brady), *Cytherella lata* G. S. Brady, *C. polita* G. S. Brady, *C. pulchra* G. S. Brady and *Platella punctata* (G. S. Brady).

THE PACIFIC OCEAN

In a recent survey of the marine podocopids and platycopids of the Pacific, Benson (1964) has admirably assembled and analyzed data on 465 species from this area and has recognized the following 12 realms (*see* Fig. 9):

Nova Zealandica Realm: Ostracod fauna of this area has been studied by Brady (1880, 1898), Chapman (1906) and Hornibrook (1952), who described or reported sixty-eight species from this region which consists of:

Aglaiocypris clavata (Brady), *Bradleya arata* (Brady), *B. cuneazea* Hornibrook, *Bythoceratina decepta* Hornibrook, *B. edwardsoni* Hornibrook, *B. fragilis* Hornibrook, *B. maoria* Hornibrook, *B. mestayerae* Hornibrook, *B. powelli* Hornibrook, *B. tuberculata* Hornibrook, *B. utilazea* Hornibrook, *Cypris littoralis* Thomson, *Cytheralison fava* Hornibrook, *C. pravacaudata* Hornibrook, *Cythere truncata* Thomson, *Cythereis finlayi* Hornibrook, *C. gravizea* Hornibrook, *Cytherella eburnea* Brady, *C. polita* Brady, *Cytheridea aoteana* Hornibrook, *C. mosaica* Hornibrook, *Cushmanidea novaezealandiae* (Brady), *Cythereopteron acutangulum* Hornibrook, *C. confusum* Hornibrook, *C. curviaudum* Hornibrook, *C. dividentum* Hornibrook, *C. fornix* Hornibrook, *C. improbum* Hornibrook, *C. latiscalpum* Hornibrook, *C. obtusalum* Hornibrook, *C. terecaudum* Hornibrook, *C. vertex* Hornibrook, *C. wellingtoniense* Brady, *C. wellmani* Hornibrook, *C. willetti* Hornibrook, *Cytherura hexagona* Hornibrook, *C. laticauda* Hornibrook, *C. sericava* Hornibrook, *Eucythere gravepuncta* Hornibrook, *E. inaequa* Hornibrook, *E. mytila* Hornibrook, *E. rotunda* Hornibrook, *E. subovalis* Hornibrook, *Hemicythere brunnea* (Brady), *H. innominata* (Brady), *Hemicytherura delicatula* Hornibrook, *H. fereplana* Hornibrook, *H. gravis* Hornibrook, *H. pandorae* Hornibrook, *H. quadrazea* Hornibrook, *H. radiata* Hornibrook, *Leptocythere murrayana* (Brady), *Loxoconcha punctata* Thomson, *L. crassa* Hornibrook, *Loxocythere kingi* Hornibrook, *Macrocypris tumida* Brady, *Miracythere novaspecta* Hornibrook, *Quadracythere mediaruga* Hornibrook, *Q. truncula* (Brady), *Saida truncala* Hornibrook, *Trachyleberis thompsoni* Hornibrook, *T. zeacristata* Hornibrook, *Xestoleberis atra* (Thomson), *X. compressa* Brady, *X. luxata* Brady, and *X. olivacea* Brady.

Two biogeographic provinces, the Aupourian in the north and Fosterian in the south, are recognized by Benson (1964).

Austral-Tasman Realm.—The following species characterize this realm which includes southern and south-eastern coasts of Australia, Tasmania and south Tasmania ridge. This fauna, according to Benson (1964), is related with Antarctic fauna.

Bairdia fusca Brady, *Bradleya rostromarginata* Brady, *Cythere clavigera* Brady, *C. davisi* Chapman, ? *C. polytrema* Brady, *C. vellicata* Brady, *Cytherella ovalis* Brady, *Leptocythere canaliculata* (Reuss), *Loxoconcha cumula* (Brady), *Macrocypris setigera* (Brady).

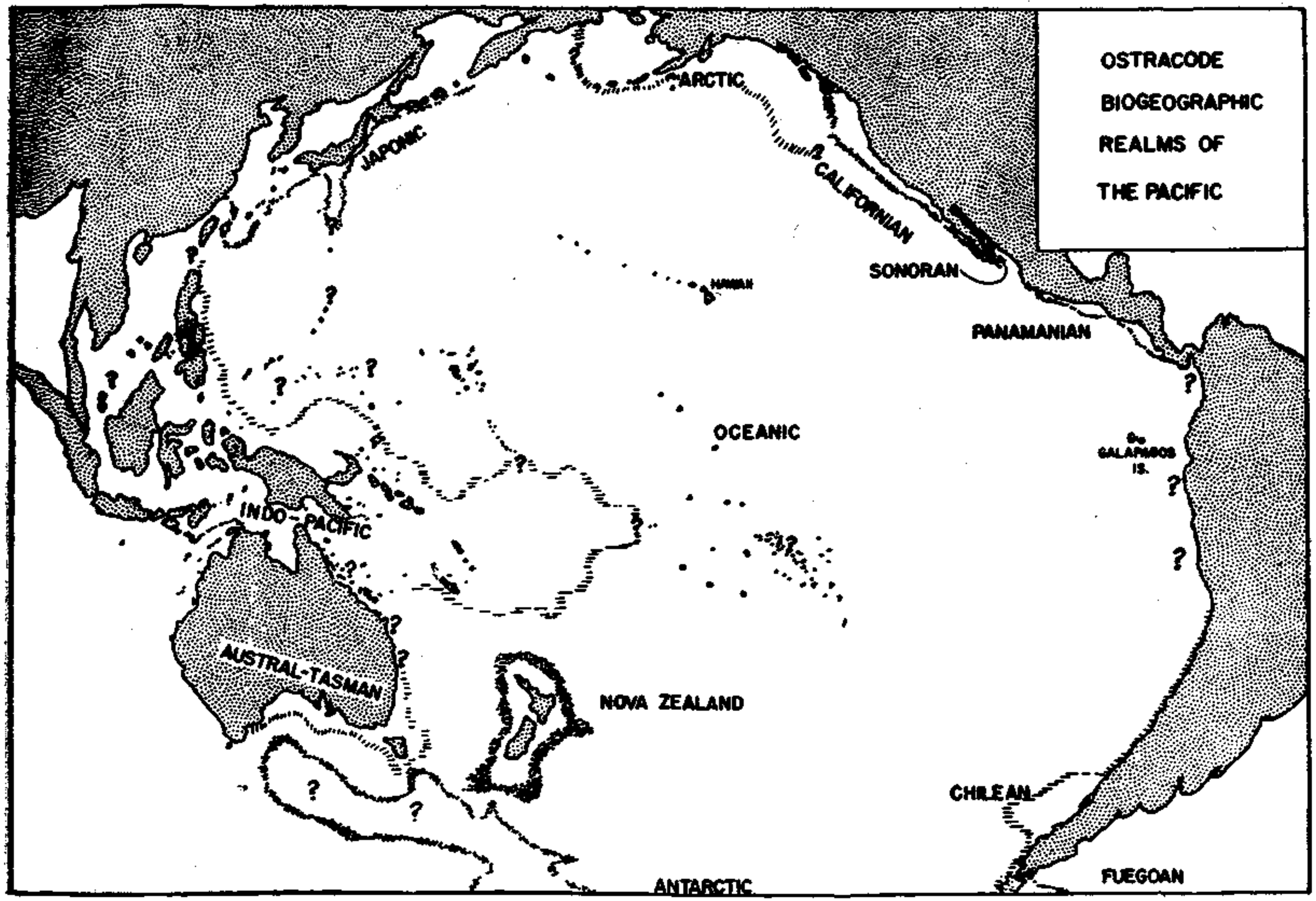


FIG. 9. Ostracod Biogeographic Realm Pacific (after Benson, 1964).

Indo-Pacific Realm.—This area has a very heterogeneous fauna of 141 species, which may represent several ecologically distinct assemblages in this wide biogeographic unit (E.W. Sumatra to Samoa; N.S. Philippine Island to Northern Australia). The reader is referred to Benson (1964) for a list of the species encompassed in this area.

Japonic Realm.—This zoographic unit includes the north-eastern coast of Asia, Hong Kong to Kuril Island and Poluostrov Kamchatka Peninsula. The ostracod fauna has been studied from scattered localities by Brady (1880), Kajiyama (1913) and recently by Hanai (1957, 1959). The following 52 species occur in this area:

Aurila cymba (Brady), *A. punctata* (Munster), *Callistocythere alata* Hanai, *C. haymenensis* Hanai, *C. japonica* Hanai, *C. minor* Hanai, *C. nipponica* Hanai, *C. pumila* Hanai, *C. rectangulata* (Kajiyama), *C. reticulata* (Hanai), *C. rugosa* Hanai, *C. setanensis* Hanai, *C. subjaponica* Hanai, *C. undata* Hanai, *C. undulatifacialis* Hanai, *Cushmanidea japonica* Hanai, *C, kashwarensis* Hanai, *C. miurensis* Hanai, *C. subjaponica* Hanai, *C. bicarinata* (Brady), *C. darwini* (Brady), *C. hodgii* (Brady), *C. kishinouyei* Kajiyama, *C. lutea omotenipponica* Hanai, *Cythereis assimilis* Kajiyama, *C. subconvexa* Kajiyama, *Cytheropteron miurense* Hanai, *Cytherura miurensis* Hanai, *C. quadrata* Hanai, *Cythere rectangulata* Kajiyama, *Cytherura skippa* Hanai, *C. tetragona* Hanai, *Echinocythereis* ? *cribriformis* (Brady), *Hemicytherura cuneata* Hanai, *H. kajiyama* Hanai, *H. tricarinata* Hanai, *Krithe hyalina* Brady, *Loxoconcha bispinosa* Kajiyama, *L. rhomboidea* (Fischer), *L. sinensis* Brady, *Munseyella japonica* Hanai, *Paradoxostoma coniforme* Kajiyama, *P. oblongum* Kajiyama, *P. ovulare* Kajiyama, *P. pilosum* Kajiyama, *P. quadratum* Kajiyama, *P. triangulum* Kajiyama, *P. yatsui* Kajiyama, *Parakrithella pseudadonta* Hanai, *Pontocypris pirifera* G. W. Müller, *Tanella pacifica* Hanai, *Xestoleberis sagamiensis* Kajiyama.

Arctic Realm.—There is virtually nothing known about the Northern Pacific ostracod faunas and effort should be made to sample and study this area.

Californian Realm.—This unit is not well defined on the north but does represent distinct biogeographic division with a characteristic fauna which consists of:

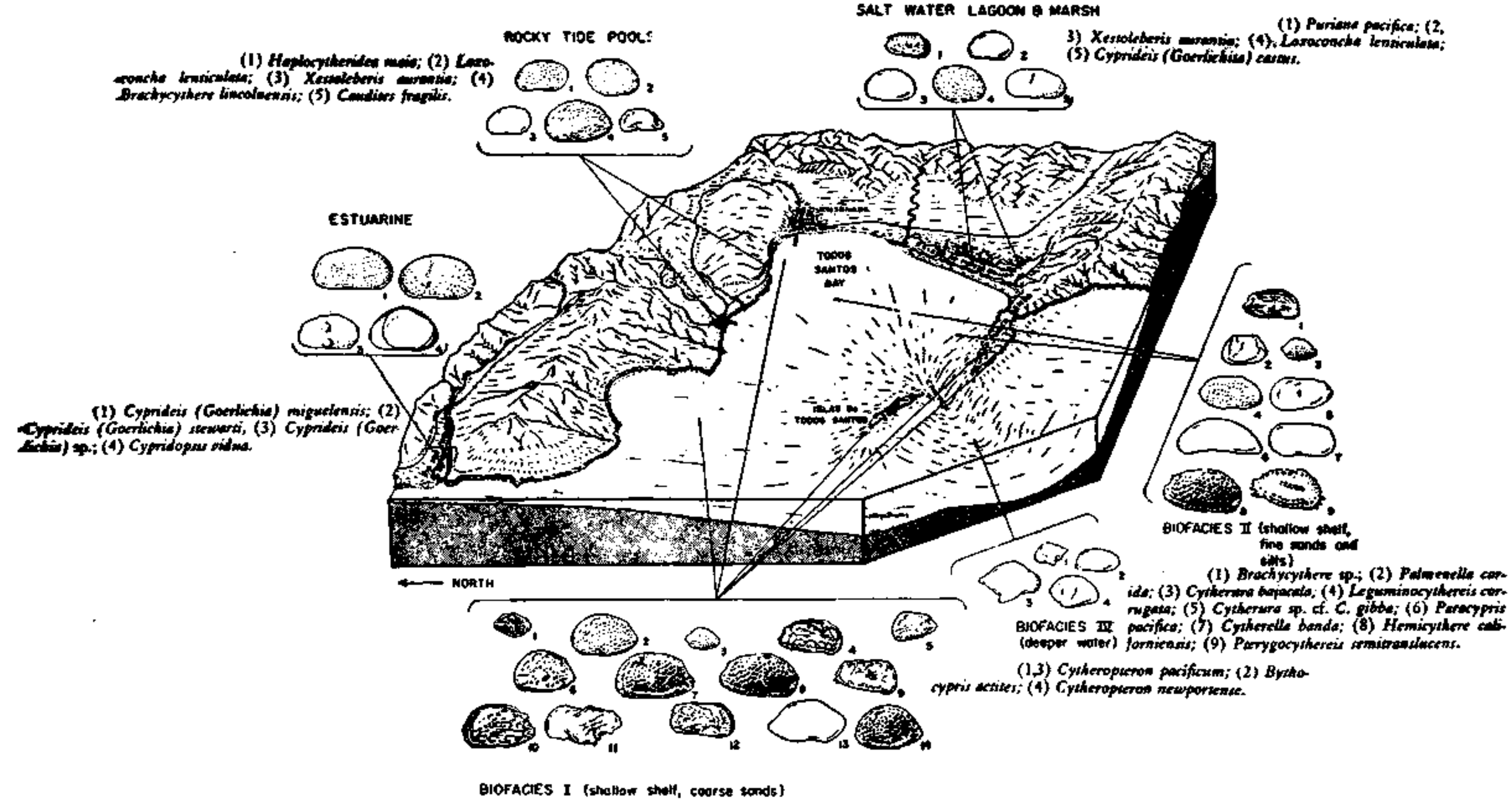
Argilloecia conoidea Sars, *A. cylindrica* Sars, *Bairdia verdensis* Le Roy, *Basslerites delreyensis* Le Roy, *Brachycythere driveri* Le Roy, *B. schumannensis* Le Roy, *Bradleya* cf. *B. schencki* Le Roy, *B. diegoensis* Le Roy, *B. pennata* Le Roy, *Bythocypris actites* Benson, *Cativella semitraslucens* Crouch, *Caudites fragilis* Le Roy, *Cyprideis stewarti* Benson, *Cythere alveolivalva* Smith, *C. lutea* O. F. Müller, *C. mala* Benson, *C. unifalcata* Smith, *Cythereis arachis* Lucas, *C. aurita* Skogsberg, *C. dunelmensis* Norman, *C. filoplumosa* Lucas, *C. glauca* Skogsberg, *C. longiductus* Skogsberg, *C. montereyensis* Skogsberg, *C. obesa* Lucas, *C. polita* Skogsberg, *C. pacifica* Skogsberg, *C. pusilla* Sars, *C. serridentata* Smith, *Cytherella banda* Benson, *Cytherelloidea californica* Le Roy, *Cytherois pusilla* Sars, *Cytheroma similis* Skogsberg, *Cytheropteron ensenadense* Benson, *C. newportense* Le Roy, *C. pacificum* Le Roy, *Cytherura bajacala* Benson, *C. gibba* O. F. Müller, *Hemicythere bicarina* Smith, *H. californiensis* Le Roy, *H. lincolnensis* Le Roy, *H. obesa* Lucas, *H. palesensis* Le Roy, *H. regalia* Benson, *Hemicytherura* sp. cf. *H. clathrata* (Sars), *Leguminocythereis corrugata* Le Roy, *Loxoconcha dentarticula* Smith, *L. fragilis* Sars, *L. lenticulata* Le Roy, *L. teninungula* Smith, *Macrocythere rostrata* Lucas, *Mutilus* ? *jollaensis* (Le Roy), *Palmanella californica* Triebel, *Paracypris pacifica* Le Roy, *Paracytheridea granti* Le Roy, *P. pedrensis* Juday, *Paradoxostoma cuneata* Lucas, *P. fraseri* Smith, *P. stringulum* Smith, *Pellucistoma scrippsi* Benson, *Perissocytheridea* ? *palda* (Benson), *Pontocypris clemensi* Smith, *Puriana pacifica* Benson, *Sclerochilus nasus* Benson, *Triebelina reticulopunctata* Benson, *Xestoleberis aurantia* (Baird), *X. banda* Benson, *X. depressa* Sars, *X. dispar* G. W. Müller and *X. hopkinsi* Skogsberg.

The various assemblages recorded from the Todos Santos Bay appear on Fig. 10.

Sonoran Realm.—This biogeographic division, according to Benson (1964), represents a cul-de-sac in the Western Coast since it represents faunal elements which have affinities with species of the California Realm, the Panamanian Realm and the Gulf of Mexico. These species are:

Aurila conradi californica Benson and Kaesler, *Basslerites sonorensis* Benson and Kaesler, *Cativella* cf. *dispar* Hartmann, *Caudets serrata* Benson and Kaesler, *Clithrocytheridea sonora* Benson and Kaesler, *Cushmanidea sagena* Benson and Kaesler, *Cythere* ? *yorktownensis* (Malkin), *Cytherura johnsoni* Mincher, *Megacythere johnsoni* (Mincher), *Parakrithella perspicilla* Benson and Kaesler, *Perissocytheridea meyerabichi* (Hartmann), *P. swaini* Benson and Kaesler and *Puriana horrida* Benson and Kaesler.

Panamanian Realm.—As a result of recent studies by Hartmann (1956, 1957, 1959), shallow faunas of this regior are well known. The following species occur in this biogeographic unit;



(1) *Haplocytheridea maia*; (2) *Loxoconcha lenticulata*; (3) *Xestoleberis aurantia*; (4) *Brachycythere lincolnensis*; (5) *Candites fragilis.*

(1) *Puriana pacifica*; (2, 3) *Xestoleberis aurantia*; (4) *Loxoconcha lenticulata*; (5) *Cyprideis (Goerlichia) castus.*

(1) *Cyprideis (Goerlichia) miguelensis*; (2) *Cyprideis (Goerlichia) stewarti*, (3) *Cyprideis (Goerlichia)* sp.; (4) *Cypridopsis vidua.*

(1) *Brachycythere* sp.; (2) *Palmenella corrida*; (3) *Cytherura bajacala*; (4) *Leguminocythereis corrugata*; (5) *Cytherura* sp. cf. *C. gibba*; (6) *Paracypris pacifica*; (7) *Cytherella banda*; (8) *Hemicythere californiensis*; (9) *Pterygocythereis semitranslucens.*

(1,3) *Cytheropteron pacificum*; (2) *Bythocypris actites*; (4) *Cytheropteron newportense.*

BIOFACIES I (shallow shelf, coarse sands)

(1) *Hemicytherura* sp. cf. *H. clathrata*; (2) *Brachycythere lincolnensis*; (3) *Cytherura bajacala*; (4) *Bradleya diegoensis*; (5) *Quadracythere regalia* (molt); (6)*Hemicythere jollaensis*; (7) *Quadracythere regalia* (adult); (8) *Hemicythere californiensis*; (9) *Bradleya pennata*; (10) *Bradleya aurita*; (11) *Paracytheridea granti*; (12) *Cythereis glauca*; (13) *Bairdia* sp. aff. *B. verdesensis*; (14) *Brachycythere driveri.*

FIG. 10. Ostracod assemblages in the Todos Santos Bay Area, California (after Benson, 1961).

Catlvella dispar Hartmann, *Cobanocythere labiata* Hartmann, *C. subterranea* Hartmann, *Cyprideis pacifica* Hartmann, *Cytherella mejanguerensis* Hartmann, *Cythereis salvadoriana* Hartmann, *Cytherura ostriicola* Hartmann, *C. palacii* Hartmann, *Loxoconcha lapidiscola* Hartmann, *L. schusterae* Hartmann, *Palaciosa vandenboldi* Hartmann, *Paracytheroma costata* Hartmann, *P. levis* Hartmann, *P. magna* Hartmann, *P. undulimarginata* Hartmann, *Paradoxostoma salvadorianus* Hartmann, *Parvocythere dentata* Hartmann, *P. elongata* Hartmann, *Pericythere foveata* Hartmann, *Perissocytheridea dentatomarginata* Hartmann, *P. meyerabichi* Hartmann, *P. punctata* Hartmann, *Sclerochilus centroamericanus* Hartmann, *Thalassocypria aestuarina* Hartmann, *Tribelina gierloffi* Hartmann and *Xestoleberis eulitoralis* Hartmann.

Chilean Realm.—The shallow water fauna of this biogeographic unit has been described recently by Hartmann (1962) and the following species occur in this area:

Ambocythere dentata Hartmann, *Aurila frequens* (Skogsberg), *Callistocythere dispersocostata* Hartmann, *C. fischeri* Hartmann, *Cyprideis lengae* Hartmann, *Cytherois minor* G. W. Müller, *Hemicythere foveata* Hartmann, *Hemicytheria chilensis* Hartmann, *H. pokornyi* Hartmann, *Hemicytherura reticulata* Hartmann, *Hermanites ? cekalovici* Hartmann, *H. firma* Hartmann, *Leptocythere patagonica* Hartmann, *Loxoconcha fluctushumbolti* Hartmann, *Paracytheroma araukanensis* Hartmann, *Paracytheridea longicaudata chilensis* Hartmann, *Paradoxostoma stichkini* Hartmann, *Parakrithella hanaii* Hartmann, *Patagonacythere tricostata* Hartmann, *Propontocypris calderensis* Hartmann, *P. iquiquensis* Hartmann, *Pterygocythereis irregularis* Hartmann, *Quadracythere clathrata* Hartmann, *Semicytherura portomonttensis* (Hartmann), *Semixestoleberis debueni* Hartmann, *S. typica* Hartmann, *Xestoleberis chilensis* Hartmann, *X. dichatoensis* Hartmann, *X. simplex* Hartmann and *X. ventribullata* Hartmann.

Fuegoan Realm.—The fauna of this biogeographic unit has been studied mostly by Skogsberg (1928); the ostracod fauna shows affinities with both the Southern Ocean and the Antarctic and consists of the following species:

Aurila discophora (Skogsberg), *A. ephippiata* (Skogsberg), *A. mesodiscus* (Skogsberg), *A. recurvirostra* (Skogsberg), *A. taeniata* (Skogsberg), *A. theeli* (Skogsberg), *Bairdia angulata* Brady, *Paradoxostoma magellanicum* G. W. Müller, *Procythereis igandersoni* Skogsberg, *P. polita* Skogsberg, *P. radiata* Skogsberg, *P. torquata* Skogsberg, *Pseudocythere fuegiensis* Brady.

Oceanic Realm.—This unnatural biogeographic division consists of littoral areas of the Hawaiian Island, the Galapagos Islands and the abyssal areas of the Pacific. Ostracod fauna was studied largely from the "Challenger" material (Brady, 1880). The following species, which have been reported from this region, may represent several different environments:

Argilloecia eburnea Brady, *Bairdia abyssicola* Brady, *B. attenuata* Brady, *B. crosskeiana* Brady, *Bradleya dictyon* (Brady), *B. sweeti* Chapman, *Cyprideis stenopora* Triebel, *Cythere acanthoderma* Brady, *C. circumdentata* Brady, *C. convoluta* Brady, *C. floscardui* Brady, *C. fortificata* Brady, *C. parallelogramma* Brady, *C. phylloides* Chapman, *C. sulcatoperforata* Brady, *Cytherella venusta* Brady, *Cytheropteron mucronalatum* Brady, *Echinocythereis dasyderma* (Brady), *Krithe angusta* Brady and Norman, *K. producta* Brady, *K. tumida* Brady, *Loxoconcha alata* (Brady), *L. anomala* Brady, *Loxoconchella honoluliensis* (Brady), *Pterygocythereis ? suhmi* (Brady), *Trachyleberis stolonifera* (Brady) and *Xestoleberis arcturi* Triebel.

Antarctic Realm.—The ostracod fauna of this region, which circumscribes the Antarctic continent, has been studied by Müller (1908), Chapman (1916, 1919), Scott (1912), Skogsberg (1928) and Benson (1964). The following assemblage may be considered as a Southern Ocean one although some species extend both into the Atlantic and the Pacific (Benson, 1964):

Aglaiocypris pusilla (Brady), *Argilloecia affinis* Chapman, *Argilloecia badia* Brady, *A. gracilior* Chapman, *Australicythere polylyca* (Müller), *Bradleya wyvillethompsoni* (Brady), *B. ? dictyon* (Brady), *Bythocypris bosquetiana* (Brady), *Bythocythere ilex* Chapman, *B. mawsoni* Chapman, *Copytus elongatus* Benson, *Cythere lactea* Brady, *C. mosleyi* Brady, *C. normani* Brady, *C. subrufa* Brady, *Cythereis devexa* Müller, *C. longiductus* Skogsberg, *C. polylyca* Müller, *Cytheropteron abyssorum* Brady, *C. antarcticum* Chapman, *C. assimile* Brady, *C. foveolata* (Brady), *Cytherura costellata* Brady, *Echinocythereis dasyderma* (Brady), *Hemicythere kerguelensis* (Brady), *Loxoconcha davidiana* Chapman, *Loxoreticulatum fallax* (Müller), *Machaerina complanatus* Brady, *Paradoxostoma antarcticum* Müller, *P. hypselum* Müller, *Patagonacythere devexa* (Müller), *P. longiducta antarctica* Benson, *Pseudocythere* aff. *P. caudata* Sars, *Semicytherura* aff., *S. costellata* (Brady), *Xestoleberis meridionalis* Müller and *X. setigera* Brady,

THE INDIAN OCEAN

Very little is known about the Indian Ocean ostracods. The following ostracods were reported by Brady (1880) from scattered localities in the South Indian Ocean:

Aglaia obtusata G. S. Brady, *Paracypris eburnea* (G. S. Brady), *Macrocypris decora* G. S. Brady, *M. maculata* G. S. Brady, *M. tumida* G. S. Brady, *Bythocypris reniformis* G. S. Brady, *Bairdia simplex* G. S. Brady, *B. victrix* G. S. Brady, *B. villosa* G. S. Brady, *Echinocythereis acanthoderma* (G. S. Brady), *Urocythereis audei* (G. S. Brady), *Bradleya dictyon* (G. S. Brady), "*Cythereis*" *foveolata* (G. S. Brady), *Hemicythere kerguelensis* (G. S. Brady), *Bradleya normani* (G. S. Brady), *Normanocythere parallelogramma* (G. S. Brady), *Pterygocythereis polytrema* (G. S. Brady), *Hemicythere securifer* (G. S. Brady), *Orionina* (?) *subrufa* (G. S. Brady), *Bosquetina viminea* (G. S. Brady), *Quadracythere wyvillethomsoni* (G. S. Brady), *Krithe bartonensis* (Jones) (This is a new species), *K. producta* G. S. Brady, *Xestoleberis curta* G. S. Brady, *X. depressa* G. O. Sars, *X. setigera* G. S. Brady, *Semicytherura costellata* (G. S. Brady), *Hemicytherura lilljeborgi* (G. S. Brady), *Cytherura obliqua* G. S. Brady, *Cytheropteron abyssorum* G. S. Brady, *C. angustatum* G. S. Brady, *C. assimile* G. S. Brady, *C. fenestratum* G. S. Brady, *C. scaphoides* G. S. Brady, *Bythoceratina pumilio* G. S. Brady, *Pseudocythere caudata* G. O. Sars, "*Cytherideis*" *laevata* G. S. Brady, *Sclerochilus contortus* (Norman), *Xiphichilus complanatus* G. S. Brady, *Paradoxostoma abbreviatum* G. O. Sars, *Cypridina danae* G. S. Brady, *Halocypris inflata* Dana, *Conchoecia atlantica* (Lubbock) and *Polycope orbicularis* G. O. Sars.

It is hoped that the collections of the Indian Ocean Expedition will enrich our knowledge of this very interesting area.

DEEP-SEA COSMOPOLITAN FAUNAS

Cosmopolitan faunas have been reported from the various areas; some of these species have worldwide distribution. The following fauna is reported from deep water up to 3,630 meters in the Gulf of Mexico by Tressler (1954):

Cytherura lineata Brady, *Echinocythereis echinata* (Sars), *Eucytherura complexa* (Brady), *Eucytherura declivis* (Norman), ??*Krithe bartonensis* Jones, *Krithe tumida* Brady, *Loxoconcha avellana* (Brady), *Loxoconcha dorsotuberculata* (Brady), *Loxoconcha elegans* (Brady), *Macrocypris decora* (Brady), *Macrocypris maculata* Brady, *Macrocypris similis* (Brady), *Macrocypris tumida* Brady, *Bairdia amygdaloides* (Brady), *Bairdia ovata* (Bosquet), *Bairdia victrix* (Brady), *Paracytherois flexuosa* (Brady), *Paradoxostoma ensiforme* Brady, *Polycope orbicularis* Sars, *Pontocypris intermedia* Brady, *Pontocypris subreniformis* Brady, *Pontocypris trigonella* Sars, *Pseudocythere caudata* Sars, *Xestoleberis curta* (Brady), *Xestoleberis expansa* Brady, *Xestoleberis minima* Brady, *Argilloecia cylindrica* Sars, *Asterope elliptica* Phillippi, *Bythocythere turgida* Sars, *Bythocythere bosquetina* Brady, *Bythocypris complexa* Brady, *Echinocythereis echinata* (Sars), *E. erica* (Brady), *Bradleya dictyon* (Brady), *Cushmanidea silicula* (Brady), *Cytheropteron alatum* Sars and *C. macronatum* (Brady).

From the Adriatic Sea, Ascoli (1964) has reported a fauna from the "Bathyal" zone (between 243 and 1,192 m.) which is characterized by an assemblage of *Macrocypris*, *Argilloecia* and *Krithe*. Species like *Pseudocythere caudata* Sars, *Bythocythere turgida* Sars and *Echinocythereis dasyderma* (Brady) are deep-water cosmopolitan species. More studies of deep-water faunas are needed to establish the exact identity of some of these forms as most of them have been described from only carapaces.

CONCLUSIONS

From the data presented in this study, it is clear that ostracods inhabit every conceivable habitat from purely terrestrial to deep-sea abyssal. Of the factors which influence their distribution, temperature is the most important. Salinity plays a decisive role in the distribution of oligohaline assemblages. Type of substrate is a controlling factor in as much as it determines the type of vegetation and supply of food. In the deep-water assemblages, depth becomes an important factor because of the pressure that it exerts. The modern distributions of ostracods have been controlled by evolution and paleogeography in both space and time. Barriers and suitable habitats have modified the distribution of ostracod assemblages.

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