J. Mar. Biol. Ass. India, **51** (2) : 145 - 157, July - December 2009

†Mean trophic index of fish fauna associated with trawl bycatch of Kerala, southwest coast of India

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Abstract

Fishing using mobile gears such as trawlnets has been identified as one of the major threats to the marine biodiversity and to the sustainability of marine fisheries. Studies on the fish fauna associated with bycatch of bottom trawlers of Kerala, on the southwest coast of India recorded 217 species classified under 21 orders, 90 families and 154 genera. Among the fish fauna in the trawl bycatch, 103 species (47%) belonged to the trophic level 3.5-3.99, 56 species (26%) to the trophic level 3.0-3.49, 40 species (18%) to the trophic level 4.0-4.49, 13 species (6%) to the trophic level 2.5-2.99 and five species (2%) to the trophic level 2.0-2.49. The diversity indices recorded significantly higher values for the trophic level 3.5-3.99 and it was the lowest for the trophic level 2.0-2.49. In general, the dominant fraction of fish fauna (73%) of the trawl bycatch represented by 159 species was the mid level carnivores included in the trophic level 3.0-3.99. The diversity of fish fauna in the trawl bycatch differed significantly at different trophic levels; presence of large number of mid level carnivores in the trawl bycatch may indicate large scale removal of top level predators from the ecosystem. The length class distribution of fishes of the trawl bycatch at various trophic levels showed that fishes in the length group below 15cm were dominant in all the trophic levels. The mean trophic index of fish species in the trawl bycatch was estimated as 3.12. Reduction of fishing pressure and use of bycatch reduction devices are suggested for the sustainable management of trawl bycatch in the southwest coast of India.

Keywords: Trophic level, Mean Trophic Index, trawling, bycatch, Kerala

Introduction

The most important feature of an ecosystem is the flow of energy through various trophic levels of the food webs. Trophic levels express the position of organisms within the food webs that largely define the ecosystem (Odum, 1969). Each organism playing either a major or minor role in an ecosystem contributes to the proper functioning of the ecosystem. Knowledge on species diversity at various trophic levels of an ecosystem would help maximizing resource utilization in a sustainable manner besides preserving biodiversity. Fishing alters the ecology, biological structure and dynamics of marine ecosystem (Dayton, 1998). The changes induced by modern fishing methods such as bottom trawling differ from natural predation, as it is detrimental not only to the target organisms but also to the large spectrum of species in the oceans.

Pauly *et al.* (1998) recorded a sharp decline in mean trophic levels of global fisheries landings during 1950-1994 at a rate of about 0.1 per cent per decade. This phenomenon, often referred to as ‘fishing down marine food webs’, indicates a gradual transition in landings from long-lived, late maturing

†Presented in the International Symposium “Marine Ecosystem-Challenges and Opportunities (MECOS 09)” organized by the Marine Biological Association of India during February 9-12, 2009 at Kochi.

high trophic level, piscivorous bottom fish towards short-lived early maturing low trophic level planktivorous pelagic fish. Since the publication of Pauly *et al.* (1998), trophic level changes are widely used in monitoring the sustainability of marine fisheries catches and in realizing the impact of fishing on marine ecosystems. Considering these features, mean trophic level of fisheries catches or the Mean Trophic Index or Marine Trophic Index (MTI) has been identified as one of the indicators of marine biodiversity by the Convention on Biological Diversity (CBD, 2004; Pauly and Watson, 2005).

Reports from various fishing grounds of the world, including those from tropical countries (Christensen, 1998), recorded decline in mean trophic levels of fishery landings (Baisre, 2000; Pauly *et al.*, 2001; Furness, 2002; Valtysson and Pauly, 2003). Vivekanandan *et al.* (2005) recorded a decline in MTI of fish landings along southeast coast of India, while Bhathal and Pauly (2008) observed that the fishing down marine food web phenomenon is happening all along the Indian coast. Changes in demersal and pelagic ecosystem structure due to the removal of species through mobile fishing gears such as trawlers could be explained through the mean trophic level of fish in the catch. Bijukumar (2008) recorded 534 species associated with the trawl bycatch of Kerala coast, which included 10 species each of Porifera and Cnidaria, 3 species of Annelida, one species each of Bryozoa and Sipunculida, 135 species of Mollusca, 72 species of Arthropoda, 18 species of Echinodermata, 279 species of Pisces and 5 species of Reptilia. This paper records the trophic level and MTI of fish fauna in the trawl bycatch landings of Kerala, southwest coast of India.

Material and Methods

Monthly samples collected from the biodiversity survey of trawl bycatch by the first author (Bijukumar, 2008) from Neendakara, Sakthikulangara (Kollam district), Munambam (Ernakulam district), Ponnani (Malappuram district), Puthiyappa (Kozhikkode district) and Azheekkal (Kannur district) of Kerala coast during 2004-2006 periods were used for the analysis of MTI. The collection methodology was stratified random sampling of bycatch from each of the fishing harbours. In the present analysis data on 217 species of fishes, which were identified up to species level and where data on trophic level was available were used for calculating MTI. The ontogenic variations in feeding were not considered and the data on adult fishes alone were taken into account for analysis. Considering the non-availability of data on the trophic level of many invertebrate species along southwest coast of India, fishes alone were considered for assessing MTI.

The term bycatch in this paper denotes all the fish species deposited by trawlers in the fishing harbours after sorting the commercially important species; bycatch is primarily used for making fish meal and manure, and this may include juveniles of commercially valuable species. Each fish species in the trawl bycatch was identified up to species level, following Fischer and Bianchi (1984), Talwar and Kracker (1984), Smith and Heemstra (1986) and FishBase (Froese and Pauly, 2007). Each specimen was measured for standard length and total length to the nearest 0.1 centimeter and weighed individually to the nearest 0.01gram.

The trophic level of individual fish in the bycatch was gathered from FishBase (Froese and Pauly, 2007). Diversity of fish fauna at each trophic level was calculated using Shannon diversity, Simpson dominance, evenness and Fisher-alpha indices, following Magurran (1988). The Shannon diversity indices at various trophic levels were compared using t-test. The length class of fishes at each trophic level was also recorded.

MTI of the bycatch was calculated by multiplying the bycatch of each species with their corresponding trophic level and then by taking the weighed mean (Pauly *et al.*, 1998), that is,

$$MTI = \frac{\sum ij\, TLj\, Yij}{\sum Yij}$$

where, TLj is the trophic level of individual species j, Yij is the biomass of that species, ij is the summation of TLj x Yij, and Yij is the total weight of all species.

Results and Discussion

The list of 217 species of finfishes in the trawl bycatch of Kerala coast and their trophic level, size range in catch, maximum size, habitat and resilience is given in Table 1. The 217 species fishes in the trawl bycatch, classified under 21 orders, 88 families and 155 genera, are represented predominantly by demersal (79 species) and reef-associated forms (78 species). The results are in corroboration with the reports that trawlnets operating in tropical waters catch higher biodiversity than those in temperate waters, predominantly demersal forms (Alverson *et al.,* 1994; EJF, 2003; Bijukumar and Deepthi, 2006). In terms of resilience, high and medium resilience values were recorded for 86 and 76 species respectively, while 27 species recorded low and 8 species very low resilience values. This warrants frequent monitoring of biodiversity of bycatch species and population studies of species with low resilience.

Around 47 per cent (103 species) of the fish fauna belonged to the trophic level 3.5 - 3.99, and about 26 per cent (56 species) to the trophic level 3.0-3.49. This indicates that dominant fraction of fish fauna (73 per cent) in the trawl bycatch, represented by 159 species are the mid level carnivores (trophic level 3.0-3.99) (Table 2). The next major trophic group of fish in the trawl bycatch was the top level carnivores (trophic level 4.0-4.5), represented by 40 species. Only five species in the trawl bycatch was found in the trophic level 2.0-2.49, while the trophic level 2.5-2.99 consisted of 13 species (Table 2). The dominance indices were higher in the case of fishes at the base of the trophic level. The distribution of fishes was not even at various trophic levels, reflecting the domination of certain species in the trawl bycatch. In general, the Shannon diversity indices of fish fauna of the trawl bycatch differed significantly at different trophic levels.

Table 1. List of fish fauna associated with trawl bycatch of Kerala, southwest coast of India and their trophic indices

Species	Size Range in bycatch (cm)	Max. size (cm)*	Habitat*	Trophic index*	Resilience*
CLASS : ELASMOBRANCHII					
Order : Orectolobiformes					
Family : Hemiscylliidae					
Chiloscyllium griseum Muller & Henle	10.9-21.6	80	RA, D,	3.7	L
Chiloscyllium indicum (Gmelin)	26.5-34.5	65	D, OC	4.0	L
Order : Carcharhiniformes					
Family : Carcharhinidae					
Carcharhinus melanopterus (Quoy & Gaimard)	13.8-15.1	200	RA, D,	3.9	VL
Scoliodon laticaudus Muller & Henle	14.6	100	D, AM	3.8	VL
Family : Rhinobatidae					
Rhinobatos annandalei Norman	18.6-20.3	56	D, AM	3.5	L
Rhinobatos obtusus Muller & Henle	10.9-18.6	93	D	3.6	L
Rhinobatos thouiniana (Shaw)	18.4-18.5	275	D	3.8	L
Order : Torpediniformes					
Family : Torpedinidae					
Narcine brunnea Annandale	9.5-12.3	22	D	3.1	L
Narcine timlei (Bloch & Schneider)	9.4-12.7	38	D	3.2	L
Order : Rajiformes					
Family : Dasyatidae					
Dasyatis bennetti (Muller & Henle)	32.0	50	D	3.5	L
Dasyatis zugei (Muller & Henle)	14.7	29	D, AM	3.5	L
Himantura bleekeri (Blyth)	8.4-11.4	105	BP	3.6	L
CLASS : TELEOSTII					
Order : Anguilliformes					
Family : Muraenidae					
Gymnothorax reticularis Bloch	11.3-32.4	60	D	4.0	—
Strophidon sathete (Hamilton)	32.9-76.2	410	D	3.98	—

Family :	Ophichthydae					
	Cirrhimuraena(Jenkinsiella)					
	playfairii (Gunther)	63.2	39	D	3.7	H
	Lamnostoma orientalis (McClelland)	42.1-45.2	36	D	3.7	H
	Ophichthus (Centrurophis) cephalozona (Bleeker)	31.1	100	D	3.9	M
	Ophichthus erabo (Jordan & Snyder)	32.4	72	RA	3.8	M
Family :	Muraenesocidae					
	Muraenesox bagio					
	(Hamilton- Buchanan)	21.6	200	D	4.0	—
Family :	Congridae					
	Conger cinereus Ruppell	8.4-29.2	103	RA	4.34	L
	Uroconger lepturus (Richardson)	12.2-43.2	52	D	3.5	M
Order :	**Clupeiformes**					
Family :	Engraulidae					
	Stolephorus devisi (Whitley)	1.9-10.6	10	P	3.3	H
	Stolephorus indicus (van Hasselt)	2.3-12.9	15	P	3.6	H
	Thryssa hamiltonii (Gray)	6.9	27	P, AM	3.5	H
	Thryssa mystax (Bloch & Schneider)	8.2-14.8	15	P	3.6	H
	Thryssa setirostris (Broussonet)	9.8-11.3	18	P	3.3	H
	Thryssa vitrirostris (Gilchrist & Thompson)	6.1	20	P	3.3	H
Family :	Chirocentridae					
	Chirocentrus dorab (Forsskal)	19.6-23.1	100	P, AM	4.5	M
Family :	Clupeidae					
	Anodontostoma chacunda					
	(Hamilton – Buchanan)	9.22-11.2	22	P, AM	2.8	H
	Dussumieria acuta Valenciennes	13.2	20	P	3.4	H
	Escualosa thoracata (Valenciennes)	6.5-8.9	10	P, AM	3.2	H
	Ilisha megaloptera (Swainson)	2.5-8.5	28	P, AM	3.0	H
	Opisthopterus tardoore (Cuvier)	13.1	20	P, AM	3.4	H
	Sardinella brachysoma Bleeker	6.4-10.9	13	P	2.9	H
	Sardinella fimbriata (Valenciennes)	3.9-11.8	13	P	2.7	H
	Sardinella longiceps Valenciennes	2.6-15.4	23	P	2.4	H
Order :	**Siluriformes**					
Family :	Ariidae					
	Arius arius Hamilton	11.3-15.4	40	D, AM	3.5	M
Family :	Plotosidae					
	Plotosus canius Hamilton	6.4-21.9	150	D, AM	3.9	VL
	Plotosus limbatus Valenciennes	8.7-10.6	40	D, AM	3.9	M
	Plotosus lineatus Thunberg	12.5	36	RA	3.5	M
Order :	**Stomiiformes**					
Family :	Sternoptychidae					
	Polyipnus indicus Schultz	2.1-5.1	60	BP	3.3	H
Family :	Astronasthidae					
	Astronesthes trifibulatus					
	Gibbs, Amaoka & Haruta	4.2-12.9	15	BP	3.9	M
Order :	**Aulopiformes**					
Family :	Chlorophthalmidae					
	Chlorophthalmus bicornis Norman	14.2-22.9	15	BP	3.44	M
Family :	Synodontidae					
	Saurida tumbil (Bloch)	3.9-15.6	60	RA, AM	4.4	M
	Saurida undosquamis (Richardson)	1.5-24.4	50	RA, AM	4.5	M
	Synodus indicus (Day)	15.4	33	RA	4.3	H
	Trachinocephalus myops (Forster)	2.9-20.9	40	RA	4.4	M
Order :	**Polymixiiformes**					
Family :	Polymixiidae					
	Polymixia japonica Gunther	8.6-9.5	30	BP	4.2	M

Order : Ophidiiformes					
Family : Ophidiidae					
Ophidion smithi (Fowler)	6.1-8.4	14	D	3.4	H
Order : Gadiformes					
Family : Moridae					
Physiculus argyropastus Alcock	19.4	—	BNP	3.7	H
Family : Bregmacerotidae					
Bregmaceros mcclellandii Thompson	7.8		P	3.3	H
Order : Lophiiformes					
Family : Lophiidae					
Lophoides mutilus Alcock	4.6-6.9	45	BD	4.2	M
Family : Antennariidae					
Antennarius nummifer (Cuvier)	6.4-8.9	13	RA	4.2	H
Family : Ogcocephalidae					
Halieutaea stellata (Vahl)	6.5-9.1	30	D	3.5	L
Order : Mugiliformes					
Family : Mugilidae					
Valamugil cunnesius (Valenciennes)	10.7	41	D, AM	2.0	M
Order : Beryciformes					
Family : Trachichthyidae					
Hoplostethus mediterraneus Cuvier	6.9-7.5	42	BNP	3.5	L
Family : Berycidae					
Beryx decadactylus Cuvier	11.5	100	BD	4.13	L
Family : Holocentridae					
Sargocentron rubrum (Forsskal)	4.6-8.2	32	RA	3.5	H
Order : Zeiformes					
Family : Zeidae					
Cyttopsis rosea (Lowe)	4.1	31	BP	4.0	—
Order : Gasterosteiformes					
Family : Syngnathidae					
Hippocampus kuda Bleeker	9.8	30	RA	3.6	M
Hippocampus trimaculatus Leach	16.5	22	RA	3.8	H
Ichthyocampus carce (Hamilton)	29.6	15	D, AM	3.3	H
Syngnathoides biaculeatus (Bloch)	11.58	29	RA	3.6	M
Trachyrhamphus longirostris Kaup	30.6	40	D	3.78	M
Trachyrhampus serratus (Schlegel)	21.5-32.8	30	D	3.7	H
Family : Fistulariidae					
Fistularia petimba Lacepede	6.4-48.1	150	RA	4.5	—
Family : Centriscidae					
Centriscus scutatus Linnaeus	4.9-10.2	15	RA	3.4	H
Order : Scorpaeniformes					
Family : Dactylopteridae					
Dactyloptena orientalis (Cuvier)	1.6-16.7	40	RA	3.7	—
Family : Scorpaenidae					
Brachypterois serrulata (Richardson)	6.8	12	D	3.5	M
Choridactylus multibarbus Richardson	4.6	12	D	3.8	A
Minous monodactylus (Bloch & Schneider)	3.1-11.0	15	D	3.8	—
Pterois russelii (Bennett)	10.3-29.3	30	RA	3.69	L
Pterois volitans (Linnaeus)	6.9-13.8	38	RA	4.45	L
Scorpaenopsis venosa (Cuvier)	3.7-9.1	25	RA	4.18	L
Family : Triglidae					
Pterygotrigla guezei Fourmanoir	12.1	—	D	3.5	M
Pterygotrigla hemisticta (Temminck & Schlegel)	3.5-11.6	30	D	3.5	M
Family : Platycephalidae					
Grammoplites scaber (Linnaeus)	3.9-16.8	30	D, AM	3.8	M
Grammoplites suppositus (Troschel)	5.9-16.8	25	D	3.7	M
Platycephalus indicus (Linnaeus)	8.6-23.1	100	RA	3.6	M
Suggrundus rodericensis Cuvier &Valenciennes	2.9-22.8	25	D	3.7	M

Order	**: Perciformes**					
Family	: Acropomatidae					
	Synagrops adeni Kotthaus	7.2-7.8	11	BD	3.4	H
	Synagrops japonicus (Doderlein)	10.6	35	BD	4.27	M
Family	: Serranidae					
	Cephalopholis miniata (Forsskal)	3.9	45	RA	4.4	L
	Epinephelus areolatus (Forsskal)	10.6	47	RA	3.58	M
	Epinephelus chlorostigma (Valenciennes)	6.8-10.7	75	RA	3.99	M
	Epinephelus diacanthus (Valenciennes)	3.5-13.5	55	D	3.8	M
	Epinephelus fuscoguttatus (Forsskal)	4.9-16.9	90	RA	4.14	M
	Epinephelus malabaricus (Bloch & Schneider)	11.2	234	RA, AM	3.75	VL
	Epinephelus radiatus (Day)	9.6-12.9	70	D	4.0	L
	Epinephelus undulosus (Quoy & Gaimard)	14.2	75	RA	3.66	L
Family	: Opistognathidae					
	Opisthognathus nigromarginatus Ruppell	10.8-16.8	18.6	—	3.6	—
Family	: Priacanthidae					
	Priacanthus hamrur (Forsskal)	4.6-17.3	45	RA	3.6	H
Family	: Apogonidae					
	Apogon aureus (Lacepede)	6.5-11.3	14.5	RA	3.5	H
	Apogon ellioti Day	6.5	16	RA	3.6	H
	Apogon septemstriatus (Gunther)	2.4-5.3	5.3	RA	3.4	H
	Apogon taeniatus Cuvier	4.8-6.9	17	RA	3.5	H
	Apogonichthys ocellatus Weber	12.5	6	RA	3.3	H
Family	: Sillaginidae					
	Sillago sihama (Forsskal)	7.4-12.2	30	RA, AM	3.4	H
Family	: Lactariidae					
	Lactarius lactarius (Bloch & Schneider)	6.9-10.6	40	P	4.0	H
Family	: Echeneidae					
	Echeneis naucrates Linnaeus	21.4-26.8	110	RA	3.4	—
	Remorina albescens (Temminck & Schlegel)	18.5	30	P	3.3	—
Family	: Rachycentridae					
	Rachycentron canadum (Linnaeus)	16.5	200	RA	4.0	M
Family	: Carangidae					
	Alectis ciliaris (Bloch)	2.4-8.4	150	RA	3.8	L
	Carangoides malabaricus (Bloch & Schneider)	5.2-11.3	60	RA, AM	4.4	M
	Caranx ignobilis (Forsskal)	6.5	170	RA	4.2	M
	Decapterus macrosoma Bleeker	8.4-16.4	35	RA	3.4	H
	Decapterus russelli (Ruppell)	2.9-17.2	45	BP	3.7	M
	Gnathanodon speciosus (Forsskal)	3.4-15.7	110	RA	3.8	L
Family	: Menidae					
	Mene maculata (Bloch & Schneider)	6.1-10.9	30	RA	3.5	H
Family	: Leiognathidae					
	Leiognathus bindus (Valenciennes)	2.1-7.3	11	D, AM	2.5	H
	Leiognathus blochii (Valenciennes)	2.7-5.1	19	D, AM	2.9	H
	Leiognathus daura (Cuvier)	5.2-5.8	14	D	3.0	H
	Leiognathus elongatus Gunther	6.5	12	D	2.91	H
	Leiognathus equulus (Forsskal)	2.9-6.9	28	D, AM	3.0	H
	Leiognathus splendens (Cuvier)	1.6-10.9	17	D, AM	2.9	H
	Secutor insidiator (Bloch)	1.9-11.6	11	D, AM	2.8	H
	Secutor ruconius (Hamilton)	2.6-8.7	8	D, AM	3.4	H
Family	: Lutjanidae					
	Lutjanus bengalensis (Bloch)	12.3-13.5	30	RA	3.8	H
	Lutjanus biguttatus (Cuvier & Valenciennes)	11.3	25	RA	4.37	H
Family	: Gerreidae					
	Gerres filamentosus Cuvier	3.1-11.2	35	D, AM	3.3	H
	Gerres oblongus Cuvier	2.0-10.3	30	RA	3.5	M
	Gerres setifer (Hamilton)	7.4-8.6	15	BP, AM	3.3	H
	Pentaprion longimanus (Cantor)	8.3	15	D	3.41	H

Family : Haemulidae					
Diagramma pictum (Thunberg)	6.5-13.2	100	RA	3.5	M
Pomadasys maculatus (Bloch)	2.4-14.9	59	RA, AM	4.04	M
Family : Nemipteridae					
Nemipterus japonicus (Bloch)	2.9-16.2	32	D	3.8	M
Parascolopsis aspinosa (Rao & Rao)	10.5	21	D	3.5	H
Scolopsis bimaculatus Ruppell	9.8	31	RA	3.8	H
Scolopsis vosmeri (Bloch)	3.4-12.4	25	RA	3.5	H
Family : Sciaenidae					
Johnius amblycephalus (Bleeker)	2.9-12.6	25	D	3.3	H
Johnius belangerii (Cuvier)	3.5-17.5	30	D, AM	3.3	H
Johnius elongatus Mohan	5.7-11.5	30	D	3.3	H
Johnius macropterus (Bleeker)	6.8-11.0	25	D	3.9	H
Otolithes cuvieri Trewavas	5.9-12.3	39	BP	4.05	H
Otolithoides biauritus (Cantor)	6.4-11.5	160	D, AM	3.3	M
Family : Mullidae					
Mulloidichthys flavolineatus (Lacepede)	3.2-9.3	43	RA	3.3	M
Parupeneus cyclostomus (Lacepede)	9.7	50	RA	4.2	M
Upeneus vittatus (Forsskal)	5.4	28	RA	3.5	H
Family : Pempheridae					
Pempheris vanicolensis Cuvier	9.5	20	RA	3.5	H
Family : Drepanidae					
Drepane punctata (Linnaeus)	3.2	45	RA, AM	3.3	M
Family : Chaetodontidae					
Heniochus acuminatus (Linnaeus)	7.1	25	RA	3.5	H
Parachaetodon ocellatus (Cuvier)	12.3	18	RA	2.76	H
Family : Pentacerotidae					
Histiopterus typus Temminck & Schlegel	21.5	42	RA	3.5	—
Family : Teraponidae					
Pelates quadrilineatus (Bloch)	7.6	30	RA	3.5	M
Terapon jarbua (Forsskal)	3.2-8.9	36	D, CA	3.9	M
Terapon puta (Cuvier)	6.4-11.6	16	BP, AM	3.1	H
Terapon theraps (Cuvier)	4.7-5.9	30	RA	3.5	H
Family : Cepolidae					
Owstonia weberi (Gilchrist)	10.50	52	BD	3.4	M
Family : Pomacentridae					
Chrysiptera biocellata (Quoy & Gaimard)	3.1	11	—	2.0	H
Family : Labridae					
Halichoeres marginatus Ruppell	12.4	18	RA	3.26	H
Xyrichtys bimaculatus Ruppell	5.6-9.8	28.5	E	3.35	M
Xyrichtys cyanifrons Valenciennes	4.9-13.6	14.9	P	3.29	M
Family : Pinguipedidae					
Parapercis punctata (Cuvier)	3.6-18.9	NA	D	3.5	H
Family : Percophidae					
Bembrops platyrhynchus (Alcock)	12.7	25	BD	4.1	M
Family : Uranoscopidae					
Uranoscopus guttatus Cuvier	2.9-17.9	20	D	4.0	H
Family : Blenniidae					
Xiphasia setifer Swainson	31.4-41.8	53	D	2.0	M
Family : Callionymidae					
Callionymus japonicus (Houttuyn)	4.0-18.6	20	D	3.4	M
Callionymus sagitta Pallas	4.6-12.2	11	D	2.9	H
Family : Gobiidae					
Odontamblyopus rubicundus (Hamilton)	8.4-22.5	25	BP	3.8	M
Oxyurichthys tentacularis (Valenciennes)	3.9-6.8	17	D, AM	4.2	M
Parachaeturichthys polynema (Bleeker)	5.3	15	D	3.1	M
Trypauchen vagina Bloch & Schnieder	3.9-19.8	22	D, AM	3.5	M

Family	: Platacidae					
	Platax pinnatus (Linnaeus)	10.1	45	RA	3.3	—
Family	: Scatophagidae					
	Scatophagus argus (Linnaeus)	12.1	38	RA, AM	3	—
Family	: Siganidae					
	Siganus canaliculatus (Park)	11.9	30	RA, OC	2.8	H
	Siganus javus (Linnaeus)	6.7	53	RA	2.4	M
Family	: Acanthuridae					
	Acanthurus bleekeri Gunther	6.8-9.5	50	RA	2.5	L
Family	: Sphyraenidae					
	Sphyraena barracuda (Walbaum)	6.2-16.9	200	RA	4.5	L
	Sphyraena putnamae Jordan & Seale	16.5-19.9	90	RA	4.47	M
Family	: Gempylidae					
	Thyrsitoides marleyi Fowler	48.6-50.1	200	BP	4.19	VL
Family	: Trichuridae					
	Lepturacanthus savala (Cuvier)	15.1-49.6	100	BNP, AM	4.3	H
	Trichiurus lepturus Linnaeus	16.5-49.6	234	BNP, AM	4.4	M
Family	: Scombridae					
	Rastrelliger kanagurta (Cuvier)	6.1-35.58	35	P	3.2	H
Family	: Centrolophidae					
	Psenopsis cyanea (Alcock)	9.1-18.4	20	BD	3.5	M
	Selaroides leptolepis (Cuvier)	5.6-11.2	22	RA, AM	3.5	H
Family	: Stromateidae					
	Pampus argenteus (Euphrasen)	6.4	60	BNP	3.1	M
Family	: Peristediidae					
	Peristedion investigatoris (Alcock)	4.1-10.6	23	BD	3.5	M
	Satyrichthys adeni (Llyod)	19.6-20.4	7	D	3.7	VL
Order	**: Pleuronectiformes**					
Family	: Bothidae					
	Arnoglossus tapeinosoma (Bleeker)	10.9-11.5	12.7	D	3.5	H
	Bothus myriaster (Temminck & Schlegel)	3.2-12.4	27	D	3.5	M
	Chascanopsetta lugubris Alcock	16.1-16.8	40	BD	3.5	M
	Crossorhombus azureus (Alcock)	5.4-11.9	18	D	3.5	H
	Engyprosopon grandisquama (Temminck & Schlegel)	2.4-6.8	15	D	3.1	H
	Laeops nigromaculatus von Bonde	5.9-14.6	21	D	3.5	H
	Pseudorhombus arsius (Hamilton)	2.9-19.6	45	D	4.16	M
	Pseudorhombus dupliciocellatus Regan	12.5-24.6	40	D	4.2	M
	Pseudorhombus elevatus Ogilby	2.7-13.5	20	D	3.5	H
	Pseudorhombus triocellatus (Schneider)	7.5-7.6	15	D	3.5	H
Family	: Pleuronectidae					
	Samaris cristatus Gray	7.3-12.8	22	D	3.5	—
Family	: Soleidae					
	Aesopia cornuta Kaup	4.2-15.8	25	RA	3.5	M
	Brachirus annularis Fowler	6.9-9.6	13	D	3.5	H
	Solea elongata Day	3.4-12.6	30	D	3.5	M
	Solea ovata Richardson	4.8-6.7	10	D	3.5	H
	Synaptura albomaculata (Kaup)	8.9-13.4	30	D	3.7	M
	Synaptura commersonnii (Lacepede)	10.6-14.3	32	D, AM	3.5	M
	Zebrias synapturoides (Jenkins)	6.7-14.1	15	D	3.5	H
Family	: Cynoglossidae					
	Cynoglossus arel (Bloch & Schneider)	4.9-19.4	40	D, AM	3.3	M
	Cynoglossus dubius Day	5.9-12.4	50	D	3.5	L
	Cynoglossus lida (Bleeker)	4.3-11.6	21.3	D	3.3	M
	Cynoglossus macrostomus Norman	1.9-14.3	17.3	BNP	3.28	H
	Cynoglossus puncticeps (Richardson)	5.8-16.4	35	D	3.3	H
	Cynoglossus zanzibarensis Norman	10-11.7	32	D	3.6	M

Order : Tetradontiformes					
Family : Triacanthodidae					
Atrophacanthus japonicus Kamohara	5.4-9.7	10.4	BP	3.65	—
Macrorhamphosodes platycheilus Fowler	11.7-13.2	13	D	4.23	—
Family : Triacanthidae					
Triacanthus biaculeatus (Bloch)	1.9-9.9	30	D	2.8	M
Family : Balistidae					
Abalistes stellatus (Lacepede)	8.5	60	RA	3.54	M
Odonus niger (Ruppell)	10.5-14.3	50	RA	3.2	M
Sufflamen fraenatus (Latreille)	17.3-28.1	38	RA	3.4	M
Family : Ostraciidae					
Lactoria cornuta (Linnaeus)	3.8	46	RA	3.5	—
Tetrosomus gibbosus (Linnaeus)	4.6-8.0	30	RA	3.5	H
Family : Tetraodontidae					
Arothron stellatus (Bloch & Schneider)	5.4-26.4	120	RA	3.34	VL
Arothron leopardus (Day)	8.9-24.5	—	D	3.3	M
Chelonodon patoca (Buchanan)	36.2	38	RA, AN	3.1	M
Family : Lagocephalidae					
Lagocephalus inermis (Temminck & Schlegel)	12.6-14.8	90	D	3.9	L
Lagocephalus sceleratus (Gmelin)	11.2-12.8	110	RA	3.6	VL
Family : Diodontidae					
Cyclichthys orbicularis (Bloch)	17.9	30	RA	3.6	—
Diodon hystrix Linnaeus	6.9-19.6	91	RA	3.4	L

*Data from FishBase (Froese and Pauly, 2007).

AM = Amphidromous; AN = Anadromous; BD = Bathydemersal; BNP = Benthypelagic; BP = Bathypelagic; CA = Catadromous; D = Demersal; H = High; L = Low; M = Medium; P = Pelagic; RA = Reef Associated; VL = Very Low.

Table 2. Diversity of fish fauna in trawl bycatch at different trophic levels in Kerala, southwest coast of India

Diversity Indices	Trophic levels				
	2.0-2.49	2.5-2.99	3.0-3.49	3.5-3.99	4.0-4.5
Number of species	5	13	56	103	40
Number of individuals	109	448	857	1159	612
Shannon diversity	0.801	1.490	2.899	3.660	2.823
Simpson index	0.498	0.694	0.912	0.952	0.914
Dominance	0.502	0.307	0.088	0.048	0.086
Evenness	0.446	0.341	0.324	0.377	0.421
Fisher-alpha	1.082	2.504	13.420	27.310	9.588

Vivekanandan *et al.* (2005) recorded higher landings of top level predators along the Indian coast during 1950-2002. Elimination of predatory fish communities has been reported from oceans around the globe due to rampant fishing activities, with potentially serious consequences for ecosystems (Myers and Worm, 2003; Worm *et al.*, 2005). Presence of a large number of mid level carnivores in the trawl bycatch indicates the large scale removal of top level predators, as suggested by Vivekanandan *et al.* (2005). Presence of species with higher trophic level in the bycatch could have far reaching consequences, considering high level of carnivores and top level predators sustaining the fisheries in this region. As predatory fishes are selectively removed from the oceans, the trawl must increasingly rely on species in the lower trophic level. This is found true in the case of species in the trawl bycatch of Kerala coast, as the bycatch is dominated by mid level carnivores, particularly the demersal species. Due to trawling the longer-lived demersal species tend to decline faster than the shorter-lived pelagic species (Pauly *et al.*, 2002). Occurrence of 143 species of fish with higher trophic level (>3.4) in the trawl bycatch (more than 50 per cent of total fish diversity in trawl bycatch) can have far reaching consequences, considering high level carnivores and top level predators sustaining the fisheries in the region. However, studies extending over longer time-scale are required to unequivocally establish the decline of predatory fishes in trawl landings.

Table 3. t-values for comparing Shannon diversity index of fish fauna of the trawl bycatch at different trophic levels

Trophic levels	Trophic levels			
	2.0-2.49	2.5-2.99	3.0-3.49	3.5-3.99
2.0-2.49				
2.5-2.99	8.1933**			
3.0-3.49	25.875**	20.916**		
3.5-3.99	36.353**	33.81**	13.002**	
4.0-4.5	24.755**	19.568**	1.22^{ns}	14.113**

***p< 0.01; ns: non significant*

In terms of species diversity fish at the bottom of the trophic level (herbivores and detritivores) together represented only about 8% of the trawl bycatch in Kerala coast. A similar trend was noticed in the case of Shannon, Simpson and Fisher-alpha indices, all recording the highest value in the trophic level 3.5-3.99 and the lowest in the group 2.0-2.49. In the trophic levels 2.0-2.49 and 2.5-2.99 however, the dominance index of fishes was higher (0.502 and 0.307 respectively) than in the remaining trophic levels. This could be due to the presence of lower trophic level fishes such as *Sardinella longiceps* and *Leiognathus splendens* as dominant fraction throughout the period of study. In the higher trophic levels, none of the species dominated the bycatch as revealed by the lower value of dominance index. Evenness index recorded lower values in all the trophic levels; it was maximum (0.446) in the trophic level 2.0-2.49 and minimum (0.324) in the group 4.0-4.5 (Table 2). The Shannon diversity indices of various trophic levels, except between 3.0-3.49 and 4.0-4.5, differed significantly (p<0.01) (Table 3).

Species composition and species richness determine jointly the structure, function and stability of communities and therefore, biodiversity loss will transform and destabilise complex food webs, irrespective of which species are affected (Worm and Duffy, 2003). Higher species diversity exhibits the characteristic non-selectivity of trawlnets, and the lower cod end mesh size of the gear (Bijukumar and Deepthi, 2006). The multispecies nature of trawl fishing and multiday fishing could also have contributed to the greater biodiversity of bycatch.

List of two frequently occurring fish species in the trawl bycatch at each trophic level is presented in Table 4. Out of five species recorded in the trophic level 2.0-2.49, *Sardinella longiceps* and *Uranoscopus guttatus* were found to be the most frequent species in the trawl bycatch; the former was more abundant (60.6%) than the latter (36.7%). Out of 13 species recorded in the trophic level 2.5-2.99, *Leiognathus splendens* (40.6%) and *Callionymus japonicus* (35.9%) were the most abundant species. *Gerres oblongus* (17%) and *Cynoglossus macrostomus* (15.4%) were the most frequent species at the trophic level 3.0-3.5. Out of 105 species recorded in the trophic level 3.5-3.99, *Callionymus sagitta* (14.2%) and *Pseudorhombus elevatus* (8.9%) were the most frequent species. *Parapercis punctata* (18.6%) and *Saurida undosquamis* (10.8%) were the most abundant species in the trophic level 4.0-4.5.

Table 4. Top two frequent species in the trawl bycatch of Kerala, southwest coast of India at different trophic levels

Trophic levels	Species	Abundance	Percentage abundance
2.0 - 2.49	*Sardinella longiceps*	66	60.6
	Uranoscopus guttatus	40	36.7
2.5 - 2.99	*Leiognathus splendens*	182	40.6
	Callionymus japonicus	161	35.9
3.0 - 3.49	*Gerres oblongus*	146	17.0
	Cynoglossus macrostomus	132	15.4
3.5 - 3.99	*Callionymus sagitta*	164	14.2
	Pseudorhombus elevatus	103	8.9
4.0 - 4.5	*Parapercis punctata*	114	18.6
	Saurida undosquamis	66	10.8

The length class distribution of fishes in trawl bycatch showed that the length class below 15 cm was dominant in all the trophic levels (Table 5). In the trophic level 2.0-2.49, the length class 10-15 cm was represented by four species and the length class 5-10 by one species. The length class 5-10 cm represented the length class at all other trophic levels. Only 15 species of fishes were collected in the large length class (above 30 cm); most of the species in this category were carnivores.

Table 5. Length class distribution of fishes of the trawl bycatch of Kerala, south west coast of India at different trophic levels

Trophic levels	Length class (cm)	Number of species	Number of individuals
2.0 - 2.49	5 - 10	1	66
	10 - 15	4	43
2.5 - 2.99	≤ 5	3	236
	5 - 10	6	42
	10 - 15	4	170
3.0 - 3.49	≤ 5	4	155
	5 - 10	30	525
	10 - 15	14	134
	15 - 20	3	9
	20 - 25	1	2
	25 - 30	1	1
	Above 30	3	31
3.5 - 3.99	≤ 5	7	38
	5 - 10	43	758
	10 - 15	29	212
	15 - 20	12	56
	20 - 25	4	62
	25 - 30	1	5
	Above 30	7	28
4.0 - 4.5	≤ 5	2	7
	5 - 10	17	272
	10 - 15	10	182
	15 - 20	4	22
	20 - 25	4	104
	Above 30	3	25

The MTI of fish species in the trawl bycatch of southwest coast of India was 3.12, indicating higher biomass of low trophic level fishes in the trawl bycatch. Trophic level and mean trophic index indicate the complex interactions between fisheries and marine ecosystem and provide clues for measuring species replacement induced by fisheries (Pauly and Watson, 2005). Change in fish diversity has been related to fishing pressure prevailing in the ecosystem (Jennings and Kaiser, 1998). Vivekanandan *et al.* (2003) recorded the mean trophic levels of commercial catches along southwest coast of India during 1994-1996 as varying between 2.59 and 2.61 and the lower value of mean trophic level was attributed to the abundance of catches of pelagics low in the food chain occurring in the habitat. The mean trophic index of 3.12 in the present study did not give any confirmatory clues regarding the "fishing down food web" phenomenon. Pauly *et al.* (1998) reported a sharp decline in mean trophic level of global fish catch during 1950 - 1994. Along the Indian coast a decline of mean annual trophic level at the rate of 0.04 per decade was recorded in the landings of southeast coast during 1950-2002; such a trend, however, was not effervescent along southwest coast (Vivekanandan *et al.,* 2005). In the Gulf of Thailand ecosystem, which is dominated by trawl fishing, the trophic level of catches declined from 3.12 in 1963 to 3.01 in 1980 (Christensen, 1998). Ontogenetic shifts in feeding habits also need to be taken into account before arriving at definite conclusion on MTI values. The fishery of southwest coast is dominated with plankton feeding pelagics and the analysis of trawl bycatch landings would provide data primarily centered around demersal species. Further, the invertebrate fauna, particularly penaeid prawns, stomatopods and crabs which are well represented in trawl bycatch in the southwest coast of India are also not included in the study and this could be one of the reasons for higher MTI value recorded. Regular monitoring of trawl bycatch is required for sustainable management of marine fishery primarily because a major portion of marine fishery landings in the southwest coast is the contribution of trawlers.

According to Bhathal and Pauly (2008), even though the deployment of mechanized fleet increased the catches, there has been a negative impact on the mean trophic level of marine fisheries in India. The relative abundance of various species in the ecosystem is also affected by fishing. In the long run these changes may affect community structure, biodiversity and functioning of the ecosystem (Jackson *et al*., 2001). The trophic levels of fish are conservative attributes and they cannot change much over time, even when ecosystem structure changes (Pauly *et al*., 1998). Fishing affects ecosystems by removing biomass from the complex of species that feed upon each other in the food web. Fisheries production of an ecosystem depends significantly on food web dynamics (Link, 2002). Commercial fishing can decrease the average body size and age of a stock, causing the truncated population to track environmental fluctuations directly (Anderson *et al.,* 2008).

A clear trend of higher diversity of high trophic level fishes and lower MTI revealed by the trawl bycatch data from the Kerala, southwest coast of India, indicates absence of sustainability of trawl fishing and the need for interventions to reduce the amount of bycatch. In all the trophic levels, fishes in smaller length groups dominated the landings indicating that juveniles are landed in larger proportions in the trawl bycatch. The current features of trophic levels of trawl bycatch warrants policy interventions to reduce fishing pressure and to implement bycatch reduction devices along the southwest coast of India.

Acknowledgements

The first author is thankful to Kerala State Council for Science, Technology and Environment for the financial support of the work.

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Received : 12/02/09
Accepted : 19/08/09