SYMPOSIUM ON
CRUSTACEA

PART IV

MARINE BIOLOGICAL ASSOCIATION OF INDIA

MARINE FISHERIES P.O., MANDAPAM CAMP

INDIA

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PROCEEDINGS

OF THE

SYMPOSIUM ON CRUSTACEA

HELD AT

ERNAKULAM

FROM JANUARY 12 TO 15, 1965

PART IV

SYMPOSIUM SERIES 2

MARINE BIOLOGICAL ASSOCIATION OF INDIA

MARINE FISHERIES P.O., MANDAPAM CAMP

INDIA

PRINTED IN INDIA
AT THE BANGALORE PRESS, BANGALORE
1967

CONTENTS

PART IV

ON CIRRIPED CRUSTACEANS (BARNACLES), AN IMPORTANT FOULING GROUP IN BOMBAY WATERS

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ABSTRACT

The paper deals with three different aspects of cirripedes, an important group of crustaceans incident in Bombay waters, whose biology is not adequately described: (*a*) the taxonomic status of the different barnacles, (*b*) the breeding pattern in the more important intertidal species, and (*c*) the associates of these barnacles. The importance of information obtained under these three heads in relation to the development of a suitable biological assay procedure is discussed.

CIRRIPED crustaceans constitute a major group of fouling organisms in the sea. On account of the great reproductive capacity, gregarious habit and nature of settlement they are of greater consequence than the other fouling groups. Therefore, cirripedes attracted the attention of biologists and paint technologists. For the ultimate control of these organisms studies on their biology are necessary.

The object of the present study is to collect as much information as possible on this group of fouling organisms so that the same could be employed usefully for obtaining a regular supply of fertilized egg masses and larval stages at all the seasons of the year for conducting experimental work. In the present communication, three different aspects of cirriped biology, namely, (i) taxonomy, (ii) breeding pattern, and (iii) their associates, are dealt with. The importance of information obtained under all these in relation to the development of a suitable biological assay procedure is also discussed.

MATERIAL AND METHODS

For taxonomic study, the usual method of cleaning the valves, mouth-parts and other appendages of the specimens with caustic potash was employed. The diagrams were made with the help of a camera lucida.

For the observations on breeding, specimens of *B.a. communis* and *B.a. hawaiiensis* were collected from the intertidal rocks at Chaupati seaface and those of *Ch. withersi* and *Ch. malayensis* were collected at the boat shed at the Naval Dockyard, Bombay. Collections were generally made thrice a month and 25 specimens of each species were examined at a time.

The condition of the ovary was determined by microscopic examination. On the basis of the development of the ova, five stages were identified and points assigned as shown in Table I. A mean ovary index was obtained for the individuals collected at the end of every month.

With a view to determining the intensity of breeding, the growth of the above ovarian stages in all the specimens examined (excluding specimens with Stages IV and V) was visually determined. On the basis of growth, five categories were identified and points sasigned as shown in Table II. A mean growth index was determined for the specimens collected at the end of every month.

TABLE I

Stage	Condition of ovary/egg	Ovary (maturity) index score
I	Ovary not seen	0
II	Ovary with developing ova	1
III	Fertilized eggs	2
IV	Eggs with embryos (nauplii) inside ..	3
V	Free nauplii in the mantle cavity	4

TABLE II

Category	Growth of the ovary	Ovary (growth) index score
I	No ovarian mass observed	0
II	Poor ovary with a few egg lamellae ..	1
III	Moderately developed ovary	2
IV	Well-developed ovary filling mantle space ..	3
V	Fertilized egg masses	4

This investigation was carried out during 1961–62 and 1962–63. The observations on one of the four barnacles, *viz.*, *Ch. malayensis* were carried out during 1961–62 and the same have been published earlier (Karande and Palekar, 1963 *b*). The data on atmospheric temperature and sunshine was obtained from the meteorological station, Colaba Observatory, Bombay.

RESULTS

Observations on systematics of barnacles.—In the course of studies on the incidence and nature of fouling at different places along the Bombay coast, a large collection of barnacles was made and it has been possible to add eleven more species, subspecies, varieties and forms to the four previously recorded along the Bombay shores (Bhatt and Bal, 1960; Nilsson-Cantell, 1938; Karande and Palekar, 1963 *a*). The following is a classified list of the barancles encountered in Bombay harbour.

Sub-order .. **BALANOMORPHA** Pilsbry, 1916.

Family .. BALANIDAE Grey, 1825.

Sub-family .. **Balaninae** Darwin, 1854.

Genus: .. *Balanus* Da Costa, 1778.

Sub-genus: .. *Megabalanus* Hoek, 1913.

1. *Balanus tintinnabulum* var. *tintinnabulum* Linne, 1758.
2. *Balanus tintinnabulum* var. *zebra* Darwin, 1854.

Sub-genus .. *Balanus* Da Costa, 1778.

3. *Balanus amphitrite* var. *variegatus* Darwin, 1854.
4. *Balanus amphitrite* var. *communis* Darwin, 1854.
5. *Balanus amphitrite* var. *hawaiiensis* Broch, 1922.
6. *Balanus amphitrite* var. *denticulata* Broch, 1927.
7. *Balanus amphitrite* var. *cochinensis* Nilsson-Cantell, 1938.
8. *Balanus amphitrite* var. *insignis* Nilsson-Cantell, 1938.
9. *Balanus amphitrite* var. *venustus* Darwin, 1854.
10. *Balanus calidus* Pilsbry, 1916.

    Sub-genus .. *Chirona* Gray, 1835.

11. *Balanus amaryllis* forma *euamaryllis* Broch, 1922.
12. *Balanus amaryllis* forma *nivea* Gruvel, 1905.

    Sub-family ... *Tetraclitinae* Nilsson-Cantell, 1921.
    Genus .. *Tetraclita* Schumacher, 1817.

13. *Tetraclita purpurascens* Wood, 1818.

    Family ... CHTHAMALIDAE Darwin, 1854.
    Genus ... *Chthamalus* Ranzani, 1817.

14. *Chthamalus malayensis* Pilsbry, 1916.
15. *Chthamalus withersi* Pilsbry, 1916.

Barnacle species such as *B.a. variegatus*, *B.a. communis*, *B. amaryllis euamaryllis* and *B. tintinnabulum tintinnabulum* largely contribute to the fouling community on ships' hulls in Bombay harbour. *B.a. euamaryllis* and *B.t. tintinnabulum* besides being present on the ships' hulls are also found plentifully on surf washed rocky shores at various localities around Bombay.

A detailed account of the taxonomic study of cirripedes is published elsewhere (Karande and Palekar, 1966). Comments on interrelationships amongst varieties of *Amphitrite* are offered in the present paper.

Amongst fifteen barnacles noted in Bombay waters seven are varieties of *B. amphitrite*. Of these, *B.a. variegatus, B.a. insignis, B.a. venustus* and *B.a. denticulata* are essentially off-shore species. On the other hand, *B.a. communis, B.a. hawaiiensis* and *B.a. cochinensis* are intertidal barnacles. *B.a. communis* besides being an intertidal variety is also found on the hulls of ships, chains, buoys and other structural material. It would be interesting to recall that in Japanese waters this variety together with *B.a. hawaiiensis* does not settle on the intertidal rocks but is found only on ships' hulls. Hiro (1939) has suggested the possibility of classifying the barnacles according to their habits. The varieties of *Amphitrite* series found at Bombay can be conveniently divided into two groups, intertidal and off-shore, as indicated earlier in this paragraph.

Separation of one variety from the other amongst barnacles in general and *amphitrite* series in particular has been always a difficult problem. Whereas off-shore varieties can be easily separated from one another on the basis of their colour, shape, size and the opercular valves, identification of the intertidal varieties needs careful study of both the hard and the soft parts of the animal. In this paper figures of the adult specimens (Plate I, Figs. 1–7), opercular valves (Plate II, Figs. 8–14) and the labrum (Figs. 15, *a* to 15, *f*) are presented, which it is hoped may be found useful in identifying various *Amphitrite* varieties occurring in Bombay harbour.

As regards *B.a. denticulata*, Utinomi (1960) has reported that this variety is a synonym of *B.a hawaiiensis*. His observation is supported by Costlow and Bookhout. In Bombay waters, however, these two varieties are clearly separable from one another. Besides the variations in the opercular valves (Figs. 10, 12) the number of teeth on the labrum also shows difference. In var. *hawaiiensis*, there are up to 36 teeth whereas in var. *denticulata*, the number does not exceed 8 (Fig. 15 *c*).

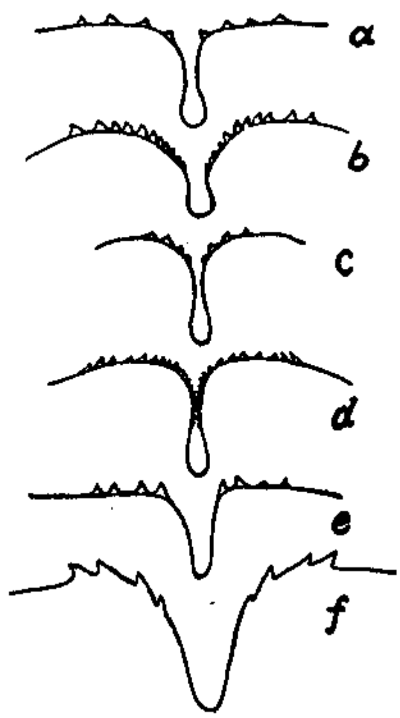


FIG. 15 (*a-f*). Labrums of barnacles. (*a*) *Balanus amphitrite variegatus*; (*b*) *B. a. communis*; (*c*) *B. a. denticulata*; (*d*) *B. a. hawaiiensis*; (*e*) *B. a. insignis* and (*f*) *B. a. venustus*.

Stubbings (1961) has rightly pointed out the difficulty in distinguishing var. *denticulata* from var. *communis*. A careful study will show that the opercular valves in var. *denticulata* are weaker than those of var. *communis*. The drawn-out carinal margin (Fig. 12) at the apex of the tergum of var. *denticulata* distinguishes this barnacle from the other varieties of *Amphitrite* series. A similar feature has been noted by Broch (1927) and Stubbings (1961) in W. African specimens of *denticulata*. The specimens of var. *communis* at Bombay have about 25 teeth on the labrum (Fig. 15, *b*), as has been also observed in many parts of the world (Stubbings, 1961). Var. *denticulata* shows only 8 teeth on the labrum. Var. *communis* is further characterised by the presence of a white strip along the tergal margin of the scutum, this feature is absent in var. *denticulata*.

Difficulties in separating var. *hawaiiensis* from var. *communis* have been mentioned by many workers. These two varieties in Bombay waters are easily distinguishable from one another. The description and figures of the opercular valves of *B.a. hawaiiensis* given by Hiro (1937) closely resemble those observed in Bombay specimens. The specimens of var. *hawaiiensis* are easily distinguishable from others by virtue of a deep sinuous suture between the opercular valves (Fig. 4) and the horizontal disposition of the latter in contrast to the inclined position noted in other varieties.

Observations on breeding of barnacles.—The results on the observations of the development of gonads and breeding activity of four intertidal barnacles are presented in Table III. The breeding activity may be judged from the percentage of individuals fertilized at the end of every month (Patel and Crisp, 1960). For the convenience of explaining the results, monthwise observations starting with March (instead of January) have been given in this table.

TABLE III

Showing mean ovary (growth) index, mean maturity and percentage of fertilized individuals in four species of barnacles

Period	*B.a. communis*			*B.a. hawaiiensis*			*Ch. malayensis*			*Ch. withersi*		
	Mean ovary growth index	Mean ovary maturity index	% fertilized	Mean ovary growth index	Mean ovary maturity index	% fertilized	Mean ovary growth index	Mean ovary maturity index	% fertilized	Mean ovary growth index	Mean ovary maturity index	% fertilized
1. March	3·3	2	66	3·0	2·24	63	3·16	2·0	56	1·25	1·89	38
2. April	3·0	2·1	64	3·3	2·08	68	3·0	2·4	40	1·4	0·84	3
3. May	2·88	1·1	13	1·0	0·96	6	2·7	3·0	64	2·22	1·02	8
4. June	2·1	1·86	44	3·0	2·22	66	2·05	2·5	60	1·16	0·85	0
1. July	2	1·3	20	2·0	1·24	18	0·74	0·65	2	0·46	0·69	11
2. August	2·8	1·0	13	1·6	1·12	30	0·81	0·60	0	0·72	0·54	1
3. September	1·8	1·65	30	1·8	1·1	3	2·02	1·28	10	1·15	1·35	21
4. October	3·0	2·22	64	3·0	2·65	70	2·21	1·26	38	2·32	1·08	16
1. November	1·22	0·98	16	2·2	1·28	25	0·78	0·56	5	0·98	1·04	6
2. December	1·73	0·94	19	..	..	..	0·79	0·80	6	0·92	0·92	0
3. January	2·41	1·48	32	..	..	..	0·73	0·64	0	1·07	0·96	1
4. February	2·44	1·2	23	..	..	..	2·46	1·2	13	1·07	1·1	18

It is very clearly seen from Table III that except for *Ch. withersi* which shows an irregular pattern of breeding, all the other barnacles, *viz.*, *B.a. communis*, *B.a. hawaiiensis* and *Ch. malayensis* breed during the warmer months of March to June and again during October. It is, however, interesting to observe that both the varieties of *Amphitrite* do not breed during the month of May. This has been observed during the last two years and has been also confirmed by the examination of the test panels exposed in the sea at Trombay (Bombay) which did not show any settlement during this period.

During monsoon months, *viz.*, July to September and again during winter (November to December) the maturity index falls considerably and the number of individuals with fertilized egg masses dwindles. In *Ch. malayensis* this condition prersists till the end of January. During February, the rebuilding of the ovarian tissue commences and by the beginning of March, many individuals show compact ovarian lamellae in various stages of development with a high maturity index. With reference to breeding therefore, four distinct phases as follows are recognised in three of the four species studied.

(i) Active maturation and breeding during March to June.

(ii) Lack of breeding during July to September.

(iii) Recurrence of maturation during late September and October.

(iv) Lack of breeding during November to February.

It has been held by Orton (1920), Thorson (1946) and Rünnstrom (1928) that the breeding in majority of marine organisms is controlled by the temperature of sea. Recently, Crisp (1954) considered this view with respect to barnacles and explained how in tropical species breeding activities are controlled by temperature. Barnes (1959) observes that gametogenesis, fertilization, incubation and liberation of the fully developed nauplii from the mantle cavity are well-defined phases and any or all of them may be dependent on temperature.

Figure 16 shows the salinity data and temperature of the sea-water in Bombay Harbour for the period 1953–56 and for 1963–64. The data on the atmospheric temperature and total hours of sunshine as collected at Meteorological Station, Colaba, Bombay, has been presented in Table IV.

TABLE IV

Showing monthwise mean sea-water temperature, mean atmospheric temperature and total hours of sunshine during 1963–64

Sl. No.	Period	Mean sea-water temperature	Mean atmospheric temperature	Range maximum temperature (° C.)	Mean sunshine (hrs.)
1	March	27·0	30·7	27·6–35·0	9·3
2	April	31·4	32·1	29·6–35·4	10·1
3	May	33·0	33·4	32·6–34·1	10·4
4	June	30·6	32·0	27·7–35·0	5·75
5	July	29·0	30·0	26·7–31·7	3·0
6	August	26·9	29·0	26·4–31·3	2·2
7	September	28·1	30·5	26·5–32·8	5·4
8	October	29·1	32·1	29·6–34·7	8·4
9	November	28·0	32·9	27·2–35·5	7·9
10	December	26·4	28·5	27·4–35·6	7·4
11	January	24·4	27·7	23·8–34·6	9·0
12	February	24·4	28·5	25·4–34·2	9·3

It is evident from Table IV and Fig. 16 that during March to June, the water temperature is generally high. During November to February which are colder months in Bombay, the water temperature remains at its lowest. As regards salinity, only during July to September low values are noted, as a result of very heavy monsoon showers. In the midst of monsoon period, salinity as low as 10‰ has been recorded in Bombay waters. During other periods, salinity values remain uniformly at 34–35‰.

As has been mentioned earlier, alternation of the breeding and non-breeding phases in barnacles may be attributed to specific environmental conditions, including the temperature variations in the atmosphere (Barnes, 1959). The breeding pattern amongst the intertidal barnacles at Bombay appears to be governed by these factors. During March to June when the sea-water temperature is high and the salinity is normal, development of the ovary leading to the subsequent emergence of the larvae progresses rapidly. A similar condition prevails during the month of October also. Lack of breeding during May in both the *amphitrite* varieties may be due to very high water temperature (33° C.). It may be mentioned here that Patel and Crisp (1960) have noted that variety *denticulata* does not breed if the water temperature exceeds 32° C. The effect of atmospheric temperature on the breeding of the barnacles has been suggested by Barnes (1959). In Bombay, the

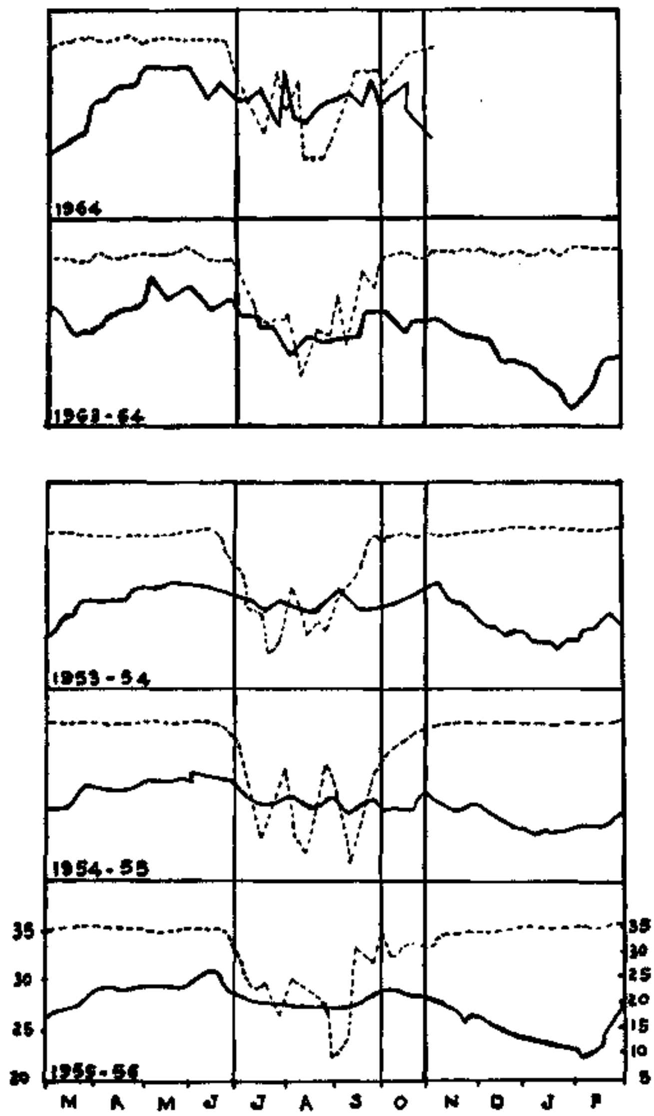


FIG. 16. Graph illustrating variations in (average) salinity and temperature values of the sea-water in Bombay Harbour for the periods 1953–56 and 1963–64 (The scale for temperature——on the Y-axis is given on the left-hand side and that for salinity - - - - is given on the right hand side).

atmospheric temperature during May is maximum (33·4° C.). Incidentally the total hour of sunshine was also found to be maximum during this period (*see* Table IV).

Lack of breeding observed during the monsoon (July to September) can easily be attributed to the low salinity noted during this period. It is known that most of the fouling organisms do not survive under low salinity conditions, though some of them do tolerate very low salinities at certain stations (Hutchins, 1952). Iyengar and others (1957) while reporting on fouling in Bombay Harbour noted stunted growth during periods of low salinity. This author has also noted on various occasions large-scale mortality amongst the barnacles examined at Chaupati and on the test panels at Trombay. Under these severe conditions, cessation of gametogenesis and fertilization leading to the failure of breeding activities can easily be understood.

Whereas during the monsoon, salinity becomes a controlling factor for breeding, during November to January it is the low temperature that affects the breeding. The poor growth index and particularly poor maturity index (Table III) noted in *B.a. communis* and *Ch. malayensis* suggest that the low water temperature affects the maturation phase of the ovary. Increase in the temperature from the latter half of February promotes the maturation of the eggs and their subsequent fertilization.

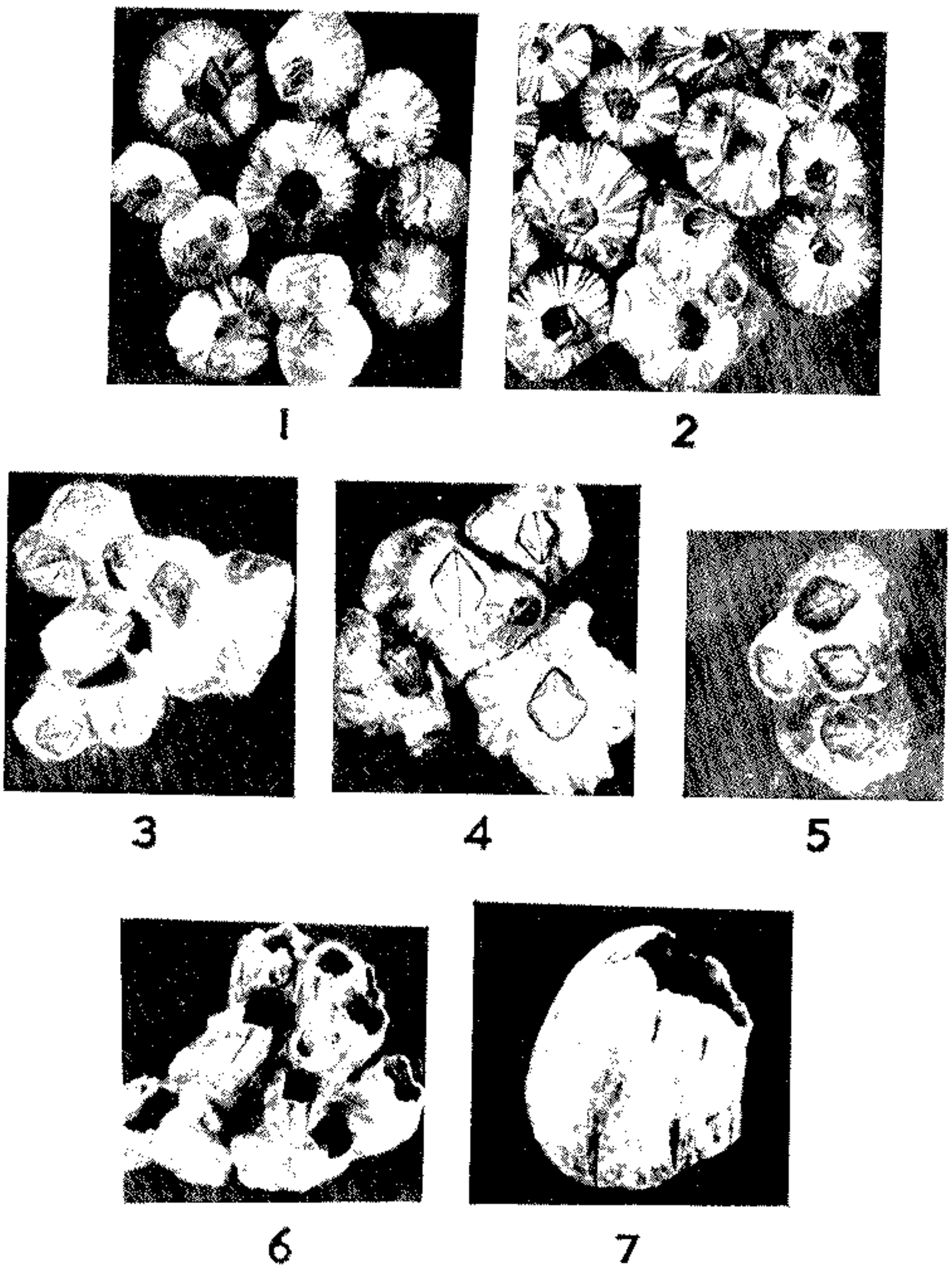
Observations on associates of Ch. malayensis.—Many workers have reported that amongst certain barnacles, parasitic castration is caused by the association of *gregarian* protozoans and an isopod *Hemioniscus balani* Bate (Crisp, 1960; Henry, 1938; Barnes, 1953). During the present investigation in one of the barnacles, *viz., Ch. malayensis* two regular associates were encountered. These were (i) Peritrichidan ciliate and (ii) *Echiniscoides* sp. (Tardigrada, Arachnida). Of these, former was always found on the respiratory organ of the host and the latter was noted anchored on the ovarian mass. *Echiniscoides* sp. is characterised by the presence of four pairs of stumpy legs provided with spiny claws (8–9 in number) with oral stylets and a suctorial pharynx. It is thus well equipped to suck and feed on the sap from the ovarian lamellae of its host. *Echiniscoides* are interesting in their capacity for resisting desiccation during the low tides. They shrivel up with loss of water, absorbing it again during the high tides. Judging from the morphological and physiological characters of *Echiniscoides*, it appears that this arachnid is a parasitic associate of *Ch. malayensis*.

Discussion

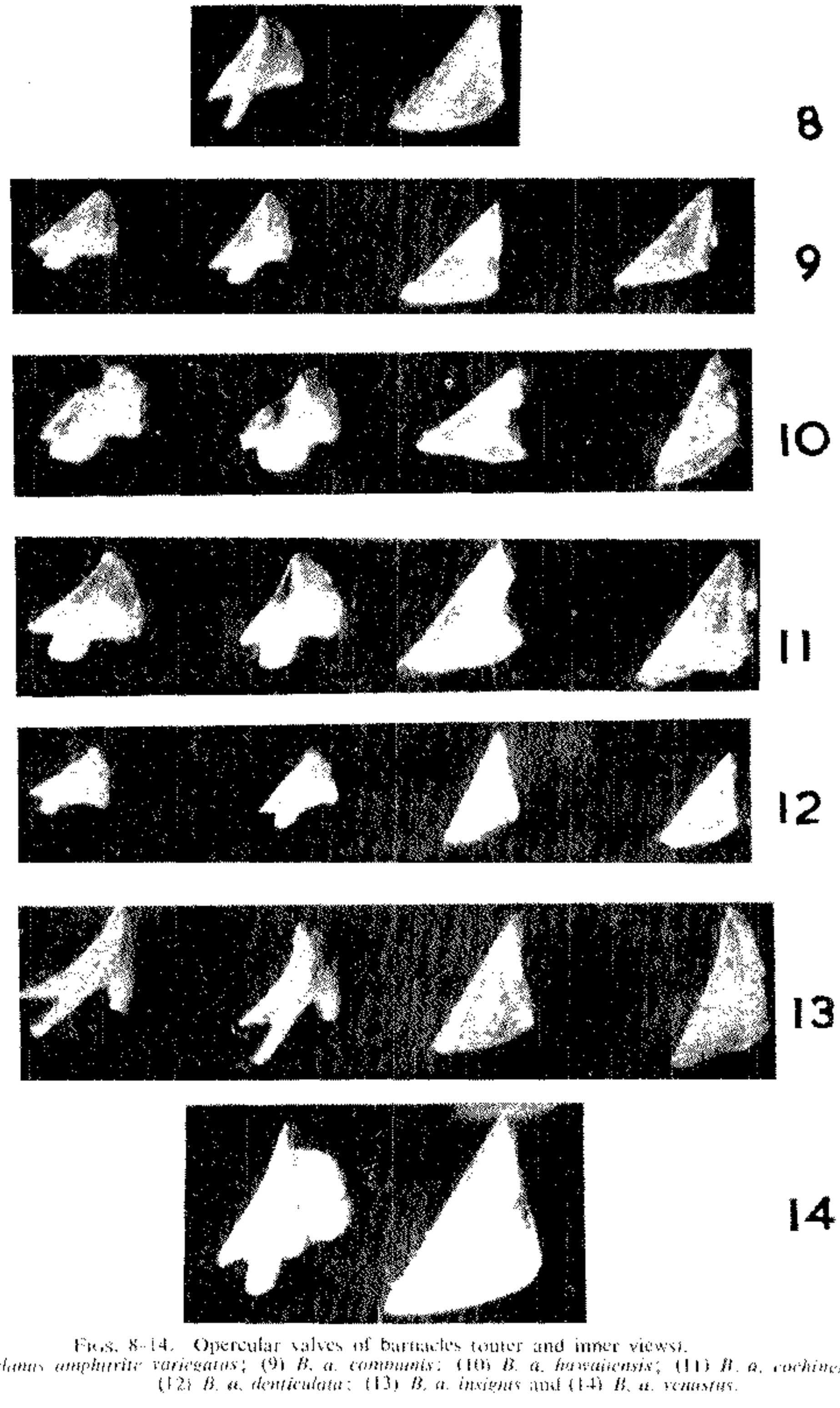
Whereas there has been a phenomenal progress in the development of suitable bioassay procedures for testing the toxins against the terrestrial pest, a standardised bioassay for the marine organisms is seriously lacking. A prerequisite for such work is adequate knowledge of the biology of the organisms concerned. With this end in view, the present study was undertaken.

The cirriped fauna incident in Bombay waters is rich and varied. Of *Amphitrite* series alone, there are seven varieties. Great care therefore must be taken in establishing the correct identity of the barnacles before they are used as test organisms. It is a well-known fact that closely related species may have different life-history patterns, different anatomical features, and different reactions even though superficially they appear quite similar (*see* Turner, 1959). The observations on systematics incorporated in this paper may prove useful in identifying the barnacles incident in Bombay-waters.

One of the most important prerequisites for rearing larval stages of barnacles under laboratory conditions is adequate knowledge of the breeding habits and time and duration of their reproductive phase. Such knowledge is also useful for assessing the results of the field toxicity tests. It has been emphasised by Crisp (1956), Crisp and Spencer (1958), Becker (1959), Bookhout and Crisp (1959) and Patel and Crisp (1960) that the liberation of the larvae in the laboratory would be possible if the breeding cycle of the animal is very well understood. In many western countries, this has been brought about by stimulating mature individuals with a hatching substance which is a metabolic product of the barnacle tissue (Crisp and Spencer, 1958). Studies on the breeding of the four



FIGS. 1-7. Shells of barnacles (1) *Balanus amphitrite variegatus*; (2) *B. a. communis*; (3) *B. a. denticulata*; (4) *B. a. hawaiiensis*; (5) *B. a. cochinensis*; (6) *B. a. insignis* and (7) *B. a. venustus*.



FIGS. 8–14. Opercular valves of barnacles (outer and inner views).
(8) *Balanus amphitrite variegatus*; (9) *B. a. communis*; (10) *B. a. hawaiiensis*; (11) *B. a. cochinensis*; (12) *B. a. denticulata*; (13) *B. a. insignis* and (14) *B. a. venustus*.

barnacles reported in this paper have indicated that it is possible to get a regular supply of larvae, not only during the natural phase of their breeding but during the non-breeding phase as well. This can be accomplished under controlled laboratory conditions by suitably adjusting the temperature and salinity conditions.

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SEASONAL SETTLEMENT OF MARINE FOULING AND WOOD BORING CRUSTACEANS AT COCHIN HARBOUR, SOUTH-WEST COAST OF INDIA

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ABSTRACT

The distribution and seasonal settlement of *Balanus amphitrite communis* Darwin, and *Sphaeroma terebrans* Bate were studied at Cochin harbour with the help of a system of short-term and long-term test panels. The vertical distribution of these organisms was noted on experimental poles. The occurrence and relative abundance of these organisms in the area have been examined during the pre-monsoon, monsoon and post-monsoon periods. The influence of hydrographic conditions on the settlement and growth of these crustaceans living in this estuarine habitat is discussed.

INTRODUCTION

A KNOWLEDGE of the composition, seasonal cycles in reproduction and settlement, growth rates and ecology of sedentary organisms is an essential prerequisite for an understanding and interpretation of the problem of marine fouling. This information must be supplemented by data on regional differences in the occurrence and relative abundance of fouling organisms. In India the different members of the fouling community have been identified and studied in some detail at Krusadai (Kuriyan, 1950), Madras (Paul, 1942; Daniel, 1954; Antony Raja, 1958) and Visakhapatnam (Ganapati *et al.*, 1958). Practically very little information is available on the nature, periods of settlement, and characteristics of growth and other ecological factors of the major fouling and wood boring organisms of the west coast. Erlanson (1936) in her preliminary study of the marine wood borers of Cochin Harbour gave brief references to the 'surface growths' on the wooden panels installed at the north-east shore of the Willingdon Island and near the harbour entrance but her findings were confined only to the low salinity period of this area, namely May to November. The present paper presents part of the results of a detailed study based on the observations on a system of test panels on the settlement and distribution of two species of crustaceans, namely *Balanus amphitrite communis* (Darwin), a major component of the fouling community and *Sphaeroma terebrans* Bate, a destructive isopod borer in the Cochin Harbour.

THE ENVIRONMENT

Cochin Port (Lat. 9° 58′ N., Long. 76° 15′ E) is a natural harbour (Fig. 2) on the south-west coast of India and is part of a long chain of backwaters connected with the Arabian Sea on the west by a gut about 450 m wide. To the north and south the harbour is continuous with extensive, shallow brackish water lagoons which receive the waters of several large rivers. The Cochin Backwaters form the northward extension of the Vembanad Lake (Fig. 1). Depth of the backwaters in the vicinity of the harbour varies from one to five meters except in the three dredged shipping channels, namely the Cochin Approach Channel, the Mattancherry Channel and the Ernakulam Channel where the depth is maintained at about twelve meters for navigation.

This area receives the full benefit of the south-west Monsoon as well as some precipitation from the north-east Monsoon. Of the total rainfall of this region more than half falls from May to August. This causes a large inflow of freshwater into the backwaters affecting the life of the organisms in this habitat. The hydrographical conditions are typically estuarine, being influenced both by the sea and freshwater.

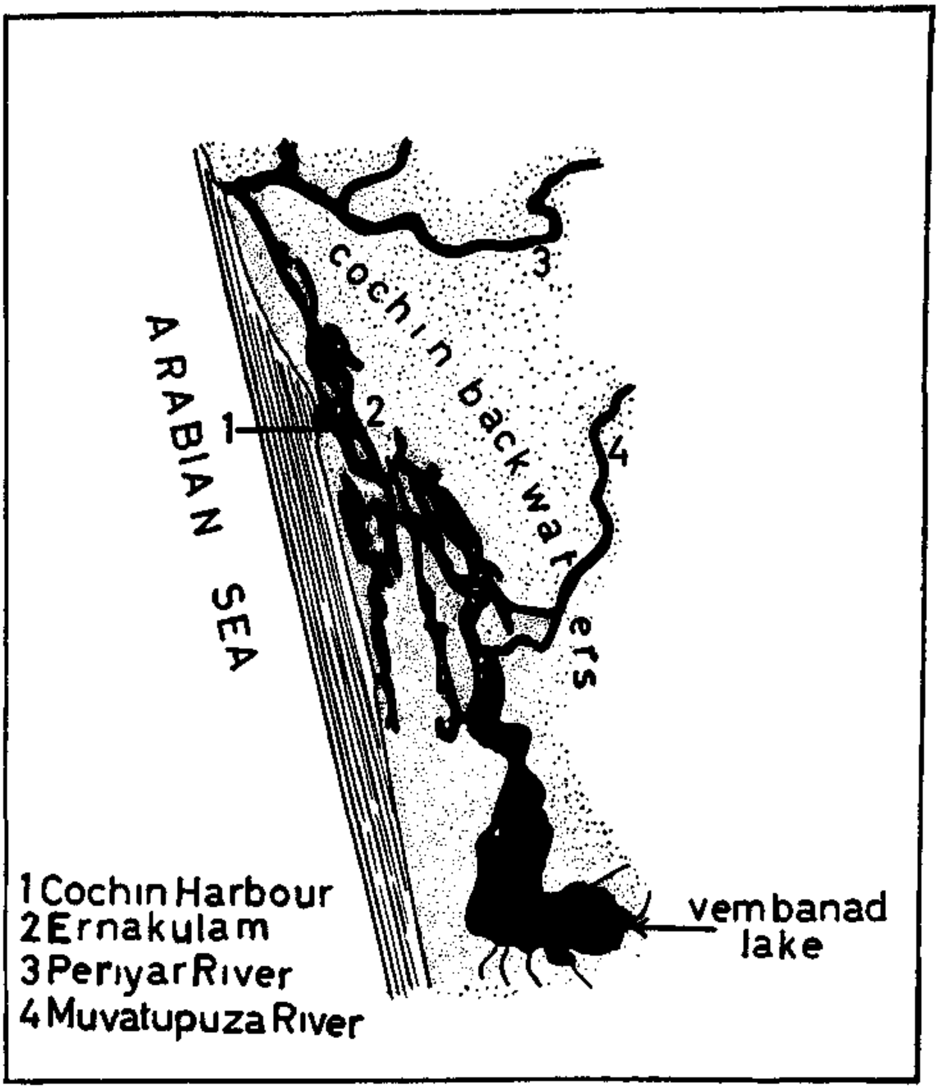

FIG. 1. Map of Vembanad Lake and Cochin backwaters.

Based on the influence of the south-west monsoon and associated meteorological conditions the year can be conveniently split into three well-defined periods having characteristic hydrographic conditions. According to the trend of surface salinity of the Ernakulam Channel George and Krishna Kartha (1963) recognised three seasons in any year. Nair (1964) has also recognised three such periods based on the influence of the south-west Monsoon in this area in his studies of marine fouling and wood boring organisms. The pre-monsoon (February to May) is comparatively a dry period with very little rainfall and is characterised by a fairly uniform and high salinity and high temperature for the surface water. The monsoon period (June to September) is characterised by a very heavy rainfall and a consequent lowering of the salinity of the surface waters which become practically fresh. The surface temperature also falls during this season. The post-monsoon

(October to January) is a period showing an upward trend in surface salinity values with characteristic fluctuations. An increase in temperature is also evident.

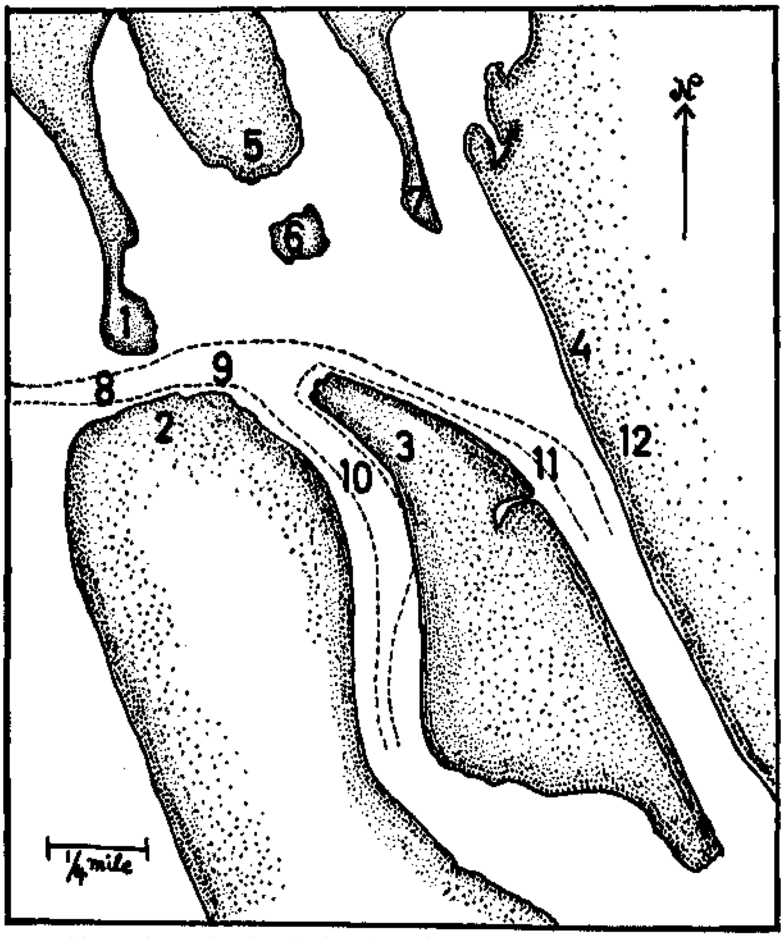

FIG. 2. Map of Cochin Harbour showing the location of the test site. (1) Vypeen island, (2) Fort Cochin, (3) Wellingdon Island, (4) Ernakulam, (5) Wallarpat Island, (6) Candle Island, (7) Bolghatty, (8) Bar mouth, (9) Approach channel, (10) Mattancherry channel, (11) Ernakulam channel, (12) Oceanographic Laboratory.

MATERIAL AND METHODS

Settlement of the foulers and borers was determined by exposing at the quay of the Oceanographic Laboratory on the Ernakulam Channel a system of wooden test blocks 15 × 10 × 5 cm. cut out from the soft tibmer *Mangifera indica* and conditioned for a period of 15 days by soaking in filtered sea-water. The blocks were suspended and kept in position at three levels (inter-tidal, below low-water and above mud-line), in two series (short-term and long-term) as shown in Tables II and III. With a view to getting a more detailed picture of the settlement of barnacles and other fouling organisms during the course of each month two series (A and B, *see* Table IV) each consisting of ten clear glass plates 12 × 10 cm. were exposed. These were secured endwise in a wooden rack which was suspended to lie at a depth of 15 cm. below the low tide level. The short-term panels (A series) were put out and changed every three days while the ten units of the long-term series (B series) were exposed together at the beginning of each month and examined one by one at the end of every three days. Thus A1 and B1 were examined on the 4th of every month, A1 was replaced by A2 which was exposed along with B2 on the 7th and so on. These panels furnished a more accurate picture of the settlement of barnacles for the different periods of each month as well as for the different months of the year. The long-term panels of this series also provided data regarding the influence if any exerted by those which have already settled, on the settling forms. The vertical distribution was examined on old fender piles pulled out from the harbour as well as on experimental bamboo poles installed for this purpose. Temperature and salinity were measured regularly during the period of observation and the data presented represent the monthly averages of weekly samples.

Results and Discussion

The results of the examination of the short-term and long-term test blocks (wood) are presented in Tables II and III. These give information regarding the settlement of *Balanus amphitrite communis* and the invasion of the migrating crustacean, *Sphaeroma terebrans* during the different months of 1963–64 at the three levels. The twelve sets of the long-term B series exposed in three bunches of four each for each period as shown in Table III and removed one by one at intervals of thirty days give an idea of the settlement of this barnacle for the respective period of immersion from one month to four months and show how the monthly set is modified by animals already present on the blocks.

It may be seen from Table II that out of a total of 1,276 barnacles that settled on the short-term blocks during the pre-monsoon period 837 were on the intertidal blocks, 284 on the top blocks and 154 on the bottom blocks, the maximum settlement being on A4 exposed during the period 14 May to 14 June. The least settlement was recorded on A1 exposed during 14 February and 14 March. During the pre-monsoon period the blocks did not give any evidence of attack by the isopod borer.

Table I

Monthly average of maximum and minimum temperature (atmospheric), relative humidity, monthly rainfall, temperature and salinity of the surface water at the Ernakulam Channel and at the fourth buoy beyond the barmouth in the Arabian Sea for the period January 1963 to January 1964

Month	Atmospheric temp. °C		Rainfall in mm.	Relative humidity percentage	Ernakulam channel		Fourth buoy	
	Maximum	Minimum			Temperature °C.	Salinity ‰	Temperature °C.	Salinity ‰
January ..	31·5	22·4	25·0	66	28·10	32·56	27·93	32·92
February ..	32·1	22·6	5·3	73	28·50	32·97	28·00	33·32
March ..	32·5	25·0	45·8	73	30·92	33·23	31·25	33·76
April ..	33·0	24·5	63·4	72	32·33	33·47	32·35	33·77
May ..	32·9	25·7	120·8	79	32·35	33·48	31·50	32·50
June ..	30·5	24·0	440·9	80	28·70	11·30	28·60	15·96
July ..	29·4	23·7	525·5	87	28·40	2·46	27·55	11·94
August ..	25·9	23·8	539·8	86	28·85	1 ·43	27·50	15·21
September ..	30·1	23·8	405·3	82	29·70	3·33	28·32	14·38
October ..	30·4	23·9	269·3	76	30·60	5·58	29·00	22·97
November ..	31·7	24·3	153·1	73	29·23	16·97	29·33	22·88
December ..	31·4	22·4	53·3	73	29·85	12·75	29·50	29·47
January ..	31·7	21·0	Trace	64	28·00	31·12	27·95	32·00

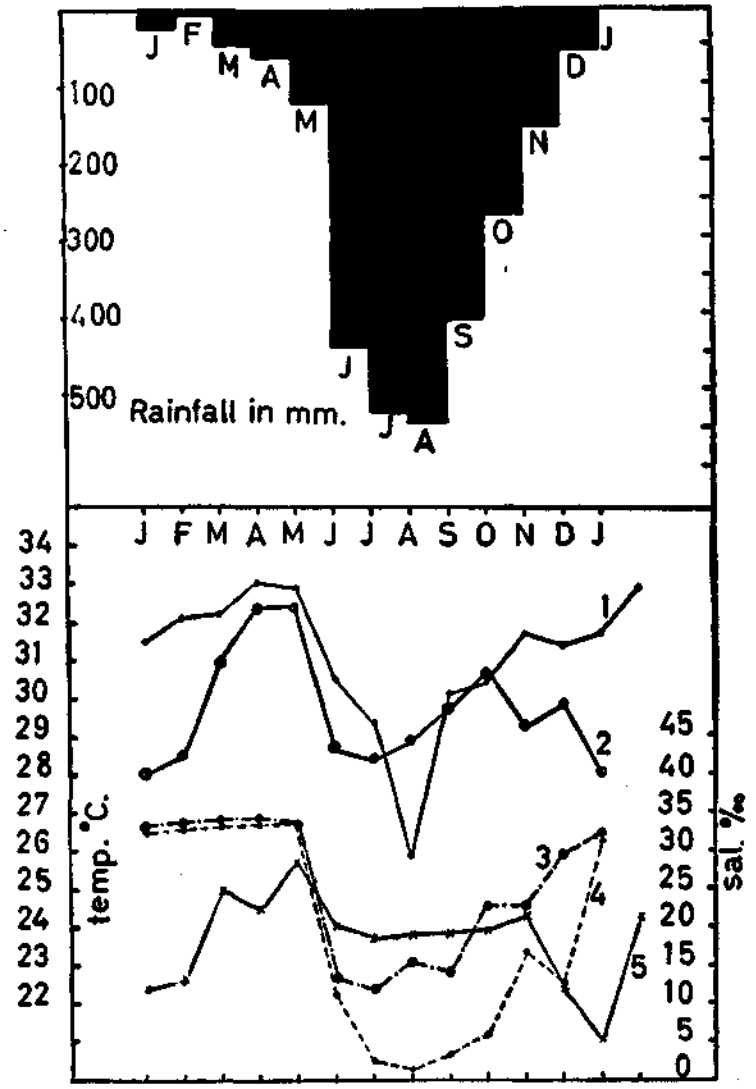

FIG. 3. Temperature, salinity and rainfall (I.N.S. Garuda) data for the period of investigation. (1) Average maximum atmospheric temperature (I.N.S. Garuda), (2) Average water temperature (surface), Ernakulam channel, (3) Average salinity (surface), beyond the barmouth in the sea, (4) Average salinity (surface), Ernakulam channel, (5) Average minimum atmospheric temperature (I.N.S. Garuda).

The monsoon period characterised by important changes in the hydrographic conditions (Table I, Fig. 3) influenced the nature of settlement of these crustaceans. The barnacle settlement showed a steep fall the total settlement for the period being only 265. An examination of the figures for the three levels, namely the intertidal block, the top block placed below low water mark and the bottom block placed above the mud-line during this period seems to show a shift in the nature of settlement from intertidal, through the top block to the bottom block. During June there is greater settlement over the intertidal block than the other two blocks but this trend seems to have been reversed by the close of the season when the intertidal block registered practically no attack. The

TABLE II

Short-term blocks, A-series showing the monthly settlement of Balanus amphitrite communis *and* Sphaeroma terebrans at the three levels

Period of immersion	Block No.	*Balanus amphitrite communis* Position of block			Total	*Sphaeroma terebrans* Position of block			Total
		Intertidal	Top	Bottom		Intertidal	Top	Bottom	
Pre-Monsoon:									
14 Feb. to 14 March ..	A1	22	15	34	71	0	0	0	0
14 March to 14 April ..	A2	19	17	39	75	0	0	0	0
14 April to 14 May ..	A3	207	47	28	282	0	0	0	0
14 May to 14 June ..	A4	589	205	53	847	0	0	0	0
Total for pre-monsoon ..		837	284	154	1,275	0	0	0	0
Monsoon:									
1 June to 1 July ..	A1	40	22	16	78	0	0	0	0
1 July to 1 August ..	A2	0	0	0	0	0	4	0	4
1 August to 1 Sept. ..	A3	0	34	0	34	7	5	0	12
1 Sept. to 1 Oct. ..	A4	0	1	152	153	0	0	0	0
Total for Monsoon ..		40	57	168	265	7	9	0	16
Post-Monsoon: ..									
1 Oct. to 1 Nov. ..	A1	8	114	7	129	1	0	0	1
1 Nov. to 1 Dec. ..	A2	626	370	483	1,479	14	0	0	14
1 Dec. to 1 Jan. ..	A3	46	44	4	94	15	0	0	15
1 Jan. to 1 Feb. ..	A4	0	8	44	52	2	0	0	2
Total for post-monsoon ..		680	536	538	1,754	32	0	0	32
Total for the year ..		1,557	877	860	3,295	39	9	0	48

TABLE II A

Analysis of variance based on data presented in Table II. A-series

Source of variation ..	d.f.	s.s.	m.s.	F.	
Between months ..	11	716555·67	65141·42	6·98	†
Between levels ..	2	26347·17	13173·59	1·41	N.S.
Error ..	22	205172·16	9326·01		
Total ..	35	948075·00			

overall picture indicates a reversal of settlement during this season. Another feature of this period is the settlement of *Sphaeroma terebrans* which was conspicuously absent from the test blocks during the pre-monsoon period. Though the record of their settlement over the short-term blocks is not very steady the data from the long-term blocks (Table III) show a fairly steady increase in settlement over the blocks. More numbers of *Sphaeroma* settled over the intertidal blocks than either the top or the bottom blocks.

During the post-monsoon period the overall pattern of settlement of the barnacles shows a resumption of the trend noted during the pre-monsoon period. It is clear from Table II that while over the blocks A2 and A3 more barnacles settled in the intertidal zone, over A1 the maximum settlement is over the top block and A4 has none in the intertidal region. The total for each level gives the impression of a fairly uniform settlement at all the three levels with a small increase for the intertidal blocks. In the case of *Sphaeroma* all the thirty-two specimens collected during the period settled over the intertidal blocks. *Sphaeroma* settlement continued and reached a peak during December as may be seen from both the short-term and long-term blocks.

TABLE III

Long-term blocks, B-series showing the settlement of Balanus amphitrite communis *and* Sphaeroma terebrans *at the three levels during the respective periods of immersion*

Period of immersion	Block No.	*Balanus amphitrite communis* Position of the block			Total	*Sphaeroma terebrans* Position of the block			Total
		Intertidal	Top	Bottom		Intertidal	Top	Bottom	
Pre-monsoon:									
14 Feb. to 14 March ..	B1	22	15	34	71	0	0	0	0
14 Feb. to 14 April ..	B2	3	12	39	54	0	0	0	0
14 Feb. to 14 May ..	B3	184	34	50	268	0	0	0	0
14 Feb. to 14 June ..	B4	22	29	59	110	0	0	0	0
Total for pre-monsoon ..		231	90	182	503	0	0	0	0
Monsoon:									
1 June to 1 July ..	B1	40	22	16	78	0	0	0	0
1 June to 1 August ..	B2	0	0	0	0	0	4	2	6
1 June to 1 Sept. ..	B3	0	0	8	8	7	6	1	14
1 June to 1 Oct. ..	B4	0	9	287	296	52	5	0	57
Total for monsoon ..		40	31	311	382	59	15	3	77
Post-monsoon:									
1 Oct. to 1 Nov. ..	B1	8	114	7	129	1	0	0	1
1 Oct. to 1 Dec. ..	B2	80	50	76	206	2	0	0	2
1 Oct. to 1 Jan. ..	B3	866	15	81	962	166	18	3	187
1 Oct. to 1 Feb. ..	B4	27	6	4	37	16	1	0	17
Total for post-monsoon ..		981	185	168	1,334	185	19	3	207
Total for the year ..		1,252	306	661	2,219	244	34	6	284

The data obtained from blocks of the B series (Table III) serve to confirm the observations from the blocks of the A series. The number of barnacles remaining over the blocks at the time of examination after prolonged periods of exposure ranging from one month to four months need not give a correct indication of the number that actually settled over the blocks. Owing to the interaction and influence of several ecological factors, both physico-chemical and biological,there is the possibility of the number of originally settled individauls undergoing changes leading to the survival and dominance of entirely new forms in course of time. The very heavy settlement of generations of fouling and boring organisms during the later part of the post-monsoon and the whole of the pre-monsoon periods and the resulting competition of barnacles with oysters, encrusting bryozoans, and rapidly growing mats of compound ascidians also will have to be taken into consideration while examining the data of the long-term blocks. The slight disparities in the occurrence of barnacles over the different test panels can be explained in the light of this observation. However, it may be noted that the overall picture confirms the general trend noted from the short-term blocks.

A statistical analysis of the data based on Table II regarding barnacle settlement as presented in Table II A shows that the monthly variations are highly significant. This data, however, does not indicate any significant difference in the nature of settlement between the levles. A more elaborate experiment with replications during each month at the various levels might have brought out the trend of barnacle settlement more clearly than has been noted from the analysis of the present data.

Table IV presents the details of the nature of settlement of *B. amphitrite* during the different months from November 1963 to October 1964 on short-term and long-term glass panels. This series was devised with a view to following more closely the pattern of settlement of the fouler during the different 3-day time intervals for each month and to find out the progress of settlement during the course of each month. In spite of the fact that the period of exposure of the glass panels and wooden blocks was not the same there is agreement with regard to pattern of settlement during the two years, the maximum settlement being during the same period for both the series, though the time of least settlement during the pre-monsoon showed a slight shift to April.

Table IV A presents the number of barnacles that settled during the ten 3-day intervals for each month. There is some amount of variation between the numbers that settled in the ten intervals. This may be called the 'within-month' variation. It is possible that there is a 'between-month' variation as well. To test if the variation between the months is significantly different the data of Table IV A was analysed by the usual method of analysis of variance. The results of the analysis of variance are presented in Table V A. It will be seen that the 'between-month' variation is highly significant. Looking into the mean value of the number of barnacles that settled within a 3-day interval for each month it was found that it varied from 0 in August to 169·2 in November. If the month of November is excluded the variation is from 0 to 17·6. So it is likely that the 'between-month' variation was found highly significant because of the high amount of settlement for the month of November. An analysis of variance of the same data but excluding the data for November is presented in Table V B. This shows that in this case the monthly variations are not significant. The highest settlement obviously takes place for the month of November at a rate of 169·2 per 3-day interval and though there is no statistically significant difference in the rate of settlement during the other months, the period July to September and January appear to be the months of least barnacle settlement.

Apart from taking 3-day-interval samples, samples of glass plates were also taken for the determination of barnacle settlement at the end of 3, 6, 9, etc., days-intervals. These figures are given for each month in Table IV B, figures within brackets are the corresponding figures for the 3-day intervals. This experiment was done with a view to finding out the effect of settled barnacles on further settlement of barnacles. The relevant analysis of variance are presented in Table V C. It shows that the variations between months are as obtained from the short-term panels, highly significant but no significant differences are seen between the different settlement showing that already settled barnacles have apparently no significant influence on the further settlement of barnacles. The analysis with the exclusion of November shows the same types of results as obtained in Series A.

TABLE IV

Details of the nature of settlement of Balanus amphitrite communis *on short-term and long-term glass panels*

Series No. of panel	February		March		April		May		June		July		August		September		October		November		December		January	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	20	20	7	7	9	9	5	5	13	13	22	22	0	0	15	15	40	40	40	40	0	0	0	0
2	15	19	3	26	6	4	5	7	12	16	0	0	0	0	13	65	73	104	427	387	0	0	0	7
3	21	61	3	117	1	47	2	55	4	45	0	0	0	0	0	33	0	56	816	1,576	0	3	0	19
4	3	71	5	133	0	87	4	148	17	48	0	0	0	0	0	39	0	38	320	1,450	0	95	0	13
5	73	347	4	83	1	58	0	118	35	185	0	0	0	0	0	20	0	0	45	1,311	0	110	0	30
6	3	295	2	195	6	58	0	55	0	220	0	0	0	0	0	5	0	0	20	840	0	168	13	123
7	0	226	1	148	0	34	3	233	0	210	0	0	0	0	0	0	0	0	0	973	0	91	0	101
8	7	157	0	159	0	87	31	160	2	240	0	5	0	0	0	4	0	0	4	1,189	5	97	0	137
9	34	260	33	134	10	99	23	320	17	200	0	0	0	0	0	1	0	0	0	1,316	10	110	0	88
10	0	0	0	170	0	255	19	317	0	345	0	0	0	7	16	35	0	0	20	1,410	18	102	0	271
Total ..	176	1,457	58	1,172	33	738	92	1,418	100	1,522	22	27	0	7	44	217	113	238	1,692	10,492	33	776	13	789

Total settlement for pre-monsoon period—5,144

Total settlement for monsoon period—1,939

Total settlement for post-monsoon period—14,146. A = short-term panel, B = long-term panel.

TABLE IV A

The settlement of barnacles during the 3-day intervals for each month during 1963–64

A-series		1	2	3	4	5	6	7	8	9	10	Mean
February	..	20	15	21	3	73	3	0	7	34	..	17·6
March	..	7	3	3	5	4	2	1	0	33	0	5·8
April	..	9	6	1	0	1	6	0	0	10	0	3·3
May	..	5	5	2	4	0	0	3	31	23	19	9·2
June	..	13	12	4	17	35	0	0	2	17	0	10·0
July	..	22	0	0	0	0	0	0	0	0	0	2·2
August	..	0	0	0	0	0	0	0	0	0	0	0
September	..	15	13	0	0	0	0	0	0	0	16	4·4
October	..	40	73	0	0	0	0	0	0	0	0	11·3
November	..	40	427	816	320	45	20	0	4	0	20	169·2
December	..	0	0	0	0	0	0	0	5	10	18	3·3
January	..	0	0	0	0	0	13	0	0	0	0	1·3
TOTAL	..	171	554	847	349	158	44	4	49	127	73	23·76

TABLE IV B

The settlement of barnacles at the end of 3, 6, 9-day intervals. Figures within brackets are the corresponding figures for the 3-day intervals

B-series		1	2	3	4	5	6	7	8	9	10	Total
February	..	20 (20)	19 (9·5)	61 (20·33)	71 (17·75)	347 (69·4)	296 (49·33)	226 (32·29)	157 (19·625)	260 (28·88)	– (–)	267·11
March	..	7 (7)	26 (13)	117 (39)	133 (33·25)	83 (16·6)	195 (32·5)	148 (21·14)	159 (19·88)	134 (14·88)	170 (17·0)	214·25
April	..	9 (9)	4 (2)	47 (15·66)	87 (21·75)	58 (11·6)	58 (9·66)	34 (4·86)	87 (10·875)	99 (11·0)	255 (25·5)	121·41
May	..	5 (5)	7 (3·5)	55 (18·33)	148 (37·0)	118 (23·6)	55 (9·17)	233 (33·28)	160 (20·0)	320 (35·55)	317 (31·7)	217·13
June	..	13 (13·0)	16 (8·0)	45 (15·0)	48 (12·0)	185 (37·0)	220 (36·66)	210 (30·0)	240 (30·0)	200 (22·22)	345 (34·5)	236·38
July	..	22 (22·0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (0·625)	0 (0)	0 (0)	22·63
August	..	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (0·7)	0·70
September	..	15 (15·0)	65 (32·5)	33 (11·0)	39 (9·75)	20 (4·0)	5 (0·833)	0 (0)	4 (0·50)	1 (0·11)	35 (3·5)	77·19
October	..	40 (40·0)	104 (52·0)	56 (18·66)	38 (9·5)	2 (0·4)	0 (0)	12 (1·71)	5 (0·625)	3 (0·33)	5 (0·5)	121·73
November	..	40 (40)	387 (193·5)	1576 (525·33)	1450 (362·5)	1311 (262·2)	840 (140·0)	973 (139·0)	1189 (148·62)	7316 (146·22)	1410 (141·0)	2098·37
December	..	0 (0)	0 (0)	3 (1·0)	95 (23·75)	110 (22·0)	168 (28·0)	91 (13·0)	97 (12·125)	110 (12·22)	102 (10·2)	122·30
January	..	0 (0)	7 (3·5)	19 (6·33)	13 (3·25)	30 (6·0)	123 (20·5)	101 (14·43)	137 (17·125)	88 (9·77)	271 (27·1)	108·01
Mean	..	171·00	317·50	670·64	530·50	452·80	326·65	289·71	280·03	281·18	291·20	..

TABLE V A

Analysis of variance (taking all 12 months)

Source of variation		d.f.	s.s.	m.s.	F
Between months	..	11	246275·60	22388·69	3·538†
Within months	..	108	683521·60	6328·90	
Total	..	119	929797·20		

TABLE V B

Analysis of variance (11 months) excluding the data for November

Source of variation		d.f.	s.s.	m.s.	F
Between months	..	10	2780·76	278·08	1·862 N.S.
Within months	..	99	14782·00	149·31	..
Total	..	109	17562·76	..	..

TABLE V C

Analysis of variance of the data in Table IV B

Source of variation		d.f.	s.s.	m.s.	F
Between months	..	11	360078·53	32734·41	18·563†
Between types	..	9	16257·34	1806·37	1·024 N.S.
Error	..	99	174577·53	1763·41	..
Total	..	119	550913·40	..	..

In Table VI is presented the details of the examination of old fender piles pulled out from the harbour and the result of observation of a representative bamboo pole installed at the experimental site to study the pattern of vertical distribution of the two crustaceans. It will be seen that the zone of maximum settlement of these two species is almost the same. The noteworthy feature here is the fact that these two species manage to share the same zone without serious competition. During the monsoon period the region between the tide marks of piles is almost bare except for the growth of a thin mat of green algae and is free from any serious obstruction by major fouling organisms. The major part of the barnacle populations of the pre-monsoon period has been killed and sloughed off the substrata by freshwater. This seems to be advantageous for the settlement, without any hindrance, of *Sphaeroma* which gets free access to the wood to begin its excavation. If the empty shells of barnacles of the pre-monsoon still remain, the borers get an effective hiding place and partial protection during the initial stages of burrowing. During the present study this borer was collected many times while taking shelter in the empty barnacle shells. Fresh *Sphaeroma* settlement in this locality takes place before the great wave of barnacle cyprids that settle during the November-December period. The sharing of this limited substratum by these two species lead to both intra and interspecific competition in this zone resulting in a spread of population upwards and downwards over the surface of a pile.

In any consideration of the patterns of the fouling process many factors will have to be taken into careful consideration before drawing even tentative conclusions. Of these the intrinsic features of the particular life-cycles, seasonal responses to the physico-chemical changes in the environment, the availability of suitable substratum for settlement and competitive factors operating within established communities are of great importance.

An important feature of the results obtained from the studies based on experimental test panels is the influence of the seasons on the settlement of these crustaceans. Almost throughout the year

TABLE VI

Vertical distribution of Balanus *and* Sphaeroma *on old fender piles pulled out from the Cochin Harbour and on a representative experimental bamboo pole installed at the pier of the Oceanographic Laboratory*

Height in cm. from mud-line	Old fender pile I		Old fender pile II		Old fender pile III		Experimental bamboo pole	
	Balanus	*Sphaeroma*	*Balanus*	*Sphaeroma*	*Balanus*	*Sphaeroma*	*Balanus*	*Sphaeroma*
240–270	0	0	0	1	0	12	0	0
210–240	2	0	10	9	10	23	0	0
180–210	600	12	480	41	1200	58	1580	3
150–180	94	9	60	38	180	40	550	1
120–150	30	1	45	2	48	12	113	1
90–120	24	0	30	1	38	13	340	0
60– 90	13	0	35	0	17	2	210	0
30– 60	24	0	40	0	31	7	80	0
0– 30	100	1	78	5	94	0	129	0

the larvae of *B. amphitrite* settled on newly submerged panels but the settlement showed significant monthly variations in its intensity. This variation in settlement may either be the result of seasonal rhythms in reproduction or the peculiarities of the prevailing hydrographic conditions characteristic of this locality or both.

At Madras and Visakhapatnam *B. amphitrite communis* is reported as a continuous breeder (Paul, 1942; Ganapati *et al.*, 1958). The settlement based on weekly attachment on test panels shows (*see* Daniel, 1954) variations during the different months of the year. According to Pillay (1958) this barnacle breeds throughout the year along the Kerala Coast. During the high salinity period (December to April) the number of larvae in the plankton and the number of settled stages on test panels show maximum intensity. However, during the rainy months (May to August) when the salinity is low (6 or 7‰) their number is also very low indicating relationship between the two. Pillay (*loc. cit.*) also noted the presence of large numbers of larvae in the brood pouch even during the rainy months which indicates that they are capable of reproduction if conditions are favourable. Therefore, the comparative freedom from the settlement of barnacles on surfaces in this area during the major part of the monsoon period is attributable to the seasonal changes in salinity which acts as a limiting factor. At this stage it will be interesting to analyse the hydrographic conditions of this area during the different seasons and their possible effects on barnacle and *Sphaeroma* settlement.

A dominant feature of this region is the influence of the south-west monsoon which brings about important changes in the hydrographic conditions of this area (Table I). The pre-monsoon (February to May) is characterised by very little rainfall and the salinity of the harbour area is uniformly high almost equal to that of the inshore water. This condition remains till about the end of May depending on the onset of the south-west monsoon rains. During the pre-monsoon the surface temperature also shows a high value. According to Ramamirtham and Jayaraman (1963) the important features of the bottom water during this period are a gradual warming up with very little difference between surface and bottom temperatures owing to vertical mixing, fairly uniform salinity conditions and an intrusion of more saline water from the sea to the estuary. The conditions prevailing during the pre-monsoon closely approximates to those in the inshore waters allowing the normal settlement of barnacles in this estuarine area and the pattern of settlement during this period can, therefore, be considered that which is normal for the species. According to this assumption this species seems to settle in greater numbers in the intertidal region and capable of spreading downwards when conditions become unsatisfactory.

The monsoon period (June to September) is characterised by very heavy rainfall. By about the end of May or early June there is a sudden drop in the salinity of the surface waters owing to the commencement of the rains. During this period the surface layer consists practically of freshwater as a result of the heavy rains, land drainage and the inflow of great quantities of freshwater into the Vembanad Lake and the Cochin Backwaters through the large rivers. The tidal influence during this season is slight due to the high water level in the backwaters and the consequent powerful seaward flow of freshwater on the surface leaving the cold, dense layer of sea-water at the bottom. This causes a sharp gradient of salinity between the surface and the bottom. By the onset of the monsoon the surface temperature falls and then remains almost steady at that level till about the end of the season. Though the bottom temperatures during June are not very much different from that of the surface, two rapid falls have been noticed in succession one in July and another just after August due to the intrusion of low temperature water from the sea causing steep vertical thermal gradients between surface and bottom temperatures (Ramamirtham and Jayaraman, 1963).

The great reduction of the salinity especially at the surface and the consequent salinity gradient between the surface and the bottom may be responsible for the slight reversal of the pattern of settlement of the barnacles noticed during this season (Table II). The barnacles colonising the intertidal zone are found to be dead during the monsoon period. The conditions prevailing during the later part of the season and the early half of the post-monsoon seem to be suitable for the settlement of *Sphaeroma*. No information is available regarding the migratory habits and period of attack on fresh surface by *Sphaeroma* though the allied Isopod borer *Limnoria* has been studied in great detail (Kramp, 1927; Johnson, 1935; Somme, 1940; Menzies, 1957; Nair, 1962; Nair and Leivestad, 1958; Eltringham and Hockley, 1961). In India *Limnoria* is not a serious pest in spite of the fact that nine species have so far been reported from the Indian waters. Literature concerning the biology of *S. terebrans* contains no observations on seasonal variations in the attack. To elucidate the question whether invasion of *Sphaeroma* takes place in a restricted season in this habitat or does it occur evenly throughout the year, the system of test blocks gives a direct answer. In Cochin Harbour the first evidence of migration based on their settlement on fresh surfaces is from A2 and B2 monsoon blocks. The B series give the impression of a seasonal migration by these crustaceans during the monsoon and post-monsoon periods while the pre-monsoon period characterised by high temperature and high salinity registering no fresh attack either on the short-term or on the long-term blocks. Apart from the reproductive rhythm many other factors also serve to influence heavy settlement of barnacles. Skerman (1956) noted in Auckland Harbour that silt or other suspended detritus in sheltered regions can get incorporated in the slime films that develop on panels and these granular films can promote barnacle settlement on these surfaces. However, he observed that continued deposition of this material may affect the survival of these pioneer populations. By the onset of monsoon rains in June, the silt-laden waters drained into the lake and backwaters by the rivers raises the turbidity in the area and a fine silt readily settles on the panels. The greater settlement noticed on the short-term wooden panels and both the short-term and long-term glass panels in May-June period may be attributed to this silt factor also.

During the post-monsoon (October to January) an upward trend in surface salinity values is evident owing to a general decrease in rainfall and increased evaporation and tidal influence. A progressive mixing of sea-water with the freshwater leading to a general increase in salinity is also evident. This period, however, does not show a steady increase in salinity values but shows fluctuations due to precipitation under the influence of the north-east monsoon. The increase in temperature of the surface water initiated in September is maintained about that level until almost December and the bottom water also shows evidence of warming up.

It is interesting to note that during this period with characteristic salinity fluctuations the barnacle settlement also shows variations in its pattern at the three levels.

From these observations some tentative conclusions can be drawn regarding the period and pattern of settlement of these two species of crustaceans and their practical applications. *Balanus amphitrite* settles most abundantly during the post-monsoon period with a distinct peak of settlement during November-December period. *Balanus* settlement is heavy during the pre-monsoon period. Their settlement is least during the monsoon period, July and August being months with very sparce settlement. This information has important practical value. The period of comparative freedom from barnacle fouling can be effectively exploited by mooring the ships in areas with freshwater influence in the harbour. This procedure will aid in preventing fresh settlement of these organisms. It will also have an added advantage of a partial cleaning effect on the hulls especially at the upper zones where a sloughing action can be expected as a result of freshwater influence. However, caution needs to be exercised in relying too much on these results. Variations in hydrographic conditions can upset and alter the settling periods and therefore, due allowances must be given for such changes while considering the time of settlement of this species.

A precise knowledge of the period of swarming and the time and region of maximum settlement of marine crustacean borers will be of value for protecting wooden structures from their ravages.

From the data available at present it seems that the best period for dry-docking and repainting of the hulls of boats and ships of this area is during the November-December period. By this procedure the vessels can avoid the peak settling period of both foulers and borers. The fresh antifouling paint on the hulls with its full properties will be most effective during the rest of the post-monsoon and pre-monsoon periods. The few that may settle will get sloughed off during the monsoon period. This schedule will help to keep the hulls of vessels almost completely free from the attachment of barnacles. Thus by a planned procedure heavy barnacle settlement on the hulls of ships can be controlled to a very considerable extent.

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BIOLOGICAL ANALYSES OF *SPHAEROMA* ATTACK ON TIMBER TREATED WITH CONVENTIONAL WOOD PRESERVATIVES

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ABSTRACT

A study was made of specimens of *Sphaeroma terebrans* that had attacked test pieces of timber treated with pure creosote, copper-resinate, creosote-coal tar 70:30, and creosote-coal tar 60:40. Data are given to show the relationship of the four types of preservatives with regard to the intensity of attack, interval before first attack, depths of the burrows, size of animal and reproduction capabilities. The data give the clues about the relative efficacy of the four preservatives.

INTRODUCTION

NEARLY twenty-five species of *Sphaeroma* have so far been recorded. Of these only about ten species are known to burrow into wood or stone (Barrows, 1919; Richardson, 1910; McNeill, 1932; Calman, 1936; Pillai, 1955 and Shino, 1957). Detailed information on the destructive activity of *Sphaeroma*, when compared with that of its nearest ally *Limnoria* and that of the teredenids is rather meagre. This appears to be mainly because *Sphaeroma* is very active only in typical estuarine habitats.

Cochin Harbour, 76° 14′ E. and 9° 57′ N., offers such a habitat and *S. terebrans* Spence Bate is very abundant here. The present paper presents data together with certain conclusions about the relative efficacy of four preservatives, based on the attack of *S. terebrans* on treated wood.

PROCEDURE

Test pieces of *Pinus longifolia* with dimensions of $18'' \times 1\frac{1}{2}'' \times 1\frac{1}{2}''$, treated under pressure, with pure creosote, creosote-coal-tar mixtures 70:30 and 60:40 and copper resinate were exposed in the Cochin Harbour to the attack of *Sphaeroma* from February to December 1963. The test pieces under a particular treatment consisted of a set of nine samples. Counts of the number of individuals of *S. terebrans* on each test piece were made once in every thirty days. The data presented on the intensity of attack under a given treatment is the average of the number of individuals present on the nine test pieces which formed one set under a particular treatment. For determining the size groups and reproductive capabilities, a single representative test piece each of a treatment was split open and the animals measured individually from their anterior to the hind ends of the telson. They were then dissected out to count the intra-ovarian and brood pouch stages within them.

RESULTS

Intensity of attack under the different treatments and the interval before the first attack occurred.—The preservatives used showed total resistance to *Sphaeroma* for varying periods and Table I shows the number of days under each treatment, before signs of any attack was evident, and also the intensity of occurrence of the animal after three hundred days' exposure.

TABLE I

Interval before the first attack occurred and the intensity of occurrence of the animal (average of the intensity of nine test pieces each)

	Pure creosote	Creosote + coal-tar 70:30	Creosote + coal-tar 60:40	Copper resinate
Number of days before the first attack occurred ..	210	210	150	135
Number of individuals after 300 days ..	16	24	56	94

It will be seen that test pieces treated with pure creosote and 70% mixture of creosote with coal-tar resisted the attack of *Sphaeroma* for a longer period than the others and that those treated with copper resinate showed resistance for the minimum period. It will also be seen that after three hundred days, the maximum number of individuals was present on test pieces treated with copper resinate and the minimum on those treated with pure creosote. In the case of the mixtures with coal-tar, the intensity of *Sphaeroma* increased with the percentage of coal-tar in the mixture.

The rate of increase of population of Sphaeroma *under each treatment.*—Table II gives the number of individuals of *Sphaeroma* found on a single test piece of each treatment for successive months after the first attack was noticed. The data will work out to a 135% increase of population in the case of creosote, 167% for the 70% mixture with coal-tar, 520% for the 60% mixture and 603% for the copper resinate. This again shows that pure creosote and a higher content of creosote in the mixture with coal-tar showed substantial resistance to the increase of population while copper-resinate and 60% mixture of creosote with coal-tar failed to have exerted little influence against the increase of population.

TABLE II

Counts of Sphaeroma *on a single test piece during successive months*

	Pure creosote	Creosote + coal-tar 70:30	Creosote + coal-tar 60:40	Copper resinate
After 4 months ..	Nil	Nil	Nil	3
After 5 months ..	Nil	Nil	2	6
After 6 months ..	Nil	Nil	2	13
After 7 months ..	6	13	3	44
After 8 months ..	8	45	15	75
After 9 months] ..	17	56	25	94
After 10 months ..	10	71	52	94

Extent of burrowing activity.—The depth of the burrows occupied by each individual at the end of the experiment was measured from a single test piece under each treatment and Table III gives the depth classes of the burrows on the test pieces.

It shows that the average depth of a burrow in creosoted samples was 0·5 mm., in samples with creosote mixture of 70% with coal-tar it was 10 mm., in those with 60% mixture it was 9 mm. and in those with copper resinate it was 18 mm.

TABLE III

The number of burrows in each depth class

	Pure creosote	Creosote + coal-tar 70:30	Creosote + coal-tar 60:40	Copper resinate
mm.				
1– 3	14	1	6	Nil
3– 5	Nil	6	10	Nil
5– 6	3	Nil	19	6
6– 9	Nil	Nil	6	Nil
9–11	2	Nil	5	1
11–13	1	Nil	10	2
13–15	Nil	4	8	6
15–19	Nil	Nil	3	40
19–20	1	1	2	22

Size of the animals.—The number of animals that occurred in the different length groups, at the end of the experiment from the representative test pieces is given in Table IV. The data will work out to the following:

TABLE IV

Number of animals that occurred in different length groups (from a single test piece each)

	Pure creosote	Creosote + coal-tar 70:30	Creosote + coal-tar 60:40	Copper resinate
mm.				
12	2	1	1	4
11	Nil	2	Nil	5
10	Nil	Nil	3	8
9	21	Nil	Nil	7
8	Nil	Nil	Nil	Nil
7	Nil	Nil	20	Nil
6	Nil	Nil	Nil	8
5	Nil	Nil	Nil	Nil
4	12	15	5	Nil
3	5	5	37	109

The average length of an individual from creosoted samples was 5·4 mm., that from samples with 70% mixtures of creosote it was 5·2 mm., in those with 60% mixture of creosote it was 4·5 mm, and in copper resinate-treated pieces it was 4·4 mm.

Reproductive capabilities.—The realised reproductive performance of a population may be measured in the number of surviving young ones at a given time (Beckman *et al*., 1957). Table V shows the number of young ones, intraovarian and brood pouch and just hatched ones found on the representative test piece of each treatment. The data show that there were 50·5 young ones per gravid female in the creosoted sample, 46 in the test piece treated with creosote mixture of 70% content, 29·2 in that treated with 60% mixture of creosote and 42·5 in that treated with copper resinate.

TABLE V

Number of individuals as per their state of maturity

	Pure Creosote	Creosote + coal-tar 70:30	Creosote + coal-tar 60:40	Copper resinate
Females ..	2	2	20	20
Males ..	1	Nil	4	4
Intraovarian stages ..	32	28	272	266
Brood pouch stages ..	52	45	263	367
Juveniles ..	17	19	50	117

DISCUSSION

Unlike the boring molluscs which are incapable of discarding their burrows once they have made one, adult *Sphaeroma* are capable of migrating to new surfaces if the conditions at a particular place is found unsuitable. The young ones of *Sphaeroma* possess all the structural features of the adult except the seventh pair of pereiopods. They cluster around their parents for two or three days after hatching and then make independent burrows. Thus, while in the case of molluscs, initial settlement is effected by the larval stages which are practically defenceless, in the case of *Sphaeroma* it is made by the adults and juveniles which are also equally hardy as the adults. So, if in the case of boring molluscs the preservatives can be aimed at taking advantage of the larval stages which may be vulnerable to even small doses of toxic substances, in the case of *Sphaeroma* it has to be sufficiently toxic to kill the hardy adults and the juveniles.

In evolving a successful preservative against *Sphaeroma* its feeding habit has also to be taken into consideration. Whether the wood is being actually digested or not, the molluscan borers as well as the other isopod wood borer *Limnonia* (Lane, 1959) pass the particles of wood through their gut to the outside of the burrow. But *Sphaeroma* while burrowing, merely wafts out the particles of wood by the fanning movements of the pleopods (John, 1962). In view of this, a preservative, even if it is toxic and impregnated in wood, has little chance of coming into contact with the inner tissues of the animal. This makes it imperative that instead of trying to kill the animals with the preservative, it should have chemical or physical properties which will render them a strong repellant, preventing the settlement of the animals.

From the data it was seen that among the four preservatives used, the rate of increase of population and the intensity of occurrence of the animal was minimum in pure creosote-treated pieces. A higher content of creosote, in mixture with coal-tar, also seems to have fairly withstood the fresh settling of *Sphaeroma*. In both the cases the interval before the first attack occurred was also the maximum. This shows that pure creosote can act as a repellant to the attachment of *Sphaeroma*. It was seen that the incidence of *Sphaeroma* is increased in proportion to the content of coal-tar in the mixture with creosote and that it was maximum in copper resinate-treated pieces. This shows that copper-resinate and coal-tar has little effect as repellants against *Sphaeroma*.

After once settled, creosote seems to have had little inhibitory effect on the normal activities of *Sphaeroma* because it was seen that the growth rate and reproductive capabilities were maximum in the animals occupying the creosoted samples. This shows that even though creosote may be a better repellant than coal-tar and copper resinate against *Sphaeroma*, it has little effect on its metabolic activities. It may therefore be not wrong to presume that none among the four preservatives tried can be claimed as totally efficient against the attack of *S. terebrans* on wood.

ACKNOWLEDGEMENTS

The treated test pieces were received from the Wood Preservation Branch of the Forest Research Institute and Colleges for which the author is indebted. He is also grateful to Dr. N. Krishna Pillai, Marine Biological Laboratory, Trivandrum, for his suggestions in the preparation of the paper.

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THE ROLE OF CRUSTACEA IN THE DESTRUCTION OF SUBMERGED TIMBER

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ABSTRACT

During the last fifty years considerable attention has been paid to the study of the marine animals, which directly or indirectly bring about the deterioration of submerged timber. They belong to two groups, molluscs and crustaceans. A lot of work has been done on the molluscan wood-borers but even now information on the crustacean wood-borers is scanty. The present paper gives a classified list of the crustaceans which are known to bore into timber and a resume of the published information on their biology.

INTRODUCTION

DURING the last fifty years marine animals which directly or indirectly cause deterioration of submerged timber attracted the attention of biologists and harbour engineers. These animals mainly belong to two groups, Mollusca and Crustacea. The molluscs have been fairly extensively studied, but no comparable work has been done on the crustaceans.

The crustacean wood-borers belong to three families, Cheluridae, Limnoriidae and Sphaeromidae; the first belongs to the order Amphipoda and the other two to Isopoda. From the waters around the Indian mainland *Chelura* has not so far been recorded. Six species of *Limnoria* have been recorded but none of them is abundant enough to cause any appreciable damage. Four species of *Sphaeroma* have so far been recorded. Of these three are very abundant. Underwater wooden structures, especially those standing in estuarine waters, are heavily attacked by *Sphaeroma.*

Limnoria, particularly *L. lignorum*, has a world-wide distribution and hence attracted the attention of biologists very early. Consequently the biology of *Limnoria* is fairly well known. On the other hand, *Sphaeroma* has a rather restricted distribution and causes serious damage only in estuarine waters. Hence the biology of *Sphaeroma* is little known. In the present report I have summarised the available information on marine crustacean borers with the hope that it may prove of some value to those engaged in the study of these animals, especially in India.

TAXONOMY

Order .. **AMPHIPODA**

Sub-Order .. GAMMAROIDEA

Family .. CHELURIDAE

Genus .. ***Chelura*** Philippi

Chelura terebrans Philippi (Barnard, J. L., 1950, p. 90, pls. 32–33; 1959, p. 4, figs. 1, 4, F–G).

Genus ***Tropichelura*** J. L. Barnard

Tropichelura insulae (Calman) (Barnard, J. L., 1959, p. 6, figs. 2, 4, C–E).

Genus ***Nippochelura*** J. L. Barnard

Nippochelura brevicauda (Shiino) (Shiino, 1957, p. 186, figs. 13–15, *Chelura*; Barnard, J. L., 1959, p. 6, figs. 3, 4, A–B).

Order	..	**ISOPODA.**
Sub-Order	..	FLABELLIFERA.
Family	..	LIMNORIIDAE.
Genus	..	***Limnoria*** Leach.
Sub-genus	..	*Limnoria* Menzies.

Limnoria lignorum (Rathke) (Shiino, 1950, p. 334, figs. 1–3; Menzies, 1957, p. 123, fig. 9).

Limnoria pfefferi Stebbing (Stebbing, 1905, p. 714, pl. 53 *a*; Menzies, 1957, p. 135, fig. 15).

Limnoria japonica Richardson (Richardson, 1909, p. 95, fig. 21; Menzies, 1957, p. 165, figs. 27–28).

Limnoria septima K. H. Barnard (Barnard, K. H., 1936, p. 174, figs. 11–12; Menzies, 1957, p. 168, fig. 29).

Limnoria quadripunctata Holthuis (Holthuis, 1949, p. 167, fig. 2; Menzies, 1957, p. 127, figs. 10–14).

Limnoria tripunctata Menzies (Menzies, 1951, p. 86, pl. 36; 1957, p. 137, fig. 16).

Limnoria platycauda Menzies (Menzies, 1957, p. 139, fig. 17).

Limnoria saseboensis Menzies (Menzies, 1957, p. 141, fig. 18).

Limnoria simulata Menzies (Menzies, 1957, p. 144, fig. 19).

Limnoria multipunctata Menzies (Menzies, 1957, p. 170, figs. 30–31).

Limnoria unicornis Menzies (Menzies, 1957, p. 173, fig. 32).

Limnoria faveolata Menzies (Menzies, 1957, p. 175, fig. 33).

Limnoria sublittorale Menzies (Menzies, 1957, p. 175, fig. 34).

Limnoria insulae Menzies (Menzies, 1957, p. 178, fig. 35).

Limnoria indica Becker and Kampf (Becker and Kampf, 1958, pl. 1, figs. 2–3; Pillai, 1961, p. 23, pl. 2, figs. 4–5, t.-figs. 11–12).

Limnoria carinata Menzies and Becker (Menzies and Becker, 1957, p. 88, figs. 1–3).

Limnoria bombayensis Pillai (Pillai, 1961, p. 29, pl. 2, fig. 6, t.-fig. 16).

Limnoria magadanensis Jesakova (Jesakova, 1961, p. 180, figs. 1, 2, 5; Kussakin, 1963, p. 287, figs. 1 C, 4).

Limnoria borealis Kussakin (Kussakin, 1963, p. 287, figs. 1, *d–f*, 5, 6).

Sub-genus *Phycolimnoria* Menzies

Limnoria segnis (Chilton) (Chilton, 1883, p. 76, pl. 2, fig. 1; Menzies, 1957, p. 182, fig. 37).

Limnoria antarctica (Pfeffer) (Pfeffer, 1887, p. 96, pl. 2, figs. 12–13, pl. 5, figs. 2–22; Menzies, 1957, p. 180, fig. 36).

Limnoria algarum Menzies (Menzies, 1957, p. 146, figs. 20–21).

Limnoria segnoides Menzies (Menzies, 1957, p. 184, fig. 38).

Limnoria nonsegnis Menzies (Menzies, 1957, p. 186, fig. 39).

Limnoria rugosissima Menzies (Menzies, 1957, p. 189, fig. 40).

Limnoria stephenseni Menzies (Menzies, 1957, p. 189, figs. 41–42).

Limnoria bituberculata Pillai (Pillai, 1957, p. 151, figs. 1–2; 1961, p. 31, pl. 2, fig. 7, t.-figs. 17–18).

Limnoria sinovae Kussakin (Kussakin, 1963, p. 281, figs. 1*a*, 2).

Genus *Paralimnoria* Menzies

Paralimnoria andrewsi (Calman) [Calman, 1910, p. 184, pl. 5, figs. 7–14 (*Limnoria*); Menzies, 1957, p. 148, figs. 22–24].

Family SPHAEROMIDAE

Genus *Sphaeroma* Bosc

Sphaeroma terebrans Spence Bate (Spence Bate, 1866, p. 28, pl. 2, fig. 5; Stebbing, 1904, p. 16, pl. 4; Pillai, 1961, p. 2, pl. 1, fig. 1, t.-figs. 2–3).

Sphaeroma walkeri Stebbing (Stebbing, 1905 *a*, p. 31, pl. 7; Pillai, 1961, p. 8, pl. 1, figs. 2–3, t.-figs. 4–5).

Sphaeroma annandalei Stebbing (Stebbing, 1911, p. 181, pl. 10; Pillai, 1961, p. 13, pl. 1, fig. 4, t.-figs. 6–7).

Sphaeroma triste Heller (Heller, 1868, p. 142, pl. 12; Barnard, K. H., 1936, p. 177, fig. 13 *a*; Pillai, 1961, p. 17, pl. 2, figs. 2–3, t.-fig. 9).

Sphaeroma sieboldii Dollfus (Dollfus, 1889, p. 93, pl. 5, fig. 3; Shiino, 1957, p. 161, figs. 1–3, 12).

Sphaeroma retrolaevis Richardson (Richardson, 1904, p. 47, fig. 23; Shiino, 1957, p. 167, fig. 4–6, 12).

Sphaeroma quoyana Milne Edwards (Paradice, 1926, p. 319; Chilton, 1911, p. 134; Nierstrasz, 1917, p. 106).

Sphaeroma pentodon Richardson (Richardson, 1905, p. 286).

Sphaeroma peruvianum Richardson (Richardson, 1910, p. 83).

Sphaeroma laeviusculum Heller (Heller, 1868, pl. 138).

Sphaeroma exosphaeroma Boone (Boone, 1918, p. 599; Nierstrasz, 1930, p. 8).

Sphaeroma obesum Dana (Dana, 1853, p. 779; Kossmann, 1880, p. 112; Thompson and Chilton, 1887, p. 155).

Sphaeroma granti Walker and Scott (Walker and Scott, 1903, p. 218).

Sphaeroma serratum Fabricius (Stebbing, 1910, p. 220; Torelli, 1930, p. 303).

Sphaeroma bigranulatum Budde-Lund (Budde-Lund, 1908, p. 304).

Sphaeroma tuberculato-crinitum Hildendorf (Hildendorf, 1878, p. 846).

Sphaeroma propinquum Nicolet (Gerstaecker and Ortmann, 1901, p. 264).

Sphaeroma laevigatum Philippi (Gerstaecker and Ortmann, 1901, p. 264).

Sphaeroma gayi Nicolet (Gerstaecker and Ortmann, 1901, p. 264).

Note: The above list may probably include species of doubtful validity. It is also not sure that all are wood-borers.

Distribution

Chelurids have a comparatively restricted geographical distribution. *C. terebrans* is the most widely distributed and has been recorded from several localities in the Western and Northern Atlantic, Mediterranean, Black Sea, South-Eastern Atlantic and South-Western and Eastern Pacific. J. L. Barnard (1959) has given a list of the actual localities. *T. insulae* has been recorded from the Hawaiian, Caroline and Mariana islands in the Pacific, Costa Rica, Trinidad and Puerto Rico in the Caribbean Sea and Christmas island in the Indian Ocean. *N. brevicauda* has so far been recorded only from Misaki, Japan.

Because of the large number of species involved and the absence of precise information, it is rather difficult to summarise the data on the geographical distribution of *Limnoria*. Menzies (1957) observed that no species of *Limnoria* has been found living in truly arctic water though *L. lignorum* is found to occupy the fringe of the Arctic. Only *L. lignorum* among the known species has a truly boreal distribution. Likewise only one species, *L. quadripunctata*, is known as a typical temperate water species. *L. tripunctata* has a distribution extending from the temperate to the tropical waters. A vast majority of the known species inhabit tropical waters and, therefore, limnoriids can be considered as an essentially warm water group of animals.

The distribution of *Sphaeroma* is still less understood. Members of the family Sphaeromidae attain maximum development in tropical waters and are poorly rapresented elsewhere. Among the species recorded from the Indian waters only three have a wide distribution. *S. annandalei* has been recorded from South Africa and India, *S. walkeri* from South Africa, Suez Canal, Egypt, India, Ceylon and New South Wales. *S. terebrans*, the most destructive of all the species, has a truly circumtropical distribution and is known from the Mediterranean, North Africa, South Africa, Congo, Mosambique, Zanzibar, India, Ceylon, Queensland, Florida and Brazil. The distributional pattern appears to indicate that uniformly high temperature is essential for their maximum development.

Factors Influencing the Distribution of the Crustacean Borers

Among the factors which directly or indirectly affect the distribution of the crustacean borers the most important are salinity, temperature and the availability of food.

Salinity

Limnoria and *Chelura* are truly marine animals and have so far been known to inhabit only the open sea or harbours directly connected with the sea. It has been reported (Menzies, 1957) that they cannot survive a day in freshwater. So also areas having uniformly low salinity below 10‰ or those having widely fluctuating salinity (0·00— to 35·00‰) are unfavourable for the establishment and growth of *Limnoria*. Menzies (1957) concluded that field data on the salinity tolerance of *Limnoria* is conflicting and in several cases erroneous and that the animal appears to be moderately euryhaline.

Sphaeroma is extremely euryhaline. All the sphaeromids are inhabitants of littoral waters and slow acclimatisation to gradual variation in salinity inherent in the littoral, appears to have helped them to invade and colonise estuaries and brackish water localities. At least one species, *S. terebrans*, can tolerate even absolutely freshwater for polonged periods. According to McNeil (1932) this species is a most adaptable one and has been recorded from freshwater in the Brisbane river. The distribution of the Indian species is very significant in this context. *S. triste* has so far been collected only from the open sea. *S. walkeri* is predominently marine but stray individuals wander into the bar mouth of the lakes. *S. annandalei* is present in the sea but is more abundant in typically estuarine localities. On the other hand, *S. terebrans* has become an exclusively brackish or freshwater form. In the backwaters of Kerala (West coast of India) it is extremely abundant but during my several collection trips I have not seen it in any typically marine localities. What we find here is the progressive evolution of a group of typically marine animals into brackish and freshwater forms (Pillai, 1961, p. 35).

Temperature

According to J. L. Barnard (1959) the winter isotherm of 22 °C. in both hemispheres provides an effective isolation between *C. terebrans* and *T. insulae*. The former is restricted to waters colder than 22° and the latter to waters warmer than 22°. Chelurids have not been recorded from the immediate vicinity of India but *T. insulae* can be expected to inhabit these waters.

In the case of *Limnoria* much more field data is necessary for arriving at any definite conclusion about the effect of temperature on their distribution. Menzies (1957, p. 156) observed that temperature above or below an optimal range might adversely affect a species by killing the adults, causing a cessation of the breeding activity or slowing the rate of egg production. But the information so far gathered from laboratory experiments and field observations has shown that the critical range of temperature, both optimal and minimal, varies for different species. Depending on temperature Menzies broadly grouped *Limnoria* populations into five categories, arctic, boreal, temperate, temperate-tropical and tropical. It may, however, be remarked that there is considerable overlapping in the known distribution of many species. This is quite natural since the borders of two zoogeographical realms can always be inhabited by the representatives of both the realms.

As stated above the wood-boring species of *Sphaeroma* are more or less confined to the tropical waters where uniformly high temperature prevails. In the backwaters of Kerala shallow bodies of water get isolated during low tide. In such temporary pools the temperature sometimes goes up to nearly 40 or 50° C. Yet *Sphaeroma* living there is apparently unaffected. Specimens of *S. terebrans* can be easily transported over long distances in a piece of wet cloth. The widely fluctuating temperature of the estuarine waters has conditioned at least the wood-boring species of *Sphaeroma* to such an extent that they are at present extremely eurythermic.

Food

Because all the records of *C. terebrans* have been from wood it has always been considered a true wood-borer. But experimental evidence showing that *Chelura* subsists on wood was lacking till recently. From detailed experiments conducted in the laboratory, J. L. Barnard (1955) produced evidence to show that *C. terebrans* is a true wood-borer. However, whether it eats and digests wood is not yet definitely known. J. L. Barnard (1955, p. 94) observed that chelurids might be browsing on microscopic organisms which grow on the wood and that the ingestion of woody matter is a consequence of the scraping off of this other food material. In this connection it may be observed that *Melita zeylanica*, an amphipod, was observed to scrape the surface of submerged timber in the Kerala backwaters (John, 1955). This browsing action results in the formation of shallow furrows on the surface of the wood.

Younge (1927) found that cellulase is absent in the digestive tract of *Limnoria* and he also failed to find the presence of wood digesting protozoa. He, therefore, concluded that *Limnoria* feeds on the microscopic fauna and flora within the burrow. Ray and Julian (1952) disputed this contention on the basis of experiments and observed that the cells of the intestinal diverticula of *Limnoria* produce cellulase.

Based on the feeding habits Menzies (1957) divided limnorias into two groups, *Phycolimnoria* (algal borers) and *Limnoria* (wood-borers). Menzies (1957, p. 153) succeeded in keeping both in the laboratory on a diet of particulate cellulose which shows that the diet requirements of both are the same. Yet in nature wood-borers have never been found to bore into algae or algal borers into wood. According to Chilton (1914) the scarcity or nonavailability of timber necessitated the development of the weed-boring habit. This has resulted in certain changes in the feeding and masticating apparatus with the result that the two groups of animals are unable to change their feeding habits. Wood-boring species have a rasp and file-like series of grooves on the incisor process of the mandibles while this is lacking in sea-weed borers. Wood is rather scarce in the sea except in harbours. But sea weeds of some kind are available practically everywhere in the littoral region. This practice of boring into sea-weeds obviously helped *Limnoria* to enjoy a very wide distribution.

Sphaeroma apparently does not eat wood. At any rate there is no conclusive evidence that they digest wood. Working on *S. terebrans* John (personal communication) demonstrated the presence of cellulose digesting enzymes in the alimentary tract. It appears that *Sphaeroma* subsists on plant or animal matter which grow or settle on the surface of the wood.

Majority of the known species of *Sphaeroma* are free living. The few that are true wood-borers have a restricted distribution and are predominantly brackish-water inhabitants. Food appears to have exerted considerable influence in this distribution. As already stated wood is rather scarce in the open sea. Unlike *Limnoria*, *Sphaeroma* cannot bore into algae because of their comparatively large size. Hence they were forced to go in search of wood. Wood is always present in sufficient quantities in the estuaries. It is, therefore, likely that *Sphaeroma* braved the hazards of the estuaries in their search for wood. It is significant that they bore even into the stem of trees growing in water. Whether they subsist on wood or bore only for the sake of protection, wood of some sort is absolutely essential for the existence of the truly wood-boring members. This appears to explain why *Limnoria* is not found in the estuaries while *Sphaeroma* thrives there, in spite of the fact that both are essentially inhabitants of the littoral waters of the sea.

Reproduction

All the known wood-boring crustaceans belong to Peracarida, in which the development of the young takes place in a brood pouch and the young leave the brood pouch of the female in an advanced stage of development when they are quite capable of taking care of themselves. This obviously is one of the reasons for the crustacean borers becoming a very successful group of animals.

Chelurids have undergone very little morphological change consequent on taking up a wood-boring habit. As in free-living amphipods pairing probably takes place outside the burrows while the adults migrate from one wood to another. The eggs are very few (according to Shiino, 1958, only 3 in *N. brevicauda*), and are shed into a brood pouch formed of four pairs of small oostegites.

Limnoriids generally live in pairs but the members of a pair are not always of different sexes. How pairing takes place is hence not clearly known. Probably the sexes make contact by entering the burrow through the external openings or through the openings on the side walls. The eggs number 10–15 but the number varies from region to region. As in *Chelura* the eggs are incubated in a brood pouch formed of four pairs of overlapping oostegites. The brood pouch projects on the ventral side of the peraeon.

Sphaeroma generally lives singly though there are reports that more than one specimen are occasionally found in the same burrow. Even if this is true it must be very rare since generally each burrow is only just sufficient to accommodate one individual. Therefore, pairing must obviously take place outside the burrow. Unlike *Limnoria*, *Sphaeroma* has no true brood pouch formed by the usual oostegites. The eggs are, therefore, incubated in an internal brood pouch which occupies a large part of the available space within. The eggs number up to fifty. Breeding is apparently continuous at least in the Kerala waters. According to McNeil (1932) breeding is continuous in all the crustacean borers in the Australian waters.

The newly hatched young in all the three groups are very much similar to the adult except in colour and in the absence of the seventh pair of legs. Within a short period after emerging from the brood pouch the young are capable of burrowing into wood.

BURROWING

J. L. Barnard has given a detailed account of the burrowing activity of *C. terebrans*. In the laboratory he found evidence of attack after two weeks, consisting of a surface furrowing in the soft layers of the wood. The furrowing always started on the darker side. The concave surface of the furrows was smooth. The furrows made by chelurids are the result of collective rather than individual effort.

In nature chelurids attack only wood previously attacked by *Limnoria*. They settle in the uncovered and abandoned limnoriid tunnels and the large furrows created by the combined activity of several limnorias. Chelurids do not bore distinct furrows but by some sort of browsing action creates hemicylindrical furrows which are unroofed. Attack of fresh timber is always started by the adults and in nature adults are always found in the outer tiers and the young ones deeper. Available data show that though *Chelura* is able to make its own furrows, in nature it fails to survive on smooth fresh wood. Invariably it settles on wood previously attacked by limnoriids. It is concluded that as its burrowing capacity is rather low it is subject to attack by predators. Hence chelurids prefer a previously constructed protective niche. The attack of *Chelura*, therefore, supplements that of *Limnoria*. Nevertheless McNeil (1932) observed that in favourable localities *Chelura* soon becomes more abundant than *Limnoria* particularly on soft wood.

Unlike chelurids limnoriids are efficient burrowers. Here also attack of fresh timber is started by the adults. In the early stages of attack they produce burrows which run parallel to the surface one to two millimetres below it. The entrance is oval or rounded and at first penetrates the wood obliquely. The burrow is circular in cross-section and so narrow that the animal within cannot turn back. Hence the animals within always face the blind end of the burrow. Occasionally more than one individual may enter through the same entrance, in which case there will be a number of interconnected burrows, each branch excavated by a separate individual. An unbranched burrow may sometimes lodge more than one individual (Shiino, 1950).

The burrows communicate with the exterior by a series of holes at short intervals in addition to the original hole. This facilitates proper aeration of the burrows. Necessity for a large supply of oxygen appears to be the reason why the burrows are always located parallel to the surface. When there is heavy infestation the nature of the burrows shows change. The latecomers are forced to burrow deep to reach a supply of wood and hence the initial part of their burrows is vertical. *Limnoria* produces innumerable holes on the surface of the wood giving it a sponge-like texture and a lace-like appearance. Up to 300–400 individuals can be taken from one cubic inch of wood (McNeil, 1932).

The newly liberated young always remain at the end of the burrow. Though a few may leave the burrow, most of them begin tunnelling from the original burrow itself. Therefore, an attack once begun is continued by successive generations.

In the case of *Sphaeroma* both the adults and the young attack fresh timber. Given the chance the softer parts are attacked first but the texture of the wood is not of much consequence. Even the wood of cocoanut and palmyra palms, whose vascular bundles are perhaps the hardest, are cut across. In all field and laboratory observations I have found that *Sphaeroma* has a tendency to attack the vertical surfaces first. The burrows are generally straight, a centimetre deep and perfectly circular in cross-section, the end of the burrow is hemispherical. In each burrow the animal just fits in and the head is turned to the blind end and the tip of the telson is just visible from outside. When the attack is heavy, as is the case in estuarine waters, the burrows are so close to each other that only a thin film of wood separates the adjacent burrows. The timber then presents a typical honeycomb appearance.

Economic Consequence of the Activity of the Crustacean Borers

More than the purely scientific interest, it is the economic consequence of the activity of these boring animals that focussed the attention on them. It is rather difficult to assess the destructive potential of any one of these groups separately since the crustaceans combine their effort with that of the molluscs. The sea also plays a very dominent role in the destruction of timber. Precise data is lacking since the sudden and dramatic collapse of marine structures alone gets publicity (Menzies, 1957, p. 107).

Though it has been reported that *Limnoria* attacks wood from the mud line right up to the high watermark, the attack is heaviest in the intertidal level. The attack of *Sphaeroma* is concentrated at this level. The same is true of the molluscs, particularly *Martesia*. When the attack is heavy the holes of *Limnoria* become vertical and very close to each other making the wood spongy. *Sphaeroma* bores mainly for shelter and in all cases of heavy attack the adjacent holes are saparated by only a thin film of wood. This renders the wood fragile. Natural agencies like the waves will easily make the wood crumble exposing the animals. The animals would then burrow deeper, *Limnoria* for eating fresh wood and *Sphaeroma* for further shelter. The action of water and that of the animals regularly alternate with the result that the pilings get considerably thinned at the intertidal level and evantually breaks.

The loss due to the attack of the borers is rather heavy. According to Menzies (1957) the loss in the United States alone comes to about 50 million dollars a year.

A lot of money and effort have been spent in devising methods to protect marine pilings from the attack of marine borers. The usual practices areto pressure creosote or impregnate the wood with poisonous compounds under pressure. These have to some extent succeeded in protecting the piles from the attack of molluscs which begin the attack as larvae. The preservatives are nearly always highly toxic to these delicate larvae. But in the case of the crustaceans the attack is always started by the adults which are comparatively resistant. Even if a treated wood resists the attack for some time sooner or later slow leaching of the preservatives will make the wood susceptible to attack. Pressure creosoting has succeeded to some extent in reducing the attack of limnoriids since they eat wood. But *Sphaeroma* bores into wood only for protection and they are extremely euryhaline and eurythermic. Therefore, *Sphaeroma* is likely to pose a more serious problem wherever they are present in large numbers, like the backwaters of Kerala.

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MARK-RECOVERY EXPERIMENTS IN CRUSTACEANS*

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ABSTRACT

Mark recovery experiments employing different techniques in marking, like tagging and staining is an important tool in the study of migration and movements in the economically important crustaceans such as shrimps, lobsters and crabs. The various methods used in these marking studies in the case of the penaeid prawns, spiny lobsters, craw fishes and crabs along the Gulf of Mexico, the Atlantic coasts and the Indo-Pacific region are described. The typical movements elucidated so far are also described.

INTRODUCTION

THE mark-recovery technique has proved a very valuable tool in many areas of fishery research. Devised just prior to the turn of the century, it was initially used to determine movements of anadromous fishes and to assist in estimating abundance of marine bottomfishes. Today its utility seems limitless. One of the major implements of the inland fishery researcher for measuring population size, the mark-recovery experiment is also being widely employed by marine biologists to determine migration, dispersal and growth patterns of a variety of ocean fishes and invertebrates.

Properly designed and implemented, mark-recovery experiments can provide information on: (1) migration and dispersal, (2) growth, (3) rate of exploitation in fish and shellfish populations and (4) estimation of population sizes. Such information, often supplemented by that obtained by other techniques, represents the foundation upon which resource management programmes are erected. These are of interest to commercial fishermen since any management programme's aim is to protect their interests by ensuring on a continuing basis, the availability of the greatest quantity of a specified resource supportable under any combination of natural and artificial factors.

In essence, the mark-recovery technique consists of capturing, marking for future identification, releasing and recapturing samples of fish or shellfish populations. Such samples are, in effect, experimental populations whose characteristics are known, and which are expected to behave like the parent populations from which they are drawn and into which they are reintroduced. In fact the over-all usefulness of information gained through this method hinges entirely upon how well the experimental or sample population reflects the whole population whose maintenance is of concern. The success of any mark-recovery experiment also depends critically upon the number of marked specimans subsequently recaptured or recovered. It is appropriate to point out here that marking and recapturing phases of such experiments go hand in hand. Unless equal, if not added, effort is extended towards the latter phase any mark-recovery experiment can be counted a failure.

Many kinds of devices each having its advantages and disadvantages have been used in mark-recapture experiments in fishes as well as Crustaceans. In the case of the latter the frequent ecdysis taking place in the animals render it all the more difficult to device a suitable tag or mark to stay through these moultings. Numbered tags of corrosion-resistant metal and plastic have proved useful, being widely used in a variety of freshwater and marine fishes and shellfishes. The tags may

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be regular or irregular in shape and attached directly to the body with non-corrosive wire or nylon. Another method of marking is by mutilating body parts like fins and appendages. Although quite suited for determining migration patterns this method does not lend itself to growth studies because once released each individual involved loses its identity. To be useful for the latter purpose individuals making up population marked in this manner must be reasonably uniform in size, a requirement not easily met. The same can be said for the third means of marking, *i.e.*, injection with biological dyes. One other decided disadvantage in both the mutilation and staining methods is the facility with which specimens so marked go undetected in commercial landings. This is particularly serious in the case of Crustaceans where stained specimens must be recovered through close scrutiny of voluminous landings, a tedious and difficult task. The best that persons responsible for carrying out these mark-recovery experiments can do is widely publicise such experimants, encourage and reward the alertness and co-operation of fishermen, processors and other interested parties, and if in fact marked specimens are present hope for their detection.

Despite the many shortcomings of the methods, the recapture of commercial shrimps, crabs and lobsters marked with various tags and dyes has resulted in acquiring information about the shrimps of the Gulf of Mexico and South Atlantic, King crabs of Alaskan waters, the swimming crabs of the Scottish coast as well as both Atlantic and Pacific American coasts, and lobsters and crayfishes of the Japanese, North Sea, Australian, South African and American waters, which could be obtained in no other way. Among the various authors who contributed substantially to these studies may be mentioned Lindner and Anderson (1956), Dawson (1957), Racek (1959), Costello and Allen (1960), Iversen and Jones (1961), Kutkuhn (1962), Allen and Costello (1963) and Costello (1964) in penaeid prawns, Cronin (1949), Mason (1962), Weber *et al.* (1962), Fischler and Walburg (1962), Hayes and Montgomery (1963) and Powell (1964) in the case of crabs, and Allen (1916), Templeman (1935 and 1947), Wilder (1947), Von Bonde (1935), Sheard (1949 and 1962), Dawson and Idyll (1951), Thomas (1955) and Smith (1958) in spiny lobsters and crayfishes. Though limited these studies have provided important clues as to which coastal estuaries are utilised by maturing shrimps spawned from parent stocks inhabiting off-shore fishing grounds and frequency of moults and inshore off-shore movements of crabs and lobsters. Such information is valuable in that it permits, with reservation, to define ranges of populations or stocks, an obvious first step in setting up an effective management programme.

Penaeid Prawns

Tags and Tagging Methods

In the study of the migration pattern of penaeid prawns the only method used extensively since 1934 and before 1957 was tagging with numbered plastic or celluloid discs known as Petersen discs. The method of this tagging is quite simple. The materials needed are two small celluloid discs, preferably of different colours and with perforations in the centre, and one sharp nickel pin of about 2 inches in length (Fig. 3). One of the discs is numbered consecutively and the other bore instructions for returning the shrimp. The discs are of opaque celluloid or plastic, usually about ten-one-thousandths of an inch thick. The diameter of the discs vary from 8–10 mm. according to the size of the shrimp marked. Usually the tagging is done on board a boat where there are facilities for keeping the shrimps alive in tanks with circulating water. The pins are kept in readiness for tagging by pinning them with one of the discs mounted according to serial numbers on some sponge or cork panel. When attaching the tags on the animal the pin with the numbered disc mounted is thrust through the side of the first abdominal somite about midway between the dorsal and ventral surfaces, the other disc is slipped over the end of the pin protruding from the other side of the shrimp, and a loop made in the pin with surgical forceps in order to prevent the disc from slipping off. In making this loop approximately $\frac{1}{8}$th to $\frac{1}{4}$th inch ply should be left between the sides of the shrimp and each disc to allow for growth. While inserting the pin care should be taken not to penetrate any of the vital organs. Measurements are also recorded of the tagged specimens. As far as possible both measuring and tagging are done under water. As the shrimps are measured and tagged they are placed in tubs of fresh running sea-water and releases are made in batches of 25 or 50 after examination and substitution for all that appear to be in poor condition due to the effect of tagging. Records are maintained of the date, time and place of capture, tag number, sex and length of each shrimp, and the date, time and place of release. Several hundreds of specimens are tagged like this and released at different spots. By the recovery of these specimens their movements and growth are studied. There are several drawbacks for this method and opinions differ as to the suitability of the method of study. It is doubted whether these discs on the sides of the small animals might affect their swimming, and whether they might have an adverse effect on the moulting frequency, etc. However some valuable results have been obtained by employing this method.

The U.S. Fish and Wildlife Service initiated tests in 1954 to find a more suitable method for marking shrimp because of the severe limitations in the mechanical tags. As a result Charles Dawson in 1957 reported successful use of biological stains as marking agents in penaeid shrimps. This method of staining slowly replaced the tagging method and now it is used extensively in different parts of the Gulf of Mexico for all mark-recovery experiments on shrimps. Dawson experimented with different dyes and found some of the stains like fast green and trypan blue most suitable. But his work was confined to laboratory experimentation. The problem remained to adapt his technique for field use and to determine whether these stains would remain fast and recognisable under natural conditions. Since 1957 extensive field studies have been conducted by the different federal and state agencies of U.S.A. and the use of this technique for conducting mark-recovery experiments to determine migration and growth of the Gulf shrimp has been established.

For marking shrimps with stains three methods could be made use of, immersion, injection and feeding. In the immersion method the animals are placed in an aerated stain solution like 0·1% Nile Bule Sulphate in sea-water for about 3 minutes and then transferred through changes of fresh sea-water in order to remove excess stain adhering to the exterior or trapped within the branchial chamber, as done by Racek (1959). In the injection method the technique is to inject a dilute solution of these dyes on the animal. After a few hours the stain collects in the gill area and remain coloured (Fig. 1). The feeding method is to fead the shrimps with food previously stained by these dyes for a certain period. Among these three methods the injection method gave very good results and was proved to be quite suitable for extensive field studies.

In the injection method of staining shrimps three stains have been proved to be quite useful for mark-recovery experiments, namely, fast green, trypan blue and trypan red. The first two give distinct easily recognisable markings. Trypan red also gives a distinct colour but tends to blend with the natural colour of the shrimp and also it is subject to more fading when compared to the others. Sterile, nonelectrolytic distilled water should be used as a base for all staining solutions. There is no advantage in aging solution and in fact aging of the solution was found to render it more toxic. So the stain solutions in distilled water are prepared just before use. 0·5% solution of the dyes gives best results. Before using for injection the solution is shaken well and filtered once through a sheet of Whatman No. 1 filter-paper. Unfiltered solutions are not found satisfactory. The injection is best done with a ½ c.c. tuberculin syringe equipped with No. 25 or 27 by ½ or ¼ inch hypodermic needle. For smaller shrimps 30 gauge needle can be used with advantage. Holding the syringe in the right hand, a shrimp is held with the left so that its head is pointed towards the left wrist and its abdomen held in a flexed position by the left thumb and forefinger. The needle is then introduced through the articular membrane of the 6th abdominal joint slightly to the left of the mid-dorsal line and at an angle approximating 45 degrees. For very small shrimps (12 mm. carapace length) injection laterally through exoskeleton of the 1st abdominal segment joint is preferable. The needle is inserted to a depth of from 2 to 4 mm. until stain is visibly entering the blood vascular system through the dorsal abdominal artery. Care must be taken not to puncture the hindgut when the needle is inserted through the articular membrane. Volume of individual injections generally range from 0·1 0·05 c.c. with optimum at about 0·03 c.c. Injection of greater volumes frequently result in rapid death and does not produce more vivid or durable staining. During the process of staining care must be taken to avoid air bubbles in the syringe and also to minimise handling of the specimens as much as possbile (Ref. Costello, 1964).

As in the case of tagging with Petersen discs in the staining experiments also the stained specimens are kept in tanks with circulating sea-water for a few hours before they are released in batches of hundreds, after substituting for all those which appear to be in poor condition. Stained shrimp should not be released during the first four hours following injection for they might easily fall prey to predators. The staining can best be done in the field on board small boats equipped with staining tables and tanks for holding the shrimps both before and after staining with facilities for running sea-water in the tanks. The main disadvantage in the staining method of marking is that for growth studies growth information secured through recovery of stained shrimps must depend upon the releases whose components are practically uniform in size, which is not a problem in tagging programmes, where in each specimen carries an identifying number.

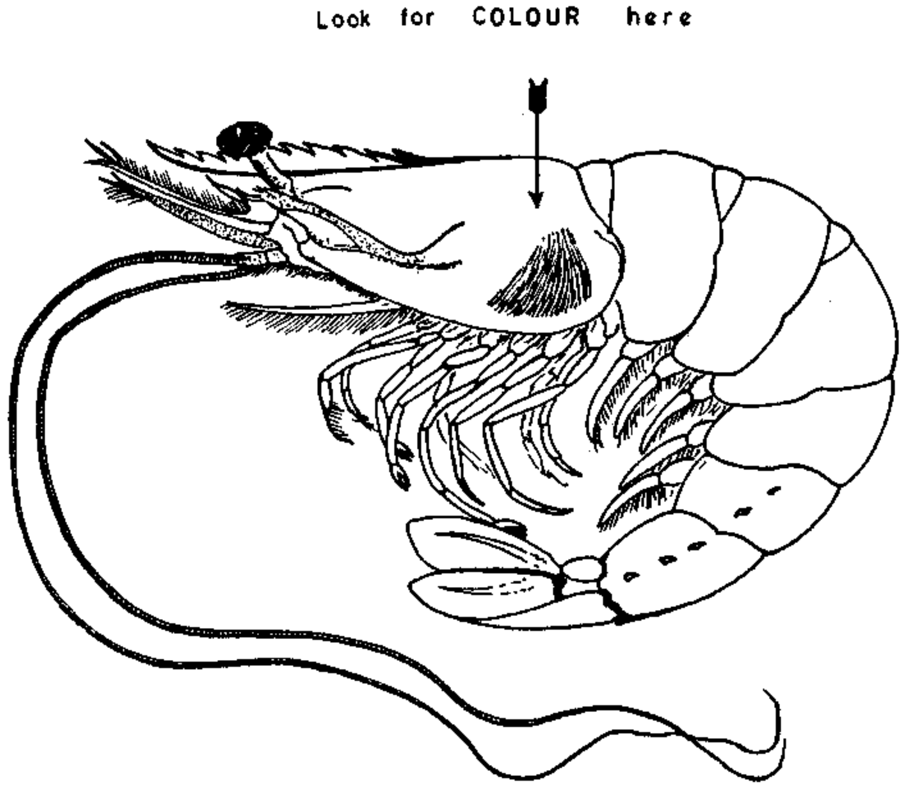

FIG. 1. Panaeid prawn showing the colour marking on the gills.

Recently, Allen and Costello (1963) after laboratory experiments extending to over three or four months reported on the possible use of a modified Atkins-type of tags for use in mark-recapture experiments on shrimps as an improvement on the Petersen disc tags. This tag is composed of a small oblong strip of cellulose acetate, 0·8 mm. thick and inscribed with printed information, secured to short length of monofilament nylon line which has a loop in the free end. The tag is attached to a shrimp by means of a surgical needle with the eye cut open on one side. The nylon loop is hooked by the needle eye and the needle then inserted laterally through the muscle tissue of the first abdominal somite of the shrimp, taking care not to injure any of the vital organs. After the nylon line is drawn through, the plastic strip is passed through the nylon loop twice, securing the tag in position. Although indications are that this Atkins tag which is light weight and flexible is an improvement over the Petersen tag the advantages are yet to be proved by large-scale field experiments.

Results

The Petersen disc tagging as well as the stain injection method has been used extensively in the mark-recovery experiments on commercial shrimps of the Gulf of Mexico and South Atlantic by several agencies, the former in earlier years and the latter in the past 4 or 5 years and much valuable data on migration of these shrimps have been obtained. Petersen disc tagging was first used in the field for shrimp studies in the Gulf of Mexico in 1935 and resulted in recoveries of almost 25 per cent. The typical inshore off-shore movements and the migration of juveniles from the inside waters like inland bays and bayous to off-shore waters in the various regions of the South Atlantic and Gulf of Mexico coast in the case of the white shrimp *Penaeus setiferus* was elucidated by recoveries of Petersen disc tagged shrimps by Lindner and Andersen (1956). The growth of the shrimp also has been traced to a certain extent as a result of these recoveries. The largest time between release and recapture recorded by them is that of a shrimp marked at Cape Canaverel in January and recaptured off the Georgia coast 257 days later. In the case of the pink shrimp *Penaeus duorarum* recoveries of marked shrimps using both Petersen disc method and staining method have proved that the Florida bay estuaries are the nursery grounds for the heavily exploited Tortugas pink shrimp fishery (Iversen and Idyll, 1960 and Costello and Allen, 1960). Iversen and Idyll (*op. cit.*) obtained recovery after 123 days during which time the shrimp moved 60 miles. Costello and Allen (*op. cit.*) obtained recoveries of stained shrimps which moved a maximum of 90 miles in 85 days. Subsequent mark-recovery experiments using stains have conclusively proved that juvenile shrimp make extensive movements in migrating from estuaries to off-shore waters. Much valued data on growth of the shrimps have also been accumulated as a result of these studies. Experiments conducted on the brown shrimp, *Penaeus aztecus*, also have given results regarding the movements and growth of the species along Louisiana and Texas coast as evidenced by the various reports from the biological laboratories engaged in these studies.

A start in this kind of study has already been made in the Central Marine Fisheries Research Institute in 1963–64 and preliminary experiments using the three stains fast green, trypan blue and trypan red have been conducted at Ernakulam in order to determine the suitability of stains and also to select the proper species in which future studies could be conducted. It has been found as a result of this that for the smaller species like *Metapenaeus dobsoni* the staining method is not suited and that in the bigger species *Penaeus indicus* the method could be used with advantage.

Crabs

Mark-recapture experiments using different types of tags have been conducted in several edible crabs in different regions. Among these are the studies on the blue crab *Callinectes sapidus* of America, the swimming crab of the Scottish coast, *Cancer pagurus*, the dungeness crab, *Cancer magister*, the king crab of the Alaskan waters, *Paralithodes camschatika*, and the predator horse-shoe crab, *Limulus polyphemus*.

Tags and Tagging Methods

Several types of tags have been used in the crab tagging experiments. One of the earliest tag used in tagging studies on the blue crab in Chesapeake Bay (Fiedler, 1925) is one similar to the fish body cavity tag. It consists of a strip of silver 1″ × ¼″ size stamped with serial number and other information and two pieces of silver wire one on each side (Fig. 2). The silver strip is attached on the dorsal surface of carapace of the crab by looping the silver wires around the lateral spines.

Nesbit type of fish belly tags is another tag used on these crabs later. The material for the tag is only a strip of red plastic bearing serial numbers and other details regarding date of release, etc. This tag has been used in tagging experiments in three different ways: (1) Inserted into the branchial chamber of the crab through the inhalent aperture above base of cheliped. (2) Inserted into the branchial chamber through a slit cut into the carapace. (3) Attached on the carapace with both ends inserted into slots cut into the same. The same plastic tag has been used in another way also by attaching by means of pieces of wires on each side looped around the lateral spines so that the plastic tag remains on the dorsal surface across the carapace like in the method of Fiedler (Cronin, 1949).

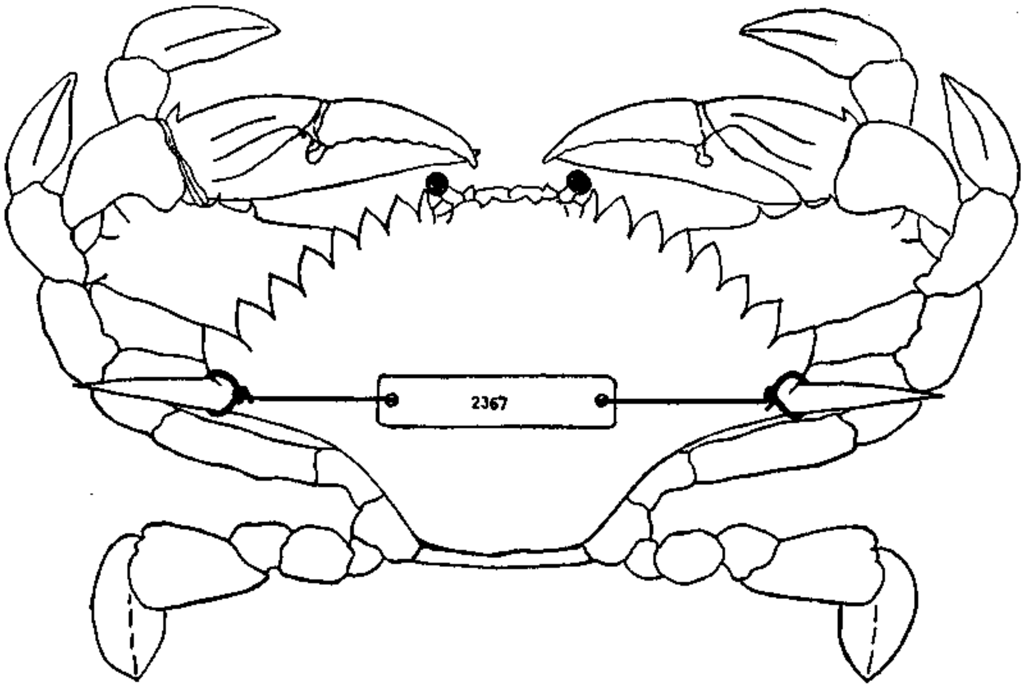

FIG. 2. Swimming crab showing the carapace tag attached.

Cronin (*op. cit.*) used a Petersen type tag also for the blue crab tagging experiments, the material for the tag consisting of 2 discs and a nickel pin. The discs are attched by pinning through at the base of the lateral spine of the carapace. But this method gave less returns when compared with the other methods. From the results obtained in these experiments it is evident that a bright tag of the Nesbit type attached on the carapace by the Fiedler method, *i.e.*, by looping wires on the lateral spines, is the best suitable and this was in use in the blue crab studies for several years from 1943 onwards. The Alaskan king crabs were tagged with Petersen disc-type tags on a leg or through the carapace from the initiation of these crab tagging studies in 1954.

In the blue crab movement studies in coastal South Carolina in 1955-59 a carapace tag which is more or less similar to the Nesbit type of tag with the Fiedler method of attachment was made use of by Fischler and Walburg (1962). This tag consists of a strip of celluloid in bright colour bearing the serial number, name and address of the tagging agency, etc., and a piece of stainless steel wire. The tag is attached to the dorsal surface of the carapace by the wire going round the body of the animal. The main disadvantage of these tags is that they can be made use of only in mark recapture experiments to study short range movements since the tag is shed off during moulting of the crab. However some of these methods were used in the crab tagging studies on the Scottish coast also.

A tagging method that permits tag retention through successive moults is essential to study growth and long range movements. The location of an insertion point along the splitting line of the crab shell during moulting which makes retention of the tag through several successive sheddings possible came as a major break through in the study of migration, distribution and growth rates of crabs by tagging recapture experiments. This insertion point for the tag was located on the isthmus at the base of the last pereiopod of the crab in tagging program on the dungeness crab *Cancer magister* of the Oregon Fish Commission. Ever since the location of this site for tagging most of the experiments on the dungeness crab, the blue crab and the king crab are being conducted by using this method. Two types of tags are being used in these studies, namely, the spaghetti type loop tag and the dart tag. These tags are inserted through the muscular isthmus between the postero dorsal portion of the cephalothorax and the abdomen. Here the isthmus is covered with a parchment-like chitinous membrane which is one of the first parts of the exoskeleton to slough away during ecdysis. The moulting crab exsheaths through a posterior split between the abdomen and the carapace along this isthmus by means of a series of alternate body shifts. Since the tag is attached to the arthral muscle in the isthmus it is freed at the time of this split and does not appear to hinder moulting.

The spaghetti type loop tag is made from a 12-inch length of polyvinyl chloride plastic tubing with an oval plastic button bearing identification, number, etc. In attaching the tag the abdomen is spread from the carapace to expose the isthmus and the tag is then threaded through the muscular part of the same with a curved stainless steel needle, taking care to avoid the large blood sinus anterior to the muscular part. After threading through, the two ends of the plastic tubing are brought together and tied. The trailing ends of the 'sphagetti' provide conspicuous identfication of tagged crabs even at a distance.

After tagging the crabs are immediately returned to holding boxes containing salt-water which promotes blood clotting and consequent prevention of excessive bleeding and released after some time. Instead of the spaghetti loop tag dart tag also is used in which case a dart tag is inserted in the isthmus, leaving a portion of the tip projecting outside.

Recently Allen and Costello (1963) experimented with stain injection method for marking the blue crab *Callinectes sapidus*. Trypan blue and fast green stains were tried. Injections were made in the ventral surface of the swimming legs at the articulation of the coxa and the basis. In laboratory experiments crabs marked with fast green were found to retain the colour in sufficiently detectable quantity in the gill filaments after 40 days. Since the exoskeleton of the crab is opaque it is difficult to detect the stained gill filaments without lifting the carapace and that is one of the main disadvantages of the method. However the authors are of opinion that the results indicate that the stain injection techniques of marking crabs could be made use of in limited studies of local populations where captures could be examined by trained observers.

Results

Tagging recapture studies by Cronin and others in Chesapeake Bay using Nesbit type of tags yielded valuable results of the movements and growth of the blue crab *Callinectes sapidus*. Recoveries upto 23% were obtained in these experiments. The movements of adult blue crabs in the estuaries and adjacent coastal waters of South Carolina were elucidated by Fischler and Walburg (1962) by using a carapace tag. During this study a female crab released in January 1958 in South Carolina was recovered in May 1958 from Florida, 145 miles away from the site of release. In the crab tagging experiments of the Oregon Fish Commission considerable results have been obtained in *Cancer magister* by using the nylon spaghetti type and plastic dart type tags. Out of the 10% recoveries made till 1962 one recovered crab was tagged in July 1961 and recaptured in June 1962. This crab measuring 4·5 inches across the carapace when released grew to 6·5 inches and regenerated a claw which was missing whan tagged. Movements upto 20 miles have been noticed in these crabs. Much valuable results on the movements, growth and moulting periodicity of the King crab *Paralithodes camschatica* in Alaskan waters have been obtained by using spaghetti loop type tags in mark-recapture experiments. By measuring tagged crabs at release and recovery Weber and Miyahara (1962) arrived at a growth per moult of approximately 16 mm. for male crabs more than 110 mm. in length. Hayes and Montgomery (1963) conducted extensive tagging studies on the same crab using the same tag from 1957 through 1962. They observed migrations of the crab ranging from 35 miles to 110 miles. Two crabs were recovered after moving 110 miles from the site of release in 200 days and 1 year respectively. Their tagging recoveries also indicated a growth of nearly 17 mm. per moult in large-sized crabs and also biennial as well as triennial moult periods in the case of large crabs. On January 28, 1964, a tagged crab was caught near the Shumagin Islands in Alaska, which had been released within 10 miles of the area six and one-half years earlier. This is the longest period between release and recapture recorded to date. During the time the crab shows a growth from 4·1–7·6 inches in carapace width.

Results obtained by tagging the commercial crab *Cancer magister* with the suture tag in Canadian waters indicate that sub-legal size male crabs move about as much and in some cases more than those of commercial sizes and growth of the male crabs also has been traced (Butler, 1957). The suture method of tagging used on the edible crab *Cancer pagurus* in Norwegian waters have yielded valuable results on growth and movement. Tagged crabs recaptured in 1962 showed a mean increase in breadth of carapace of 27 mm. during 1 year. Tagging recapture experiments on *Cancer pagurus* on the Scottish coast also has yielded encouraging results.

LOBSTERS

Tagging and recapture experiments on the crayfishes and spiny lobsters of commercial importance have been conducted in various regions of the world resulting in very valuable results on their movements and intermoult growth. Among others may be mentioned the studies by Allen (1916) on *Panulirus interruptus* in California waters, Templeman (1935 and 1940) on the American lobster *Homarus americanus* in New Foundland waters, Von Bonde *et al.* (1935) on *Jasus lalandii* from South Africa, Wilder (1947) in Canadian waters, Sheard (1949 and 1962) on the Australian crayfish *Panulirus longipes* in Western Australia, Dawson and Idyll (1951) and Smith (1958) on the spiny lobster *Panulirus argus* of Florida, Thomas (1955) on *Homarus vulgaris* of the Scottish coast and Gundersen (1964) on *Homarus vulgaris* in Norwegian waters.

Tags and Tagging Methods

On the New Foundland lobsters Templeman used barb tags made of celluloid, consisting of a straight shaft that is pushed into the tissues in between the abdominal segments, and depending for holding wholly on one or more barbs. The same type of barb tag was later used in the tagging experiments in Florida waters by Dawson and others and is still being used successfully. These tags are plastic darts 40 mm. long, 6 mm. wide and 0·5 mm. thick (Fig. 3) of white or any other suitable colour. One side of the tag bears the address of the institution to which the tag is to be returned and the obverse side bore serial number and other instructions. The head of the dart is 14 mm. in length and with three serrations on each side. The tags are thrust into the muscles of the crayfish at an angle of approximately 45 degrees between the first and second segments of the abdomen on the dorsal side and to the right of the midline. One-quarter to one-half inch of the tag protrudes and is readily visible against the exoskeleton. This type of tag has the advantage of remaining in position while the animal sheds, at least in many cases, whereas the other types of marks like the carapace tags are lost during the process of moulting.

In the tagging experiments on Cape crawfish *Jasus lalandii* in South Africa marking was done by attaching a small brass label by means of a wire to the basal joints of the antennae. Sheard (1949 and 1962) tested small celluloid and plastic tags used internally with both *Jasus lalandii* in South Australia and *Panulirus longipes* in Western Australia. But he found that suitable punch marks on the tail fan gave better results than the internal tag and he used punch markings in his field studies. This method of marking is quite simple. Using lamb ear-marking pliers with dies of a suitable simple pattern (diamond, heart, bar, circle, oval or star) a punch is made on the tail fan (telson and uropods). It was found by him that the design was readily identifiable upto and including the second moult after marking and in several cases the mark was discernible even after the third moult. Where filled in the design was marked by paler colouring, absence of spines and an alteration in the direction of the telson ridges and canals. George (1957) also used the punch marking method in his studies on *Panulirus longipes* in Western Australia.

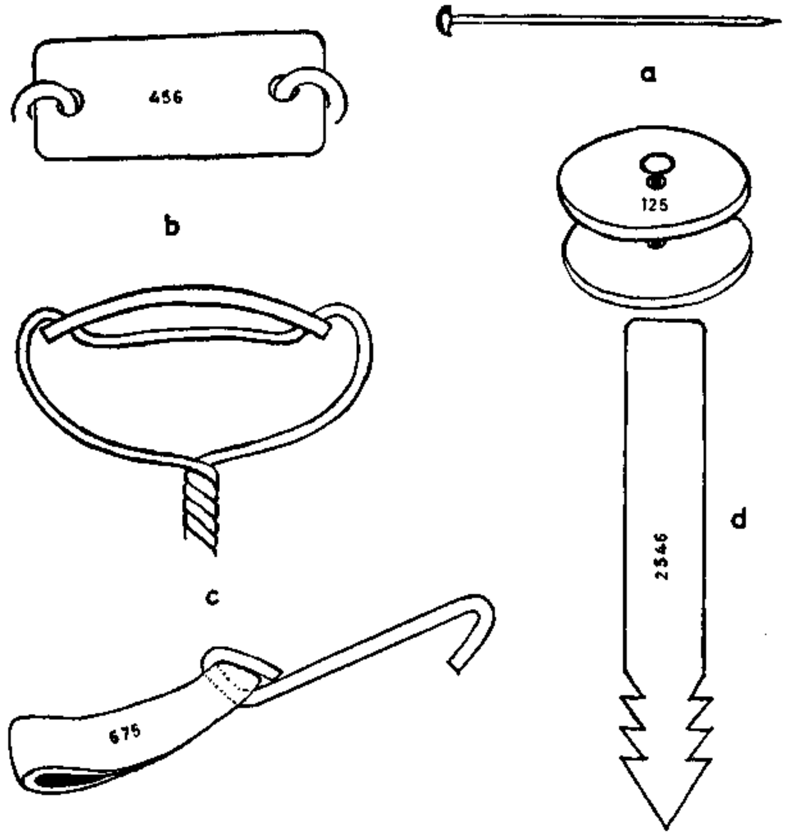

FIG. 3. (*a*) Petersen disc tag. (*b*) Celluloid and wire, carapace tag for lobster. (*c*) Metal and rubber carapace tag for lobster. (*d*) Dart tag for lobster.

Petersen disc tags and carapace tags were also used in tagging experiments on the American lobster *Homarus americanus* and others. Scattergood used both these methods. Discs of 10 mm. diameter were used in the disc tagging. The carapace tags are typically 2 different types, although there are various other modifications, namely, the metal and rubber tag and the celluloid and wire tag (Fig. 3). In the former the rubber is passed over the rostrum and the metal hook over the posterior end of the telson. In the latter, as explained in the case of crabs, the tag consists of a bright celluloid strip bearing serial number, etc., and a piece of stainless steel wire. It is attached to the dorsal surface of the carapace by the wire going round the body of the animal. All these tags have the disadvantage of being lost when the animal sheds.

Recently Gundersen in his experiments on the lobster *Homarus vulgaris* used three methods. In the first method he used the Norwegian suture tag for crabs. The internal tag is put in through a hole made in the dorsal midline of the carapace. In the second method the same tag is used and the internal part is put inside the lobster through the soft skin between the carapace and abdomen on the dorsal side. In the third method an external crab tag is fixed to the lobster by nylon gut. The nylon gut is thread through the lobster by means of a curved needle which is stung through the lobster dorsally from side to side in the soft part between carapace and abdomen.

Allen and Costello (1963) has experimented with biological stain injection for marking the Florida Spiny lobster *Panulirus argus*. Two stains were used, one a 0·25 per cent aqueous solution of trypan blue and the other a 0·5 per cent solution of fast green. Injections are made laterally into the abdomen at the articulation of the fourth and fifth segments where the needle is inserted its full length at an angle of about 45 degrees. Almost immediately after injection the lobsters acquire a general faint bluish or greenish tinge, depending upon the stain used, which could be seen through the more transparent portions of the exoskeleton and disappearing within 2 days. The gill filaments are clearly marked with the stains even after holding in laboratory tanks over 40 days. The colour is also found to be retained after moulting. But as in the case of crabs detection of the stains is difficult without lifting the carapace. Hence this method could be used only where captures could be examined by trained observers.

Results

Allen (1916) tagged *Panulirus interruptus* in California and observed some migratory movements. The largest migration reported by him was 9·6 miles in 28 days and he found that size and sex had no bearing on the direction or extent of the movement. Von Bonde *et al.* (1935) reports experiments carried out by Gilchrist in South Africa on the migration of the cape crawfish or rock lobser *Jasus lalandii*. These experiments revealed that considerable movements do take place but in a haphazard manner. A maximum movement of 13½ miles in 11 days was observed.

Templeman's (1935 and 1940) tagging work gave some very interesting results on the movements of *Homarus americanus* in the Gulf of St. Lawrence and New Foundland waters based on the tagging recoveries of a considerable extent. Sheard (1949) did tagging and punch marking tests on about 10,000 Western Australian crayfishes *Panulirus longipes* and got a maximum of 11·6 per cent recoveries, which gave distinct results about the direction and rate of movement of the crayfish over the Abrolhos fishing grounds in Western Australia, the rate and nature of replacement of the population under fishery conditions, the duration of the intermoult period at different sizes and growth increments. Some crayfishes marked and released in 1947 were recaptured after about 9 months showing an increase in length from 0·7–1·1 inch during the period. George (1958) and Sheard (1962) give valuable results on the mean growth increments over 1 and 2 years in white crayfish.

Dawson and Idyll (1951) give results of extensive tagging experiments conducted on *Panulirus argus* in Florida in 1946 through 1949. 5,345 lobsters were tagged in these 4 years and a total of 251 recoveries were made, *i.e.*, 4·7 per cent. Although most of the recoveries show a movement less than 5 or 6 miles, a few individuals had made extensive migrations over 100 miles. The longest migrations of 119 to 125 miles recorded were accomplished by 4 lobsters in 436, 451, 457 and 472 days respectively. The tagged crayfishes were free on an average of 71·5 days and the average distance travelled was 9·7 miles. They found that as a result of these movements a gradual mixing of the lobster population occurs over the whole area of the fishery. Lobsters which were free for about 6 months after release were found to have increased by a mean length of 1·14–1·22 inches. Tagging experiments by Wilder (1947 and 1953) using punch marking of holes on tail fans and Scattergood have yielded interesting results on the movements of the American lobster *Homarus americanus*. Tagging done by Thomas (1955) has helped in the elucidation of the movement of *Homarus vulgaris* on the Socttish coast.

In the beginning of 1964 experiments in tagging the spiny lobster *Panulirus homarus* have been conducted on the south-west coast of India. Dart tag quite similar to the one used in Florida has been used in these studies. Preliminary experiments with this tag has shown encouraging results regarding the suitability of the tag for field studies and tagging mortality.

Conclusion

Among the various types of tags used in crustacean mark-recapture experiments each tag or mark has its own advantage or disadvantage. The suitability of a tag or mark for any tagging recapture experiment depends upon several factors such as the length of time the tag should remain on the animal, the species, personnel and other facilities available for tagging, methods of capture and handling of the specimens, etc. and all these factors have to be taken into consideration before selecting a suitable tag for a particular study. The problems in crustacean tagging experiments are all the more difficult to be solved because of the frequent shedding of the exoskeleton taking place in these animals. Nevertheless as described in the preceding pages mark-recovery experiments employing the various tags and stain injections for marking has yielded much valuable wealth of information about the movements and growth of commercially important crustaceans in their respective fishing areas which could be obtained in no other way. The success of any mark-recovery experiment, however, will depend largely upon the degree of co-operation received in the detection and disposition of recaptured experimental specimens, for which complete co-operation of the industry is absolutely essential.

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THE USE OF PLASTIC TAGS FOR TAGGING SMALL SHRIMPS (BROWN SHRIMP, *CRANGON VULGARIS* FABRICIUS) AND ON THE PROBLEM OF TAGGING EXPERIMENTS OF THIS SPECIES OF SHRIMP

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ABSTRACT

A progress report on the tagging experiments conducted by the Institut fur Küsten-und Binnenfischerei, Hamburg, is given.

Since the beginning in October 1962, 41,236 shrimps were marked by means of a silver ring and of 1 or 2 small plastic disks. Plastic disks of different colour combinations were used and there is indication that a white/red colour-combination brings the best return rates. The highest return rate was achieved with 1·96% in an experiment conducted on the fishing grounds of the fishermen of Cuxhaven in June 1964.

The 205 returns obtained from all of the 13 experiments were made within an area of 20 nautical miles from the place of release and 189 of these were recaught within a period of 6 weeks. Only 5 shrimps were for 3–5 months in freedom before recapture during an experiment performed in winter. The tagging method described might be suitable for a comparative study of the relative strength of fishing mortality on different fishing grounds.

TAGGING experiments on crustacea face the added difficulty in that the animal moults from time to time and that tags externally attached to the skeleton are lost latest after the first moult. In crabs, this difficulty has been overcome by using the so-called suture tags which are inserted into the muscle through a suture of the skeleton, at which the exuvium breaks during the moulting process. In other large crustacea, such as lobsters or cray fish, holes—being visible over several moults—have been punched into the telson.

All these methods cannot be applied when tagging *Crangon* because of its small size. The only method used so far to tag the brown shrimp in the field was by the dying technique with the methyl-violet "gentiana violett B" of Fa. Merck (Münzing, 1960, 1962; Meyer-Waarden and Tiews, 1962). By this method great numbers of shrimps can easily be tagged, but only anonymously and unfortunately only over short periods extending at the latest until the next cast. The doubt that the animals would be blinded through the dying procedure and, therefore, would not behave naturally, could not be confirmed in recent experiments conducted by the Institut für Küsten—und Binnenfischerei. It was found that dyed shrimps show the same phototactic behaviour as undyed shrimps. They bury in the sand at daylight and swim restlessly during the dark, as demonstrated in aquaria experiments.

In searching for a method to tag *Crangon* individually and over longer periods extending over several moults, Tiews (1953) wrapped a thin silver wire, having a diameter of 0·22 mm, around the animal between the carapace and the first abdominal segment, keeping all swimmerets free, and he was able to keep shrimps tagged up to 3 successive casts. Shrimps tagged by this method were observed to behave normally, *i.e.*, to bury in the sand, to follow the common light-dark rhythm, even to copulate, to deposit eggs between their swimmerets and to hatch larvae. Many of the shrimps can moult despite the wire ring, as the cast breaks dorsally between the carapace and the first abdominal segment and as its ventral connection tissues are so tender that they break rather easily during the powerful moulting movements of the shrimp. The stripping of the silver ring is being prevented in both directions by the carapace and the first pair of swimmerets, which cover the ring.

There is no certainty as to how many moults an animal can be kept tagged, since shrimps kept in captivity always show a rather high mortality rate at the time of moulting. Tiews (1954) had even difficulties in keeping untagged shrimps alive for more than two moults when he studied the morphological changes of the shrimp from moult to moult, although he kept the shrimps single in separate tanks to eliminate one of the main factors causing high mortality rates in shrimps kept in aquaria, *i.e.*, the cannibalism among freshly moulted animals. He came to the conclusion that tagged shrimps kept in captivity show a similar lifespan as untagged shrimps. However, he doubts that tagged shrimps can pass more than 3–4 moults. The majority may pass even less than two moults.

For tagging shrimps in the field, a silver wire having a diameter of 0·18 mm. was chosen. Small coloured disks were dorsally attached to the silver ring. In the beginning, these disks were simply punched out of plastic covers as commonly used for keeping documents by means of an ordinary office puncher. They had a diameter of 6 mm. In order to keep their weight as low as possible, in some experiments the disks were divided into halves and later, the diameter of the plastic disks was reduced to 4 mm., which also reduced the resistance of the tag in water to about one half. A special puncher was used for this purpose. Colours used were white, yellow, red, blue and black as well as combinations of these in sets of 2.

Since it cannot be expected that the majority of shrimps can survive tagging for more than 1–2 moults, the duration for keeping shrimps tagged will depend greatly on the temperature of the water. According to Tiews (1954) the moulting frequency depends on the age of the animal and also on the water temperature. At water temperature of about 10° C., the time interval between 2 moults will be 40 days in adult shrimps, while it will be about 25 days when temperature is around 15° C., and more than 80 days when the temperature is as low as 5° C. Therefore, it can be expected that shrimps can be kept tagged longest during the low winter temperatures.

The following tagging experiments have been carried out using the silver ring (Table I).

TABLE I

List of German field tagging experiments

No. of experiments	Date of tagging	Locality of release	Colour of tags	No. of shrimps tagged	No. of shrimps recovered	Percentage of recovery in total
1	31 Oct.–13 Nov. 1962	Norddeich harbour	Blue resp. yellow	10,000	13	0·13
2	15 Nov.–22 Nov. 1962	Neuharlingersiel harbour	red	10,000	65	0·65
3	11 Dec.–20 Dec. 1962	Cuxhaven harbour	White	5,320	2	0·04
4	20 Dec. 1962	Lightvessel Elbe 1	White/red combined	916	3	0·33
5	11 Nov.–15 Nov. 1963	Cuxhaven harbour	White/red combined	2,500	23	0·92
6	9 Dec.–13 Dec. 1963	Cuxhaven harbour	Half white/full red combined	1,500	0	0
7	9 Dec.–13 Dec. 1963	Cuxhaven harbour	Full white/half red combined	1,500	0	0
8	3 June– 6 June 1964	Cuxhaven harbour	White/red (4 mm. combined)	2,500	49	1·96
9	6 July–10 July 1964	Büsum harbour	White/black (4 mm.)	1,500	1	0·07
10	6 July–10 July 1964	Büsum harbour	Yellow/black	1,500	5	0·33
11	6 July–10 July 1964	Büsum harbour	Yellow/red	1,500	15	1·00
12	28 Sept.–2 Oct. 1964	Cuxhaven harbour	White/red	2,000	27	1·35
13	22 Sept.–24 Sept. 1964	Cuxhaven harbour	White/black	500	2	0·40
				41,236	205	0·50

Tagging was done by bare hands without using any special tools. Before tagging operation the silver wire had been prepared as shown in Fig. 1. On average 60 shrimps could be tagged by one skilled worker per hour, the maximum being 100 animals per hour. The tagged specimens were kept in special containers, where they recovered very quickly after the tagging procedure before returning them to sea-water. They were not released into the sea, until they had fully recovered. There was no immediate tagging mortality.

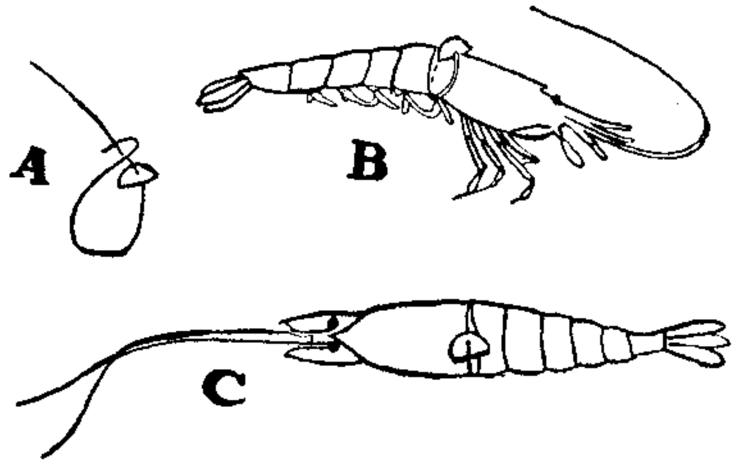

FIG. 1. (A) Preformed tag; (B) lateral view; (C) Dorsal view of shrimp showing the attachment of the tag.

Experiments No. 9, 10 and 11 have been specially designed to find out whether any particular colour combinations does influence the return rate. 1,500 shrimps each were marked with white/black, yellow/black and yellow/red tags. In order to ensure that each of the colour combinations has the same chance to be detected in the catches, the shrimps were tagged in sets of 500 each and the colour combination was changed set by set. The experiment showed clearly that the colour combination used greatly influences the return rate. The yellow/red combination was returned thrice as much as the yellow/black combination, and even 15 times as much as the white/black colour combination.

To get a more comprehensive knowledge on this aspect, cooked shrimps were tagged using 9 different colour combinationsand also single colours, and were smuggled into the landings intended for peeling by the women peelers. With each of the colour combinations 10 cooked shrimps were tagged. The colour combination white/red yielded 50%, the highest return rate, followed byyellow/black and white/black, 20% each. Red, black and yellow tags yielded 10% returns and yellow/red and white tags no returns (Table II). This preliminary experiment also indicated that different colour combinations do not possess the same chance to be recovered. Further research into this problem is needed.

As shown in Table I, the return rates differed greatly from experiment to experiment. The highest return rate was obtained in experiment No. 8, when nearly 2% of the tagged specimen were returned. Experiments No. 12, 11 and 5 yielded return rates close to 1%, *i.e.*, 1·35%, 1·00% and 0·92%. In 3 of these four most successful experiments the colour combination white/red was used and in the fourth the combination was yellow/red. In view of what has been stated above, it is likely that the colour combination used has considerably influenced the results of these experiments when compared with the other experiments.

In nearly all of these field experiments it was found that only a part of the fishing fleet—usually about 50%—returned recaptured shrimps, but the rest did not. It seemed that only half of the fleet was really able to co-operate with us. When estimating the total recapture rate, it must be kept in mind that the return rate is likely not identical with the recapture rate. Estimates of recapture rates have to be based on the return rates per boat as calculated from those boats successfully co-operating. In other words, the return rates given in Table I have practically to be doubled, if recapture rates are to be estimated.

TABLE II

Return rates for tags of different colour combinations from shore experiments with peelers

Colour combination	No. of shrimps tagged	No. of returns	% in total
White/red	10	5	50
Yellow/black	10	2	20
White/black	10	2	20
Red/black	10	1	10
Red	10	1	10
Black	10	1	10
Yellow	10	1	10
Yellow/red	10	0	0
White	10	0	0

In general, it can be said that the chances of getting recaptured shrimps reported back are not very great and it is true that the better the catches are the smaller the chances. An example may demonstrate this. Supposing the catches per a net hole amount to 2 baskets of shrimps only, this would mean that roughly 20,000–100,000 shrimps—depending on the size composition of the catch, had to be checked. However, good catches are much greater, even more than 10 times, which means that 200,000–1,000,000 shrimps are on the deck at a time after dragging the two nets for roughly 1 hour only. After 1 day's fishing, catches amounting to 6,000,000 shrimps may be loaded on one of the small fishing vessels when returning to the port. The probability to find a tagged shrimp is thus limited. The fishermen may find it when sorting the catch or when cleaning and washing the catch before cooking, or when cleaning the catch a second time from small fish, etc., after cooking. In some localities, where fishing during the night is practised, it is quite impossible for the fishermen to discover tagged shrimps.

One thing, which astonished very much, was that there is likely only a low probability that peelers discover recaptured shrimps, although one would be rather inclined to expect the contrary. Just the peelers handle each shrimp determined for peeling, manually. This has become obvious by a series of experiments, when tagged and cooked shrimps were smuggled into the peeling good. On an average only some 10–20% of tagged shrimps can be expected to be returned by the peelers. The reason for this may be that peelers peel shrimps practically blind because of their great routine.

Shrimps having the size of edible shrimps only were tagged. It might be recalled in this connection that the majority of the German shrimp catches consist of small shrimps utilized for industrial purposes and that only 1/5 to 1/8 of the catch can be used for human consumption (Tiews, 1953). The results of these tagging experiments as to the migration habits of the brown shrimp can be summarized as follows: All recaptures were made close to the locality of release within a radius not exceeding about 15–20 nautical miles. At autumn-experiments most of the recaptures had migrated to the open off-shore waters. This is in accordance with the general migration theory, according to which the shrimp migrates to off-shore waters during late autumn and back to the coastal waters during spring (Tiews, 1954 *b*). In all experiments except in 2, *i.e.*, Nos. 3 and 4, the recaptures were made within a period of 6 weeks. The 5 recaptures of experiments 3 and 4, which were executed at the very end of the fishing season, were made at the beginning of the new fishing seasons in spring 1963. Two of these shrimps were approximately 5 months in freedom after tagging, one for 4 months and two for a little more than 3 months. All these 5 shrimps had left the fishing grounds of the Cuxhaven fishermen in the meantime and had migrated to the more western fishing grounds of their neighbour-fishermen, however, were also recaught in an area within 15 nautical miles from their places of release. A similar experiment conducted in December 1963 did not yield any returns.

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TEMPERATURE LIMITATIONS ON THE SUPPLY OF NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN MAINE (U.S.A.) WATERS

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Abstract

Statistics of the Maine shrimp (*Pandalus borealis*) fishery for the entire 27-year period of its history suggest that fluctuations in sea-water temperature have greatly influenced the magnitude of supply in Maine waters. Data on optimum as well as unfavourable temperatures are presented and discussed.

Shrimp taken commercially in the Maine fishery are of the species *Pandalus borealis* found chiefly north of Cape Cod. As a sex reversal species most of the young mature as males during initial development and after a transition phase become mature females. Frequently in the early part of the season fishermen report many of the shrimp taken are not of commercial size and have to be discarded. Later, only egg-bearing females of acceptable market size are found in quantity.

Catches are made during the fall-to-spring fishing season on spawning grounds within an eighty-kilometer radius of Boothbay Harbor by small draggers from nearby ports. Landings have fluctuated widely from year to year and appear to be related to abundance.

Since shrimp is the only species of commercial interest which is naturally more readily available during the winter, the species has attracted a considerable amount of fishing effort throughout the last 27-year period.

The principal fishing areas are Casco Bay and the adjacent inshore waters to the east which produce more than three-quarters of the annual catch. Landed value has ranged from less than $ 90 to more than $ 700 per ton.

A Boston firm, General Seafoods, carried on experimental shrimp fishing in the Gulf of Maine as early as 1927 (Walford, 1936). In 1938, with the co-operation of the Fish and Wildlife Service and the Department of Sea and Shore Fisheries, a survey was made from Cape Ann, Massachusetts, to Petit Manan, Maine.

The first commercial-scale operations were commenced that year in Casco Bay (Scattergood, 1952). During the next several years, the fishery expanded rapidly and landings increased to the 1945 peak of more than 250 tons. Thereafter, catches declined to a low of three tons in 1950.

Another cycle of increasing landings commenced in 1951 but was short-lived, and after 1953 no shrimp were landed until 1958 when less than two tons were taken. Since then, production has increased rapidly and amounted to a record of 407 tons during the 1963–64 season.

In addition to an apparent cyclic variation in abundance, as indicated by landings (Table I) and suggested by Scattergood (1952), there is evidence that sea-water temperature is an important factor. It is likely that sea-water temperature has more influence on the abundance of northern shrimp than any other one factor.

Analyses of sea-water temperatures and catch data two years later support this assumption (Dow, 1963). It is evident that the monthly mean temperatures from October through July as

TABLE I

Fishing season	Duration	Peak month	Total landings in metric tons
1937–38	February–April	March	37
1938–39	..	.	8
1939–40	January–June	March	4
1940–41	December–May	February	25
1941–42	December–March	February	36
1942–43	December–April	March	132
1943–44	November–April	March	177
1944–45	January–April	March	251
1945–46	January–March	March	73
1946–47	February–April	March	88
1947–48	February–April	March	12
1948–49	February–June	February	4
1949–50	March–May	April	3
1950–51	February–April	March	20
1951–52	February–April	March	47
1952–53	February–April	February	17
1953–54	..	..	0
1954–55	..	..	0
1955–56	..	..	0
1956–57	..	..	0
1957–58	March	March	2
1958–59	February–March	February	5
1959–60	November–April	February	41
1960–61	January–April	March	29
1961–62	December–May	February	154
1962–63	October–March	February	240
1963–64	October–April	February	407

TABLE II

October–April mean sea-water temperature and Northern shrimp landings two years later 1938–64

Oct.–April temp. °C.	Shrimp landings in metric tons	Oct.–April temp. °C.	Shrimp landings in metric tons	Oct.–April temp. °C.	Shrimp landings in metric tons	Oct.–April temp. °C.	Shrimp landings in metric tons
10·1	0	9·6	17	8·5	88	7·1	8
10·0	0	9·6	47	8·2	4	6·9	4
10·0	0	9·1	5	8·0	41	5·7	25
9·7	0	9·0	2	8·0	240	5·6	36
..	..	9·0	3	7·9	407	..	..
..	..	..	..	7·7	29	..	..
..	..	..	..	7·7	154	.	..
..	..	..	..	7·7	37	..	..
..	..	..	..	7·6	12	..	..
..	..	..	..	7·5	20	..	..
..	..	..	..	7·5	132	..	..
..	..	..	..	7·4	73	.	..
..	..	..	..	7·3	177	..	..
..	..	..	..	7·2	251	..	..

measured at Boothbay Harbor influence the magnitude of shrimp landings two years later. This relationship for selected months of that period is shown in Tables II, III and IV.

TABLE III

June sea-water temperature and Northern shrimp landings two years later 1938–64

June temp. °C.	Shrimp landings in metric tons	June temp. °C.	Shrimp landings in metric tons	June temp. °C.	Shrimp landings in metric tons
14·4	5	13·5	177	11·5	29
14·3	0	13·4	4	11·3	41
14·2	17	13·2	47	11·1	36
14·1	20	13·0	154	9·9	25
13·9	0	12·8	240	..	..
13·7	8	12·4	407	..	..
13·6	0	12·3	2	..	..
13·5	0	12·2	4	..	..
..	..	12·0	3	..	..
..	..	12·0	12	..	..
..	..	12·0	88	..	..
..	..	11·8	132	..	..
..	..	11·7	37	..	..
..	..	11·7	251	..	..
..	..	11·6	73	..	..

TABLE IV

March sea-water temperature and Northern shrimp landings two years later 1938–64

March temp. °C.	Shrimp landings in metric tons	March temp. °C.	Shrimp landings in metric tons	March temp. °C.	Shrimp landings in metric tons
6·1	0	2·5	240	0·2	4
4·9	0	2·2	154	0·0	25
4·7	17	2·1	88	−1·1	36
4·2	0	2·0	132	..	..
4·2	0	1·8	407	..	..
4·1	5	1·7	29	..	..
3·4	47	1·6	3	..	..
3·2	2	1·1	73	..	..
3·1	8	1·1	177	..	..
3·1	12	0·9	251	..	..
3·0	41	..	..	..	..
3·0	37	..	..	..	..
2·8	20	..	..	..	..
2·5	4	..	..	..	..

The effect of very high sea-water temperature upon the abundance of shrimp is indicated by Table II, October–April mean temperature and shrimp landings two years later, The effect of low sea-water temperature on shrimp abundance two years later is illustrated by Table III which shows the relationship between June temperatures and shrimp landings two years later.

The characteristic pattern of the greatest abundance of shrimp being associated with sea-water-temperature in the lower half of the temperature column is apparent from the 27-year record of March temperatures, the principal month of spawning in Maine waters, and shrimp landings shown in Table IV.

Summing up it may be stated that during the 27-year period from 1937–38 to 1963–64;

1. Very high temperatures have been associated with virtually no shrimp landings (Table II).

2. Highly variable temperatures have been associated with landings of less than five metric tons (Tables II and IV).

3. High temperatures have been associated with landings ranging from 5 to 20 metric tons (Table III).

4. Medium, high and low temperatures have been associated with landings ranging from approximately 12 to less than 50 metric tons (Tables III and IV).

5. Landings greater than 70 metric tons have been consistently associated with the optimum temperatures during the entire October–July period shown in Table V.

TABLE V

Month		Optimum temperature °C.
October	..	9·6–11·6
November	..	7·1– 9·2
December	..	3·0– 5·6
January	..	0·5– 3·9
February	..	0·0– 2·2
March	..	0·9– 2·5
April	..	2·8– 6·4
May	..	7·9–10·0
June	..	11·6–13·5
July	..	13·1–16·0

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SIGNIFICANCE OF ENVIRONMENTAL AND ECONOMIC FACTORS IN THE MAINE (U.S.A.) LOBSTER (*HOMARUS AMERICANUS*) FISHERY

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Abstract

The influence of seasonal seawater temperature fluctuations on growth and subsequent recruitment, and variations in fishing effort induced by the response of demand to fluctuations in supply are discussed in terms of their significance to the fishery.

Introduction

Previous studies have indicated that the average annual available supply of lobsters in Maine waters has not fluctuated more than $\pm$ 8·8 per cent. from the mean during the last 25 years (Dow and Trott, 1956). Population fluctuations have been associated with environmental changes, and the response of fishing effort to demand suggests that this knowledge might be used to manage the fishery in terms of both biology and economics.

Materials

Sampling the catch for size frequency distribution was carried on by the United States Fish and Wildlife Service from 1939–46 and by the Maine Department of Sea and Shore Fisheries from 1947–56.

Seawater temperature observations have been made by the Service at Boothbay Harbor since 1905. Data on the number of fishing units were collected by the Department from 1897–1906, sporadically from 1924–38, and continuously by the two agencies since 1939.

Sampling of fishermen for number of fishing months and days had been done at irregular intervals in the early 1950's and continuously since 1958 by the Department. Production, landed value, number of fishermen and other related data have been collected by the Department or co-operatively by the two agencies since 1939; before that time by the Department.

Methods

Estimates of available supply have been based on sampling the catch for size composition (Table II) and fishermen for the number of fishing units and the length of the fishing year.

Sampling has indicated that the number of moult-recruited, previously sub-legal lobsters in the catch had increased about seven per cent. by the time a consistently high intensity fishery had developed in the mid-1950's. The average fishermen has fished 20 days each month for six and one-half months per year.

The natural one-year mortality rate from sub-legal to legal size (79·4 mm. carapace length) has been estimated from size composition measurements to be approximately 30 per cent. A range of $\pm$ 20 per cent. in estimated mortality from the probable mean is attributed to deviations from average moult increment and differences in growth rate associated with changes in seawater temperature.

TABLE I

Maine Lobster fishery data

Year	Lobster landings in metric tons	Number of fishing units in thousands (effort)	Average landed value in dollars per ton	Mean January-May seawater temperature ° C.
1939	3,006	260	345	1·9
1940	3,467	222	365	1·6
1941	4,054	194	390	3·9
1942	3,812	187	478	3·4
1943	5,202	209	564	2·5
1944	6,376	252	635	3·2
1945	8,677	378	884	4·0
1946	8,517	473	844	3·5
1947	8,290	516	822	4·1
1948	7,223	459	892	3·4
1949	8,742	462	766	5·0
1950	8,325	430	770	5·2
1951	9,416	383	766	6·5
1952	9,088	417	937	6·0
1953	10,115	440	832	7·0
1954	9,828	488	823	6·0
1955	10,305	532	846	6·1
1956	9,332	533	977	4·7
1957	11,069	565	809	5·6
1958	9,667	609	1,080	4·9
1959	10,128	717	1,111	3·9
1960	10,884	745	1,007	4·5
1961	9,488	752	1,172	4·1
1962	10,013	767	1,118	3·7
1963	10,344	731	1,222	4·6

Projections of these data without consideration of other biological limitations suggest a recruit-stock terminal yield of 10,500–12,750 metric tons, varying with the rate of temperature-influenced recruitment.

Discussion

Between 1919 and 1952 economic considerations largely determined the magnitude of lobster landings. In 1952 and thereafter, factors other than economic had become critical in determining the annual yield of the fishery. The principal factor was seawater temperature which influenced the time and frequency of moult.

Declines in temperatures since 1953 either decreased or delayed recruitment. Concurrent increases in demand induced greater effort in terms of additional fishing units. Increased fishing effort maintained production within ± 10 per cent. of the annual mean of 10,000 tons for the 1951–63 period, although landed value fluctuated ± 25 per cent. from the annual mean of $ 980 per ton.

TABLE II

Size composition of catch in per cent. by lobster (July–June) Years

Carapace length mm.	1947–48	1948–49	1949–50	1950–51	1951–52	1952–53	1953–54	1954–55	1955–56
79·4	19·6	21·8	24·0	23·1	24·5	25·0	23·4	23·3	22·0
82·6	21·6	24·1	22·2	21·3	22·7	23·5	23·0	23·9	23·8
85·7	20·8	22·7	20·2	20·2	20·4	20·9	21·8	20·5	19·7
88·9	17·5	17·3	16·3	17·2	16·8	16·9	17·4	17·2	16·4
92·1	8·6	8·6	7·0	7·9	6·5	6·7	7·1	7·1	7·7
95·3	4·3	1·8	3·3	3·3	2·4	2·2	2·7	2·3	3·0
98·4	2·6	1·2	2·1	2·1	1·9	1·4	1·5	1·6	1·9
101·6	1·9	1·0	1·5	1·6	1·3	1·0	1·1	1·2	1·5
104·8	1·4	0·8	1·2	1·3	1·1	0·8	0·7	1·0	1·3
108·0	0·7	0·2	0·7	0·7	0·7	0·6	0·5	0·6	0·9
111·1	0·5	0·4	0·5	0·5	0·5	0·4	0·4	0·5	0·6
114·3	0·3	0·2	0·4	0·4	0·4	0·3	0·2	0·4	0·6
117·5	0·2	0·1	0·2	0·3	0·3	0·2	0·2	0·2	0·3
120·7	0·1	0·1	0·2	0·2	0·3	0·2	0·2	0·2	0·2
123·8	0·1	0·0	0·2	0·2	0 2	0·1	0·1	0·2	0·3
Total measurements	3,218	1,994	60,388	59,044	61,000	55,820	17,772	18,359	13,326

Since significant increases in effort are unlikely in view of the 1962 effort-to-yield ratio of 1–0·8 as compared with 1–3·9 in 1941–43, benefits to the fishery will most probably come from a decrease in annual production fluctuations.

SUMMARY

Results of this study indicate that data on sea water temperature, the number of fishing units, the length of the fishing year and the size composition of the lobster population provide means for effectively managing the fishery.

Table I suggests that the lobster resource can support an annual yield of 10,000 tons with a combined natural and fishing mortality rate of approximately 85–90 per cent.

Fishing effort response to increased demand has maintained Maine lobster landings within ± 10 per cent. of the annual mean of the past thirteen years, although declines in sea water temperature have reduced the rate of recruitment. Adjusting fishing effort for the remainder of the years to average January–May seawater temperature would probably reduce production and economic fluctuations to a negligible amount.

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OBSERVATIONS ON THE BIOLOGY AND FISHERY OF THE SPINY LOBSTER *PANULIRUS HOMARUS* (LINN.)*

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ABSTRACT

Panulirus homarus (Linn.) supports an active fishery along the south-west coast of India. The main areas of fishing lie between Trivandrum and Cape Comorin in the south and between Tikkoti and Cannanore in the north. The trends in the seasonal and annual production at the two zones are described and discussed. The fishing season is from November to April in the southern region whereas in the north it commences in August and lasts only for a couple of months. The fishing methods which are different in the two areas are outlined.

Length-frequency studies reveal that larger sizes enter the fishery in the commencement of the season and smaller sizes are recruited into the fishery towards the latter half. The peak of the breeding season is from November to January as revealed by the high percentage of berried females in the catches and no segregation of of sexes is noticed in the fishing ground at any part of the year.

Results of the preliminary experiments to evolve suitable tagging technique for the lobster are given. The factors that contribute to the large annual fluctuations in the fishery and the influence of the pressure of fishing on the conservation of stocks are discussed.

THE spiny lobster *Panulirus homarus* (Linn.) contributes to a fairly good seasonal fishery on the south-west coast of India and supports a lobster tail freezing industry. Although a general account of the fishery and some results of experimental fishing for these lobsters respectively have been recently published by Miyamoto and Shariff (1961) and Balasubramanyan *et al.* (1960 and 1961) no attempt has been made so far to study the different biological aspects of this fishery. Prasad and Tampi (1959) described the phyllosoma stage of *Panulirus burgeri*. During the years 1958 through 1964 a study has been conducted on this fishery with special reference to growth and age class representation of the lobsters in the fishery and certain other biological aspects and the results are presented here.

Holthuis (1946) proposed synonymising *Panulirus dasypus* and *Panulirus burgeri* as *Panulirus homarus* and this was accepted by later authors (Gordon, 1953; George, 1963 and 1964 and Kubo, 1963). However so far all the authors studying these species from Indian waters including the recent, Miyamoto and Shariff (*op. cit.*) have mentioned the two species, namely *P. dasypus* and *P. burgeri*, as separate. In the present report the two species are treated as synonyms and recorded as *Panulirus homarus*.

On the south-west coast of India the fishery of this species is restricted to two areas, the rocky coast south of Trivandrum extending from north of Colachel to Cape Comorin and another small strip north of Kozhikode. Details regarding the topography of the area of the fishery, fishing methods, etc., of the Cape Comorin–Colachel area is given by Miyamoto and Shariff (*op. cit.*). The northern fishing area consists of 4 fishing villages in a stretch of 2·5 miles about 15 miles north of Kozhikode. The villages are (1) Tikkoti Kodikal, (2) Vanmukkam, (3) Kadaloor and (4) Nandi Light House shore. For the present study 2 of the important fishing villages of the southern area, namely Muttom and Colachel [Ref.: map given by Miyamoto and Shariff (*op. cit.*)] and Tikkoti Kodikal and Kadaloor centres of the northern area (from 1963 onwards) have been selected and lobster landings from these centres regularly sampled.

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Fishing Season and Methods

The fishing season at Colachel-Muttom zone commences by November or December and ends by April. The season at Tikkoti is very short and usually lasts for one or two months in August to October period.

The gear and methods employed in the fishery at Colachel-Muttom, namely anchor hook, lobster trap and scoop net are fully described by Miyamoto and Shariff (*op. cit.*). In addition to these three, bottom set gill nets are also employed to a certain extent, mostly in the villages south of Muttom. At Tikkoti mainly 2 types of gear are used in the lobster fishery. The most important gear is a type of cast net locally called *Muru vala* with mesh size 4·5–5·0 cm. and made of hemp twines. The net is operated from a dug-out canoe at a depth of 2–3 fathoms mostly during day-time and when the water is clear. Another type of cast net, *Kara vala* with the only difference of mesh size which is 3·0 cm. also is in use.

The second type of gear is a bottom set gill net locally called *Kantati vala.* The length of one piece of this net measures 40 feet long and 12 feet in depth, with a mesh size of 8·0 cm. also made of hemp twines. Eight to twelve pieces of these nets are attached together to form one unit and set at the bottom at a depth of 2–3 fathoms during night at the rocky region. Occasionally few lobsters are caught on hooks and lines operated mainly for perches.

Catch Variations

The estimated total landings of lobsters by the different gears employed at Muttom and Colachel for the years 1958–62 and at Tikkoti for the seasons 1963–64 and 1964–65 are shown in Table I.

Among the three gears employed at Colachel-Muttom zone, trap is the most important. Anchor hook is equally, if not more, important in catching ability at Muttom. But at Colachel this is not so, as is evident from the table. Scoop net is more prevalent in Colachel than at Muttom. It is also clear from the table that December and January are the more productive months in the fishery of the area.

It is noticed that there is a gradual decline in the catches of all the gears at both Muttom and Colachel from 1958–59 season to 1960–61 season. However 1961–62 season shows considerable improvement in the catches, although not equalling the catches of 1958–59 season. This might indicate that the decline noticed in the earlier seasons may probably be due to natural fluctuations rather than due to overfishing. Nevertheless a close watch on the fishery is necessary to determine the effect of the fishing on the stock available.

In the Tikkoti fishery the catches of 1964 shows an improvement over that of 1963.

Breeding Season

By taking the indirect evidence of the maximum percentage frequency of occurrence of females with berry on the underside of the abdomen the breeding season appears to be in the early months of the season, namely November-December. These months show the maximum number of females with berries at both Muttom and Colachel (Table II), although small percentages of berried females are present in the catches in all the months of the fishery as can be seen from the table. De Bruin (1962) also observes the peak of breeding of the species in Ceylon water in December, though he gives the breeding season as prolonged from August to March. It is also seen from the table that there are more berried females occurring in the catches at Muttom than at Colachel, which might indicate that the breeding area is likely to be nearer to Muttom.

TABLE I

Showing landings of P. homarus (in numbers) *by different gears at Muttom, Colachel and Tikkoti*

Season	Months	Muttom Trap	Muttom anchor hook	Muttom Scoop net	Colachel Trap	Colachel anchor hook	Colachel Scoop net	Tikkoti cast net
1958–59	December	7,359	46,286	..	16,398	..	3,560	..
	January	4,608	5,212	22	18,228	..	1,064	..
	February	6,920	2,222	58	9,196	60	50	..
	March	2,752	57	..	3,255	70	—	..
	April	328	267	..	1,114	..	—	..
1959–60	December	4,866	12,852	..	6,616	..	338	..
	January	4,608	5,212	22	4,046	1,370	120	..
	February	3,244	2,342	..	1,919	—	—	..
	March	926	212	..	745	—	—	..
1960–61	December	6,754	11,409	..	5,226	1,346	953	..
	January	4,960	8,786	—	4,210	247	32	..
	February				No data			
	March	2,186	112	—	1,064	—	..	..
	April	496	..	—	776	—	..	..
1961–62	November	3,028	14,050	..	2,844	1,534	808	..
	December	7,930	31,870	..	4,820	2,404	964	..
	January	10,537	18,340	..	3,026	1,154	1,355	..
	February	1,942	1,486	..	1,484	786	216	..
	March	192	22	—	295	547	32	..
1963	August	—	—	—	—	..	—	50
	September	—	—	..	..	..	..	1,535
	October	..	..	..	..	..	..	3,040
1964	August	..	..	..	..	..	..	35
	September	..	..	..	..	..	..	6,011

TABLE II

Showing the percentage of berried females in the lobster catches at Muttom and Colachel for the seasons 1958–59 to 1963–64

Season	Percentage of berried females: Muttom Nov.	Dec.	Jan.	Feb.	March	April	Colachel Nov.	Dec.	Jan.	Feb.	March	April
1958–59	..	70·9	36·1	51·6	40·0	22·5	..	57·1	52·7	42·9	17·2	17·0
1959–60	..	78·0	36·1	20·7	13·5	..	..	65·4	38·0	19·6	14·6	..
1960–61	..	60·4	43·8	27·5	18·4	7·8	..	54·7	25·6	17·1	11·5	11·4
1961–62	81·3	72·6	51·1	28·8	43·3	..	63·1	49·3	24·7	26·0	44·4	..
1962–63	..	..	..	7·7	..				No data			
1963–64	..	60·0	28·0	46·9	40·6	21·2	..	..	32·1	..	44·9	..

During the months of the fishery at Tikkoti region percentage of berried females obtained in the catches are considerably less (only 8·3 per cent. in 1963 and 35·3 per cent. in 1964), indicating that these months of the fishery are not the breeding months of the species there. It is possible that the population supporting the fishery at both the areas are derived from the same stock having a common breeding ground.

Sex Ratio

The overall monthly sex ratios of 11,072 lobsters observed from 1958–64 show 53·0 and 51·9 per cent. males and 47·0 and 48·1 per cent. females in Muttom and Colachel respectively. At

Table III

Showing the sex ratios of P. homarus *by months at Muttom and Colachel during the years* 1958–64

Months	Muttom		Colachel	
	% males	% females	% males	% females
November ..	55·8	44·2	54·3	45·7
December ..	50·3	49·7	58·2	41·8
January ..	51·8	48·2	55·8	44·2
February ..	50·2	50·8	50·3	49·7
March ..	56·3	43·7	48·8	51·2
April ..	54·2	45·8	44·3	55·7
Total ..	53·0	47·0	51·9	48·1

Muttom in March, April months there seem to be slightly more of males, whereas at Colachel in these months female percentage is slightly on the higher side. Except for these the sex ratio is almost 1 : 1, not showing any segregation of sexes.

The sex ratios in the catches at Tikkoti area show a slight preponderance of females in both seasons of observation.

Growth Rate

Growth rates of several of the commercially important lobsters such as *Panulirus argus*, *P. japonicus*, *P. interruptus*, *P. longipes*, *Jasus lalandii*, etc., have been either fully or partially studied by different authors by using either one or other or all the three methods, namely length-frequency, tagging and holding. Attempts have been made in the present investigations to determine the growth rate of adult lobsters of the present species by the length-frequency method. Though De Bruin (*op. cit.*) gives length-frequency polygons of *P. dasypus* from Ceylon waters during the fishery of the species in 1960 and 1961 no attempt is made by him, however, to determine its growth rate and age composition of the catches.

Length Frequencies

During the period 1958–64 a total of 11,072 lobsters were measured from the catches at Muttom and Colachel. The measurements are made from the rostrum (between the horns) to the end of the telson. The combined data from the two centres for length frequencies in intervals of 10 mm. for the season December 1960 to April 1961 for males and females separately is shown in Fig. 1.

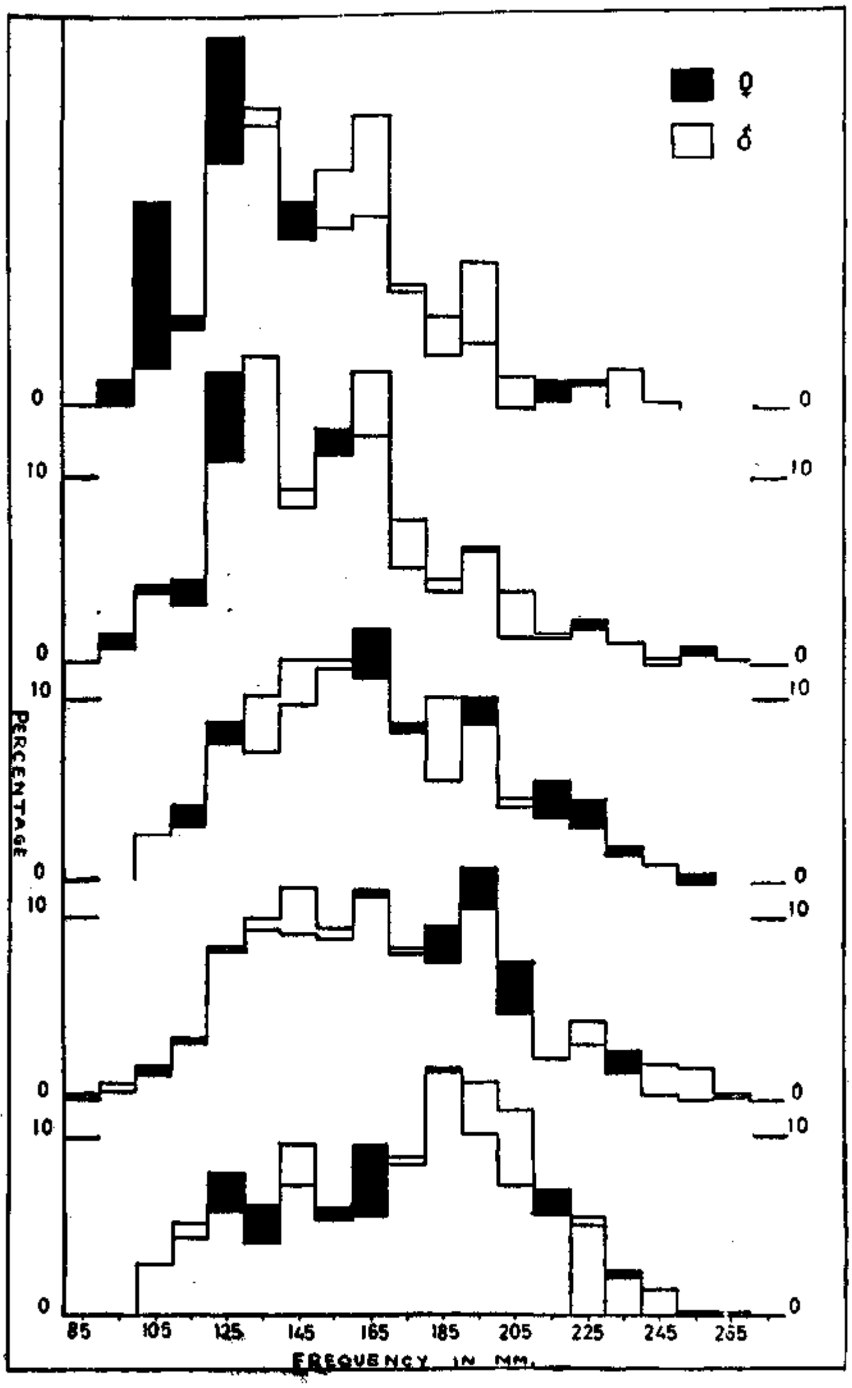

FIG. 1. Length-frequency distribution for the season 1960-61.

Although the number and complexity of the modes preclude the possibility of identifying the various age groups and of tracing their growth rates, shifting of some modes are apparent so that some deductions are possible as to the average length increments. Length frequencies for most of the seasons show more or less a similar pattern. In the case of males it can be seen from the figure that the mode at 141–150 mm. length group in December shifts to 161–170 mm. by April, thus showing a growth of 20 mm. in 4 months. But the mode at 181–190 mm. in December shifts to only 191–200 mm. by April, showing only 10 mm. growth in 4 months. Similarly in the case of females also the mode at 141–150 mm. group in December shifts to 161–170 mm. by April and shows a growth of 20 mm. in 4 months. Another December mode at 181–190 mm. moves only to 191–200 mm., again 10 mm. in 4 months. Other minor modes also could be traced to show shifts of 10 mm. during a period of 4 months. This gives an average growth rate of about 30–40 mm. per year which compares very well with the results obtained in other lobsters.

Age Composition and Population Characteristics

Monthly size frequency modal distribution in the fishery for the seasons 1958–59 through 1963–64 are given in Fig. 2. Plotted serially for all the years under observation and fitted with

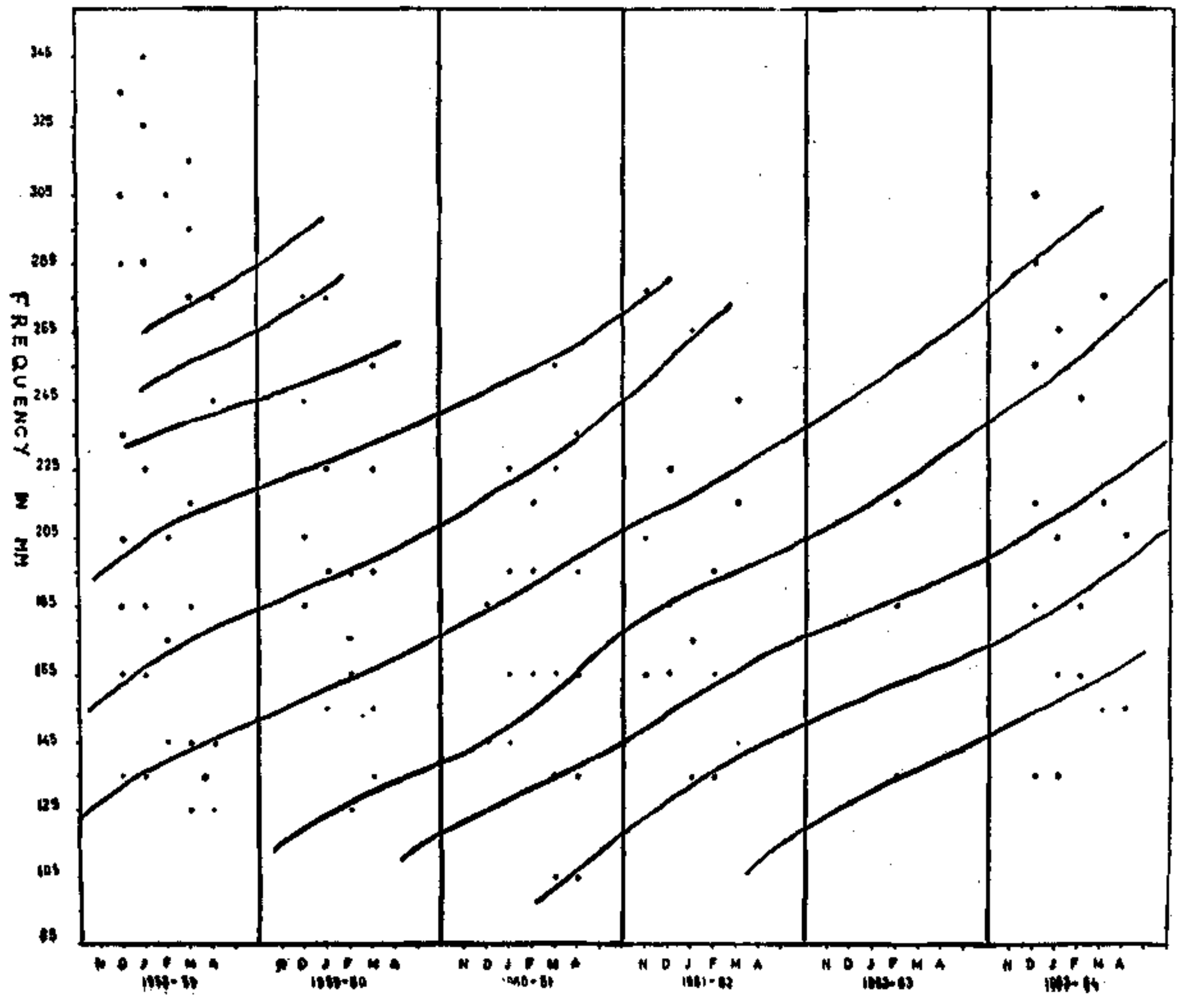

FIG. 2. Length-frequency modal distribution of *P. homarus*.

smooth curves the size distribution modes can be seen to trace each brood from its recruitment to its disappearance from the fishery. From the curves the interrelationships of successive broods seem to be sufficiently clear. However, slight variations in the fitted lines do pose a question regarding their causes. Perhaps part of this variation could be attributed to sampling error and disproportionate availability and differential growth in sexes.

A close scrutiny of the figure will show that about 6 year groups are represented in the fishery. An year group which comes into the fishery at 131–140 mm. size is seen to be represented in subsequent 5 years, reaching by that time a size of about 300 mm. The representation of the year groups which could be made out from the figure is shown in Table IV.

TABLE IV

Showing the year class representation in the fishery

Season	Year classes in February (length group mm.)							
1958–59	141–150	171–180	231–240	251–260	..	..	..	..
1959–60	161–170	191–200	251–260	271–280	121–130	..	..	..
1960–61	191–200	221–230	..	..	161–170	131–140	..	..
1961–62	215–225	261–270	..	..	191–200	161–170	131–140	..
1962–63	251–260	..	..	..	210–220	181–190	161–170	131–140
1963–64	291–300	..	..	..	241–250	210–220	181–190	161–170

The yearly progression of the modes can be clearly seen from the table. The year class with the mode at 141–150 mm. length coming into the fishery in 1958–59 reaches 291–300 mm. length in 1963–64 (Fig. 2 and Table IV). So it may not be far from the truth if it is concluded that altogether 6 year classes are represented in the fishery. The growth increase per year varies from 20–40 mm. The average annual growth rate works out to 28 mm. which compares very well with that obtained by the monthly length-frequency progression.

Taking into account the yearly growth rate obtained above and the fact that growth may be faster in younger stages, it may be concluded that the year class which gets recruited into the fishery at 131–140 mm. or 141–150 mm. size may probably be the 3rd year class, thus making a total of 9 year classes to reach a size of about 300 or 310 mm. In other words a lobster measuring 300 or 310 mm. length may be said to be 10 year old. This estimated age of *P. homarus* compares very well with the age obtained by other workers in other species of lobsters. In *P. interruptus* a specimen measuring about 260 mm. in total lengths is 7–8 years according to Lindberg (1955). In *P. argus* Travis (1954) observed the same age. In the case of *Jasus lalandii* according to Fielder (1964) specimen measuring about 250 mm. in total length is 10+ years, which, however, shows a slightly lesser growth rate in this species.

The actual growth rate obtained in the present species *P. homarus* is quite similar to the rate of growth observed in other lobsters. In the case of *Panulirus japonicus* (Von Siebold) Nakamura (1940) found that animals between 22 and 40 mm. carapace length increased in length 9·4–16·7 per cent. at moult. In *P. interruptus* (Randall) Lindberg (1955) arrived at a yearly growth increase of 3–4 cm. (1¼–1½ inch) by means of tag recoveries and holding experiments. For the same species Backus (1960) estimated a yearly growth of 2·0 cm. for females and 1·7 cm. for males for animals between 27 and 40 cm. total length. Smith (1948 and 1951) reported an annual growth of 1 inch for the species *P. argus* (Latreille). In the same species Dawson and Idyll (1951) observed annual growth of 1¼–1½ inch. Travis (1954) showed an annual increase of 9–12 mm. carapace length, also for *P. argus*. In the case of *P. longipes* (M. Edw.) Sheard (1962) estimated growth by tagging and he calculated mean carapace length increments of 0·31 inch and 0·61 inch for females and 0·44 inch and 0·62 inch for males for animals free for 1 and 2 years respectively. In *Jasus lalandii* (M. Edw.) Bradstock (1950) noted an increase of 1·9 cm. and 2·1 cm. for two-tagged animals recovered after 1 year. For the same species Fielder (1964) records an annual growth of 1 inch total length in animals between 4·0 and 7·9 cm. carapace length and 0·6 inch in animals between 8·0–9·0 cm. carapace length. The average annual growth rate of about 30 mm. observed in the case of *P. homarus* as a result of the present investigations seem to be quite in agreement with the earlier observations on other species.

EXPERIMENTS IN TAGGING

Early in 1964 some preliminary experimants in tagging the lobsters were conducted at Muttom. Dart tag similar to the one used by Dawson and Idyll (1951) and others has been used. Few lobsters were tagged with this tag and kept in the sea inside experimental lobster traps. Feeding was done every alternate day. These lobsters were alive in these traps for nearly 2 months during which time some underwent moulting. Final measurements of the lobsters could not be taken since the traps were lost and could not be tracad after about 2 months due to very heavy seas. However the experiment has proved beyond doubt the suitability of the tag for field studies. It has also shown that mortality due to the effect of tagging is quite negligible.

DISCUSSION

Miyamoto and Shariff (1961) describing the lobster fishery of Kanyakumari District gives certain observations of the local fishermen with the suggestion that it should be pursued and investigated by fishery biologists. One of such observations is "female lobsters caught throughout the fishing season bear eggs". Data presented in Table II gives the percentages of berried females occurring in the fishery during the entire period of present investigation. The observation seems to be partly correct. Even though their percentages are very low in the latter half of the fishing season berried females do occur in the fishery throughout the 4 or 5 months of fishing there. But the females occurring in the fishery are not all berried at any time. Another observation is that small lobsters 1–1½ inches in body length are caught during the season in traps fixed near the coast. This observation does not appear to have any truth in it since throughout the period of observation of the present study of 7 years not a single specimen of such small lobster was obtained from these catches. The minimum size obtained in the trap is about 80–90 mm. in total length which is very much larger than the size mentioned.

The trend of the total landings of lobsters in Muttom Colachel zone seems to suggest that stocks are not seriously depleted. Because of the lack of data available on total landings of lobsters for the seasons 1962–63 and 1963–64 this conclusion must be tentative. But the earlier data shows that but for some natural fluctuations taking place in the fishery the stocks are not much low as is evident from the decline in the catches from 1958–59 season onwards and later increase in the catches in 1961–62 season to almost the 1958–59 level. The temporary decline in catches noticed in 1959–60 and 1960–61 seasons may be due to natural fluctuations caused by any one or more of a combination of factors such as temporary hydrographic barriers like unfavourable currents, temperature variations, etc., scarcity of food and unfavourable meteorological conditions. However, observations made throughout the present study tend to indicate that indiscriminate capture of all sizes of lobsters including the smaller sizes from 90–140 mm. total length, which are not favoured by the freezing industry and thus fetch only very low price and are fished mostly by traps, might sooner or later affect the total production at a later stage. It is felt that fixation of a minimum size limit for lobster catches might be useful to avoid this. Hence it is suggested that a minimum size limit of about 130 or 140 mm. total length should be enforced in the fishery, prohibiting the landing of lobsters of lesser sizes.

ACKNOWLEDGEMENT

I wish to take this opportunity to thank Shri K. Rajasekharan Nair for the help in collecting the data.

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THE *PANDALUS BOREALIS* IN THE NORTH SEA AND SKAGERAK

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ABSTRACT

The Danish catch of *Pandalus borealis* started about 1930 and increased to 1·9 mill. kg. in 1963. Until 1960 it was carried out in the Skagerak and northern Kattegat but since this year an increasing part has been taken in the western North Sea.

According to a Danish-Norwegian-Swedish convention of 1952 the minimum mesh in the cod-end of the trawl in the Skagerak-Kattergat is 17 mm. knot to knot. Some decreases of the stock in the Skagerak may seem to have been found, in that the older trawl in some seasons now seems to give diminished catches and is replaced by larger trawls.

A great diminution of relative abundance of the larger prawns has been found in the course of 50's.

Catch and fishing places. The *Pandalus* is found from about 100 m. depth during the winter and from about 150 m. during the summer, out to about 450 m. *See* map in my paper: The Nephrops, etc., in this volume. The catch of *Pandalus* started at the beginning of the century from Sweden and Norway when great quantiies were found in some fjords from the Skagerak. The fishery soon spread to other fjords, and about 1910 a Swedish prawn fishery began also in the open Skagerak. The Danish fishery started about 1930.

Afterwards all three countries extended their prawn fisheries to the western Skagerak and also to the deep channel in the north-eastern North Sea, and in 1960 a Danish and Norwegian fishery for the *Pandalus* started at the Fladen ground in the north-western North Sea. In 1961 the total catch of *Pandalus* in the Skagerak was 8·7 mill. kg. of which 4·4, 2·4 and 1·9 mill. kg. from Sweden, Norway and Denmark, respectively. In the North Sea 3·9 mill. kg. were taken by Norway, 1·2 mill. kg. from Denmark.

The fishing season in the Skagerak is for Denmark March–October but some fishing is carried out also in the other months, the Swedish is more uniform the whole year, but with a maximum during the summer. The Norwegian fishery is to a large part carried out in the winter months when the prawns carry roe. At the Fladen ground the fishery takes place only April–July.

The gear is the special Prawn-trawl, a relatively high implement with long and broad wings. In recent years the size of the trawl has increased, especially in Sweden, in some cases a very large herring trawl has been used. According to a Danish-Norwegian-Swedish convention of 1952 the minimum mesh in the cod-end is 17 mm. knot to knot, but most of the fishermen use larger meshes, up to 22 mm. in order to avoid the smallest prawns.

Release through the meshes and by a sieve on board has been investigated but is not reported here. *The bycatch* of fish in the eastern Skagerak is about ⅔ of the total weight, in the western in Skagerak about ½, at the Fladen it is relatively large in the summer and autumn, which is the main reason for the short fishing season here.

A great change in the length distribution was found in the eastern Skagerak between 1956 and 1960. In the other regions the lengths have been investigated only in recent years. From Fig. 1 it is seen that in May–August 1934–38 and 1949–53 the largest number of prawns were between 70

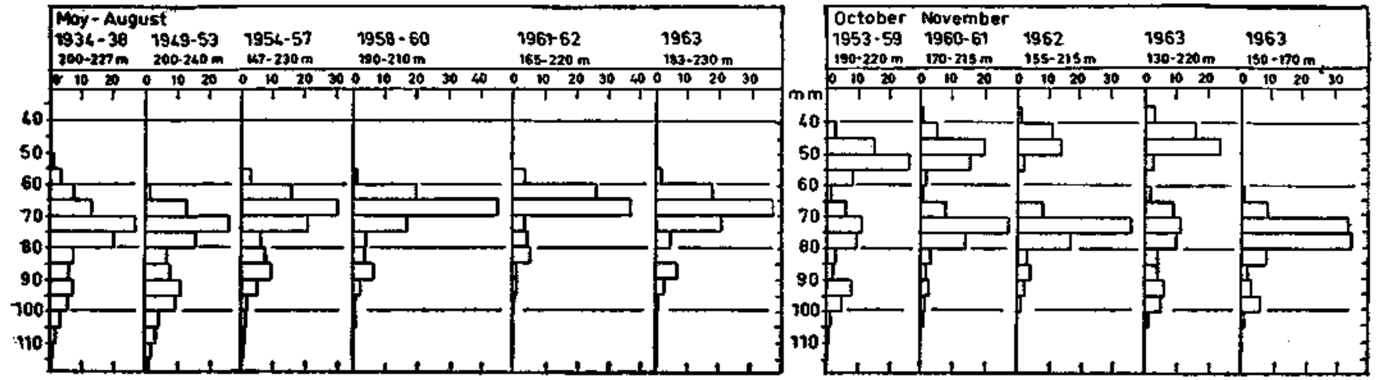

FIG. 1. Percentage length distribution of *Pandalus borealis* in the eastern Skagerak in about 200 m. depth.

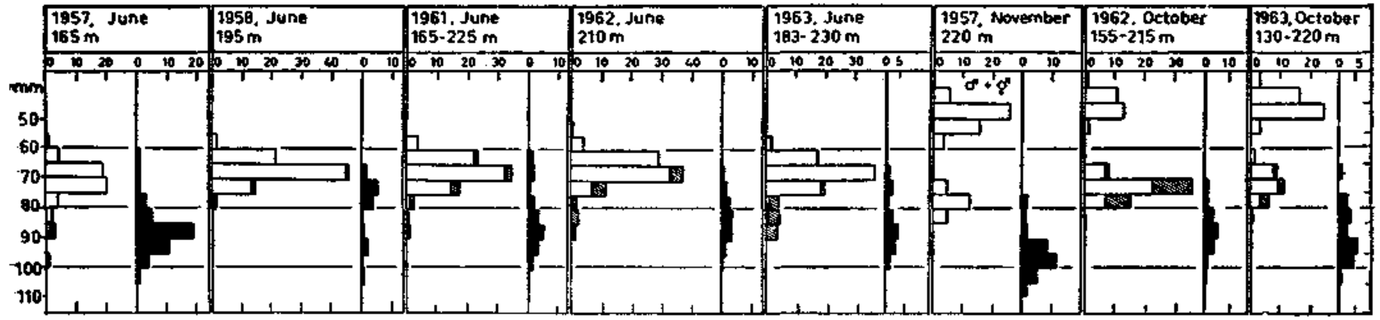

FIG. 2. Percentage length distribution of sexual stages of *Pandalus borealis* in the eastern Skagerak in about 200 m. depth. White, males; hatched, transition; black, females.

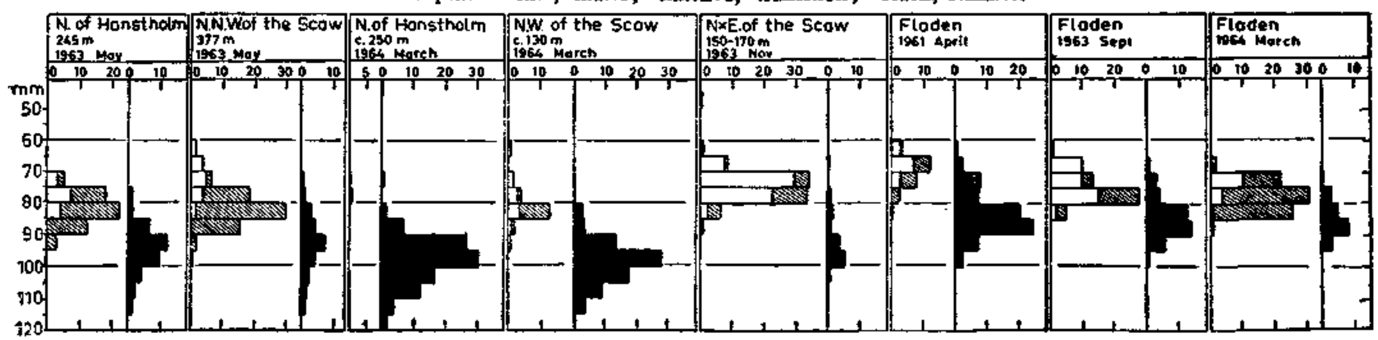

FIG. 3. Percentage length distribution of sexual stages of *Pandalus borealis* in the Skagerak and on the Fladen ground. All from commercial catches except from the Fladen, September 1963. White, males; hatched, transition; black, females.

and 80 mm. long, but in 1958–63 between 60 and 70 mm., and in 1961–62 very few were in the 70–74 mm. group, in 1963 a few more. For October–November a similar change was found for the smallest group, the ½ year old, with 1960–61 as the transition years. In the next length group, about 70–80 mm., 1½ years old, the length was less in 1960–62, but in 1963 about the same as in 1953–59. In the commercial catch the smallest group is not found and neither any of the smaller prawns in the next group on account of the larger meshes used.

The analyses of the samples have been carried out until 1938 by E. M. Poulsen, 1949–53 by J. B. Kirkegaard, J. Knudsen, K. Sick and myself, after 1954 by K. Salmberg.

In Fig. 2 it is seen that the change in the summer was due to the fact that the average length of both males and females became less. For the females the length of the two-years-old decreased from 1957–58 to 1961–62, but in 1963 it was only very little lower than in 1957–58. Most remarkable is the occurrence of 1-year-old females. In 1961 they were of the same average length as the males, in the other years 1958–63 a little larger. They are either primary females without or with a very short-lasting male stage. This may be an example of a law that growth rate and sexual development are in reverse relation to each other.

The change in the autumn is the same. The mean length of the ½ year old males in November 1957 was a little under 50 mm., in October 1962–63 a little over 45 mm., and the lengths of the 1½ years old males culminated at 75–79 and 70–74 mm., respectively, and in this age-group with a relatively large number in the transition stages, and also with relatively more females.

The cause of this change is as yet unknown. The fishery cannot have any influence upon the sexual development. In an earlier paper I assumed that it might be due to an immigration, but more probable it may be caused by a fluctuation in the food supply or the temperature.

In Fig. 3 some commercial catches from the middle and western Skagerak and from the Fladen ground in the North Sea are compared. It is seen that two samples from NW of the Skaw and north of Hanstholm from March 1964 consist of very large female prawns and very few per cent. of males and transitional stages. The trawl mesh sizes have not been noted for these catches, but it must be assumed that they have been very large.

From Fig. 3 and also by comparing with Fig. 2 it appears that the females (of 2 years and older) caught on the Fladen ground were smaller than those found in the Skagerak at the same time of the year, the sizes of the males and transition stages were nearly the same. The mean length of the whole catch in nearly all samples investigated has been a little less on the Fladen than in the Skagerak, and especially prawns over 10 cm. total length seem to be very rare or missing on the Fladen.

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THE NORWAY LOBSTER, *NEPHROPS NORVEGICUS* IN THE NORTH SEA, SKAGERAK AND KATTEGAT

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ABSTRACT

The Danish fishery for *Nephrops* started in 1931, and in 1957-63 it has been about 1·7 mill. kg. a year. It has been carried out in the Skagerak and Kattegat.

The fishery seasons seem mainly to be restricted to the yearly periods when the bottom temperature is over 5° C., and it may seem that the *Nephrops* hibernate deep in the bottom when the temperature is lower. The relative number of the larger ones has shown a strongly progressing decrease in the course of the years in each of the regions where it has been investigated.

Taggings by a plastic tag fixed to the tail have shown no migrations or perhaps migrations of some few miles. The length distribution measured in mm. for each locality with a certain depth has shown summits of about 8–11 mm. distance in males between 80 and 140 mm. total length, corresponding to the growth by a moulting.

Distribution and landings. In the North Sea, Skagerak and Kattegat the Norway lobster is found from about 30 m. to about 300 m. mostly on soft clayish bottom and on sand mixed mud. It is very rare in the Sound and in the south-western Kattegat and the northern part of the Belts, because its distribution is limited by a salinity of about 30‰ and it is rare even in water of less than 32‰. In the northern North Sea it is frequent on some grounds, to the south to off Northumberland (*see* Cole, Pope and Thomas).

The landings from the Skagerak started about 1910 from the eastern part where the Norway lobster was taken as bycatch by the *Pandalus* fishery which then was extended from the fjords into the open Skagerak and a special fishery for *Nephrops* developed from Sweden. The Danish fishery for *Nephrops* began about 1930 as bycatch of the *Pandalus* fishery to the north of the Skaw and in a special fishery in the northern Kattegat. Afterwards the fisheries extended over larger parts of the Skagerak and to the middle and southern Kattegat. In the beginning of the 60'ies the Swedish catch had grown to about 900 tons a year, the Danish to 1,700 tons. From Norway upto about 100 tons are taken annually as bycatch of the *Pandalus* fishery, from Germany a similar part by the ordinary bottom trawl fishery in the Kattegat and eastern Skagerak.

The annual Scottish landings, mainly from the Moray firth and Firth of Forth, are growing, and in the beginning of the 60'ies they were about 1,500 tons. From England about 600 tons are taken partly in a special fishery, partly as bycatch. The bycatch of *Nephrops* by Belgian trawlers is about 350 tons, but for the other countries a total of only under 200 tons is noted in the statistics.

In this summary of the biology the selection by the meshes, the food and the fecundity and other items have not been mentioned.

Yearly variations in the Danish landings from the Skagerak and Kattegat are shown in Fig. 2 together with the temperature where the *Nephrops* is caught. It is seen that they are only caught when the temperature is over 5 or 6° C., and that the seasonal increase of the catch at the various grounds follows the rise of the temperature until about 11°. An exception is a maximum of landings at Hirtshals and Skagen in February-March, which is due to a bycatch from the fishery for *Pandalus* when this takes place mainly in 100–150 m. depth to the north-west and west of the Scaw.

In the rest of the year almost the whole catch is taken by special *Nephrops* fisheries, from Hirtshals mostly in 60–100 m. depth from west to north-east of this harbour, from the Scaw the fishery is mostly carried out to the north-west, east and south-east of the harbour in 40–70 m. From Frederikshavn it is carried out mostly in about 40 m. depth to the east of the harbour, partly also to the north-east in 40–70 m., from Grenaa mostly south and east of Anholt in about 40 m. depth, partly also to the north-east of Anholt. The rise of the temperature comes later in the northern Kattegat than in the Skagerak and still later in the southern Kattegat because the water of the lower water layer which had been upper layer in the Skagerak moves southwards only little influenced by the surface temperature. The landings culminate earlier than the temperature because many of the cutters leave the fishery when the rough autumn weather begins.

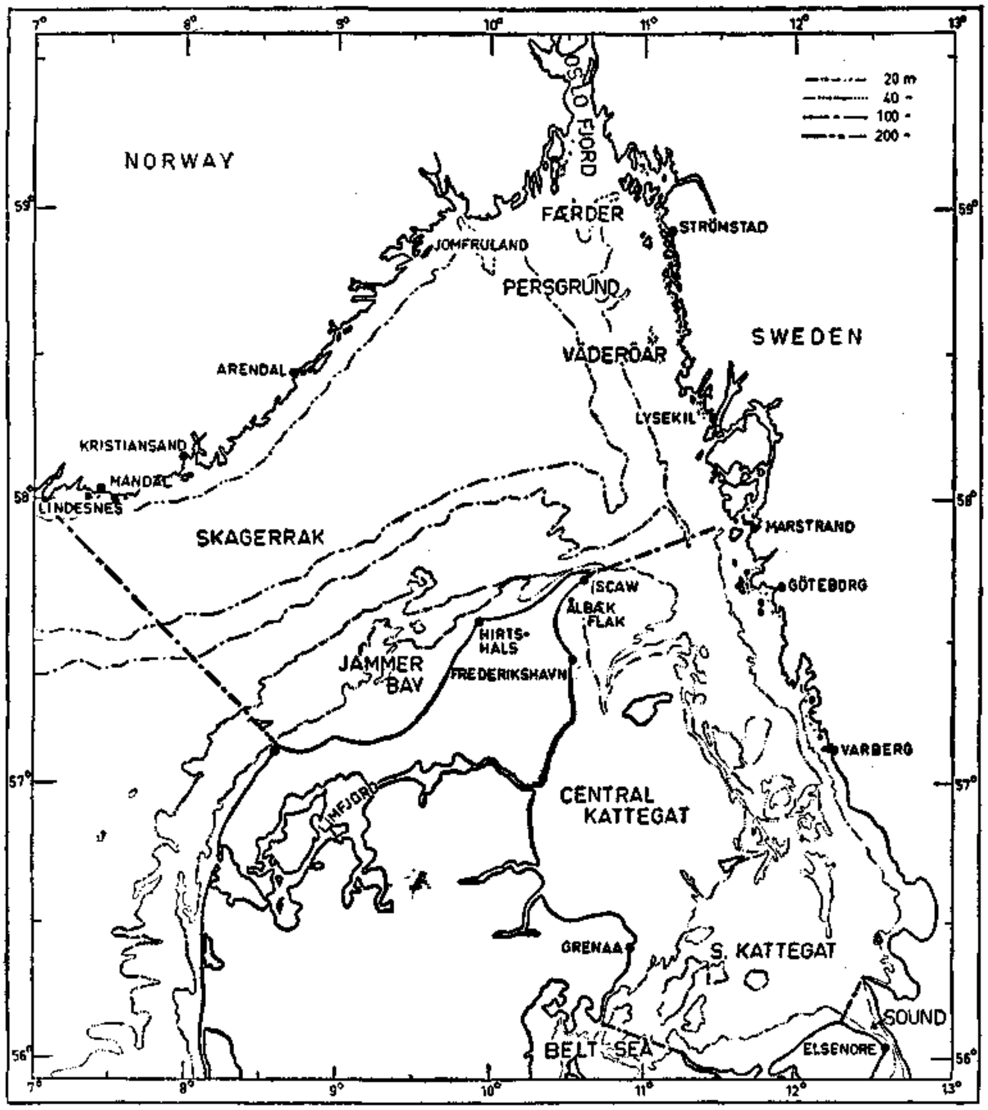

FIG. 1. The Skagerak and Kattegat.

Day and night hauls have shown that at depths smaller than about 80 m. the *Nephrops* are least available by day especially during the summer. The smaller hide more in the bottom than the larger ones. The phenomenon has been studied by Thomas and Simpson, by Sögaard Andersen (at the Faroes) and less systematically by myself. In Fig. 4 catches from day and night off Marstrand in 1961-62 have been compared, and also for the northern Kattegat, but here not for the same years and partly not for the same places. Fishing by night from the research vessel started in 1960 when the stock in the northern Kattegat was so depleted that the catches by day became very small during the summer. Also dark days may improve the catches, on light days most often only a few large *Nephrops* are caught. The same may be the case if currents has lifted the trawl so it has moved too lightly over the bottom.

The length distribution of those caught is never that of the total stock; the *Nephrops* are always more scarcely represented in the catch the smaller they are. When catches have been made more or less under the same conditions they may be considered comparable.

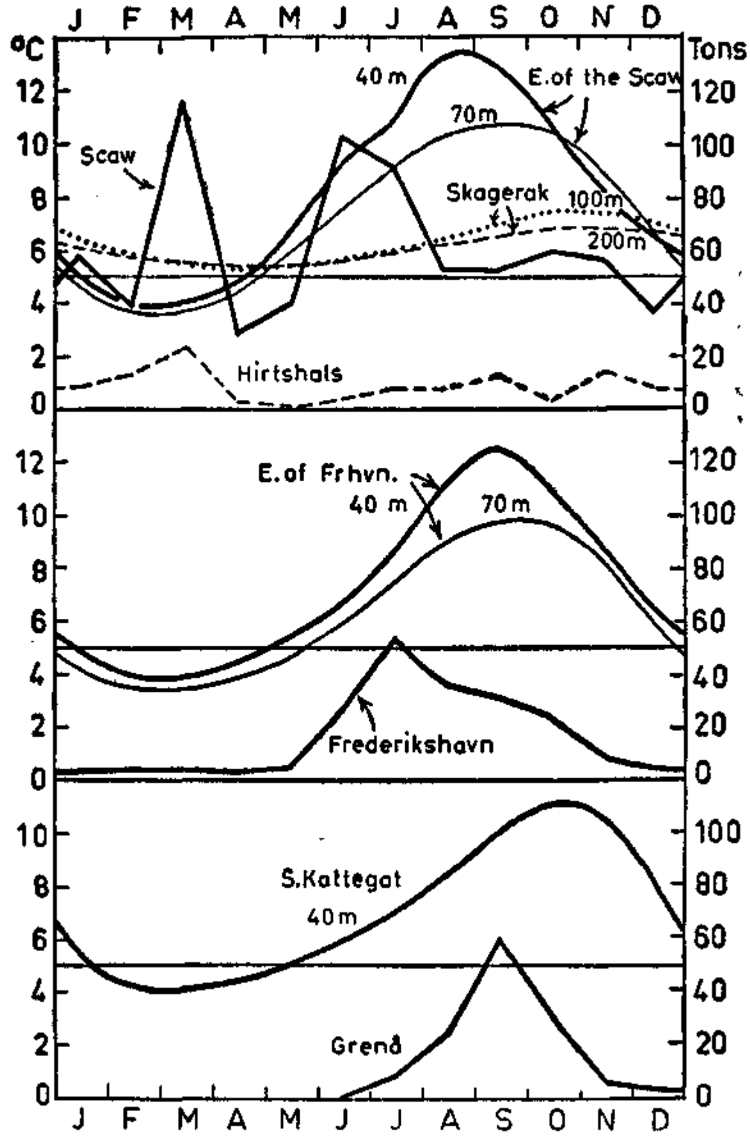

FIG. 2. Mean monthly landings of *Nephrops* 1959-63 (broken curves) compared with the average temperature for a longer period of years.

The length distributions in different regions are shown in Figs. 2 and 3. Smoothing for each 3 cm. has been used in order to eliminate irregularities in the curves due to a too small material, except for the large Scottish material (Thomas, 1962). The smoothing has flattened the curves a little.

It should be noted that the Scottish length distributions are published in 5 mm. groups of carapace length and have been recalculated to total length. The figures used here are the means of the percentage distributions in the single years, whereas the other means for series of years are calculated from the sum of the *Nephrops* caught in the period in question.

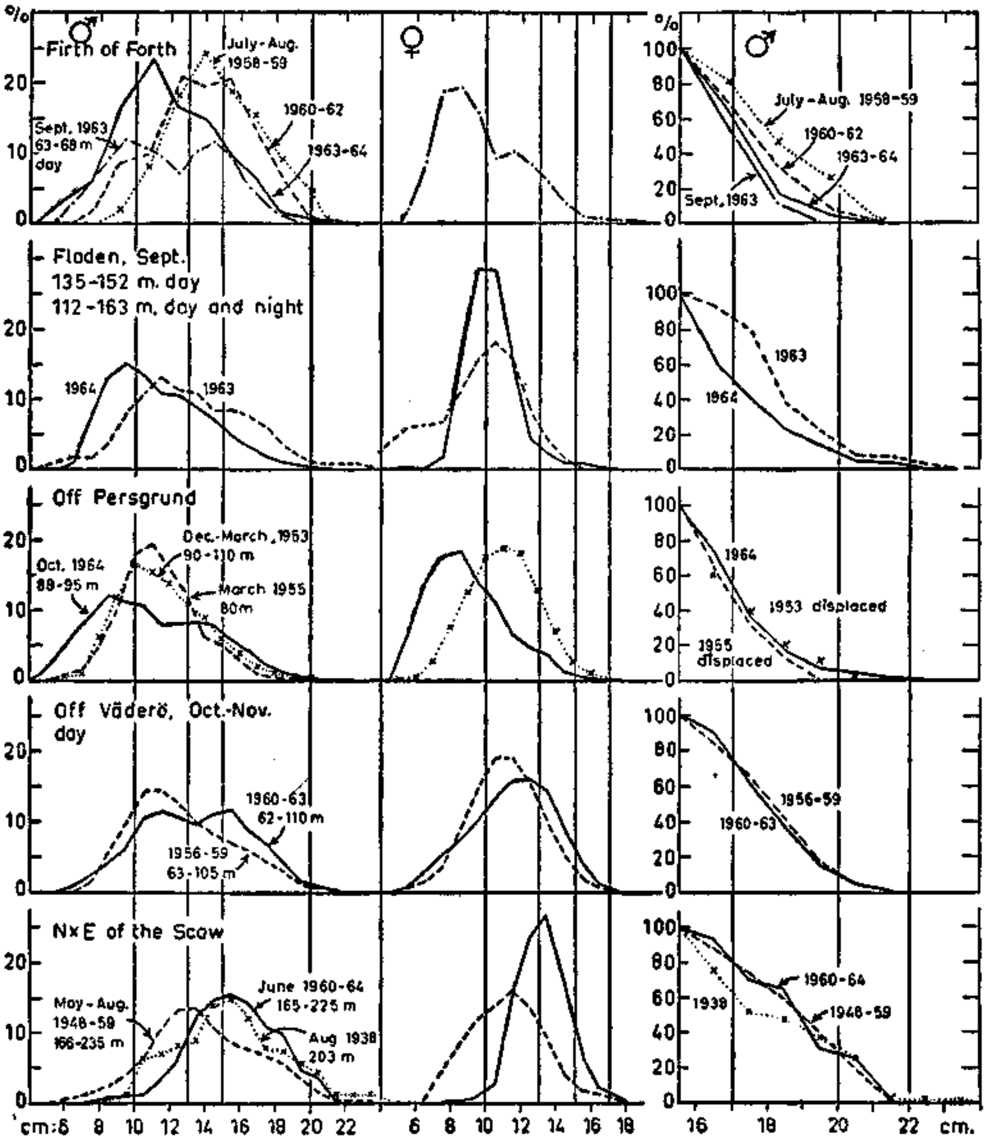

FIG. 3. Two left-hand columns: Percentage length distribution of males and females *Nephrops*. Right-hand column: Percentage number of male *Nephrops* in relation to number at 150–159 mm. = 100%.
For the Scottish, Norwegian and Swedish measurements, which are to the nearest whole cm., the curves have been displaced ½ cm. to the right
According to Danish investigations except for Firth of Forth: Years at right-hand side in the columns from Thomas, and off Persgrund: 1953 from Birger Rasmussen, 1955 from H. Höglund.

In the Firth of Forth the mean length of the males shows a tendency to decrease as Thomas has pointed out, although they have varied much from year to year, due to some unknown different conditions during the fishing which, *e.g.*, may have caused the smaller ones to hide more in the bottom in one year than in an other (comp. Thomas, 1962). The rather regular increase of the steepness of the declining parts of the curves for the males indicates the increased reduction of the stock by the fishing.

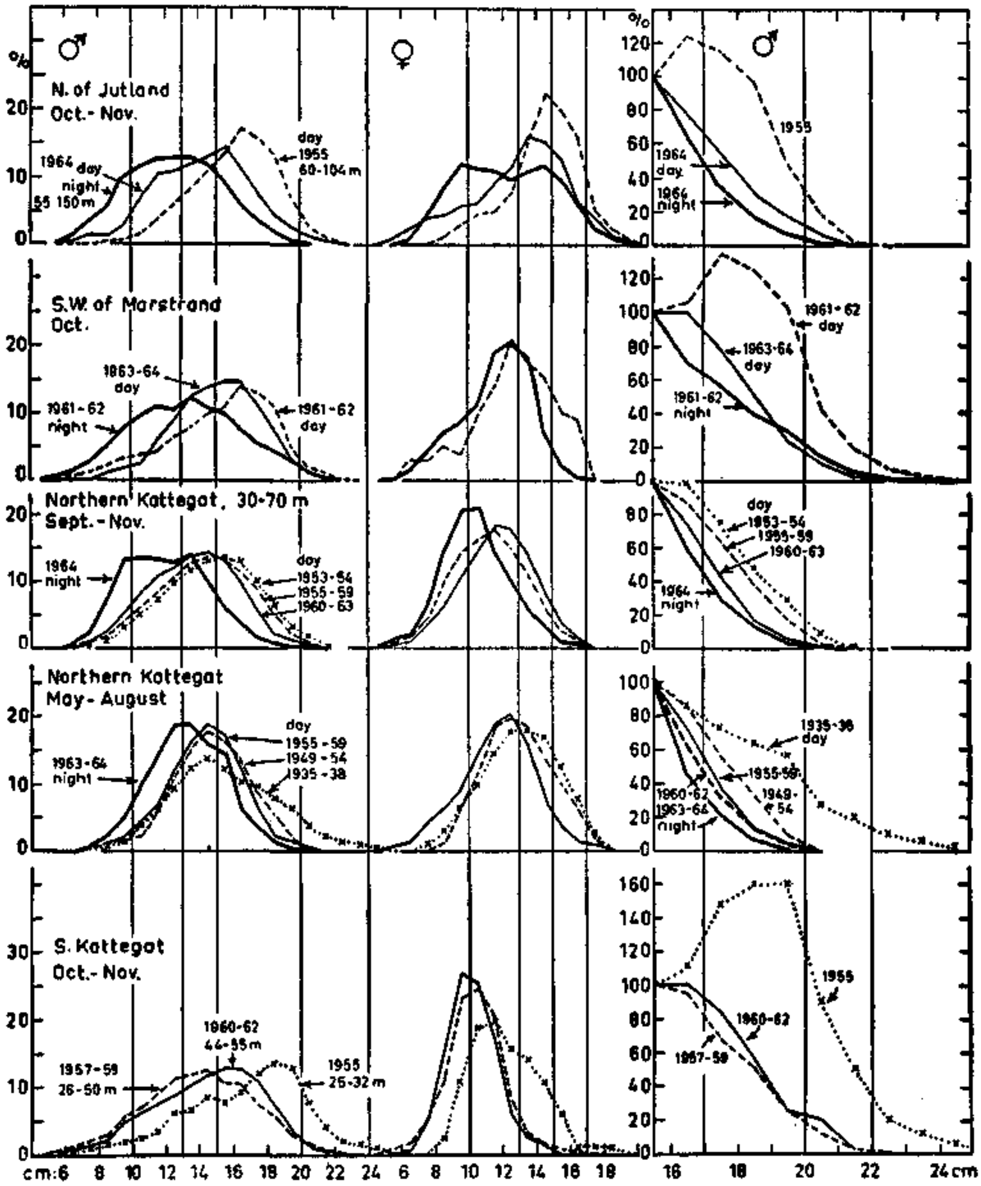

FIG. 4. Continuation of Fig. 3.

On the other hand the large difference in the distribution and the decline at the Fladen ground in 1963 and 1964 may be due to the small material in 1963 or to differences in places and depths for the stations.

In the northernmost Skagerak, off Persgrund, a decrease of the mean length is found, but the steepness of the decline of the number of males over 15 cm. has not changed. The small mean length and the steep decline off Persgrund most likely is due to the intensive fishery which has been carried out here especially from Sweden.

Off Väderöar the mean length has increased. This might be due to a smaller recruitment of the stock in some recent years which is indicated by the minimum in the length distribution of the males especially at 12–14 cm. which is seen also off Persgrund. A smaller recruitment of *Nephrops* including also those of 15 cm. should result in a temporary slower decline of the number of males over 15 cm., and the fact that the decline is unchanged on the two grounds may indicate that actually the reduction by the fishery is faster now than it was previously.

To the north of the Scaw at about 200 m. the decline has also been essentially the same. Here the *Nephrops* is only a small bycatch of the prawn fishery and perhaps the length distributions of the small number caught by the research vessel are not comparable from one year to another.

To the north of Jutland at depths of 50–150 m. a decrease in the average length and an increase of the steepness of the decline of larger males are found. Actually in 1955 an accumulated stock of *Nephrops* over 15 cm. was found but in 1956 it had disappeared, and in 1964 the decline was still steeper. To the south-west of Marstrand an accumulated stock existed in 1961–62 but had disappeared in 1963–64. Here the decline in the number of large *Nephrops* is very slow which may be due to the protection provided by the stony grounds surrounding the narrow fishing place. Although the migrations of the *Nephrops* are very small there are indications that the larger individuals may stray a little more than the smaller ones.

In the northern Kattegat relatively many very large *Nephrops* were found in 1935–38 when the fishery had been carried out in a few years only. In 1949–54 those over 20 cm. had become very rare, and in the following years this development continued.

In the southern Kattegat the commercial fishery started about 1950. An accumulated stock of large *Nephrops* was found in 1955 but it had disappeared in the following years. The positions and depths where the hauls were made have not been exactly the same in these years, and perhaps the results are not fully comparable. An accumulated stock had been found at some places even in 1961.

No doubt the steady decrease of the average length and of the relative number of larger *Nephrops*—the increasing steepness of the decline—must be due to the increasing fishery being so intensive that the slow growth of the *Nephrops* cannot compensate for the removal of the larger animals by the fishery. Especially we can follow this decrease in the northern Kattegat, and the commercial value of the stock here is now very reduced. Improvements of the trawl and the shifting during the summer to fishing only by night have until now secured a profitable fishery.

The different lengths in different regions. The mean length is very small in the Firth of Forth (and in the Moray Firth), at the Fladen, in the northernmost Skagerak and by night in the northern Kattegat. It is evident that the cause in the northern Kattegat is the steadily more intensive fishery, and this may be the cause also for the northernmost Skagerak and for the Firth of Forth. In fact Thomas has shown that the reducing effect of the fishery seems to explain the differences in the mean length in different regions at Scotland.

The low mean length at the Fladen can hardly be caused by the fishery here which is not very intensive for *Nephrops*, but must be assumed to be due to natural conditions. It may be that number of predatory fish is very large here. The predators, and especially the cod eat many *Nephrops* also on the other grounds.

The largest *Nephrops* are found off Marstrand (by day) as explained above, and to the north of the Scaw and in the southern Kattegat where the fishing is relatively new.

Protection of the stock against overfishing. A convention between Denmark, Norway and Sweden in 1952 introduced a common total minimum length of 150 mm. Denmark had 160 mm. from 1936 to 1953. In 1959 the international minimum was changed to 130 mm., but Denmark has kept to 150 mm. although just as many under this length has to be thrown overboard at the most important Danish fishing grounds, the northern Kattegat, as in the northernmost Skagerak. It may seem that the high Danish minimum size is a contributory cause for the fast development of the Danish fishery. A lowering of the minimum length must accelerate very strongly the destruction of the commercial value of the stock because the previous curve of decline in a few years will be displaced in the main parallel to itself from the old to the new size-limit.

The growth can be determined by the Petersen method because the migrations are very small. Figure 5 in my paper (1962) shows the length distribution of the males in some large catches where the depth has not varied more than 1 or 2 m. during the haul.

The total lengths of the *Nephrops* were measured for the haul from October 1960, for the other hauls the lengths from the eye were measured.

According to the distance between the maxima the growth of the males by one moulting in mm. is as follows:—

At a total length of	*100 mm.*	*120 mm.*	*140 mm.*
Off Väderöar ..	8	9	9
Off Marstrand ..	10	10	8?
N. Kattegat .	8–9	8–9	8–10
S. Kattegat ..	12?	12	10?

Almost 30% of the *Nephrops* tagged since 1962 have been under 14 cm. but of these only 3% are recaptured partly because the smaller specimens hide more in the bottom than the larger, partly because a number of those recaptured have been shoveled overboard when the larger were sorted from the catch. Also those over 190 mm. have shown a recapture of only 3%, which may indicate that they have a larger tagging mortality or natural mortality.

About 15% of the tags found have not been observed on board but were noted in port. For many of those found at sea the places of recapture have not been stated accurately.

The time intervals between tagging and recapture were as follows:—

Months after tagging ..	1–2	3–5	6–8	9–11	12–13
April–June 1958–64:					
Number recaptured ..	147	11	.	1	
Mean distances, miles ..	4 (71)	4 (6)		1 (1)	
Smallest and greatest ..	0–15	1–6		1	
October–November 1947–63:					
Number recaptured ..	44	9	4	9	4
Mean distance, miles ..	6 (36)	3 (6)	3 (3)	7 (8)	6 (1)
Smallest and greatest ..	0–13	1–7	1–11	0–19	4–8

The longest distance reported was 19 miles for one-tagged on 19, October 1961 and recaptured by a German fisherman on 15, September 1962, but it has not been possible to get the position verified.

The average distance is the same notwithstanding the time elapsed. Because the distance covered by a haul is about 8 miles in consideration of the uncertainty of the places of recapture it must be concluded that the *Nephrops* only in few cases undertakes any migrations.

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THE CRUSTACEAN FISHERY RESOURCES OF INDIA

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Abstract

The crustacean fisheries of India have assumed considerable importance in recent years in the economy of the country. Exports of frozen and canned prawns and frozen lobster tails have been steadily on the increase earning very valuable foreign exchange. The commercially important crustaceans consist of the prawns, lobsters and crabs caught from the sea and brackish waters. Except the giant freshwater prawn, limited quantities of which are exported in frozen condition, the freshwater crustaceans contribute only to a sustenance fishery of minor importance.

The annual marine crustacean landings in India average about 80,000 tonnes of which 97·5% is constituted by prawns. The paper discusses the present condition of the crustacean fisheries of India.

The estimated average landings of marine crustaceans in India comes to nearly 80,000 metric tons which is about one-tenth of the total marine fish production. If the prawns caught from backwaters, creeks and estuaries which are essentially of marine origin, are excluded, the purely freshwater species are of negligible importance. The freshwater prawns and crabs form merely a sustenance fishery and the only species of some commercial importance is the giant freshwater prawn which is caught in very limited quantities from certain areas. No statistics of freshwater crustacean catches are available and therefore this account deals mainly with the marine forms which are not only of considerable economic importance now but have potentialities for further development also.

The crustacean fisheries could be broadly grouped under prawns, lobsters and crabs and of these, the prawns are the most important accounting for about 98% of the marine crustaceans landed. The growth of the prawn industry during the past one decade has been most phenomenal. While before the Second World War, and immediately after, exports of prawn products consisted only of dried and semi-dried prawns to the neighbouring countries of Ceylon, Burma and Malaya the picture has completely changed with the adoption of freezing and canning methods. A chain of events took place within a short time which helped the industry to the unique position it occupies today. The main factor that contributed to the rapid development of the industry was the ever-increasing demand for prawns in the United States. Some of the West European countries also which had made quick economic recovery after the war began to show interest in the import of prawns. By the early fifties a number of ice factories with cold storage and freezing facilities came into existence which enabled preservation of prawns in good condition for long periods. Use of mechanised fishing craft and nylon nets began to bring in larger catches than ever before. Improvement in road transport facilitated quicker movement of catches from landing centres to processing centres. Availability of fresh prawns in good quantities encouraged the development of an export industry and the increasing demand for prawns and allied products gave additional fillip to the trade. The annual exports now (1964) stands at about 50 million rupees.

The estimated landings of marine crustaceans in India are given in Table I. It could be seen that the west coast accounts for more than 80% of the catches (Fig. 1). The catches are higher in the northern section comprising of the coasts of Maharashtra and Gujarat than in the southern section but are dominated by the smaller sized species (Fig. 2). Bulk of the exports are from the southern section comprising the coasts of Mysore, Kerala and a part of Madras. The exports of prawns and lobsters and of crustacean products are given in Tables II and III.

TABLE I

Estimated landings of prawns and other crustaceans in India during the years 1958-64
(Quantity in metric tons)

Year	West coast				East coast				
	Penaeid prawns	Non-penaeid prawns	Other Crustaceans	Total	Penaeid prawns	Non-penaeid prawns	Other Crustaceans	Total	Combined total
1958	26,293	53,501	256	80,050	2,910	2,486	1,252	6,648	86,698
1959	23,548	36,775	461	60,784	4,084	1,030	1,632	6,746	67,530
1960	27,503	35,004	460	62,967	4,256	1,267	2,111	7,634	70,601
1961	32,864	22,018	297	55,179	6,219	1,667	1,741	9,267	64,806
1962	42,227	34,576	168	76,971	6,023	409	863	7,295	84,266
1963	30,747	39,554	223	70,524	10,323	969	1,838	13,130	83,654
1964	52,018	30,164	235	82,417	11,369	1,342	4,330	17,041	99,458

N.B. (i) West coast figures are inclusive of Goa except for the years 1962-64 for which data were not received.

(ii) Landings in Andamans and Laccadives are not included. The same amount to less than 5 m. tons.

(iii) The combined totals are nearly 82,000 tonnes and 95,000 tonnes for 1965 and 1966 as per information available at the time of the printing of this article.

TABLE II

Export of crustacean products from India 1960-64

	1960	1961	1962	1963	1964
1. Frozen prawns					
Quantity ..	12,11,165	14,62,656	22,38,190	39,66,899	58,70,031
Value in Rupees ..	58,66,123	73,66,872	1,08,20,276	2,12,03,766	3,15,18,242
2. Canned prawns					
Quantity ..	3,19,510	6,21,773	9,69,928	12,31,274	10,73,927
Value in Rupees ..	17,84,047	42,22,907	65,58,924	75,75,594	69,91,927
3. Frozen lobster-tails					
Quantity ..	..	..	39,763	53,304	41,304
Value in Rupees ..	..	..	2,26,364	3,12,721	3,71,021
4. Dried prawns					
Quantity ..	..	..	..	28,08,675	30,08,650
Value in Rupees ..	..	..	..	93,24,698	89,96,764
5. Prawn powder					
Quantity ..	..	..	..	2,55,015	5,11,187
Value in Rupees ..	..	..	..	84,363	1,25,768
6. Prawn pickles ..					
Quantity ..	..	..	..	..	683
Value in Rupees ..	..	..	..	..	2,805

TABLE III

Export of prawns and lobsters from India 1953–64

Year	Frozen prawns Quantity (Kg.)	Frozen prawns Value (Rupees)	Canned prawns Quantity (Kg.)	Canned prawns Value (Rupees)	Frozen lobster-tails Quantity (Kg.)	Frozen lobster-tails Value (Rupees)
1953	13,268	57,740	..	..	..	..
1954	60,600	2,72,893	..	..	..	..
1955	48,145	2,94,002	..	..	..	..
1956	1,90,186	10,96,716	..	..	..	..
1957	4,96,410	21,33,546	..	..	..	..
1958	7,79,526	37,90,200	..	..	..	..
1959	10,49,527	49,23,203	3,72,850	23,23,667	..	..
1960	12,11,165	58,66,123	3,19,510	17,84,047	..	..
1961	14,62,656	73,66,782	6,21,773	42,22,907	..	..
1962	22,38,190	1,08,20,176	9,69,923	65,59,924	39,763	2,26,364
1963	39,66,899	2,12,03,766	12,31,274	75,75,594	53,304	3,12,721
1964	58,70,031	3,15,17,242	10,73,927	69,91,927	41,304	3,71,021

West Coast—Northern Section

The average annual production is about 47,000 tonnes, bulk of which comes from Maharashtra alone. In Maharashtra the fishery is dominated by small non-penaeid species like *Palaemon tenuipes*, *Hippolysmata ensirostris* and *Acetes indicus* which are caught in enormous quantities in the periods April-May and November-December. *Metapenaeus affinis*, *Parapenaeopsis hardwickii*, *P. stylifera* and *Solenocera indicus* are the main medium to large-sized prawns found in this region. The main species of commercial value in the Gujarat region are *M. kutchensis* and *Penaeus indicus*. Fixed bag nets and stake nets are the main gear types used in this region. Detailed accounts of the prawn fisheries of the Maharashtra and Gujarat coasts are presented by others in this symposium.

West Coast—Southern Section

The average annual production of the marine prawn fishery of this area is about 14,000 tonnes. An equally good quantity of prawns are landed from the backwaters also. The same species of penaeids contribute to both fishery, the important species being *Penaeus indicus*, *Metapenaeus dobsoni*, *M. affinis*, *M. monoceros* and *Parapenaeopsis stylifera*, the last one contributing to only marine fishery. The giant freshwater prawn *Macrobrachium rosenbergii* is also caught in good quantities from the backwaters of Kerala. Trawl nets and boat seines are the main gear employed in the fishing from sea, while stake nets, fixed dip nets and cast nets are used in the backwaters. The paddy field prawn fishing is also practiced to a great extent in Kerala backwaters, the season being from November to April. The total catches from this area are estimated at over 10,000 tonnes.

East Coast

The marine landings along the east coast comes to about 9,000 tonnes annually. The commercially important species are *Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *Metapenaeus dobsoni*,

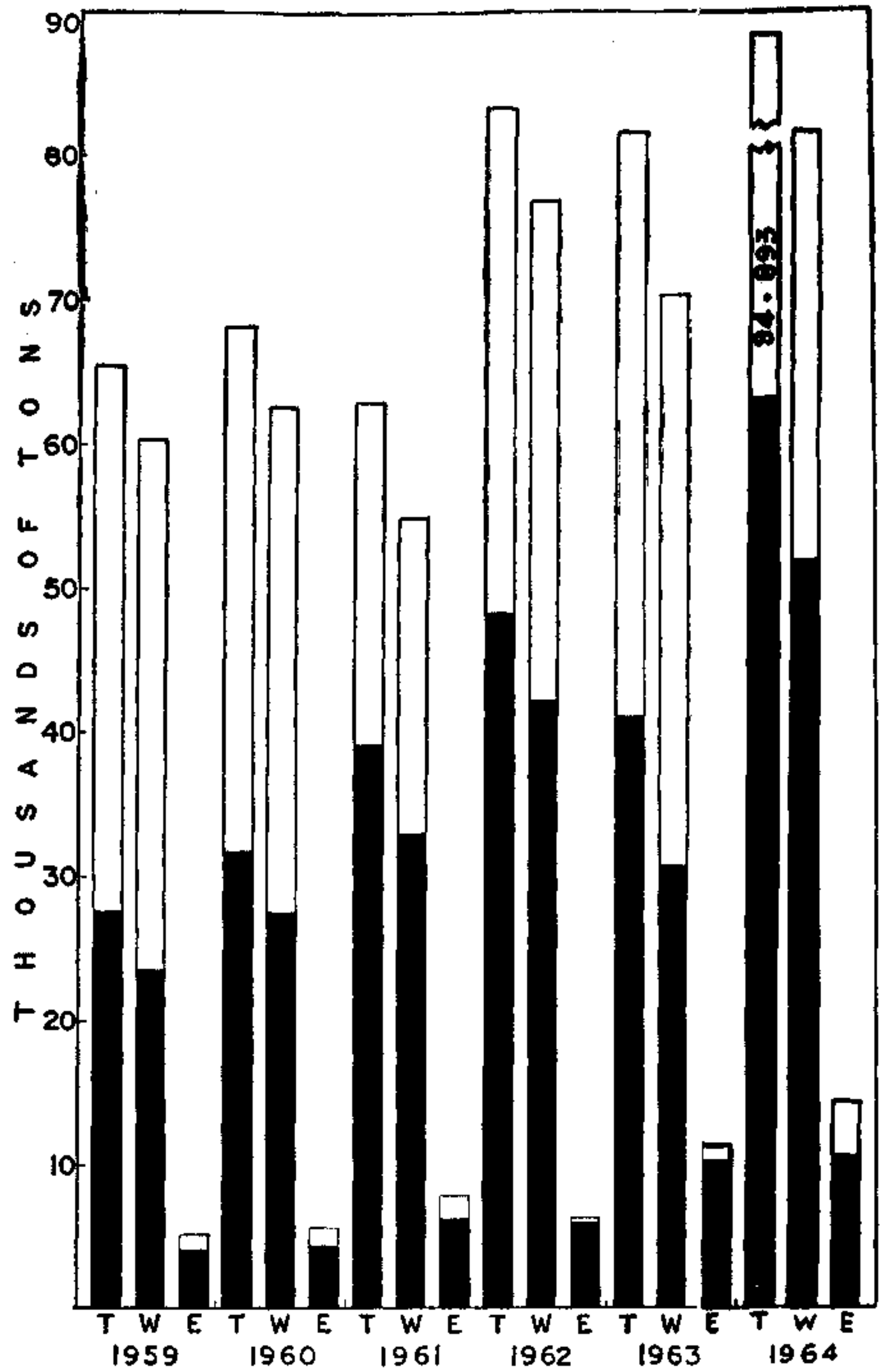

FIG. 1. Estimated annual landings of prawns in India during 1959–64. T—Total landings for west and east coasts; W—west coast; E—east coast; ■ penaeid prawns; □ non-penaeid prawns.

M. affinis, *Palaemon styliferus*, *Metapenaeus brevicornis*. Good quantities of prawns of marine origin are caught from estuarine and other brackishwater areas along the coast of which the most important are the Chilka, Kolleru (Collair) and Pulicat Lakes and the deltaic areas of the Ganges (Sundarbans), Mahanadi and Godavari.

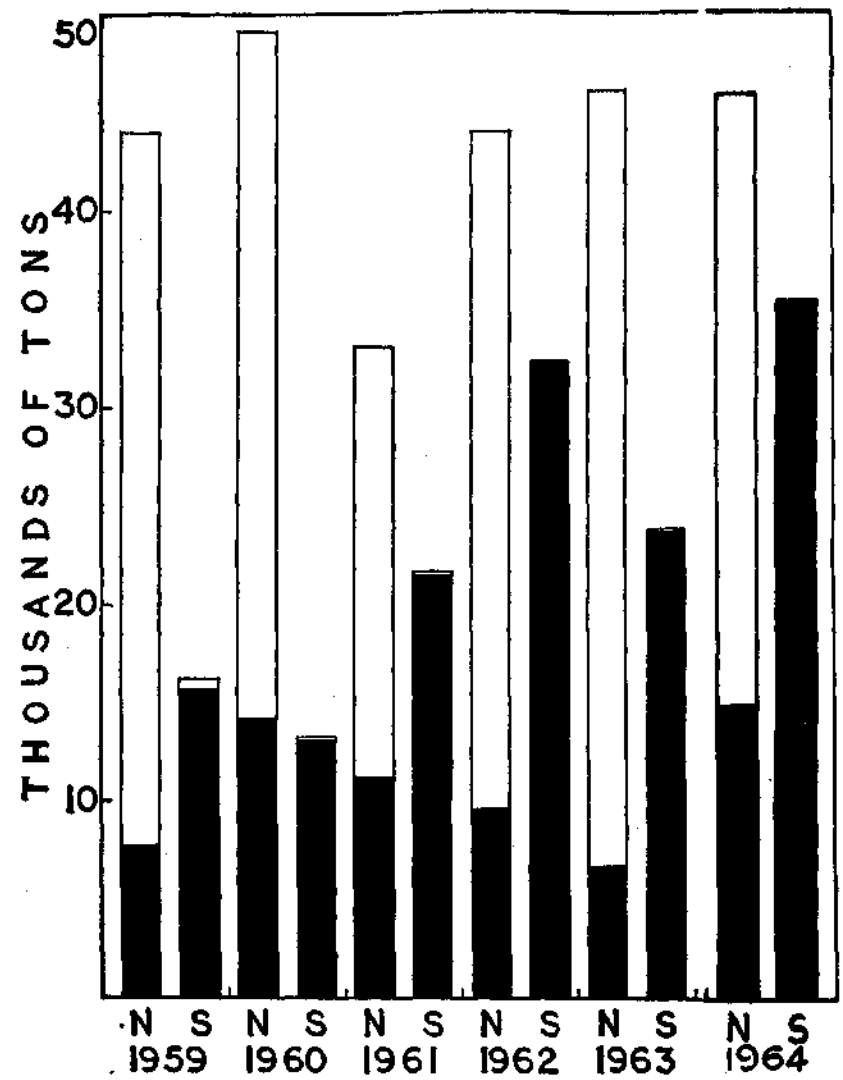

FIG. 2. Estimated annual landings of prawns along the west coast of India. N—northern sector (Maharashtra and Gujarat); S—southern sector (up to Mysore). ■ penaeid prawns; □ non-penaeid prawns.

Chilka Lake. The average annual production is around 1,000 tonnes. *Panaeus indicus* is by far the dominant species which accounts for about 75% of the total fishery. Vast majority of the catches are taken in the monsoon months of June–September, though fishing is carried on in a restricted scale in the other months also. Traps, locally known as "daudi" and "thatta" set along the shore in suitable localities are the main device with which the prawns are caught. Almost the entire quantity is sent to the city markets of Calcutta and Howrah.

Sundarbans. In the winter months of November–February there is a good prawn fishery in the foreshore marine region outlying the Sunderbans, as also in the numerous creeks and "bheris" where fishing is carried out throughout the year except during the monsoon months of June–August. The main gear used in the estuaries is a type of fixed bag net ("Behundijal") worked by the force of tidal current. Dip nets, cast nets and traps are also employed in the estuary to a limited extent. The average annual production is estimated at nearly 1,000 tonnes.

The bulk of the fishery is composed of four prawn species, *viz., Metapenaeus brevicornis, Palaemon styliferus, Acetes indicus* and *Parapenaeopsis sculptilis.* A number of other penaeid and palaemonid prawns also occur in the fishery, some of them in appreciable numbers. The entire quantity is disposed off in the city markets of Calcutta and Howrah.

PRAWNS

Penaeids

Though marine, most of the species are able to live in brackishwaters of very low salinity.

Penaeus indicus Milne-Edwards (Fig. 3).—Taking into consideration the availability in the commercial catches throughout the coastal waters, estuaries and backwaters of India, and maximum size attained this is the most important species. It attains a maximum size of 20–23 cm. The young ones come to the backwaters and estuaries where they grow to about 12–13 cm. The breeding takes place in the sea. It contributes to a good percentage in the backwater fisheries and also paddy field prawn fishery of Kerala.

P. indicus is caught in different types of boat seines in the inshore waters by the indigenous craft and in shrimp trawls in deeper areas by mechanised boats. Occasionally it is caught in shore seines also. In the backwaters and estuaries stake nets and cast nets are the most imporatant gear employed in the fishery of this species. In the Chilka Lake good quantities are caught by traps. In the Kerala backwaters the picturesque fixed dip nets ("Cheena-vala") catch appreciable quantities of these prawns along with the other species. The same fishing methods apply for all the other species of penaeid prawns. In the estuaries and backwaters the species is available almost all through the year though in different sizes. In the sea it is commonly fished during the post-monsoon months.

Penaeus monodon Fabricius.—More common on the east coast especially along the northern parts (Bengal and Orissa). On the west coast it is frequently caught in stray numbers in the northern section and in less numbers along the south-west coast. But in size this is perhaps the largest, attaining a maximum length of about 30 cm. In habits it is similar to the previous species. It breeds in the sea and the juveniles enter estuaries and brackishwater lakes.

Penaeus semisulcatus de Haan.—This species also is more common on the east coast although not as important as *P. monodon* nearly to which size it grows. It contributes very little to the fishery on the west coast.

Penaeus merguiensis de Man.—Till recently this was considered as a variety of *P. indicus* and in view of the similarity of the two species this would have been confused with the above in several localities. Quite recently this is found to contribute to the commercial fishery along the Karwar coast along with the other species. Attains a maximum of about 20 cm.

Penaeus canaliculatus Olivier.—Contributes to a very small percentage in the fishery along the Madras coast especially in Pulicat lake and in small numbers in Bombay and other places. Attains a maximum of 12–15 cm.

P. monodon, *P. semisulcatus* and *P. canaliculatus* are caught in the east coast mainly during the post-monsoon months.

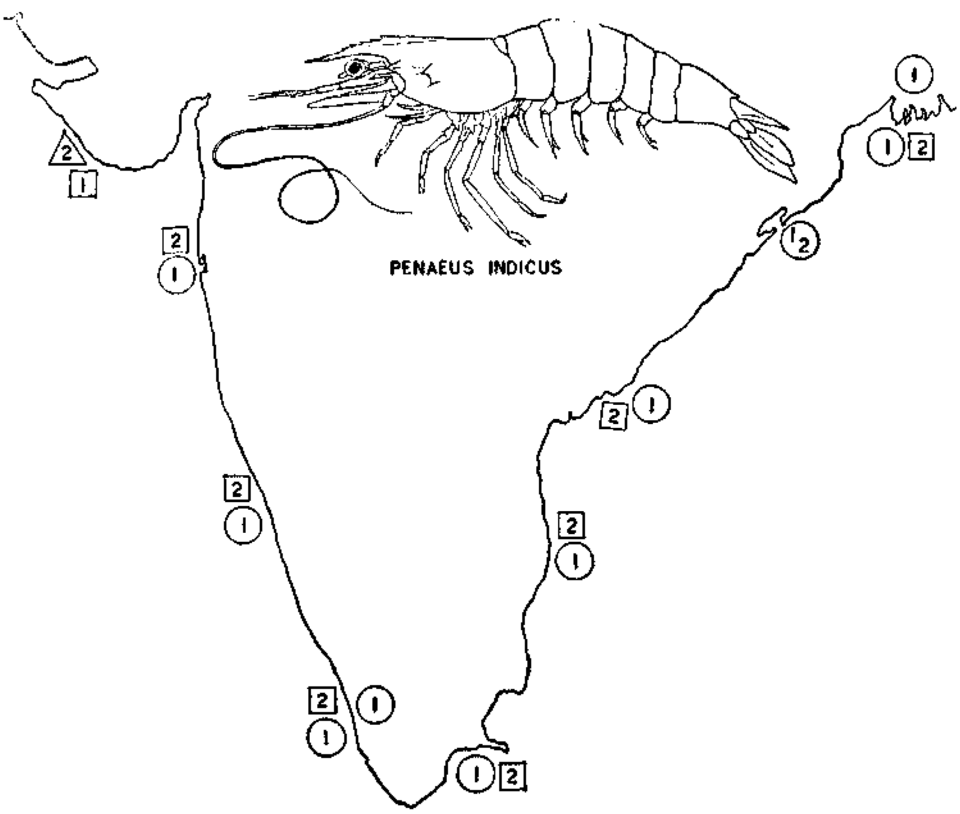

FIG. 3. Fishery of *Penaeus indicus* and *P. monodon*. O regular; □ occasional; △ stray.
1. *Penaeus indicus*. 2. *P. monodon*.

Metapenaeus dobsoni (Miers) (Fig. 4).—This is one of the major species contributing to the inshore fishery as well as trawl fishery of the south-west coast of India as far as Goa. On the east coast also it is common in the southern region only mostly in Pulicat and Ennore lakes. Grows to a maximum of 12–13 cm. The paddy field prawn fishery in the backwaters of Kerala is mostly dependent on the habit of the species breeding in the sea almost throughout the year and the post-larvae entering the backwaters to use these extensively as nursery grounds where it grows to about 6–7 cm.

In the backwaters, estuaries and sea this species is caught throughout the year though the intensity of abundance varies from month to month. In the monsoon period this species supports the mud bank fishery constituting the chief component of the catch of the area.

Metapenaeus affinis (Milne-Edwards).—This is the most important species of *Metapenaeus* on account of its occurrence in the commercial fishery, along the entire west coast and southern region of the east coast and because of the comparatively larger size of 16–18 cm. it attains. Juveniles are caught in small numbers from backwaters, creeks and estuaries. Caught mainly during the post-monsoon months, the peak season is October to December in the south-west coast of India. The immature prawns are fished almost throughout the year.

Metapenaeus monoceros (Fabricius).—Grows to a maximum of about 16–18 cm. Although the percentage contribution of this to the fishery of each locality is comparatively less this is perhaps the only species of *Metapenaeus* occurring in the commercial fishery along the entire coastline of India. It contributes to the estuarine and backwater fishery also, attaining a length of about 10–11 cm. in these environments. Breeding takes place in the offshore waters. As in *M. affinis*, post-monsoon period is the good fishing season for this species. The immature prawns occur in varying quantities in all the months of the year in the backwaters and estuaries.

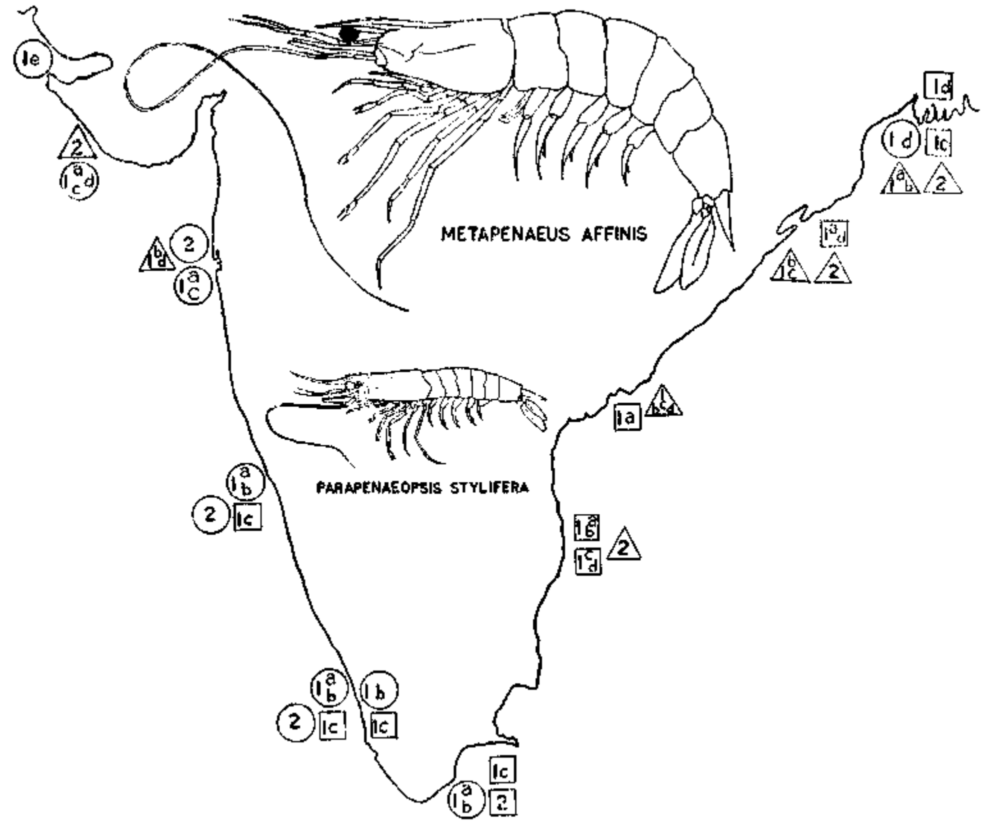

FIG. 4. Fishery of *Metapenaeus* and *Parapenaeopsis*. O regular; □ occasional; △ stray. 1. (*a*) *Metapenaeus affinis*, (*b*) *M. dobsoni*, (*c*) *M. monoceros*, (*d*) *M. brevicornis*, (*e*) *M. kutchensis*. 2. *Parapenaeopsis stylifera*.

Metapenaeus brevicornis (Milne-Edwards).—This is one of the commonest penaeids of Bengal inhabiting marine to almost freshwater zones throughout the year and is common in the northern region of the west coast also but does not occur in the southern region of both west and east coasts. It attains a maximum of about 13 cm. and spawning takes place in inshore waters. It occurs throughout the year, the large-sized individuals being taken from the inshore waters during the winter months.

Metapenaeus kutchensis George *et al.*—This attains a maximum of about 14–15 cm. and contributes to a good percentage of the fishery in the Gulf of Kutch area.

Incidentally it may be stated here that *Metapenaeus lysianassa* has been reported by some to be an important prawn in some parts of the west coast, but this remains to be confirmed.

Parapenaeopsis stylifera (Milne-Edwards).—Unlike other species it is confined to the sea, not migrating to estuaries and backwaters. Most common on the west coast and comparatively more abundant in the Bombay waters than in the southern region. Along the east coast the species is present in the southern region. It grows to about 14 cm. and is caguht throughout the year and forms one of the main species in the inshore waters.

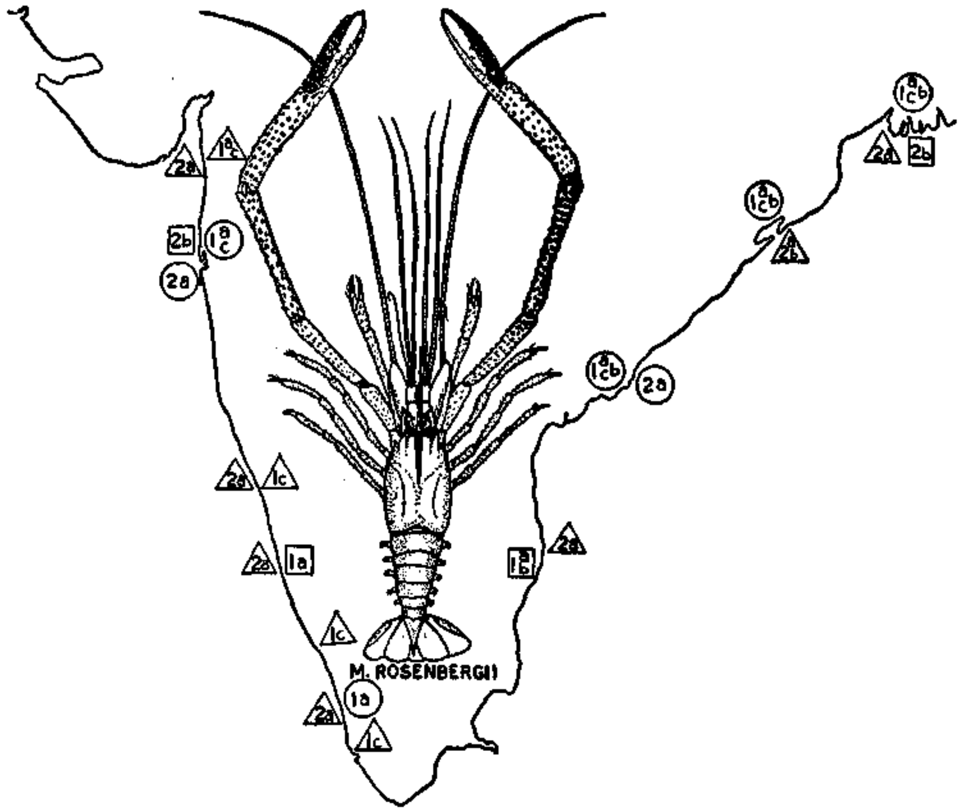

FIG. 5. Fishery of palaemonid prawns. O regular; □ occasional; △ stray. 1. (*a*) *Macrobrachium rosenbergii*, (*b*) *M. malcomsonii*; (*c*) *M. rudis*; 2. (*a*) *Palaemon styliferus*; (*b*) *P. tenuipes.*

Parapenaeopsis sculptilis (Heller).—This species is available in the commercial fishery of the marine zone of the Hooghly in certain months especially during winter and in Bombay waters throughout the year although in small quantities averaging about 4% of the catches. It grows to a maximum of about 15 cm. But the sizes obtained in Bombay are small. In the commercial fishery the species is available during the monsoon and winter months. The larger specimens are generally caught in the inshore waters.

Parapenaeopsis hardwickii (Miers).—This species, slightly smaller in size than the above and growing to about 13 cm. is also present in Bombay waters and is caught in small quantities along with the other species.

Solenocera indicus Nataraj.—This is of commercial importance only in the inshore waters of Bombay where it forms about 10% of the catches. It grows to about 14 cm.

Trachypenaeus curvirostris (Stimpson).—This also is caught in small numbers from Bombay waters. Small numbers of this species were caught from further south also during the exploratory and research cruises of *R. V. Varuna.* Maximum size is about 10–12 cm.

Penaeopsis rectacuta (Bate) and *Aristeus semidentatus* (Bate) are penaeids of potential commercial importance in view of the fact that they were obtained in fairly large numbers from the deep-waters ranging from 100–200 fathoms during the recent exploratory cruises of *M. V. Kalava*.

Palaemonids

Excepting a few species most of the members inhabit freshwater but are capable of tolerating brackish waters and some even marine environments.

Macrobrachium rosenbergii (de Man) (Fig. 5).—This is the giant freshwater prawn growing to a maximum of about 30–32 cm. in length, common in most of the lakes and estuaries in India. Spawning takes place in the gradient zones of the estuaries. The young ones ascend the rivers and the juveniles are caught mostly in the freshwater zones. It contributes to a fairly good freezing industry in the Kerala backwaters during the monsoon and post-monsoon periods. In the east coast the species is fished from December to July in the gradient zone, while the immature prawns are caught during other months from the freshwater.

Macrobrachium malcolmsonii (Milne-Edwards).—This is a comparatively smaller species attaining a maximum of 20–22 cm. (males). Growth is much different in males and females, the former attaining a larger size. It is most common in the estuaries and lakes of Madras and Andhra and also in Chilka Lake. Habits are similar to those of the previous species. The fishery, although limited, is during the monsoon months.

Macrobrachium rudis (Heller).—Though caught in small numbers in most of the lakes and estuaries this species is of commercial importance mostly in Bengal, Orissa and Andhra. Fishery season is from August to November . It attains a maximum length of about 12–13 cm. males being larger than females. In Bengal, the species is available during August-October, and in Chilka Lake it is fairly common from September to November. Young individuals are generally found during February-March.

Macrobrachium idae (Heller).—This species attains a maximum size of about 10–11 cm. and is represented in the catches during September to December period in Kerala backwaters area and other regions.

Macrobrachium scabriculum (Heller), *Macrobrachium mirabilis* and *Macrobrachium lamarrei* (Milne-Edwards) are other species of this genus caught in small numbers in various estuaries and freshwater areas.

Palaemon styliferus(Milne-Edwards).—This is one of the smaller species of palemonids of commercial importance. It attains a maximum size of about 10 cm. and is very common in the Gangetic delta and also in Bombay waters, occurring in the tidal and gradient zones. Spawning occurs in the more saline areas and juveniles migrate to the estuary. There is no difference in growth rate of sexes.

Palaemon tenuipes (Henderson).—This is fished along with the previous species in more or less the same areas. It grows to a maximum of about 7–8 cm. and is similar in habitat.

Leptocarpus fluminicola (Kemp).—This is an endemic species inhabiting the brackishwater areas of the Gangetic delta. It grows to about 4–5 cm. and is caught in very large numbers.

Hippolytids

Hippolysmata ensirostris Kemp.—This is a very small species of caridean prawn growing upto a maximum of about 3 cm. in length, common in Gangetic delta and some other parts of peninsular India.

Sergestids

Acetes indicus Milne-Edwards (Fig. 6) is the largest among the commercially important sergestids and attain a maximum size of 3–4 cm. The species occur in vast shoals in midwater or near the surface in the inshore waters near estuaries and backwaters. It contributes to a good percentage of the fishery in the inshore waters of Bombay in certain months and also along the Bengal and Madras coasts.

Acetes erythraeus Nobili and *A. serrulatus* (Kroyer) are two other species of commercial importance especially along Madras and Kerala coasts. Besides providing an important fishery, shoals of these *Acetes* spp. form an important food item of the larger fishes.

Mysids

Species of Mysids, *Macropsis orientalis* and *Potamomysis assimilis* popularly known as the 'mud shrimps' and 'opposum shrimps' which are barely 1 cm. in length and frequently caught mixed with are other shrimps in amall quantities.

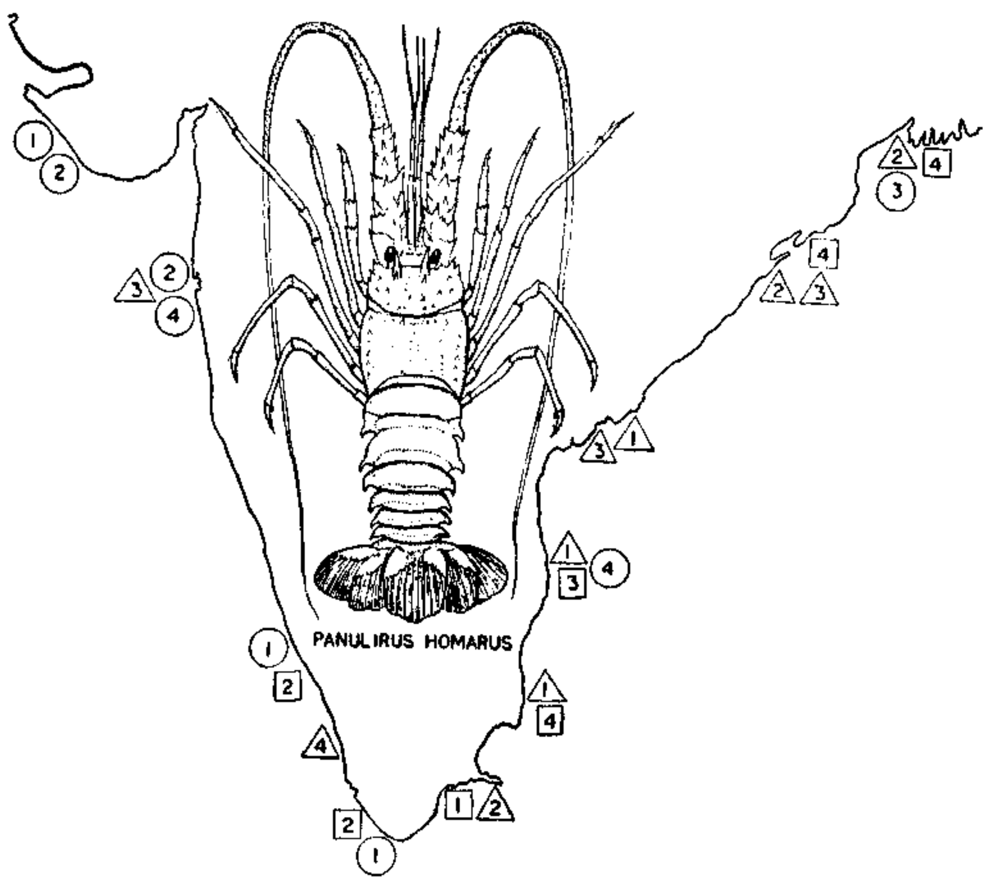

FIG. 6. Fishery of lobster and *Acetes*. O regular; □ occasional; △ stray.
1. *Panulirus homarus*. 2. *P. ornatus*. 3. *P. polyphagus*. 4. *Acetes indicus*.

SPINY LOBSTERS

Palinurids

Panulirus polyphagus (Herbst.) (Fig. 6).—This species occurs in several localities with rocky bottom along both the coasts of India, though more common along the east coast. It grows to about 35–37 cm. in length. In Bombay waters, lobsters are chiefly caught in bully nets locally called '*Gadas*', in wall seine nets and in lobster pots. The main fishing season is from November to March.

Panulirus ornatus (Fabricius).—This attains a slightly smaller size of about 30–32 cm. and is commoner along the Bombay coast. It occurs generally in shallow waters.

Panulirus homarus (Linn.).—This species grows to about 30–31 cm. and occurs mostly in the rocky areas of the southern coasts. It contributes to a fairly good fishery supporting a lucrative freezing industry on the south-west coast of India mostly in the area south of Trivandrum during the months of December to April. It is caught in anchor hooks, lobster traps and gill nets.

Puerulus sewelli Ramadan is another species of potential commercial importance along the south-west coast.

CRABS

Scylla serrata (Forskal.) (Fig. 7).—This is a very widely distributed brackishwater species well adapted to live in freshwaters for fairly long periods, usually growing to about 15–20 cm. across the carapace. It is available almost throughout the year and is the largest and commonest food crab. Generally it is trapped in 'dip nets' using baits. In shallow waters and creeks, 'seine nets' are employed. Hooked iron rod is also used for extracting the crabs from crevices. An indigenous method of operation of a line stretched across a suitable creek, one end tied to a pole fixed in the bank, and the other to a post in a boat which is rowed to the opposite bank is found in the Gangetic delta. The line is weighted and pieces of dead fish are suspended as baits.

Portunus pelagicus (Linn.).—This is another swimming crab widely fished in several areas along the coastline. It inhabits the inshore waters but is capable of tolerating brackishwaters. In the Chilka Lake it is sometimes found almost under freshwater conditions. It attains a maximum size of about 15 cm. across the carapace.

Portunus sanguinolentus (Herbst).—This is common in all the areas in which its congener is fished and is similar in habits, distribution and size.

Both *P. pelagicus* and *P. sanguinolentus* are caught in shore seines, cast nets and appreciable numbers are found in the trawl nets also. The indigenous gear used for crab fishing are the modified *kanthabale* and *aliburle* (crab net), gill nets, *nandu valai* in the Gulf of Mannar and Palk Bay and *nolijal* in the Chilka Lake. The main season is from January to March. In the monsoon months crabs are fished from river mouths and estuaries.

Varuna litterata (Fabricius).—This is not a swimming crab as the previous ones. It attains a maximum size of only about 5 cm. across the carapace and is common in the Gangetic delta area.

Paratelphusa spinigera (Wood-Mason).—This is the common freshwater crab growing to about 7–8 cm. across the carapace. It is most common in the freshwaters of Bengal.

Paratelphusa jacquemontii and *P. hydrodromus* are two other freshwater crabs common in the freshwater areas of Bombay and southern regions of the east coast respectively. These are available almost throughout the year.

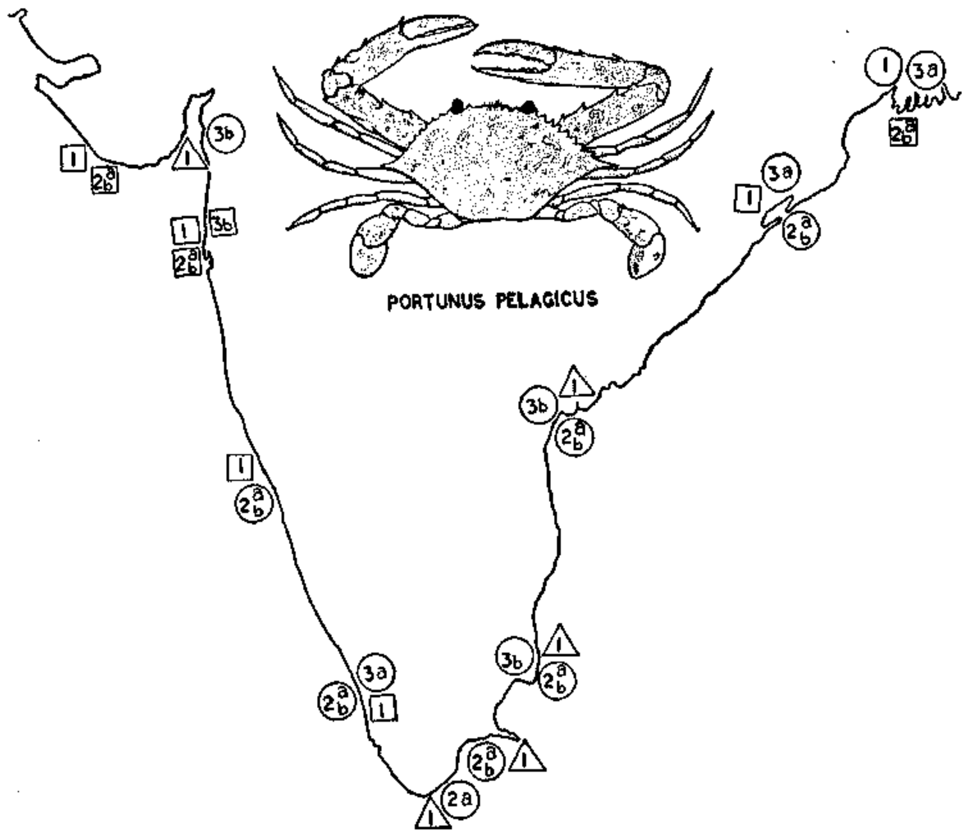

FIG. 7. Crab Fishery. O regular; □ occasional; △ stray. 1. *Scylla serrata*, 2. (*a*) *Portunus pelagicus*. (*b*) *P. sanguinolentus*; 3. (*a*) *Paratelphusa spinigera*; (*b*) *P. hydrodromus*.

GENERAL REMARKS

In spite of the appreciable expansion in the use of mechanised fishing craft in recent years the greater part of the crustacean landings are made with indigenous craft and gear. Provision of in-board engines in indigenous craft especially in the Bombay areas has helped a great deal in shortening the journey time, from the base to the fishing grounds and back. The power boats which operate shrimp trawls are comparatively small-sized, not more than about 10 m. in length. Most of the fishing is done within the 20 fathoms line but there seems to be scope for extending the fishing range beyond this depth.

Exploratory fishing has shown the presence of some species of deepwater prawns between 100 and 200 fathoms along the west coast. Further survey is necessary to estimate the extent of the resources. Sections of the east coast especially off the larger river deltas also remain to be surveyed. On the whole the future of the crustacean fisheries of India appears to be bright.

A PRELIMINARY INVESTIGATION OF THE SPINY LOBSTER RESOURCES OF THE MALDIVE ISLANDS

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ABSTRACT

The writer spent almost two months in 1961 on a professional survey of the spiny lobster resources of the Maldive Islands for an American concern.

The survey was conducted mainly by diving techniques using basic equipment as well as self-contained apparatus. Specimens were collected almost entirely by hand, traps being unsuccessful. Considerable experimentation with traps and bait was done. All specimens collected were identified, measured, sexed, weighed and notes made of any unusual features. There were also careful weighings of tails, enabling data to be obtained in respect of the most commercially desirable species.

This paper, which is made up from data and observations made on this expedition, concerns itself mainly with the systematics, distribution, habits and enemies of the genus *Panulirus*. Three species of *Panulirus* viz., *P. japonicus*, *P. versicolor* and *P. penicillatus* were collected. Two specimens of a species of *Thenus* were also collected.

INTRODUCTION

THE writer was assigned to undertake a commercial survey of the spiny lobster resources of the Maldive Islands with a view to a fishery in February/March 1961. The substance of this paper is derived from facts, figures and observations made in the course of this survey which lasted for 37 days. In the course of the survey a good deal of data on the behaviour, habits and enemies of spiny lobsters were accumulated.

The main part of the survey was done by diving methods and underwater observation. Three Atolls in the Maldives Archipelago were investigated, and a total of 18 separate islands. Efforts were made, in view of the limited time and restricted space for work, to survey places about which information from local Maldivians was available. An estimated total of 300 nautical miles were covered by the Survey Team and the two divers working covered approximately 75 miles under and above water, using basic skin-diving apparatus, in the course of the investigations.

Limitations encountered were in respect of adverse sea and weather conditions on rare occasions preventing any work from being done in the water, indisposition from exposure and illness by the divers, and, very rarely, the attentions of potentially dangerous sharks.

The survey also utilised traps which, on the whole, were adjudged a failure after several attempts were made to operate them.

SPECIES OF THE GENUS *Panulirus* IN MALDIVIAN WATERS

From specimens collected by hand at night using skin-diving techniques, only three species of *Panulirus* were obtained in the Maldive Islands. It is highly unlikely that any other species of *Panulirus* are present as no remains whatever of them were encountered. The three species are: *Panulirus penicillatus* (Olivier), *P. versicolor* (Latr.) and *P. japonicus* (Von Siebold). All the three species were found to be nocturnal in habit.

Table I gives the actual calculated species' proportions based in specimens collected, and the estimated proportions from visual observations. (From experience, it was found that some species were more difficult to collect than others. Traps, of course, did not provide any data.)

TABLE I

Species		% of total catch	Estimated % population
		%	%
Panulirus versicolor	...	23	25
Panulirus japonicus	..	67	60
Panulirus penicillatus	..	10	15

Note.—A total of 127 specimens of *Panulirus* were collected by divers in the course of the survey.

DISTRIBUTION OF *Panulirus* SPECIES

The entire Maldivian Archipelago is purely coralline in structure and the conditions of the littoral waters are, to a great extent, constant along the 700-odd mile-long chain of about 2,000 islands.

All the specimens of *Panulirus* observed or collectad were in relatively shallow waters from 1–4 fathoms and in coral formations. Several dives were made by day into deep water below the 10 fathom line but no specimens were observed. The specimens appear to prefer the shallower reefs where food is more abundant and predators less numerous. Most of the islands explored had fringing reefs which abruptly dropped to over 12 fathoms from a "ledge" approximating 4 fathoms in depth. The *Panulirus* population seldom were encountered on the edges of this ledge but occurred well within the sheltered shallows with ample cover and protection.

The temperature of the water averaged 23° C., but there were regular drops encountered especially at the turn of the tide in waters surrounding islands at the mouths of atolls. In one instance a sudden temperature drop of 8° C. was recorded. It would appear that the spiny lobsters have a good tolerance which must range from at least 22° C. to 33° C. where in the very shallow waters heated by the sun, some specimens were collected from under dead coral heads.

The three species displayed a certain degree of preference for localisation in their main habitat.

Panulirus penicillatus was collected and observed only in the very exposed, shallow and surf-swept areas of the reefs and never in still water or over sand-bottom. The estimated 15% of total population for this species is probably far below the actual figure as it was seldom possible, from the point of view of diving, to count them at night. Of the remains often picked up on shores, the most predominant was in respect of this species but it cannot be deduced that *P. penicillatus* is therefore the most abundant species of the three until accurate figures for ecdysis frequency are available.

Panulirus japonicus was the most commonly collected and observed species and preferred a habitat in the densest coral formations appearing only at night. Not one was ever observed by day, as also in the case of *P. penicillatus*. It was observed to be attracted by bait in traps but only one *Panulirus* entered and was caught.

Panulirus versicolor was the only species seen by day but very occasionally. It was also the only species observed in relatively still water, often in semi-stagnant conditions in very sheltered lagoons and in conditions of poor visibility owing to debris, freshwater from rainfall and pulverised coral.

It was the main species observed to take any interest in traps, however the only trap-caught specimen was one *P. versicolor* which crept into an unbaited trap which had been left under a pier to soak in shallow water.

The estimated nightly radius of foraging for the three species was derived on a few occasions by actual observation. When conditions permitted a stay of over three days in a particular area on an island, individual spiny lobsters were carefully noted but not disturbed and watched over a period of from 2-4 hours at intervals. The relative paucity of *Panulirus* enabled the observers to recognise individuals with ease. It was seen that of the three species *P. versicolor* foraged the greatest distance from their hiding-places (up to 50 metres), *P. japonicus* came second with 20 metres, and *P. penicillatus* appeared to be the least venture-some with only 14 metres.

These figures are, admittedly, extremely hypothetical and must have considerable margin of error yet they indicated the approximate distances at which traps should be placed from the hide-outs, although, in actual practice the traps proved unsuccessful.

Experiments with Lobster Traps

The survey used about twenty modified Canadian "Parlour and bed-room" lobster traps made in Ceylon under supervision of a Candain expert. The wood used was Jak (*Artocarpus itegrifolia*) and slats covered the traps completely except where the funnels were fitted. The funnels were made of nylon and imported specially for the purpose. The entry rings were of wood. Weighting of the traps was done by means of flat tiles purchased in Ceylon nailed by transverse slats to the bases of the traps.

The traps measured on an average 32 in. long, 20 in. broad and 12 in. high. The rings in the funnels were 6 in. in diameter but this was increased later on in the hope of catching broad-carapaced *P. penicillatus*. (It was found by measurement that most of the *P. penicillatus* collected were too broad to enter the funnels even if they wanted to.)

The traps had to be soaked for many days to reduce buoyancy. Even after a week they remained semi-buoyant and it was only after further weighing with coral stones that they sank. The original average weight of 40 lb. per trap was thereby increased to well over 50 lb.

To facilitate and speed up operations, the traps were placed by divers in pre-selected locations. It was necessary for divers to check the position of each trap since haphazard dropping from boats in these conditions seldom permitted the traps to settle properly. The extreme visibility of the water was of great advantage in this. Traps dropped from boats usually ended up in awkward positions over coral growths and were sometimes in danger of toppling over the reef edge into very deep water.

The traps were placed at suitable intervals and in spots where spiny lobsters had been seen earlier, or by day, in the case of *Panulirus versicolor*.

To begin with, the bait used was obtained by cutting chunks of freshly speared *Caranx stellatus*, *Lutianus bohar*, *Caranx ignobilis*, *Macolor niger*, *Trachinotus blochi*, *Gaterin lineatum*, *Gaterin albovittatus* and species of *Siganus*. These were placed in net bags and suspended inside the traps.

Early trapping experiments were done by day and it was soon observed that this was of no avail. The bait was immediately attacked by the many species of *Labridae*, *Balistidae* and *Lutianidae* which abounded on the coral reefs, the worst offender being *Odonus niger*. The bait-bag, bait, and pieces of the funnel were destroyed in a few minutes. It was further observed that the fresh bait, especially if bloody, would attract small specimens of sharks, *viz.*, *Carcharinus albimarginatus*, *Carcharinus melanoptera* and occasionally *Carcharinus menisorrah*. The presence of sharks round traps would naturally drive any spiny lobsters away from the vicinity.

Night setting of traps was resorted to next, and this operation required the services of divers even more than before, for successful installation. Trap-setting commenced at dusk when the diurnal reef fishes had retired; and another advantage was that often spiny lobsters were in the open when traps were placed near them in the hope of trapping them.

It was then observed soon enough that the nocturnal predators were almost as destructive to the traps and bait as the diurnal ones. The bait attracted large *Muraenids* which in turn drove away the spiny lobsters in the vicinity when excited by the presence of fresh fish bait. There were also small sharks (*Carcharinus albimarginatus*) constantly in attendance.

Finally it was decided to use different bait and the most readily available were the mantles and muscles of *Tridacna*. The results were gratifying by night in that sharks and *Muraenids* were not attracted to it and that spiny lobsters were definitely drawn to the traps baited thus.

It is possible that more than the one specimen of *Panulirus japonicus* which was caught in a trap entered them and then escaped by climbing on the coral rocks used to weight them down. *P. penicillatus* was never observed to be attracted to the bait in a trap.

P. versicolor was the most frequently-observed species attracted to clam-baited traps but a careful look revealed they employed their long first pairs of walking-legs to seize the bait through the slats of the traps. Whether or not they were able to convey small fragments of bait to their mouths in this manner is uncertain and merits further study in aquarium conditions. At any rate they were attracted to the traps by the calm-bait and were often seen on the traps or by the sides of them employing the first walking-legs but only one was collected in a trap, and this too, in an unbaited one left to soak under a jetty over a sand-bottom. It was thought that this specimen had sought shelter after having lost its way over the sand after day had dawned.

Trapping was finally abandoned in favour of diving methods to collect spiny lobsters. The survey continued with divers only, in the expectation of encountering large concentrations which could be economically and effectively collected by trained native divers.

Experiments with Divers for Collecting Spiny Lobsters

The technique of collecting spiny lobsters using skin-divers was evolved in Ceylon from 1946 when basic diving gear, *viz.*, face-plates or masks and swim-fins enabled swimmers to have better vision and speed underwater. De Bruin (1960) indicated the effectiveness of this method under suitable conditions in experiments on the five species then recorded in Ceylon.

The diver, equipped with mask, swim-fins and gloves descends holding his breath and catches spiny lobsters from the crevices in which they hide. This technique is most effective for *P. dasypus* provided the depth and visibility factors are suitable. (The average working depth for a skin-diver without breathing apparatus is 40 ft. in Ceylon and the minimum visibility required is 6 ft.) With breathing-gear (self-contained compressed-air units) the depth can be increased to over 100 ft. with greater duration, and the visibility of even 3 ft. is sufficient in well-stocked locations.

By night, the diver uses a waterproof flashlight of sufficient power to afford a minimum visibility of 4 ft. The catches by night are very much better owing to the increase in number of the spiny lobsters in the open. (The best figure reliably obtained so far for skin-divers without breathing-gear is a total of 202 *P. dasypus* collected by hand inside Colombo harbour by two divers working at night with flashlights for approximately two hours).

The catches made by divers can be further increased by spearing lobsters with hand-spears and trident-heads. In this manner few ever escape. It is doubtful as to whether this method would prove suitable for a commercial fishery unless immediate deep-freeze facilities are obtainable for the catch.

In the Maldive Islands two trained divers operated almost every night doing the observations and collecting the spiny lobsters when necessary. Without divers the survey would have been completely useless and no data whatever forthcoming except of a negative nature.

The conditions for skin-diving in the Maldive Islands were almost ideal. Extreme visibility of water (often exceeding 100 ft.), comfortable temperature and relatively shallow area where spiny lobsters occurred. Were it not for the great paucity of spiny lobsters in the areas surveyed, in comparison with some parts of Ceylon, diving methods for spiny lobsters in the Maldive Islands would be the most effective of all for a commercial fishery in view of the cheapness of local labour.

The only detriment to skin-diving activity was the presence of potentially dangerous sharks; specially in those islands with human habitation where the practice of throwing fish-offal into the sea resulted in the comparative fearless of the littoral sharks, especially *Carcharinus menisorrah*. It was for this reason that almost always two divers entered the water and worked side by side, one covering the other when sharks were sighted.

The other less lethal yet irksome factor was that of prolonged exposure to sea-water and coral-cuts, jelly-fish stings, etc., which caused considerable discomfort is not permitted to heal and dry by curtailing the frequency of immersion.

The greatest advantage of diving techniques is that trained divers can readily spot, catch and store spiny lobsters working with a simple craft and the minimum of equipment and personnel. The capital costs are low and there is no great loss of gear and deterioration as when traps available, a brief training would suffice to make native divers of such islands very effective collectors of spiny lobsters.

The survey revealed the unsuitability of the Maldive Islands for a commercial spiny lobster fishery, using either traps or divers. It is presumed that the relative paucity of spiny lobster populations in these waters is due to the general conditions of extreme clarity and too great mortality of larvae.

De Bruin (1960) demonstrated that of five species in Ceylon only *P. dasypus* was present in any commercial concentrations and could be caught in traps; *Panulirus versicolor*, *P. penicillatus* and *P. japonicus* were seldom caught in traps. *P. dasypus* does not occur in the Maldive Islands as far as is known. *P. dasypus* has a preference for relatively murky, shallow water away from coral reefs but near and under rocks. It also has a fair tolerance for dilution of its environmental waters with freshwater from rivers, estuaries and sudden floods. These latter conditions are not found in the Maldive Islands.

The best days' collection of spiny lobsters by two trained divers for nine hours yielded results as in Table II.

TABLE II

Location: Eidafuri Island, South Malosmadulu Atoll

Species	Diving hours	Number taken
Panulirus versicolor ..	7 (days) 2 (nights)	2
Panulirus penicillatus ..	do.	0
Panulirus japonicus ..	do.	24
Total ..		26

Compared with the figure obtained in Colombo, Ceylon, for *P. dasypus* (202 in 2 hours by night using two divers) this is hardly economical.

Experiments with Collected Spiny Lobsters

Since every Spiny lobster collected by divers was utilised for food and not released, the opportunity presented itself for weighing, measuring and sexing the specimens. Data thus derived (Tables III, IV and V) are of commercial and academic interest if a fishery involving the same or similar species in another part of the world is contemplated.

Table III

Maximum lengths and weights of spiny lobsters

(In all three species examined the largest were always males)

Species	Maximum length in.	Maximum weight oz.	Sex
Panulirus versicolor ..	17	98	Male
Panulirus japonicus ..	13·5	45	do.
Panulirus penicillatus ..	14	98	do.

Table IV

Average weights and lengths of spiny lobsters of both sexes taken from 12 specimens freshly-caught by divers

Species	Sex	Average length in.	Average weight oz.	Weight per unit inch oz.
Panulirus versicolor	Male	14	48	3·3
	Female	12	36	3·0
Panulirus japonicus	Male	10	17	1·7
	Female	8	10	1·2
Panulirus penicillatus	Male	15	52	3·4
	Female	13	40	3·0

Table V

Average weights of tails (whole and cleaned) of both sexes of spiny lobsters from 12 specimens collected by divers

Species	Sex	Average weight of	
		Whole tail oz.	Cleaned tail oz.
Panulirus versicolor	Male	16	12
	Female	14	8
Panulirus japonicus	Male	12	9
	Female	6	4·5
Panulirus penicillatus	Male	13	10
	Female	12	8

The above table indicates that of the three species *P. penicillatus* is the heaviest per unit inch.

The commercial value of *P. japonicus* (female) is clearly demonstrated by the above table, as against *P. versicolor* both sexes.

From a comparison of the two Tables it is demonstrated that of all the three species, the least economical to catch is the male *P. penicillatus* whose total weight is 5·2 times as much as the cleaned tail which is the main marketable portion, and the most economical is the female *P. japonicus* whose total weight is only 2·2 times that of the cleaned tail.

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Discussion

Dr. J. H. Wickstead: I want to know whether a fishery was not established in Maldives due to the paucity of divers or lobsters themselves.

Mr. R. Jonklaas: Due to the paucity of lobsters.

Dr. Qasim: Could it be possible that the lobster ate the bait, remaining outside the trap, with its first pair of legs?

Mr. R. Jonklaas: I could not observe this exactly.

Mr. R. Balasubramanian: What is the best bait for lobsters?

Mr. R. Jonklaas: Tridacna was preferred to fishes like *Caranx*, *Lutianus*, etc., as food.

PRAWN CATCHES BY MECHANISED VESSELS IN THE TRAWLING GROUNDS OF BOMBAY AND SAURASHTRA*

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ABSTRACT

The relative abundance in the regional, seasonal and depthwise distributions of prawns between latitudes 16° N, south of Bombay, and 24° N, of Kutch, based on the landings of two sets of bull-trawlers, '*Arnalla-Paj*' and '*Satpati-Pilotan*' of the New India Fisheries Company, and of the otter trawlers M.F.V. *Jheenga*, M.F.V. '*Bumili*', M.L. '*Meera*' and M.L. '*Sagarkanti*' of the Government of India Deep Sea Fishing Station, Bombay, has been studied.

The average annual yields of 20,690 kg. of prawns forming 0·63% and 8,367 kg. forming 2·04% of the total catches of all fish were obtained by the bull-trawlers for the period 1956–63 and the Government of India vessels for 1961–64 respectively. The highest catch of 38,070 kg. of prawns was obtained in 1962 for the bull trawlers with 9·78 kg. per hour of trawling and 10,540 kg. for Government of India vessels in 1961 with a catch rate of 6·04 kg. per trawling hour.

Taking Bombay and Saurashtra together it has been observed that the prawn catches begin to increase from April–May and peak catches are obtained in some of the months from July–September and occasionally even October as in 1961. The fishing operations were generally in the 8 m. to 70 m. depth ranges which have been considered in detail regionwise. The prawn resources in trawling grounds appear to increase from north to southwards along the west coast. While in Kutch to Veraval region, the catches have been either poor or only moderate, in Cambay and Bombay regions they have been fairly good. The annual average in percentage of prawns in Kutch to Bombay region ranged between 0·16–1·29.

Metapenaeus affinis, *M. monoceros*, *M. dobsoni*, *Penaeus indicus* and *Parapenaeopsis stylifera* are the common species of the Bombay and Saurashtra waters.

INTRODUCTION

THE importance of the prawn fishery of India has been well emphasised by Panikkar and Menon (1955) who observed that it ranks second only to that of U.S.A. Their observation was based mostly on the catches from the inshore regions and backwaters which have been exploited fairly efficiently and extensively by fishermen from ages past employing indigenous craft and gear. The effective use of trawlers and other mechanised vessels in fishing for 'shrimps' exclusively or along with commercially important fishes has come into vogue in recent years, *i.e.*, in the last two decades only. From published accounts, unfortunately no information is available on the prawn catches by commercial or exploratory fishing trawlers operating in deeper waters off the Indian coasts beyond the zones which the local fishermen reach with their non-mechanised or even mechanised craft and gear. In the accounts given by Jayaraman *et al.* (1959) very valuable information is found in respect of various commercially important species of fish excepting prawns, the latter having been evidently treated along with other miscellaneous catches.

The inshore catches of prawns in Bombay and other parts of the north-western coast of India, although forming a considerable part of the total landings, are mostly unsuitable for export in the frozen or canned state as they are composed mainly of small varieties like *Palaemon tenuipes*.

* Published with the permission of the Director, Central Marine Fisheries Research Station, Mandapam Camp.

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Annually several crores of rupees of foreign exchange is earned from the export of prawn by the canning and freezing factories located in the south-western part of the country where the economically important species abound. As the trawlers invariably catch larger varieties like the penaeid prawns, it is felt that a knowledge of their distribution and relative abundance in different regions would provide the basic information which is highly essential for promoting the export trade of 'shrimp'.

The present paper deals with the season wise and region wise distribution of the prawns based on catches landed by the bull-trawlers of the New India Fisheries Co., Ltd. and otter-trawlers of the Government of India Deep Sea Fishing Station, Bombay, which operated in Bombay and Saurashtra waters, including the Gulf of Kutch.

Vessels, Areas of Operation and Analysis of Catches

The bull-trawlers, 'Arnalla'-'Paj', and 'Satpati' 'Pilotan' of the New India Fisheries Co., Ltd. which operated in pairs, were each of 92·67 gross tonnage and 250 B.H.P. The trawl nets used by these vessels had 67·06 metre of head rope, 68·58 metre of foot rope with the cod end of 50·8 metres. The length of the hunt rope varied from 180 to 200 metres.

The fishing grounds covered by these vessels are the same that have been charted out and published earlier (Jayaraman *et al., loc. cit.*). On the basis of certain latitudes passing from the coastline across the continental shelf, the regions have been demarcated as follows: Bombay from 18° N. to 19° 40′ N.; Cambay 19° 50′ N. to 20° 40′ N., Veraval 20° 50′ N. to 21° N.; Porbundar 21° 10′ N. to 22° N., Dwarka 22° 10′ N. to 22° 40′ N. and Kutch 22° 50′ N. to 24° N.

These regions are divided into areas, 30 minutes latitude by 20 minute longitude, thus giving 600 square miles each (Fig. 1).

Besides the areas covered in the operations by *M.T.* '*Ashok*', *M.T.* '*Pratap*' and '*Taiyo Maru*' (Jayaraman *et al., loc. cit.*) the following areas also have been exploited by the New India Fisheries vessels, *viz.*, '43 A', '42', '37' and '36' in Bombay region, '23', '16', '13', '12' and '9' in Cambay; '1' in Veraval and 'G' and 'I' in Porbundar and all the areas 'P' to 'Z' in Kutch. In Cambay region areas '26' and '20' covered by *M.T.* '*Ashok*' and *M.T.* '*Pratap*' have not been fished by these vessels.

The catch data of the motor fishing vessels '*Jheenga*' of 153 B.H.P. and '*Bumili*' of 135 B.H.P. as also the motor launches '*Meera*' of 60 B.H.P. and '*Sagarkanti*' of 40 B.H.P. of the Government of India Deep Sea Fishing Station, Bombay, operating between latitudes 16° N. and 23° N. from January 1961 to June 1964 have also been considered in the present study. These vessels differ much in their gross tonnage, 11·77 of '*Sagarkanti*' to 48·61 of '*Jheenga*'. All these vessels were operating Russain and Indian types of otter-trawls of 11–16 metres.

The charting of the fishing grounds by the Government of India vessels is based on latitudes and longitudes chosen at one degree interval so that major areas are obtained having 3,600 nautical square miles each and these are subdivided at intervals of 10 minute longitude by 10 minute latitude, each sub-area thus giving 100 natuical square miles as seen from Fig. 2. In a major area, taking the numbers 1–6 at 10 minute interval on the longitude and A–F at the same interval on the latitude, the sub-areas are designated as 18–72: 1 A, 6 E, etc.

The log sheets of New India Fisheries vessels recorded the haul-wise number of cases of prawns at each area fished with particulars of depths and the time of shooting and hauling. While analysing the log data, each of the cases was allotted the weight of 18 kg. in respect of prawns and also small fish. The weights of larger fish are reckoned according to the standard tables adopted by the Central Marine Fisheries Research Institute based on average weights. The logs of the Government

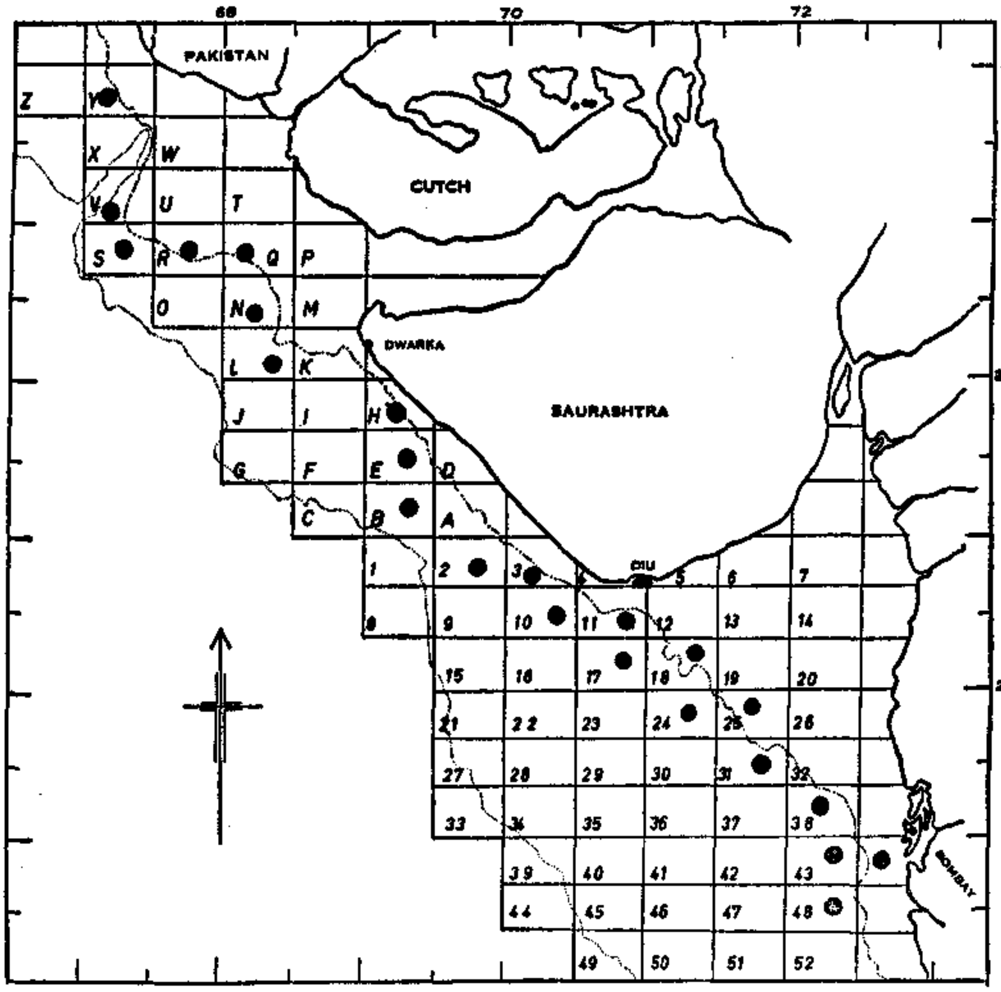

Fig. 1. Trawling grounds of Bombay-Saurashtra waters fished by the bull-trawlers of the New India Fisheries Co. Black circles indicate either rich or fairly rich prawn grounds.

of India vessels show direct entry of the weight of prawns and different categories of fish in kilograms. From the log data the monthly catch and catch rates in each area per hour of trawling, depth-wise distribution of prawns and their seasonal variations in different regions were worked out.

The Annual Prawn Yields by Trawls during 1956-64

The New India Fisheries trawlers showed an average annual yield of 20,624 kg. of prawns forming 0·62% of the total landings at a catch rate of 4·72 kg. per hour. The maximum yield of 38,070 kg. (Table I) was in 1962 forming 1·07% of the total landings with a catch rate of 10·04 kg. and the next high yield of 28,980 kg. was in 1957 forming 0·88% with a catch rate of 5·31 kg. per hour of trawling. The catches in 1956, 1958, 1959 and 1963 were below average ranging between 12,204 kg. and 15,174 kg. There was no fishing in the first three months in 1956 and the last two

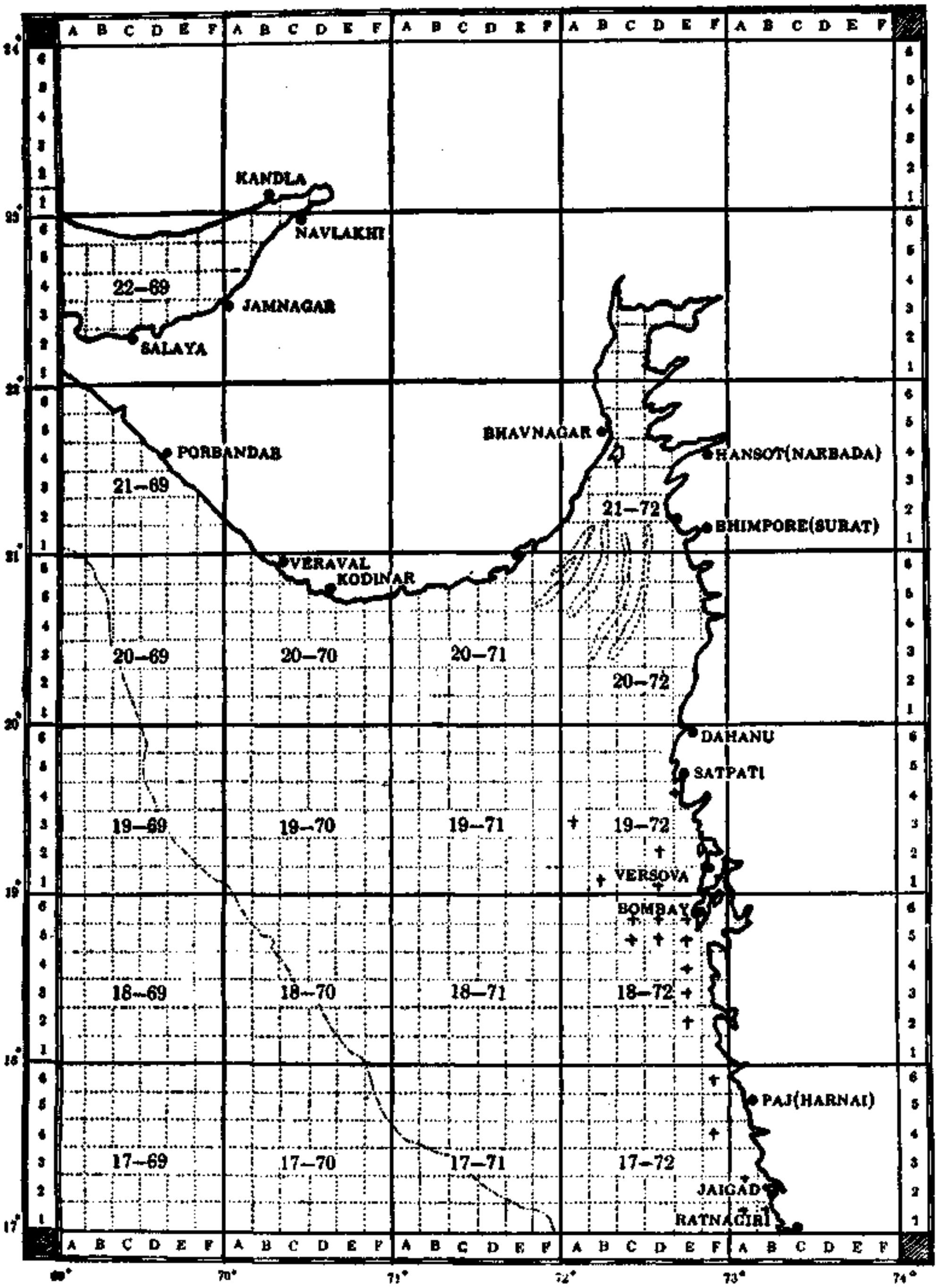

FIG. 2. Trawling grounds of Bombay-Saurashtra waters. Sub-areas indicated by + denote rich or fairly rich prawn grounds covered by Government of India vessels in exploratory fishing operations.

months in 1963; even if there was fishing in the said months the annual prawn landings for those years might not have been appreciably high as those months form the off-seasons for this fishery.

TABLE I

Annual regionwise distribution of prawn catch by bull-trawlers of New India Fisheries Co.

Region / Year	Kutch catch in kg. (catch rate) %	Dwarka catch in kg. (catch rate) %	Porbundar catch in kg. (catch rate) %	Veraval catch in kg. (catch rate) %	Cambay catch in kg. (catch rate) %	Bombay catch in kg. (catch rate) %	All regions catch in kg. (catch rate) %
1956	..	504 (0·66) 0·08	36 (0·80) 0·20	234 (2·77) 0·38	6,390 (5·09) 0·58	4,968 (7·05) 0·99	12,204 (4·28) 0·52
1957	..	2,304 (1·64) 0·31	612 (0·42) 0·06	1,620 (3·08) 0·52	23,526 (11·70) 1·82	918 (12·11) 3·73	28,980 (5·31) 0·88
1958	18 (0·48) 0·10	2,700 (0·03) 0·42	1,242 (0·77) 0·13	1,044 (1·50) 0·23	9,990 (5·70) 0·76	144 (1·80) 0·53	15,174 (3·00) 0·42
1959	477 (0·69) 0·06	693 (0·83) 0·14	945 (1·03) 0·55	2,196 (4·33) 0·77	9,939 (7·76) 1·44	504 (5·49) 1·36	14,760 (3·43) 0·54
1960	10,386 (3·14) 0·34	720 (8·52) 0·25	7,740 (20·98) 1·39	2,664 (6·90) 1·15	774 (5·38) 2·61	54 (4·80) 1·96	22,338 (4·28) 0·52
1961	6,498 (2·44) 0·25	486 (2·03) 0·24	1,836 (2·83) 0·36	3,420 (8·30) 1·18	8,730 (13·32) 2·31	18 (10·28) 4·08	20,988 (4·54) 0·53
1962	4,860 (2·57) 0·26	1,026 (7·30) 0·87	13,752 (14·87) 1·73	5,130 (19·44) 3·11	12,954 (18·06) 2·22	378 (66·43) 12·58	38,070 (10·04) 1·07
1963	3,979 (2·98) 0·34	486 (4·09) 0·47	3,528 (3·58) 0·50	1,062 (3·01) 0·46	3,222 (4·27) 0·65	18 (3·42) 0·79	12,475 (3·50) 0·46
Average	3,745 (2·60) 0·27	1,115 (1·88) 0·28	3,711 (3·97) 0·60	2,171 (5·39) 0·16	9,441 (8·81) 1·28	875 (7·18) 1·18	20,624 (4·72) 0·62

The Government of India vessels had an average annual yield of 8,367 kg. of prawns forming 2·04% of the total landings with the catch rate of 5·01 kg. per hour of trawling as shown in Table II. The highest catch of 10,540 kg. was obtained in 1961 with the maximum catch rate of 6·04 kg. per hour, but at the same time its percentage was the lowest being 1·74 only in the total landings. The highest per cent of 2·30 was in 1962 when the catch was 10,372 kg. In 1963 the catch was comparatively low being 7,466 kg. but in 1964 the catch of 5,091 kg. should be considered fairly good as it was obtained in the first half of the year only.

TABLE II

Annual prawn catch in the otter-trawls by the Government of India vessels at Bombay

Year	All fish	Prawns	%	Kg./hour
1961	602,335	10,540	1·74	6·04
1962	449,535	10,372	2·30	4·80
1963	354,335	7,466	2·10	5·27
1964	233,447	5,091	2·18	3·76
Average ..	409,913	8,367	2·04	5·01

REGIONAL ABUNDANCE AND RICHNESS OF THE AREAS IN RESPECT OF PRAWN CATCHES BY THE NEW INDIA FISHERIES VESSELS

Based on the average annual percentage of prawns in the total catches, the regions Cambay and Bombay are far better than those of Kutch and Dwarka, Veraval ranking last. From the point of view of quantitative abundance of the prawn catch, irrespective of the effort expended, Cambay region ranked first followed by Kutch, Porbundar, Veraval, Dwarka and Bombay. According to catch rates, Cambay, Bombay, Veraval, Porbundar, Kutch and Dwarka were in the order of abundance of the prawn resources.

Kutch Region

It may be seen from Table I that the average annual percentage of 0·27 was almost the same in this region as for Dwarka but, the catch rate was slightly better than in the latter, giving 2·60 kg. per hour. There was no fishing in this region during 1956. In 1957 the trawlers had just touched this region and the catch was nil. In the remaining four years the catch rates ranged from 0·48 kg. in 1958 to 3·14 kg. per hour in 1960 with the catch of 18 kg. and 10,386 kg. respectively.

The most extensively fished areas were 'R' and 'Q'; 'S', 'Y', 'V' and 'U' were moderately fished and the least fished areas were 'P', 'T', 'W', 'X' and 'Z'. The effort put in this region in 1957 was too small to record prawn catch.

In 'R' and 'Q' (Table III), the average annual effort put in was 807·10 hours and 343·79 hours respectively; but the catch rates were almost the same being 2·90 kg. and 2·64 kg. per hour respectively. The annual catch rates in the area 'R' ranged from 1 kg. with the lowest catch of 351 kg. in 1959 to 3·69 kg. per hour with the catch of 4,428 kg. in 1961; the highest catch of 5,184 kg. with the catch rate of 2·85 kg. per hour being observed in 1960.

In 'Q' area the lowest catch of 36 kg. with the catch rate of 0·14 kg. per hour was recorded in 1959. The highest catch of 2,376 kg. with the catch rate of 2·77 kg. per hour was in 1960, but the highest catch rate of 4 kg. per hour was noticed in 1962 when the catch was only 1,494 kg.

Amongst the moderately fished areas, 'U' recorded the lowest average annual catch rate of 0·77 kg. per hour and 'S', the highest of 8·53 kg. per hour. Area 'Y' followed 'S' with the average annual catch rate of 5·76 kg. per hour. In area 'S' the catch rates ranged between 0·97 kg. and 10·55 kg. per hour when the catches were 18 kg. in 1959 and 36 kg. in 1962 respectively. The highest catch of 1,278 kg. with the catch rate of 10·40 kg. per hour was in 1960.

The catch rates in the area 'Y' ranged from 5·17 kg. per hour with the catch of 270 kg. in 1961 to 6·64 kg. per hour with the catch of 162 kg. in 1960, the highest catch of 306 kg. with the catch rate of 6·54 kg. per hour being in 1962.

In the area 'V', the catch rates fluctuated between 2·24 kg. per hour with the catch of 324 kg. in 1961 and 5·89 kg. per hour with the catch of 882 kg. in 1963; however, the catches fluctuated between 198 kg. with the catch rates of 2·60 kg. per hour in 1962 and 1,008 kg. with the catch rate of 2·99 kg. per hour in 1960.

TABLE III

Areawise distribution of prawn catch (catch-per-hour) in kg. by bull-trawlers of the New India Fisheries Co. in Kutch region

Area / Year	Q	R	SJ	T	U	V	X	Y
1957	0	..	..	..	..	..	..	..
1958	0	0	0	..	0	0	18 (7·20)	.. ..
1959	36 (0·14)	351 (1·00)	18 (0·97)	.. ..	72 (1·30)	0 ..	.. ..	.. ..
1960	2,376 (2·77)	5,184 (2·85)	1,278 (10·40)	90 (4·88)	288 (2·44)	1,008 (2·99)	0	162 (6·64)
1961	1,296 (2·15)	4,428 (3·69)	72 (3·20)	0	108 (0·49)	324 (2·24)	0	270 (5·17)
1962	1,494 (4·00)	2,592 (3·15)	36 (10·55)	..	126 (0·35)	198 (2·60)	108 (2·47)	306 (6·54)
1963	1,170 (3·67)	1,531 (2·35)	288 (9·64)	..	108 (0·65)	882 (5·89)	..	..
Average	910 (2·64)	2,348 (2·90)	282 (8·53)	45 (3·78)	117 (0·77)	402 (3·28)	31 (1·83)	246 (5·76)

The area 'U' had the catch rates ranging from 0·35 kg. per hour with the catch of 126 kg. in 1962 to 2·44 kg. per hour when the catch of 288 kg. was the highest in 1960. The lowest catch of 72 kg. with the catch rate of 1·30 kg. per hour was registered in 1959.

In the remaining areas, the average annual catch rates varied between zero (in 'P', 'W' and 'Z') and 3·78 kg. per hour (in 'T').

From the above it can be inferred that the areas 'S' and 'Y' are rich, 'V' fairly good and 'Q' and 'R' moderately rich in their prawn resources. Area 'T' if sufficiently exploited may also yield fair catches.

Dwarka Region

This region (Table I) recorded the lowest average annual catch rate of 1·88 kg. per hour, but the average annual percentage of prawn yield was 0·28 which is as good as that of Kutch and better than that of Veraval. The highest catch of 2,700 kg. was in 1958 with the lowest catch rate of 0·03 kg. per hour. The lowest catch of 486 kg. was in 1961 and 1963 when the catch rates were 2·03 kg. and 4·09 kg. per hour respectively.

In spite of the fairly high amount of fishing effort put in this region during 1956 the prawn yield for that year was poor because fishing was done during November and December, the lean months for this fishery. The average annual catch rates ranged between 0·88 kg. per hour in 'K' and

2·81 kg. per hour in 'L' (Table IV) the catch rates at 'M' and 'N' being 1·89 kg. and 2·58 kg. per hour respectively. The highly exploited areas were 'N', 'M', and 'K'. Though the area 'L' showed the best catch rate, the effort put during different years was extremely poor, at times almost insignificant, leading to nil catch as noticed during the period 1960–62. The catch rates ranged from 1·91 kg. per hour with the highest catch of 108 kg. in 1957 and 16·7 kg. per hour with the lowest catch of only 18 kg. in 1·08 hours in 1963.

TABLE IV

Areawise distribution of prawn catch (catch-per-hour) in kg. by bull-trawlers of New India Fisheries Co. in Dwaraka region

Area / Year	K	L	M	N
1956	0	..	504 (1·10)	0
1957	216 (0·41)	108 (1·91)	1,188 (2·62)	792 (2·17)
1958	378 (2·42)	108 (3·81)	954 (2·17)	1,260 (4·20)
1959	180 (0·42)	36 (7·57)	144 (1·22)	333 (1·15)
1960	270 (5·25)	0	0	324 (1·03)
1961	36 (1·73)	0	0	450 (3·15)
1962	54 (4·32)	0	18 (4·60)	954 (7·75)
1963	18 (1·85)	18 (16·70)	0 ..	450 (4·29)
Average	144 (0·88)	39 (2·81)	351 (1·89)	570 (2·58)

The catch rates in the area 'N' varied between 1·03 kg. per hour in 1960 with the catch of 324 kg. and 7·75 kg. per hour with the catch of 954 kg. in 1962. The highest catch of 1,260 kg. was in 1958 with the catch rate of 4·20 kg. per hour.

The effort put in the area 'M' was quite good only from 1957 to 59 and not in rest of the years. The catch rates fluctuated between 1·10 kg. per hour with the catch of 504 kg. in 1956 and 4·60 kg. per hour with the catch of 18 kg. in 1962. The highest catch of 1,188 kg. was in 1957 with the catch rate of 2·62 kg. per hour.

In 'K' the catch rates ranged from 0·41 kg. per hour with the catch of 216 kg. in 1957 to 5·25 kg. per hour with the catch of 270 kg. in 1960. The maximum catch of 378 kg. with the catch rate of 2·42 kg. per hour was in 1958 while the minimum of 18 kg. with the catch rate of 1·85 kg. per hour was in 1963. It may thus be seen that the areas 'L' and 'N' have good prawn grounds.

Porbundar Region

The average annual percentage of 0·60 (Table I) in this region came next to that of Cambay and Bombay; but, the catch rate was only 3·97 kg. per hour. The prawn yield in this area was very good in 1962 giving 13,752 kg. at a rate of 14·87 kg. per hour. The highest catch rate of

20·98 kg. per hour was in 1960 when the catch obtained was 7,740 kg. ; the lowest catch of 36 kg. was in 1956 with the catch rate of 0·80 kg. and the lowest catch rate of 0·42 kg. per hour was in 1957 when the catch was 612 kg.

TABLE V

Areawise distribution of prawn catch (catch-per-hour) in kg. by bull-trawlers of New India Fisheries Co. in Porbunder region

Area / Year	A	B	D	E	H	I
1956	0	36 (2·76)	–	0	–	–
1957	486 (0·42)	18 (3·57)	36 (0·26)	72 (0·49)	..	..
1958	702 (0·78)	108 (1·83)	180 (0·76)	252 (1·12)	..	..
1959	675 (0·96)	108 (2·73)	36 (0·70)	126 (1·05)	..	..
1960	810 (5·43)	198 (5·17)	54 (3·34)	1,242 (6·67)	5,382 (10·69)	54 (13·67)
1961	270 (3·13)	90 (5·76)	0	504 (2·80)	972 (2·73)	..
1962	2,772 (22·40)	162 (10·18)	54 (1·61)	5,094 (13·46)	5,670 (15·18)	..
1963	2,160 (6·17)	324 (5·86)	54 (3·27)	846 (2·88)	144 (0·52)	..
Average	984 (2·28)	130 (4·32)	57 (0·82)	1,017 (5·22)	3,042 (8·04)	54 (13·67)

The fishing effort put was very good in the areas 'A' and 'E' throughout and moderate in 'D' and 'B'. The areas 'G' and 'I' were the least exploited, with no prawn catch in the former. The area 'H' was exploited from 1960 onwards and fairly good amount of effort was spent here. The average annual catch rate ranged from 0·82 kg. in 'D' to 8·04 kg. per hour in 'H'. The area 'H' registered the lowest catch of 144 kg. (Table V) in 1963 with the catch rate of 0·52 kg. per hour and the highest of 5,670 kg. with the catch rate of 15·18 kg. per hour in 1962.

In area 'D' the minimum catch of 36 kg. with the catch rate of 0·26 kg. per hour in 1957 and the maximum of 180 kg. with a catch rate of 0·76 kg. per hour in 1958 were observed. The highest catch rate of 3·34 kg. per hour was in 1960 when the catch was only 54 kg.

The catches in 'A' ranged between 270 kg. with the catch rate of 3·13 kg. per hour in 1961 and 2,772 kg. with the catch rate of 22·40 kg. per hour in 1962. The lowest catch rate of 0·42 kg. per hour with the catch of 486 kg. was in 1957.

The catch rates in the area 'B' fluctuated between 1·83 kg. per hour with the catch of 108 kg. in 1958 and 10·18 kg. per hour with the catch of 162 kg. in 1962. But the maximum yield of 324 kg. with the catch rate of 5·86 kg. per hour was in 1963 and the minimum of 18 kg. with the catch rate of 3·57 kg. per hour in 1957.

Area 'E' recorded the minimum catch of 72 kg. with the catch rate of 0·49 kg. per hour and the maximum of 5,094 kg. with the catch rate of 13·46 kg. per hour in 1957 and 1962 respectively.

TABLE VI

Areawise distribution of prawn catch (cacth-per-hour) in kg. by bull-trawlers of New India Fisheries Co. in Veraval region

Area / Year	2	3	4
1956	36 (1·03)	198 (4·11)	..
1957	1,242 (3·74)	378 (1·96)	..
1958	648 (1·80)	396 (1·19)	..
1959	1,224 (6·68)	972 (3·59)	..
1960	1,242 (7·75)	1,422 (6·27)	..
1961	612 (6·51)	2,754 (8·84)	54 (46·15)
1962	954 (8·95)	2,124 (13·49)	..
1963	540 (3·31)	522 (2·75)	..
Average	812 (4·53)	1,096 (5·07)	54 (46·15)

A catch of 54 kg. with the catch rate of 13·67 kg. per hour was noted in the area 'I' in 1960, indicating high prawn resources although not well exploited.

The areas 'H', 'E' and 'B' prove to have good prawn grounds.

Veraval Region

This region recorded the lowest annual average per cent of 0·16 of prawns (Table I), but the average catch rate was fairly good being 5·39 and it is higher than those obtained in Porbundar, Dwarka and Kutch. The highest catch of 5,130 kg. with the catch rate of 19·44 kg. per hour was in 1962 and the lowest catch of 234 kg. with the catch rate of 2·77 kg. in 1956. The lowest catch rate was 1·50 kg. per hour when the catch was 1,044 kg. in 1958.

Of the four areas fished in this region, '1' and '4' were the least exploited. There was no record of prawn in the area '1' and only a small catch of 54 kg. in the area '4' (Table VI) at a catch rate of 46·15 kg. per hour in 1·17 hours in 1961.

The average annual catch rate was 5·07 kg. for '3' and 4·53 kg. per hour for '2'. The catch rates in the area '3' ranged from 1·19 kg. per hour with the catch of 396 kg. in 1958 to 13·49 kg. per hour with the catch of 2,124 kg. in 1962. The minimum catch of 198 kg. with the catch rate of 4·11 kg. per hour was in 1956 and the maximum of 2,754 kg. with the catch rate of 8·84 kg. per hour was in 1961.

Coming to the area '2' the catch rates ranged between 1·03 kg. per hour when the minimum catch was 36 kg. in 1956 and 8·95 kg. per hour in 1962 when the catch was 954 kg. However, the highest catch of 1,242 kg. with the catch rate of 7·75 kg. per hour was obtained in 1960.

The areas '2' and '3' appear almost equally rich for prawns; area '4', if exploited intensively may throw some more light on the prawn grounds in this region.

Cambay Region

From the point of view of the highest catches obtained giving an annual average yield of 9,441 kg. (Table I) forming 1·28% of the total catches and with the highest catch rate of 8·81 kg. per hour, this is the best of the five regions covered by the New India Fisheries vessels. The catch rates varied between 4·27 kg. with a catch of 3,222 kg. in 1963 and 18·06 kg. with a catch of 12,954 kg. in 1962. Catch was the highest in 1957 forming 23,526 kg. with a high catch rate of 11·70 kg. per hour and lowest in 1960 forming 774 kg. yet with fairly good catch rate of 5·38 kg. per hour.

Areas '11' and '10' were highly exploited and '12', '17' and '18' moderately fished. The effort put in the areas '25', '24' and '19' was far below average and that put in the areas '23', '16' '13' and '9' was so poor that there was no prawn catch.

TABLE VII

Areawise distribution of prawn catch (catch-per hour) in kg. by bull-trawlers of New India Fisheries Co. in Cambay region

Area / Year	25	24	19	18	17	12	11	10
1956	0	54 (2·00)	0	990 (6·00)	270 (2·31)	540 (6·53)	2,142 (6·90)	2,394 (4·37)
1957	522 (9·70)	1,674 (12·59)	0	2,574 (13·64)	792 (8·33)	1,782 (15·99)	7,326 (13·21)	8,856 (10·18)
1958	36 (6·00)	72 (3·54)	72 (7·11)	1,008 (7·72)	756 (5·89)	756 (7·11)	6,480 (5·88)	810 (3·27)
1959	..	72 (4·84)	..	315 (7·85)	381 (1·93)	666 (12·67)	593 (8·29)	2,574 (8·37)
1960	..	...	..	..	0	0	216 (4·25)	558 (7·16)
1961	...	..	...	36 (2·88)	288 (4·65)	..	5,292 (17·26)	3,114 (11·35)
1962	..	0	...	198 (12·70)	1,620 (31·2)	756 (13·30)	6,498 (15·45)	3,882 (24·09)
1963	0	0	...	0	72 (2·25)	0	1,746 (4·51)	1,404 (4·47)
Average	140 (8·33)	312 (9·24)	24 (3·29)	732 (9·12)	491 (5·57)	643 (4·02)	3,787 (7·87)	2,949 (8·43)

The average annual catch rates ranged from 3·29 kg. per hour (Table VII) for the area '19' to 9·24 kg. per hour for area '24'. The catch rates in the area '11' varied from 4·25 kg. per hour with the minimum catch of 216 kg. in 1960 to 17·26 kg. per hour with the catch of 5,292 kg. in 1961. The maximum catch of 7,326 kg. with the catch rate of 13·21 kg. per hour was in 1957.

The lowest catch rate in area '10' was 3·27 kg. per hour with the catch of 810 kg. in 1958 and the highest of 24·09 kg. per hour with the catch of 3,882 kg. in 1962. The lowest catch of 558 kg.

with the catch rate of 7·16 kg. per hour and the highest of 8,856 kg. with the catch rate of 10·18 kg. per hour was in 1960 and 1957 respectively.

The catch rates in area '12' ranged from 6·53 kg. with the minimum catch of 540 kg. in 1956 and 15·99 kg. with the maximum catch of 1,782 kg. in 1957.

Area '17' showed the catch rates fluctuating between 1·93 kg. per hour with the catch of 381 kg. in 1959 and 31·2 kg. per hour with the maximum catch of 1,620 kg. in 1962. The minimum catch of 72 kg. with the catch rate of 2·25 kg. per hour was in 1963.

Area '18' recorded the lowest catch of 36 kg. per hour with the catch rate of 2·88 kg. per hour in 1961 and the highest of 2,574 kg. with the catch rate of 13·64 kg. per hour in 1957.

The minimum catch of 36 kg. with the catch rate of 6·00 kg. per hour in 1958 and the maximum of 522 kg. with the catch rate of 9·70 kg. per hour in 1957 were recorded by the area '25'.

In area '24' the lowest catch rate of 2 kg. per hour with the catch of 54 kg. was noticed in 1956. the highest catch rate of 12·59 kg. per hour here was in 1957 when the yield was 1674 kg.

Out of three years of fishing from 1956 to 58 in the area '19' the last one recorded 72 kg. with the catch rate of 7·11 kg. per hour.

The areas '25', '24', '18', '17', '11' and '10' prove to have rich prawn grounds in Cambay region.

Bombay Region

The percentage of prawns in the annual average of total landings being 1·18 (Table I) and the average annual catch rate being as high as 7·18, this region is next to Cambay which ranks first.

The extensively fished areas were '43' and '38', the areas '48', '43 A', '31' and '30' having been fished only occasionally. The rarely fished areas '42', '37', '36' and '32' recorded no prawns.

The average annual catch rates ranged (Table VIII) between 1·50 kg. per hour in the area '30' and 12·25 kg. per hour in '43 A'. Of the two extensively fished areas, area '38' recorded an average annual yield of 7·76 kg. per hour. The catch rates in this area ranged between 3·93 kg. with the catch of 18 kg. in 1958 and 83·62 kg. per hour with the catch of 378 kg. in 1962. The high catch rate in the latter was on account of three rich hauls for an effort of only 3·35 hours as mentioned earlier. The maximum catch of 1,152 kg. with the catch rate of 7·77 kg. per hour was obtained in 1956.

The catch rates in the area '43' ranged from 3·63 kg. per hour with the catch of 108 kg. in 1958 and 7·05 kg. per hour with the catch of 3,528 kg. in 1956.

The area '48' showed a catch of 195 kg. with the catch rate of 11·76 kg. per hour in 1956; area '43 A' catch rate of 13·04 kg. per hour with a catch of 234 kg. in 1957; area '37' a catch rate of 2·46 kg. per hour with the catch of 18 kg. in 1956; area '31' a catch rate of 8·49 kg. with a catch of 72 kg. in 1956 and lastly the area '30' a catch rate of 13·53 kg. with a catch of 18 kg. in 1958.

The areas '48', '43 A', '43', '38' and '31' prove to have rich prawn grounds. Sufficient effort was not expended in other areas but there are indications that areas like '30' may also prove to yield good quantities of prawns in this region.

TABLE VIII

Areawise distribution of prawn catch (catch-per-hour) in kg. by bull-trawlers of New India Fisheries Co. in Bombay region

Area / Year	48	43 A	43	38	37	31	30
1956	198 (11·76)	..	3,528 (7·05)	1,152 (7·77)	18 (2·46)	72 (8·49)	0
1957	..	234 (13·04)	378 (28·35)	306 (8·14)	..	0	..
1958	..	..	108 (3·63)	18 (3·93)	..	0	18 (13·53)
1959	0	0	162 (4·40)	342 (7·31)	..	..	..
1960	..	..	0	54 (7·67)	..	..	..
1961	..	..	..	18 (10·29)	..	..	..
1962	..	..	0	378 (83·62)	..	..	..
1963	..	..	0	18 (5·80)	..	..	..
Average	99 (10·95)	117 (12·25)	597 (7·11)	286 (7·76)	18 (2·46)	24 (5·12)	9 (1·50)

From south of Bombay these trawlers brought very good prawn catches in July 1963. The catches were like 108 kg. with the catch rate of 48 kg. per hour from the area '53' and 72 kg. with the catch rate of 21·6 kg. per hour from '60'. However, there was no catch from the area '54'.

Mention must be made here that a small catch of 72 kg. with the catch rate of 4·32 kg. per hour was obtained from an unclassified area in 1956.

PRAWN YIELDS FROM SUB-AREAS COVERED BY THE GOVERNMENT OF INDIA EXPLORATORY FISHING VESSELS

The Government of India fishing vessels explored the Arabian Sea from Kutch (23° N-68° E.) in the north to beyond Ratnagiri (16° N-72° E.) in the south. The sub-areas between 19° N. and 17° N. off Bombay and Ratnagiri where fishing was adequate showed some interesting results. In others fishing being occasional, it was not possible to judge the richness of those areas.

Major Area 19–72

This area is close to Versova, a fish landing place about 20 miles north of Bombay. It recorded (Table IX) an average annual fishing effort of 118·43 hours when the catch rate was 3·78 kg. per hour. The catch rates ranged from 0·70 kg. in 1962 to 7·52 kg. per hour in 1961 when the catch of 1,394 kg. was the highest.

The average annual catch rates in this area ranged from 0·21 kg. in the sub-area '1 E' to 40·66 kg. per hour in '4 E'. The most regularly fished sub-areas were '1 B', '1 C', '1 D';

moderately fished were '1 E', '2 A', '2 B', '2 C', '3 B' and '4 A' and rarely fished were the remaining ones. The annual average catch rates were good in the sub-areas '4 E', '2 D', '1 D', 1 B' and '3 A'. There was no prawn catch in the sub-areas '2 C' to '6 C' and '3 F'.

TABLE IX

Sub-areawise distribution of prawn catch (catch-per-hour) in kg. by the Government of India vessels in area 19–72

Year / Sub-area	1961	1962	1963	1964	Average
1 B	155 (5·61)	22 (7·33)	0	..	59 (5·43)
1 C	5 (1·32)	67 (1·49)	0	44 (11·0)	36 (1·82)
1 D	854 (20·25)	36 (0·83)	76 (9·92)	..	242 (10·18)
1 E	4 (0·84)	0	..	..	2 (0·21)
2 A	70 (6·08)	0	..	..	35 (3·18)
2 B	120 (5·16)	44 (1·54)	..	..	82 (3·16)
2 D	70 (35·00)	..	..	..	70 (35·0)
3 A	70 (4·72)	0	0	..	63 (4·48)
3 B	20 (1·15)	0	..	..	10 (0·73)
4 A	..	..	30 (4·93)	..	15 (2·90)
4 E	..	..	85 (40·66)	..	85 (40·66)
Total	1,394 (7·52)	169 (0·70)	191 (6·47)	44 (2·11)	450 (3·78)

Major Area 18–72

The combined effort of all these vessels was the maximum in the area 18–72, close to Bombay. An average annual effort of 1,173·15 hours was spent here bringing 6,910 kg. of prawns at a rate of 5·88 kg. per hour. The annual catch rates (Table X) ranged between 4·17 kg. per hour with the lowest catch of 4,343 kg. in 1964 (for the first six months only) and 7·55 kg. per hour with a catch of 8,503 kg. in 1961. The highest catch of 9,457 kg. was in 1962 and the catch rate was 6·62 kg. per hour.

The most extensively fished sub-areas were '5 C' to '5 E', '6 C' to '6 E' and excepting the sub-areas '2 C', '3 C', '4 A', '5 B' and '5 F' which were rarely fished, all the remaining sub-areas shown in the Table were moderately fished. The average annual catch rates fluctuated between 0·15 kg. in '4 C' and 21·65 kg. per hour in '5 B'. In the extensively fished sub-areas, the average annual catch rates ranged between 4·70 kg. in '6 D' and 12·92 kg. per hour in '5 E'. Sub-areas '3 E', '6B' and '6 E' had high average annual catch rates of 18·29 kg., 17·43 kg. and 10·90 kg. per hour respectively. The sub-areas '2 E' to '4 E', '5 C' to '5 E' and ' 6 C' to '6 E' prove to have fairly rich prawn grounds. There was no prawn catch in the sub-areas '1 B', '1 C' to '3 C' and '4 A'.

Major Area 17–73

This is close to Ratnagiri and showed a very good average annual catch rate of 10·80 kg. per hour (Table XI) with a catch of 135 kg. In 1963 the catch rate was as high as 57·26 kg. per hour when the catch was 205 kg.

TABLE X

Sub-areawise distribution of prawn catch (catch-per-hour) in kg. by the Government of India vessels in area 18–72

Year / Sub-areas	1961	1962	1963	1964	Average
1 D	30 (3·48)	55 (3·28)	0	0	21 (1·79)
1 E	0	30 (0·50)	0	0	8 (0·29)
1 F	0	41 (2·05)	78 (8·83)	0	30 (3·18)
2 D	180 (3·55)	0	0	..	60 (2·30)
2 E	270 (7·34)	50 (1·94)	...	0	107 (5·10)
3 D	40 (0·87)	0	0	46 (4·60)	22 (0·96)
3 E	215 (18·29)	..	..	..	215 (18·29)
4 C	0	0	5 (4·00)	0	1 (0·15)
4 D	58 (1·49)	0	0	0	15 (0·69)
4 E	13 (13·00)	–	0	20 (8·88)	11 (6·70)
5 B	..	..	157 (21·65)	..	157 (21·65)
5 C	7 (0·34)	200 (2·43)	831 (9·36)	200 (17·02)	310 (6·11)
5 D	2,100 (9·38)	2,318 (6·88)	957 (2·66)	404 (7·31)	1,445 (5·93)
5 E	1,607 (13·21)	1,514 (14·34)	1,430 (16·71)	13 (0·32)	1,141 (12·92)
5 F	–	8 (4·00)	–	...	8 (4·00)
6 B	340 (24·28)	..	0	..	170 (17·43)
6 C	200 (20·87)	202 (2·29)	278 (3·79)	379 (8·22)	265 (4·88)
6 D	3,071 (9·65)	2,072 (3·39)	1,068 (2·76)	3,113 (6·67)	2,331 (4·70)
6 E	732 (5·57)	3,300 (33·59)	533 (11·68)	168 (1·05)	1,183 (10·90)
Total	8,503 (7·55)	9,457 (6·62)	5,337 (4·87)	4,343 (4·17)	6,910 (5·88)

TABLE XI

Sub-areawise distribution of prawn catch (catch-per hour) in kg. by the Government of India vessels in area 17–73

Year / Sub-areas	1961	1962	1963	1964	Average
1 A	20 (5·71)	105 (19·1)	30 (20·00)	20 (4·90)	49 (13·39)
1 B	..	..	175 (84·14)	0	88 (42·40)
2 A	110 (9·16)	60 (34·30)	..	..	85 (12·37)
Total	130 (7·42)	185 (6·78)	205 (57·26)	20 (1·64)	135 (10·80)

Very good average annual catch rates ranging between 12·37 kg. in the sub-area '2 A' and 42·40 kg. per hour in '1 B' were noticed in this region. Sub-area '1 B' recorded 84·14 kg. per hour with a catch of 175 kg. in 1963. All the 3 sub-areas '1 A', '1 B' and '2 A' prove to be good for prawn. There was no catch in the sub-areas '3 A' and '4 F'.

Major Area 17–72

This is further off the previous area in Ratnagiri. The average annual catch rate of 3·47 kg. per hour (Table XII) was again low and the catch was 145·5 kg. Good catch rates were observed in 1962 and 1963 with the catches of 135 kg. and 364 kg. respectively.

Only some of the sub-areas fished have yielded prawn catch. The average annual catch rates ranged between 0·09 kg. in the sub-area '3 F' and 15·45 kg. per hour in '6 F'. The sub-area '4 F' with an average annual catch rate of 5·39 kg. per hour together with '6 F' indicate good prawn grounds in this region. In most of the sub-areas, namely, '1 C' to '1 F', '4 A', '4D' to '6 D', '5 C', '5 E' and '6 C' there was no prawn catch.

TABLE XII

Sub-areawise distribution of prawn catch (catch-per-hour) in kg. by the Government of India vessels in area 17–72

Year / Sub-areas	1961	1962	1963	1964	Average
3 F	5 (0·09)	...	...	...	5 (0·09)
4 E	0	..	30 (3·61)	0	10 (1·66)
4 F	78 (1·43)	30 (10·00)	35 (4·21)	..	48 (5·39)
5 F	0	40 (5·00)	0	..	13 (3·64)
6 E	0	0	30 (0·53)	..	10 (2·09)
6 F	0	65 (8·1)	234 (4·14)	..	100 (15·45)
Total	83 (1·28)	135 (8·43)	364 (5·61)	0	146 (3·47)

DEPTH-WISE DISTRIBUTION

To understand the pattern of distribution of prawns at different depths, the haul-wise catch data in different months, in different regions, have been studied for one year, *i.e.*, 1962 when catches were the highest in the entire 8 years period of the observations of the New India Fisheries vessels. For this purpose the depth ranges covered have been grouped at 5 metre intervals and the results are shown in Figs. 3–8.

Kutch Region

The depth ranges fished (Fig. 3) were between 16–20 and 66–70 metres. But the fishing was concentrated mostly between 21–25 metres and 46–50 metres. The catch rates ranged between 0·51 kg. per hour with a catch of 36 kg. in December at a depth of 26–30 metres and 13·04 kg. per hour when the highest catch of 558 kg. was in May at a depth of 55–60 metres. There was no fishing in June and July. Usually the catch rates were less than 10 kg. per hour at different depth ranges in this region.

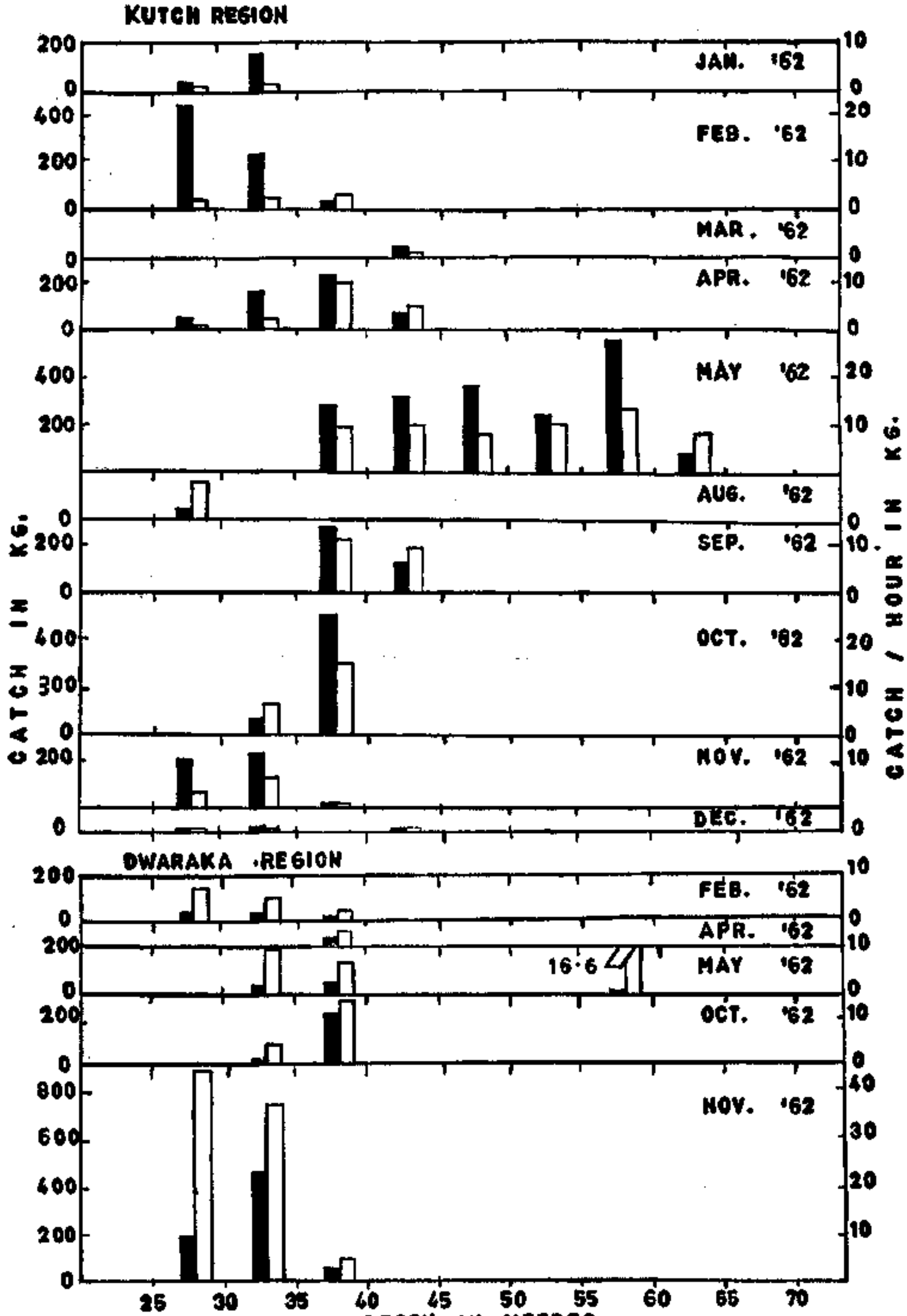

FIG. 3. Depth-wise distribution of prawns in the landings of New India Fisheries bull-trawlers in Kutch and Dwarka regions.

Dwarka Region

There was either no fishing or the catches were nil in most of the months. The fishing depth ranges varied between 21–25 metres and 56–60 metres (Fig. 3). When prawns were obtained, the catch rates ranged between 1·66 kg. per hour with a catch of 18 kg. at a depth range of 36–40 metres in February and 44·33 kg. per hour with a catch of 180 kg. at a depth range of 26–30 metres in November. Excepting in the depth ranges of 56–60 metres in May, of 36–40 metres in October and of 31–35 metres in November when the catch rates were 16·66 kg., 12·90 kg. and 36·00 kg. per hour respectively, the catch rates in all other depth-ranges were less than 10 kg. per hour.

Porbundar Region

There was no fishing in October and the catch was nil in February when the fishing was between the depth-ranges of 31–35 metres and 41–45 metres (Fig. 4). Most of the fishing was between the depth-ranges of 31–35 metres and 46–50 metres. The catch rate of 0·84 kg. per hour was the lowest in March at a depth-range of 36–40 metres and the highest of 62·06 kg. per hour in July at a depth range of 31–35 metres. The catch rates mostly were above 10 kg. and at times exceeding even 20 kg. per hour at various depth-ranges.

Veraval Region

The fishing depths ranged between 26–30 metres and 61–65 metres (Fig. 5) but much of the fishing was done in the depth-ranges of 36–40 metres and 41–45 metres. There was no prawn catch during January to March and also October when the fishing was below 41–45 metres depth-range. In September there was no fishing. The catch rates ranged between 3·10 kg. per hour with a catch of 36 kg. in April at a depth-range of 36–40 metres and 66·93 kg. per hour with the highest catch of 1,692 kg. in August at a depth of 41–45 metres. High catch rates of 57·27 kg. in August and 35·79 kg. per hour in June were registered at the depth-ranges of 46–50 metres and 51–55 metres respectively. Catch rates above 15 kg. were very often met with at various depth-ranges.

Cambay Region

Fishing was more or less uniformly distributed between the depth-ranges of 26–30 metres and 71–75 metres (Fig. 6). Fishing with no prawn yield was at the dapth-ranges of 36–40 metres in February and 31–35 metres and 36–40 metres in December. The lowest catch rate of 2·78 per hour with the catch of 18 kg. at the depth-range of 41–45 metres. in September and the highest catch rate of 37·26 kg. per hour with the catch of 702 kg. at the depth range of 61–65 metres in July were observed in this region. In general the catch rates were mostly above 15 kg. per hour at different depth-ranges.

Bombay Region

Fishing in 1962 was carried out during May and September only. In May the fishing was at the depth-range of 41–45 metres when the prawn catch was nil. In September there was an exceptionally good catch of 378 kg. with a catch rate of 112·82 kg. per hour at the depth-range of 46–50 metres.

The Government of India vessel, *M.F.V. 'Jheenga'*, fished between the depths 9 and 60 metres in different areas in 1962, covering the major areas between 23° N. and 17° N. Most of the areas fished in different months at all the depth-ranges could not give any picture of the depth-wise distribution as the prawn catch was nil except in 20–72, 19–72, 17–72 and 17–73 as detailed below.

In January the area 20–72 had the maximum of 5 kg. per hour with the catch of 10 kg. in the depth-range 36–40 metres. The catch of 37 kg. with 1·89 kg. per hour was in the depth-range of

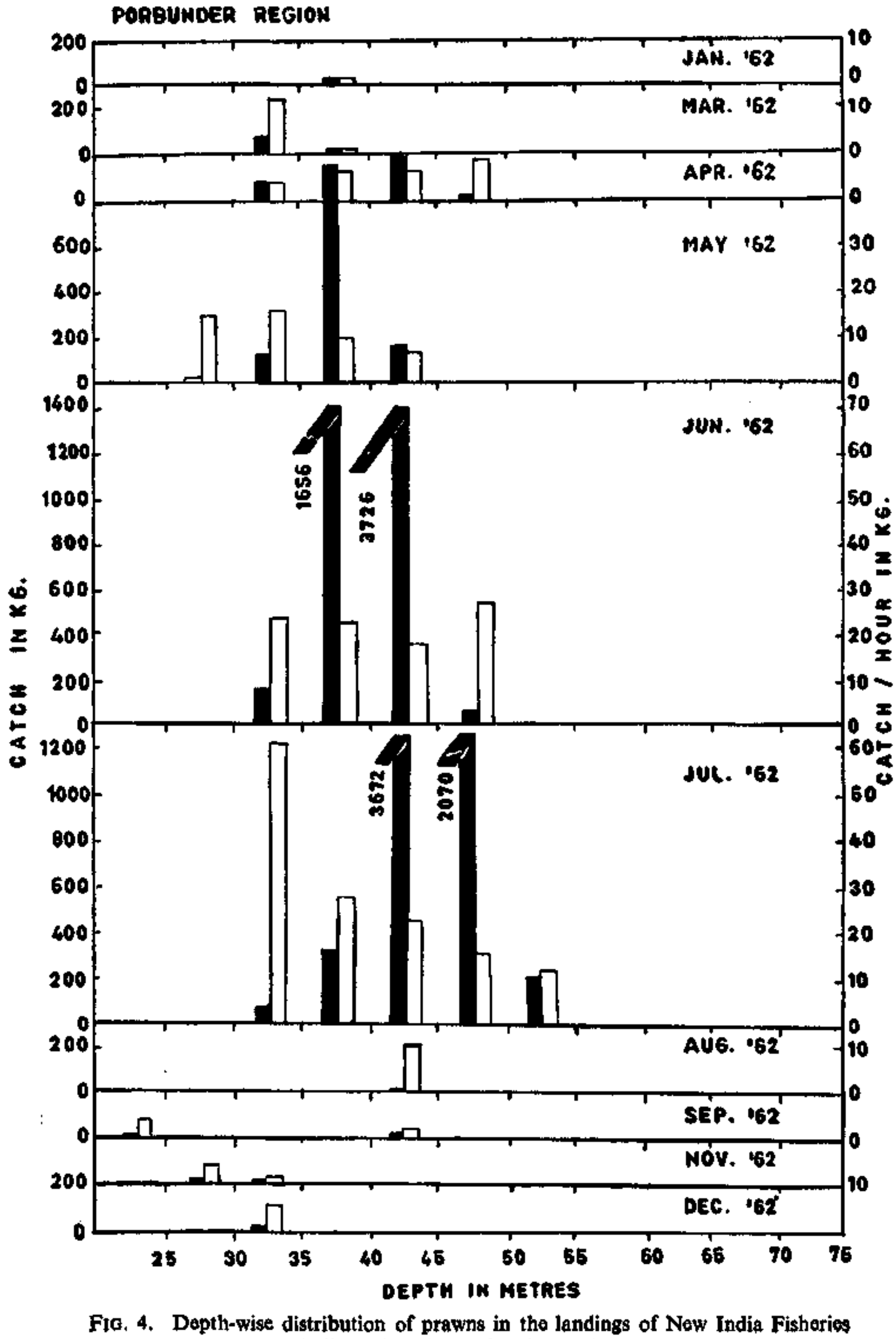

FIG. 4. Depth-wise distribution of prawns in the landings of New India Fisheries bull-trawlers in Porbundar region.

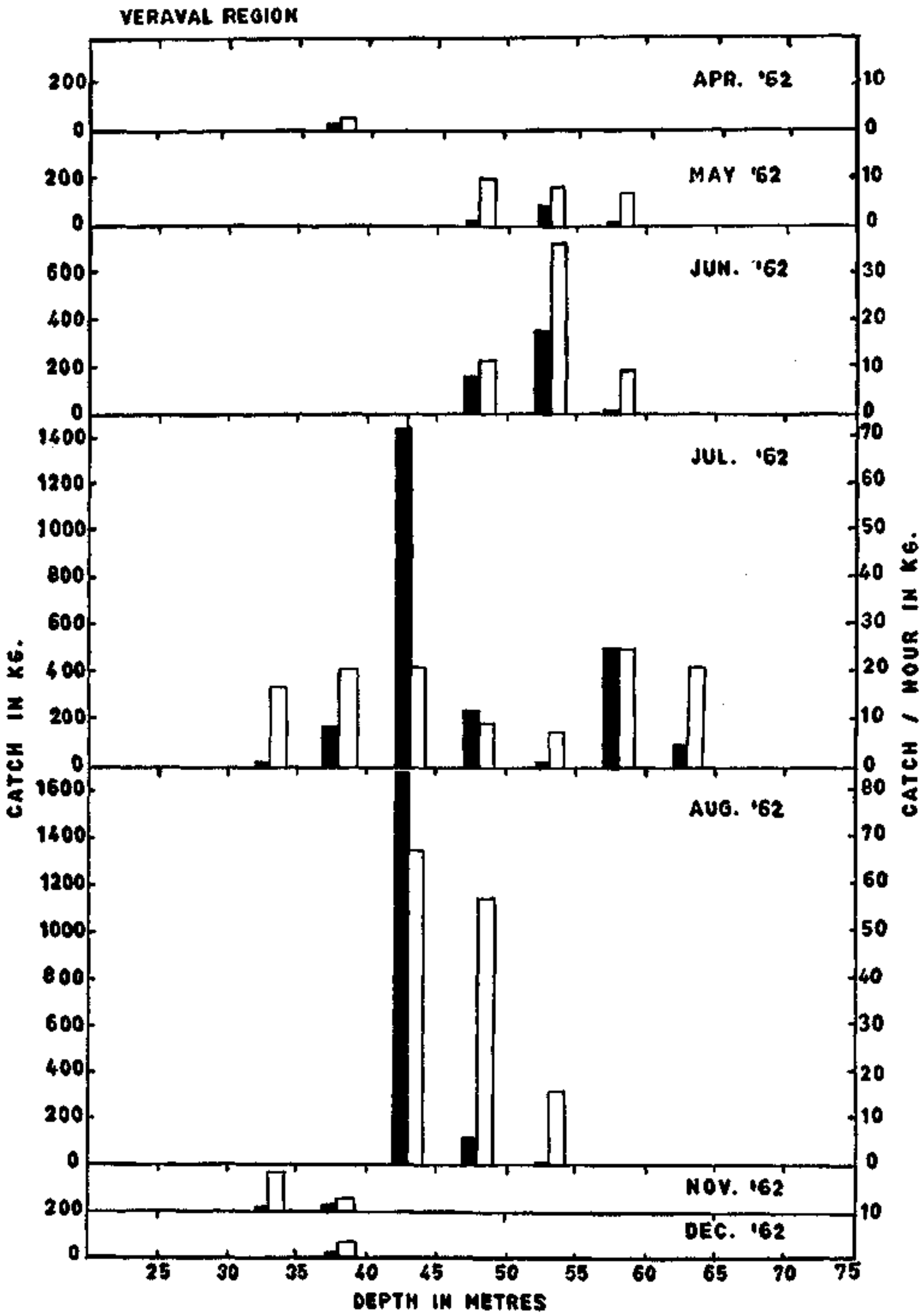

FIG. 5. Depth-wise distribution of prawns in the landings of New India Fisheries bull-trawlers in Veraval region.

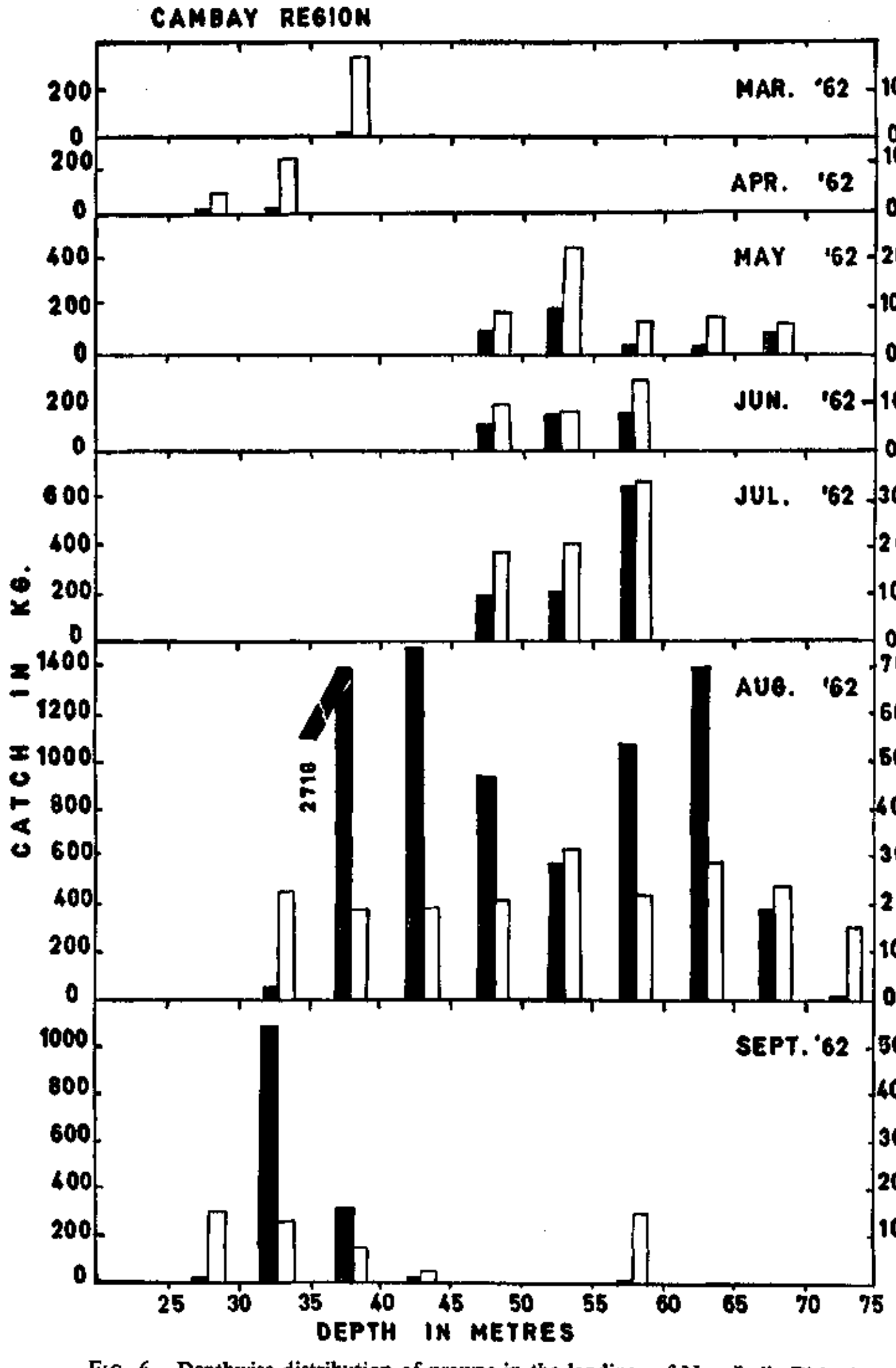

FIG. 6. Depthwise distribution of prawns in the landings of New India Fisheries bull-trawlers in Cambay region.

26–30 metres while in the depth-range of 31–35 metres the catch of 30 kg. had 1·62 kg. per hour of fishing.

The area 19–72 was fished from January to March and also in June and October (Fig. 7) with no prawn catch in January when the fishing was between the depth-ranges 26–30 metres and 46–50 metres and in March in the depth-ranges of 31–35 metres and 36–40 metres. February showed the catches of 14 kg. with 1·27 kg. per hour and 30 kg. with 1·61 kg. per hour in the depth ranges of 31–35 and 36–40 metres. In the very next higher and lower depth-ranges, the catch was nil. In June the catch rates were fairly good ranging between 4 kg. and 16·66 kg. per hour in the different depth-ranges fished. The highest of 16·66 kg. for the catch of 25 kg. was in the depth-range of 31–35 metres. There was a small catch of only 1 kg. with the catch rate of 0·28 kg. per hour in December in the depth-range of 16–20 metres while in the next two higher depth-ranges, the catch was nil.

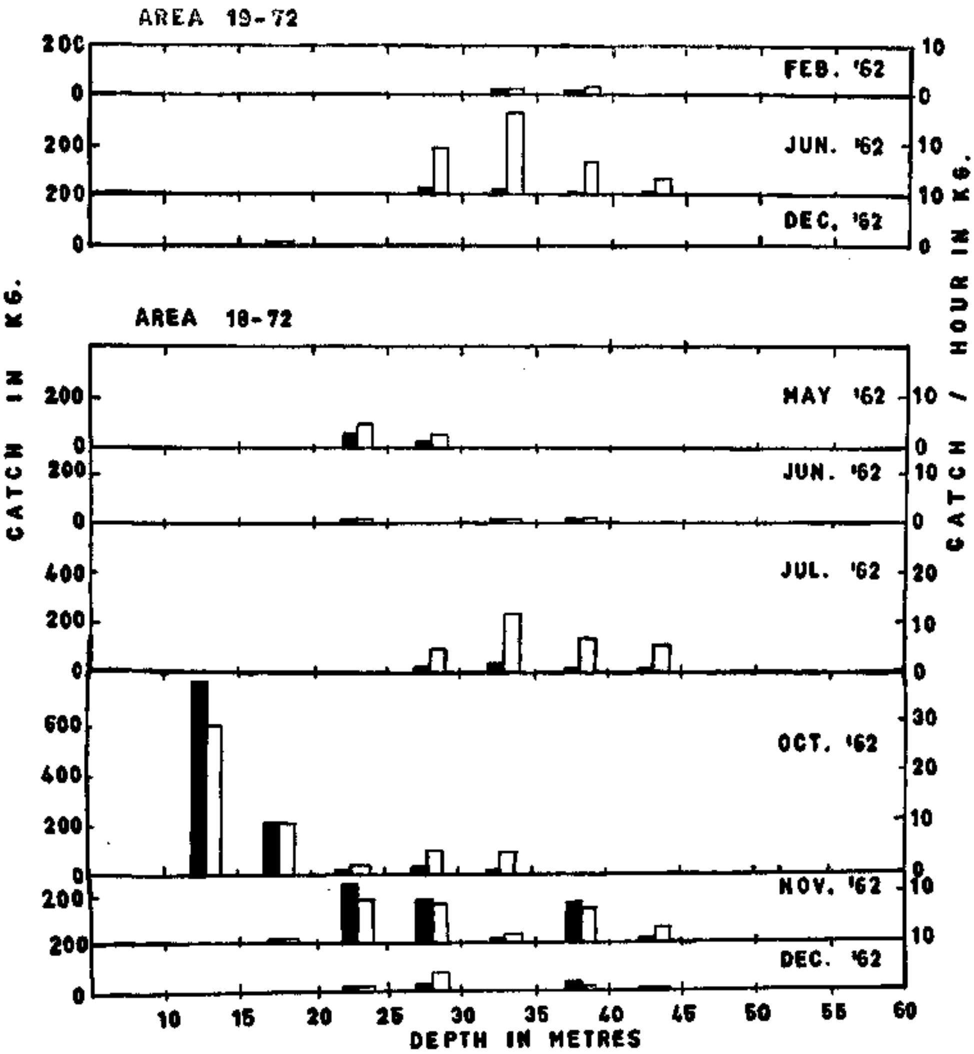

FIG. 7. Depthwise distribution of prawns in the landings of otter-trawlers of Government of India Deep Sea Fishing Station, Bombay, in the areas 19–72 and 18–72.

Fishing in area 18–72 in the first 4 months of the year, covering the depth ranges between 16–20 metres and 51–55 metres (Fig. 7) did not register any prawn catch and there was no fishing in August and September. During rest of the 6 months, the catch rates ranged between 0·64 kg. per hour for the catch of 5 kg. in the depth-range of 21–25 metres in December and 29·98 kg. per hour for the highest catch of 788 kg. in the depth-range of 11–15 metres in October. In fairly good number of other depth-ranges, the catch rates varied between 5 and 12 kg. in different months.

The area 17–72 was fished in May at the two successive depth-ranges of 21–25 metres and 26–30 metres when the catches were like 65 kg. with the catch rate of 8·12 kg. per hour and 70 kg. with the catch rate of 5·60 kg. per hour respectively.

The area 17–73 which was also fished in May had a very good catch rate of 21·14 kg. per hour for the catch of 185 kg. in the depth range of 26–30 metres.

Generally fishing by these trawlers was concentrated between the depth-ranges of 21–25 metres and 46–50 metres. It is observed that the catch rates were less than 10 kg. per hour in Kutch and Dwarka regions, and up to 20 kg. and even more in other regions at differant depth-ranges covered by bull-trawlers. The catch rates were between 5 and 12 kg. per hour in the Bombay region and 8 and 21 kg. in south of Bombay for the vessel *M.F.V. 'Jheenga'*.

The above observations, based on the operations of bull-trawls and other trawls in Bombay-Saurashtra waters show that the prawns are not confined in their distribution to any particular depth range; that they inhabit in higher or lower densities of populations at all depths between 9 and 72 metres and that they occur in good quantity in as shallow a depth-range as 11–15 metres and as deep a depth-range as 61–65 metres.

Seasonal Variations

Unlike some of the commercially important fish species, the prawns in general are not highly seasonal in their occurrence in the trawler landings. They are found all round the year. All the same, in certain months they occur in comparatively greater abundance. The catch usually begins to rise by May and dwindles down by November, accompanied with slight variations and exceptions in the trawling grounds of the different regions.

Kutch Region

This region was fished regularly in almost all the months from 1960 onwards. Prawn catch showed a tendency to increase from May onwards, with an annual average of 0·5% and to decrease after October when the annual average was 0·36%. The period from July to October was the peak one for prawn catches, the percentage in July ranging between 0·69 with the catch of 810 kg. in 1961 and 1·03 with the catch of 216 kg. in 1960 whereas in October between 0·15 with the catch of 450 kg. in 1960 and 0·92 with the catch of 1,080 kg. in 1963. However, a fairly good catch of 1,026 kg. forming 0·64% of the total landings was met with in March 1963 (Table XIII).

Dwarka Region

Excepting in 1960 and 1961, there was almost no fishing from May to September in the Dwarka region. Though the catch was good forming 1·24% in April 1963, 1·12% in May 1962 and 1·28% in June 1960 and with no sufficient information about July and August, high catch percentages were obtained in most of the years from September to December. Very high percentages of 4·54 with the catch of 666 kg. and 4·10 with the catch of 162 kg. were obtained in November 1962 and October 1963 respectively (Table IV).

TABLE XIII

*Monthly prawn catch by bull-trawlers of New India Fisheries Co. in Kutch region**

Year / Month	1958 Catch in kg. (catch rate) %	1959 Catch in kg. (catch rate) %	1960 Catch in kg. (catch rate) %	1961 Catch in kg. (catch rate) %	1962 Catch in kg. (catch rate) %	1963 Catch in kg. (catch rate) %	Average Catch in kg. (catch rate) %
January	..	..	198 (0·62) 0·06	558 (1·58) 0·17	198 (0·50) 0·04	414 (1·31) 0·14	342 (3·95) 0·10
February	..	..	36 (0·10) 0·01	180 (0·51) 0·04	702 (1·98) 0·19	36 (0·11) 0·01	238 (0·70) 0·06
March	..	0	270 (0·65) 0·06	558 (1·42) 0·14	54 (0·16) 0·01	1,026 (4·95) 0·64	362 (1·28) 0·13
April	..	261 (1·09) 0·12	1,350 (3·75) 0·42	1,242 (4·17) 0·42	486 (2·96) 0·36	252 (2·26) 0·29	718 (3·06) 0·34
May	..	..	744 (3·04) 0·32	396 (3·11) 0·36	1,854 (9·30) 0·96	..	998 (5·25) 0·50
June	..	..	522 (14·59) 2·02	54 (0·80) 0·12	..	...	144 (4·87) 0·76
July	..	..	216 (10·64) 1·03	810 (4·22) 0·69	..	18 (4·15) 0·90	348 (4·82) 0·74
August	..	..	2,070 (5·97) 0·96	126 (1·40) 0·26	54 (3·10) 0·60	..	750 (4·97) 0·82
September	..	..	846 (2·46) 0·30	630 (4·58) 0·51	432 (7·11) 1·01	1,153 (5·29) 0·61	555 (2·92) 0·42
October	..	0	450 (1·49) 0·15	648 (3·49) 0·29	576 (12·06) 0·86	1,080 (6·33) 0·92	551 (3·60) 0·36
November	18 (0·57) 0·11	54 (0·48) 0·03	774 (3·51) 0·29	738 (4·85) 0·47	432 (3·19) 0·35	..	403 (3·09) 0·28
December	..	162 (0·75) 0·06	1,260 (2·79) 0·34	558 (1·77) 0·15	72 (0·41) 0·04	..	362 (1·91) 0·19

* There was no fishing in 1956 in this region. In 1957 there was fishing only in December and the catch was nil.

TABLE XIV

Monthly prawn catch by bull-trawlers of the New India Fisheries Co. in Dwarka region

Year / Month	1956 Catch Kg. (c.p.h.) %	1957 Catch Kg. (c.p.h.) %	1958 Catch Kg. (c.p.h.) %	1959 Catch Kg. (c.p.h.) %	1960 Catch Kg. (c.p.h.) %	1961 Catch Kg. (c.p.h.) %	1962 Catch Kg. (c.p.h.) %	1963 Catch Kg. (c.p.h.) %	Average Catch Kg. (c.p.h.) %
January	..	54 (0·17) 0·02	36 (0·29) 0·04	90 (0·96) 0·18	54 (0·56) 0·08	0	0	0	33 (0·35) 0·05
February	..	0	126 (0·72) 0·06	90 (0·40) 0·06	0	0	90 (3·67) 0·47	0	44 (0·41) 0·06
March	...	54 (0·22) 0·04	0	144 (0·53) 0·10	0	72 (1·07) 0·01	0	0	39 (0·34) 0·05
April	0	0	..	63 (0·52) 0·09	0	0	18 (1·84) 0·35	90 (7·37) 1·24	24 (0·60) 0·11
May	..	..	..	..	72 (2·81) 0·31	36 (2·94) 0·39	108 (7·80) 1·12	..	72 (4·20) 0·05
June	..	..	..	..	288 (15·44) 1·28	18 (1·43) 0·20	..	..	153 (9·80) 0·97
July	..	..	..	..	..	18 (1·02) 0·20	..	..	18 (1·02) 0·20)
August	..	..	..	..	0	18 (2·37) 0·39	..	..	9 (0·95) 0·18
September	..	..	..	..	216 (3·10) 0·41	126 (12·35) 2·87	..	234 (5·96) 0·50	192 (4·83) 0·55
October	..	990 (11·30) 1·81	90 (2·66) 0·31	18 (0·28) 0·04	0	198 (4·28) 0·32	144 (10·21) 0·68	162 (23·41) 4·10	229 (6·17) 0·74
November	504 (1·66) 0·14	1,080 (3·02) 0·74	1,746 (6·23) 0·75	216 (5·1) 0·50	18 (1·54) 0·29	..	666 (26·57) 4·54	..	705 (4·29) 0·54
Dcember	0	126 (1·05) 0·24	702 (4·04) 0·63	72 (3·54) 0·71	72 (2·98) 0·68	0	0	..	139 (1·26) 0·21

Porbundar Region

The fishing operations in this region were carried out in almost all the months every year, but the catch with an exception in October 1963, when it formed 0·97%, proved to be quite poor in almost all the years from September to November. The catch started increasing from May and showed a good peak from June to August with the highest annual average of 1·70% in July when the percentages ranged from 0·37 with the catch of 216 in 1958 and 2·69 with the lowest catch of 18 kg. in 1956. The highest catch of 6,372 kg. in July was in 1962 and it formed 2·61% of the total landings. A fairly good catch of 468 kg. giving 0·68% was observed in April 1962 (Table XV).

Veraval Region

The fishing was fairly good throughout. Very high percentages of prawns were noticed from May to October extending even upto December. The best months were from July to September when the average annual percentages ranged between 1·31 and 1·75. The catch in May was fairly good and excepting in 1957 and 1958, it ranged from 0·50% with the catch of 297 kg. in 1959 to 1·32% with the catch of 162 kg. in 1962. August catch was the best with its percentages varying between 0·44 with the catch of 324 kg. in 1958 and 6·67 with the catch of 1,836 kg. in 1962. November showed an indication of a good catch with 0·66% for a small catch of 36 kg. in 1962. In December 1961 very high percentage of 4·81 was shown with a catch of 54 kg. In March 1958, there was a fairly good record of 126 kg. forming 0·73% (Table XVI).

Cambay Region

Fishing was good throughout. High prawn yields in this region were noticed for a fairly prolonged period every year, from March to November when the average annual percentages were 0·55 and 0·86 respectively. The best period for prawn was observed to be from June to October when the average annual percentages varied from 1·08 to 1·83. Fairly good prawn catches forming 1·43% and 1·32% in March 1962 and 1963 respectively and also in certain years forming above 0·46% in April were observed in this region. Very high percentage of 7·44 with the catch of 2,304 kg. was recorded in July 1962. In most of the years, the highest catch recorded was in September when the percentages varied between 1·01 with the catch of 1,458 kg. in 1962 and 2·94 with the catch of 6,732 kg. in 1957. In November 1957 the highest prawn percentage of 5·88 for the year was recorded when the catch was 54 kg. (Table XVII).

Bombay Region

The fishing by the bull-trawlers in this region was comparatively very poor. The effort of 703·92 hours put in the 9 months fishing in 1956 alone was good, but in the subsequent 3 years it was less being 75·77, 79·74 and 91·75 hours. In the last 3 years the effort was reduced to 11·24, 1·75 and 5·69 hours only. However, the data are far too insufficient to draw any conclusions (Table XVIII).

Prawns started appearing in the catches of this region from March and continued to occur in increasing quantities till October, the peak period shown being from July to October with the last two months as the best months. In September 1962, the highest percentage of 16·32 with a catch of 378 kg. and in October also of the same year, a very high percentage of 15 to 29 with the catch of 234 kg. were recorded. The highest yield of 1,782 kg. in this region giving 3·56% was in July 1956.

To supplement the information and to substantiate the results obtained, the data from operations of the Government of India vessels in the major area 18–72 was made use of. Prawns started appearing in good quantity from May and extended upto December with July to October as an extremely good period for this fishery. Highest of 28·25% with a catch of 4,826 kg. was obtained in September 1962. The highest yield of 4,827 kg. had 11·79% in October 1961. A catch of 1,340 kg. formed 10·31% in August 1963. A very good catch of 2,833 kg. forming 6·59% was met

TABLE XV

Monthly prawn catch by bull-trawlers of New India Fisheries Co. in Porbundar region

Year / Month	1956 Catch Kg. (c.p.h.) %	1957 Catch Kg. (c.p.h.) %	1958 Catch Kg. (c.p.h.) %	1959 Catch Kg. (c.p.h.) %	1960 Catch Kg. (c.p.h.) %	1961 Catch Kg. (c.p.h.) %	1962 Catch Kg. (c.p.h.) %	1963 Catch Kg. (c.p.h.) %	Average Catch Kg. (c.p.h.) %
January	..	0	18 (0·05) 0	180 (0·56) 0·09	0	90 (3·84) 0·50	18 (0·81) 0·17	0	44 (0·35) 0·05
February	..	0	36 (0·24) 0·04	54 (0·31) 0·05	36 (0·59) 0·08	..	0	0	21 (0·21) 0·03
March	..	0	0	54 (0·35) 0·06	0	..	90 (3·16) 0·30	18 (0·13) 0·01	27 (0·19) 0·04
April	0	0	36 (0·39) 0·04	36 (0·75) 0·10	0	72 (1·53) 0·15	468 (6·22) 0·68	216 (1·90) 0·23	104 (1·17) 0·15
May	18 (1·56) 0·34	0	360 (2·78) 0·39	45 (1·25) 0·17	306 (3·52) 0·39	252 (2·21) 0·23	1,062 (40·84) 1·05	90 (8·13) 2·08	267 (3·99) 0·46
June	..	0	468 (6·71) 1·23	234 (3·37) 0·59	3,150 (10·72) 2·00	612 (2·64) 0·37	5,580 (19·38) 2·04	504 (1·45) 0·21	1,507 (8·06) 1·16
July	18 (4·31) 2·69	540 (5·48) 1·42	216 (1·78) 0·37	342 (3·65) 0·83	3,816 (10·88) 1·95	540 (4·84) 0·87	6,372 (20·24) 2·61	2,610 (8·71) 1·26	1,807 (10·37) 1·70
August	0	..	..	..	414 (13·42) 3·91	216 (3·52) 0·74	36 (2·87) 1·45	36 (3·13) 0·97	140 (0·58) 1·51
September	0	0	..	..	..	0	36 (1·69) 0·44	0	7 (0·83) 0·32
October	..	0	0	0	0	36 (3·16) 0·43	..	54 (8·09) 0·97	15 (0·92) 0·14
November	0	54 (0·35) 0·07	0	0	0	0	36 (1·50) 0·20	..	13 (0·28) 0·04
December	0	18 (0·06) 0·01	108 (0·38) 0·05	0	18 (1·03) 0·11	18 (0·54) 0·03	36 (3·34) 0·58	..	28 (0·30) 0·04

TABLE XVI

Monthly prawn catch by bull-trawlers of New India Fisheries Co. in Veraval region

Year / Month	1956 Catch Kg. (c.p.h.) %	1957 Catch Kg. (c.p.h.) %	1958 Catch Kg. (c.p.h.) %	1959 Catch Kg. (c.p.h.) %	1960 Catch Kg. (c.p.h.) %	1961 Catch Kg. (c.p.h.) %	1962 Catch Kg. (c.p.h.) %	1963 Catch Kg. (c.p.h.) %	Average Catch Kg. (c.p.h.) %
January	..	0	18 (0·34) 0·06	9 (0·17) 0·03	0	90 (2·40) 0·21	0	0	17 (0·64) 0·08
February	..	0	0	0	18 (0·82) 0·09	..	0	0	3 (0·11) 0·01
March	..	0	126 (3·66) 0·73	0	0	0	0	90 (1·57) 0·20	31 (1·61) 0·24
April	0	0	0	0	18 (1·09) 0·11	0	36 (3·10) 0·25	54 (1·00) 0·12	14 (0·74) 0·08
May	36 (3·58) 0·84	0	18 (0·72) 0·10	297 (2·96) 0·50	432 (6·68) 0·98	162 (4·54) 0·74	162 (3·07) 1·32	..	158 (4·10) 0·67
June	..	486 (2·76) 0·44	216 (4·20) 0·84	756 (6·44) 1·01	828 (6·42) 1·07	450 (7·18) 1·24	558 (20·72) 4·61	360 (2·66) 0·49	522 (5·23) 0·89
July	0	828 (5·16) 1·17	216 (0·86) 0·14	792 (7·89) 1·57	810 (8·44) 2·06	414 (6·42) 1·78	2,484 (18·77) 3·29	468 (6·77) 1·04	752 (6·88) 1·31
August	198 (10·77) 0·72	306 (11·77) 1·34	324 (3·4) 0·44	270 (5·91) 1·38	540 (17·22) 4·50	1,656 (11·46) 1·38	1,836 (64·19) 6·67	90 (4·35) 1·09	652 (12·79) 1·68
September	0	0	126 (4·11) 0·62	54 (46·15) 5·35	..	576 (15·67) 3·01	..	..	151 (8·86) 1·75
October	..	0	0	18 (3·77) 1·44	..	18 (5·14) 2·27	0	..	7 (1·51) 0·66
November	0	0	..	0	18 (4·07) 0·45	..	36 (4·85) 0·66	..	11 (1·94) 0·28
December	0	0	0	0	..	54 (38·57) 4·81	18 (1·68) 0·36	..	12 (0·33) 0·06

TABLE XVII

Monthly prawn catch by bull-trawlers of New India Fisheries Co. in Cambay region

Year / Month	1956 Catch Kg. (c.p.h.) %	1957 Catch Kg. (c.p.h.) %	1958 Catch Kg. (c.p.h.) %	1959 Catch Kg. (c.p.h.) %	1960 Catch Kg. (c.p.h.) %	1961 Catch Kg. (c.p.h.) %	1962 Catch Kg. (c.p.h.) %	1963 Catch Kg. (c.p.h.) %	Average Catch Kg. (c.p.h.) %
January	..	0	0	27 (0·27) 0·05	0	0	..	0	5 (0·19) 0·03
February	..	..	0	18 (0·20) 0·01	18 (3·15) 0·37	..	0	0	7 (0·22) 0·01
March	—	0	0	0	—	..	18 (5·50) 1·43	540 (9·81) 1·32	112 (3·38) 0·55
April	0	0	90 (0·69) 0·09	36 (2·42) 0·46	72 (3·74) 0·66	36 (3·55) 0·65	54 (7·71) 0·79	90 (1·54) 0·25	47 (0·83) 0·13
May	432 (1·96) 0·22	738 (4·94) 0·73	180 (1·30) 0·21	450 (3·68) 0·80	18 (0·90) 0·27	288 (6·11) 1·15	534 (10·12) 2·08	0	330 (3·51) 0·53
June	288 (4·41) 0·72	4,878 (14·53) 1·01	180 (3·04) 0·60	396 (5·41) 1·06	36 (3·44) 0·63	432 (5·22) 1·13	450 (10·14) 2·22	72 (2·52) 0·52	842 (9·63) 1·78
July	540 (3·19) 0·27	1,890 (7·47) 1·01	270 (2·20) 0·36	864 (8·08) 1·45	504 (8·25) 1·86	252 (4·82) 0·97	2,304 (32·43) 7·44	414 (5·77) 0·90	880 (7·76) 1·08
August	2,412 (7·89) 1·49	6,714 (13·88) 1·81	3,024 (7·73) 0·95	3,720 (11·79) 2·00	126 (6·78) 1·40	2,358 (12·52) 2·45	8,658 (22·02) 2·33	1,602 (3·52) 0·53	3,577 (11·22) 1·46
September	2,106 (10·11) 1·30	6,732 (18·05) 2·94	3,654 (9·19) 1·19	3,060 (10·12) 1·71	..	5,364 (19·61) 2·88	1,458 (10·19) 1·01	504 (7·80) 1·24	3,268 (12·98) 1·83
October	612 (3·63) 0·48	2,520 (10·06) 1·94	2,592 (7·32) 0·82	1,368 (12·03) 3·40	..	..	..	0	1,418 (7·96) 1·15
November	0	54 (7·54) 5·88	0	..	..	..	..	..	18 (2·95) 0·86
December	..	0	0	..	..	..	..	..	0

with in May 1964. A fairly good prawn catch appeared in December also, forming 3·09% with the catch of 480 kg. in 1963. However, in January 1961, there appeared exceptionally good catch of 400 kg. giving 1·61% in this region.

TABLE XVIII

Monthly prawn catch by bull-trawlers of New India Fisheries Co., Bombay region

Year / Month	1956 Catch Kg. (c.p.h.) %	1957 Catch Kg. (c.p.h.) %	1958 Catch Kg. (c.p.h.) %	1959 Catch Kg. (c.p.h.) %	1960 Catch Kg. (c.p.h.) %	1961 Catch Kg. (c.p.h.) %	1962 Catch Kg. (c.p.h.) %	1963 3Ctch Kg. (c.p.h.) %	Average Catch Kg. (c.p.h.) %
January	..	0	..	..	..	..	..	..	0
February	..	..	0	0	..	..	..	..	0
March	..	..	0	0	..	..	..	18 (3·42) 0·79	6 (0·74) 0·17
April	..	378 (81·00) 25·59	0	18 (3·54) 0·88	18 (5·26) 2·67	—	—	—	104 (22·22) 8·84
May	54 (1·37) 0·28	0	0	18 (0·08) 0·38	36 (8·16) 3·38	—	0	—	18 (0·93) 0·19
June	810 (3·13) 0·47	0	54 (2·93) 1·16	0	..	—	..	..	216 (3·05) 0·48
July	1,782 (11·56) 3·56	18 (5·66) 1·23	18 (13·53) 2·55	..	0	—	..	—	454 (11·20) 3·42
August	0	0	0	..	..	18 (10·28) (4·08)	..	..	5 (2·76) 0·80
September	828 (8·90) 0·70	288 (8·05) 4·74	54 (4·44) 1·27	216 (12·86) 3·51	..	..	378 (112·83) (16·32)	..	353 (10·96) 1·28
October	1,494 (9·57) 1·07	234 (93·60) 15·29	18 (1·63) 0·35	252 (21·31) 5·68	..	..	..	—	500 (11·03) 1·33
November	0	..	0	..	..	..	..	..	0
December	..	..	..	0	..	..	..	..	0

Right from Kutch in the north to Bombay in the south, the prawn catch shows a good rise from May onwards till October. The tendency towards increase is observed as early as March-April in almost all the regions. In regions excepting Kutch and Porbundar, the fishery continues to be good till November-December. In general, July to October with slight shift at times by a month this side or that, is noticed to be the peak period in all the regions excepting Dwarka where it is from September to December. The best months within this peak period vary in different regions, January and February are the poorest months for this fishery in Bombay region.

PRAWN CATCH FROM TRAWLS IN OTHER PARTS OF INDIA

Several of the Government of India exploratory fishing vessels are operating on the east and west coasts of India with bases at Mangalore ,Cochin, Tuticorin and Waltair. At Mangalore in addition to these, a good number of mechanised vessels belonging to the State Fisheries Department and at. Karwar and Cochin, vessels belonging to the Indo-Norwegian Project are also engaged in fishing. The reports (monthly offshore catch data: Central Marine Fisheries Research Institute, Mandapam Camp) on the operations of the above vessels for the period April 1963 to March, 1964 give the following information.

Karwar

The fishing started in September 1963. The effort put in 7 months was 844·8 hours for a total catch of 167,092 kg., of which prawn formed 11,131 kg. giving 6·66% with a catch rate of 13·17 kg. per hour. There was no record for prawns in September and October 1963. The percentages of prawn catches ranged between 4·50 in January for a catch of 1,186 kg. and 14·01 in February for a catch of 3,938 kg. with the highest catch rate of 33·28 kg. per hour of fishing in the latter month.

Mangalore

There was no fishing during the monsoon months of June to August. A number of boats working here had an annual landing of 1,432,149 kg. of which 487,146 kg. forming 34% were prawns. The monthly analysis of the Government of India vessels alone showed that the highest of 27·07% and the catch rate of 61·33 kg. per hour for the prawn yield of 1,840 kg. was obtained in January 1964. But April showed a maximum catch of 4,327 kg. forming 24·54% with 55·47 kg. per hour of fishing. The lowest catch of 120 kg. giving 5·27% and 7·50 kg. per hour of fishing was in February 1964.

Kozhikode

The recorded data for Kozhikode show fishing operations during April, May and October to December 1963. A very high prawn catch of 159,786 kg. in the total landings of 225,910 kg. fished in 4,208 hours was obtained giving 70·72% with 38 kg. per hour of fishing during the period. The catch which was almost steady ranged between 66·19% in April and 78·07% in November. But in the previous year though November showed a high catch of 111,681 kg. forming 80·78%, the highest of 82·70% for a catch of 45,612 kg. was obtained in February.

Cochin

The Indo-Norwegian vessels based at Cochin did not fish in July 1963. They showed a poor prawn catch of only 20,323 kg. forming 20·68% with 23 kg. per hour of fishing. The Government of India vessels working there had 22·59% for the prawn catch of 26,966 kg. when the catch rate was 47 kg. per hour. This year proved to be poor for prawns in this region because in the earlier two years the Indo-Norwegian vessels had the annual prawn percentages of 52·06 and 46·44. The monthly percentage catch in 1963–64 ranged from 2·55 in September to 70·33 in June, but in the earlier two years the highest of 79·42% and 59·30% were in February.

Tuticorin

Coming to the east coast where the general catch is much smaller, the annual prawn yield in Tuticorin was 3,833 kg. giving 2·95% at a cacth rate of 4·29 kg. per hour when the effort put was 892·44 hours and the total landings were 129,798 kg. In April 1963, February and March 1964, the prawn catch was nil. The catch ranged between 0·06% in January and 10·96% in September.

Waltair

The prawns formed 3·46% of the total catch of 238,737 kg. fished in 2,200 hours. The prawn yield was 8,272 kg. with the catch rate of 3·75 kg. In January there was no record of prawn. The percentage of catch ranged from 0·03 in August for the catch of 4 kg. and 19·81 in February for the catch of 1,720 kg.

There were no fishing operations by the trawlers at Calcutta during this year, but the earlier records show that in 1962–63 the annual prawn catch of 119 kg. gave 0·11% and in 1961–62, the catch of 15,059 kg. gave 3·09%.

From the foregoing account it is seen that the prawn resources in the grounds trawled increase from north to south along the west coast of India, being fair to moderate from Kutch to Veraval, good in Cambay and Bombay, better in Karwar and Mangalore and best in Kozhikode-Cochin regions. On the east coast, however, the resources all through appear to be poor off Tuticorin, Waltair and West Bengal in so far as the data reveal.

General Considerations

That richness of different areas is judged on the basis of catch rates obtainad in trawling is well known. If the catch rates are thus to be used as an index, it is desirable that the vessels and the gear employed should be identical. In the case of bull-trawling by the New India Fisheries vessels, the size and construction of 'Arnalla'-'Paj' and 'Satpati'-'Pilotan' as also their gear are identical. The coverage obtained so far in the regions and areas in different months over several years is very adequate and the results are comparable. For determining the relative seasonal and regional abundance of prawn catches the conclusions arrived at are mostly based on the operations of the vessels of the New India Fisheries Company. The vessels operated by the Government of India Deap Sea Fishing Station are of different constructional design and fishing powers, as pointed out by Rao and Meenakshisundaram (1964) it is imperative in such cases to know their relative fishing power factors and convert accordingly the fishing time of different vessels to standard units for assessing the relative potentialities of the resources in different areas.

It may be noted that the gear employed by the New India Fisheries vessels or the Government of India fishing vessels are not specially suited for shrimp trawling. The bull-trawls by the former and the otter-trawls by the latter are no doubt efficient for catching varieties of demersal fish but their prawn catches should be considered only incidental. In Veraval region in May 1964, in area 20–70: 6 B, fished by the Government of India vessel *M.L. 'Sagarpravasi'*, the prawn catch by Shrimp trawl was 600 kg. with 35·29 kg. per hour of trawling as compared to 394 kg. of catch at 19·95 kg. per hour by Otter-trawl. It may thus be seen that the amount of catch can be substantially increased by using the right type of gear in areas shown as very productive ones. For instance very rich prawn grounds have been revealed by the present investigations in Bombay and Cambay regions which if sufficiently exploited by suitable gear in May to October months will not fail to yield adequate amount of large-sized prawns fit for export trade.

It is worthwhile giving here a brief account of the distribution of the prawn species in the offshore waters and comparing them with those obtained in the inshore waters. In Bombay the more commonly occurring species obtained in the trawler catches are *Metapenaeus affinis, M. monoceros, Parapenaeopsis stylifera* and *P. hardwickii* along with less common species as *Solenocera indicus, Palaemon tenuipes, Penaeus penicillatus, P. monodon* and *Hippolysmata ensirostris*. In the inshore waters there is a rich variety of species of which the more common are *Palaemon tenuipes, Parapeneopsis hardwickii, P. stylifera, P. sculptilis, Metapenaeus affinis, M. brevicornis, Solenocera indicus* and *Hippolysmata ensirostris* along with the less common forms as *M. dobsoni, M. monoceros, Metapenaeopsis novaeguineae, Parapenaeopsis cornutus, Palaemon stiliferus, Penaeus monodon, P. semisulcatus* and *P. penicillatus*. *Macrobrachium rosenbergii* and *M. malcolmsoni* which are found common in Hooghly estuary and Kerala backwaters are only occasionally met with in the region (Shaikmahmud and Tembe, 1960; Kunju, 1964*).

In Kutch region *M. monoceros, M. brevicornis* and *M. kutchensis* comprise the important prawn species. In Veraval *M. affinis* constitutes the bulk of the catch followed by *M. monoceros, Penaeus indicus* and *Parapenaeopsis stylifera*. South of Bombay upto Mangalore, *Metapenaeus affinis* is the dominant species in the offshore catches followed by *M. dobsoni, Parapenaeopsis stylifera* and *Penaeus indicus*. At Cochin *M. dobsoni* and *Parapenaeopsis stylifera* are the main species contributing to the major portion of the catches followed by *M. affinis* and *P. indicus*. On the east coast of India, in the landings by trawlers at Tuticorin and Visakhapatnam *P. indicus, P. monodon* and *M. monoceros* are the dominant species and at Calcutta in addition to these, *M. brevicornis* and *Parapenaeopsis stylifera* also occur in fair quantities (Annual and Quarterly Scientific Reports, Central Marine Fisheries Research Institute, 1963, 1964).

One interesting point to be noted in regard to the location of the rich prawn grounds in all the regions from Kutch in the North to Bombay in the South is that almost all of them fall about 20 fathom (36 metres) line on the continental shelf (Fig. 1). The areas falling about these depth zones are productive not only in regard to the prawn species, but also in respect of all commercially important fishes in general as observed by several workers of Central Marine Fisheries Research Sub-Station, Bombay, engaged in the analysis of landings by trawlers.

SUMMARY

With a view to finding out the regional and seasonal abundance of the prawn catches in Bombay and Saurashtra waters, the catch data of the New India Fisheries Company's vessels and the Government of India vessels of the Deep Sea Fishing Station, Bombay, were analysed.

The New India Fisheries Company operated two pairs of bull-trawlers, 'Satpati'-'Pilotan' and 'Arnalla'-'Paj' between the latitudes 18° N. and 24° N. from April 1956 to October 1963; the Government of India vessels, *M.F.V. 'Jheenga'*, *M.F.V. 'Bumili'*, *M.L. 'Meera'* and *M.L. 'Sagarkanti'* fished between latitudes 16° N. and 23° N. on the continental shelf on the west coast of India, from January 1961 to June 1964, using Indian and Russian types of otter-trawls. For convenience of description, the areas covered by these vessels are grouped into Kutch, Dwarka, Porbundar, Veraval, Cambay and Bombay regions.

During the period for which the catch data have been analysed the prawn landings for bull-trawlers were the best in 1962 with a catch of 38,070 kg. and a catch rate of 10·04 kg. per hour of fishing, comprising 1·07% of the total landings. The highest prawn catch of 10,540 kg. for the otter-trawlers, was in 1961 with a catch rate of 6·04 kg. per hour, forming 1·74% in the total landings.

From the point of view of the abundance of the catch, the highest catch rates and also the highest percentage of prawns in the total landings, Cambay region ranked first. Catch rates were in the decreasing order in other regions, *viz.*, Bombay, Veraval, Porbundar, Kutch and Dwarka.

Of the areas covered by the bull-trawlers 'Q', 'R', 'S', 'T', 'V' and 'Y' in Kutch, 'L' and 'N' in Dwarka, 'H', 'E' and 'B' in Porbundar, '2' and '3' in Veraval '25', '24', '18', '17', '11' and '10' in Cambay and '48', '43 A', '43', '38' and '31' in Bombay regions appear to yield good prawn catches.

In the sub-areas '4 E', '2 D', '1 D', '1 B' and '3 A' in 19–72, '2 E' to '4 E', '5 C' to '5 E' and '6 C' to '6 E' in 18–72, '1 A', '1 B' and '2 A' in 17–73 and 4 F, and '6 F' in 17–72 covered by the otter-trawlers prawn resources are revealed to be high.

* Information elicited in personal discussion.

In the off-shore grounds covered by the bull-trawlers and the otter-trawlers in Bombay-Saurashtra waters, prawns were found at all depths from 9–72 metres. There was no marked concentration of prawns in any definite depth-zone.

In all the regions from Bombay to Kutch prawns occur throughout the year in the off-shore fishing grounds; the catches begin to increase from March; the best months for the fishery are from July to October and in some regions it extends to November or even December.

Prawn resources in the off-shore fishing grounds appear to increase from north to south off the west coast of India with the most potentially rich grounds in Kozhikode-Cochin region. On the east coast the resources appear to be much restricted.

The possibility of stepping up prawn catch has been visualised by introducing instead of the present types of gear, suitable shrimp trawls in certain months in Bombay-Saurashtra waters in areas shown to be rich in the present investigations. An account of the distribution of prawn species contributing to the off-shore catches along the east and west coasts of India has been given.

Acknowledgements

The author takes the opportunity to offer sincere thanks to Dr. S. Jones, the Director, Central Marine Fisheries Research Institute, for the interest shown in this work, to Shri K. Virabhadra Rao, Senior Research Officer, for suggesting this problem and critical perusal of the manuscript and to Shri M. M. Kunju, Assistant Research Officer, for valuable information on the species composition of prawns in the fish landings.

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OBSERVATIONS ON THE PRAWN FISHERY OF MAHARASHTRA COAST*

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ABSTRACT

About 80% of the total prawn production of the country comes from the Ratnagiri-Broach region, which practically makes up the entire output of the Maharashtra coast. Based on observations carried out from October 1959 to December 1963 from three representative sampling centres, *viz.*, Arnala, Versova and Sassoon Dock, the magnitude of the fishery, species and size composition, and relative abundance of the various species are given in the paper. Unlike any other part of the country the prawn fishery of Maharashtra is supported by a number of species occurring throughout the year, of which at least ten are of commercial value, being caught in large quantities. More than half the total catch is made up of small shrimps such as *Palaemon tenuipes, Hippolysmata ensirostris* and *Acetes indicus* and the larger prawns, *viz.*, *Metapenaeus affinis* and *Parapenaeopsis* spp. have only a limited fishery. *Solenocera indicus, Hippolysmata ensirostris* and *Atypopenaeus compressipes* are landed in marketable quantities only along this coast.

INTRODUCTION

THE average annual catch of prawns and other crustaceans† along the Indian coast is 94,911 metric tons constituting 14·60% of the total marine fisheries of India (Table I, Jones, 1963). The magnitude of the catches of the Maharashtra coast can be assessed from the available statistics for the coastline from Ratnagiri to Broach, which excludes the Goa Ratnagiri region of Maharashtra in the south and includes the Daman-Broach region of Gujarat in the north. The crustacean fishery of the Maharashtra coast south of Ratnagiri is so very poor that it can be equated with the equally poor crustacean fishery north of Daman, facilitating the consideration of the available statistics from Ratnagiri to Broach as representing the fishery of Maharashtra State. The average annual crustacean landings from Ratnagiri to Broach is 81,672 metric tons constituting about 80% of the total fishery in India (Table I).

A critical qualitative appraisal of the prawn fishery of the State has not been made so far. The only available information is from Rai (1933) and Shiakhmahmud and Tembe (1960), the former being a limited account of the fishery of the then Bombay Presidency and the latter a numerical assessment of species of prawns based on samples selected from Sassoon Dock alone.

MATERIAL AND METHODS

A preliminary survey of the main prawn fishing centres of the Maharashtra coast was undertaken in 1959, with a view to finding out the magnitude of the fishery at the different centres, on the basis of which three approximately equidistant centres, namely, Sassoon Dock, Versova and Arnala representing different levels of fishing along the coast, were selected for regular periodic observations.

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** Present Address : Central Marine Fisheries Research Substation, Bombay-1.

† Other crustaceans form a very negligible percentage in the catches.

The main fishing gear employed for catching prawns in the region are fixed bag nets, locally known as *dol* and *bokshi*. The *dol* is more or less similar to the *Behundi jal* of Bengal (Naidu, 1942), except for the absence of wings. Setna (1949) gave a detailed account of the design and operational techniques of the *dol* along the Maharashtra coast. The *bokshi* is only a smaller version of the *dol* and is invariably operated very close to the shore in shallow waters. The *dol* is the chief gear used for obtaining the bulk of the prawn catch. Its length varies from place to place along the coast, ranging from 40–50 metres at Sassoon Dock and 50–60 metres at Versova and Arnala.

Regular observations were started in October, 1959 at Sassoon Dock and Versova and in November 1959 at Arnala. After obtaining the requisite information to understand the prawn resources at Arnala, observations were discontinued there since July 1962 while they were continued at the other two centres upto December, 1963.

The centres were visited once in a week to make sample studies of the prawn catches obtained in the different fishing units. Each boat-net combination was considered as a fishing unit in the present study. On each observation day about 10–15% of the total number of fishing units recorded to be in operation were examined. The species composition by weight of the total prawn catch in each observed unit was noted down.

The average catch per fishing unit was calculated on the basis of the sample observations and the total catch on the day of observation was estimated by multiplying the average value with the total number of fishing units in operation. The average weight per day of the total catch of prawns and that of each of the component species were worked out by dividing the summed up total catch for the observed days with the number of days of observation. The total prawn catch as well as the catch of each species in the different months was estimated by multiplying the average values per day with the number of fishing days in the month at each centre.

TABLE I

Total annual production of marine fish and crustaceans in metric tons

Year	Total fish production for India	Total crustacean catch for India	Percentage of crustacean catch to total fish catch	Total crustacean catch for zone 11 (Ratnagiri to Broach)	Percentage of zone 11 crustacean catch to total crustacean catch for India	Source
1950	5,70,860	73,694	12·91	57,558	78·10	C.S.I.R.*
1951	5,25,482	75,584	14·38	57,256	75·75	,,
1952	5,20,002	75,785	14·57	61,015	80·51	,,
1953	5,72,278	89,254	15·66	76,550	85·77	,,
1954	5,78,966	1,51,789	26·22	1,40,972	92·87	,,
1955	5,86,315	1,04,942	17·90	89,528	85·31	,,
1956	7,07,349	1,57,024	22·19	1,23,714	78·79	,,
1957	8,61,634	1,34,357	15·59	1,06,167	79·02	,,
1958	7,43,799	85,334	11·47	61,228	71·75	,,
1959	5,74,993	66,426	11·55	42,730	64·33	,,
1960	8,79,681	70,600	8·76	..	..	F.A.O.†
1961	6,83,569	64,806	9·48	..	..	,,
1962	6,44,244	84,248	13·08	..	..	,,
Average	6,49,936	94,911	14·60	81,672	80·53	

* *Fish and Fisheries of India, Wealth of India Ser.*, C.S.I.R., 1962.

† *Year-book of Fishery Statistics*, F.A.O., 1960–62, 13–15.

Species Occurring in the Fishery

Thirty species of prawns were found to occur along the Maharashtra coast, a classified list of which is given below:

Section **PENAEIDEA**

Family PENAEIDAE

Subfamily PENAEINAE

Genus *Miyadiella*

1. *M. pedunculata* Kubo

Genus *Penaeus*

2. *P. canaliculatus* Olivier
3. *P. monodon* Fabricius
4. *P. penicillatus* Alcock
5. *P. semisulcatus* de Haan

Genus *Metapenaeus*

6. *M. affinis* (Milne Edw.)
7. *M. monoceros* (Fabr.)
8. *M. brevicornis* (Milne Edw.)
9. *M. dobsoni* (Miers)

Genus *Parapenaeopsis*

10. *P. stylifera* (Milne Edw.)
11. *P. sculptilis* (Heller)
12. *P. hardwickii* (Miers)
13. *P. cornutus* (Kishinouye)
14. *P. acclivirostris* (Alcock)

Genus *Trachypenaeus*

15. *T. curvirostris* (Stimpson)

Genus *Metapenaeopsis*

16. *M. novae-guineae* (Haswell)
17. *M. mogiensis* (Rathbun)

Genus *Atypopenaeus*

18. *A. compressipes* (Henderson)

Subfamily SOLENOCERINAE

Genus *Solenocera*

19. *S. indicus* Nataraj

Family SERGESTIDAE

Genus *Acetes*

20. *A. indicus* Milne Edw.

Section **CARIDEA**

Family PALAEMONIDAE

Genus *Palaemon*

Sub-genus *Nematopalaemon*

21. *P. tenuipes* Henderson

Sub-genus *Exopalaemon*

22. *P. styliferus* Milne Edw.

Genus *Macrobrachium*

23. *M. rosenbergii* (de Man)
24. *M. idae* (Heller)

Family HIPPOLYTIDAE

Genus *Hippolysmata*

25. *H. ensirostris* Kemp
26. *H. vittata* Stimpson

Genus *Tozeuma*

27. *Tozeuma* sp.

Genus *Latreutes*

28. *Latreutes* sp.

Family CRANGONIDAE

Genus *Pontocaris*

29. *P. lacazei* (Gourret)

Family ALPHEIDAE

Genus *Alpheus*

30. *Alpheus* spp.

Rai (*loc. cit.*), Chopra (1939, 1943) and Panikkar and Menon (1955) have mentioned that *Palaemon styliferus* forms a major component of the prawn catches of Bombay. During the present investigations, however, it was observed that by far the most abundant species was *Palaemon tenuipes* and not *P. styliferus* which occurred only to a limited extent.

Among the penaeids, *Penaeus indicus*, which is of great commercial value along the Malabar and Madras coasts has bean found to be scarce along the Maharashtra coast, though Shaikhmahmud and Tembe (*loc. cit.*) have reported that it constituted about 12% (numerically) in their samples from Sassoon Dock. In this connection, it is of interest to note that the three varieties of *P. indicus* decribed by Alcock (1906) have subsequently been raised to the status of separate species, *i.e.*, *P. indicus*, *P. penicillatus* and *P. merguiensis*, according to which the species available along the Maharashtra coast has been identified as *P. penicillatus*. Of the other penaeid prawns, two species belonging to the genus *Parapenaeopsis*, namely, *P. cornutus* and *P.maxillipedo*, were recorded from Bombay by Mehendale and Tambe (1958) and Shaikhmahmud and Tembe (*loc. cit.*) respectively, of which the latter was reported to be a species of commercial value. These two species closely resemble each other. During the present study only *P. cornutus* was found occasionally. *Para-*

Table II

Prawn species occurring in the fishery of Maharashtra coast

\+ Rare; ++ Present; +++ Abundant; ++++ Very abundant

Species	Harnai	Murud	Alibag	Sassoon Dock	Worli	Versova	Arnala	Satpati	Dahan
Miyadiella pedunculata	..	..	..	+	..	+	..	..	..
Penaeus canaliculatus	..	..	..	+	..	+	+	..	..
P. monodon	+	+	+	+	+	+	+	+	+
P. penicillatus	+	+	+	++	+	+	++	+	+
P. semisulcatus	..	..	..	+	..	..	..	..	..
Metapenaeus affinis	++	++	+++	+++	+++	+++	++	++	++
M. monoceros	++	+	++	++	++	++	+	+	+
M. brevicornis	+	..	+	+++	+	++	++	+	++
M. dobsoni	..	..	..	+	..	+	+	..	..
Parapenaeopsis stylifera	+++	+++	+++	+++	++	+++	++	+	+
P. cornutus	..	..	..	+	..	+	..	..	..
P. sculptilis	..	+	++	+++	+	++	+++	+	+++
P. hardwickii	++	+++	+++	+++	+++	+++	++	++	++
P. acclivirostris	..	..	..	++	..	+	..	..	..
Atypopenaeus compressipes	..	..	+	++	+	+++	+	..	..
Trachypenaeus curvirostris	..	..	..	+	..	+	..	..	..
Metapenaeopsis novae-guineae	..	..	..	+	++	..	..	..	..
M. mogiensis	..	..	..	..	..	+	..	..	..
Solenocera indicus	++	+	+++	+++	++	+++	++	++	+
Acetes indicus	+++	+++	++++	++++	+++	++++	++	++	++
Palaemon tenuipes	++++	++++	++++	++++	++++	++++	++++	++++	+++
P. styliferus	+	..	+	++	+	+	++	..	++
Macrobrachium rosenbergii	..	..	+	..	..	+	...	..	..
M. idae	..	..	..	..	..	+	—	..	..
Hippolysmata ensirostris	++	++	+++	+++	+++	+++	++	++	++
H. vittata	..	..	..	+	..	+	...	..	..
Tozeuma sp.	..	..	..	++	..	+	..	..	..
Latreutes sp.	..	..	+	+	..	+	..	..	..
Pontocaris lacazei	...	..	..	+	..	..	..	...	..
Alpheus sp.	...	+	+	++	..	+	+	...	+

penaeopsis hardwickii and *Atypopenaeus compressipes* occurring along the west coast of India and their commercial importance were first pointed out by Kunju (1962).

Miyadiella pedunculata, a new penaeid genus and species, described by Kubo (1949),is recorded for the first time in Indian waters. It was found always along with juvenile *Atypopenaeus compressipes*.

The extent of occurrence of the various species at important prawn fishing centres covered in the preliminary survey along the Maharashtra coast is shown in Table II.

TRENDS IN THE FISHERY

Fishing activities were practically suspended during the S.W. monsoon all along the coast of Maharashtra. However at Sassoon Dock the *dol* fishery was found to continue during this period though on a reduced scale. *Bokshi* operations were usually more at Arnala than at the other two centres and during the monsoon months a still larger number of units were used.

The estimated average monthly prawn landings and their species composition, at the three centres is given in Table III. It may be seen that the best catches were obtained at Versova followed by Sassoon Dock and Arnala in that order. Based on the preliminary survey it has been observed that the magnitude of the prawn fishery decreases southward and northward of Bombay.

During the period April-May the prawn landings were comparatively high at all the centres, while during October-November they were high only at Sassoon Dock and Versova. The prawn catches were generally higher at Versova than at Sassoon Dock, but during the monsoon months, when *dol* net operations were suspended at the former centre, they were continued to some extent at the latter. The period from February to May was found to be the best season at Arnala.

Of the thirty species occurring in the catches only ten contributed to one per cent. or more of the total fishery at the three centres taken together and hence considered commercially important; the rest were grouped together under miscellaneous prawns. *Atyopenaeus compressipes,* however, constituted over 3% only at Versova. The annual averages of species contributing to the prawn fishery at the three centres in the different months are shown in Fig. 1.

SEASONAL VARIATION IN ABUNDANCE OF THE DIFFERENT SPECIES

Metapenaeus affinis

It was abundant at Versova and Sassoon Dock from September to November, when it contributed to about 90% of its average annual catch at these two centres. The species was observed to occur in considerable quantities only sporadically at Arnala without being restricted to a particular season.

In certain periods it formed the mainstay of the prawn fishery; *e.g.*, in the month of October 1961 it was recorded to constitute 86·2% of the total catch at Versova.

It is interesting to note that the period of abundance commences immediately after the S.-W. monsoon and declines suddenly by the middle of November every year.

M. brevicornis

About 60% of the total catch of *M. brevicornis* for all the three centres was found at Sassoon Dock alone. It constituted 2·08%, 1·60% and 0·46% of the average annual prawn fishery at Sassoon Dock, Arnala and Versova, respectively, indicating its scarcity at Versova.

TABLE III

Average species composition of the prawn fishery in kg. at different centres

		M. affinis		*M. brevicornis*		*P. stylifera*		*P. hardwickii*		*P. sculptilis*		*S. indicus*	
Months	Centres	Average catch	%	Average catch	%	Average catch	%	Average catch	%	Average catch	%	Average catch	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14
January	Versova	7,317	2·55	4,158	1·45	5,025	1·75	16,818	5·86	18,063	6·29	49,432	17·22
	S. Dock	2,288	1·20	2,273	1·19	5,072	2·66	9,742	5·11	24,333	12·75	10,142	5·32
	Arnala	2,899	3·01	733	0·76	1,102	1·14	1,043	1·08	13,413	13·93	5,298	5·57
February	Versova	2,512	0·88	941	0·33	4,156	1·46	26,675	9·38	8,616	3·03	55,950	19·60
	S. Dock	619	0·57	1,403	1·29	1,103	1·01	4,343	4·00	9,228	8·50	9,417	8·67
	Arnala	302	0·14	1,125	0·53	1,808	0·85	2,448	1·15	18,138	8·54	11,203	5·27
March	Versova	9,434	2·89	2,019	0·62	5,417	1·66	27,269	8·34	7,956	2·43	65,938	20·17
	S. Dock	2,420	1·63	1,425	0·96	3,307	2·22	6,509	4·38	6,713	4·51	27,856	18·73
	Arnala	633	0·42	4,000	2·66	187	0·12	11,097	7·37	5,317	3·53	10,867	7·22
April	Versova	7,724	1·59	669	0·14	1,618	0·33	10,845	2·24	2,032	0·42	65,110	13·42
	S. Dock	4,275	2·13	1,846	0·92	919	0·46	3,361	1·68	7,735	3·86	13,999	6·99
	Arnala	2,433	1·15	2,467	1·17	167	0·08	8,500	4·02	9,600	4·53	12,250	5·79
May	Versova	11,409	2·45	1,140	0·25	164	0·04	16,481	3·54	5,872	1·26	58,184	12·50
	S. Dock	3,619	1·41	1,993	0·77	1,179	0·46	4,259	1·65	14,930	5·80	14,799	5·75
	Arnala	3,883	2·43	375	0·23	150	0·09	9,192	5·74	10,233	6·39	9,467	5·91
June	Versova	335	2·79	..	..	..	..	133	1·11	495	4·13	2,063	17·20
	S. Dock	637	0·33	2,983	1·54	175	0·09	1,243	0·64	7,505	3·88	3,006	1·56
	Arnala	17	0·10	200	1·18	..	..	150	0·88	7,517	44·30	..	..
July	Versova	..	..	..	..	..	..	..	..	..	..	..	..
	S. Dock	3,576	3·28	3,148	2·89	13,166	12·07	2,772	2·54	12,369	11·34	442	0·41
	Arnala	75	0·51	413	2·82	75	0·51	..	..	6,600	45·12	..	..

August	Versova	2,456	14·37	130	0·76	308	1·80	..	..	462	2·70	..	..
	S. Dock	3,431	2·54	4,572	3·38	6,911	5·15	1,209	0·89	12,112	8·97	..	..
	Arnala	..	..	810	7·15	315	2·78	..	..	5,963	52·65	..	..
September	Versova	60,414	48·26	330	0·26	25,556	20·41	206	0·16	1,179	0·94	112	0·09
	S. Dock	53,380	29·50	4,552	2·52	26,301	14·54	1,443	0·80	5,170	2·86	15	..
	Arnala	2,540	13·87	2,278	12·44	825	4·50	..	..	2,570	14·03	..	..
October	Versova	2,41,783	52·47	162	0·04	70,075	15·21	5,827	1·26	1,012	0·22	8,232	1·79
	S. Dock	1,55,500	52·39	12,290	4·14	46,085	15·53	10,645	3·59	10,740	3·62	2,302	0·78
	Arnala	585	1·66	1,425	4·05	1,125	3·20	1,350	3·84	8,250	23·47	1,950	5·55
November	Versova	1,17,783	24·51	4,273	0·89	42,167	8·77	72,733	15·14	14,843	3·09	89,608	18·65
	S. Dock	1,09,683	46·72	7,300	3·12	28,317	12·06	12,417	5·29	11,317	4·82	11,467	4·88
	Arnala	4,866	15·82	1,420	4·62	3,628	11·80	2,642	8·59	6,118	19·89	2,233	7·26
December	Versova	9,450	4·14	712	0·32	7,171	3·12	44,256	19·40	10,446	4·58	48,234	21·14
	S. Dock	2,270	2·34	937	0·96	3,240	3·34	1,275	1·31	4,900	5·04	14,520	14·95
	Arnala	823	3·03	503	1·85	303	1·12	2,347	8·64	8,868	32·65	2,654	9·77
Average annual catch	Versova	4,70,621	14·83	14,564	0·46	1,61,732	6·10	2,21,243	6·97	71,171	2·24	4,42,863	13·96
	S. Dock	3,41,698	15·87	44,722	2·08	1,35,775	6·31	59,218	2·75	1,27,052	5·90	1,07,965	5·01
	Arnala	19,056	1·93	15,749	1·60	9,685	0·98	38,769	3·93	1,02,587	10·41	55,922	5·68

TABLE III (*Contd.*)

Months	Centres	*A. compressipes* Average catch	*A. compressipes* %	*A. indicus* Average catch	*A. indicus* %	*P. tenuipes* Average catch	*P. tenuipes* %	*H. ensirostris* Average catch	*H. ensirostris* %	Miscellaneous Average catch	Miscellaneous %	Total
1	2	15	16	17	18	19	20	21	22	23	24	25
January	Versova	8,382	2·92	1,10,165	38·39	49,073	17·10	18,505	6·45	58	0·02	2,86,996
	S. Dock	..	..	77,400	40·57	30,590	16·03	25,087	13·15	3,875	2·03	1,90,802
	Arnala	..	..	6,537	6·79	56,423	58·59	4,962	5·15	3,899	4·05	96,309
February	Versova	11,974	4·21	1,10,756	38·95	55,533	19·53	6,300	2·22	974	0·34	2,84,387
	S. Dock	..	..	53,664	49·43	26,070	24·01	1,374	1·27	1,353	1·25	1,08,574
	Arnala	..	..	15,418	7·26	1,45,079	68·29	13,904	6·54	3,029	1·43	2,12,454
March	Versova	20,728	6·34	89,650	27·42	94,158	28·80	4,288	1·31	69	0·02	3,26,926
	S. Dock	..	..	75,006	50·44	20,682	13·91	3,528	2·37	1,268	0·85	1,48,714
	Arnala	..	..	9,233	6·13	1,04,067	69·11	3,320	2·20	1,854	1·23	1,50,575
April	Versova	9,131	1·88	1,29,653	26·73	2,52,830	52·13	4,930	1·02	496	0·10	4,85,038
	S. Dock	..	..	52,155	26·04	1,04,524	52·18	10,441	5·21	1,064	0·53	2,00,319
	Arnala	..	..	4,300	2·03	1,65,700	78·27	5,283	2·50	1,000	0·47	2,11,700
May	Versova	5,635	1·21	64,074	13·77	2,93,261	63·02	8,668	1·86	462	0·10	4,65,350
	S. Dock	..	..	54,238	21·06	1,46,868	57·03	12,210	4·74	3,451	1·34	2,57,546
	Arnala	..	..	1,133	0·71	1,19,592	74·72	3,558	2·22	2,475	1·55	1,60,058
June	Versova	18	0·15	888	7·40	7,590	63·29	450	3·75	20	0·18	11,992
	S. Dock	..	..	41,581	21·52	1,09,909	56·89	24,856	12·86	1,314	0·68	1,93,209
	Arnala	..	..	433	2·55	6,717	39·59	483	2·85	1,450	8·55	16,967
July	Versova	..	..	..	..	..	..	..	..	..	..	..
	S. Dock	..	..	20,764	19·03	26,683	24·46	24,418	22·38	1,757	1·61	1,09,095
	Arnala	..	..	75	0·51	3,338	22·82	563	3·85	3,488	23·85	14,627

August	Versova	..	..	3,519	20·59	7,344	42·98	2,500	14·63	369	2·16	17,088
	S. Dock	..	..	12,630	9·35	72,925	53·98	20,273	15·00	1,040	0·77	1,35,103
	Arnala	..	..	375	3·31	2,400	21·19	300	2·65	1,163	10·27	11,326
September	Versova	..	..	11,809	9·43	14,713	11·75	9,806	7·83	1,072	0·86	1,25,197
	S. Dock	..	..	16,478	9·10	43,185	23·87	28,845	15·94	1,519	0·84	1,80,888
	Arnala	..	..	170	0·93	6,050	33·03	2,238	12·22	1,643	8·97	18,314
October	Versova	70	..	61,187	13·28	12,925	2·80	52,758	11·45	6,812	1·48	4,60,843
	S. Dock	..	..	13,128	4·42	19,627	6·61	19,967	6·73	6,520	2·20	2,96,804
	Arnala	..	..	1,350	3·84	2,815	8·01	14,725	41·89	1,575	4·48	35,150
November	Versova	33,208	6·91	32,525	6·77	2,192	0·46	25,408	5·29	45,821	9·53	4,80,561
	S. Dock	..	..	22,800	9·71	10,277	4·38	11,392	4·85	9,791	4·17	2,34,761
	Arnala	..	..	133	0·43	528	1·72	8,484	27·59	701	2·28	30,753
December	Versova	15,931	6·98	61,324	26·88	20,772	9·10	8,010	3·51	1,859	0·82	2,28,165
	S. Dock	..	..	49,075	50·52	14,175	14·59	4,885	5·03	1,860	1·91	97,157
	Arnala	..	..	17	..	6,138	23·26	3,809	14·03	1,515	5·58	27,157
Average annual catch	Versova	1,05,077	3·31	6,75,565	21·29	8,10,579	25·55	1,41,623	4·46	58,031	1·83	31,73,069
	S. Dock	..	..	4,88,919	22·70	6,25,515	29·05	1,87,276	8·70	34,812	1·62	21,52,952
	Arnala	..	..	39,174	3·98	6,19,027	62·82	61,629	6·25	23,792	2·41	9,85,390

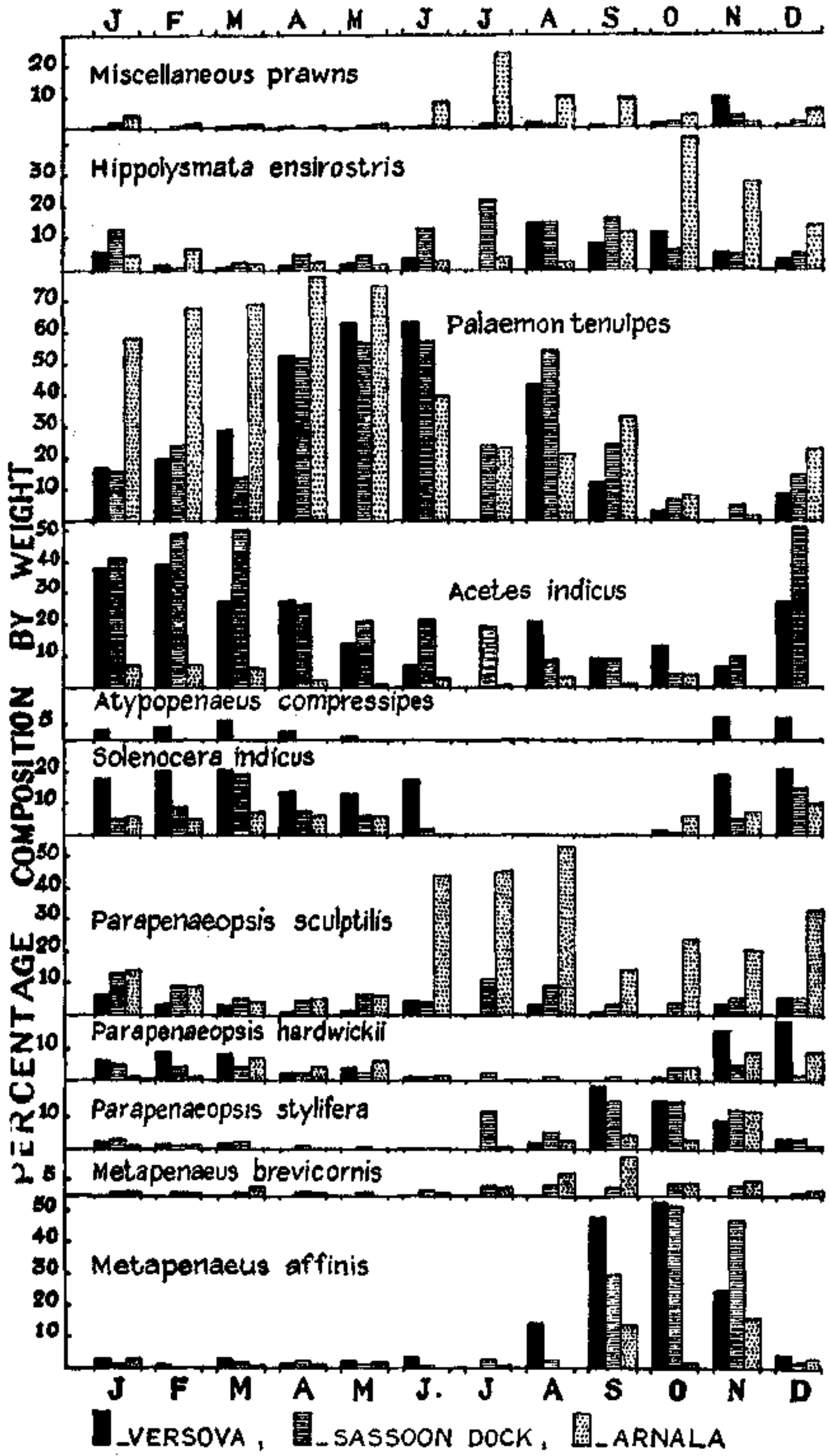

FIG. 1. Average species composition of the prawn fishery in different months at the three centres of observation.

Its season at Sassoon Dock started in June with a gradual rise in catch which reached a peak in October when it constituted 4·14% of the total prawn catch in that month, and declined suddenly from December onwards. At Arnala, the season for the fishery was during March-April, but it was also found to be relatively more abundant than the other species in September.

Parapenaeopsis stylifera

The season for the fishery of this species coincides with that of *M. affinis* (September to November), comprising 79% of its average annual yield from the three centres together. In July and August the species was observed to make up 12·07% and 5·15% respectively of the total catch at Sassoon Dock.

P. hardwickii

The season for this fishery at Versova was found to start suddenly in November coinciding with the decline of *M. affinis* and continued on a lesser scale upto May, with a gradual decrease. At Sassoon Dock its peak of abundance was in October-November when 39% of its total annual catch was obtained. The seasonal occurrence of this species at Arnala was observed to be different from the other two centres, being more abundant from March to May.

P. sculptilis

As in the case of *M. brevicornis* its yield at Sassoon Dock and Arnala was quite considerable, contributing 42·23% and 34·10% respectively of the total annual landings of the prawn. It was found to be the second most important fishery at Arnala constituting 10·41% of the total prawn fishery at the centre. Though the fishery was observed to be relatively less important at Versova, the maximum landings at the centre were comparable with those at Sassoon Dock in the month of January. At Arnala, the species was most abundant in the month of February. The prominence of this fishery at Sassoon Dock and Arnala was partly due to its relative abundance during the monsoon months of June to August, during which period at Arnala the species comprised 44·30% to 52·65% of the total fishery while at Sassoon Dock only 3·88% to 11·34%.

Solenocera indicus

It supported a very important fishery at Versova, where the yield was 73% of its total landings at the three centres. At Versova and Sassoon Dock, synchronising with the appearance of *P. hardwickii*, maximum catches of this species were obtained in November, though the period of abundance extended upto May. The peak period of its abundance at Arnala was from February to April. Its virtual disappearance from the coastal waters during the monsoon months is of interest.

Atypopenaeus compressipes

As mentioned earlier this small penaeid prawn was observed to have commercial importance only at Versova. It appears suddently in November along with *P. hardwickii* and *S. indicus*. The fishery continued at a steady level upto May with a minor peak in Ma rch.

Acetes indicus

This small shrimp was observed to be the second important species in magnitude only to *P. tenuipes* at Versova and Sassoon Dock, where it constituted about 97% of its fishery at the three centres taken together. The best landings were obtained from January to April at these two centres. Its abundance at Sassoon Dock was comparatively high even in May to July. The maximum catches at Arnala were recorded during the period January to March.

A. indicus formed the bulk of the prawn fishery at Versova in the months of October, 1960 (60%) and December 1963 (60%) and at Sassoon Dock in December 1959 (70%) and April 1963 (60%).

Palemon tenuipes

It was found to be the most important species from the point of view of its abundance. Its fishery extended from January to June at all the three cantres. At Arnala the importance of this fishery was far higher than at the other two centres. The maximum landings were observed in April-May in all the three centres, when about half of its annual catch was obtained. A minor period of abundance was also observed at Sassoon Dock (July to September). The period of October–November was the poorest for the fishery in all the centres.

In certain months (April and May, 1960 and May 1961) *P. tenuipes* was found to dominate the catches to the extent of more than 80% of the total prawn fishery.

Hippolysmata ensirostris

The periods of maximum abundance of the species were January, October and November at Versova, January and June to September (monsoon months) at Sassoon Dock, and February and October at Arnala. Thus it could be seen that the periods of seasonal abundance varied from centre to centre, the causes of which are not yet known.

Miscellaneous Prawns

The species grouped under miscellaneous prawns are shown in Table II. Of these, *Penaeus penicillatus* and *P. monodon* were observed to be of more frequent occurrence than the others, at all the three centres. In the months of October and November large mature individuals of *Metapenaeus monoceros* and *Metapenaeopsis novae-guineae* were obtained at Versova and Sassoon Dock in appreciable numbers, coinciding with the peak period of abundance of *M. affinis* and *P. stylifera*, which resulted in a higher percentage composition of miscellaneous prawns during these months at the two centres. The high percentage composition of miscellaneous prawns at Arnala from June to September was due to the incidence of *Palaemon styliferus* in large numbers, caught mainly in the *bokshi* nets.

General Considerations

The foregoing account shows that the prawn fishery of the Maharashtra coast is mainly supported by the small prawns and shrimps, such as *Palaemon tenuipes*, *Acetes indicus* and *Hippolysmata ensirostris*, the three together contributing to about 58% of the total prawn fishery in the region, of which 33% of the total fishery is made up of *Palaemon tenuipes* alone (Table IV). *Solenocera indicus* belonging to the subfamily *Solenocerinae*, members of which usually inhabit deep waters (Alcock, 1901) is found to support a fishery of commercial magnitude along the Maharashtra coast only, constituting about 10% of the total prawn fishery in the region. In their account of the prawn fishery of Bombay Shaikhmahmud and Tembe (*loc. cit.*) regarded the above four species as unimportant prawns of no commercial value.

Of the species bigger in size *M. affinis* is the most important, making up 13% of the total prawn fishery. The three species of *Parapenaeopsis*, namely, *P. stylifera*, *P. hardwickii* and *P. sculptilis* together form about 14% of the fishery (Table IV).

On the basis of seasonal abundance, the prawn fishery of Maharashtra coast is found to follow an annual cycle of species predominance during different periods. The prawn catches were found to be particularly rich in respect of *P. tenuipes* from April to May, of *M. affinis* and *P. stylifera* from September to November and of *A. indicus*, *S. indicus* and *P. hardwickii* from December to March.

The prawn fishery of Maharashtra coast is remarkable for the occurrence of *S. indicus*, *H. ensirostris* and *A. compressipes* in adequate proportions to support fishery of commercial importance. The species are not known so far to occur in abundance in other parts of the Indian coast. *A. compressipes* and *Solenocera* sp. are however, reported to form a small percentage of the fishery in the Seto Inland Sea of Japan (Yasuda, 1955).

TABLE IV

Percentage composition of the prawn species at different centres

Species		All the three centres	Versova	Sassoon Dock	Arnala
Palaemon tenuipes	..	32·56	25·55	29·05	62·82
Acetes indicus	..	19·07	21·29	22·70	3·98
Metapenaeus affinis	..	13·17	14·83	15·87	1·93
Solenocera indicus	..	9·61	13·96	5·01	5·68
Hippolysmata ensirostris	..	6·19	4·46	8·70	6·25
Parapenaeopsis hardwickii	..	5·06	6·97	2·75	3·93
P. stylifera	..	4·87	6·10	6·31	0·98
P. sculptilis	..	4·77	2·24	5·90	10·41
Atypopenaeus compressipes	..	1·66	3·31	..	—
Metapenaeus brevicornis	..	1·19	0·46	2·08	1·60
Miscellaneous prawns	..	1·85	1·83	1·62	2·41

Several factors, namely the force and duration of the tidal current, the extent of rainfall over the adjoining land mass, the annual cycle of upwelling of coastal waters and the depth and location of fishing grounds, seem to influence the success or failure of the prawn fishery of Maharashtra coast as well as its species composition.

Since the prawn fishery of this coast is based mainly on fixed bag nets entrapping the prawns and fish that move in with the tidal current, its success depends on the strength of the flow of the prevailing tide. During the present study it was noticed that the extremes of tidal currents, *i.e.*, neap and spring tides of certain months, had an adverse effect on the prawn fishery. When *dol* nets were operated in strong currents, the usual close-meshed cod end was replaced by another cod end with a wider mesh resulting in the elimination of *Acetes indicus*, *Palaemon tenuipes* and other small prawns. The magnitude of the tidal influence on the content and composition of the prawn fishery along the Maharashtra coast is being studied, the results of which will be published elsewhere.

Some prawns like the penaeids are migratory in habit with an obligatory period of life in waters of low salinity. An analysis of the annual rainfall data of the Konkan coast for the past fifteen years *vis-a-vis* the prawn catches revealed a diect relationship, as found in other parts of the world by Gunter and Hildebrand (1954) and Thomson (1955). Details of these findings are being published elsewhere.

Carruthers *et al.* (1959) indicated the effect of annual upwelling of the coastal waters of Bombay on the fisheries in general. The shoreward migration and consequent abundance of the penaeid prawns such as *M. affinis*, *M. monoceros*, *P. stylifera* and *M. novae-guineae* in the post-monsoon period of October-November along the Bombay coast, may probably be attributed, along with other possible factors, to this momentous upwelling taking place at this time every year resulting in the shoreward slope of the oxygen minimum layer on the continental shelf.

The incidence of *Metapenaeus brevicornis*, *Parapenaeopsis sculptilis* and *Palaemon styliferus* in comparatively large numbers in the *bokshi* nets of Arnala and the *dol* nets of Sassoon Dock may be due to the location of the fishing sites at these centres close to the shore within a depth range of five to fourteen metres. These prawns are known to be estuarine penetrating species prefering a shallow water habitat (Kunju, 1955; Rajyalakshmi, 1961).

Knowledge of the extent and the periods of availability of the different species of prawns useful for freezing, canning, curing by sundrying, etc., and marketing them in fresh condition according to consumer preferences is important for the concerned industries to plan and execute their operational activities. The present studies have revealed that the small-sized species like *Palaemon tenuipes* and *Acetes indicus* and the large-sized ones like *Metapenaeus affinis*, *Parapenaeopsis stylifera*, *P. hardwickii* and *Solenocera indicus* were regular in their periodicity of abundance to meet the demands of the different industries for continuous supplies.

SUMMARY

The magnitude of the prawn fishery of the Maharashtra coast and its very high place in the crustacean fisheries of India have been stated.

The seasonal abundance of different species constituting the prawn catches has been studied from regular samples collected at three centres representing different levels of the fishery.

Thirty species of prawns and shrimps have been found in the fishery, of which those comprising one or more per cent. of the total fishery in their order of abdunance are *Palaemon tenuipes*, *Acetes indicus*, *Metapenaeus affinis*, *Solenocera indicus*, *Hippolysmata ensirostris*, *Parapenaeopsis hardwickii*, *P. stylifera*, *P. sculptilis*, *Atypopenaeus compressipes* and *Metapenaeus brevicornis*.

Palaemon tenuipes, *Acetes indicus* and *Hippolysmata ensirostris* among the smaller species contitute the major portion of the catches. Among the larger species, *Metapenaeus affinis*, *Parapenaeopsis hardwickii*, *Parapenaeopsis stylifera*, and *Parapenaeopsis sculptilis* are of considerable commercial importance.

That *Solenocera indicus*, *Hippolysmata ensirostris* and *Atypopenaeus compressipes* occurring in quantities to support fisheries to some extent has been pointed out for the first time.

Palaemon tenuipes in April and May, *Metapenaeus affinis* and *Parapenaeopsis stylifera* in September to November and *Acetes indicus*, *Parapenaeopsis hardwickii* and *Solenocera indicus* in December to March have been found to be particularly abundant.

The influence of tidal current, rainfall, and upwelling in deeper waters of the continental shelf on the fishery has been indicated.

ACKNOWLEDGEMENTS

I am indebted to Dr. S. Jones, Director, Central Marine Fisheries Research Institute, Mandapam Camp, for his constant encouragement during the course of the investigations. I am thankful to Shri K. Virabhadra Rao, Senior Research Officer, Central Marine Fisheries Research Sub-Station, Bombay, for going through the manuscript and offering helpful and critical suggestions. My thanks are also due to Shri K. Srinivasa Rao for his help in the praparation of this paper.

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LA CREVETTE GRISE (*CRANGON CRANGON* L., 1758) DANS LE SUD DE LA MER DU NORD

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ABSTRACT

The brown shrimp is found in appreciable numbers along the coasts of the southern North Sea and forms an important coastal fishery.

The fishery is carried out by small fishing boats (motors of 35-120 h.p.). Most of them use the "beam-trawl" and some of them "ottertrawl". The minimum width of the meshes of the shrimp trawl varies between 16 and 20 mm.

In France, Belgium and the United Kingdom all shrimps landed are used for human consumption, whilst in the Netherlands and in the German Federal Republic, 60-80% of the landings are taken up by fish-meal factories.

The annual catches are subject to marked seasonal fluctuations and in all countries concerned a reduction of the catches in relation to the fishing effort has been observed during the last few years.

DISTRIBUTION DE LA CREVETTE DANS LE SUD DE LA MER DU NORD

LA CREVETTE grise est très répandue le long des côtes sableuses et sablo-vaseuses ainsi que dans les eaux saumâtres de la partie orientale du Sud de la Mer du Nord. Sur les côtes belges, néerlandaises et allemandes, la crevette donne lieu à une très importante pêcherie. Elle se montre moins abondante sur la côte Est de l'Angleterre et clairsemée sur les côtes danoises.

FLOTILLES DE PECHE

Belgique.—En 1961, le nombre des côtres ayant exercé la pêche aux crevettes s'élevait à 102; leur force motrice variait entre 35 et 120 C.V., soit en moyenne 64 C.V.

Pays-bas.—En 1961, le nombre des côtres ayant exercé la pêche aux crevettes s'élevait à 385; la force motrice de certains de ces côtres développait jusque 150 C.V.

France, Allemagne, Danemark et *Angleterre.*—Pas d'indications sur le nombre et la force motrice des côtres crevettiers.

ENGINS DE PECHE

Méthode de pêche

Belgique.—90% des crevettiers exercent la pêche au moyen d'un chalut à plateaux et 10% avec des chaluts à gaules dont l'un est traîné à bâbord et l'autre à tribord.

Pays-bas.—Pas d'indications précises; mais sur la grande majorité des côtres, la pêche se pratique avec deux chaluts à gaules.

Allemagne.—A quelques exceptions près, la pêche s'exerce avec deux chaluts à gaules.

Danemark, Angleterre et *France.*—Pas d'indications.

Dimensions minimales des mailles des filets

Belgique.—17, 5 à 20 mm.

Pays-bas.—En général 20 mm.

Allemagne.—14 à 16 mm.

France, Danemark et *Angleterre.*—Pas d'indications.

Destination des Apports

France, Belgique, Danemark et *Angleterre.*—La totalité des apports est destinée á la consommation humaine (consumptie garnaal, consumption shrimps, Speisegarnele). La taille de ces crevettes aussi appelées grandes crevettes, est > 50 mm., alors que la taille des crevettes destinées aux usines de farine de poisson est en dessous de 50 mm. (crevettes immatures, ondermaatse garnalen ou garnaalnest, immature shrimps, Futtergarnele).

Pays-bas.—Pour l'ensemble des années 1957–1961, une moyenne de 7·943 t, soit 59,9% des apports annuels de crevettes sont transformés en farine de poisson.

Allemagne.—Pour l'ensemble des années 1957–61, une moyenne de 23·045 t, soit 82,6% des apports annuels de crevettes sont transformés en farine de poisson.

Apports de Crevettes au Cours de la Periode 1957–61

(Tableau I)

Crevettes pour la consommation humaine

France.—Entre 40 t (1960) et 130 t (1957): moyenne annuelle 71 t.

Belgique.—Entre 565 t (1960) et 1·313 t (1959): moyenne annuelle. 1·042 t.

Pays-bas.—Entre 4·831 t (1961) et 3·968 t (1960): moyenne annuelle 4·362 t.

Allemagne.—Entre 3·603 t (1961) et 6·045 t (1958): moyenne annuelle 4·849 t.

Danemark.—Apports de crevettes minimes, négligés dans la statistique des pêches.

Angleterre.—Les pêches aux crevettes sont un mélange de crevettes grises (Brown Shrimps) et de crevettes roses (Pink Shrimps—*Pandalus montagui* Leach). On estime que les deux espèces sont a égalitè, de sorte que le poids des crevettes grises est égal au poids total des crevettes débarquées divisé par deux. Selon cette estimation, les apports annuels de la crevette grise oscillaient entre 263 t (1961) et 791 t (1957): moyenne annuelle 546 t.

Crevettes immatures

France, Belgique, Danemark et *Angleterre.*—Pas d'apports.

Pays-bas.—Pour l'ensemble de la période 1957–61, entre 6·947 t (1958) et 8·623 t (1959): moyenne annuelle 7·943 t ou 64, 35% du poids total de crevettes débarquées.

Allemagne.—Pour l'ensemble de cette même période, entre 20·276 t (1960) et 29·052 t (1957): moyenne annuelle 23·045 t ou 82, 62% du poids total de crevettes débarquées.

Répartition, d'après les pays, des apports totaux

Au cours de la période 1957–61, les apports de creettes totalisaient 209·292 t: 54·351 t ou 25, 96% de crevettes pour la consommation humaine et 15v4·941 t ou 74, 04% de crevettes immatures.

La répartition des apports d'après les pays est la suivante:

Crevettes pour la consommation humaine

France	355 t ou 0,66%
Belgique	5·208 t ou 9,58%
Pays-Bas	21·811 t ou 40,13%
Allemagne	24·247 t ou 44,61%
Angleterre	2·730 t ou 5,02%

Crevettes immatures

Pays-Bas	39·717 t ou 25,63%
Allemagne	115·224 t ou 74,37%

Crevettes pour consommation et crevettes immatures

France	355 t ou 0,17%
Belgique	5·208 t ou 2,49%
Pays-bas	61·528 t ou 29,40%
Allemagne	139·471 t ou 66,64%
Angleterre	2·730 t ou 1,30%

TABLEAU I

Apports de crevettes en t au cours de la période 1957-61

Année	France	Belgique	Pays-bas	Allemagne	Angleterre	Total
1. Crevettes pour consommation humaine						
1957	130	1·229	4·186	5·690	791	12·026
1958	55	924	4·187	6·045	642	11·853
1959	86	1·313	4·639	4·413	599	11·050
1960	40	565	3·968	3·603	435	8·611
1961	44	1·177	4·831	4·496	263	10·811
Total	355	5·208	21·811	24 247	2·730	54·351
%	0,66	9,58	40,13	44,61	5,02	100,00
Moyenne	71	1·042	4·362	4·849	546	10·870
2. Crevettes immatures						
1957	..	–	7·646	29·052	.	36·698
1958	..	..	6·947	22·284	..	29·231
1959	..	..	8·623	21·278	..	29·901
1960	..	..	8·606	20·276	..	28·882
1961	..	..	7·895	22·334	..	30·229
Total	..	..	39·717	115·224	..	154·941
%	..	..	25,63	74,37	..	100,00
Moyenne	..		7·943	23·045	–	30·988
3. Crevettes pour consommation et crevettes immatures						
1957	130	1·229	11·832	34·742	791	48·724
1958	55	924	11 134	28·329	642	41·084
1959	86	1·313	13·262	25·691	599	40·951
1960	40	565	12·574	23·879	435	37·493
1961	44	1·177	12·726	26·830	263	41·040
Total	355	5·208	61·528	139·471	2·730	209·292
%	0,17	2,49	29,40	66,64	1,30	100,00
Moyenne	71	1·042	12·306	27·894	546	41·858

EVALUATION DU NOMBRE DE CREVETTES DETRUITES PAR LA PECHE CREVETTIERE

(Tableau II)

Le nombre moyen de crevettes pour consommation est évalué à 539 par kilo et celui des crevettes immatures à 1·381 (Ch. Gilis, 1952).

Calculée sur cette base, pour l'ensemble des années 1957–61, la destruction moyenne par an atteindrait 48·654 millions de crevettes:5·859 millions ou 12, 04% de crevettes pour consommation et 42·795 millions ou 87,96% dcrevettes immatures.

Dans le nombre des immatures, il n'est pas tenu compte de la mortalité des individus rejetés á la mer par les pêcheurs qui ne débarquent que les crevettes á consommation humaine. C'estele cas pour les pêcheurs francais, belges et anglais. Il s'ensuit que le nombre des immatures détruicts par la pêche est encore sous-estimé.

TABLEAU II

Estimation du nombre de crevettes détruites par la pêche crevettière en millions d'individus

Année	France	Belgique	Pays-Bas	Allemagne	Angleterre	Total
			1. Crevettes pour consommation humaine			
1957	70	662	2·256	3·067	427	6·482
1958	30	498	2·257	3·258	346	6·389
1959	46	708	2·500	2·379	323	5·956
1960	21	305	2·139	1·942	234	4·641
1961	24	634	2·601	2·423	142	5·827
Total	191	2·807	11·756	13·069	1·472	29·295
%	0,65	9,58	40,13	44,61	5,03	100,00
Moyenne	38	561	2·351	2·614	294	5·859
			2. Crevettes immatures			
1957	..	..	10·559	40·121	..	50·680
1958	..	..	9·594	30·774	..	40·368
1959	..	..	11·908	29·385	..	41·293
1960	..	..	11·885	28·001	..	39·886
1961	..	..	10·903	30·843	..	41·746
Total	..	..	54·849	159·124	..	213·973
%	..	..	25,63	74,37	..	100 00
Moyenne	..	..	10·970	31·825	..	42 795
			3. Crevettes pour consommation et crevettes immatures			
1957	70	662	12·815	43·188	427	57·162
1958	30	498	11·851	34·032	346	46·757
1959	45	708	14·408	31·764	323	47·249
1960	21	305	14·024	29·943	234	44·527
1961	24	634	13·507	33·266	142	47·573
Total	191	2·807	66·605	172·193	1·472	243·268
%	0,08	1,15	27,38	70,78	0,61	100,00
Moyenne	38	561	13·321	34·439	294	48·654

Causes de l'appauvrissement des Stocks

A. Hypotheses fomulees par les chercheurs

Plusieurs chercheurs ont attiré leur attention sur la crise crevettière qui sévit depuis quelques années dans la région Sud-Est de la mer du Nord.

Leurs recherches démontreraient qu'outre la forte mortalité naturelle de la crevette, les dégâts causés par la pêche elle-même conditionnent dans une certaine mesure, la disette de la crevette, ce qu'on peut imputer à l'intensité accrue de la pêche et à la récente modernisation des engins.

Sans aucun doute, la forte hécatombe de crevettes immatures que la pêche entraîne, doit entraver le renouvellement normal des stocks.

Ci-après, nous donnons un aperçu sur les hypothèses avancées acquises par les chercheurs.

B. Havinga (1930) est d'avis que l'intensité croissante de la pêche crevettière a atteint la capacité productive du stock dans les eaux néerlandaises. Il note que l'on se plaint de défférents côtès de l'insuffisance des captures.

B. Havinga (1950) estime que la mortalité naturelle de la crevette est très grande. Il se demande si la mortalité causée par la pêche peut avoir une influence importante sur le stock bou s'il faut considérer cette influence comme négligeable étant donné la forte mortalité naturelle. Toutefois, s'il était prouvé que la modernisation des méthodes de pêche entame sérieusement le stock, il faudrait envisager des mesures protectrices.

B. Havinga (1955) constate que la crise crevettière continue á s'aggaver dans les embouchures de l'Escaut et du Rhin et tout le long de la côte néerlandaise, avec exception cependant pour le Waddenzee.

Ch. Gilis (1951) conclut que les mailles de 18 mm en usage chez les crevettiers belges, retiennent un trop grand pourcentage de crevettes immatures et qu'elles peuvent être élargies de plusieurs millimètres sans devoir craindre une perte appréciable de crevettes á taille commerciale. L'auteur se prononce pour une réglementation internationale de la pêche crevettière sur les côtes du Sud de la mer du Nord.

E. Leloup (1952) est d'avis que la pénurie de crevettes au large de la côte belge au cours du second semestre 1948 et au début de 1949, provient de la température exceptionnellement basse qui a règné pendant l'hiver 1946–47 et qui a entravé le renouvellement normal du stock des crevettes; le déficit du stock de l'hiver 1948–49 se fit également sentir sur la production de 1950.

Ch. Gilis (1952) observe que la crevette compte nombre d'ennemis parmi les poissons qui fréquentent la côte belge oú y apparaissent périodiquement. Parmi ceux-çi, le merlan est considéré comme étant de loin le plus grand destructeur de crevettes.

Quant à l'influence de la pêche sur le stock, l'auteur constate (1°) que la dimension des mailles du filet commercial est tellement étroite (16 á 18 mm) que même les toutes petites crevettes ne parviennent que difficilement à s'échapper pendant le trait de chalut; (2°) que les crevettes immatures forment le plus souvent la majorité dans les pêches; (3°) que l'augmentation de la dimension des mailles va de pair avec une sélection plus profitable au maintien du stock.

M. N. Mistakidis (1958) traite de la pêche sur la côte Est de l'Angleterre oú la crevette grise se capture simultanément avec la crevette rose (*Pandalus montagui*).

Basées sur un grand nombre de pêches expérimentales exercées au cours des années 1954 à 1956, ces expériences peuvent être résumées comme suit: (1°) depuis la guerre, les pêches aux crevettes accusent une diminution sensible; (2°) les mailles des filets commerciaux retiennent de grandes quantités de crevettes immatures; (3°) l'augmentation de la dimension des mailles va de pair avec une sélectivité plus profitable pour le stock; (4°) le nombre des survivances dépend surtout de la durée de leur exposition sur le pont; pour une exposition d'environ une demi-heure, la proportion des survies est de 1,5 à 15% pour la crevette rose et de 75 à 86% pour la crevette grise.

R. de Visser (1962) rapporte que lors d'une tournée d'enseignement dans le milieu des pêcheurs, R. Boddeke, s'est prononcé en faveur d'une protection du stock de la crevette, soit en limitant la pêche destinée aux usines de farine de poissons soit en appliquant une dimension des mailles plus favorable.

R. Boddeke (1962) est d'avis que, si l'on veut augmenter la capture des crevettes pour consommation, il faut en premier lieu attirer l'attention sur les crevettes immatures, dont des grandes quantitées sont capturées en même temps que les crevettes pour consommation. Exprimé en poids, plus ou moins 63% des crevettes pêchées sont immatures, soit une quantité d'environ 8 millions de kilos par an. Tenant compte de la petitesse de la taille de ces immatures, un kilogramme contient environ 3,2 plus de crevettes immatures que des crevettes adultes. Cela signifie que 84% des crevettes capturées sont immatures. L'auteur conclut que ce prélèvement inconsidéré doit fortement influencer défavorablement la pêche des crevettes pour consommation.

L'examen du cycle annuel de la crevette a démontré que les mâles changent de sexe. Le passage au sexe féminin se vérifie intérieurement par un commencement de production d'oeufs et extérieurement, par le développement de l'appendice du premier pléiopode.

On peut conclure que toutes les crevettes qui ne sont pas pêchées prématurément, peuvent atteindre la taille des crevettes pour consommation. Ceci par opposition à l'opinion ancienne selon laquelle la grande majorité des crevettes immatures sont des mâles qui pouvaient être détruites étant donné qu'ils n'atteindraient jamais la taille des crevettes pour consommation. Conséquemment le problème des crevettes immatures est à reconsidérer.

R. Boddeke (1962 *a*) l'auteur constate que la prohibition de l'usage de filets à petites mailles peut être bénéfique pour la pêche mais qu'elle ne peut résoudre complètement la problème de la crevette. Une autre manière de protection des jeunes crevettes est de les retourner le plus tôt possible à la mer après la pêche en les laissant s'écouler le long d'une goutière avec de l'eau de mer courante.

Lors de la fermeture de l'Escaut oriental et du Lauwerszee qui constituent des fonds de nourrisseries pour la crevette néerlandaise, il faudra freiner la destruction inconsidérée des petites crevettes.

P. F. Meyer-Waarden et K. Tiews (1962) constatent que les pêches aux crevettes sur la côte allemande sont sujettes á des oscillations sensibles et il paraît qu'au cours des dernières années, les conditions de pêche furent principalement défavorables. Plusieurs facteurs peuvent être rendus responsables notamment la température de l'eau, la salinité, la dérive des larves et l'abondance des prédateurs de la crevette. Le problème étant trés compliqué: il n'est pas possible de préciser dans quelle proportion chacun de ces facteurs a influencé la production des crevettes. Par conséquent les recherches doivent être poursuivies.

L'analyse du contenu stomacal a démontré que parmi les poissons qui fréquentent la zone côtière allemande, on compte beaucoup de prédateurs de la crevette. Parmi ceux-cilemerlan, par son abondance, est capable de causer des dégâts énormes au stock de la crevette. De ce fait, il est considéré comme un hôte indésirable.

H. Bohl et R. Koura (1962) Bien qu'une dimension des mailles de 14 mm soit autorisée, les pêcheurs de Schleswig-Holstein emploient en général des mailles de 16 mm. Ces petites mailles sont responsables des grandes quantités de petites crevettes débarquées.

D'après les résultats des pêches expérimentales avec des filets à mailles de dimensions différentes, l'application d'une maille d'environ 22 mm. de largeur, conviendrait pour une pêche aularge de la côte allemande. L'emploi des filets avec cette dimension de mailles augmenterait les prises des crevettes pour consommation tandis que celles des crevettes immatures subiraient une diminution.

B. Facteurs abiotiques

Parmi les facteurs abiotiques qui peuvent influencer soit favorablement soit défavorablement le renouvellement des stocks de crevettes et partant le rendement de la pêche, il y a lieu de retenir:

1. le nombre et la force motrice des côtres crevettiers qui exploitent le même stock.

2. l'efficacité de prises des différentes méthodes de pêche, ainsi que la largeur des mailles employées.

3. les conditions hydrologiques: (*a*) température et salinité et (*b*) les courants de marées.

4. les tempêtes, turbulence de l'eau.

5. la pollution des eaux côtières, etc.

C. Facteurs biotiques

Parmi ces facteurs, il y a lieu de considérer:

1. la mortalité(*a*) naturelle causée par les épidémies et la vieillesse, (*b*) accidentelle causée par l'homme et les animaux prédateurs.

2. les migrations annuelles ou saisonnières.

MESURES DE PROTECTION DES STOCKS

1. *Motifs*

Depuis quelques années, le plafond belge des quantités de crevettes pour consommation est en baisse. On constate des variations sensibles avec parfois une augmentation temporaire des captures probablement due à l'introduction dans les concentrations d'une génération abondante. Car, les repeuplements des stocks dépendent des réussites des pontes qui, deux ans après, influencent la composition des populations. Les causes de la pénurie actuelle peuvent être diverses: soit une reproduction ou une croissance ou une mortalité anormales de la crevette soit une exploitation trop intensive soit une combinaison de ces facteurs.

Actuellement, les données de ce problème ne permettent pas de définir le degré d'influence que tel ou tel facteur exerce sur la production crevettière. Ni les pêcheurs ni les chercheurs ne peuvent en donner une explication satisfaisante ni suggérer des remèdes efficaces pour prévenir rapidement une période de crise.

Impuissant devant les facteurs sans relation avec la technique de la pêche, l'homme doit agir sur les modalités de sa propre activité.

2. *Mesures de protection á envisager*

1. *En mer.*

(*a*) limitation des flottilles et de la puissance motrice.

(*b*) restriction de la pêche aux petites crevettes.

(*c*) clôture de zones déterminées, soit d'une manière permanente ou temporaire.

(*d*) réglementation de la largeur des mailles.

(*e*) tamisage mécani ue á bord, de façon que les petites crevettes soient replongées direct dans la mer.

2. *A terre*

Règlementation de la taille minimale des ventes.

Conclusions

Dans les six pays considérés, les apports saisonniers des crevettes subissent d'importantes fluctuations.

En France, en Angleterre et au Danemark, la crevette ne joue qu'un rôle restreint ou minime dans l'économie de leurs pêches côtières, alors qu'en Belgique et surtout aux Pays-Bas et en Allemagne, son exploitation assure le gagne-pain des petits pêcheurs côtiers.

La destruction inconsidérée des jeunes crevettes par la pêche exerce indiscutablement une action nocive sur les stocks de crevettes. Ceci est surtout le cas pour les Pays-Bas et l'Allemagne où les crevettes immatures sont livrées aux usines de farine de poisson.

Quant à l'influence de la pêche aux immatures pratiquée aux Pays-Bas, les données actuelles ne permettent pas d'arriver à une conclusion suffisamment certaine à ce sujet. Cependant, d'aucuns tendent à soutenir la thèse d'après laquelle la pêche néerlandaise de petites crevettes n'aurait aucune influence sur la pêche crevettière belge.

Dès lors pour protéger le stock belge contre l'action nocive de nos crevettiers, une réglementation nationale pourrait être utilement envisagée.

ENGLISH SUMMARY

GREY SHRIMP IN THE SOUTH OF THE NORTH SEA

Grey shrimp is widely spread along the sandy salty coasts as well as in the brackish waters of the western part of the south of the North Sea. The coastal areas of Belgium, Netherlands and Germany have offered a great scope for shrimping. It is less abundant on the eastern coast of England and is sparse on the Danish coast. In this general survey, the authors present a study on various subjects such as the shrimping craft, the strength of the shoal of shrimps (immature as well as shrimp for human consumption) available during the period 1957–61 in France, Belgium, the Netherlands, Germany, and England. The survey gives a description of the problems connected with the wastage through destruction of the shrimp shoal, mentions the hypothesis formulated by certain prominent research workers.

For the period 1957–61, the shoal in the abovementioned countries was as under:

Shrimps for human consumption and immature shrimps

Year	France	Belgium	Netherlands	Germany	England	Total
1957	130	1·229	11·832	34·742	791	48·724
1958	55	924	11·134	28·329	642	41·084
1959	86	1·313	13·262	25·691	599	40·951
1960	40	565	12·574	23·879	435	37·493
1961	44	1·177	12·726	26·830	263	41·040
Total	355	5·208	61·528	139·471	2·730	209·292
%	0,17	2,49	29,40	66,64	1,30	100,00
Average	71	1·042	12·306	27·894	546	41·858

Estimate of the destruction caused by shrimping, in millions

Year	France	Belgium	Netherlands	Germany	England	Total
1957	70	662	12·815	43·188	427	57·162
1958	30	498	11·851	34·032	346	46·757
1959	46	708	14·408	31·764	323	47·249
1960	21	305	14·024	29·943	234	44·527
1961	24	634	13·507	33·266	142	47·573
Total	191	2·807	66·605	172·193	1·472	243·268
%	0,08	1,15	27,38	70,78	0,61	100,00
Average	38	561	13·321	34·439	294	28·654

Protective Measures Suggested

A. *On Sea*

(*a*) Limitation of the fleets and motor power, (*b*) restriction of fishing of small shrimps, (*c*) closure of certain well-defined zones permanently as well as temporarily, (*d*) regulation of the width of meshes and (*e*) mechanical sifting on board in such a manner that small shrimps be plunged back directly into the sea.

B. *On Land*

Regulation of the minimum size of shrimps for sale.

Conclusions

In the six countries with reference to which the study pertains, the seasonal shoals of shrimps are subjected to serious fluctuations.

In France, England and Denmark, the shrimp plays only a restricted or minimum role in the economy of coastal fishing, while in Belgium and especially in the Netherlands and Germany, its exploitation assures daily bread to small coastal fishermen.

Reckless destruction of small shrimps is undoubtedly injurious to the stock of shrimps. This especially is the case with the Netherlands and Germany where immature shrimps are supplied to the fish-meal factories.

The available data do not permit to arrive to a sufficiently assuring conclusion about the influence of fishing of immature shrimps in the Netherlands. There is a tendency to support the thesis according to which the Dutch fishing of small shrimps has no influence on the Belgian shrimping.

In order to protect the Belgian shoal of shrimps against injurious action, a national regulation could be usefully envisaged.

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PENAEID PRAWNS IN THE COMMERCIAL SHRIMP FISHERIES OF BOMBAY WITH NOTES ON SPECIES AND SIZE FLUCTUATIONS*

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ABSTRACT

Among the maritime states of India, Maharashtra contributes over 50% of the total marine prawn catches of the country. There are about a dozen species of prawns contributing to the commercial fisheries of this region. Analysis of the data obtained by regular sampling from two centres—Sassoon Dock and Versova—for the years 1957–59 shows the species composition in different months and size frequencies. An attempt is made to find out the nature of recruitment of the various species into the fishery at different seasons. The spawning seasons of these species are determined by observations on the preponderance of ripe individuals in the catches.

DURING the past ten years shrimp industry has developed considerably in India and it now occupies a prominent place among the three major fisheries of the country. Although prawns are landed throughout the coastline of India, majority of the catches come from the west coast, particularly from the Maharashtra coast which accounts for more than half the annual production of shrimps in the country. Earlier accounts on this fishery (Rai, 1933; Chopra, 1943; Panikkar and Menon, 1955, etc.) dealt with general distribution of the resources and the species composition in the landings of the region. Shaikhmahmud and Tembe (1958, 1960) have studied the reproductive organs of *Parapenaeopsis stylifera* and have given a general account of the seasonal abundance of prawns in Bombay based on observations made on the stake net catches landed at Sassoon Dock.

The Central Marine Fisheries Research Institute has initiated a programme of work in early 1957 to study the species succession and detailad size frequencies of commercially important prawns of Bombay as part of the life-history studies. The data collected by this programme which continued till the end of 1959–60 fishing season is analysed and presented here.

MATERIAL AND METHODS

The data were collected from regular weekly samples taken from Versova and Sassoon docks, two important fish landing centres of Bombay City representing the inshore and offshore fishery of the locality. While the catches at Versova came from the stake net fishery operated at 12–15 fathoms depth, those at Sassoon Dock came from the stake net fishery as well as from the trawlers working in deeper waters (15–22 fathoms). The samples for analysis from Sassoon Dock were taken from the trawler landings in order to ensure comparison of the inshore and off-shore catches of prawns. One to two kg. samples were taken at random from the landings and are brought to the laboratory every week. In the laboratory counts and weights of each specific constituent were recorded, and sex ratio and maturity determined before length measurements are taken with the help of a suitably designed measuring board.

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THE FISHERY

Prawn fishery in Maharashtra coast commences by September, soon after the south-west monsoon; bulk of the catch being landed by the stake net fishermen from grounds lying within 15 fathoms depth. The stake net is a 'fixed engine' net used at the sea bottom with the help of two poles taking full advantage of the current prevailing in the area. Prawns as well as fishes are subjected to capture in this net only if they happen to filter through the net while being passively transported by the current or otherwise (Setna, 1949). The trawl net fishery which normally operates in the deeper waters up to 25 fathoms contribute to only a relatively smaller portion of the total production of shrimps, nevertheless, data obtained by their operations provide details regarding the prawn populations of the region. Although the prawn fishery exists throughout the fishing season from September to May the bulk of the landings are taken in the peak season October to January. There is a subsidiary pre-monsoon peak from late March to May. During the monsoon period—July and August—the inshore fishery is practically nonexistent while the trawl fishery continues depending on the weather conditions.

Nearly 30 species of prawns belonging to the section Penaeidea and Caridea (Crustacea, Decapoda) are known to exist in Bombay waters (Kunju, unpublished) but the commercial fishery is supported by nine species of Penaeid prawns and a few species of Caridean prawns. The Penaeid prawns of commercial value are *Penaeus indicus* (Milne Edw.), *P. monodon* Fabricius, *Metapenaeus affinis* (Milne Edw.), *M. monoceros* (Fabr.), *M. brevicornis* (Milne Edw.), *Parapenaeopsis stylifera* (Milne Edw.), *P. sculptilis* (Heller), *P. hardwickii* (Miers) and *Solenocera indicus* Nataraj. Considerable amount of *Acetes indicus* (Milne Edw.) is caught throughout the year along with the other prawns but it seldom appeared in the samples as the fishermen generally sorted it out before landing.

SUCCESSION OF SPECIES IN THE COMMERCIAL CATCHES

The relative magnitude of the fishery of each species and their succession as observed from the sample analysis is brought out in Figs. 1 and 2. The fishery at Versova, which represents the inshore fishery, commences in September with equal representation to *M. affinis* and *P. stylifera*; other prawns being insignificant at this time of the year. The magnitude of the catch of *M. affinis* shows gradual increase till November. As a general trend the catch of this species decline from December onwards till February and thereafter, till the end of the season it remains as the major constituent of the fishery. It is seen that throughout the season this species contributes to the bulk of the prawn catches at Versova. *M. monoceros* forms a minor fishery at Versova and appear in the catches for only a short period in October-November and sometimes in February. *M. brevicornis* seems to be present almost throughout the year in small quantities with relative preponderance in the catches in January and February. The fishery of *P. stylifera* which appear in the beginning of the season maintain more or less the same trend for the next month also but declined from November onwards. A secondary peak of this fishery was seen in January-February during 1958 and 1960. *P. hardwickii* and *P. sculptilis* begin to appear in the catches from November onwards when the catches of *P. stylifera* and *M. affinis* begin to decline. Both these species have their peak occurrence in December and January. In 1957–58 season the continued occurrence of *P. stylifera* till February seems to have reduced the impact of these two species in the catches. *Solenocera indicus* support an important fishery at Versova from November onwards and continue to exist in large quantities till the end of the fishing season. February and March are the peak months of occurrence of this species. The existence of this species as a commercial fishery is of great scientific interest as the species is not known to support any commercial fishery of value in any other part of the world. *Penaeus indicus* and *P. monodon* are seen in the catches of Versova only occasionally and there seems to be no regularity in their occurrence here. Non-penaeids contribute to the fishery only during the beginning and end of the fishing season.

The off-shore catches sampled from Sassoon Dock present yet another picture. While *M. affinis* substantially remains as the major componant of the catches, there are other species as well forming large portions of the landings here. The erratic occurrence of some of the species in large quantities seems to have upset the regularity of succession and sequence observed at Versova, a fishing village hardly fifteen miles from Sassoon Dock. This can only be due to the selectivity of the gear used by the trawlers and also due to their capacity to fish in different grounds widely separated from one another as compared with the fixed stake nets. For the same reason the general sampling of the off-shore catches will not be of significant value unless continued samples are studied from the same grounds.

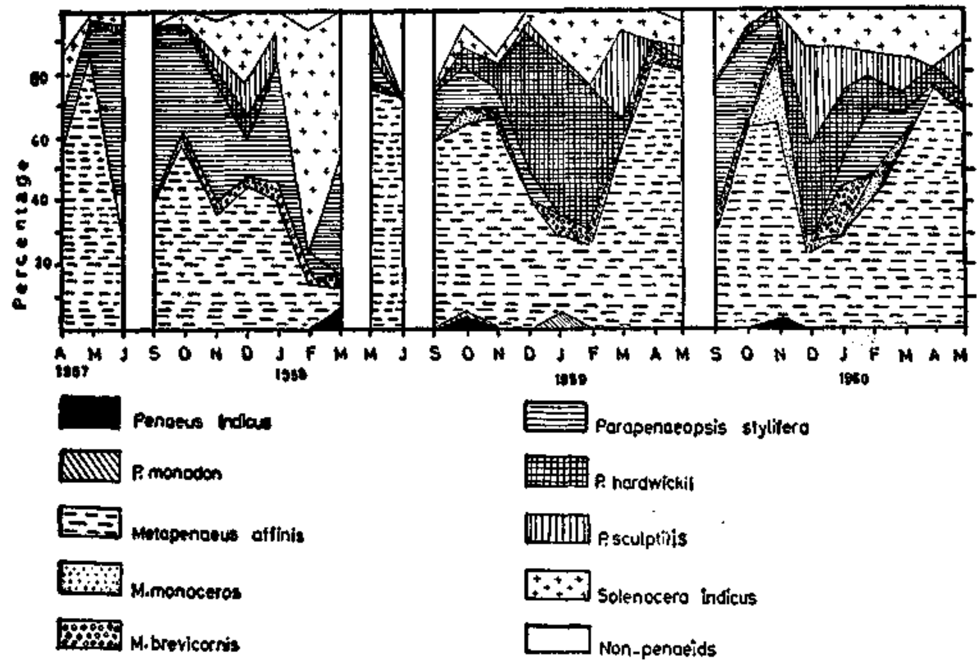

FIG. 1. Magnitude and succession of the different species of prawns in the commercial catches at Versova 1957–58 to 1959–60

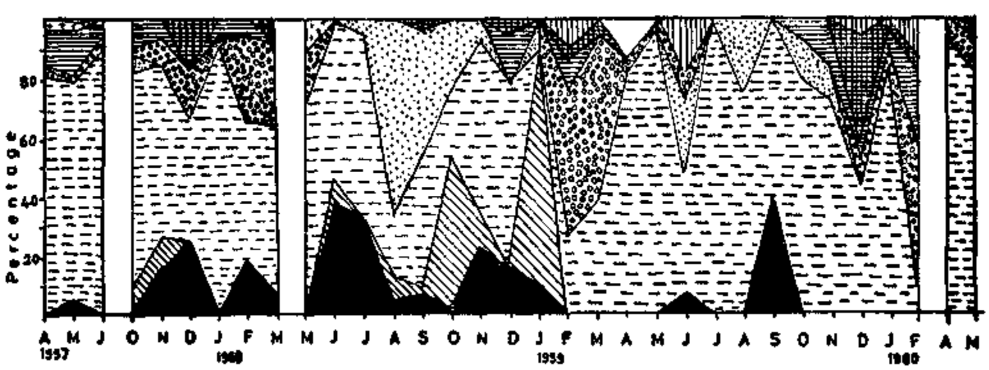

FIG. 2. Magnitude and succession of different species of prawns in the commercial catches at Sassoon Dock 1957–58 to 1959–60

The significant feature noticed from the general picture of distribution of species at Sassoon Dock (Fig. 2) is the occurrence of *P. indicus* and *P. monodon*. Both these species contributed substantially to the catches in certain months, but there appears to be no regularity in their appearance, *M. affinis* remained as the major item of the catches throughout with the exception of a few months. If the changes brought out by the occurrence of *P. indicus* and *P. monodon* are not considered the curve of *M. affinis* assumes more or less the same trend as seen at Versova. The preponderance of *M. monoceros* in the catches was greater than what was observed at Versova especially in the last two seasons. The species appears in the catches with the onset of monsoon and remains in the catches till November although the intensity of the catch is reduced by that time. *M. brevicornis* has the same pattern of occurrence as seen in Versova samples. But its relative proportion in the catches is high, indicating a relatively deep water habitat of the species. All the three species of *Parapenaeopsis* appeared in the catches of Sassoon Dock with lesser magnitude; their time of appearance and disappearance in the landings being substantially similar to what was observed at Versova. *S. indicus* appeared in the catches only in the first season and for all practical considerations it need not be considered as forming part of the off-shore catches. The bigger mesh size of trawl nets is probably the reason why the smaller sized prawns such as *P. stylifera, P. hardwickii, P. sculptilis* and *S. indicus* are poorly represented in the off-shore samples.

Breeding Season

Year round data on percentage preponderance of mature females in the catches is available only in respect of *M. affinis, P. stylifera, P. hardwickii* and *S. indicus*. For all the other species the data are not sufficient to warrant conclusions. Table I shows the percentage prevalance of mature individuals among females of the species in different months. *M. affinis* seems to be a continuous breeder, but its spawning activity seems to be relatively more intense during the periods December to February and the monsoon period of June to August. In the other three species, while there is no data for the monsoon months there appears to be definite periodicity of breeding showing more or less the same pattern. In these species—*P. stylifera, P. hardwickii* and *S. indicus*—the breeding period appears to be protracted extending throughout winter. In *P. stylifera* the period extends from September to February. A few mature individuals were obtained in May also. In *P. hardwickii* the spawning takes place from October to February with maximum intensity in December and January. *S. indicus* seems to breed from December to May; in February, however, no mature females were obtained.

TABLE I

Showing the percentage preponderance of mature individuals among females
(Monthly averages)

	M. affinis	*P. stylifera*	*P. hardwickii*	*S. indicus*
January	37·5	5·0	17·2	8·6
February	26·1	21·4	12·0	Nil
March	10·8	Nil	Nil	7·3*
April	13·4	Nil	Nil	11·0
May	14·2	100·0*	Nil	2·4
June	21·0	..	..	Nil
July	75·0*	..	..	..
August	29·4	..	..	..
September	Nil	2·0	..	..
October	2·1	8·0	7·2	Nil
November	4·7	8·6	6·6	Nil
December	20·9	16·6	30·4	13·1

* Poor sample.

SIZE AND GROWTH

Metapenaeus affinis

The size frequency histograms obtained by plotting samples from Versova and Sassoon Docks are given in Figs. 3 and 4. It is seen that the usual size differences noticed in the growth of other prawns in males and females are observed in this species also. There is a wide range of size, from 45 to 130 mm., at the beginning of the fishing season, *viz.*, September. This is due to the continuous breeding habit of the species and due to the same reason it is seen that there are a number of modes. The earliest mode at this time (September, 1958) is seen at 71–80 mm. for males and 86–90 mm. for females. The progressive shift of these modes in the subsequent months towards the right is clear from the histograms and in January 1959 they could be seen at 121 mm. and 126 mm. for males and females respectively, indicating a growth of 40–45 mm. in four months. Therefore, the monthly growth increment at this stage can be reckoned to be around 10 mm. February onwards new recruits, both young and old, again appear in the fishery though the proportion of the smaller size groups is relatively small. It is therefore clear that the new recruits observed in September are the brood from the December to February spawning and that when they enter the fishery they are in 0-year class having completed 9 to 10 months of life. Their growth during the first year is about

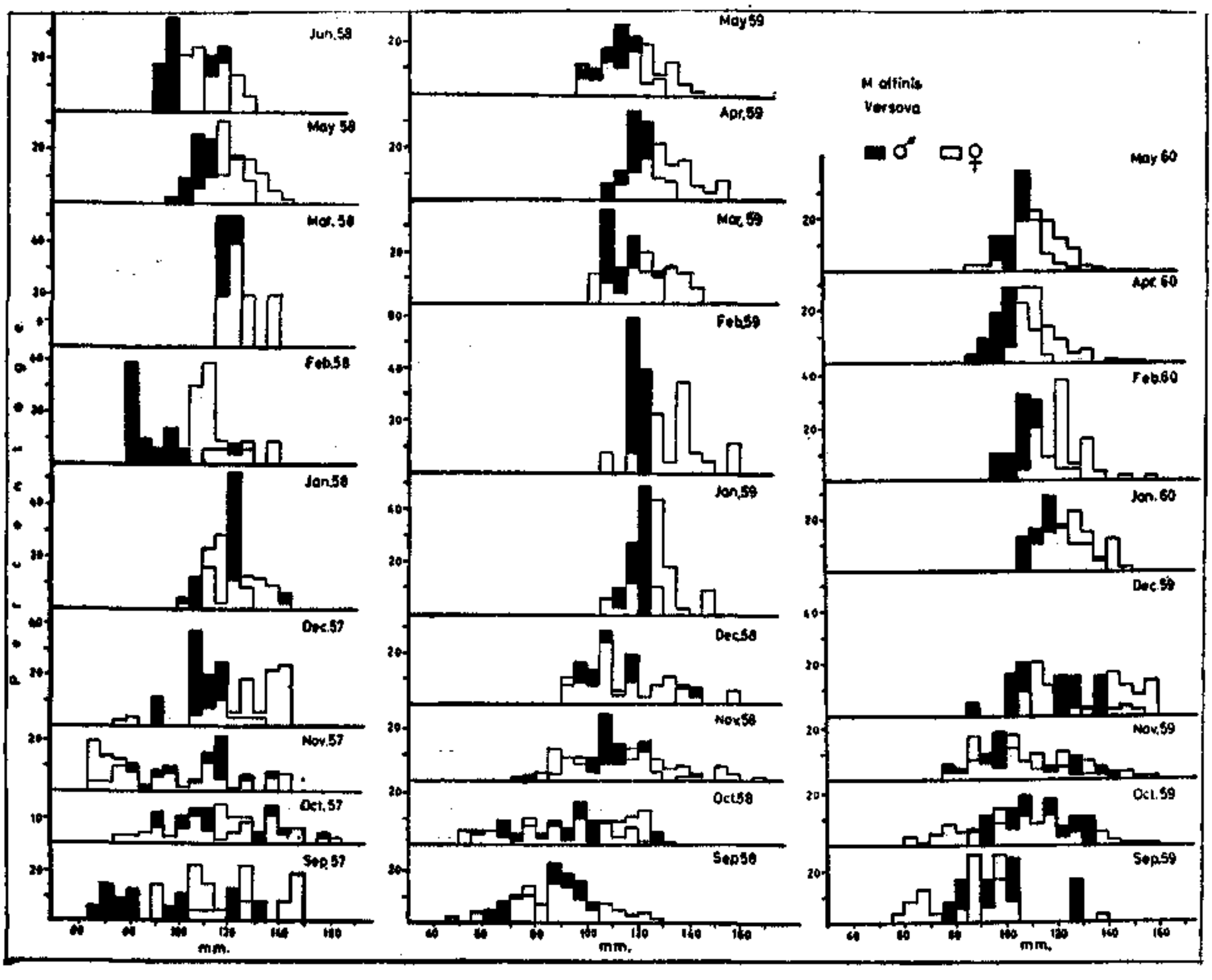

FIG. 3. Size frequency distribution of *M. affinis* in the commercial catches at Versova from 1957–58 to 1959–60

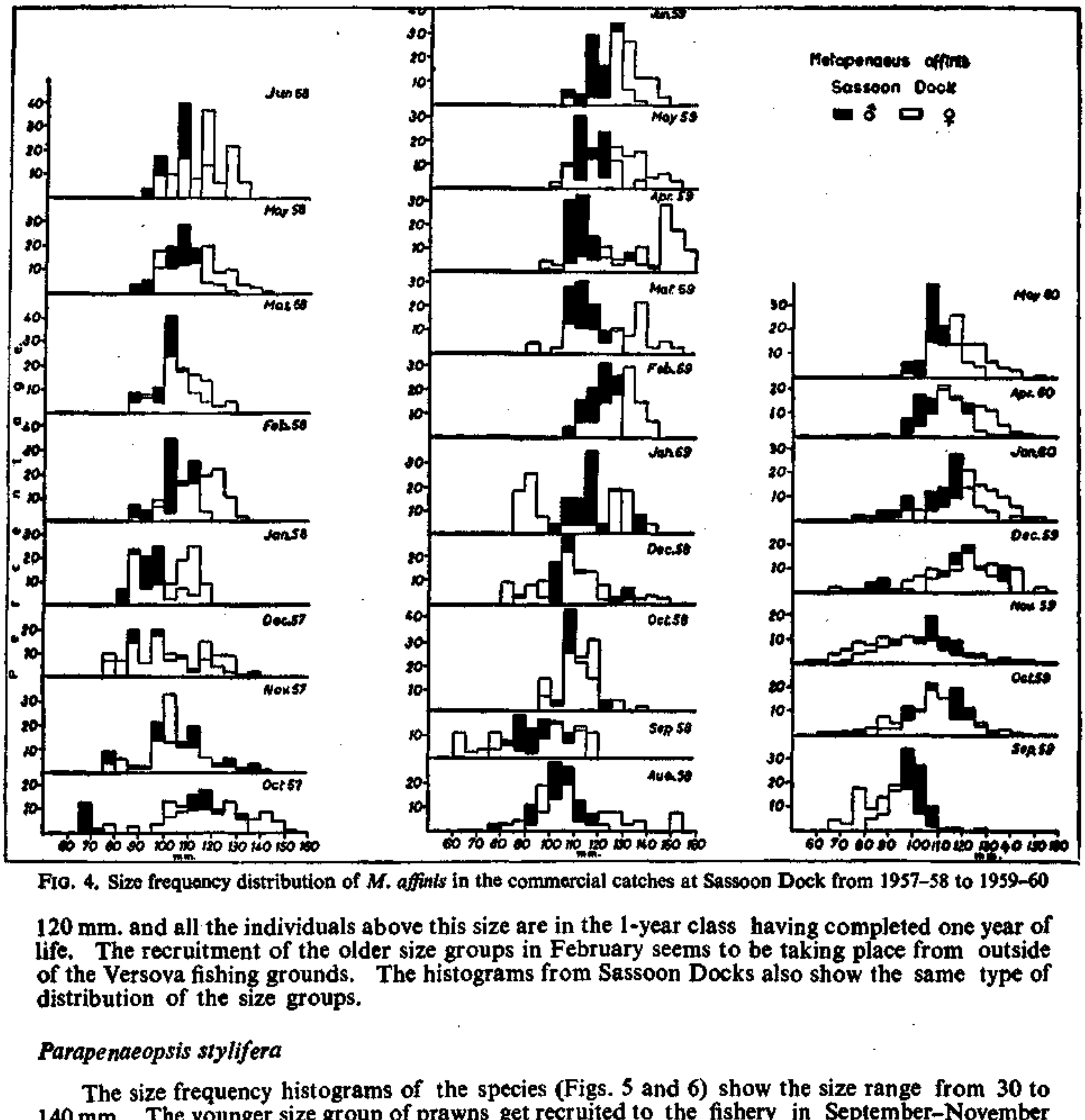

FIG. 4. Size frequency distribution of *M. affinis* in the commercial catches at Sassoon Dock from 1957–58 to 1959–60

120 mm. and all the individuals above this size are in the 1-year class having completed one year of life. The recruitment of the older size groups in February seems to be taking place from outside of the Versova fishing grounds. The histograms from Sassoon Docks also show the same type of distribution of the size groups.

Parapenaeopsis stylifera

The size frequency histograms of the species (Figs. 5 and 6) show the size range from 30 to 140 mm. The younger size group of prawns get recruited to the fishery in September–November period. In November 1957 the modes representing the youngest individuals are seen at 51–55 mm. for males and 61–65 mm. for females. These modes are progressively shifted to the right and are traced at 81–85 mm. and 91–95 mm. in February 1958 thereby showing a growth of about 30 mm. in three months. The monthly growth rate at this stage is therefore about 10 mm. The fresh recruits of younger prawns observed in November must have been born in May or June and they would have completed only 5–6 months of life. It therefore follows that the entire fishery of this species is supported by 0-year class. This observation is not in full agreement with those of Menon

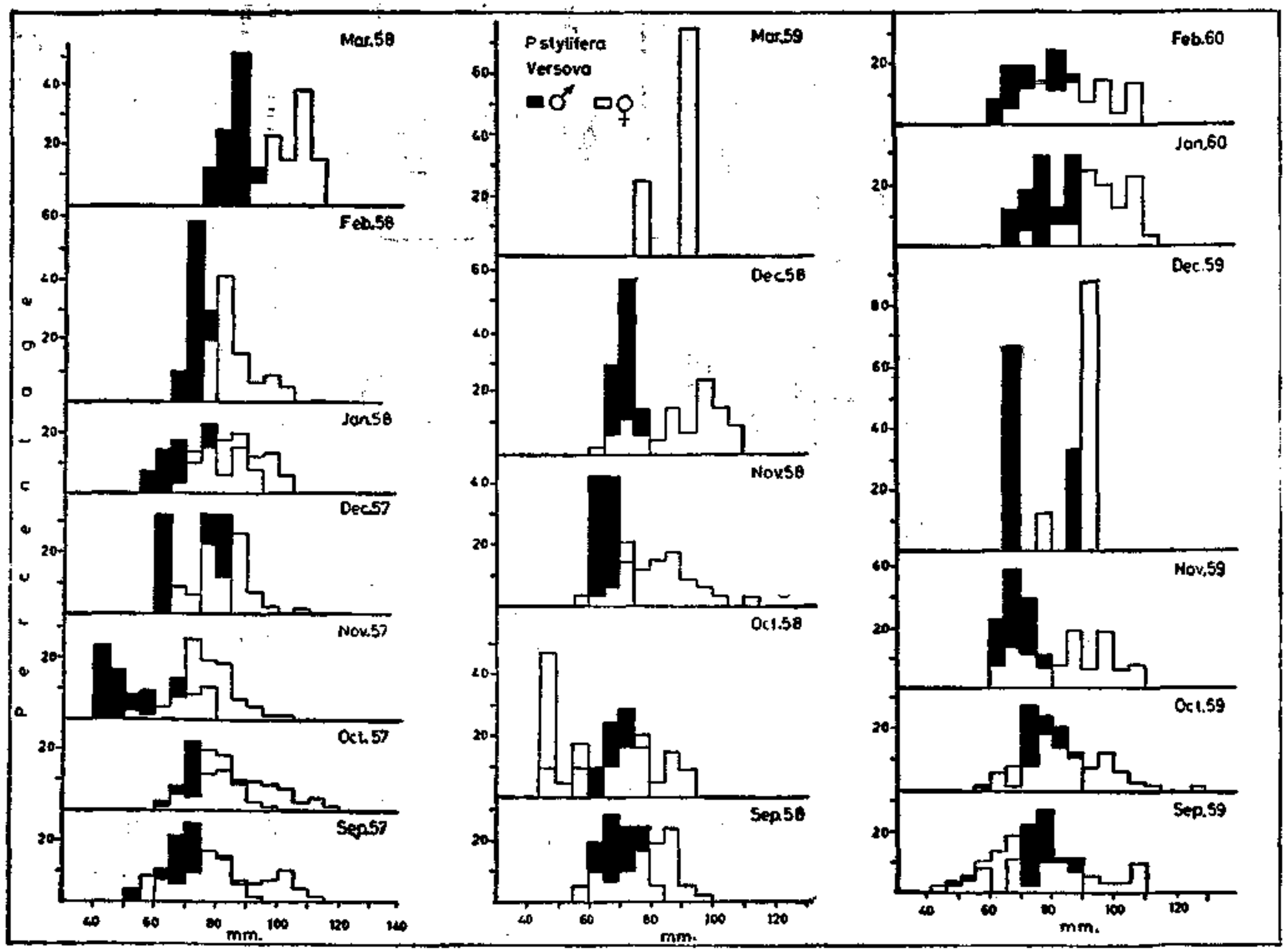

FIG. 5. Size frequency distribution of *P. stylifera* in the commercial catches at Versova from 1957–58 to 1959–60

(1953) and George (1961) who have observed that 0-year and 1-year classes supported the fishery at Kozhikode and Alleppey. The differential growth rate in males and females is observed throughout the period of observation. The larger size range of females seen is probably due to the increased rate of growth of females in the later part of their life as observed by Panikkar and Menon (1955). The breeding season of the species observed at Bombay is more protracted than what was observed by these authors.

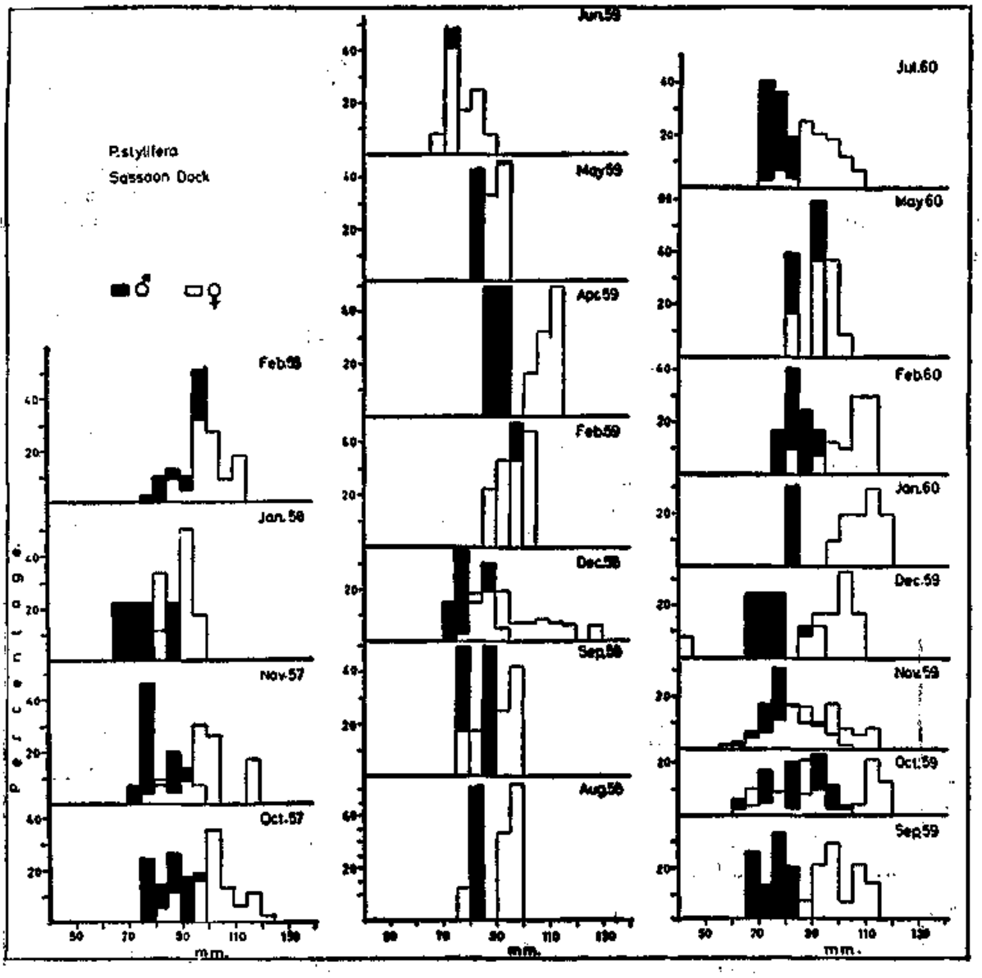

FIG. 6. Size frequency distribution of *P. stylifera* in the commercial catches at Sassoon Dock from 1957–58 to '59–60

Parapenaeopsis hardwickii

The total number of specimens of this species in the samples was very poor in all the months except November, December and January. The size frequency histograms (Fig. 7) obtainad from these samples do not present a connected picture for following the growth. However, these polygons brought out another interesting feature of this species. The wide disparity of the sizes of males and females is very striking. The females are recorded up to a size of 125 mm. while the largest size of males seen is only 85 mm. Males are very poorly represented in the catches also. In the distribution of sizes it is seen that the size range of females begin from the point where the size range of males end giving more or less a continuous picture when both the sexes are considered together.

Solenocera indicus

This is a smaller species; the maximum recorded length during this investigation being only 110 mm. The species appeared in the catches of Versova only. The histograms showing the size frequency of the species (Fig. 8) show wide disparity in the sizes of males and females; the largest male observed being less than 90 mm. The youngest size group of this prawn begin to appear in the catches from October-November onwards. The youngest size group in November 1959, being constituted by males, stand at 41–50 mm. In the succeeding months this mode is seen shifting towards right side of the histograms indicating growth. In May 1960 this mode stands at 76–80 mm. showing a growth of about 25 mm. in 6 months. The monthly growth increment, therefore, appears to be around 4–5 mm. In females the mode at 61–70 mm. observed in December is seen shifting to 86–90 mm. in five months showing the same rate of growth. By back-calculating on the basis of this rate of growth it can be seen that the young individuals at 41–50 mm. seen in November have completed nearly 10 months of life having been born in January or December. Fresh young recruits seen in January are probably those born in April. Therefore the mode seen at about 90 mm. in December are due to the 1-year class. This year class is entirely supported by females only. The entire fishery is therefore constituted by 0-year class of males and 1-year class of females.

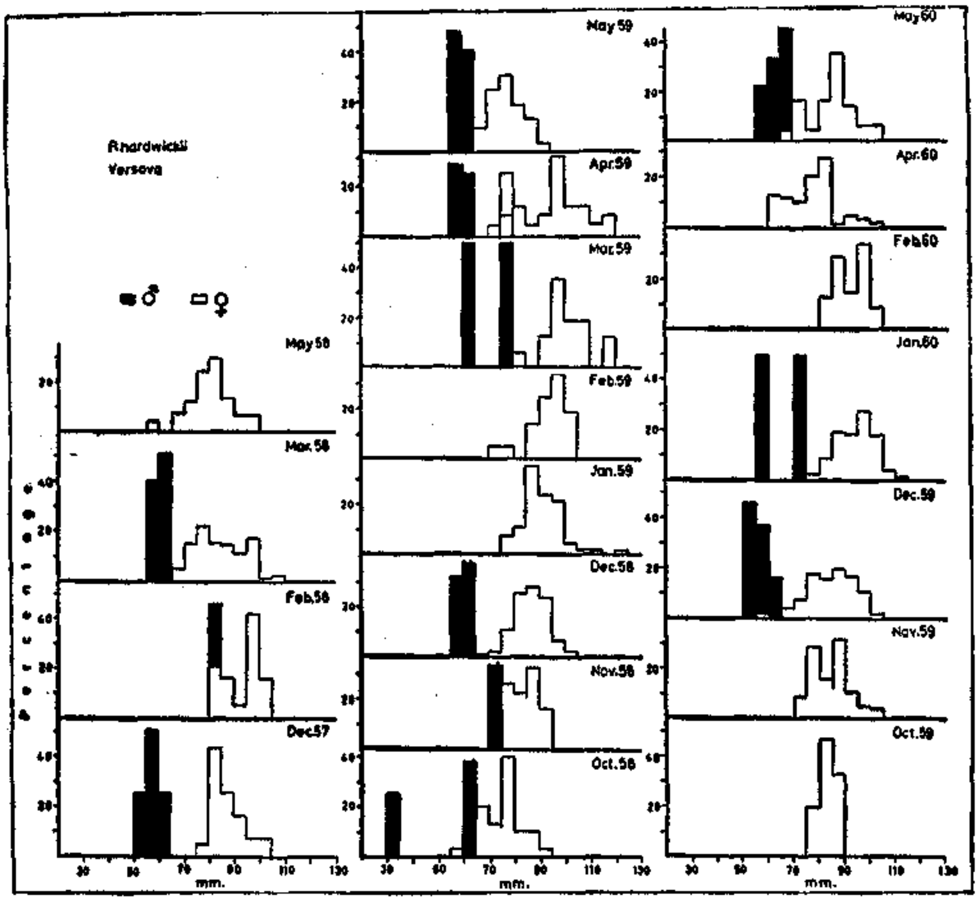

FIG. 7. Size frequency distribution of *P. hardwickii* in the commercial catches at Versova from 1957–58 to '59–60.

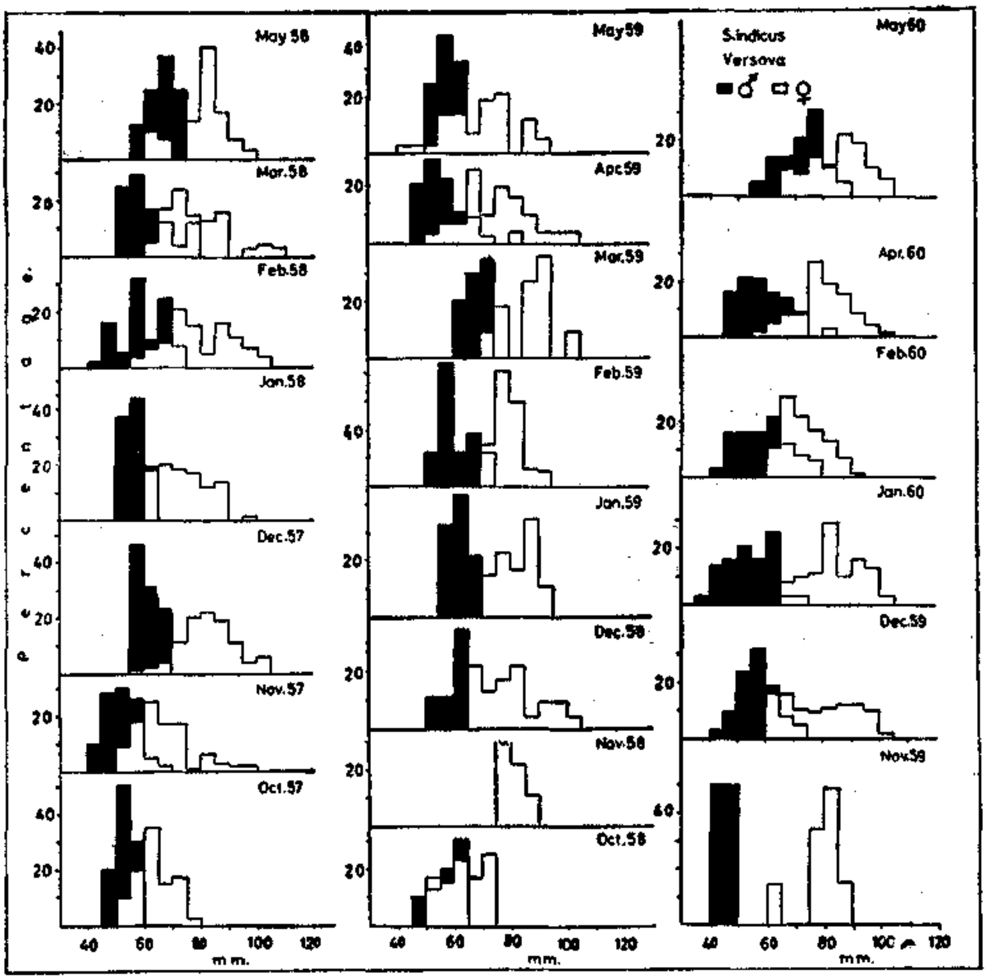

FIG. 8. Size frequency distribution of *S. indicus* in the commercial catches at Versova from 1957–58 to 1959–60

DISCUSSION

The prawn fishery at Bombay is probably unique in having a wide range of species supporting commercial fishery. At least 12 species of prawns among the 30 listed (Kunju, 1967) are being commercially exploited. Some of these species, particularly the caridean prawns, do not exist as a fishery in other parts of the country. The occurrence of *Solenocera indicus* as a fishery adds significance to the region as in no other part of the world this species supports a fishery.

Figures 1 and 2 show the relative preponderance of important penaeid prawns in the catches and their sequence of occurrence. The magnitude of occurrence of different species in inshore and off-shore catches shows some amount of variation which can be due to many reasons. The migratory habit of the prawns, the selectivity of the gear and the capacity of the trawlers to move from one ground to another are the chief reasons for this variation. The regularity of the succession of these species, when fully established, will enable to make short-term predictions which will be of benefit to the industry. Details of the life-history of many of the species remain unexplained and the present observations clearly indicate that some of the species that occur in Bombay waters are only passing through these waters at certain times of the year.

Shaikhmahmud and Tembe (1960) have observed the breeding period of *M. affinis* in April, May and June while the present observations show that the species breeds throughout the year with intensity of breeding during the period December–February and June–August. The same authors have observed the breeding season of *P. stylifera* as February to June whereas from the present observations the breeding of the species seems to take place from September to February and also in May. Their observations on *S. indicus* did not include mature specimens.

The continuous breeding habit of *M. affinis* is seen from the multimodal distribution of sizes in practically all the months. The striking disparity of sizes of males and females seen in *P. hardwickii* and *S. indicus* need further investigation. In *P. hardwickii* males and females are found in distinct and widely separated size groups, males being always smaller. In fact, the size range of females begin from the point where the size range of males end. In *S. indicus* although the size range of males and females overlap to some extent their modes are widely separated. This is probably due to extreme segregation of sexes involving males leaving the fishing ground early in life. As a possible explanation to this phenomenon sex reversal (Protandrous hermaphroditism) in these species should not be completely ruled out. Such conditions are known to exist in the European prawn *Pandalus borealis* (Rassmussen, 1942). *P. borealis* functions as male in earlier part of its life and as female in the later part of life. Only directed and continued research can elucidate this point in respect of the above two species.

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PRESENT STATUS OF THE KING CRAB IN ALASKA

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The Alaskan king crab fishery is a new, rapidly expanding operation conducted along over 21,000 miles of Alaska's submerged continental shelf to depths of up to 200 fathoms. Fishermen characteristically concentrate their efforts in accessible areas and gradually move to less exploited areas as success declines. Commercial harvest appears to improve stock health without jeopardizing reproductive potential.

ABSTRACT

During the past 18 years the Alaskan king crab fishery has grown from obscurity to world-wide importance. King crabs are harvested commercially along more than 21,000 miles of Alaska's coast from Juneau in South-eastern Alaska to Adak in the Aleutian Islands, and to the Bering Sea. The Bering Sea king crab resource has been historically fished by the Japanese since 1930 and is the only region of the Alaskan continental shelf where significant foreign harvest of king crabs has occurred.

The Alaskan king crab fishery is divided into eight general areas. From south to west those areas are referred to as South-eastern, Prince William Sound, Cook Inlet, Kodiak Island, Chignik, Peninsula, Aleutians, and Bering Sea. Commercial harvest began in the west and gradually moved south with Alaska's production rising from one-half million crabs in 1953 to 11 million in 1963.

American processing of king crabs began in 1920 on a small-scale with sporadic production until 1946 when two trawlers led the way into the Bering Sea and began freezing operations there. King crab catches increased steadily through 1953 with the Bering Sea as the major producer. Kodiak Island and Cook Inlet areas were second and third in importance. In 1954 Kodiak Island area became the major producer. It has retained the lead with production doubling annually during the past three years, from one million crabs in 1960 to four million crabs in 1963. Other areas with catches in excess of one million crabs during any one year include Cook Inlet, Peninsula, and the Aleutians.

The king crab fishery was pioneered by small, salmon, purseseine boats which fished for crabs during the off season winter months. Fishermen harvested crabs from bays adjacent to their villages and sold them daily since no facilities for keeping crabs alive were available aboard ship. Lucrative harvests paved the way for larger, more sea-worthy tanked vessels capable of fishing distant ocean areas for many days without unloading. Then, as now, only male crabs were utilized by the commercial fishery.

Early research by the Federal Government aided the infant industry by developing and improving food technology and processing skills. As the king crab fishery expanded basic biological research was initiated by both Federal and State agencies. The former conducted investigations on factors governing yield, *e.g.*, growth-recruitment, mortality, and abundance of stocks in the Bering Sea and the latter studied the crab populations of the Kodiak Island area. Early investigations included extensive tag and recapture programs.

King crabs migrate to shallow water in the spring, congregate in pairs and breed. Female crabs molt annually as a necessity immediately before ovulation and breeding occur. Those adult males which molt do so one to three months in advance of females.

Sexual maturity of both sexes is attained at an age of from 5–7 years. Male crabs become large enough for commercial harvest at an age of 7 or 8 (7 inches in greatest width of carapace).

King crabs are long lived animals with the Alaskan commercial population composed of approximately 7 age classes consisting of crabs from 8–14 years of age. Concentrated fishing on some stocks is exceeding annual recruitment causing a decrease in the average length and weight of crabs and a reduction of abundance. Other stocks have been relatively unexploited.

Sublegal male crabs have been observed to breed with as many as five females and field observations in the Kodiak Island area indicate the stocks are in a healthy condition. Commercial harvest appears to favor growth and increased production. At the same time a successful continuous increase in annual production from any one stock is dependent upon abundance of crabs from all age classes. Harvests exceeding the annual increment can continue only until all the older age classes are cropped. After this time production will stabilize according to abundance of recruit-size crabs. Total Alaska production will not decline markedly as long as unexploited fisheries are continually brought into production. Research has indicated that heavy utilization of crabs larger than seven inches will not adversely effect a stocks ability to reproduce even though annual commercial production from that area may decline drastically.

ON THE PRAWN RESOURCES OF KARWAR REGION*

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ABSTRACT

The scope for increased exploitation of the prawn resources is envisaged in the recent exploratory fishing operations by the Indo-Norwegian vessels during September 1963 to May 1964 in the Karwar region. *M. affinis*, *M. dobsoni* and *P. stylifera* are the important species occurring in the trawl fishery. From the high average catch rates in some of the months, it appears that the prawn fishery is comparatively better in September to February. The highest figures for catch per hour of trawling between 8–10, 10–15 and 15–20 fathoms respectively were 3·48 kg., 17·61 kg. and 12·56 kg. thus pointing to the comparatively better catches of prawns in regions between 10–15 fathoms. Detailed areawise analysis has been made of the catches in trawling operations off Karwar with special reference to prawns.

PRAWNS and other crustaceans constitute on an average about 17% of the total annual catch of food materials from our seas. The statistics of the landings collected at Karwar (North Kanara) during the last few years showed that prawns accounted for only a very small percentage, since fishing was restricted to regions upto about five fathoms. There was however unprecedented heavy prawn fishing in the Karwar Bay immediately after the South-west monsoon of 1962.

Experimental fishing at Karwar from September 1963 was carried out for a proper and scientific recording of the fish distribution and fishery potential of the area. The entire area was divided into one mile squares upto about 20 fathoms and a scheme was drawn up for sampling the area in a systematic manner throughout the fishing season. The procedure adopted was to have a minimum of two hauls of one hour duration in every month from each block. "INP 167", "M 4" and "Karwar No. I" commenced exploratory fishing in October, September and November respectively. The area operated by these three vessels were within 10 fathoms, 10–15 fathoms and 15–20 fathoms respectively. The present report relates to the data collected during September 1963 to May 1964 with special reference to prawn catches. Since prawns remain close to the bottom or partly buried in mud, it was felt that fishing with trawl nets could ensure efficient capture and hence shrimp trawls were used throughout the period of observation.

The total quantity of prawns landed at Karwar during September 1963 to May 1964 was 14,026 kg. comprising about 6% of the total trawl catches. The fishing effort put in was 1,124·30 hours and the average catch rate of prawns per hour of trawling for the period worked out to 12·47 kg. Miscellaneous fishes formed the majority of the catch (82·08%) and prawns formed the next important category, the third in the order of abundance was Elasmobranches (4·19%). The monthly percentage of prawns in the total trawl catch fluctuated between 3–14% during the period under report.

The monthwise prawn landings recorded at different depths by the three vessels together with the catch per hour of trawling are shown in Table 1. The catch per hour of trawling (catch per unit of effort) is a measure of the available stocks in the sea and it is this parameter which gives the most important clue for developing a suitable conservation and management policy for any fishery (Ricker, 1940). It is this same criterion (and not the total catch) that is valid in comparing the performance of different vessels also (Hickling, 1946 *a* and *b*).

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** Present Address: Central Marine Fisheries Research Centre, Vizhingam (*via*) Trivandrum.

TABLE I

Details of prawn landings by the mechanised vessels of the INP from September 1963 to May 1964

Name of the vessels ..	"INP 167"		"M 4"		"Karwar No. I"		All vessels combined	
Range of Operation (fathoms) ..	8–10		10–15		15–20		8–20	
Months	Fishing effort in hrs.	c.p.h. of prawns	Fishing effort in hrs.	c.p.h. of prawns	Fishing effort in hrs.	c.p.h. of prawns	Fishing effort in hrs.	c.p.h. of prawns
September 1963 ..	..	..	23·15	..	..	..	23·15	..
October 1963 ..	38·15	..	48·00	..	..	..	86·15	..
November 1963 ..	52·00	7·69	55·00	31·09	16·00	4·37	123·00	17·72
December 1963 ..	27·45	1·44	60·00	19·66	53·30	6·20	141·15	10·98
January 1964 ..	34·15	0·73	68·00	11·97	55·00	6·30	157·15	7·54
February 1964 ..	21·00	14·76	56·00	42·50	41·30	30·07	118·30	33·23
March 1964 ..	62·00	2·09	66·00	13·26	68·30	18·54	196·30	11·58
April 1964 ..	59·30	9·24	56·00	18·12	64·00	7·01	179·30	11·22
May 1964 ..	23·00	1·08	45·00	9·57	31·00	13·70	99·00	8·89
Total ..	317·45	3·48	477·15	17·61	329·30	12·56	1,124·30	12·47

A close study of the Table reveals the following points: (1) All the three vessels under operation netted prawns from November 1963 to May 1964. (2) The catch rate for prawns during November was 17·72 kg. During December and January a decline in the catch rate was noticed with 10·98 and 7·54 kg. respectively. The maximum catch was recorded in February when the catch rate rose to 33·23 kg. After February, the catches dwindled and by May it reached the minimum the catch rate being 8·89 kg. (3) It appears that the prawn fishery for the September–February period was much better than that for the March–May period, the average catch rate for these two periods being 13·63 kg. and 10·88 kg. respectively. (4) All the three vessels recorded the highest figures of catch per hour of trawling during February 1964, *i.e.*, "Karwar No. I" (15–20 fathoms) =30·07 kg. "M 4" (10–15 fathoms) = 42·50 kg. and "INP 167' (9–10 fathoms) = 14·76 kg. (5) Indications are that the prawn catches are comparatively good in regions between 10–15 fathoms. The figures for catch per hour of trawling between 8–10, 10–15 and 15–20 fathoms respectively were 3·58 kg., 17·61 kg. and 12·56 kg. (6) Towards the close of the season, *i.e.*, May 1964 the catch rate in the 15–20 fathom region showed an increase with 13·70 kg. than the previous figure in April (7·01 kg.). Whether this tendency is due to the migration of prawns to deeper waters is a question that can be answered only after continuous observations for a few years.

Metapenaeus affinis, *Metapenaeus dobsoni* and *Parapenaeopsis stylifera* are the important species that supported the trawl fishery. Based on the analysis presented, it can be presumed that the prawn beds of this area are likely to be situated in regions between 10–15 fathoms. Reference may be made here to the observations recorded earlier regarding the off-shore prawn fishery at Ernakulam that the 6–12 fathom area was found to be most productive with two distinct zones, 6–8 fathom area for *M. dobsoni* as a predominant species and 9–12 fathom with *M. affinis* predominating. The present analysis has revealed that Karwar area has proved to be an important prawn trawling ground of this coast. A point that should be stressed in this connection is that the data presented are based on exploratory fishing and not on intensive commercial fishing.

Fishing with mechanised vessels at Karwar has yielded encouraging results. A total catch of 2,36,604 kg. were netted by trawl net during the nine-month period from September 1963 to May 1964 with an average catch of 210·59 kg. per hour of trawling.

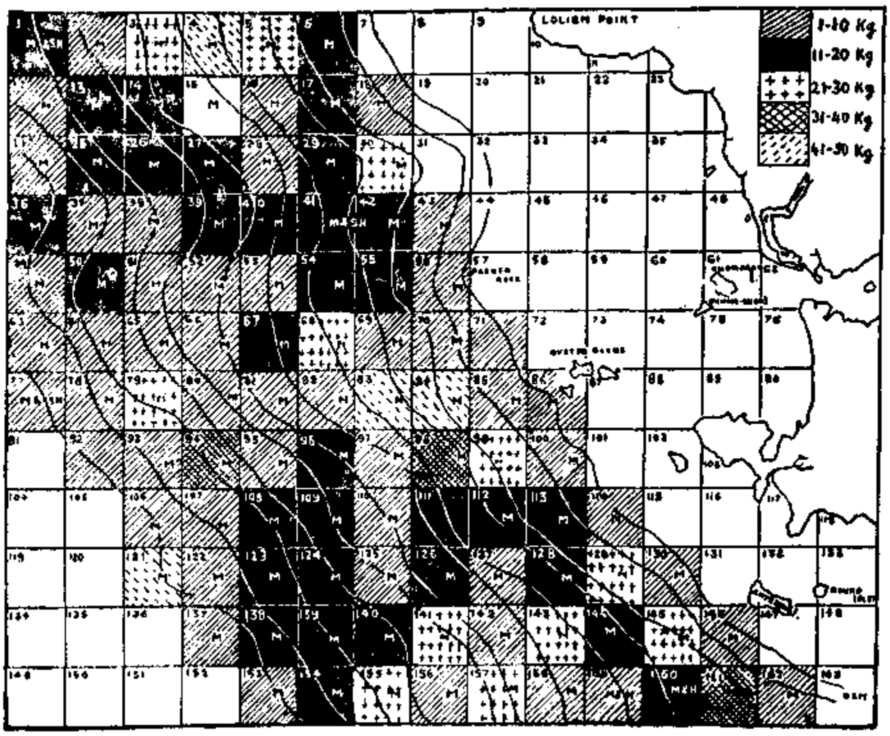

FIG. 1. Catch per hour of trawling of prawns at Karwar from September 1963 to May 1964.

Based on the data obtained, an attempt has been made to find out prospective good fishing areas which can be profitably fished. Text-Fig. 1 represent the catch per hour of trawling for prawns in the different areas of observation during September 1963 to May 1964. Since the data relate to observation for only one season, 1963/1964 this report is essentially preliminary in character. However, it is hoped that the data presented here will stimulate more intensive exploitation of the prawn resources of this area in the years to come. Observations carried out for a minimum number of at least five to six years is required for arriving at any positive conclusions.

The author is thankful to the Indo-Norwegian Project authorities at Karwar for placing at his disposal all the log sheets of the different vessels and also for giving him facilities to go on board the vessels for examining the catches.

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STUDIES ON THE PRAWN FISHERY OF KUTCH*

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ABSTRACT

This paper deals with the observations on the prawn fishery and bionomics of the commercial species during May 1959 to April 1962. The principal landings consisted of *Metapenaeus kutchensis* and *M. brevicornis* and the fishery for these occurred during the monsoon period (August–October) and winter (November–February) respectively.

Both the species appear to live for four years. In the case of *M. kutchensis* all the year classes are represented in the coastal waters and a length of 81–85 mm., 106–110 mm., 131–135 mm. and 146–150 mm. is reached by the respective year class. From the length frequency curves for this species that occurred in the creeks the monthly growth rate is estimated to be 5–7 mm. in the '0' year class. The monsoon fishery was constituted by the '0' year group. No marked disparity in the sex ratio was noted. Breeding takes place only in the sea and it extends from February to September with the peak during March–May.

The commercial catches of *M. brevicornis* in the inshore waters were constituted by the 2 year class (86–90 mm.). Towards the end of the season the 3rd year class (106–110 mm.) appeared in the fishery and a marked disparity in the sex proportion was also noticed then. From the length frequency curves for this species occurring in the lower reaches of the creek, the monthly growth rate has been estimated to be 3 mm. in the 1 year group. In the second year group it is 2·7 mm.

Evidence is presented to show that this species breeds during March–April which synchronises with the disappearance of the fishery from the coastal waters. It is, therefore, probable that it migrates into the deeper waters for breeding. The differential growth rates and survival rates in the two sexes of both the species are discussed.

INTRODUCTION

PRAWNS constitute nearly 60% of the total marine fish catch of Kutch. The present paper is the result of investigations carried out during May 1959 to April 1962 and deals with the study of commercially important species of prawns caught in the Kutch coast of the Gulf of Kutch, from the point of view of the size groups entering the fishery at different seasons and the relationship of the fishery to surface temperature, salinity and rainfall.

With the exception of the work done by Srivatsa (1953) who made a general survey of the prawn fisheries with particular reference to the Saurashtra coast and that of the author (Ramamurthy, 1963) whose account deals with the distribution of the different species of prawns in the Kutch coast, no information is available on the prawn fisheries of this region.

MATERIAL AND METHOD

Material for this investigation was collected fortnightly by random sampling of the commercial catches at Cherowari, and Takara (Text-Fig. 1). Cherowari is connected to the open sea by both Kandla and Hansthal creeks. Weekly samples were analysed from Kandla situated in the lower reaches of the Kandla creek. Apart from this, samples collected once a month from the departmental catches of *gunja* at Cherowari during May 1960 to October 1961 and during February to

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April 1962 and those collected fortnightly at Luni and Modhwa from August 1960 are also included in this study.

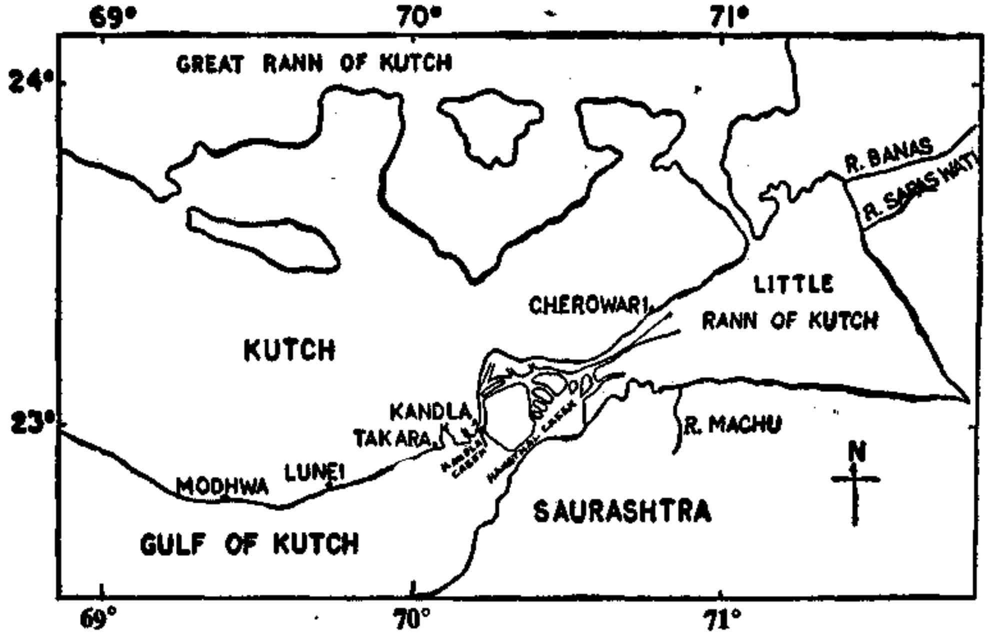

FIG. 1. Showing the location of fishing centres of observation in Kutch.

The type of net used at these centres was *gunja* (conical bag net) tied to stakes. The *gunja* used in creek-fishing is 15′ long, 9′ in diameter with a mesh size of $1\frac{3}{4}''$ near mouth to $\frac{1}{4}''$ at cod end and that used in the inshore waters of the Gulf is 72′ long, 18′ in diameter with a mesh range of $4\frac{1}{2}''$ to $\frac{1}{2}''$. At Luni, *Patti* (rectangular shore net) 40′ × 4′ with a mesh size of 1″ to $\frac{3}{8}''$ is operated. Fishing by these types of nets is done taking advantage of the strong tidal flow, between depths of 2–12 m. The tidal range at Kandla is about 6 m. While collecting the samples no distinction was made between the catches of the different types of nets. The data gathered from the open gulf centres are pooled.

In analysing the samples, the percentage values of the different species by weight were determined. For length frequency studies, total length (from tip of the rostrum to the end of the telson) was taken after separating the sexes. The maturity condition was also noted.

Salinity was determined by Mohr's method of the titration of the chlorides and the temperature was recorded by the centigrade thermometer.

FISHERY AND CATCH COMPOSITION

Since the fishing is done depending on the tidal flow, the catches were generally scanty from the 7th to 11th day and from 22nd to 26th day of the lunar month.

There are two prawn fishing seasons in Kutch. The monsoon fishery occurs in the upper reaches of the creeks during August to September, sometimes extending to October and this period coincides with the rainy season (June to October) of this region. The fishery is constituted almost entirely by *Metapenaeus kutchensis*. This species contributes to the bulk of the prawn fishery of

Kutch which is however, erratic. The fishery was a total failure during 1960-61. The total landings of prawns during 1959-60 and 1961-62 were estimated as 880 and 700 m. tons respectively. The winter fishery occurs during November to February and it was observed to be more or less regular unlike the monsoon fishery. The average annual production during the three years was 180 m. tons. The bulk of this fishery (60%) is constituted by *Metapenaeus brevicornis*. The other important species found in the catches are *M. kutchensis* (20%), *Penaeus indicus* (11%) and *Parapenaeopsis sculptilis* (7%). Occasionlaly *M. stebbingi, Parapenaeopsis stylifera, Penaeus canaliculatus, Acetes* sp., *Leander* spp. and *Hippolysmata ensirostris* also are present in the catches. The fishery and bionomics in respect of the two commercial species *M. kutchensis* and *M. brevicornis* are dealt with below.

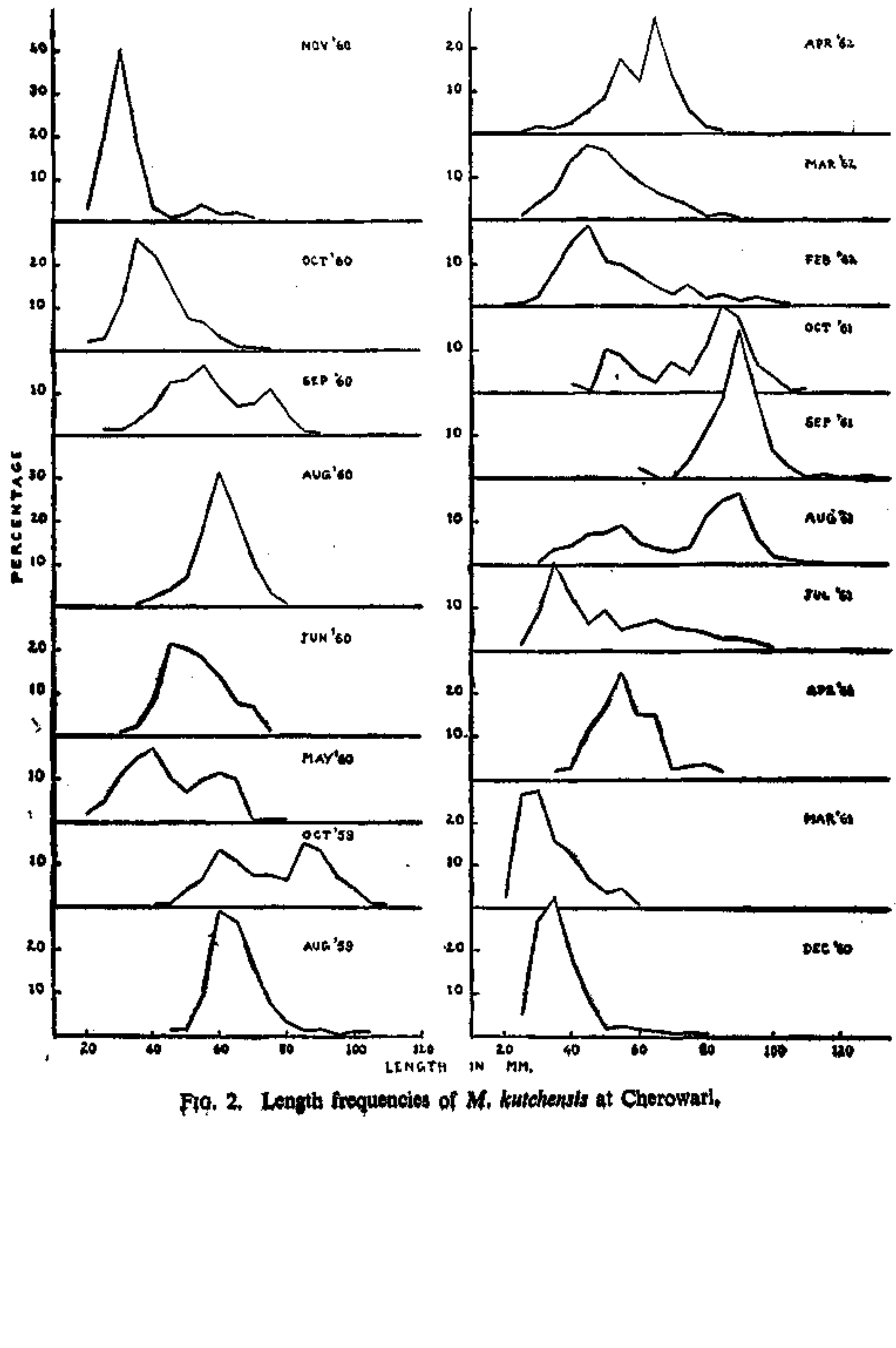

FIG. 2. Length frequencies of *M. kutchensis* at Cherowari.

I. *Metapenaeus kutchensis*

The bulk of the catch is netted in the inner creeks of the Gulf during the south-west monscon period (August to September) when the flood waters of the rivers Banas, Saraswati and Machu (Text-Fig. 1) get discharged into the creek. Outside, in the coastal waters of the open Gulf, this species is caught along with *M. brevicornis* in winter.

Growth

The commercial fishery is restricted to a very brief period every year. In order to get a picture of the occurrence of this species at other times of the year departmental *gunja* was operated once a month at Cherowari. These operations, necessarily limited in frequency due to the inaccessibility of the place, could not be planned so as to have any reference to the phases of the moon. The monthly frequency curves based on the data collected thus, together with the frequency curves for the commercial fishery are represented in Text-Fig. 2. It can be seen that during 1959-60 the length of the modal group in the commercial catches was 56-60 mm. in August while in October another group, *viz.*, 81-85 mm., was also represented. The fishery came to a close thereafter. From the month to month frequency curves in 1959-60 the modal length is found to gradually increase from 36-40 mm. in May to 56-60 mm. in August and the monthly growth rate works out as 6·7 mm. During 1960-61 the fishery failed. However, the analysis of the departmental catches revealed that in September and the following months the length of the majority group was less than that in August, reaching a minimum of 26-30 mm. in November 1960. In December the mode shifted to 31-35 mm. But in subsequent months the majority group was varying in length irregularly between 26-30 and 51-55 mm. till July 1961. In August and September 1961, when the fishing operations were on a commercial scale the principal mode was at 86-90 mm. and the 51-60 mm. group was reduced to an insignificant mode unlike the length frequency characteristics of the commercial fishery of 1959-60. It may not be that the 51-55 mm. group noticed in April 1961 could have reached the length of 86-90 mm. in August 1961 as the monthly rate of growth among these size groups is observed to be 5-6 mm. at Kandla (Text-Fig. 3). It is also seen from the length frequency curves in Text-Fig. 2 that during November-July the maximum size of the individuals was always below 100 mm. while during the period of the active fishery, *i.e.*, August-October of 1959-60 and 1961-62 specimens upto a maximum size of 128 mm., comparable to the sizes occurring outside in the sea, were encountered in the fishery. Such comparable sizes do not occur at Cherowari at other times of the year. It can therefore be inferred that *M. kutchensis* migrates into the creeks during the monsoon period and gets caught in the commercial fishery. Such individuals appear to belong to the 0-year group as will be seen later. However, it is fairly clear that specimens measuring over 100 mm. are very rare, the maximum size recorded being 128 mm. Bigger size groups are found to occur only in the sea as will be seen later. In the light of these facts it is also evident that *M. kutchensis* migrates back into the sea.

The length frequency curves for *M. kutchensis* that occur at Kandla are plotted in Text-Fig. 3. Specimens measuring over 110 mm. were very rare. The modal group from month to month does not show any progressive increase in size. During June 1961-April 1962 the majority length group was between 61-75 mm. and each was found to remain unchanged for 3-4 months. However, in the earlier years it was seen that the 56-60 mm. modal size of June 1959 has shifted to 81-85 mm. in March 1961. These indicate a monthly growth rate of 5-6 mm. among these size groups.

Though data on size groups at each of the fishing centres in the open gulf were not continuously available it is attempted here to present a picture of the age groups in fishery by clubbing the entire data of the centres available during 1961-62. The total size frequency plotted for all sexes in the coastal fishery (Text-Fig. 4) shows four modes, *a*, *b*, *c* and *d* at 81-85, 106-110, 131-135 and 146-150 mm. respectively. The sizes attained by this species as well as the rate of growth are comparable to those of *M. monoceros* (George, 1959) and hence these may be considered to represent the 0, 1, 2 and 3 year classes respectively. However, it will be worthwhile to have more data for a detailed analysis of the age groups with particular reference to the centre of observation.

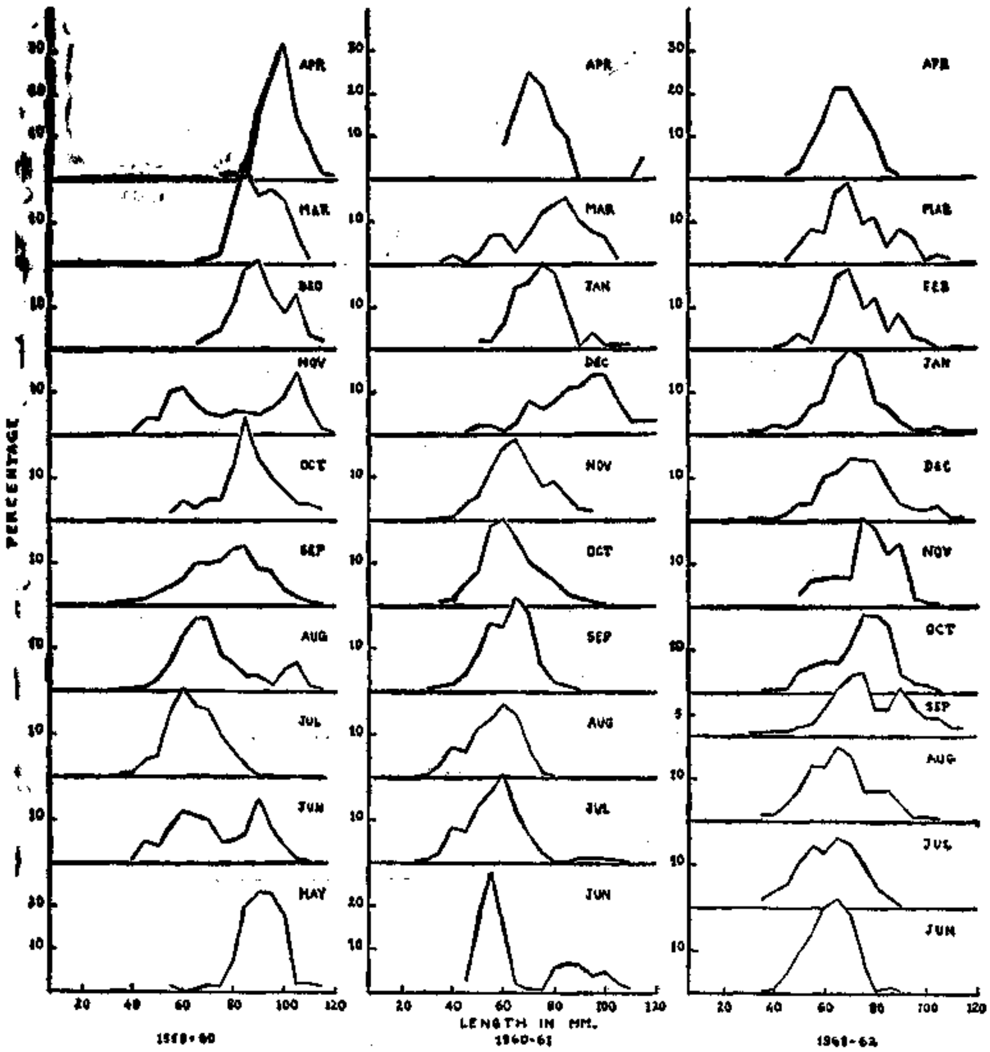

FIG. 3. Length frequencies of *M. kutchensis* at Kandla.

Differential Growth Rate in Sexes

Length frequencies for the two sexes separately in August and November 1960 and August 1961 at Cherowari and in February 1962 in the coastal fishery are shown in Text-Fig. 5. Females have a higher growth rate as observed in the case of other species of prawns (George, 1961). But it is not quite apparent early in life as the frequencies for August and November 1960 would indicate. The largest female measured 164 mm. while the largest male measured only 148 mm.

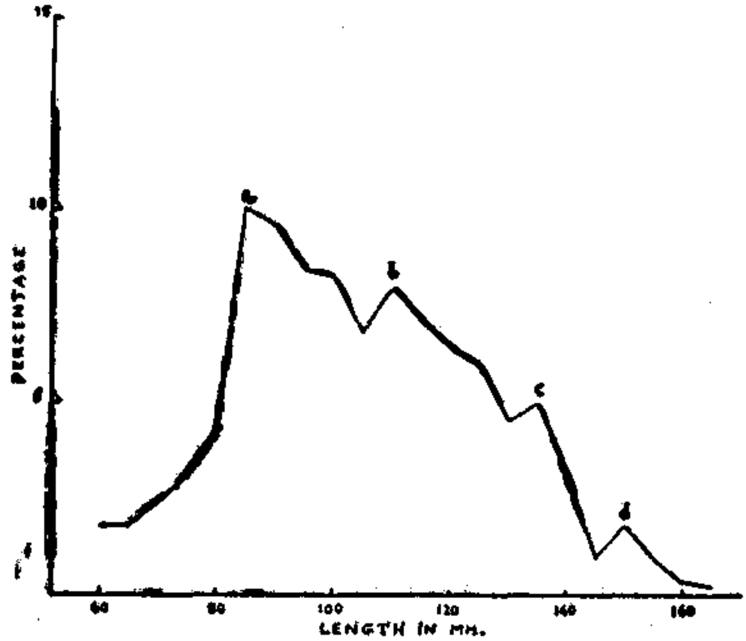

FIG. 4. Total size frequencies of *M. kutchensis* in the coastal fishery during 1961–62.

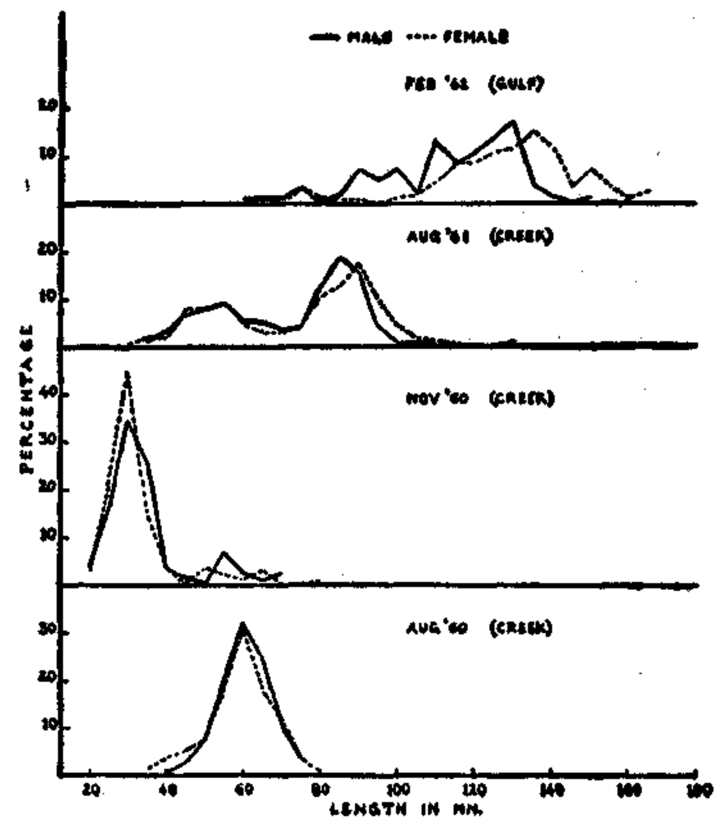

FIG. 5. Differential growth rate of sexes in *M. kutchensis*.

Sex Ratio

The determination of sex-ratio in the commercial fishery during 1959–60 and 1961–62 shows a slightly higher percentage for females in both the years, the respective percentages of males and females being 47·4 and 52·6 and 48·1 and 51·9.

The percentage of males and females in the coastal waters measuring 101–125 mm. and those measuring over 126 mm. in the total number of each sex has been calculated separately for 1961–62 and is shown in Table I.

Table I

Percentage of males and females of M. kutchensis *in specified size groups*

	101–125 mm.	126 mm. and over	Total number measured
	%	%	
Male ..	23·2	4·7	698
Female ..	21·5	13·0	738

The proportion of females of the size 101–125 mm. is more or less equal to that of males while in the next size group of 126 mm. and over, the proportion of females is markedly higher than that of males. Since these sizes (126 mm. and over) would include individuals more than 2 year old, these percentages would indicate that the proportion of prawns, particularly the males, surviving beyond 2 years, is quite small.

Food

The analysis of the stomach content of *M. kutchensis* ranging from 40–130 mm. in size revealed that they feed on the detritus at the bottom and the stomach content therefore usually shows considerable amount of mud. Sand grains were also presant. Among the recognisable remains are the crustacean appendages, molluscan shell remains and foraminiferans. Algal matter was also noticed on several occasions.

Breeding and Migration

Males measuring over 100 mm. are found to carry spermatophores. Mature females were generally rare and they were never recorded from the creeks. The smallest mature female measured 122 mm. The highest percentage of mature females occurred during February to September. Occasionally spent ones were also noticed during March–May which suggest that breeding takes place during this period.

As pointed out earlier, individuals belonging to the '0'-year group appear to migrate into the creeks during the monsoon period. They probably do so in search of low saline waters and migrate back into the sea as a result of the increase in salinity in the creeks as will be seen later. Breeding takes place only in the sea since mature females and spent ones were obtained only from the marine environment.

FACTORS INFLUENCING THE MONSOON CATCH

Among the fishermen there is a wide-spread belief that the rainfall exerts a considerable influence on the fishery. In Table II the monsoon prawn catch and rainfall together with the salinity ranges at Kandla separately for the monsoon period and for the rest of the year during May 1958 to September 1962 are presented. Salinity estimations of the water at Cherowari were also carried out during July to October of 1960–61 and 1961–62, the mean monthly range in salinity being respectively 34·21–54·28‰ and 12·43–27·84‰. It is seen from the table that the salinity ranges at Kandla reflect the effect of rainfall to a considerable extent. The fishery completely failed during 1960–61 and the rainfall also was least in that year, consequent on which the salinity remained high. Though no data on rainfall are available for 1961–62, the salinity ranges at Kandla and Cherowari indicate that the monsoon was active in that year as in 1959–60 and the fishery also was good in both these years.

TABLE II

Landings of M. kutchensis *in relation to rainfall and salinity*

Year	Prawn landing in m. tons	Rainfall in cm.	Salinity range in ‰ at Kandla	
			July–October	Rest of the year
1958–59 ..	862	31·1	No data	No data
1959–60 ..	880	82·4	15·56–24·70	29·90–37·21
1960–61 ..	No landings	13·3	36·51–38·78	36·44–41·88
1961–62 ..	700	No data	25·40–26·71	32·63–41·35

II. Metapenaeus brevicornis

The commercial catches of this species are taken only from the sea. This species is never caught in significant quantities at any time at Kandla. It is however interesting to note that the size groups occurring in the creeks were entirely different from those of the coastal waters of Kutch and hence the month to month fluctuations in the sizes occurring in the creeks were followed.

GROWTH

The size range of the species together with the modal sizes in each month at Kandla during 1961–62 are shown in Table III. During February–May it was not represented at all in the catches. The smallest modal size 26–30 mm. occurred during September. At other times the majority group varied in length between 36–40 and 51–55 mm. Individuals measuring over 65 mm. were very rare. The majority length group of 41–45 mm. in October appears to have grown to 51–55 mm. in January 1962 which indicates a monthly growth rate of 3·3 mm.

The coastal fishery during the first year could be kept under observation only till December 1959 while in the subsequent years it was followed throughout. Table IV represents the monthly average percentage values of the species by weight in the catches of the coastal waters. *M. brevicornis* appears in the inshore catches from August when they were caught in small quantities. After the period of the active fishery (November–February), when the catches comprised chiefly of this species, it was continued to be caught in small quantities till March–April.

TABLE III

Size range and modal size of M. brevicornis *at Kandla during* 1961–62

Month		Modal size in mm.	Size range in mm.
May	..	Specimens absent in the catch	
June	..	36–40	34–52
July	..	46–55	36–65
August	..	36–40	29–61
September	..	26–30	21–53
October	..	41–45	31–56
November	..	46–50	47–66
December	..	51–55	36–55
January	..	51–55	34–75
February	..	Specimens absent in the catch	
March	..	Specimens absent in the catch	
April	..	Specimens absent in the catch	

TABLE IV

Monthly average percentage values for M. brevicornis *in the marine catches*

		August	September	October	November	December	January	February	March	April
1960–61	..	11·0	25·0	30·0	27·0	41·0	..	82·0	28·0	1·0
1961–62	..	14·0	21·1	24·0	42·7	57·9	47·0	55·1	32·5	29·0

The size groups of *M. brevicornis* occurring in the sea are shown in Text-Fig. 6. When this species started appearing in August the dominant size was at 66–70 mm. in all the three years. A progression of this mode to 81–85 mm. in December 1959, 86–90 mm. in March 1961 and April 1962 is clearly noticeable. The lengthy of the majority group in the commercial catches was 86–90 mm. and the age when this length is attained could not be ascertained since no other earlier size groups are available in commercial quantities. However, according to the findings of Rajyalakshmi (1961) this may represent the two-year old group. The monthly rate of growth in this group appears to be 2·7 mm. Larger size groups enter the fishery towards the end and the modal size of 106–110 mm. noticed during February–March would seem to represent individuals in the fourth year of life (3rd year class). The rate of growth is found to be diminishing with the ageing of individuals. The largest size group 126–135 mm. has been recorded only during February to April 1962 and they were entirely females. They however form only a small part of the entire population as can be judged from the catches of the three years. It is not possible from the available data to determine whether they are older than four years. Under the circumstances it can only be stated that the species lives for four years.

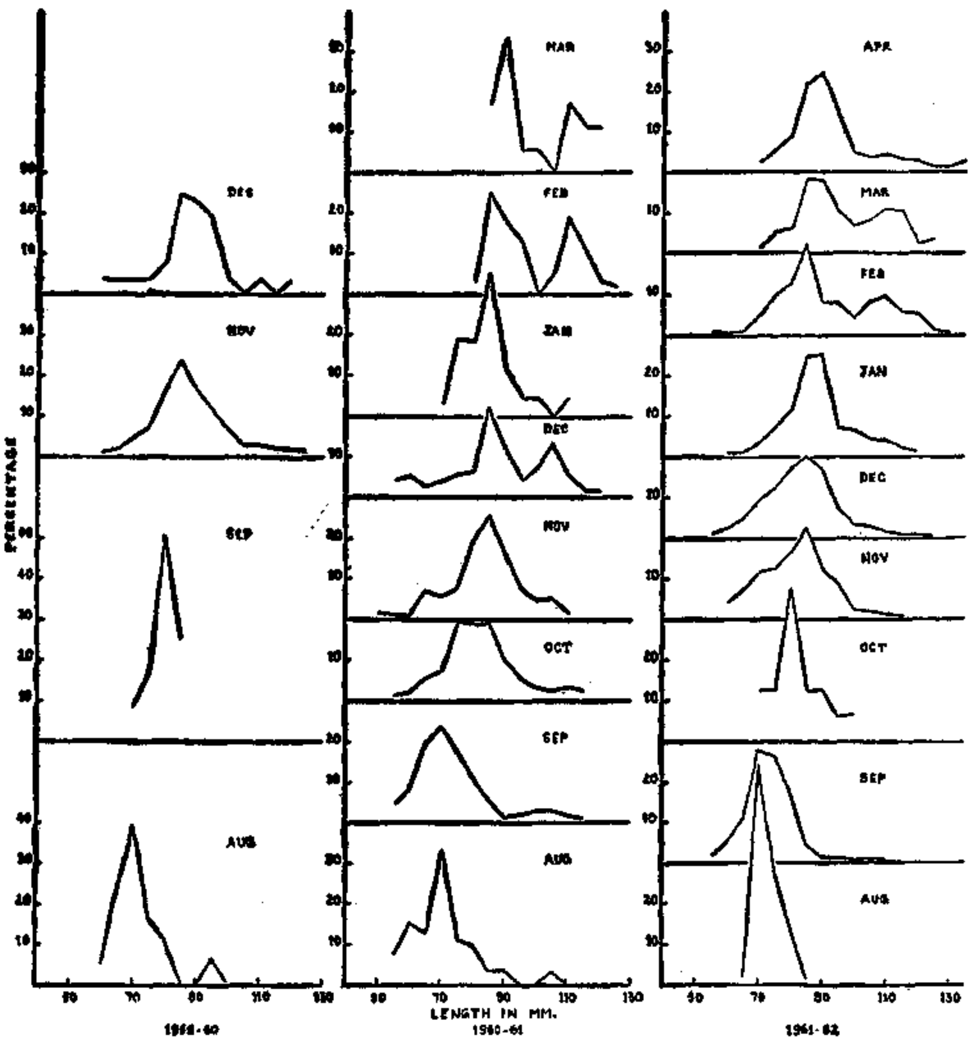

FIG. 6. Length frequencies of *M. brevicornis* in the coastal fishery.

DIFFERENTIAL GROWTH RATE IN SEXES

The study of the length frequency curves of the two sexes separately (Text-Fig. 7) shows that there is a differential growth in the sexes, females having a higher growth rate as in the case of *M. kutchensis*. The largest male and female measured 103 and 135 mm. respectively. Quite early in life such a differential growth is not apparent as the frequencies of both the sexes in the creek were noticed to be the same at Kandla. Such characteristics in the growth rate of sexes have also been observed by Rajyalakshmi (1961).

SEX RATIO

The monthwise sex ratio in the catches during the three years is shown in Table V. The disparity in the proportion was not generally great during the active period of the fishery (November–January). Towards the fag end of the season the proportion of females was much higher.

TABLE V

Percentage of males and females of M. brevicornis *in the commercial catches*

Year	Sex	August	September	October	November	December	January	February	March	April
1960–61	Male	44·4	27·0	40·0	45·5	49·3	53·8	20·0	25·0	...
	Female	55·6	71·0	60·0	54·5	50·7	46·2	80·0	75·0	...
1961–62	Male	38·6	36·1	33·3	42·3	49·3	44·5	31·8	27·5	59·5
	Female	61·4	63·9	66·7	57·7	50·7	55·5	68·2	72·5	40·5

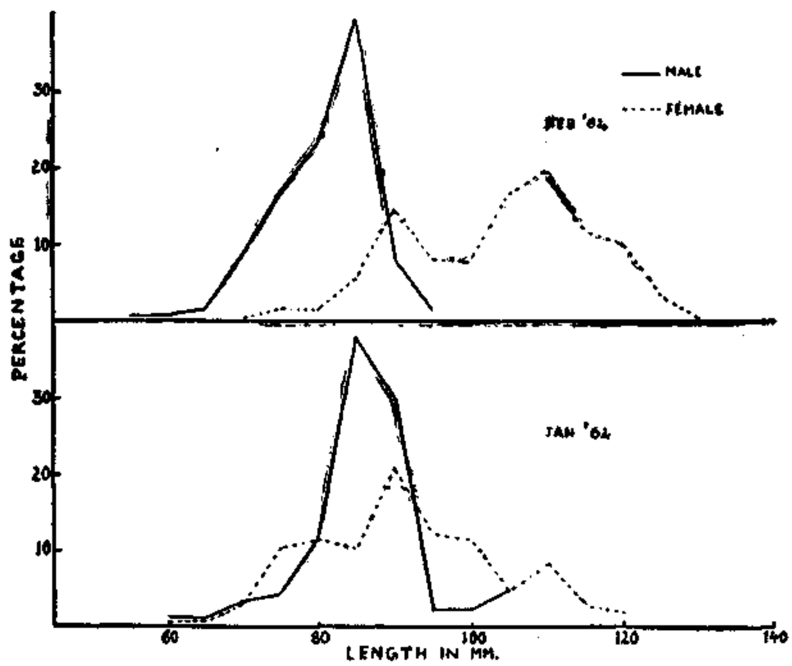

FIG. 7. Differential growth rate of sexes in *M. brevicornis.*

The percentage of males and females measuring 81–100 mm. and 101–120 mm. in the total numbers of each sex has been calculated separately for 1961–62 only and are presented in Table VI.

TABLE VI

Percentage of males and females in specified size groups of M. brevicornis

	81–100 mm.	101–120 mm.	Total number measured
	%	%	
Male ..	50·8	0·6	823
Female ..	42·1	30·9	1,120

The proportion of males in the 80–100 mm. size range is slightly higher than that of females. But in the 101–120 mm. group the proportion of females is markedly higher. Since the sizes chosen for both the sexes would almost entirely include the 2 and 3 year old groups respectively, it would appear that the proportion of males surviving in the fourth year of life is quite small.

Food

The examination of stomach content of *M. brevicornis* ranging in size from 40–110 mm. showed that the composition of food was similar to that of *M. kutchensis*. But vegetable matter and mud were less common.

Breeding and Migration

Males measuring over 70 mm. were found to have spermatophores. Mature females were very rare in the commercial catches. The smallest mature female that was captured measured 105 mm. This length is reached normally when the prawns are 3 year old. But it is difficult to conclude whether females mature only then, with the available data.

Impregnation was not noticed among individuals below 70 mm. The percentage of impregnation was highest during February–April ranging from 31–69% as against 1–12% during August to January. The majority of impregnated individuals belonged to 101–125 mm. groups. Mature females and spent ones, though rare, were obtained in the inshore catches only during March-April which appears to be the breeding period for this species. The species found in the east coast is reported to breed twice in a year (Rajyalakshmi, 1961).

M. brevicornis starts leaving the inshore waters early in March till they finally disappear in April. There appears to be some relationship between this fishery and the surface temperature of the coastal waters. The mean monthly temperature maximum (29·1–29·3° C.) was in June-July in this coast (Table VII). It was declining subsequently till the minimum was reached in January (16·5–17·7°C.). Coincident with the fall in temperature *M. brevicornis* commenced to appear in the inshore catches and the active period of the fishery was from November–February. When this species starts leaving the inshore waters early in March, the temperature was on the increase. It is therefore probable that the prawns migrate into the deep cooler waters for breeding.

As pointed out earlier *M. brevicornis* of sizes smaller than those in the sea occurs in the creek. It is likely that they are washed up by tidal action into the creeks rather than as a result of active migration since they were never caught in any significant quantities at any time of the year. Under the circumstances it can only be stated that the young ones live in the sea beyond the present fishing limits and that they migrate into the inshore waters when they are probably two year old.

TABLE VII

Mean monthly temperature (°C.) fluctuations at Kandla

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
1959–60	26·5	29·0	28·3	27·5	27·8	27·7	23·5	21·3	19·0	20·5	23·0	25·7
1960–61	27·8	29·0	29·3	28·9	28·1	27·3	23·4	19·2	17·7	18·9	24·3	25·6
1961–62	28·3	29·1	29·1	28·2	28·6	26·1	22·1	18·8	16·5	18·1	19·2	24·4

SUMMARY

This paper deals with the observations on the prawn fishery and some aspects of the bionomics of the two commercial species—*M. kutchensis* and *M. brevicornis*.

Based on the length frequency studies, the span of life and the lengths attained by the respective year groups have been estimated. The difference in the growth rates of the sexes is also elucidated. The sex ratio in the commercial fishery has been worked out and the percentage of males and females in specified sizes is calculated to show the extent of the survival of the sexes in the different age groups. The breeding and migratory habits are discussed.

The fishery for *M. kutchensis* and *M. brevicornis* is shown to be related to the rainfall and salinity and temperature of the coastal waters respectively.

ACKNOWLEDGEMENT

The author is thankful to Dr. S. Jones and Shri M. Krishna Menon for their interest in the work and to Shri K. H. Mohamed and Shri M. J. George for going through the manuscript. His thanks are due to Shri R. M. Dhawan for furnishing the hydrological data at Kandla. He is also thankful to the Directorate of Fisheries, Gujarat, for furnishing the data on fish landings of Kutch and for affording facilities in the field collections and to the local meteorological office for supplying the data on rainfall.

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THE FISHERY FOR DEEP SEA PRAWN IN NORWAY

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ABSTRACT

The deep sea prawn, *Pandalus borealis*, is a boreal species widely distributed on soft bottom areas along the coast of Norway and in the adjacent arctic water. The commercial fishery for deep sea prawns in Norway started originally in 1897 as a result of scientific marine research. In the subsequent decades substantial populations of prawns have been found in fjords and inlets along the coast as well as in off-shore areas. The commercial fishery for prawns spread slowly from south to north. Towards the end of the 1940's commercial fishing for prawn was carried on in the Arctic waters off northern Norway. The prawn fishery in many districts provides a vital substitute for failing cod and herring fisheries. Today, with about 12,000 tons of prawns landed, the fishery for deep sea prawns is the fourth most valuable commercial fishery in Norway.

Biological studies have systematically been carried out since the 1930's on the deep sea prawn. This species is a protandric hermaphrodite, *i.e.*, the prawns are males in the first period of life, and later change into females. In spite of an increasing fishery the deep sea prawn seems to be in no danger of overexploitation. There are apparently enough favourable breeding locations in areas which cannot be fished commercially, and which constitute a reservoir of prawns. There is no evidence that protection of the prawns in specific areas or seasons would be beneficial. The only protective measure enforced is a minimum mesh size of 30 mm. in the prawn trawl. This is in order to protect the small youngs which will escape through the meshes of the trawl.

NORWAY is a long and narrow country facing the North Atlantic Ocean. Its coast stretches from 58 degrees N. Lat. to 71 degrees N. Lat. Many deep narrow inlets, called "Fjords", cut into the country, and off the coast are found numerous islands, skerries and submarine rocks forming a barrier against the onslaught of the heavy ocean swell and the hard winter storms.

Many species of shrimps are found along the coast, but the only one being of commercial value is the deep sea prawn, *Pandalus borealis*. This species is only found in the northern part of the Atlantic and in quantities also in the northern part of the Pacific Ocean. The habitat of the deep sea prawn is the cool water of the deep parts of the ocean, and only few prawns of this species are found in shallow areas. Commercially it is fished for in depths between 30 and 300 fathoms. Experimental fishing has proved that the deep sea prawn also can be quite numerous in 500 fathoms of water. This prawn seems to prefer areas where the bottom temperature is 3–8° C. It is very sensitive to rapid changes in temperature even in this temperature interval. If for instance colder water suddenly covers the bottom the prawns will flee such surroundings temporarily but gradually return as they became acclimatized.

In the deep submarine valleys off the Norwegian coast, and in the fjords and inlets we find localities where a commercial fishery for deep prawns has developed. The shrimps live on soft and muddy bottom which most often is found in submarine valleys or in deep depressions on the off-shore banks.

The deep sea prawn is a protandric hermaphrodite. The prawns are all males during the first part of life, but later they change their sex and become females, a state which last for the rest of their life. The deep sea prawn spawn in late autumn, the females becoming berried usually during the month of October. Just before spawning the females cast off their old chitinous shell, so that they are in a soft-shelled stage while spawning. In this period the deep sea prawns often leave the soft bottom area and migrate into stony and uneven parts of the sea bed nearby. The probable reason for this migration is to find protection as long as they are soft-shelled and vulnerable to their enemies. The commercial catch of large prawns in this period will decrease, and the prawn ground is temporarily dominated by the small-size prawns. A similar off-season in the prawn fishery also occur in spring when the prawn eggs are hatched. Also now the females cast off their old shell and become soft-shelled. The eggs hatch in March-April. The larvae of the deep sea prawn drift with the ocean currents for about three months before they settle on the bottom. This means that the prawns produced in one area for a great deal is carried away by the currents and will settle in other areas.

Our investigations of the deep sea prawn in Norway have shown that the rate of growth and the age of the prawns upon spawning can vary greatly from one area to another. In Norway the prawn populations in the various fjords can be considered as separate biological units. We have found that generally fjord populations of the deep sea prawn often have a slower growth and reach sexual maturity at a higher age than in the open ocean. Apparently it is the temperature in the sea which is the chief factor determining the variations in growth and sexual maturity. A fishing ground with a population of slow-growing prawns cannot stand the same fishing intensity as an area with a population of fast-growing prawns. The prawn grounds in the open ocean off the coast show less variation in regard to growth and maturing. Due to the influence of the Gulf stream which runs northwards along the Norwegian coast the temperature on the off-shore prawn grounds is more uniform than what is the case in the fjords.

The fishery for deep sea prawns in Norway started originally as a result of scientific research. In 1897 professor Johan Hjort at the Oslo University carried out marine biological investigations in the Oslo Fjord in southern Norway. While sampling the bottom fauna he found a relatively rich population of deep sea prawns in the deepest parts of the fjord, and he recommended that a commercial fishery should be tried. Already the following year experimental trawling with small sailing vessels were carried out in some fjords with a primitive trawling gear. The experiment proved successful and in 1899 ten vessels were engaged in the prawn fishery on a commercial basis. From this small local fishery a new fishing industry subsequently grew up. Today prawn trawling is one of the most important fisheries in Norway. From this small beginning in Southern Norway the prawn trawling gradually spread to other parts of the coast. In the 1920'ies and 1930'ies the prawn trawling was mainly carried out in the fjords and inlets, but gradually extensive prawn grounds were also located in the open ocean. This led to the development of an extensive deep sea fishery with large motor vessels.

During World War II the high sea fishery became strongly reduced, but after the war the expansion in prawn trawling continued. This expansion must be regarded on the background of the technical development in trawl and winch construction, and the introduction of electronic instruments. Particularly the echo sounder proved of great value to the fisherman. With the echo sounder they were able to chart the soft-bottom areas where prawns would be found and where the configuration of the bottom would allow trawling. The deep sea prawn was also in increasing demand on high price export markets.

During the years before World War II it was mainly the fishermen in Southern Norway who were interested in the prawn fishery. After the war also the fishermen in Northern Norway became conscious of the possibilities in prawn fishing. Today these northern grounds bordering on the Arctic Ocean and situated between 70 and 71 degrees North Latitude, have a prawn fishery which in quantity can compete with southern Norway.

The quantity of deep sea prawns landed in Norway increased from about 2,000 tons in 1946 to approximately 12,000 tons in 1963 (*see* Fig. 1). Also the price of the prawns increased on an expanding export market. The prawn trawling today is a valuable fishery particularly for the small boat fleet in Norway. The value of the deep sea prawn landed can today compete with that of some of our great historic fisheries for cod and herring.

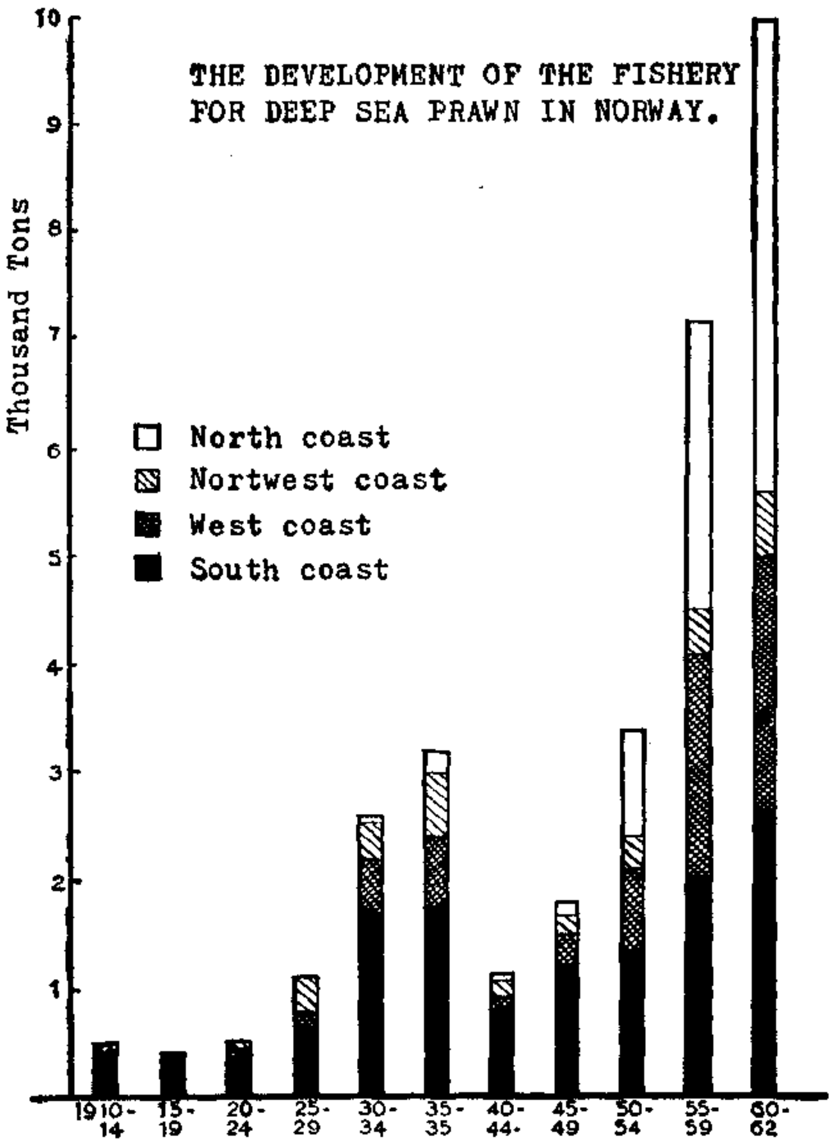

FIG. 1. The development of the fishery for deep sea prawn in Norway.

Trawling for prawns needs only a relatively small expenditure on boats and gear, and gives a fair economic compensation to the fishermen. The search for and mapping of new prawn grounds is still going on. This work is partly carried out by the fishery advisers of the Fishery Directorate and partly by the fishermen themselves. The finding of a new prawn ground can often be of great importance both to the fishermen and to the districts where the fishing boats belong. As an example may be mentioned the discovery of a large prawn ground in the open ocean off Southern Norway in 1954. This discovery resulted in a marked expansion of the prawn fishery and strongly increased landings on this part of the coast. Previously the fishermen here had been dependent upon the herring fishery which had been failing for a number of years. The development of such prawn fisheries in the open ocean has continued till today. A single county in Southern Norway may today have 2-300 vessels engaged in prawn fishing all the year around. A similar tendency to develop an all year round prawn fishery we find also in Northern Norway.

The expanding prawn fishery does not only give an increasing profit to the fishermen, but also provides a livelihood for thousands of people ashore which process and export the prawns. The majority of the prawns are peeled and thereafter partly canned and partly frozen for export. Large quantities are also cooked and marketed with the shell without beheading. These prawns are first sorted in various size categories onboard the vessel. The large size prawns are then cooked on board immediately after capture, and landed for home consumption or for export to European countries.

Many of the prawn fishermen have expressed their fear that the intense prawn fishery going on today will result in overfishing of the prawn stock, and various protective measures are proposed. They have for instance recommended that the berried females should be protected on the supposition that the prawn youngs would settle to the bottom in their district and thus increase the local stock. Such a measure would result in a closure of the prawn fishing for about six months of the year. Our investigations on the biology of the deep sea prawn have shown that a local protection of a prawn ground inshore or in the open ocean will have now significance for the protection or the increase of the local prawn population. The protection of the berried prawns in one area will probably benefit the fishery in quite another area. The reason for this is that the newly hatched larvae resulting from the protected females will drift pelagically with the currents for a period about three months and thus become distributed over a large area.

After the eggs of a female have been hatched the mother prawn has also reached the end of its life. After producing their youngs they are decimated rapidly through natural mortality. It must also be taken into consideration that deep sea prawn are protandric hermaphrodites. The small male prawns will during the winter change their sex into females, and thus constitute a new stock of spawning females the next season.

The deep sea prawns are found along the whole Norwegian coast where there are areas of soft clay or mud bottom. Besides the ordinary trawl grounds there are thousands of small spots with soft bottom which cannot be fished at all. In these numerous small areas the prawns spawn without being disturbed. Such spots therefore constitute reservoirs which ensures a steady influx of prawns to the larger fishing grounds. The whole biological picture of the deep sea prawn does not support the idea of any serious overfishing of this species. As an example that this holds true we may consider the prawn grounds in the Oslo Fjord where the prawn trawling originally started. The fjord has a shallow threshold at the entrance so that the prawn grounds largely constitute a closed area. The prawns here have been heavily fished for 65 years continuously, but even today it gives a normal production of deep sea prawns without any sign of overfishing.

In Norway we have nevertheless introduced measures to avoid needless fishing of very small prawns. A regulation imposes a minimum mesh size in the prawn trawl in order to protect the young small individuals which have no sales value. An enforced minimum mesh size of 30 mm. in any part of the trawl allows the small prawns to escape through the meshes. The escaping prawns will in relatively short time grow to a marketable size and then give a satisfactory economic yield to the fishermen.

As mentioned before the deep sea prawn is a boreal species preferring relatively cold surroundings. In this respect Norway bordering on the North Atlantic and the Arctic Ocean has a strategic position for the utilization and exploitation of this resource. But at the same time this key geographical position imposes an obligation on Norway to follow closely the development of the fishery and to consider and enforce protective measures for the prawn stock which in the long run will give the maximum sustainable yield.

DISCUSSION

Dr. C. V. Kurian: What is the size of these prawns in the commercial fishery and what type of sea bottom they prefer ?

Dr. B. Rasmussen: The size of the prawns in the commercizal fishery is within 80–120 mm. The prawns are found in muddy substratum or a bottom of fairly fine sand with clay.

A SUMMARY OF KNOWLEDGE OF SHRIMPS OF THE GENUS *PENAEUS* AND THE SHRIMP FISHERY IN MISSISSIPPI WATERS

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ABSTRACT

The shrimp fishery is based completely on species of Penaeidae. Landings in Mississippi ports showed a relatively steady increase from 1887 until 1937 when landings reached 23·6 million pounds of heads- off shrimp (37·8 million pounds heads on). Several major fluctuations occurred during this period. A trend of decreasing landings followed, reaching a low of 4·4 million pounds in 1961, as boats landed their catches elsewhere, and the total population declined.

Browns (*Penaeus aztecus*), pinks (*P. duorarum*) and whites (*P. fluviatilis*) have contributed most of the annual catch in recent years. In former years, roughly before 1950, only white shrimp were caught. Sea-bobs (*Xiphopeneus kroyeri*) have been caught in comparatively small quantities throughout the years. Royal reds (*Hymenopenaeus robustus*), from deep water, have been listed with sea-bobs in statistical publications since September 1962. *Sicyonia* spp. and *Trachypeneus* spp. occur in Mississippi waters, but the commercial catch is negligible. There has been a decrease in the numbers of white shrimp both in total catch and as a percentage of the catch, and a real population decline seems to have occurred in this species.

Analysis of the catch in Mississippi waters for the period 1959 through 1963 by area, species, size and seasonal abundance has been made. Catch per unit of effort generally showed a positive relation with the total catch.

Studies of postlarvae in Mississippi Sound in 1963 and 1964 revealed annual fluctuations in abundance and mortality. Seasonal succession of abundance of the three chief species was observed. Survival and growth were apparently affected by salinity and temperature. Prediction of the availability to the commercial fishery on the basis of postlarval abundance required consideration of mortality in the succeeding juvenile population.

Legislation permitted opening of the commercial shrimping season on the basis of biological information, rather than a set season, and this method of fishery administration seems to be advantageous.

INTRODUCTION

SHRIMP caught in State of Mississippi waters include all three major species in the Gulf of Mexico catch, the white shrimp, *Penaeus fluviatilis*, the brown shrimp, *P. aztecus*, and the pink shrimp *P. duorarum*.

Territorial waters along the Mississippi Gulf Coast cover about 900 square miles with maximum depths of about four fathoms. Shallow open water between the barrier islands covers about half of the coastline distance. Narrow, deep passes are located at the west end of the three off-shore islands, Petit Bois, Horn, and Ship. Depth over the soft mud bottom found in most of the Sound is generally two fathoms and less and does not exceed three fathoms except in very small areas. The average depth is 10·3 feet.

Pascagoula River at the east and Pearl River near the west end of the Sound bring in quantities of freshwater and nutrients into these estuarine waters. The Bay of St. Louis receives the flow of the Jordan and Wolf-Rivers and the Biloxi and Tchouticabouffa rivers enter the Bay of Biloxi, which are tributary to the Sound. Numerous bayous with smaller drainage areas and marshes add to the nursery area. The general environment of the inner salt waters and the off-shore islands has been described by Moore (1961), Priddy and Smith (1960) and Richmond (1962).

An extension of the eastern border of the state passes south about 23 nautical miles east of Louisiana's Chandeleur Islands and reaches the fifty fathom curve about thirty-three miles east of North Pass in the Mississippi River Delta at a point approximately fifty-seven miles south of Petit Bois Island. In Fig. 1 the two inner areas, 012·1 and 011·1, cover Mississippi Sound.

Area catch statistics are not available for years before 1956 but landings at Mississippi ports show large periodic fluctuations. The first catch statistics, for 1887, show 1·1 million pounds for the state. Four years later the catch was 0·6 million pounds. After 1890 there was a relatively steady increase to 23·6 million pounds in 1937. During this forty-seven year period the only major decrease occurred in 1930, a depression year. Decreasing landings after 1937 reached a low for the twentieth century in 1949 when the catch was 2·8 million pounds. Up to this time only the white shrimp, *Penaeus fluviatilis*, was commonly taken in commercial catches. Decrease in the white shrimp catch led to expanded night and deeper water fishing for the pink shrimp, *Penaeus duorarum*, and the brown shrimp, *P. aztecus*. Six years later landings had increased to 13·6 million pounds. Decreases followed in 1956, 1957 and 1958. Catches of 11·3 and 11·0 million pounds in 1959 and 1960, respectively, dropped to 4·4 million in 1961, the lowest since 1908 except for 1958 and 1949. Better catches were taken in the next two years but 1964 landings may be lower than those for 1963. These statistics are taken from various reports of the United States Fish and Wildlife Service and its predecessors. In recent years catch statistics have been collected in collaboration with the Mississippi Marine Conservation Commission.

Early catches were made by cast-nets, in small part, and mostly by haul seines up to 1,000 fathoms long. The otter trawl was introduced in 1918–20, and now all fishing is by trawl, although the haul seines persisted until the early 1930's. Boats and gear have increased tremendously in size.

Sea-bobs (*Xiphopeneus kröyeri*) have been caught in comparatively small quantities throughout the years. Royal reds (*Hymenopenaeus robustus*), from deep water, have been listed with sea-bobs in statistical publications since September 1962. *Sicyonia* spp. and *Trachypeneus* spp. occur in Mississippi waters, but the commercial catch is negligible.

Detailed biological studies of shrimp in Mississippi waters were not undertaken until late in 1962 when a study of post-larvae was started at the Gulf Coast Research Laboratory under contract with the U.S. Fish and Wildlife Service. Life-history and other information applying generally to commercial species of *Penaeus* in the Gulf of Mexico are applicable. "Gulf Coast Shrimp Data" collected by the U.S. Fish and Wildlife Service since 1956 supplies considerable pertinent data.

In general what has been referred to as the estuarine life-history (*cf.* Gunter, in press) is characteristic of the commercial penaeids of the United States Gulf coast. The adults spawn at sea and the larvae make their way inshore to the low salinity bays where they raise and return to the sea as they grow up. The larvae undergo some twelve to fourteen moults, passing through nauplius, protozoea, mysis and postmysis stages. The larval stages are quite complicated and they are very similar for the commercial and several non-commercial penaeids. They are not precisely known for any one species. It is clear, however, that after the postlarval shrimp enter the bays they grow extremely rapidly, which was discovered by Viosca (1920) but had to be rediscovered again (Gunter, 1950) before the fact was widely recognized. The growth rate in summer ranges from 0·5–1·7 mm. a day in length. Increase in weight is extremely rapid and where no shrimp are to be found at all, because they are too small and are often far back in the shallows, they suddenly appear in commercial quantities and sizes. Then the fishery begins and the shrimp move out to sea.

Practically all of the white shrimp die after the end of spawning in the first year of their life. While a few live into the second year, the species is to all intents and purposes a one year animal. The pink and the brown shrimp are certainly short-lived, although the details of their life-history are not so well known.

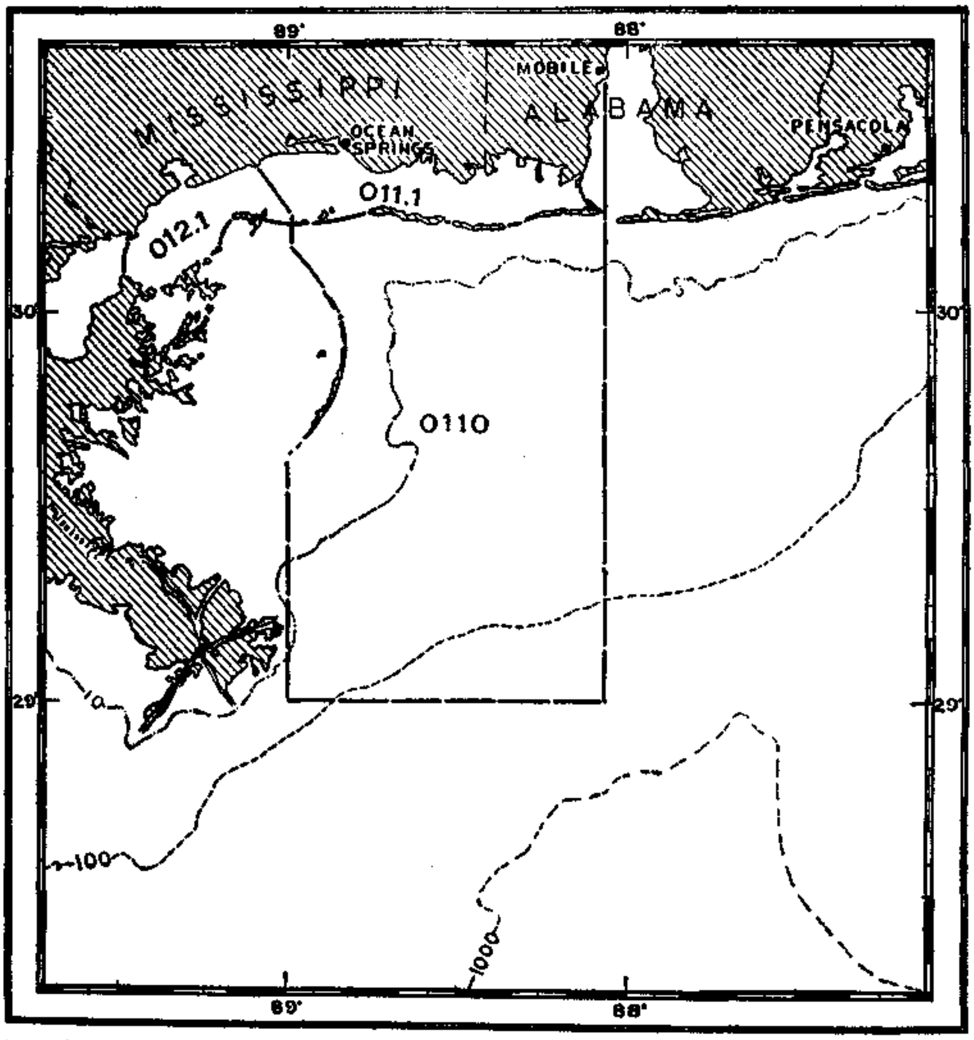

FIG. 1. Areas for the collection of statistics on shrimp catches. The upper two figures cover Mississippi Sound and the third figure is for the off-shore region which includes all of Mississippi waters and part of those of Louisiana.

SPECIFIC COMPOSITION OF THE CATCH

Statistical areas 011·1, Mobile Bay to Gulfport ship channel, and 012·1, Gulfport ship channel to Lake Borgne, cover Mississippi Sound. Although portions of these areas at the east and west ends are in Alabama and Louisiana, respectively, catches in these areas give the best description of catches in Mississippi's inland waters. Area 0110 extends from the barrier islands into the Gulf between the western edge of Mobile Bay and the Chandeleur Islands. This includes Gulf waters off the Mississippi coast. These areas are shown in Fig. 1.

Variation in the species composition, catch per unit of effort and total catch for these areas are shown in Table I. The percentage of white shrimp is greater in the western portion of Mississippi Sound than it is in the eastern area. The western portion is lower in salinity, and white shrimp prefer lower salinity than the other penaeids. Both show a greater proportion of whites than off-shore waters. The low year, 1961, shows the lowest percentage of white shrimp in all three areas. The catch per unit of effort in off-shore waters is, except in 1961, much greater than that in inshore areas. However, the figures are not directly comparable because double rigs are not allowed to fish in the Sound, but they are employed off-shore. A double rig is a two trawl outfit, one on each side of a boat. Two trawls 30 feet in wingspread catch considerably more shrimp than one large trawl 60 feet wide.

TABLE I

Catch by area and species with annual catch per unit of effort, 1959–63.
(From *U.S. Fish and Wildlife Service Statistics*)

	Brown		Pink		White		Total thousand pounds	Pounds per 24 hr. day
	Thousand pounds	%	Thousand pounds	%	Thousand pounds	%		
				Area 011·1				
1959	1,627	78·5	22	1·0	424	20·5	2,072	540·7
1960	1,399	82·9	20	1·2	268	15·9	1,688	454·3
1961	625	88·3	43	6·1	40	5·6	708	252·4
1962	818	84·2	18	1·9	136	13·9	971	487·4
1963	897	91·3	10	1·0	76	7·7	982	934·6
Total ..	5,366	83·6	113	1·8	944	14·6	6,421	..
				Area 012·1				
1959	761	75·9	9	0·9	233	23·2	1,003	494·7
1960	540	64·9	..	..	292	35·1	832	387·5
1961	194	82·6	..	..	41	17·3	234	256·0
1962	256	68·6	1	0·3	116	31·1	373	332·0
1963	194	47·0	..	..	218	53·0	412	736·0
Total ..	1,945	68·1	10	0·4	900	31·5	2,854	..
				Area 011·0				
1959	7,433	39·4	132	1·6	752	9·0	8,317	097·9
1960	6,468	91·6	45	0·6	550	7·8	7,064	848·0
1961	2,759	90·2	140	4·6	159	5·2	3,059	265·0
1962	2,831	77·4	6	0·2	821	22·4	3,658	513·2
1963	5,276	81·5	176	2·7	1,018	15·8	6,470	577·8
Total ..	24,767	86·7	499	1·7	3,300	11·6	28,568	..

Pink shrimp furnish a small but significant part of the catch in the Eastern Sound and off-shore waters. Very few are caught in the Western Sound area, which lies closest to the great freshwater flow of the Mississippi River. Gunter, Christmas and Killebrew (1964) have shown that in order of their preference for saline waters the three commercial species of Mississippi are pink shrimp, brown shrimp and white shrimp. In area 011·1, pink shrimp are taken in the spring, March through June, in a limited area south of the intracoastal waterway. The period varies from year to year, and, since catch per unit of effort is usually small, the total catch is probably controlled to a considerable extent by price.

Growth Rate

Growth rate of shrimp in Mississippi waters has not been studied in detail. Available information shows that rapid growth occurs only after water temperature rises to 20° C. Sub-adults in the estuary probably grow more rapidly than off-shore stocks. The best estimate of average growth is about 1·5 mm. per day in total length.

Spawning

Spawning undoubtedly occurs in off-shore waters. Ripe females are not ordinarily found in Sound waters and there are no records of larvae. Pink shrimp dominate the catch of post-larvae late in the fall, brown shrimp are most abundant in the spring months, and white shrimp in the early summer, indicating separate spawning peaks. In some years a second wave of browns occurs in the late summer months.

Larval and Postlarval Recruitment

There is no evidence that larval forms enter Mississippi Sound. Postlarvae with a minimum of three dorsal rostral teeth come through the passes between the islands and generally continue, without stopping, to shallow inshore estuaries. In contrast, pink shrimp postlarvae are more likely to inhabit Sound waters along the barrier islands.

The two year study of postlarvae has shown considerable annual variation in the time of first appearance, their development through postlarval stages and mortality.

Brown shrimp postlarvae appear in February or March, reach peak numbers six to eight weeks later and continue in the catch until fall. A second wave may occur in August and September.

Postlarval brown shrimp taken in the spring are significantly larger than those taken at the same stage later in the year.

White shrimp postlarvae, distinctly smaller than browns at comparable developmental stages in the spring but not separable from browns by size in summer and fall, reach inshore waters in late May or early June. Maximum recruitment occurs in June or July and may increase again in August and September.

Pink shrimp, though not abundant, may dominate the catch in October or November.

Distribution of Juveniles

Little is known about the movement of juveniles and sub-adults through the nursery grounds and into off-shore waters. In the last week of May 1964 juveniles in areas of Biloxi Bay which would be open to commercial fishing, had a range in total length of 24–90 mm. with a mean at 55 mm. Comparable size in this area is reached much earlier in some years.

In off-shore waters inside the ten fathom curve there is considerable annual variation in the dominant size in the commercial catch in June and July.

White shrimp reach larger sizes than other species in the bays. Large populations of both white and brown shrimp juveniles are sometimes found in inshore waters until late November. Their fate is unknown. A small catch of large whites is taken from the Sound in May and June.

OFF-SHORE MIGRATORY PATTERN

There is no evidence of extensive along shore migrations of shrimp off the Mississippi coast. Large white shrimp tend to concentrate to the southward near the mouth of the Mississippi River in the winter.

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DEEP SEA PRAWN (*PANDALUS BOREALIS* KR.) IN GREENLAND WATERS: BIOLOGY AND FISHERY

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ABSTRACT

The fishery on deep sea prawns at Greenland was started in 1935, and in the latest years this fishery has increased very much. The development of the fishery after World War II is the result of extensive investigations carried out by Greenland Fisheries Investigations.

The prawns are fished by means of otter trawls from small cutters (15–30 tons) in fjords and coastal areas in depths between 250 and 400 m. where the bottom is soft and even, and the water temperatures are positive (mostly 1–2° C.).

The biology of the species, which is protandric hermaphrodite, has been studied closely. Occurrence, growth, development and reproduction are influenced by water temperature. Seasonal variation in water temperature may cause variations in the yield of the fishery, as higher temperatures give better catches. Extremely low temperatures (below 1·6° C.) have a mortal effect.

Fisheries investigations have shown that overfishing is hardly an actual problem. The trawling grounds are connected with immense areas where deep sea prawns are living but where trawling is prohibited because of the bottom conditions.

INTRODUCTION

IN 1935 a prawn fishery was started in a small scale in two fjords at the town Holsteinsborg. After World War II the leader of Greenland Fisheries Investigations, Dr. Paul M. Hansen, initiated systematic investigations of deep sea prawns in West Greenland inshore waters, and these investigations resulted in the discovery of extensive prawn grounds in the southernmost fjords and in Disko Bay. An important prawn fishery has developed in the last 15 years, and to-day industries are established in seven towns at the west coast (Jakobshavn, Christianshåb, Godhavn, Egedesminde, Holsteinsborg, Sukkertoppen, Narssaq). The development of the fishery is seen from Table I, which shows the total landings (metric tons) for all the years in which prawn fishery has been carried out.

OCCURRENCE OF THE SPECIES

The deep sea prawn is arctic-boreal with a discontinuous distribution, since it has a distribution area in the northern Atlantic Ocean and another in the northern Pacific Ocean. It is widely distributed at West Greenland, where it occurs as far north as Melville Bay, and at East Greenland it occurs at least up to Angmagssalik District. It mainly occurs in depths between 200 and 500 m. where the bottom is muddy, and the water temperatures are positive (mostly 1–2° C.) due to a deep warm layer of Atlantic water. The species requires rather high salinity, as a rule between 33 and 35‰ (Hjort and Rud, 1938).

THE PRAWN GROUNDS

The trawling grounds are limited to areas where the bottom is even without stones and rocks, which may spoil the fishing gears, These grounds were found by means of a Hughes echo sounder,

TABLE I

Yield of the Greenland prawn fishery in metric tons landed

Year	Tons	Year	Tons
1935	8	1953	313
1936	26	1954	388
1937	59	1955	566
1938	54	1956	527
1939	71	1957	671
1947	42	1958	742
1948	54	1959	949
1949	25	1960	1,789
1950	175	1961	2,545
1951	124	1962	3;362
1952	228	1963	3,108

which, in addition to recording the depths and contours of the bottom, gave information whether the bottom was soft or hard. As a rule, the grounds which are suitable for fishery were found on depths between 250 and 400 m. Fig. 1 shows the known grounds suitable for commercial trawling. The most important grounds are those in Disko Bay (1, 2 and 3 in Fig. 1), at Holsteinsborg (4 and 5) and in the southernmost districts (10, 11, 12 and 13).

On the prawn grounds the invertebrate fauna over the bottom (nekto-benthos) is absolutely dominated by *Pandalus borealis*, and among the fishes the most numerous are generally Greenland halibut [(*Reinhardtins hippooglossoides* (Walb.)], redfish (*Sebastes marinus* L.) and various species of Lycodes.

BIOLOGY OF THE PRAWN

The biological investigations were made on samples from experimental and commercial fishery, and the material was, in principle, sorted and measured according to the method described by Rasmussen (1953).

(1) *Reproduction and recruitment*

As known from literature (Berkley, 1930; Leopoldseder, 1934; Jägersten, 1936) *Pandalus borealis* is a protandric species. In Greenland waters the females spawn in summer, mainly in August, and the eggs adhere to the pleopods for 8–9 months until hatching next spring, mainly in April. The ovigerous period corresponds to what Rasmussen (*loc. cit.*) found at Spitsbergen, while the ovigerous period, according to the same author, is only about 5 months at southern Norway (in Skagerak).

(2) *Growth, development and mortality*

Some variation in growth and development time has been found as the slovest development (sex reversal in 5 year olds) was found in Disko Bay and in some threshold fjords with cold bottom water, while the fastest development (sex reversal in 4 year olds) was found in the warm fjords more

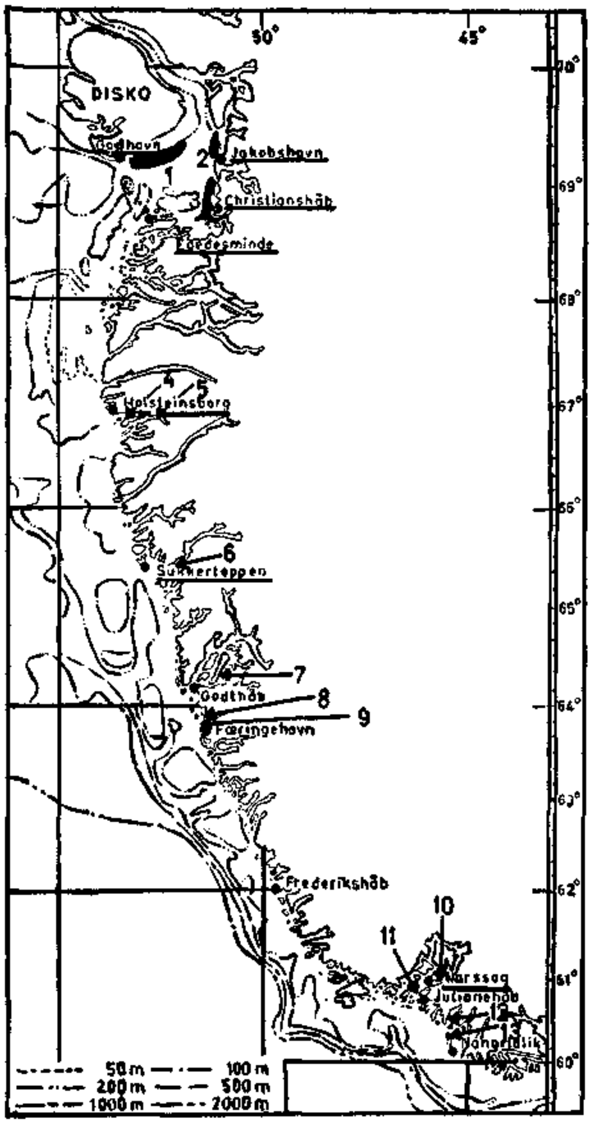

FIG. 1.

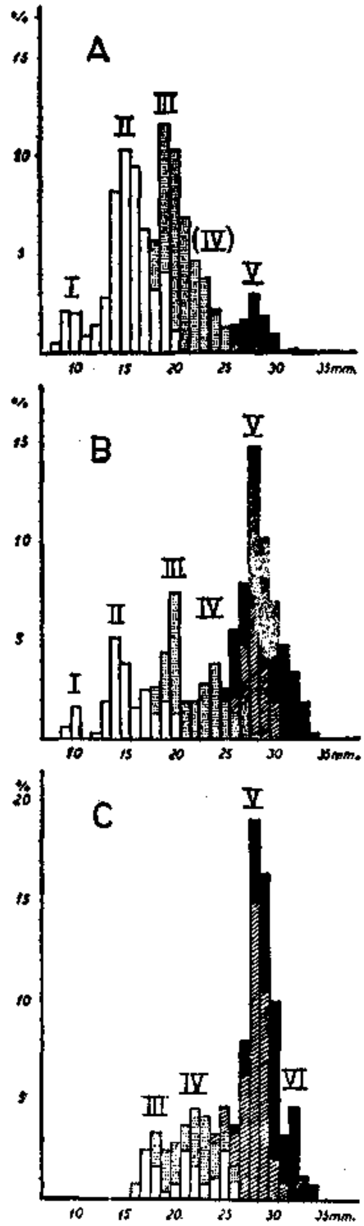

FIG. 2.

FIG. 1. Map showing trawling grounds which are now (1, 2, 3, 4, 5, 6, 10, 11, 13) or may be (7, 8, 9) exploited. Grounds in Disko Bay shown in extension grounds in the fjords only by an arrow. Towns with prawn industries are underlined.

FIG. 2. Diagrams showing year-classes (I–VI) in three samples from the Disko Bay. (A) Near land off Christianshab, depth 325 m., no. of individuals 760, August 1948. (B) Northern part of field 2, depth 450 m, no. of individuals 317, August 1948. (C) Centre of Disko Bay (outside grounds shown on map), depth abt. 500 m., no. of individuals 239, July 1950. The columns indicate number of individuals of different sizes (length of carapace measured from the base of the eye to the posteror lateral edge) in per cent. of the samples. White columns: young and males. Dotted columns: mature males. Hatched columns: transitionals (functioning as females). Black columns: females.

southerly. The development time, however, is not always constant within a particular area because a warm year can advance the development and a cold year can retard it. According to Rasmussen (*loc. cit.*) the development times at Greenland are the same as at Spitsbergen and Jan Mayen, while a far more rapid development is found in more southern and warmer waters as in the Skagerak, where sex reversal occur among 2-year olds.

The cause of the shorter or longer development cannot be the water temperatures alone as the longest development is found in Disko Bay where the temperature conditions are particularly favourable. Here, it must be assumed, is the long unproductive winter decisive. In Table II the total lengths (in m.m., from the point of the rostrum to the point of the telson) of different age groups in Disko Bay and in the fjord Tunugdliarfik (10 in Fig. 1) are compared.

TABLE II

Age group ..	I	II	III	IV	V
	mm.	mm.	mm.	mm.	mm.
Disko Bay (Aug. 1948) ..	45	64	90	110	130
Tunugdliarfik (July 1947) ..	46	74	97	120	138

The life-history of the prawns is illustrated by Fig. 2, which shows that smaller prawns predominate on shallower depths and near land (A) while the biggest prawns are most numerous in deeper water away from land as in the centre of Disko Bay (C). In the samples the smaller prawns are underrepresented because of gear selectivity, but the great decline in numbers of individuals more than 5 years old—also in areas where no fishery takes place—indicate a great natural mortality (Fig. 2, C). It ought to be said that the conditions illustrated by Fig. 2 are confirmed by a great number of other samples from different years.

(3) *Predators*

The above mentioned great mortality must be due to numerous predators as the prawns play a great part as food for many bottom fishes, first of all Greenland halibut (*Reiuhardtius hippoglossoides*), but also for various species of Lycodes. In the winter when the cod (*Cadus morhua*) lives in deep water it also finds an important part of its food in prawns.

(4) *Food*

The prawns get a considerable part of their food from the bottom (polychaets, foraminifera, etc.), but a very significant part is taken up in the water, as remains of pelagic crustaceans (Boreomysis, young prawns, copepods) and other pelagic organisms are found in their stomachs.

(5) *Effects of water temperatures*

The temperature of the water has a noticeable effect on the stocks as the species lives here near its northern limit of geographical distribution. Areas having constantly warm bottom water give a stable prawn fishery, whereas instability in temperature results in fluctuations in the occurrence of prawns and consequently in the output of the prawn fishery.

Stable temperature conditions are found in the Disko Bay, where the prawn stock, which is by far the richest at Greenland, must also be assumed to be the most secure. In the fjords the temperature conditions are more unstable, and as a particularly enlightning example we had the killing off of the prawn stocks in two fjords at Holsteinsborg (4 and 5 in Fig. 1) caused by cold water in the severe winter 1948/49, and after that catastrophe it took 4–5 years before the prawn stocks recovered. From Table III it is seen that, compared with other years, the temperature was extremely low in 1949, and judging from this and from observations made on other grounds, the lowest temperature, which the prawn stocks can tolerate, seems to lie near or a little below $-1\cdot6°$ C.

TABLE III

Temperatures in 300 m. depth in different years in the months May–August (inclusive) in the fjord Amerdloq (4 in Fig. 1)

Year ..	1909	1934	1935	1936	1937	1938	1939	1947	1949	1950	1951
°C. ..	1·0	1·4	1·4	0·9	1·0	−0·9	0·7	2·5	−1·6	0·0	0·9
Year ..	1952	1953	1954	1955	1956	1957	1958	1960	1961	1962	
°C. ..	1·0	1·8	−0·2	1·0	2·7	0·8	1·2	1·4	0·3	1·8	

Seasonal variations in bottom temperatures may cause variations in the yield of the prawn fishery as shown by Horsted (Horsted and Smidt, 1956; Horsted, 1960) in the fjord Tunugdliarfic (10 in Fig. 1). Intrusion of warm bottom water at the end of December is followed by increasing yields in the fishery. In two observation periods it was seen that the water temperature in 285 m. depth culminated in January–February to 2·5°–2·8° C. and then decreased to 1·0–1·5° C. in May and the following months. The fluctuations in the output followed the temperature, increasing in January–February, culminating in March to an average of about 70–80 kg. prawns per hour's trawling, and then decreasing to only 10–20 kg. in May. It is probable that the prawns follow the warm bottom water into the fjord as tagging experiments (Horsted, 1960) have shown that prawns can migrate from the outer part of the fjord to the inner part.

In localities with permanently cold bottom water, such as the threshold fjords, or in shallower areas (about 150 m. depth), where the effect of wintercooled water from the surface may be felt in a part of the year, *Pandalus borealis* disappears or becomes less numerous. In such localities it is, to a greater or lesser extent, replaced by *Spirontocaris machilenta* and *Nectocrangon lar*.

FISHERY AND FISHERIES INVESTIGATIONS

The prawn fishery is much influenced of the ice conditions. In Disko Bay and the fjords at Holsteinsborg (1–5 in Fig, 1) it is impeded in the winter because of ice cover. Normally the fishery there starts in May (in some years in April) and stops in November, and only exceptionally—in mild winters—it may have a longer duration. In the southernmost fjords at Narssaq (10 and 11 in Fig. 1) the best fishing season is in the period January–April, as mentioned above. Later in the year, when the prawns become scarce there, the fishing vessels move to other places, especially Lichtenau fjord (12 in Fig. 1), and at that time, mainly in May–June, pack ice (called "Storis") coming from the east coast with the Polar Current may in some years impede the transport of the catches to the factory in Narssaq.

The fishing vessels used in the Greenland prawn fishery are cutters of most by 20–30 tons, which have an engine of about 60 H.P. The gear used is an otter-trawl with a mesh size in the codend of about 40 mm.

On the rich grounds in the Disko Bay catches of about 100 kg. per hour's trawling are common. In the latest years the fishery there has been intensified very much, and in the summer 1964 about 60 cutters were engaged in that fishery. Therefore, in the summers of 1963 and 1964 fisheries investigations were carried out in the Disko Bay in order to find out whether the prawn stock there is able to bear the increased rate of exploitation. These investigations include: (1) Fishing experiments with trawls of different mesh sizes. (2) Tagging experiments. Plastic tags of different types were fixed around the prawns between carapace and the first abdominal segment. (3) Sampling of material for size measurements. (4) Hydrographic observations. (5) In addition to the trawling experiments in the Disko Bay some trawling experiments were carried out in the Davis Strait west of the Disko Bay.

Even if the investigations have not yet been finished it may be said that there seems to be no actual risk of overfishing in the Disko Bay. The trawling grounds here are in connection with great areas with prawns, where trawling is difficult or impossible because of the bottom conditions, but from where the trawling grounds can easily be recruited. In the summer of 1964 the research cutter in Disko Bay got catches which were as big as before the fishery started in 1950 (between 100 and 200 kg. prawns per hour's trawling). Outside the Disko Bay in the Davis Strait populations were discovered, which must be regarded as a valuable reserve.

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DISCUSSION

Dr. A. L. Rice: Which are the nursery grounds for these prawns?

Dr. V. Hansen: The exploited population was recruited from the western oceanic grounds.

Dr. A. L. R.: How these prawns are processed?

Dr. V. Hansen: By deep freezing and also by boiling.

DEVELOPMENT OF A COMMERCIAL FISHERY FOR THE PENAEID SHRIMP *HYMENOPENAEUS ROBUSTUS* SMITH ON THE CONTINENTAL SLOPE OF THE SOUTHEASTERN UNITED STATES

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ABSTRACT

In the early 1950's, the U.S. Bureau of Commercial Fisheries vessel OREGON found large concentrations of royal-red shrimp, *Hymenopenaeus robustus*, in the northern Gulf of Mexico on the continental slope off the Mississippi River Delta. This finding was one result of a long-term series of explorations for resources of commercial worth that began on the continental shelf of the northern Gulf and has since encompassed the shelf and slope from Cape Hatteras, North Carolina to Brazil in the Gulf, Caribbean, and Western Atlantic proper. Potentially commercial quantities of the royal-red shrimp have been found on Florida's east coast, off the Dry Tortugas, and in the northern Gulf. Lesser quantities of the shrimp have been found throughout the area explored, with some potential off Venezuela and Colombia in the Caribbean and off the Guianas in the Atlantic. By trawling the grounds where large concentrations occurred off the U.S., and making demonstration landings, as well as publishing the results of the findings, the U.S. fishing industry has been encouraged to make use of the new resource. Vessels of the Bureau have fished alongside the commercial fleet on the new grounds to encourage them, and at present a growing interest and a small-scale continuous utilization is being seen.

INTRODUCTION

THE Exploratory Fishing and Gear Research Base of the U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, was established in Pascagoula, Mississippi, in 1950. Operating as the official research organ of the Gulf States Marine Fisheries Commission, this base is, in many respects, an experiment in a new approach to fishery research, posing as it does the segregation of exploratory fishing and gear research activities from other research spheres. Originally, the base was chartered for the systematic examination of the biotic resources of the Gulf of Mexico with special attention to the stocks of tuna, shrimp, and snapper of that area. Later, however, program scope was enlarged to include also the south-eastern coast of the United States, the Caribbean Sea, and waters off north-eastern South America as well as the Gulf. Emphasis within the program today is on new or little used resources and methods of bringing them into utilization.

To facilitate handling, the total program has been broken into three major segments or programs set up geographically; Gulf of Mexico Exploratory Fishing and Gear Research; South Atlantic Exploratory Fishing and Gear Research; and Caribbean and Tropical Atlantic Exploratory Fishing and Gear Research.

Within each of these programs are three major projects: Shellfish; pelagic fish; and bottom fish. And within each project are phases devoted to the examination of specific species or species groups.

In addition to the exploratory fishing programs just outlined, the Base operates also a gear research station devoted to the development of more effective ways of harvesting the resources sought and found in explorations and in the everyday commercial fishing operations.

Explorations within the three basic exploratory programs are carried out in four principal steps, which overlap in time and to some extent in content: Basic explorations of species or areas; delineations of species by season, depth, temperature, and bottom type; commercial evaluation and industry co-operation and assistance.

In this paper, the present status of the royal red shrimp (*Hymenopenaeus robustus*) fishery of the south-eastern and Gulf States will be revealed through a discussion of the steps in fishery exploration and gear research that led up to that status.

BASIC EXPLORATIONS

Throughout most of 1950, the *Oregon* was engaged in work designed to extend the depth limits of the brown and pink shrimp (*Penaeus aztecus* and *P. duorarum*) commercial fisheries from the then existing 25-fathom outer limit to deeper levels. In the course of the study, trawl hauls were made routinely out to 100 fathoms in attempts to find concentrations of brown shrimp. At the same time, a few purely exploratory trawl hauls were made over the edge of the Continental Shelf between 190–250 fathoms.

During these deep drags, royal red shrimp were taken for the first time in commercial gear. Catch levels in the 40 foot shrimp trawl used for the explorations were sufficiently high that a possible commercial potential was indicated. Therefore, additional trawl hauls were made both east and west of the original site of discovery off the mouth of the Mississippi River.

Two basic findings resulted from the exploratory work that went on over the next fourteen years until the entire Gulf had been covered with trawls between 100 and 500 fathoms: (1) royal red shrimp were available throughout the year and throughout the Gulf in depths of 150–400 fathoms, but (2) they were available in potentially commercial quantities (50 pounds per hour or more) in only 2 Gulf areas—off the mouth of the Mississippi River where the original drags had been made and off the Dry Tortugas on the south-western coast of Florida. It was further found that bottom temperatures of about 50° F. could be correlated with good catches.

Late in 1955, a careful scrutiny of charts and temperature recordings from the south-east coast of the United States indicated that there were extensive areas between 150–400 fathoms with the proper temperature regime for the royal red shrimp. When the Bureau was asked to undertake exploratory fishing work on that coast, therefore, royal red shrimp-loomed high among the possible resources to be investigated.

In February 1956, the chartered vessel *Pelican* made its first drags off St. Augustine, Florida, and came up with commercially promising catches of royal red shrimp. In the course of the next 2 years, explorations were pursued by the *Pelican* and the *Combat* from Cape Hatteras south to the Florida Keys.

In 1957 and 58 the *Oregon* left the Gulf for explorations in the Caribbean and off the north-east coast of South America. During these explorations, the range of the royal red shrimp was found to extend past the Guianas onto the Continental Slope off Brazil and throughout the Caribbean in roughly the same depth interval as in the Gulf of Mexico.

Currently, preliminary trawl coverage of the Continental Shelf and Slope has been completed from Cape Hatteras, North Carolina, to mid-Brazil along the mainland coasts of the Americas. Royal red shrimp have been found in some concentration everywhere that it was possible to trawl on the upper slope levels and where mud bottom prevailed with a temperature at the bottom of between 45° and 55° F.

ENVIRONMENTAL DELINEATION

In the pursuance of basic explorations, it is inevitable that some areas will show up that appear to be of commercial significance. Such, for instance, are areas (1) off the Mississippi River in the northern Gulf of Mexico, (2) near the Dry Tortugas in the southern Gulf of Mexico and (3) off St. Augustine, Fla, on the south-eastern coast of the United States.

These areas, as they appear, are subjected to more detailed treatment. The environmental factors that appear invariably to be of important scope in the delineation of a bottom-dwelling species of fish or shellfish are (1) bottom temperature, (2) type of substrate, (3) season of the year and (4) depth of water. The step in exploration immediately following basic exploration, therefore, is the investigation of the animal in light of these environmental factors.

Royal red shrimp occur within a relatively narrow temperature range of from 45–55° F., with highest concentrations being restricted to the narrower zone of 47°–52 F. It was readily determined in the course of the operations that temperature has a more important effect on the shrimp than does depth *per se*. As evidence for this statement the following comparison is provided: In the Gulf of Mexico, greatest concentrations of the shrimp are found in the north between 190 and 270 fathoms, with temperatures of from 47–50° F.; in the Tortugas area, the shrimp are generally found between 190 and 250 fathoms, again at between 47° and 50°; and off St. Augustine Fla., the shrimp are found between 170 and 210 fathoms, but again at temperatures between 47° and 50°. At places in the Caribbean it has been found necessary by *Oregon* staff members to drag as deep as 300 fathoms to obtain maximum numbers of the shrimp. Invariably, however, when maximum concentrations are obtained, the temperature varies but little from 50° F. The stenothermal nature of the shrimp shows up in a second important way. At times off the Dry Tortugas, owing to current changes or other changes in the water mass, extensive areas of the bottom will be characterized by 50° temperatures, whereas at other times bottom areas so chracterized are relatively restricted. *It is when the bottom areas with 50-degree temperatures are restricted that the shrimp become concentrated and can be taken in profitable numbers.* When extensive areas of 50-degree water occur, the shrimp spread out to occupy the whole and are not massed in as great a quantity per unit area.

That royal red shrimp occur only on mud bottom in sufficient quantities or aggregations to permit profitable fishing has been established. The mud itself, however, varies considerably from one particular locality to another. Bullis (1956) states that the grounds on the Mississippi Delta fishing area are composed of "cohesive blue mud with very small quantities of sand or shell fragments..." and that the Tortugas grounds are "characterized by a light gray to gray-green calcareous mud..." In other areas, mud from royal red shrimp catches has been various shades of brown. Plans are underway at present for a more thorough-going study of the sediment types of the Continental Slope areas of the region explored.

In summary, the delineation studies showed the royal red shrimp to be present over a maximum depth range of from 150–400 fathoms, with greatest concentrations between 170 and 300 fathoms depending upon the depth of the 47° and 50° F. isotherm, and on mud bottoms.

The shrimp were also found to be present throughout the year, but seasonal variations have been noted. On the northern Gulf grounds, off the mississippi River, Bullis states that successful drags "show a gradual increase in rate...from winter...to...fall." On the Tortugas grounds, catch rates appear to be highest in the summer. Off St. Augustine, "catch rates...were high in winter with a gradual decrease until fall..." (Bullis and Rathjen, 1959).

Commercial Evaluation

During the task of preliminary delineation of the shrimp grounds, attention invariably becomes focused more and more on areas where greatest commercial potential appears to exist. As stated areas of greatest commercial importance found during early work were (1) off the Mississippi River in the northern Gulf of Mexico, (2) near the Dry Tortugas in the southern Gulf of Mexico, and (3) off St. Augustine, Fla., on the south-eastern coast of the United States. These selected areas of promise were all subjected to the third step in complete exploration—commercial evaluation. This step was accomplished through the use of what we call "simulated commercial fishing," that is, fishing with gear, methods, and timing as nearly akin to commercial practices as possible.

Since the royal red shrimp inhabit relatively deep water layers, where light is not apparently an important factor, there is no correlatable difference between catches made in night time and those made in daytime. It is thus possible to complete approximately four 5-hour drags per 24-hour day on the grounds. Proceeding on this basis, during simulated-commercial trials, catches have been as follows:

(1) *North Gulf*.—In limited production trials by the *Oregon*, winter averages of 300 pounds of heads-on shrimp per day have resulted, and daily catches in spring, summer, and fall have averaged 600, 700, and 900 pounds of heads-on shrimp respectively. It should be noted here that individual good catches by the *Oregon* indicate that wth sufficient experience to be thoroughly familiar with the grounds, a good fisherman could theoretically make round-the-clock catches of 1,000 pounds of head-on shrimp per day in winter to a high of roughly 2,400 pounds per day in summer.

(2) *Tortugas*.—Less-simulated commercial work has been done in the Tortugas. On the basis of what has been done, however, catch rates of roughly 1,000 pounds of heads-on shrimp per day seem possible the year round, except on those occasions previously referred to when the temperature structure deviates for short periods from the normal, allowing the shrimp to disperse more freely over greater areas.

(3) *Florida East Coast*.—Catch rates from the Florida east coast trials have run as follows: Winter average 2,100 pounds per day; spring average 1,900 pounds per day; summer average 1,730 pounds per day; and fall average 1,540 pounds per day of heads-on shrimp. Commercial catch rates on these grounds have ranged as high as 1,600 pounds of shrimp per fishing day and are expected to go higher as the fishermen become more proficient at deep-water dragging.

Inshore shrimp fishermen figure the break-even point in their operations lies at a catch rate of about 200 pounds of heads-on shrimp per day. Even allowing for the slightly more expensive operation entailed in this off-shore fishery, the catch rates cited above show promise by comparison. Thus, it appears definitely from the results of simulated commercial fishing and the limited amount of actual production fishing that has been accomplished to date that a true commercial potential exists.

Industry Co-operation and Assistance

The major aim of the investigations so far related is to point out to the fisherman the existence of a potentially commercial resource of some magnitude. Unless at some point in time the fisherman responds by using the results of the investigations, a large amount of effort has, in an industrial or commercial sense, been wasted.

Thus, the fourth step in fishery development is to entice the fisherman onto the grounds delimited. This is done in 2 ways: (1) Through reports on periodic checks on the resource, which include demonstration fishing and demonstration landings of the catch; and (2) through personal aid to the individually interested fisherman or fishermen's group in the forms of advice and direct help in converting his vessel and gear to the fishery, finding the grounds, and getting his gear to work on the grounds.

From 1958–62 the royal red shrimp grounds lay untouched except for periodic checks made by the Bureau's research vessel *Silver Bay*. These checks, results of which were communicated to the fishing industry, showed that although fluctuations in availability do occur, the resource remains relatively stable year in and year out.

A steady increase in interest was evident on the part of the industry throughout the period. Finally, in a period of very low catches of inshore shrimp, the *Silver Bay* made a demonstration landing of about 2,700 pounds of royal reds. This stimulated 4 commercial vessel owners to convert their vessels for the deep water fishery. Late in January 1962, these vessels set out for the grounds. The *Silver Bay* devoted several days of a routine cruise to fishing alongside this embryonic fleet, giving the vessel crews advice on catch rates to be expected, handling procedures, and location of the most profitable grounds.

Catches achieved by these vessels and the demonstration that commercial vessels could fish the deep water grounds profitably, provided further stimulus to the industry, and several additional owners sought information from the Bureau. A combination of actual fleet experience and low shrimp levels in inshore waters caused vessels from Florida and Georgia to join in the fishing until a total of 19 vessels were rigged out and participating in the fishery.

Unpublished statistics collected during 1962 show that the 19 boats averaged roughly 100 pounds of heads-off shrimp per 4-hour drag, and that 10 vessels in the fleet landed 24,380 pounds of shrimp tails in February and March. The same number of vessels landed 21,079 pounds of tails in April from twenty-one 6-day trips—an average of over 1,000 pounds per trip.

All was not "roses," however; the weather is always a limiting factor in an offshore fishery with relatively small boats; heavy currents encountered in Gulf Stream fishing interfered with efficiency; navigational methods must be precise for location of the grounds and retention of their position; and it is more difficult to detect gear failures in the course of deep water trawling than in shallow water operations.

Therefore, when shrimp stocks began to increase inshore—and because it is less expensive to fish inshore—the vessels of the royal-red-shrimp fleet retired to the inshore grounds.

We felt, however, at the end of 1962 that "It now appears that the royal red shrimp fishery will be an intermittent fishery, with the fishermen moving inshore when trial catches of inshore shrimp reach or exceed the size of catches made on the royal red grounds and moving out to the deep water grounds when inshore catches fall off."...It seems likely that the presence and availability of the deep water shrimp and boats rigged for deep water fishing will tend to provide a stabilizing effect on the shrimp industry of the South-eastern States" (Cummins and Rivers, 1962).

Since 1962, efforts on the grounds have been sporadic. In 1964, 2 vessels fished the grounds regularly. One vessel, the *Terry Ann* of Thunderbolt, Ga., accomplished exceptional catches. In the first 10 months of 1963, its total catch amounted to about 1,700 boxes of shrimp (1 box equals 100 pounds of shrimp, heads-off). The second vessel, the *Trade Wind* of Fernandina Fla., fished on an intermittent basis, but also achieved high catches. At the time of writing (November 1964), several additional vessels are rerigging for the fishery as shrimp catches inshore drop-off.

Gear Research

Although the gear used on the royal red shrimp grounds is similar to that used on the inshore grounds, there are some differences and additions. Pilot house equipment for royal red fishing must include one or more loran sets and a depth recorder capable of showing bottoms in excess of 200 fathoms. Winch capacity must necessarily be sufficient to hold 600–800 fathoms of warp. This at first caused reluctance on the part of vessel owners to convert to deep water fishing. A simple means of shackling the wire from drum to drum on multiple-drum winches (Cummins and Rivers, 1962), however, obviated the necessity of owners having to purchase new, expensive high capacity winches and allowed entrance into the fishery of several vessels.

Weather is a factor always to be taken into consideration in an off-shore fishery. The 60 to 80 foot vessels used in red shrimping have proved adequate to the task when fitted with trolling stabilizers dropped from the boom tips.

Recent acquisition by the Bureau of a motion-picture camera system capable of working in royal red depths is also proving valuable. Footage obtained to date indicates that the trawls currently being used are catching only a small percentage of available shrimp, with many individual shrimp passing under the footrope or otherwise avoiding the trawl. The footage is currently being accumulated for analysis leading to more effective gear design.

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PELAGIC COPEPODS AS FOOD ORGANISMS

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ABSTRACT

This paper refers particularly to pelagic copepods supplying food for fish larvae and human beings. Facts and figures given are based on the author's experience in the Indo-Pacific region. The abundance of copepods is indicated in terms of numbers and biomass, and their advantages as food organisms are discussed. It was pointed out that although there was a pronounced size mode at 0·7–0·8 mm., the biomass is distributed over a reasonable size range. The so-called critical period of fish larvae is discussed. Copepods help fish to get through this phase by being available and suitable as food almost from the point of hatching up to 4 cm. long, which is past this critical phase. Concentrations of copepods are such that the fish larvae need expend a small amount of energy only to catch a copepod.

From the human food aspect, the quality of copepods is discussed. On a dry weight basis they are about 60% protein. All the essential amino acids are present in about the same proportions as in a hen's egg. It is calculated that a single net, having a mouth aperture of 9 square metres, can, by using tidal flow, catch a quantity of copepods representing about 5,200 grammes of protein a day. On the basis of an adult requirement of 70 grammes of protein daily, this represents the daily protein requirement for 75 adults. Some departures from these figures are given, with reasons. The catch would need to be processed. Although probably not a very profitable venture financially, it is suggested that such a source of first class protein should be examined more closely.

MY research has been mainly concerned with the plankton of the Indo-Pacific area, particularly with the Sunda Shelf and the East African coastal areas. Therefore such general remarks I make about populations, numbers, and so on, although they might well be applicable to other areas in general, are based on my experience of these areas in particular.

All manner of organisms eat pelagic copepods; indeed it is difficult to imagine any carnivorous marine organism which does not eat them. Rather than discuss all these different organisms I would like to consider pelagic copepods as food organisms for two particular animal groups, fish larvae and man.

I have yet to meet the person who has collected a plankton sample from a coastal area in the tropics, or indeed anywhere, who has not found copepods present; almost invariably they are the most numerous of the multi-cellular animals. The indicated numbers present per unit volume of water will vary a great deal, according to the mesh of the net used.

Even with a constant mesh aperture numbers will of course be variable according to the area sampled, but it is reasonable to say that there would be about 1,500 post-naupliar copepods per cubic metre of tropical coastal water.

Plankton surveys have shown that the majority, probably the great majority, of fish eggs are laid in the shallow coastal waters. It is common to find larger numbers in the vicinity of a river mouth. When hatched the larvae are usually about 1–3 mm. long, usually smaller than their colder water counterparts. Metabolism is very rapid in these warm waters and such food reserves as are available to the newly-hatched larvae are very soon used up. The problem of finding food is then upon the larvae.

While they do take large, individual diatoms, fish larvae in general cannot be said to be plant eaters; this means that some organism will have to be a suitable go-between between the plants and the fish larvae. Pelagic copepods are admirably suited to this go-between role. There are other herbivorous organisms which are suitable as food for fish larvae but these are too erratic in their availability (*e.g.*, the Cladoceran *Penilia avirostris*), are not very concentrated (some small decapod larvae) or do not have such a good food value (appendicularians). There are some small carnivorous organisms on which fish larvae feed, but these are usually dependent on the copepods anyway. Copepods appear to fit almost perfectly the role of food for fish larvae; they form a direct go-between between plant and fish, they are almost invariably the commonest organisms in the plankton, the result being that they are more concentrated than other organisms, and they are of good food value.

Earlier I suggested a figure of about 1,500 post-naupliar copepods per cubic metre of water. I refer to post-naupliar copepods for this reason. An analysis of the stomachs of many fish larvae has shown that the average fish larva, if I may use that expression, likes to select an organism which is relatively large. For example, a 3–4 mm. larva will select copepods about $\frac{3}{4}$–1 mm. long. I remember one carangid larva about 5 mm. long having 3 *Eucalanus subcrassus*, each about 2 mm. long in the stomach—quite a good job of packing. I might add that this applies also to fish larvae caught individually in addition to those which have been crowded with copepods in a plankton net bucket. There appears to be little evidence that the larvae select the smaller nauplii.

This figure of 1,500/m.^{3} represents about one copepod per 675 c.c. or, on average, one copepod in every unit of water measuring about $8 \cdot 5 \times 8 \cdot 5 \times 8 \cdot 5$ cm. In theory then a fish larva need only expend sufficient energy to move about 20–25 times its own length in order to catch a sizeable item of food. This is not however the whole story. The majority of fish eggs are pelagic, which means that the majority of newly hatched larvae are found towards the surface. As the fish larva grows it is capable of moving vertically, but there is an upward movement at about sunset, so that whichever way one looks at it there is generally a greater number of fish larvae towards the surface, particularly at about sunset. It so happens that copepods are to be found mostly in the upper part of the water column and attain their greatest concentration at about sunset in the surface waters. Concentrations here are about 4,000–5,000/m.^{3} This is about 1 copepod per 200 c.c. of water, or one copepod in every unit of water measuring about $6 \times 6 \times 6$ cm., an appreciable reduction on the former figure. This suggests a picture of the top ten metres or so of the sea divided into a series of neat 6 cm. cubes with a copepod suspended neatly at each corner of each cube. The fish larva follows along the lines of the cubes, devouring the copepods as it goes. Of course this is not so; it is the fish larva which is usually relatively static and, as a copepod goes past in front of it, makes a sudden lunge at it. Clearly, with a milling crowd of copepods at about 5,000 for every cubic metre, it would not have to wait for very long before an opportunity for feeding came its way.

Copepods form a food for fish larvae which is always readily available; but again there is more to it than this. There is a theory held by many, perhaps the majority, of fishery workers which says that there is a 'critical period' in the life-history of a fish, at which period the chances of the fish being killed are greater than at any other time (Marr, 1956). To quote from Hjort (1914), "This again leads us to the question, at which stage of development the most critical period is to be sought. Nothing is known with certainty as to this; such data as are available, however, appear to indicate *the very earliest larval and young fry stages* as most important." Copepods help the fish larva to get past this critical stage by being available in a variety of sizes. Fig. 1 shows the size distribution of a coastal tropical copepod fauna. It must be appreciated of course that although the copepods are much fewer when the 1 mm. size is exceeded, the actual weight of meat per copepod increases considerably since the biomass goes up geometrically. If we take our figure of 5,000 copepods/m.^{3} and assume that the size distribution is as shown in Fig. 1 the total biomass will be $167 \cdot 55$ mg. [This is according to Kamshilov's formula: Body weight, mg. = (Body length, mm. $\times\ 0 \cdot 286 + 0 \cdot 005)^3$]. If this biomass is divided according to the different size groups and plotted according to the numbers present of each size group, the distribution of biomass per hundred is as shown in Fig. 1. Thus the amount of actual copepod meat available is distributed over a reasonable size range.

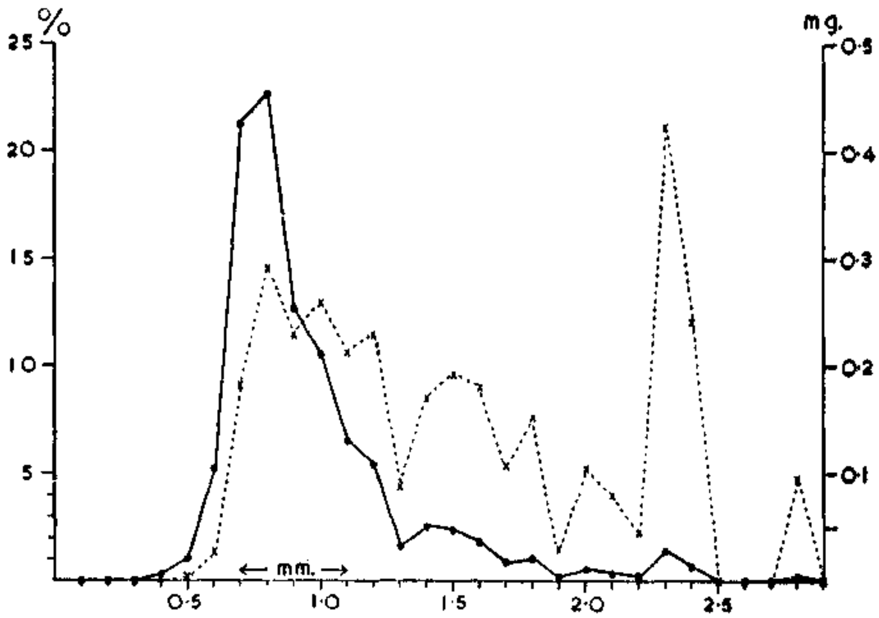

FIG. 1. Percentage length (— • —) and biomass distribution (-- × --) of tropical marine coastal copepods.

By the time the fish larva has assimilated such food reserves as were available on hatching it is just about large enough to tackle the smallest of the copepods. Its movements will be feeble at this stage, but this is compensated for by the fact that the small copepods are much the commonest. As the fish larva grows, so it becomes capable of more rapid and sustained movement so it can hunt out the larger copepods. These are more widely distributed, but one of these is equivalent to a number of the smaller ones. A fish larva does not outgrow its food supply of copepods until it is about 4 cm. long, by which time it is past this critical stage. Some fish of course continue to feed on copepods, although not necessarily selectively, all their lives. It is a common enough sight at night in shallow tropical waters to see a shoal of carangids swimming around with their mouths wide open, opercula almost at right angles to the body, filtering out the plankton with the gill bars. However, it is the availabiliy of copepods as food for fish larvae that I wish to stress. I have presented a generalized and no doubt rather idealized picture, but I hope that I have shown in some degree the great importance copepods can have in getting a population of fish larvae away to a good start, past the critical period, and thus with the potential for a good yield when they are fished commercially several years later.

Having seen the fish larva safely through its critical period and set it onto the path of maturity let us now consider if copepods can be of any help in feeding mankind. It has been said that there are more copepods than all the rest of the multi-cellular animals put together, including insects; I agree with this. It would seem a pity then if some use could not be made of them.

Before expending any effort to catch copepods one must consider if they are worth catching —what is their nutritional value, can they be of any use to balance a protein-deficient diet. Previous studies of plankton as food have tended to think in terms of the plankton providing the meal. I think this is wrong; it should be looked at from the point of view of providing a *supplement* to the normal diet; more specificially, to provide the balance of protein for an otherwise protein-deficient diet.

Proteins are essential for maintenance of tissues and organs, and of course for growth. They have a basis of some 20 amino acids. The body can synthesize most amino acids but some of them, the so-called essential amino acids, must be taken in from an outside source. These essential amino acids are Arginine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan and Valine. Any diet lacking any or all of these amino acids must be considered deficient.

Drawing mostly on the work done with *Calanus* at the Plymouth Laboratory by Cowey and Corner (1961, 1963) it will be seen that copepods contain all these essential amino acids in about the same proportions as they are present in a hen's egg. Moreover, the weight of protein per unit weight of copepod is high. For some comparative figures, the percentage of protein, on a dry weight basis, of beefsteak is 60%, of melons is 10%, of runner beans is 10%, of cod is 85%, of prawns is 70%, of bananas is 3% and of copepods is 60%. Copepods are therefore on a par with beefsteak in terms of percentage protein composition, and compare favourably with other high protein foods. I am not saying that I would as soon eat a dishful of copepods as a rare, charcoal grilled beefsteak, but any source of good protein should not be rejected out of hand in these days of widespread protein deficient diets. There have been suggestions from time to time concerning the utilisation of plankton as a source of food, but these have been considered in terms of colder waters. What can be said of tropical coastal areas?

We have seen that copeopds are always present in the plankton, and usually form the greater part. If we think in terms of dry weight the proportion will be increased. If we include the other planktonic crustacea—I feel at liberty to do this since this is, after all, a Symposium on Crustacea—the proportion will be higher still; probably about 90% of the total. However, I want to deal with just the copepods, so we can look upon other planktonic animals as a bonus. We want to expend as little manufactured energy as possible in this enterprise so we will use the tidal flow to take the water through the nets. If we assume a tidal flow of about 2 knots this means a rate of flow through a net of about 1 metre/sec. The net can be firmly mounted on rotating frames so that the mouths can face the tidal flow. Let us take the catch of a net having a mouth measuring 3×3 metres—a reasonable size. If the water flows through this at 1 metre/sec. this means that 9 cubic metres of water per sec. will be filtered. Since the net will extend down below the surface for some distance I think it more realistic to work on a basis of 3,000 copepods/m.^{3} The size and biomass distribution will, for all practical purposes, remain the same so that 3,000 copepods/m.^{3} represent a biomass of 100 mg./m.^{3} This is equivalent to a dry weight of about 17 mg./m.^{3} The protein content is about 60% of this figure—or say 10 mg. Therefore every cubic metre of water filtered represents about 10 mg. of protein. It could be arranged so that the net fished for about 4 hours in every tide—say 16 hours a day. This means that our 3×3 metre net catches protein at the rate of 90 mg. per second, 5,400 mg. per minute, 324,000 mg. per hour or 5,184 grammes of protein per day.

What are the protein requirements of the human diet? The figure generally accepted for adults is about 1 gm. of protein per kg. of body weight, making about 70 gm. of protein daily the adult necessity. Very young children need about 4–5 gm. per kg. of body weight, the figure gradually decreasing to the adult figure as age increases. Thus, on the face of it, it looks as if our 3 metre square net can supply the daily protein requirements for about 75 adults; also remember that we are dealing with a first class protein containing all the essential amino-acids.

Obviously there are going to be some snags somewhere. The net might prove to be a bit too large and unwieldy, requiring the use of several smaller nets to provide the same mouth area. This will increase the amount of attention necessary. Since we are dealing with coastal areas it could well be that the water is, or at times is rather thick with phytoplankton and the like, which will tend to clog up the net. In this case it might represent an overall saving to increase the mesh size of the net. An increase from about 200 μ upto about 300 μ would decrease the catch by about 40%, yielding then say about 3,200 grammes of protein a day—enough for about 45 adults. However it would be a cleaner sample.

Clearly the catch would have to be sorted to some extent to separate the jelly-like plankton, the medusae, salps, siphonophores and so on. This could be done fairly readily and sufficiently satisfactorily by some sort of gravitational or centrifugal separation. There is little doubt that the copepods will have to be processed in some manner. I can pass over this by saying that I am sure the food technologists can answer this one. It should be possible to make some sort of flour which, having been de-odorised, can be included in the local food.

Obviously there would be many details to overcome, but I would suggest that there is a real potential here; not perhaps a potential for making a financially profitable business set-up, but a potential for providing an adequate first class diet supplement with very little, if any, financial loss. I have given some figures for one net only of 9 square metres aperture. There could of course be more of these. Three or four men in a boat could probably work about ten of these nets. Various factors could reduce the catch to below the figures I have quoted, but do not forget the bonus in the form of other crustaceans.

Having presented a reasonably rosy-tinted picture of plankton harvesting it is necessary to add that investigations which have been made concerning the economics of plankton utilization, *e.g.*, Shropshire (1944), Jackson (1954), have been most discouraging. The nets themselves will be very expensive, and the necessary processing plant will not be cheap. These factors will make the cost of protein production from copepods high; but will it be prohibitively high? A point to the good is that labour costs in temperate countries are much higher than they would be in the tropics. Clearly, obtaining protein from copepods is a matter which, if considered seriously, must be considered from all aspects.

A last point which will tie together the two parts of this paper, albeit rather loosely I'm afraid; what about fish as a source of protein? I have calculated that a single fish about 35 cm, or 14 inches long will have a protein weight of about 70 grammes. Thus a single fish of this size a day will provide the total protein requirements, in both quantity and quality, for one adult. It might be considered an easier proposition to catch one 35 cm. fish a day rather than about 225,000 copepods. Whichever way it is done the copepods are either of great value in providing food for the fish to grow the required length or are directly of value as a source of protein.

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Discussion

Dr.. J. S S. Laxmi Narayan: I just wish to know whether in the copepods studied any analysis is carried out on the amino-acid composition.

Dr. J. H. Wickstead: Dr. Corner has worked in detail on *Calanus* at Plymouth.

Dr. V. Hansen: There is paper by Clarke and Fish on nutritional value of plankton items.

Dr. J. H. W.: In association with the habitual diets of certain types of animals there are also particular types of gut flora. Any drastic change in the diet disturbs them and brings about consequent changes in their activities as well as in those of the host.

Dr. V. Hansen: I have a few points to be mentioned. Firstly, regarding the efficiency of net catches. In one of my experiments when I dropped 500 gm. of rice grains into the sea to find out how much of it will be hauled in an immediately operated plankton net, I found no rice caught. Secondly, about the critical period of fish larva. When spawning failed in some N. Atlantic fish there was no evidence to show that scarcity of food caused any critical period for the larvae. Third point is regarding the utility of plankton as human food. The Japanese have done some useful works in this field and I hope you are aware of these. I have eaten some of the plankton items and found that *C. finmarchicus* is excellent but *Euchaeta* is bad in taste. Have you eaten plankton?

Dr. J. H. W.: I never had the occasion to taste plankton food. I do know of the Japanese work.

Dr. D. G. Frey: May I know whether the fish larvae have any preferred time of feeding?

Dr. S. Z. Qasim: In some of my studies, I found that fish larvae have preference to feed in the early hours of the morning as contrasted to the late feeding observed by Dr. Wickstead.

Dr. A. N. P. Ummerkutty: You mentioned that there is a conectration of plankton in the upper waters during dusk. Did you find that there is a corresponding migration and concentration of fish larvae during the same hours?

Dr. J. H. W.: Yes, there is such a migration.

ON THE TAXONOMY, BIOLOGY AND FISHERY OF THE SPINY LOBSTER *JASUS LALANDEI FRONTALIS* (H. MILNE-EDWARDS)[1] FROM ST. PAUL AND NEW AMSTERDAM ISLANDS IN THE SOUTHERN INDIAN OCEAN, WITH AN ANNOTATED BIBLIOGRAPHY ON SPECIES OF THE GENUS *JASUS* PARKER*

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ABSTRACT

During his participation in the Fifth Cruise of the U.S. Research Vessel ANTON BRUUN in the Indian Ocean, the author was able to visit the remote island of New Amsterdam in the Southern Indian Ocean in April 1964, and make a collection of the spiny lobster *Jasus lalandei frontalis* (H. Milne Edwards).* Recent work on the taxonomy of the genus *Jasus* Parker indicates the need for a reappraisal of the nomenclature, validity and status of the various nominal species described under the genus from the different geographical areas. In order to facilitate such work, a detailed description of the material collected is given here, along with the description of an early post-puerulus stage of this lobster from New Amsterdam Island. The phyllosoma larvae of *Jasus* collected off the islands of St. Paul and New Amsterdam are also described and illustrated. Comments on the distribution for the genus *Jasus* as well as the probable routes of dispersal of the larvae are also discussed. On the basis of the present study, a revised distributional map of the spiny lobsters of the world (Family Palinuridae) is given.

There is a seasonal fishery for *J. l. frontalis** in St. Paul and New Amsterdam Islands where at present the catch is limited to 200 tonnes of lobsters per year. A brief résumè of this fishery, as well as aspects of the biology of this lobster from these islands, is dealt with here. An annotated bibliography of over 250 papers which deal with the taxonomy, biology and fishery of species of the genus *Jasus* is also included with a subject-wise index. [* = *Jasus paulensis* (Heller)].

CONTENTS

PART I

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[1] The revised nomenclature according to Holthuis (1963) should be *Jasus paulensis* (Heller, 1863). See remarks in "Addendum". Thus for *Jasus lalandei frontalis* (H. Milne-Edwards) from the Southern Indian Ocean read *Jasus paulensis* (Heller) throughout this paper.

Part I

Introduction

In a recent Conference on "A Discussion on the Biology of the Southern Cold Temperate Zone" held under the leadership of Professor C. F. A. Pantin in December 1959, Professor G. A. Knox drew attention to the many wide gaps in our knowledge of the littoral zone of the southern cold temperate and subantarctic regions. There are practically no accounts of the littoral ecology of any of the isolated antarctic and subantarctic islands and "*....in particular St. Paul and New Amsterdam Islands are almost completely unknown*" (Knox, 1960) (Italics mine). The mere fact that these two islands are the remotest from any land mass in the area of the Indian Ocean highlights the need for a thorough investigation of the faunal and floral elements both marine and terrestrial of these islands which would undoubtedly throw considerable light on problems relating to speciation. St. Paul and New Amsterdam Islands are situated 38° 43′ S.–77° 30′ E., and 37° 51′ S.–77° 32′ E, respectively. During the last 110 years several scientific expeditions have worked in various parts of the Indian Ocean, but as will be seen from the accompanying figure (Fig. 1) only few have ever touched the islands of St. Paul and New Amsterdam. They are "Novara" (1857–1859), "Gazelle" (1874–76), "Valdivia" (1898–99), "Gauss" (1902–03), "Sapmer" (1950) and "Anton Bruun" (1964). Since 1950, "Sapmer" has made regular fishing cruises to these islands. Other than these, even occasional visits to these islands by ships in transit are rare (except taking off and bringing replacement of personal for the meteorological unit at New Amsterdam) on account of their remoteness and the inhospitable weather conditions that prevail in the area for about six months in the year during the southern winter.

An opportunity to visit one of these islands came by during my participation in the V cruise of the United States Research Vessel "Anton Bruun" in the Indian Ocean when she touched St. Paul Island on 7–4–1964 and New Amsterdam Island on 8–4–1964. One of the striking things that was noticeable in the littoral zone of New Amsterdam Island was the 'invasion' at dusk of the intertidal rocky areas by lobsters some of which were collected for study and identified by me as *Jasus*

[1] The nomenclature should according to Holthuis (1963) be *Jasus paulensis* (Heller, 1863).

lalandei frontalis[1] (H. Milne-Edwards), based on a preliminary review of the genus by Holthuis (1946).

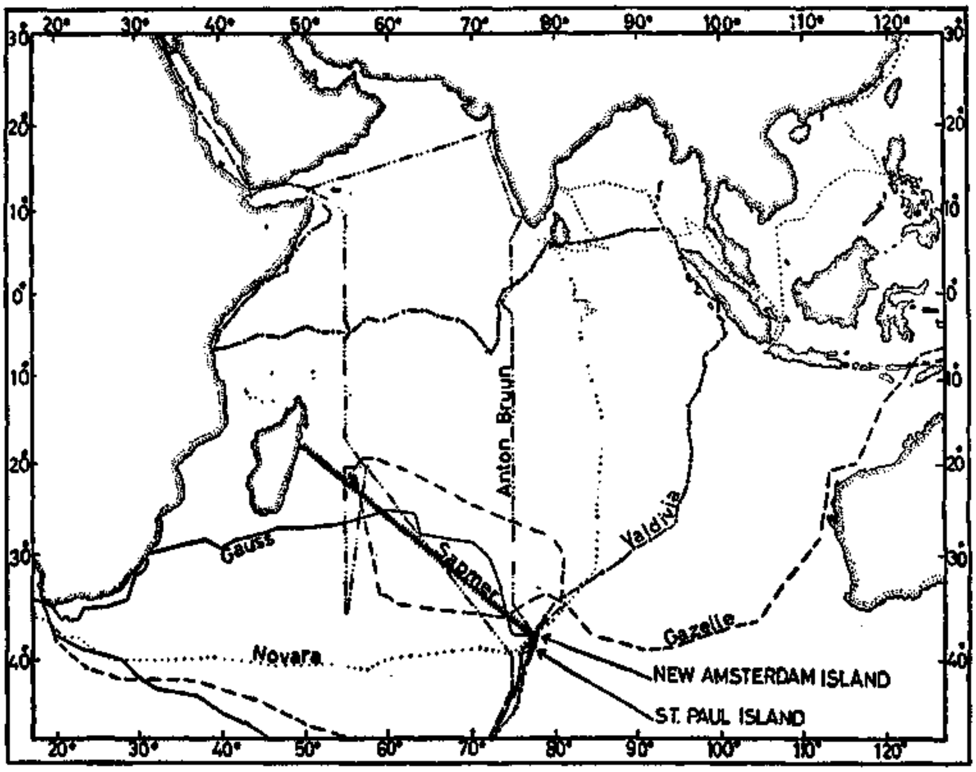


FIG. 1. Map showing the routes in the Indian Ocean of the important scientific expeditions that have also visited St. Paul and New Amsterdam Islands. (Besides these, as part of the IIO Expedition, R.V. *ARGO* stopped at St. Paul for a day in December 1961, and R.V. *ARGO* and R.V. *HORIZON* worked off these islands in November 1962. See Fisher *et al.*, 1964).

A part of the present paper is based on the collections made by me and also collections of phyllosoma larvae obtained from the vicinity of these islands in plankton hauls made at night. Holthuis (1946) in his preliminary review of the genus *Jasus* Parkerrecognises only two species and one variety (subspecies ?) and remarks that " Comparison of material from the different localities is, however, needed to obtain final certainty" about the valid forms. Remarking about *J. lalandei frontalis* from Juan Fernandez Island, Chace and Dumont (1949) say that "Although very distinct at the limits of its range, from the South African and Australian form *J. lalandei* it is not yet certain that this form is a valid subspecies." Since *J. lalandei frontalis* is the variety or subspecies which occurs in St. Paul and New Amsterdam Islands these statements are of interest. However, Angot (1951 *a*, 1951 *b*), and Grua (1960 *a*, 1960 *b*) denote the lobster here merely as *Jasus lalandii*, while the latter author (Grua, 1963, 1964) treats this under *Jasus paulensis* (Heller), which Holthuis (1946) considers a synonym of *J. l. frontalis*. In the collections that I have with me from New Amsterdam Island, there is a graded series representing sizes from the past-puerulus stage to the adult of this spiny lobster. This has enabled a study of the amount of variability with growth of the

[1] The revised nomenclature according to Holthuis (1963) should be *Jasus paulensis* (Heller, 1863).

diagnostic characters on which the subspecies is based, as well as draw attention to the salient differences between males and females of different sizes, all of which may eventually be utilized for drawing comparisons with the *forma typica*.

The description of the phyllosoma stages of this subspecies given here represents the first report of them to come from the southern Indian Ocean.

As is well known, the species of the genus *Jasus* which are confined to the temperate regions of the southern hemisphere are commercially the most important of all spiny lobsters fished at present as will be evident from the large-scale fisheries they support in South Africa, and South West Africa, Australia, New Zealand, Juan Fernandez Island, and Tristan da Cunha Island. It was possible to obtain some information from the French Meteorologists stationed at New Amsterdam Island at the time of our visit about the fishing conditions for the langouste (*Jasus*), around the two islands. The information obtained corroborates Angot's findings made 14 years earlier during the "Sapmer" expedition from 1 January to 5 April, 1950 sponsored by the Institute of Scientific Research of Madagascar (Angot, 1951 *a*, 1951 *b*), and subsequently by Grua (1960 *a*, 1963). The summary of the observations on fishing is dealt with in a separate section in this account.

The examination of the phyllosoma stages also led to a perusal of the earlier literature on the larvae of *Jasus*, necessitating some comments to be made here on patterns of distribution, transport of larvae by ocean currents, etc. The spatial distribution of *Jasus* is also discussed in the light of known facts about the biogeography of the southern oceans.

In the course of the work, it was possible to index over 250 papers pertaining to the systematics, biology, fishery, and fishery technology relating to species of the genus *Jasus* Parker. Since the coverage is comprehensive and includes almost all important works dealing with this group, an annotated bibliography and a subject-wise index is given at the end to facilitate reference.

I wish to express my sincere thanks to Dr. S. Jones, Director, Central Marine Fisheries Research Institute, Manadapam Camp, for his kind encouragement in the course of this work. A part of this work was supported by the United States National Science Foundation as part of the U.S. Program in Biology, International Indian Ocean Expedition.

In the course of the preparation of this paper I have received valuable assistance in the form of advice and much needed literature from Dr. M. Angot, Institute of Scientific Research, Madagascar; Dr. M. Andre, Paris; Dr. D. R. Fielder, University of Townsville, Australia; Dr. R. W. George, Western Australian Museum, Perth, Australia; Dr. Paul Grua, Station Biologique, Roscoff, France; Professor V. V. Hickman, University of Tasmania, Tasmania; Professor C. F. A. Pantin, F.R.S., University of Cambridge, England; Professor Otto Pesta, Akademie der Wissenschaften, Austria; Dr. R. W. Rand, Union of South Africa; and the late Dr. Keith Sheard, C.S.I.R.O., Australia. My special thanks are due to Dr. Michael M. Mullin, at present at the Scripps Institution of Oceanography, La Jolla, California, who kindly passed on to me for study the phyllosoma larvae from the special plankton collections he made while on the V Cruise of R. V. Anton Bruun, and described in this paper. I am also thankful to Mr. K. N. Prasad for his help in the preparation of the drawings. It also gives me great pleasure to record here my sincere thanks and appreciation to each and every member of the French Government Meteorological Unit stationed at New Amsterdam Island at the time of our visit but for whose help it would not have been possible for me to carry out much of the observations.

TAXONOMICAL NOTES ON THE GENUS *Jasus* PARKER

Holthuis (1960) proposed the addition of the generic name *Jasus* Parker (1883) to the official list of generic names in zoology. A distinct rostrum is wanting or the rostrum is rudimentary in the genera *Jasus*, *Palinurus*, etc., but the absence of stridulating organs in *Jasus* is characteristic for the genus. Bernard (1950) mentions in a foot note that Von Bonde, W. (1930) claimed that the peduncular joints of the first antenna show a constant ratio in the phyllosoma, puerulus and adults in the three South African genera *Jasus*, *Palinurus*, and *Panulirus*. Barnard confirms this to be the condition in the first two genera, while in *Panulirus* he finds the third peduncular joint of the antenna slightly shorter than the second. He has also experienced difficulty in separating the genera *Palinurus* and *Jasus* on the actual ratios of these segments given by Von Bonde, W., and used instead the presence or absence of the stridulating organ as the chief character to distinguish them. *Jasus* also possesses a rudimentary rostrum clasped by lateral processes. This is shown in Fig. 4 (early post-puerulus stage) and Fig. 2: 2 (adult male) given in this paper.

Jasus is the only genus of Palinuridae known so far to occur around St. Paul and New Amsterdam Islands.

At least seven species described at one time or other under the genera *Homarus*, *Jasus*, *Palinostus* and *Palinurus* are at present referable to the genus *Jasus*. Holthuis (1946) has shown that *Jasus parkeri* Stebbing (1902)should belong to the genus *Puerulus* as can be seen from its original description and figures which also indicated a distinct stridulating organ which as already mentioned is absent in *Jasus*. However, recently George and Grindley (1964) have erected a new genus *Projasus* to accommodate *J. parkeri* and have shown that as in *Jasus*, *Projasus* also lacks the stridulating organ and occupies an intermediate position between *Jasus* and *Palinurellus*, the other two genera of the division "Silantes". The two species and a variety (subspecies ?) of *Jasus* recognised by Holthuis (1946) are as follows:

1. *Jasus lalandei* (H. Milne-Edwards)

    A. *Jasus lalandei lalandei* s. str.

    B. *Jasus lalandei* var. *frontalis* (H. Milne-Edwards)

    Synonyms:

    Jasus paulensis (Heller)

    Jasus edwardsii (Hutton)

2. *Jasus verreauxii* (H. Milne-Edwards)

    Synonyms:

    Jasus hugelii (Heller)

    Jasus tumidus (Kirk)

The diagnostic character distinguishing the typical form *J. l. lalandei* from *J. l. frontalis* is the squamiform sculpturation on the back of the abdominal segments which in the former occupy the entire surface of the segment, while in the latter, a broad and conspicuous smooth band is present along the anterior and posterior margins of each segment, being most marked in the first segment. In this study it has been possible to check the consistency of this character in relation to the size of the specimens and confirm the diagnosis of the variety or subspecies used first by Parker (1887) (to separate *J. edwardsii* from *J. l. lalandei*), and Holthuis (1946).

The New South Wales, Victoria (Australia) and New Zealand (?) species *Jasus verreauxii* (H. Milne-Edwards) can be easily distinguished from *J. l. lalandei* and *J. l. frontalis* by its greenish colour; the upper part of the abdominal segments bearing pimple-like scattered elevations; and the epimeres being serrated posteriorly. In addition, no transverse grooves are present in any of the segments (*see* Gruvel, 1911 *a*; Chace and Dumont, 1949).

Jasus lalandei VAR. *frontalis* (H. Milne-Edwards)[1]

(*Palinurus frontalis* H. Milne-Edwards, 1837: Synonyms: *Palinurus paulensis* Heller, 1862 et 1865; *Palinurus edwardsii* Hutton, 1875 *a*.)

1. *Material*

Phyllosoma stages.—2 specimens from 35° 45′ S., 70° 36′ E. in night 15 minutes surface plankton tow at 21·30 hours on 2-4-1964 (Fig. 5).

Phyllosoma stage.—1 specimen from 33° 22′ S., 74° 56′ E. in night 15 minutes surface plankton tow at 21·30 hours on 10-4-1964 (Fig. 5).

Early post-puerulus stage.—1 specimen from inter-tidal rock pool at New Amsterdam Island collected on 8-4-1964.

Juveniles and adults.—2 females and 4 males collected from between rocks in inter-tidal region at New Amsterdam Island on 8-4-1964.

2. *Description of* Jasus lalandei *var.* frontalis[1] *from New Amsterdam Island*

In view of the fact that a number of drawings are given here, it is not proposed to go into descriptive details unless necessary. The adults and young including the post-puerulus stage in the collection range from 27·5 mm. to 238·0 mm. in total length measured from base of rostrum. The details are given in the accompanying table (Table I).

TABLE I

(Measurements in millimeters)

Characters	Juveniles and adults						Early Post-Puerulus stage
	1	2	3	4	5	6	7
Total length (excluding rostrum) ..	238·0	202·0	150·0	103·0	81·0	58·5	27·5
Length of carapace (excluding rostrum)	95·0	78·0	55·0	39·0	30·5	23·6	10·3
Length of rostrum ..	4·0	4·7	3·5	2·3	2·0	1·5	0·5
Length of 2nd pedunculate joint of antennule ..	15·1	13·0	9·5	5·5	4·2	3·3	0·9
Length of 3rd pedunculate joint of antennule ..	21·1	18·5	11·7	6·5	5·5	4·0	1·5
Shell condition* ..	HOS	HOS	HOS	HOS	HOS	HNS (?)	HS
Sex ..	M	M	F	M	F	M	M

* HOS = Hard old shell; HNS = Hard new shell; HS = Hard shell.

Earlier descriptions of this lobster from St. Paul and New Amsterdam Islands may be found in the works of Heller (1862, 1865), and Angot (1951 *a*, 1951 *b*), while passing references to it are to be found in the works of Veilan (1878), Andre (1932), and others. In none of these is any emphasis placed on the nature of the sculpturation on the abdominal segments. Figure 2: 2 and Fig. 3: 1–12 show the nature of the sculpturation in specimens of sizes 58·8 to 238 mm. in total length. The general pattern is more or less the same and the non-sculptured anterior and posterior parts of each segment are well marked even from the earliest stage. In the post-puerulus stage

[1] The nomenclature should according to Holthuis (1963) be *Jasus paulensis* (Heller, 1863).

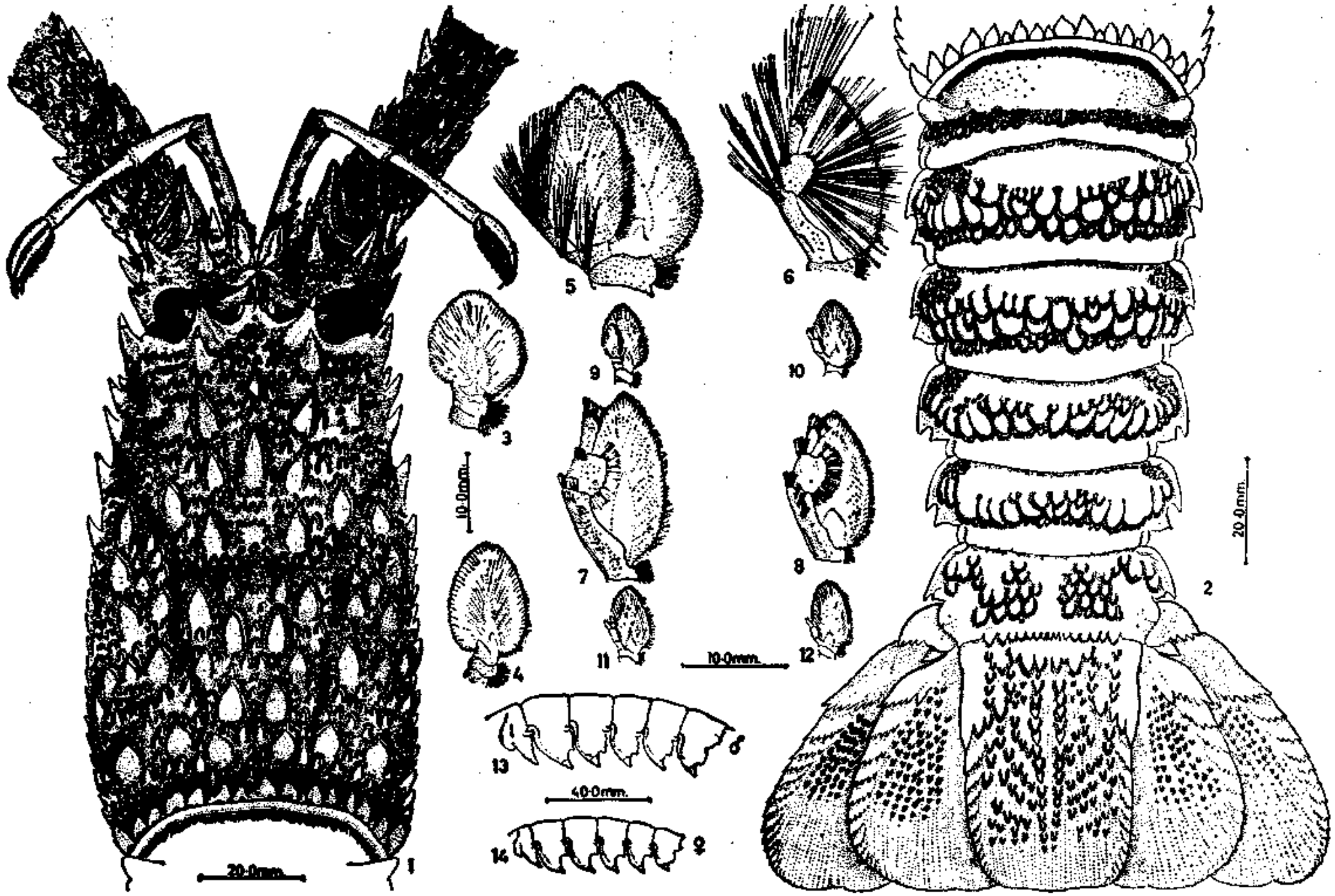


FIG. 2. *Jasus lalandei frontalis* (H. Milne-Edwards).[1] From New Amsterdam Island. (1–2) Dorsal view of carapace and abdomen of male 23·8 cm. in length. (3–4) First and third pleopods of same. (5–8) pleopods one to four respectively of female 15 cm. long (long hairy setae not shown in 3rd and 4th pleopods). (9–12) Pleopods one to four respectively of female 8·1 cm. long. (13–14) Lateral view showing the disposition of epimeres in male 20·2 cm. and female 15·0 cm. long. [1 = *J. paulensis* (Heller)].

(Fig. 4) faint indication of the sculpturation is seen not as uneven surface, but in the colouration of the area by reddish pigments, where the squamiform sculpturation eventually develops. The constancy of this character thus helps to confirm its usefulness as a reliable criteria for separating the representatives of *Jasus* from St. Paul and New Amsterdam Islands from the typical *J. l. lalandei.*

Holthuis (1946), however, remarks that the aforesaid character of squamiform sculpturation [in the case of *J. edwardsii*, and *J. l. lalandei* as given by Parker (1887)] "....is of too little importance to be of specific value." Thus the specimens of *Jasus* from Tristen da Cunha, Juan Fernandez, New Zealand, and St. Paul are considered representatives of one variety of *J. lalandei*, namely *J. l. frontalis* "....differing only in the sculpture of the abdomen." Reference may be made to the section on "Distribution" for further discussion on this point.

3. *Observation on Additional Characters of Juveniles and Adults of* Jasus lalandei frontalis

Carapace.—There appears to be no noticeable difference in the carapace in males and females. However, with age specimens show an enlargement of the spines and spinules. The rostrum is rudimentary and in the male 23·8 cm. figured (Fig. 2: 1) it is abnormal in that it exists as two short-pointed processes instead of one.

Walking legs.—Sexual dimorphism is seen in the nature of walking legs, especially in the fifth pereiopod the propodus which in the male is simple at the distal inner end and the dactylopodite armed along its inner side with spinous hairs (Fig. 3: 18). In the female the fifth pereiopod shows a conspicuous claw-like spine in the distal inner side of the propodus which when juxtaposed with the claw-like dactylopodite gives a subchelate appearance and acts as chelae in berried females helping to keep the eggs clean of foreign matter. After hatching, the egg shells attached to the ovigerous setae of the pleopods are also removed by them.

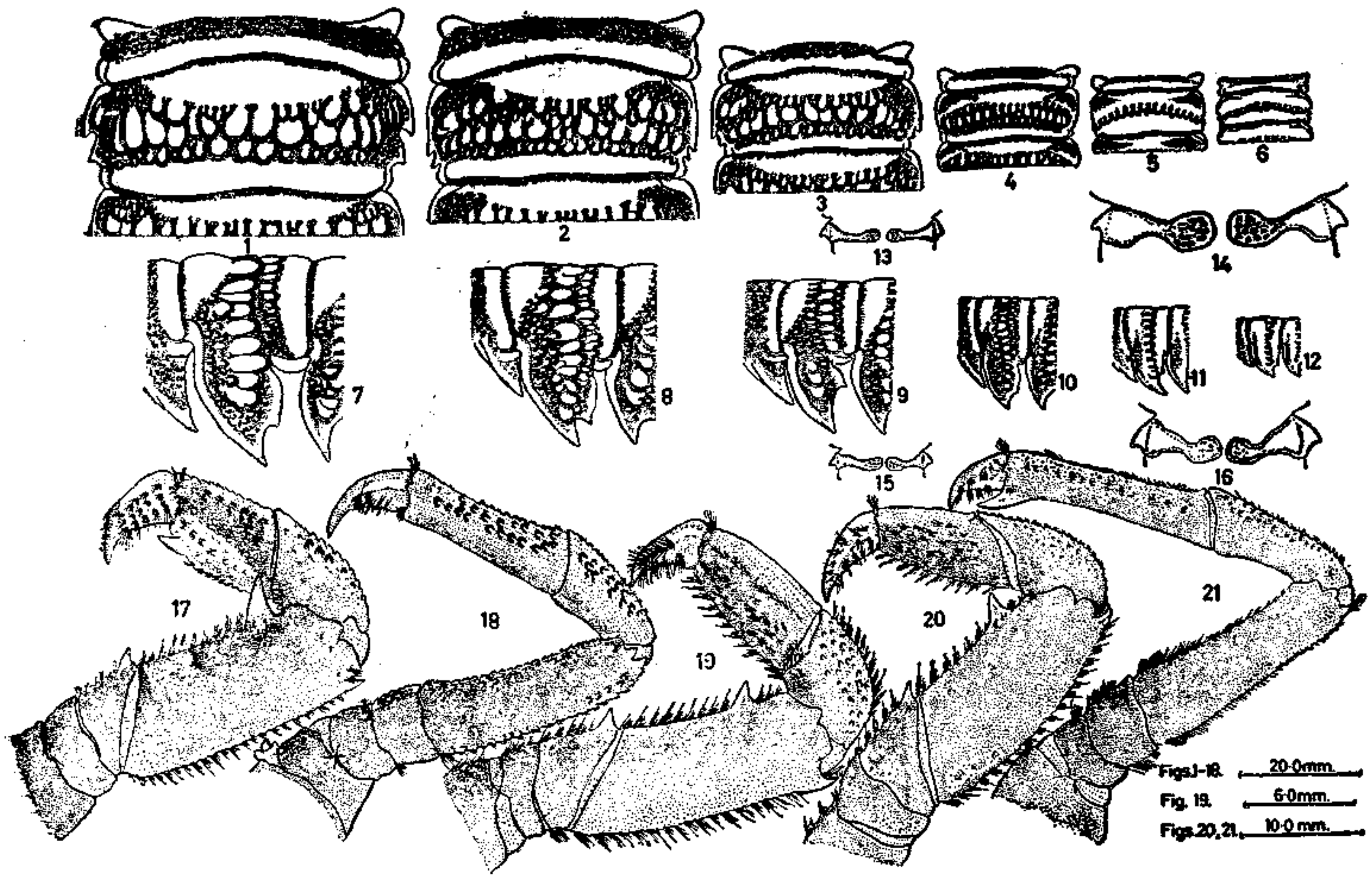
The first pereiopod in the male is robust and short (Fig. 3: 17) and unlike in the female. the propodus is more or less rectangular in outline bearing an enlarged spine at its inner distal end The ischiopodite as well as the meropodite in the male bear a strong claw-like spine each at their distal ends. In the female (Fig. 3: 20–21) the propodite of the first pereiopod is relatively narrower and tapering towards the distal end without any conspicuous spinous process at its distal inner end. The dactylopodite is also relatively smaller, so also the spines on the ischiopodite and meropodite. In a male 103 mm. the propodus of the first pereiopod does not show the strong spine at its distal inner end and as in the female, the propodus slightly tapers distally (Fig. 3: 19).

According to Angot (1951 *a*) the walking legs in the male are relatively longer than in the female.

Abdomen.—The sixth chitinous transverse plate of the tergum of the abdomen immediately preceding the telson in the male carries tufts of short setae at the inner extremities of the two halves. This is evident even in the smallest male in the collection (Text-Fig. 3: 13–14). Angot (1951 *a*) remarks that the tufts of hairs on the chitinous transverse plates are absent in the female. In the present material the large female shows the absence of the tufts of setae (Fig. 3: 16) in the place of which the tergal plates bear a few punctations. The smaller female specimen, however, shows distinct tufts of hairs as in the young and adult males (Fig. 3: 15). It will be interesting to know whether in the female the tufts of setae on the chitinous tergal plates are lost with moulting from young to adult.

The epimeres of abdominal segments of males are directed towards the rear, while in the females (larger specimens especially) they are directed vertically downwards and towards their extremity turned backwards (Fig. 2: 13–14). This difference in the disposition of the epimeres is drawn attention to by Angot (1951 *a*) in larger specimens where the character is still more marked.

The first and third pleopods of the males are figured (Fig. 3: 3–4) in order to show the uniramous condition, the endopodite being absent. The exopodite is broad and leaf-like and the



FIGS. 3. *Jasus lalandei frontalis* (H. Milne-Edwards).[1] From New Amsterdam Island. (1–6) and (7–12) Dorsal and lateral view of abdominal segments showing pattern of squamiform sculpturation in six specimens 23·8 cm. to 5·85 cm. (sequence as given in Table I) in total length. (13–14) Chitinous transverse tergal plates of males 5·85 cm. and 23·8 cm. long showing tufts of hair or setae on expanded symphysial end of plates. (15–16) Same of females 8·1 cm. and 15·0 cm. the former showing the presence and the latter the absence of the setae. (17–18) 1st and 5th pereiopods of male 23·8 cm.. (19) 1st pereiopod of male 10·3 cm. (20–21) 1st and 5th pereiopods of female 15·0 cm. long [1 = *J. paulensis* (Heller)].

inner margin of the protopodite carries elongate setae. In the females the pleopods are biramous, but the pair on the second abdominal segmant have the exopodites and endopodites equally well developed, being broad and leaf-like (Fig. 3: 5). The pleopods of the third, fourth and fifth somites have undeveloped endopodites which are narrower, three segmented, and provided with long ovigerous setae to assist in the attachment of eggs when the lobster is in berry. The pleopods of a very small female measuring 85 mm. shows the endopodite of the second somite to be considerably smaller than the exopodite and devoid of the marginal elongate setae. The endopodites of the second, third, and fourth pleopods are relatively shorter and rod-like breft of the long setae. For the purpose of comparison, drawings made to scale of these along with the pleopods of an adult female are given side by side (Fig. 2: 5–8 and 9–12).

Grua (1964) has drawn attention that at St. Paul and New Amsterdam Islands after egg-laying (May and June) and hatching takes place (August and September), the ovigerous setae become very variable in size on account of damage caused to them by the animal while removing the empty egg shells. Pilosity becomes complete again during the southern summer as a result of a moult distinct from the prebreeding moult.

Other sexual differance that can be noticed externally is the genital opening of the male which is situated on the coxopodites of the fifth pereiopod and the female on the coxopodites of the third pereiopods.

Description of Early Post-Puerulus Stage of *Jasus lalandei frontalis*[1] from New Amsterdam Island

From a rock pool at New Amsterdam Island it was possible to collect a 27·5 mm. specimen, the measurements of which are given in Table I. There is no description of the puerulus stage or early post-puerulus stage of *J. l. frontalis* from St. Paul and New Amsterdam Islands, except a brief mention by Pesta (1915) of the occurrence of such early stages in these islands and hence it is felt that the description given here may be of interest. The specimen (Fig. 4) has a light yellow body colour except the carapace and alternating bands on the antenna which are faintly reddish. Very rudimentary spinulation is seen on the carapace and the groove separating the cephalic and thoracic regions is clearly visible. Tuberculations or timble-shaped processes bearing short setae between the rudimentary spines of the carapace are absent at this stage. The setae on the dactylopodites of the pereiopods are well developed at this stage, but for which the pereiopods are smooth. As already mentioned the squamiform sculpturation on the sterna of the abdominal segments are not developed although their position is indicated by a faintly red-pigmented band along almost the middle of each segment. The sternum of the segments also show minute punctations which are not seen in adults. The telson and uropods are well developed and show the lateral marginal spinous serrations seen in the adults as well as rudimentary spinulations along their dorsal surface. The expodites and the endopodites of the pleopods are large, leaf-like and bear elongate feather-like setae. Each pleopod also possesses an appendix interna with coupling hooks.

In the case of the typical *J. l. lalandei* from South Africa, Von Bonde, C. (1936) mentions that the phyllosoma 35 mm. long changes into a puerulus of 22 mm. At this stage the puerulus resembles the adult in all characteristics except that the pleopods show difference as at this stage swimming in the animal is carried out mainly by the pleopods and not the telson and uropods as in the adults. The coupling hooks of the appendix interna join together the pleopods in pairs to form efficient swimming organs.

Phyllosoma Stages of *Jasus lalandei frontalis*[1] from the Southern Indian Ocean

In the accompanying map (Fig. 5) the locations from where phyllosoma larvae of *J. l. frontalis* were collected in surface plankton hauls at night are shown. These phyllosoma stages are pre-

[1] The nomenclature should according to Holthuis (1963) be *Jasus paulensis* (Heller, 1863).

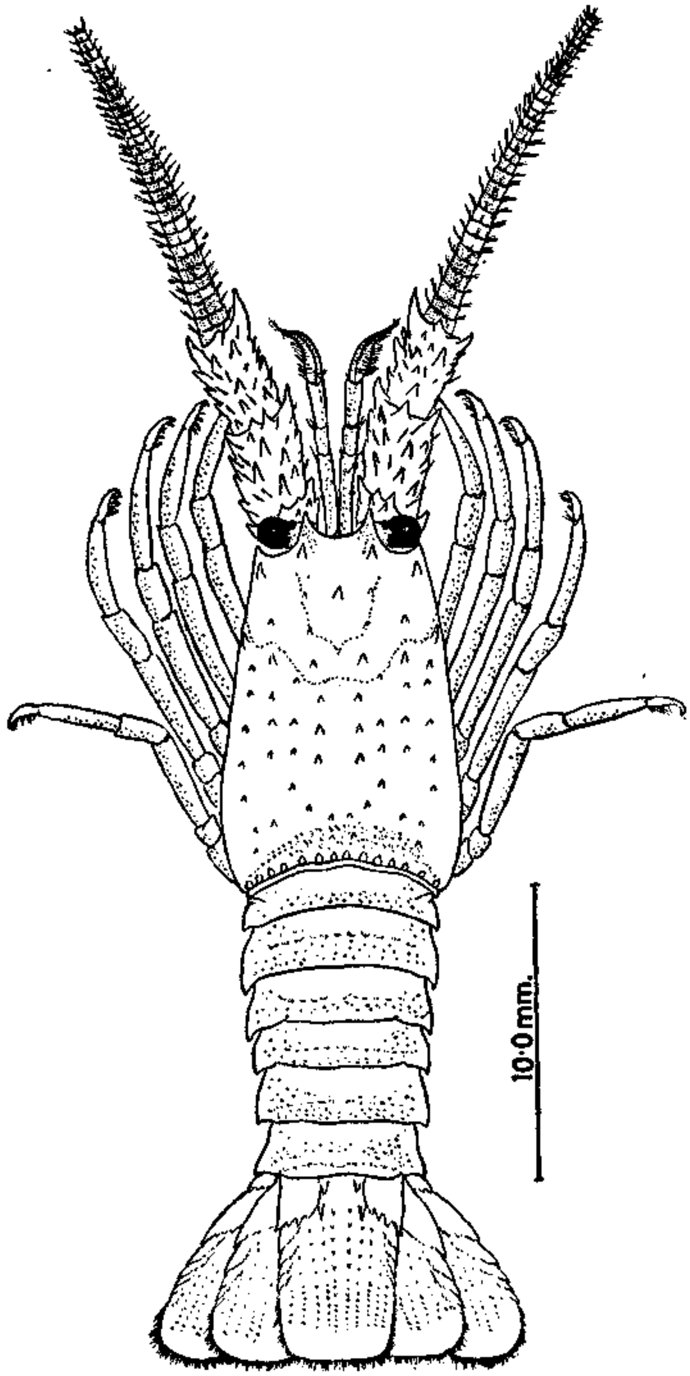


FIG. 4. *Jasus lalandei frontalis* (H. Milne-Edwards).[1] Early post-puerulus stage measuring 27·5 mm. in total length from New Amsterdam Island [1 = *J. paulensis* (Heller)]

sumed to belong to the variety *J. l. frontalis* mainly on account of their being taken in the vicinity of St. Paul and New Amsterdam islands where as already mentioned only this variety of *Jasus* is known to occur at present.[1] The possibility that the larvae could be of the typical form *J. l. lalandei* from South Africa is rather remote as shall be discussed later in the section 'Distribution'.

In Table II the salient measurements of the phyllosoma stages are given with other details, and Fig. 6 gives the drawings of the three stages in the collection. These stages correspond with stages X, XI and XII provisionally recognised by Gurney (1936). These stages are arbitrary as no hard and fast line can be drawn between the successive stages due to the partial overlap in lengths.

TABLE II

(Measurements of phyllosoma larvae in millimetres)

Characters	Southern Indian Ocean (present collection) 1	2	3	Southern Atlantic Ocean (after Gurney, 1936)* 1	2	3	4	5	6
Date ..	2-4-1964	2-4-1964	10-4-1964	..	..	..	..	..	..
Stage ..	X?	XI?	XII?	X	X	X	XI	XI	XII
Total length ..	18·6	21·5	25·9	16·85	17·80	19·65	22·75	22·90	28·5
Pre-labral length ..	7·8	9·0	10·5	7·3	7·8	8·7	9·75	9·5	12·0
Post-labral length ..	10·8	12·5	15·4	9·55	10·0	10·9	12·95	13·5	16·5
Antennule peduncular Seg. 1 ..	0·9	1·1	1·25	2·47	2·55	2·65	2·32	3·37	2·29
" " Seg. 2 ..	0·3	0·35	0·45	1·0	1·0	1·0	1·0	1·0	1·0
" " Seg. 3 ..	0·4	0·5	0·7	1·1	1·24	1·14	1·13	1·12	1·13
Antennule exopod ..	1·4	1·7	2·2	3·85	4·1	4·25	3·75	3·48	3·9
" endopod ..	0·3	0·55	0·9	1·2	1·43	1·45	1·67	1·4	2·5
Eye ..	2·0	2·4	3·0	2·3	2·4	2·4	2·5	2·65	3·0
Eye stalk ..	3·0	3·7	4·3	3·4	2·8	3·7	3·7	4·2	4·7
Antenna ..	5·2	6·8	9·3	5·6	..	6·2	8·1	8·4	11·0
Width of forebody ..	14·0	15·9	18·3	..	..	..	..	..	..
Width of hind body ..	6·0	7·0	8·7	..	..	..	..	..	..

* Out of the measurements of 9 specimens of *Jasus lalandii* given by Gurney (1936) in his Table VIII, the six taken here correspond to more or less the stages in the present collection. The remaining three specimens given by Gurney belong to stages VIII, IX and XIII, being 10·4, 12·95 and 37·5 mm. long respectively.

The complete developmental stages is not known for *J. lalandei* or *J. verreauxii*. The embryonic development and early post-embryonic stages of *J. l. lalandei* and a few of the phyllosoma stages are known chiefly through the works of Gilchrist (1913, 1916), and Von Bonde, C. (1936). Information on *J. verreauxii* is scanty. In order to facilitate comparison, the phyllosoma stages of *J. lalandei* described by Von Bonde, C. (1936), Gurney (1936), Lebour (1954), and Prasad and Tampi (1959) are given here along with the figure of an early phyllosoma stage of *J. verreauxii* taken from Dakin and Colefax (1940) (Figs. 7, 8 and 9).

When the measurements for the present specimens given in Table II are compared with measurements of phyllosomas of *J. lalandei* given by Gurney (1936) (corresponding stages of which are included in Table II) some disparity is seen in the relative proportions of some of the body characters,

[1] The nomenclature should according to Holthuis (1963) be *Jasus paulensis* (Heller, 1863).

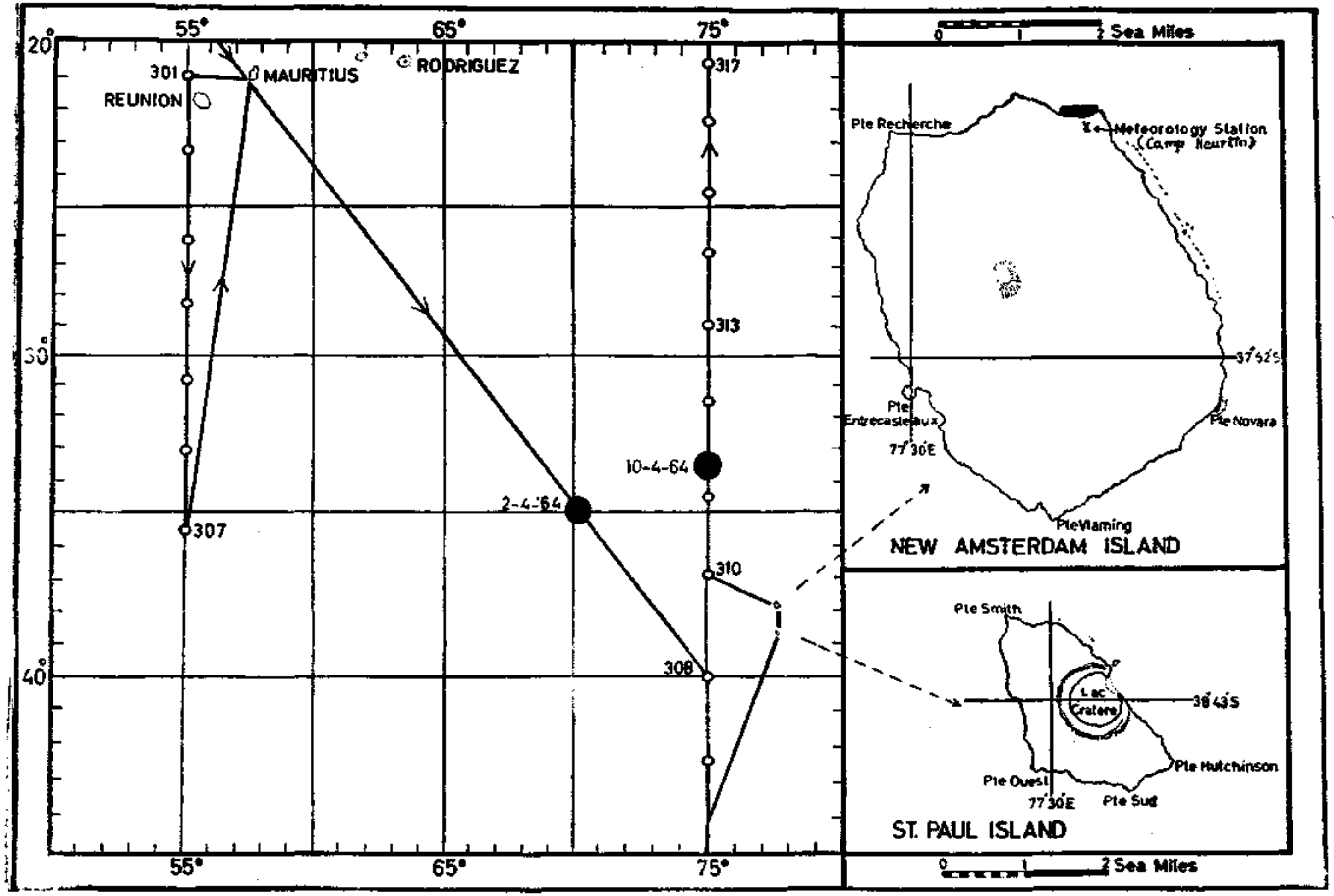


FIG. 5. Map showing a part of the track chart of the V Cruise of the U.S. Research Vessel *Anton Bruun* and the localities with dates (black circles) from where phyllosomas of *J. l. frontalis*[1] were collected. Insert maps show the islands of St. Paul and New Amsterdam, and in the latter island the shaded area indicates the place from where lobsters were collected for the present study [1 = *J. paulensis*].

This is especially pronounced in the antennule, the exopod and endopod being markedly longer in comparable specimens from off Tristan da Cunha. It is difficult to say whether this could be due to the fact the phyllosomas belong to two distinct varieties of *J. lalandei* or due to differences in the mode of taking measurements. I have used a dial calliper measuring to the nearest tenth o a mm. under a binocular microscope. As will be seen from the drawings of the three specimen in the collection (Fig. 6: 2–4) a progressive increase in the segments of the antennule and th endopod and exopod is seen in relation to size.

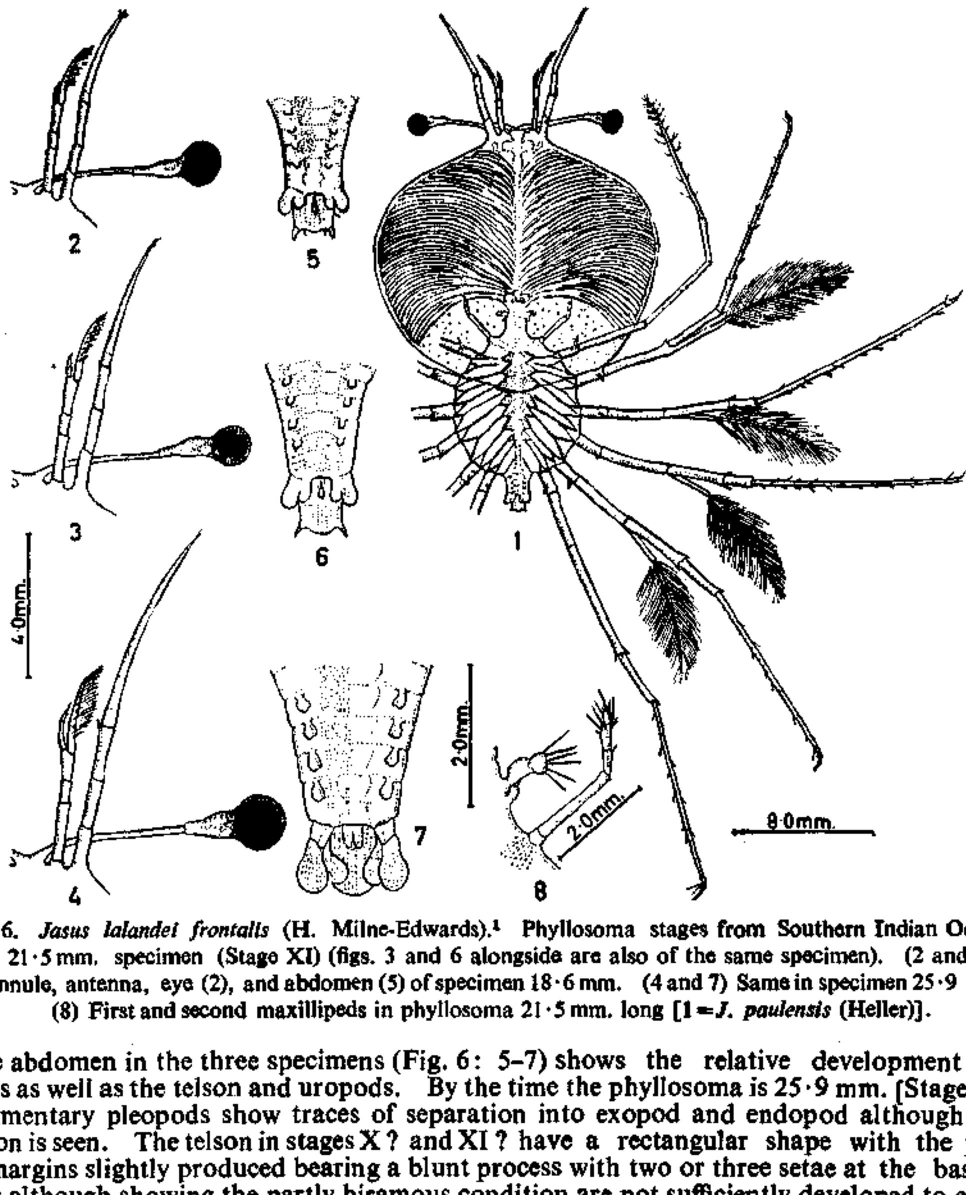


FIG. 6. *Jasus lalandei frontalis* (H. Milne-Edwards).[1] Phyllosoma stages from Southern Indian Ocean. (1) 21·5 mm. specimen (Stage XI) (figs. 3 and 6 alongside are also of the same specimen). (2 and 5) Antennule, antenna, eye (2), and abdomen (5) of specimen 18·6 mm. (4 and 7) Same in specimen 25·9 mm. (8) First and second maxillipeds in phyllosoma 21·5 mm. long [1 = *J. paulensis* (Heller)].

The abdomen in the three specimens (Fig. 6: 5–7) shows the relative development of the pleopods as well as the telson and uropods. By the time the phyllosoma is 25·9 mm. [Stage XII (?)] the rudimentary pleopods show traces of separation into exopod and endopod although no segmentation is seen. The telson in stages X? and XI? have a rectangular shape with the posterolateral margins slightly produced bearing a blunt process with two or three setae at the base. The uropods although showing the partly biramous condition are not sufficiently developed to extend to the level of the posterior margin of the telson. This is seen in stage XII? where the posterior margin of the telson is rounded. The biramous condition of the uropods is well developed and so also the basal segment.

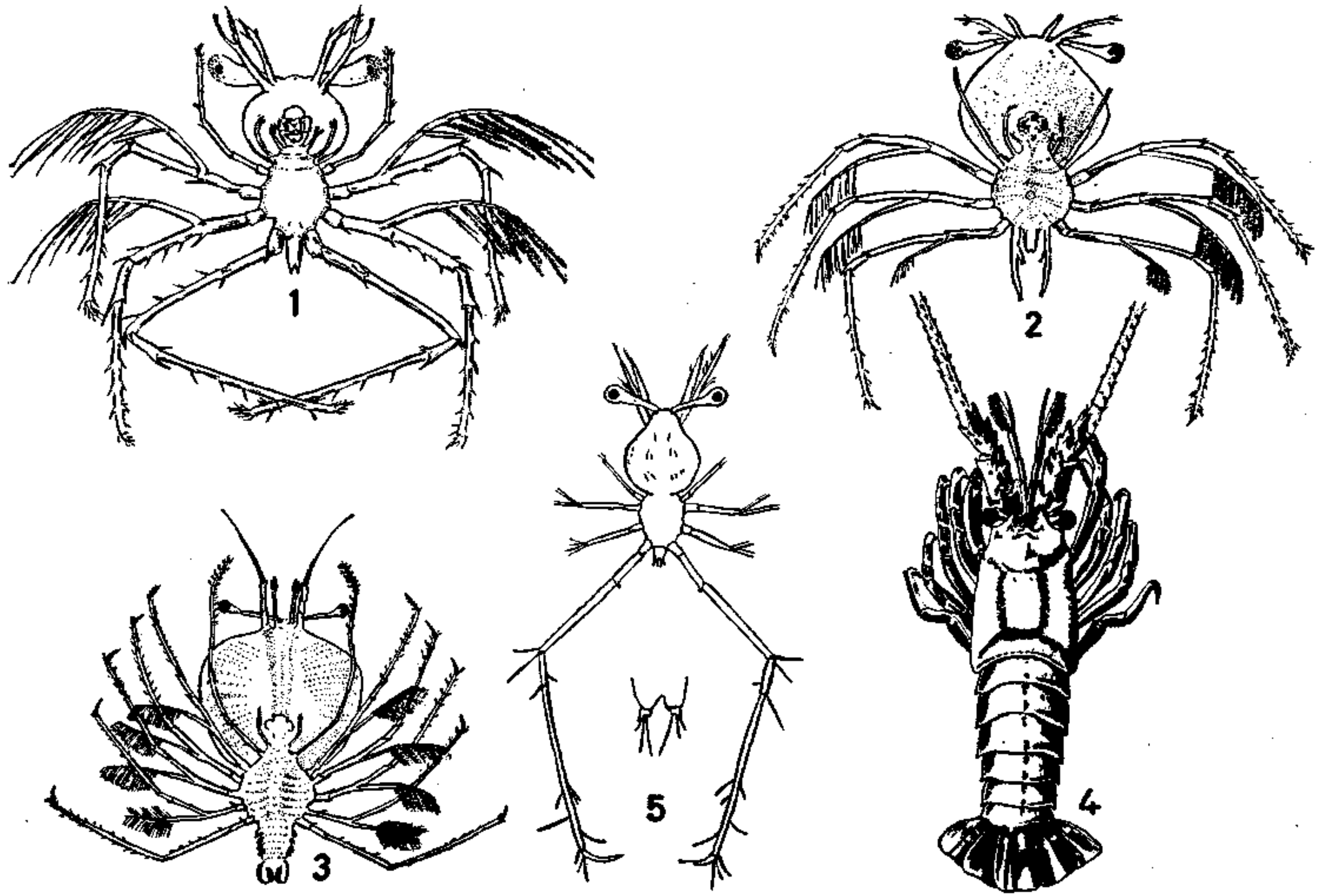


FIG. 7. *Jasus lalandei lalandei* (H. Milne-Edwards). (1–3) Phyllosoma stages (after Von Bonde, C., 1936). (4) Puerulus stage 22 mm. long (after Von Bonde, C., 1936) 1–4 from South African waters. (5) Early phyllosoma stage from Bengula Current (after Lebour, 1954).

Prasad and Tampi (1959) are the first to record *Jasus lalandei* from the tropical waters of the northern hemisphere, namely the Laccadive Sea based on two larvae 1·5 mm. each obtained in plankton haul from *R. V. Kalava* Station No. 448. The figure of the larva reproduced here (Fig. 9) illustrates the point drawn attention to by the authors that the antenna is shorter than the antennule. The antenna is also shorter than the eye which has not yet developed a distinct stalk at this stage. In similar sized (1·5 and 1·7 mm.) larvae of the typical form *J. l. lalandei* from South Africa described by Von Bonde, C. (1936), and Von Bonde, C. and Marchand (1935), the antenna is slightly longer than the antennule and the eye (*see* Figs. 7 and 9).

Distribution of the Genus *Jasus* Parker

The genus *Jasus* Parker has a circumglobular distribution in the southern hemisphere from south of the Tropic of Capricorn to about 46° S. latitude, the only exception being the record of larvae of *J. lalandei* from the Laccadive Sea by Prasad and Tampi (1959). Chace and Dumont (1949) published a map showing the world distribution of spiny lobsters of the family Palinuridae (Fig. 10). However, from the present study of the distribution of *Jasus*, one of the genera of Palinuridae, it is seen that the limits of the distribution of the family given by these authors need modifications. As such a revised distributional map for the family is given here (Fig. 11), along with another showing the distributional limits of the genus *Jasus* (Fig. 12). For the exact distributional limits of the adults reference may also be made to the exhaustive list of localities given under the respective species by Holthuis (1946).

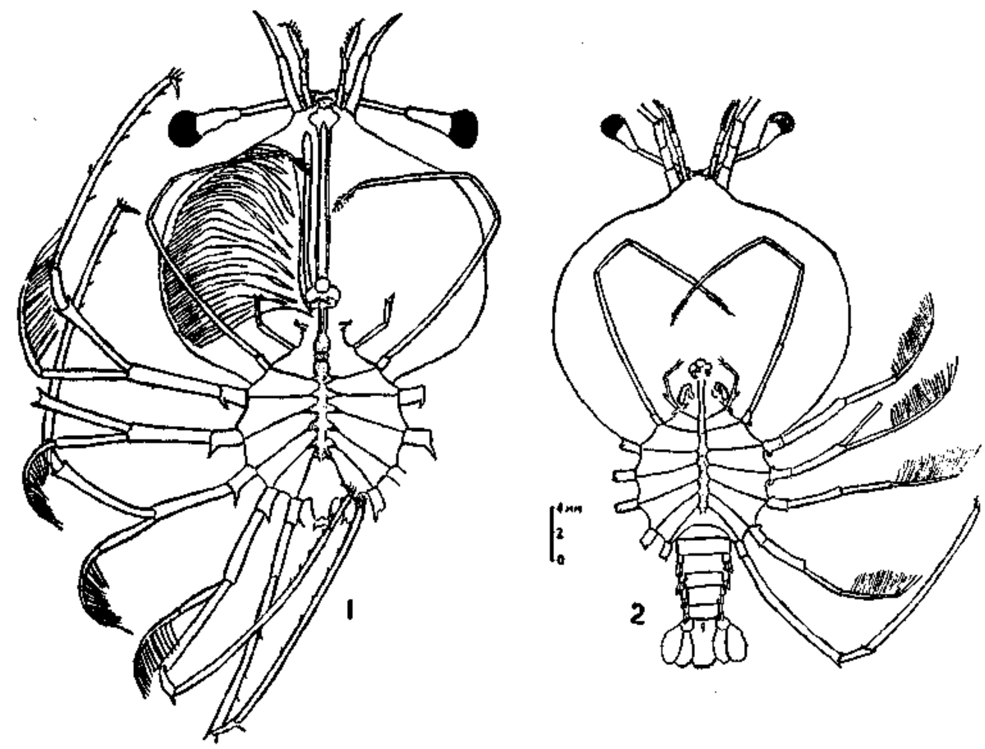


FIG. 8. *Jasus lalandei frontalis* (?). Phyllosoma stages. (1) *Jasus lalandii*, Stage VIII ?, 11 mm. from Discovery Stn. 254 (after Gurney, 1936). (2) Stage XIII ? 37 mm. from Discovery Stn. 100 B. 1–2 from the Southern Atlantic Ocean (after Gurney, 1936).

The distributional pattern of *J. lalandei* when plotted on Lambert's Azimuthal Equal-Area Projection Maps of the antarctic and subantarctic regions (Fig. 13) shows that:

1. St. Paul and New Amsterdam Islands lie almost on the boundary line between the subtropical and subantarctic zones, the mean position of the subtropical convergence on the 77° longitude lying only a few miles south of these islands.

2. A scrutiny of the known distributional limits of the two varieties of *Jasus lalandei*, namely *J. l. lalandei* and *J. l. frontalis* shows an allopatric pattern of distribution. The typical variety is confined to parts of South and South-West Africa, and South-West and South-East Australia, while *J. l. frontalis* is primarily an insular variety, being known from St. Paul and New Amsterdam Islands; New Zealand and Islands in the vicinity such as Stewart Island, and Chatham Island, Juan Fernandez, San Ambrosa and San Felix Islands off Chile, and Tristan da Cunha in the South Atlantic.

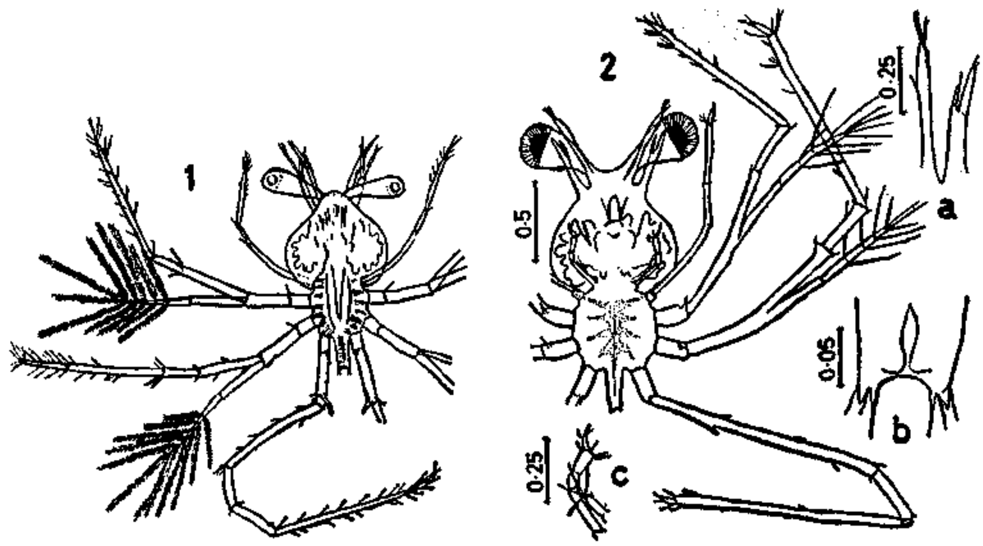


FIG. 9. Phyllosoma stages of *Jasus*. (1) Early phyllosoma stage of *Jasus verreauxii* (H. Milne-Edwards) from Australia (after Dakin and Colefax, 1940). (2 *a–c*). Phyllosoma Stage I of *Jasus lalandii* from the Laccadive Sea (*a*—antennule and antenna, *b*—abdomen, *c*—first and second maxillipeds) (after Prasad and Tampi, 1959).

J. verreauxii on the other hand shows a sympatric distribution occurring along with *J. l. lalandei* along the coasts of New South Wales and Victoria, and is also reported by some to occur in New Zealand. This then is the general pattern of distribution, but several problems need elucidation, such as the status of *J. lalandei* occurring in South-West Australia; whether or not mixed populations of *J. l. lalandei* and *J. l. frontalis* occur in New Zealand; whether the insular populations provisionally treated here under one variety, namely *J. l. frontalis* are in fact endemics in the respective areas and eventually may have to be considered as good varieties or subspecies [*e.g., J. l. paulensis* from St. Paul and New Amsterdam Islands; *J. l. edwardsi* from New Zealand; *J. l. frontalis* from 'Chile' (Juan Fernandez), etc.] or species. Some of these shall be discussed presently.

3. From Fig. 13 it will be seen that the insular areas from where adults of *J. l. frontalis* are known to occur lie almost in the same latitudes within the northern part or outer limits of the subantarctic zone and only exceptionally as in the case of St. Paul and New Amsterdam Islands do they lie just north of the mean line of subtropical convergence. This contrasts with the distribution of the typical form *J. l. lalandei* which in Australia and South Africa lie well above the line of subtropical convergence.

4. Knox (1960) has given the mean winter and summer sea surface isotherms for the southern oceans and when seen in relation to this (Figs. 14 and 15) the distribution of the typical

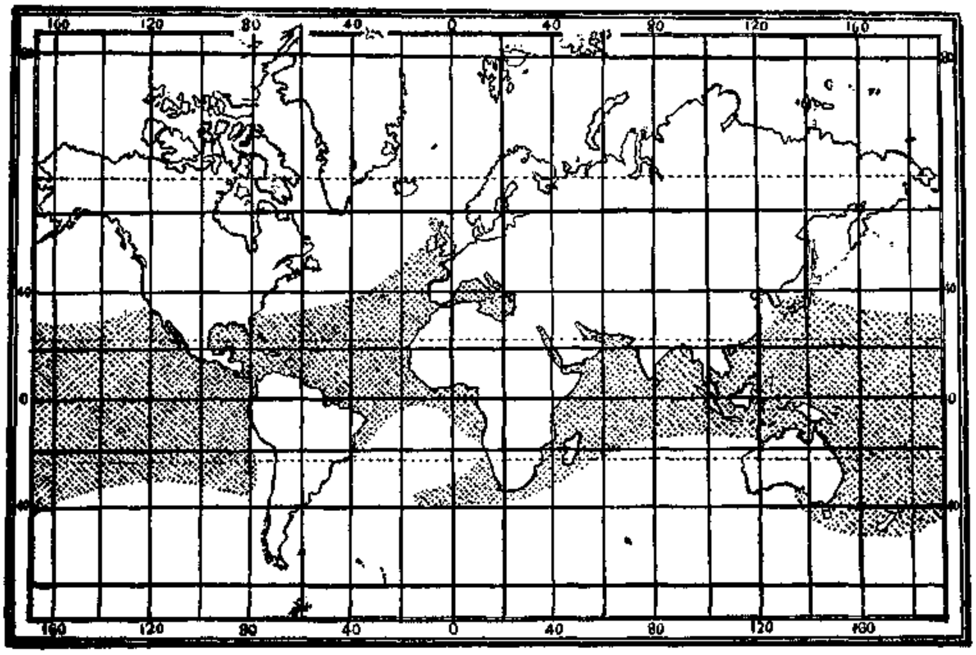


Fig. 10. Map showing the world distribution of spiny lobsters of the family Palinuridae (after Chace and Dumont, 1949).

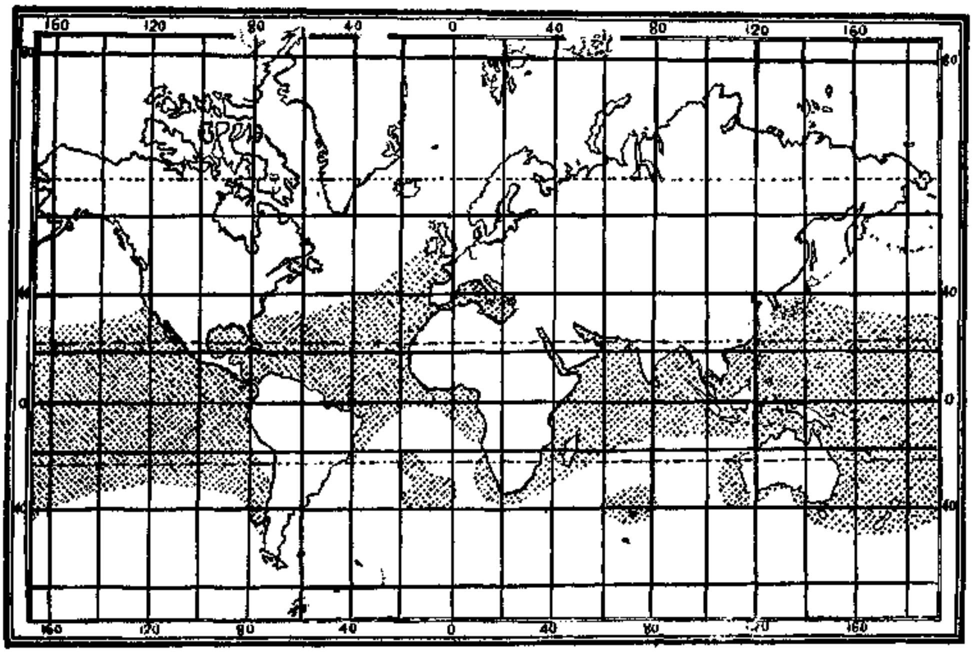


Fig. 11. Revised map showing the world distribution of spiny lobsters of the family Palinuridae.

J. l. lalandei is found to lie within the mean summer and winter sea surface isotherms of 15° and 20° C. during both seasons, except in the area around Southern Tasmania where it is even less than 12° C. during winter. In the case of *J. l. frontalis* the areas fall within the mean sea surface summer isotherms of 15° C. to less than 20° C. and mean sea surface winter isotherms of 10°–15° C. Knox (1960) has also given the coastal water types of the southern temperate and antarctic regions (Fig. 16) from which it will be seen that the distribution of the genus *Jasus* is predominantly restricted to the "Cold temperate mixed water", and rarely infringes into the "Subantarctic cold temperate water type" or into the "Transitional warm temperate water type".

5. On the basis of his studies on the littoral ecology and the biogeography of the southern oceans, Knox (1960) proposed certain biogeographic subdivisions of the southern temperate and antarctic regions mainly based on characteristic temperature and salinity ranges and water masses (Fig. 17) according to which St. Paul and New Amsterdam Islands and the entire distributional areas of the genus *Jasus* come under the "Cold temperate regions" (exceptions being the small area south-east of the Cape of Good Hope, Union of South Africa and along south-west coast of Australia which come under the "Warm temperate transitional regions".

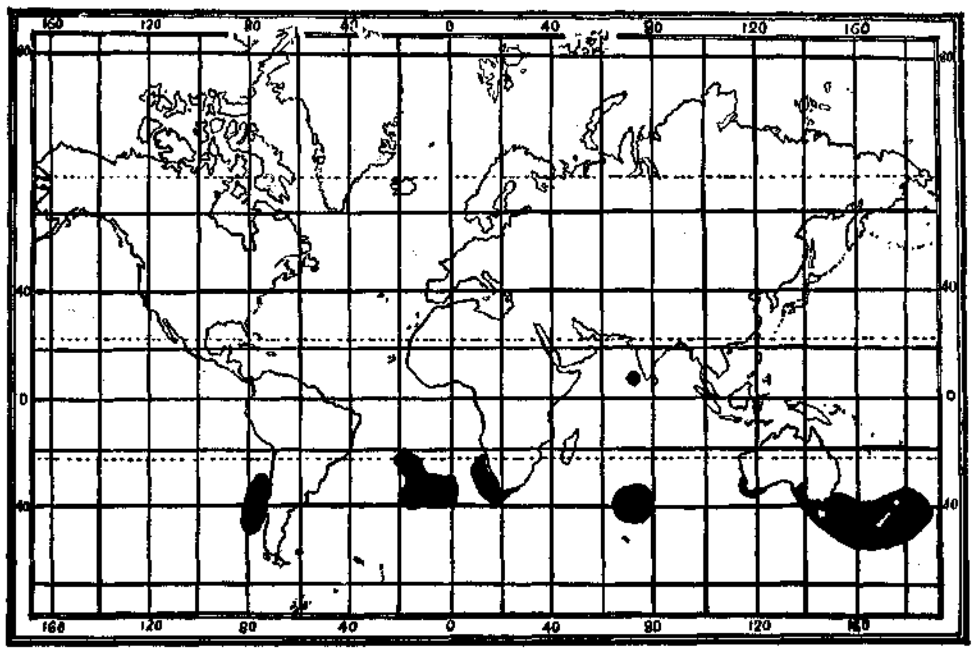


FIG. 12. Map showing the world distribution of spiny lobsters of the genus *Jasus* Parker (Areas from where larvae have been collected are also included).

6. The influence of the 'West Wind Drift' and the connected cold currents adjacant to the land masses in the southern hemisphere on the dispersal and distribution of the subantarctic faunal and floral elements has been repeatedly drawn attention to even recently by several authors at the conference on "A discussion on the biology of the southern cold temperate zone" (Deacon, 1960; Du-Ritez, 1960; Godley, 1960; Holdgate, 1960; Knox, 1960; Mackintosh, 1960; Wace, 1960; and others). A diagrammatic representation of the principle ocean currents as given by Knox (1960) is reproduced here (Text-Fig. 18) to indicate the possible role the 'West Wind Drift' and associated currents could have had or could have on the present-day distribution of *Jasus*. A further discussion is given in the section "Larval Distribution".

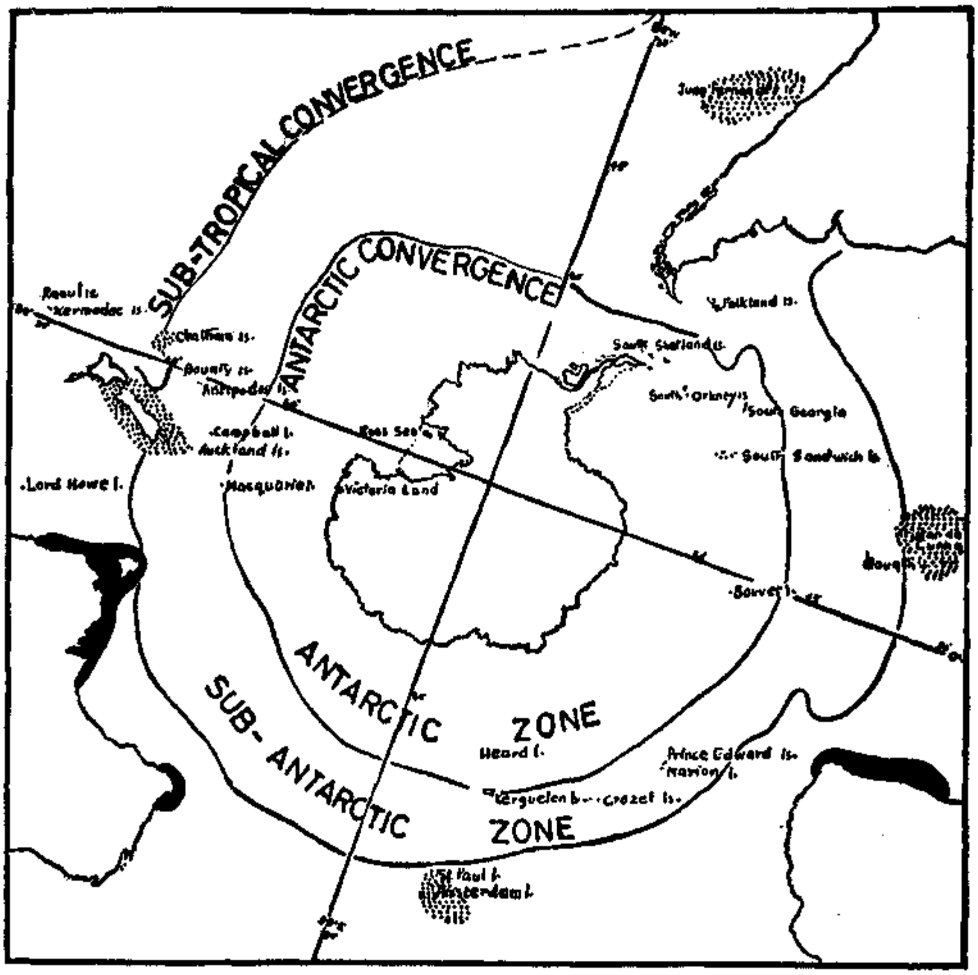


FIG. 13. Map showing the distribution of *Jasus lalandei lalandei* (blackened areas) and *J. l. frontalis* (stippled areas). The insular occurrence of the latter may be noted.

LARVAL DISTRIBUTION OF *Jasus* PARKER

The importance of studying the distribution pattern of phyllosoma larvae of spiny lobsters which could be good indicators of ocean currents and water masses has been stressed in recent years by many workers (Lewis, 1951; Lewis *et al.*, 1952; Thorson, 1960; Ingle *et al.*, 1963; and others). Ingle *et al.* (1963) in a preliminary study of the possible Carribean origin of Florida's spiny lobster (*Palinurus argus*) populations have stressed the significance of water currents on population recruitment and suggested the usefulness of studies in widely separated areas on the availability (or non-availability) of various phyllosoma stages in particular waters, as such studies may help to elucidate or identify current patterns as the long larval life span and the duration of well-differentiated stages may provide a very good natural device for establishing the directions of flow and rate of movement of water masses. In identifying water masses with such planktonic indicators, one point raised by Grice and Hart (1962) needs bearing in mind, namely that some knowledge of the reproductive cycle and longevity of the species is often valuable in deciding whether it is indicating recent or possible old intrusion of water into an area. In the case of the genus *Panulirus*, Thorson (1960) remarks that the phyllosoma of some species have a pelagic life of 150–180 days, for instance, Lewis (1951) found that the larval development in *P. argus* is completed in approximately six months, while in the allied species *P. interruptus* from the California coast Johnson (1951) found that it took slightly less than eight months for the completion of the larval development. Thorson (1960) opined that it is this prolonged planktonic phase of its life-history that has enabled some species of the genus *Panulirus* to show a circumtropical distribution.

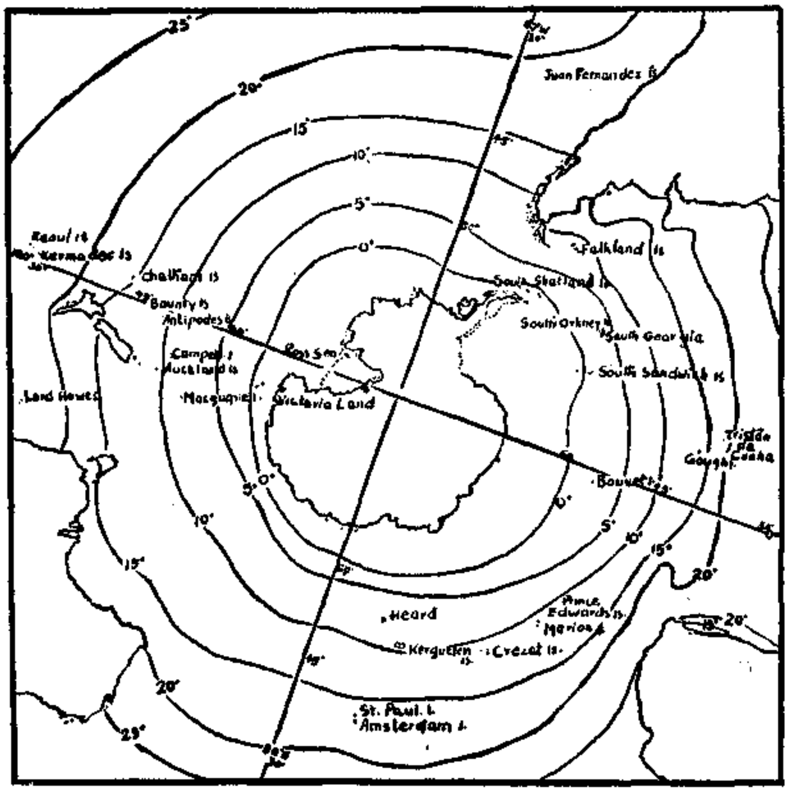


FIG. 14. Mean summer sea surface isotherms for the southern oceans (5° C. intervals) (after Knox, 1960).

Surprisingly enough, although a species of the genus *Jasus* (*J. lalandei*) is the most important commercially exploited species of spiny lobster in the world, the available information regarding the planktonic phase of its life-history is far from complete. First there is still doubt as to the total number of larval stages that may be recognised for *Jasus* though tentatively 13 stages are recognised by Gurney (1936). But for some information about the duration of the prenaupliosoma stage, and naupliosoma stage (Stage II), the actual duration of the various phyllosoma stages in nature is fragmentary and often speculative.

The description of larval stages by Thompson (1907), Anderton (1907), Archey (1916), Gilchrist (1913, 1916), and Von Bonde, C. (1936), refer to collections from coastal waters or a few stages observed in captivity. Von Bonde, C. (1936) mentions that "I have been able to obtain phyllosomata of various sizes betwean 3·8 mm. and 24 mm. and they are to be described in a paper entitled "Experiments in artificial hatching and rearing of the cape crawfish *Jasus lalandei*", *Inv. Rept. No.* 9, *Fish and Mar. Biol. Surv., South Africa* (in preparation)." Probably this report has not yet been published, as I have been unable to find any subsequent reference to it. All this is to show the fragmentary nature of the information available.

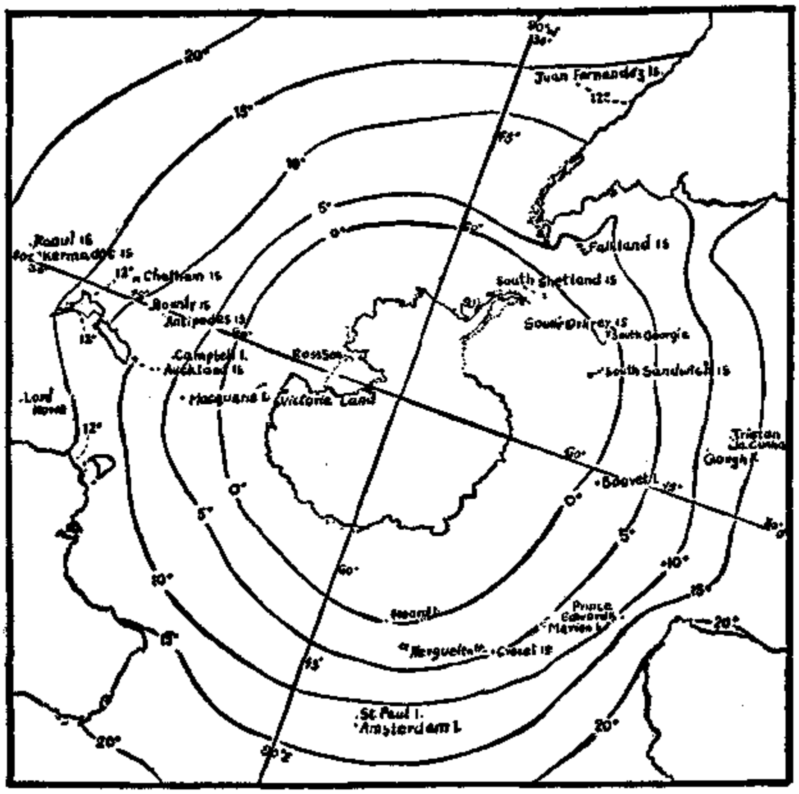


FIG. 15. Mean winter sea surface isotherms for the southern oceans (5° C. intervals) (after Knox, 1960).

Gurney (1936) who found the growth factor in six groups of phyllosoma larvae ranging from 10·4–35 mm. to be 1·3 or less, recorded a small phyllosoma of *Jasus lalandei* (Stage VII ?) about 900 miles North-West of Tristan da Cunha with the remarks that "Unfortunately, as the series of larva is so incomplete, one can only guess at the age as expressed in the number of stage and I am by no means satisfied at the assumption that the larva is in Stage VIII is correct. At all events it cannot be older. We know too little about the age and duration of stages to estimate the age in days, but a guess of six weeks may be fairly near the truth, in any case there is evidence of rapid and extensive travel." He also refers to three specimens of puerulus stage of *J. lalandei* caught at 250 meters depth about 170 miles from land where the ocean depth is over 3,000 metres, and of larvae collected from great depths of 2,480–2,580 metres which were all found to be in the last stage prior to metamorphosis into the puerulus stage.

In the present instance, the phyllosomas collected on the night of 2–4–1964 from 35° 45′ S. 70° 36′ E. were from about 390 and 435 miles from New Amsterdam and St. Paul Islands respectively. The one takan on 10–4–1964 from 33° 22′ S., 74° 56′ E. is about 270 and 345 miles north of New Amsterdam and St. Paul Islands respectively. The scarcity of the material does not permit an assessment of the probable duration that the larvae had taken to attain the sizes and stages indicated in Table II.

The known occurrence and distribution of the phyllosoma stages of *Jasus* in the Indian Ocean and the Southern Atlantic and Pacific Oceans suggest the following.

1. The general non-occurrence of phyllosoma stages of *Jasus* south of the sub-tropical convergence is interesting and probably points to the transportation of the larvae from the breeding grounds towards the sub-tropics aided by the 'West Wind Drift' and connected currents flowing northwards. Perhaps this also accounts for the non-occurrence of *Jasus* on Gough Island only 352 km. south of Tristan da Cunha; Kerguelen Island south of St. Paul Island; and Macquarie Island, Campbell Island, etc., south of New Zealand. Associated with the currents, temperature may play an important role in limiting the distribution southwards. However, the great depth from which phyllosome of *Jasus* have been collected (Gurney, 1936) indicate that the lower temperatures may be a limiting factor for the earlier stages while later stages may occur in depths where the water temperature is even lower than 10° C.

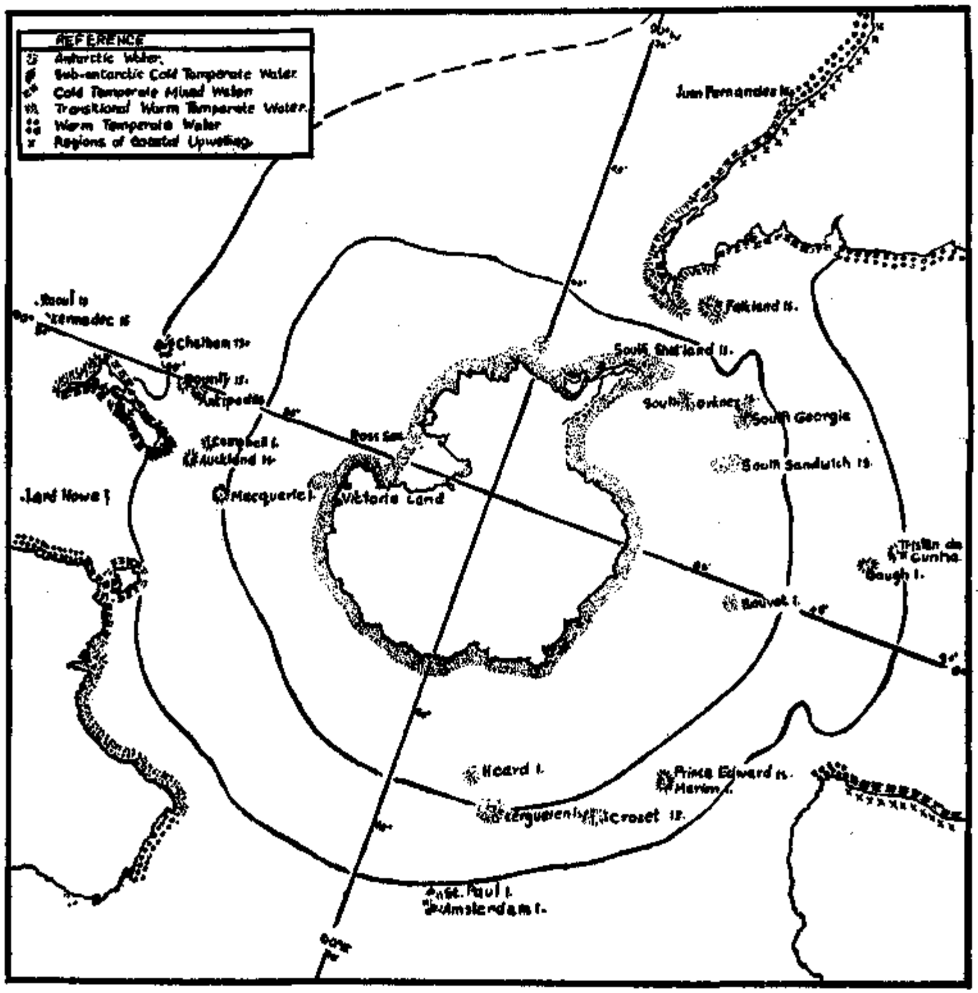


FIG. 16. Coastal water types of the southern temperate and antarctic regions (after Knox, 1960).

2. It appears likely that in the southern Atlantic and southern Indian Oceans, the larvae which are carried away from the islands by the currents are brought back to the islands caught in an "eddy system" during which period development and metamorphosis to the puerulus stage are completed. This could account for the apparently 'endemic' insular distributions of *J. l. frontalis*. The same could also apply to Juan Fernandez Island in the South-Eastern Pacific.

3. That metamorphosis into the actively swimming puerulus stage could take place far out at sea (as much as 170 miles from land over deep water) is clear from Gurney's work (Gurney, 1936). However, the significance of this is not fully understandable as in many other species of allied genera the pueruli first appear in shallow water. In the case of the intensively studied species *Panulirus argus*, Lewis *et al.* (1952) mention of only one instance where a single specimen in the puerulus stage was taken in plankton hauls in the Gulf Stream off Miami and opines that it seems certain that this stage is not normally planktonic.

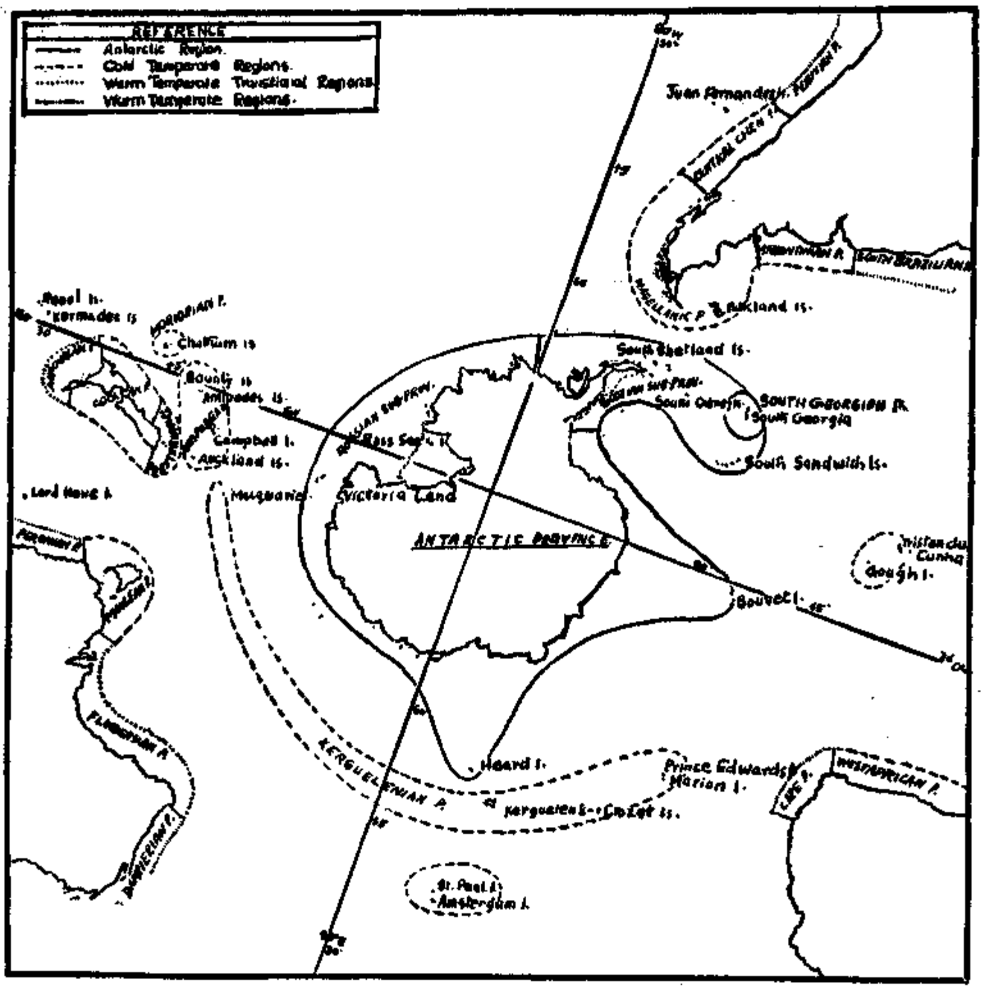


FIG. 17. Biogeographic subdivisions of the southern temperate and antarctic regions proposed by G. A. Knox, 1960.

4. A plausible explanation of the occurrence of very early stage of the larvae of *Jasus* in the tropical waters of the Laccadive Sea is a possible equatorial transgression of the genus at some earlier date and subsequent isolation. The possibility of such an equatorial transgression of the larvae at present from the area of New Amsterdam and St. Paul islands or even South Africa can be ruled out on account of the very early stage (1·5 mm.) of the larvae. Besides, the intervening warm south and north equatorial currents would only act as effective barriers for the distribution of the planktonic larvae. Whether an equatorial transgression of the genus could have taken place during

the late Pleistocene when there had been periodic oscillations in the equatorial Atlantic and Pacific and probably also the Indian Ocean with an amplitude of 6° C. may be considered. The work of Emiliani (1958) based on Radio-Carbon dating of more recent sections of deep-sea cores show that the surface waters were particularly cool about 15,000 years ago whan the tropical surface waters were about 6° C. cooler than at present. Prasad and Tampi (1959) have shown that the cooler waters at depths of about 200 metres in the Laccadive Sea may not rule out the possibility of *Jasus* occurring there. Adults have never been reported from this area, and more information is needed.

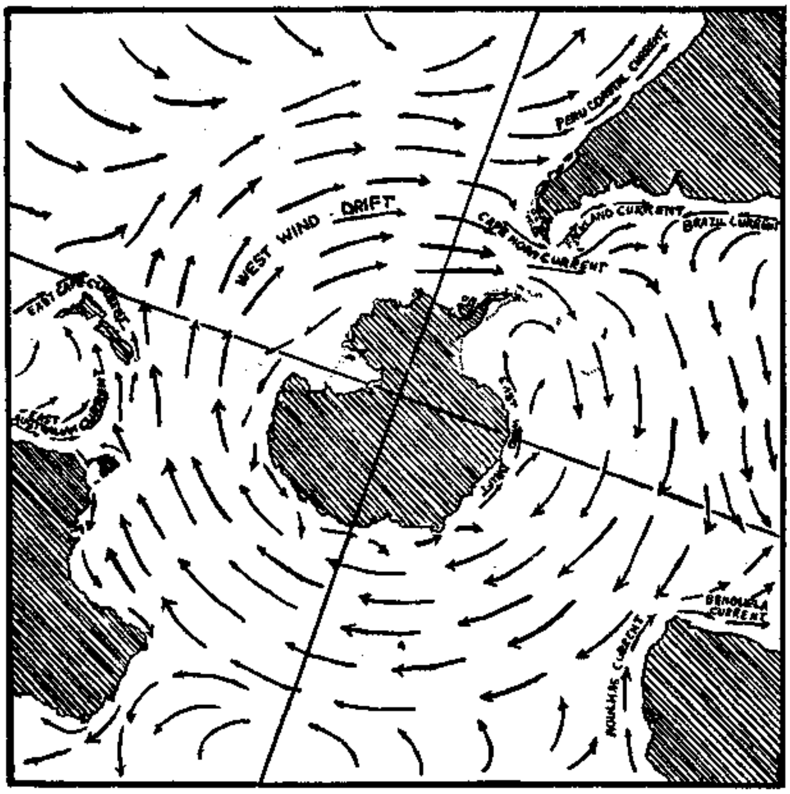


FIG. 18. Diagrammatic representation of the principal ocean current of the southern oceans (after Knox, 1960).

5. Lebour (1954) has recorded the early stages of larvae of *Jasus lalandei* from the Bengula Current and the small size of the larvae indicate that they could have come only from the breeding grounds of the species along the coast of South-West Africa and not represent the *J. l. frontalis* type from Tristan da Cunha. However, the fate of these larvae if they get into the warm South Equatorial current of the South Atlantic is not known. It is likely that an "eddy system" may help to bring back the larvae to the South-West African Coast without being carried out into the warmer current, nor drift as far west as Tristan da Cunha which lies 2,900 km. west of Cape of Good Hope. The current pattern off S. W. Africa as given by Sverdrup, Johnson and Fleming (1949) for the months of February-March which also coincides with the period of occurrence of phyllosoma off this coast indicates this possibility.

6. Stray records of the occurrence of *Jasus lalandei* from the south-western part of Australia are available (Sheard, 1949, 1962), but definite information as to the variety to which it belongs is wanting. The possibility that some larvae could be carried by the currents from the area of New Amsterdam and St. Paul Islands to the S.-W. Coast of Australia cannot be ruled out. Another

possibility is that the once continuous distribution of *J. l. lalandei* along the South-West, South and South-East Coasts of Australia has become disjunct, as along most of the southern coast of Western Australia and part of South Australia, especially in the area of the Great Australian Bight, *Jasus* has not bean reported.

7. This brings up another situation in the case of adult *Jasus* distribution which may be considered here. This is whether effective reproductive isolation in mixed populations (if any are found along mainland areas) of *J. l. lalandei* and *J. l. frontalis* occurring in any one area could take place. Influx of larvae of both varieties into an area could bring about such mixed populations and absence of reproductive isolation will no doubt also be indicated by intergradation in the patterns of squamiform sculpturation on the back of the abdominal segments. On the other hand, if the variability of the sculpturation on the abdominal segment is caused by environmental factors the role played by the duration of the planktonic phase of the developmental stages of the larvae and post-larvae needs study. These points are mentioned here, as at present the two types of abdominal sculpturation noticed in these lobsters are considered to be only of intra-specific importance.

8. A related problem is that some authors have indicated that *J. l. lalandei* and *J. l. frontalis* occur in New Zealand, while others (Parker, 1887; Holthuis, 1946) are of the opinion that the population there is composed of only one type, namely *J. l. frontalis* (=*Jasus edwardsii* of Parker). Careful scrutiny of material will be necessary as it is not unlikely that the larval stages of *J. l. lalandei* found along New South Wales, Victoria and Tasmania coasts could be carried by ocean currents to New Zealand. One point in favour of this is the reported occurrence of *J. verreauxii* in both these areas.

9. Attempts to acclimatise *J. l. frontalis* along the coasts of South Chile have proved unsuccessful, while this variety supports a sizable fishery at Juan Fernandez Island. The temperature, current patterns and the transportation of the larvae may have some bearing on this problem seen here.

10. If the two varieties considered here are eventually found to be allopatric in distribution, or if sympatric, show reproductive isolation, there is no reason why they should not be considered as good species. Elucidation of this can be carried out only by direct observations in nature. In any case, the problem of speciation in *Jasus* would necessitate considering:

(*a*) *The geological history of the genus.*—At present there appears to be no information.

(*b*) *The spatial distribution of the genus.*—Here we find that the variety *J. l. frontalis* has a much wider distribution than the typical form *J. l. lalandei.* Are we to consider that the more widely distributed variety is also the one from which the other has evolved or *vice versa*?

(*c*) This brings up the character of the squamiform sculpturation and whether the variety with the more complete sculpturation is the one from which the second type has evolved or *vice versa.* In the related species *J. verreauxii* the surface of the abdominal segments are studded with only scattered timble-shaped processes.

The wide gaps in our knowledge does not permit any generalizations. It is hoped that the points raised here would stimulate work on these aspects of this interesting group of commercially important lobsters.

Observations on the Biology and Fishery of *Jasus lalandei frontalis* from St. Paul and New Amsterdam Islands[1]

1. *Biology*

Some observations and information gathered during a day's visit is augmented here by the more detailed observations of Angot (1951 *a*) and Grua (1960, 1963). Being partly a review, it is felt that

[1] The nomenclature should according to Holthuis (1963) be *Jasus paulensis* (Heller, 1863).

there is need for drawing attention to some of the important problems connected with the biology of this lobster highlighted by these authors. Chiefly they are:

1. The lobsters around both these islands live amongst rock and sometimes in areas with gravel bottom, but are not found in places with black sandy bottom.

2. Specimens are found at different depths upto 60 m. or more, this being the depth upto which fishing is generally carried out. Actual fishing operations have shown that the depths between 10–35 metres are the most productive and this also corresponds with the areas generally occupied by beds of the giant kelp *Macrocystis*.

3. Better catch is always obtained from rocky rugged bottom areas within the zone just mentioned and fishing is concentrated in such areas.

4. Angot found three colour phases of this lobster and correlation was found between this and the depth from which the lobsters were fished. Near the coast the dominant colour is bright red. This is also the colour group I was able to collect. It is said to become dull red with a tinge of light grey in the zone of the kelp beds and dull red with a dusky tinge at greater depths. Angot found the body of specimens with the last-said colour to be profusely encrusted with the spiral white shells of *Spirorbis*. especially on the carapace. In the collection that I have, *Spirorbis* shells are present in fewer numbers even in small lobsters 8·1 and 10·3 cm. long. Angot found that after a severe storm when the sea conditions were rough disturbing the sargasam beds, individuals of all the three colour phases mentioned above were found to occur mixed. However, one or two days following the storm segregation according to depth was again re-established. Grua (1960) has also commented on these colour phases.

5. During the entire fishing season from January to April 1950, Angot found that not a single female lobster was 'in berry' except one female captured on 15 January which had a few stray eggs attached to the pleopods. Hence he concludes that these months do not correspond with the period of reproduction of this lobster. On 8–4–1964, in addition to the few that I had collected, several more lobsters had been caught that day, but none were 'in berry' which I understand from the resident meteorologists occurs prior to November and seldom are berried females seen after this until about the middle of the next winter, which is June. In the material Angot studied, he found that individual females showed much more developed genital glands during March than at the beginning of January.

6. Grua (1963, 1964) has shown that egg-laying occurs in May and June and hatching takes place in August and September. In females at both the islands during this period the ovigerous setae become variable in size due to damage caused by the removal of the empty egg shells by the animals themselves. Grua studied this phenomena by an original biometric method involving size ratios, the validity of which he discusses (Grua, 1964). Pilosity becomes complete once again by March, owing to a molt distinct from the prebreeding ones.

In the specimens in my collection, three shell conditions, namely "hard new shell", "hard old shell" and "soft new shell' are present (Table I). No freshly moulted specimens were seen nor were any moulted shells seen among the rocky inter-tidal areas which were extensively searched both to the west and south-east of Camp Heurtin. Angot also found that from January to the beginning of April not one specimen captured was found to have moulted, the carapace in all being hard. Apparently the moult in the month of March in females mentioned by Grua (1964) may not be a general phenomena, but restricted to a particular stage.

7. Angot (1951) has given the length frequency of lobsters caught during the "Sapmer" Expedition in 1950. Briefly stated the results are as follows:

Locality	No. (sexes combined)	Mean length*	No. of males	Mean length*	No. of females	Mean length*	F/M
							%
St. Paul Island ..	1,106	24·3	948	27·9	158	20·7	16·9
New Amsterdam Island ..	978	22·8	886	26·1	92	19·5	10·3
Total ..	2,084	23·6	1,834	..	250	..	13·6

* Mean lengths are given in centimetres.

It may be noted that the mean lengths differ for the sexes in both the islands. A similar trend was also noticed by Grua (1960) for the period 1958–59 sesson, which was as follows:

Sex	St. Paul Island	New Amsterdam Island
Males ...	24·1 (−3·8 cm.)†	21·9 (−4·2 cm.)
Females ..	20·3 (−0·4 cm.)	19·6 (+0·1 cm.)
Mean for males and females ..	23·53 (−0·8 cm.)	21·7 (−1·1 cm.)

† The figures in paranthesis indicate the differences from the mean observed between the figures given by Angot for the 1950 season and Grua for the 1958–59 season.

8. The graphs given by Angot (1951) are reproduced here (Fig. 19) in order to illustrate the significant point of marked disparity in the sex ratio. The proportion of females is least in New Amsterdam, being only 10·3%, and 16·9% at St. Paul Island. However, a size-wise analysis shows that the females in both the islands predominate over the males upto about 17·0 cm. length. From this size to about 20 cm. length the males predominate, but very slightly over the females. However, beyond this length the gulf is very great as the largest female taken is not more than 25 cm. while the male grows upto 35 cm. In my collection out of six juveniles and adults, only two are females.

However, there are indications that there could be fluctuations in the sex ratio and Grua (1960) remarks that the percentage of females may fluctuate between 5% and 35%. Thus there is evidence of a constant predominance of males over females. This phenomena to a much lesser degree is seen in South-West Africa where Mathews (1962) found the sex ratio of males to females in *J. l. lalandei* to be 59:41 with constant predominance of males over females of 18%. A latitude-wise analysis given by Mathews (1962) showed that in 1959, 64·7% of the lobsters of the southern areas were males, while only 51·9% were males in the northern areas; in 1960 it was 63·3% and 59·3%; and in 1961 it was 64·4% and 50·3% respectively. However, in the case of the lobsters at St. Paul and New Amsterdam Islands which are situated hardly 60 miles apart the situation is very disquieting.

A significant reduction in the female is bound to have a very marked effect on the reproductive rate and the recruitment into the area each year. In fact, the sex ratio is such that it is only reasonable to presume that if intensive fishing is resorted during any particular season or consecutive seasons resulting in the greater depletion of the females and thus a greater imbalance of the sex ratio, the entire lobster population around the islands will be adversely affected.

9. Grua (1960) suggests that the males and females may segregate when the females are "in berry'. Fortunately though, the period of reproduction does not coincide with the main

fishing season, the great disparity in the sex ratio seen in samples obtained during the fishing season as already mentioned is highly significant.

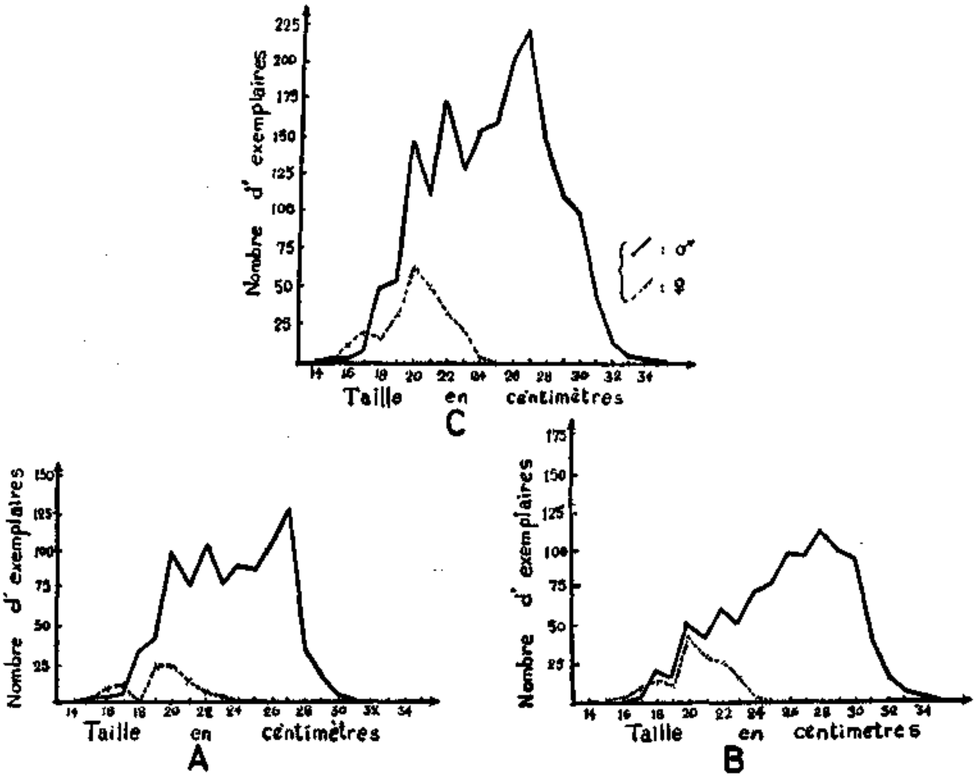


FIG. 19. Sex ratio of *Jasus lalandei* (= *J. l. frontalis*)[1] at A: New Amsterdam Island; B: St. Paul Island; and C: From both islands combined (After Angot, 1951 *a*) [[1] = *J. paulensis* (Heller)].

10. On the basis of the mean size differences of the specimens at St. Paul and New Amsterdam Islands Angot (1951) concluded that the growth of the lobsters after the larval stage at both these islands was independent of the other. The data on size and growth given by Grua (1960, 1963) also points to the same conclusion. In other words, adults do not migrate to and from between the islands, though separated by hardly 60 miles of sea. A depth barrier, as well as temperature differences of the waters surrounding the two islands are important considerations. Smith (1948) speaking of the spiny lobster fishery off British Honduras remarks that "There is no evidence that adult lobsters are able to cross deep straits and these act at least as a partial barrier to migration." The deepest part between St. Paul and New Amsterdam Islands is about 1685 metres and this may act as an effective barrier in restricting the adult populations to the narrow shelves around the two islands. Temperature as a factor affecting the sizes of adult lobsters in both the islands has been drawn attention to by Angot (1951) and Grua (1960, 1963). Both surface as well as subsurface temperatures, especially the latter show the differences very clearly as can be seen from the following:

*Mean monthly surface temperature (° C.) at St. Paul and New Amsterdam Islands**

Months	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
St. Paul	16·5	16·8	16·6	15·9	14·8	13·4	12·6	12·4	12·3	12·9	13·8	14·8
New Amsterdam	16·8	17·37	16·92	15·9	14·86	13·61	12·95	12·71	12·73	13·26	14·04	15·59

* After Treussart, 1951 and Grua, 1963.

Temperature at 400 and 600 m. off the coast at St. Paul and New Amsterdam Islands†

Date	Position	Actual depth (m.)	Depth of sampling (m.)	Temperature (°C.)
		1. St. Paul Island		
7–1–1959 ..	E.	28	20	13·99
12–1–1959 ..	N.E.	30	25	13·73
29–1–1959 ..	E.	29	24	13·97
		2. New Amsterdam Island†		
18–1–1959 ..	E.S.E.	33	28	17·8
21–1–1959 ..	W.	25	20	17·71
30–1–1959 ...	N.N.E.	33	25	18·09
2–3–1959 ...	W.	39	31	17·14
11–3–1959 ...	N.W.	45	40	17·88

† On 15–12–1958, 2 miles N.N.W. of this island where the depth to bottom is 1,000 m. the temperatures at 5 and 10 m. depths were 16·6 and 16·3°C respectively.

Thus a difference of about 4° C. is noticeable in the subsurface waters off the islands in the month of January and similar differences may be prevalent during the other months as well. The lobsters at St. Paul Island where the waters are cooler are relatively larger in size. I may add here that it is not unlikely that increased fishing effort around New Amsterdam Island could also result in a reduction in the size of the lobsters caught there, as compared to those taken around St. Paul Island which may not be so frequently exploited.

11. Angot (1951) records some difference in the behaviour of the lobster populations of the crater lake on St. Paul Island and those occurring outside the lake. In the lake area where the water is about five metres deep , not one lobster was seen during daytime, but at dusk the 'littoral area' of the lake was invaded by large numbers of lobsters which disappeared at dawn. No such phenomena was noted by him along the fringe of the island. During our visit to New Amsterdam Island a similar 'invasion' of the intertidal rocky area (between Pointe Goodenough and Pointe Hosken off Camp Heurtin) by lobsters at dusk was noticed and I was told that this is not unusual. The effect, the phase of the moon may have on such movements is not known, but our visit on 8–4–1964 was four days prior to New Moon.

2. *Fishery*

A fortnight prior to R. V. ANTON BRUNN'S visit to New Amsterdam Island, two lobster fishing boats from Reunion Island had spent about three weeks in the area chiefly fishing lobsters, returning with a catch of about 30,000 lobsters. From November to April a few fishing boats visit St. Paul and New Amsterdam Islands from Reunion Island and besides lobsters a few other fish such as the 'Poisson Blue' or blue fish (*Chilodactylus macropterus*), the 'Morue' (*Latris hecateia*), the 'Tazart (*Thyrsites atun*), and the 'Cabot' (*Polyprion americanus*) are caught with handlines. Lobster meat is usually used as bait for catching the fish, and in turn the fishermen have found that the flesh of the 'Poisson Blue' attracts more lobsters to the traps than any other bait. There were no lobster traps on the island at the time of our visit as these are used only from the fishing boats and for local needs any number of lobsters could be caught at dusk by hand or using baited hooks in the rockpools, Angot (1951) gives a brief description of the trap used, which is closely akin to the type used along the French coast and the Gulf of Maine. The trap is a semicylindrical case with a rectangular basal plate and with two openings located along the upper median line. The flat bottom enables the trap to rest in the proper position even on irregular bottom. The trap is said to be inexpensive, made of wood and capable of capturing large quantities of lobsters. Angot remarks that 50–70 kg. of lobsters are caught per trap per day, and each boat uses about 15–20 traps.

Paulin (1957) reported that while lobsters were caught in small quantities during most of the months, in the two months November-December, 1956, upto 255 tonnes were landed. The average estimated annual catch of lobsters from St. Paul and New Amsterdam Islands for the 7-year period 1951–52 to 1958–59 (excluding 1957–58 when fishing was suspended) was about 212 tonnes. Grua (1960) notes that for the 1958–59 season the limit was fixed at 200 tonnes and the estimated catch for the season was 201 tonnes. Of this, 53% of the catch was composed of 'petites' or small-sized lobsters 14–18 cm.; 32% 'moyennes' or medium-sized lobsters 18–23·5 cm.; and 15% 'grosses' or large lobsters 23·5–35 cm. and upwards, the largest specimen caught during the 1958–59 season being 37·4 cm. Since the fishing areas around the islands are greatly limited in extent, there is a great need for a judicious exploitation of this resource.

Attempts had been made earlier to establish a canning factory for canning lobster tails at St. Paul Island and one functioned for a brief period from 1928 to 1931, but had to be abandoned due to various difficulties. The factory was established in the crater, but the crater mouth was always not accessible for boats to leave or enter, so much so fishing periods had to be restricted. The inclement weather conditions and utter loneliness had a telling effect on the health and morale of the men, and so the project was abandoned in 1931.

The 'Sapmer' Expedition of 1950 was chiefly undertaken to explore the possibilities of a factory ship doing also fishing, working in the area during the summer months. This had a definite advantage as whole lobsters could be frozen or only the tails so that the rest could be reduced to lobster meal. However, it was found that the consumer preference was for whole lobsters and freezing often resulted in the damage of the appendages of the lobster. The highly oily nature of the other fish caught at the islands were not advantageous for salt curing (partly also due to limitations of ship space and the climatic conditions being unfavourable) or even canning of this product.

Concluding Remarks

From these, a few points worth mentioning are that although there is a marked disparity in the sex ratio of the lobsters here, it is not known whether this great reduction in the number of females seen in this area is really nature's control to limit the annual recruitment into this area to the extent that such a restricted area could sustain. Whether this is a periodic phenomena or a regular feature is not clear as information as to fluctuations in the sex ratio of the lobsters over a period of years is wanting. If future sampling shows that this ratio of males to females is characteristic for these islands, this may be yet another important clue as to the homogeneity of the lobster population in this area, and the unlikelihood of any influx of larvae from other areas such as South Africa, or Western or South East-Australia. Such information from other insular areas, such as Tristan da Cunha and Juan Fernandez Islands where *Jasus* occurs will be of considerable interest in this connection.

We have hardly any information regarding predation of lobsters around St. Paul and New Amsterdam Islands by other animals, especially marine mammals (the 'Elephants de Mer' *Mirounga leonina*, and the 'Otaries') and the sea brids and fish except the brief comments of Angot (1951).

Angot (1951) has perhaps rightly pointed out that there is a need to limit the fishing of lobsters to only males which will not be difficult to implement as the fishermen could be easily trained to distinguish the sexes. In fact, the females are smaller in size and so few in numbers that the fishermen may not lose much by releasing these back. Fortunately, inclement weather conditions for about six months in the year when the female lobsters are mostly 'in berry' acts as a natural control on fishing. All told, in view of the isolated position of these two islands remote from other land areas, the "lobster problem" here is one of interest not merely on account of its fishery value. It is equally interesting to the taxonomist and the biogeographer. There are many gaps in our knowledge, especially the species problem, the life-history stages and natural distribution of larvae by ocean currents all of which call for early and detailed attention.

PART II

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ADDENDUM

Since presenting this paper at the Symposium in January 1965, I have been able to see a recent paper entitled "Preliminary description of some new species of Palinuridae (Crustacea Decapoda, Macrura Reptantia)" by Dr. L. B. Holthuis [*Koninkl. Nederl. Akademie van Wetenschappen, Amsterdam, Proceedings, Series C*, **66** (1): 54–60 (1963)] wherein he has described two new species of *Jasus*, while recognising a total of six species under the genus as follows:

1. *Jasus lalandii* (H. Milne-Edwards, 1837) from South Africa.
2. *Jasus paulensis* (Heller, 1863) from St. Paul and Amsterdam Islands.
3. *Jasus* novæhollandiæ new species—from S. E. Australia and Tasmania.
4. *Jasus edwardsii* Hutton (1875) from New Zealand.
5. *Jasus frontalis* (H. Milne-Edwards, 1837) from Juan Fernandez, Chile.
6. *Jasus tristani* new species—from Tristan da Cunha.

My reasons for considering the representatives of *Jasus* from St. Paul and New Amsterdam Islands as *Jasus lalandei frontalis* were based on Holthuis's earlier work (Holthuis, 1946) discussed elsewhere in this paper. However, Holthuis (1963) has shown that in *J. frontalis* there is no sculpturation on the first somite, in which it would differ from the representative of the genus from St. Paul and New Amsterdam Islands which show sculpturation on the first somite in a narrow band just behind the transverse groove. When consistent, this is reason good enough to separote the two types and use the name *J. paulensis* for the St. Paul and New Amsterdam lobsters.

However, from the examination of the material as well as familiarity with the literature, I feel that in *Jasus lalandii* we may have a good instance of a polytypic species, rather than several independent species in the different geographical areas of distribution of the genus. This I mention as a matter of individual opinion. For instance, the nature and disposition of the squamiform sculpturation in the posterior half of the first abdominal somite in *J. paulensis* and *J. tristani* are the same, for the diagnosis of the last said species is given by Holthuis (1963) as: ". . . . the present new species has the anterior half of the first abdominal somite perfectly smooth and without sculpturation. A narrow transverse row of small squames is placed just behind the transverse groove of the somite, but the larger part of the posterior half is smooth. The following siomtes have a rather wide transverse smooth area along the anterior and along the posterior margins, these smooth areas are clearly visible even in fully stretched animals. The squamae of the abdominal somites are broad and large they are placed in 2 or 3 transverse rows per somite." "The large spines on the carapace are similar to those of *Jasus frontalis* being as long as wide and much longer than the smaller spines." But for the fact that some of the larger spines mostly in the anterior half of the carapace are slightly longer than broad in larger specimens of *J. paulensis*, the very close similarity of *J. tristani* to this is clearly indicated. In *J. paulensis* also, the smooth areas of the second and third somites are clearly visible even in fully stretched animals of different sizes. These convergent trend in the sculpturing of the somites in these two insular representatives of the genus is interesting. Having not examined any material of *Jasus* from Tristan da Cunha, I am unable to comment on any other subtle differences between *J. tristani* and *J. paulensis*.

Jasus has been reported from S. W. Australia as *J. lalandii* by some workers. However, in the light of Holthuis's recent work on the genus (Holthuis, 1963), the status of *Jasus* in this area will need elucidation. The recognition of six different species in six different geographical areas makes the task of the commercial fisherman and fishery worker easy in assigning his material from a particular area to a species. However, as already discussed, there is an almost complete lacunae in our knowledge as to the paths and patterns of dispersal of phyllosoma of *Jasus* in the different areas specially in relation to ocean currents prevalent in the areas, the duration of larval phases, the effect of prolonged larval phase as reflected in the development of adult characters such as the sculpturation on the abdominal somites, and even the presence or absence of intergrades between two or more species in the different areas. Until we know more about these, a proper evaluation of the taxonomic status of the various nominal species of *Jasus* described in literature may not be possible.

A supplementary list of recent references pertaining to species of the genus *Jasus* Parker is appended below to make the bibliography complete as far as possible. However, these are not included in the section 'Index by Subject,' nor is Part I of this paper indexed.

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[Mentions of phyllosoma of one species of *Jasus* as occurring in the eastern portion of the Indian Ocean.]

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[*Jasus edwardsii* and *J. vereauxi*; history of New Zealand cray fishery; crayfishing grounds; export figures; size composition and sex ratio in *J. edwardsii*; regional landings of crayfish; carapace length-total length, and tail width-total length relationships of crayfish from different areas around New Zealand; size composition of crayfish boats; number of licences issued from 1938 to 1965 as compared with total landings, as well as North Island and South Island landing].

KENSLER, C. B. 1967 *a*. Notes on laboratory rearing of juvenile spiny lobster, *Jasus Edwardsii* (Hutton) (Crustacea: Decapoda: Palinuridae). *N.Z.J. Mar. and Freshw. Res.*, **1** (1): 71-75 (March 1967). Also in: *Australia/New Zealand Meeting on Decapod Crustacea*, ANZDC/67/2/9: 1 p. Summary.

[Rearing of large adult *J. edwardsii* from post-puerulus specimens and juveniles in laboratory possible; growth studies for periods upto 12 months, the animals fed every other day with fresh mussels and fresh fish; Juveniles actively 'grazing' on calcarcous algae *Carallina officinalis* L., present on rocks.]

——— 1967 *b*. An annotated bibliography of the marine spiny lobster *Jasus verreauxi* (H. Milne Edwards (Crustacea: Decapoda: Palinuridae). *Trans. Roy. Soc. N.Z. Zool.*, **8** (19): 207-210.

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[*J. verreauxi*—detection of smallest size-class with external eggs, and incidence of egg-carrying females per size class intervals based on 834 females measured and examined at Spirits Bay, New Zealand in Mid-October and late December 1966.]

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[Reports also instance of feeding of Hydromedusae to phyllosoms of *Jasus lalandii* in laboratory.]

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