Indian Journal Of Geo Marine Sciences
Vol. 46 (10), October 2017, pp. 2037-2045

Species composition and temporal variation of trawl by-catch in fishing grounds off northern Andhra Pradesh, western Bay of Bengal

[*]Pralaya Ranjan Behera, Shubhadeep Ghosh, Muktha M, M Satish Kumar & Jishnu Dev M

Visakhapatnam RC of Central Marine Fisheries Research Institute, Visakhapatnam-530003, India

*[E-mail: beherapralaya213@gmail.com]

Received 15 March 2016 ; revised 15 June 2016

The by-catch composition, catch rates of major species in by-catch and its seasonal variation was studied from 53 trawl hauls of a commercial shrimp trawler for the period from December 2013 to December 2014. From 330.036 kg of by-catch, 27,854 specimens were obtained belonging to 248 taxa (89 families) from which 216 were identified upto species level. Contribution of teleosts and invertebrates to the total by-catch biomass was 87.49% and 11.48% and to the total number of individuals in by-catch was 86.83% and 13.05%. Portunidae, Carangidae, Penaeidae, Sciaenidae, Apogonidae, Engraulidae, Synodontidae and Leiognathidae were the eight most speciose families accounting for 41 % of the species. *Photopectoralis bindus* was the most numerically abundant (16.92%). Mean catch rates of total by-catch differed significantly between seasons with higher catch rates in post fishing ban period for biomass and number. Seven teleost and four invertebrate species had mean catch rates higher during post fishing ban period, while one each had higher catch rate during pre fishing ban period.

[**Key words:** By-catch, northern Andhra Pradesh, species composition, temporal variation, trawling.]

Introductions

Trawl by-catch is a globally recognized issue with intensified effects in tropical waters affecting both the ecosystem function and biodiversity, as well as causing physical damage and habitat loss[1]. Trawling in localized ecosystems removes rare and endangered species, causing loss of biodiversity. Between 6.8 million tonnes[2] and 20 million tonnes[3] of bycatch are being caught by the world fisheries each year. Demersal prawn (shrimp) trawl fisheries are responsible for about one-third of that[4]. These by-catches are usually returned to the water either dead or dying[5, 6]. Vulnerable or protected species such as sea turtles and sea snakes are also components of this bycatch in tropical prawn trawl fisheries. Major issue in tropical trawl fisheries is by-catch due to its multispecies fisheries. Species composition of multispecies trawl fishery suggests that the enormity of by-catch resulting from such fishing operations is inevitable, causing loss of species and physical damage to the ecosystem[7, 8].

In India, trawlers contribute a major part of the total marine fish production [9]. A wide range of non-targeted species is captured by trawl nets, including juveniles of species that would have otherwise contributed to a commercial catch of larger fish at a later time [4, 7]. For ensuring sustainability of all non-target species being impacted by trawling, long-term by-catch monitoring program is needed. Detailed information on the historic dimensions of by-catch is not available for many fisheries, and thus continued monitoring is necessary to assess trends and to measure the effectiveness of new technologies designed to minimize by-catch[7, 10]. It is also essential to develop a fisheries database to enable evaluation of the impacts on fisheries and biodiversity of the region, for developing macro-level policies in fisheries management[11]. In view of the above, the present study was undertaken to describe the by-catch composition with seasonal variation and the catch rates of by-catch species.

Materials and Methods

Andhra pradesh, with a coastline of about 974 km (Lat:19°01′21″N–13°18′36″N, Long: 84°52′29″E–80°24′04″E) facing the Bay of Bengal, supports diversified ecological features and forms an integral part of the central east coast of India. It has a continental shelf area of about 33,000 sq.km. The proposed study area covers the potential fishing grounds along the coastal areas off north Andhra pradesh. The trawlers operate in a wide area from Gopalpur in the north to Kakinada in the south along the Bay of Bengal.

Sampling consisted of 53 trawls hauls was conducted by trained crew from a 15 m long commercial shrimp trawler during day time at fortnightly interval. The sampling period extended from December 2013 to December 2014 with exceptions during monsoon ban. Altogether 19 samples were taken from the pre fishing ban period (December to mid-April) and 34 samples from the post fishing ban period (June to November)

A trawl net with 22 m head and foot rope lengths and mesh sizes of 30 mm at mouth, 18 mm in the middle and 11 mm at cod end was towed at a speed of about 2–3 knots in depth between 10m to 70m. Once the haul was taken on board, 2-3 random sub-samples of approximately 4-5 kg each were collected prior to sorting to assess total species composition. Quantitative assessment i.e. weight measurements of different faunal groups in target and commercial by-catch was done on-board of the shrimp trawler. All the samples were temporarily preserved in ice and brought to the laboratory. This method of sub sampling adequately represented the by catch composition[12].

In the laboratory, animals from each subsample were identified to the lowest taxonomic level (usually species) and counted. The total weight of each taxa was recorded (0.1 g), and 20 randomly chosen individuals[13] from each species were measured for their standard length (SL in mm) or total length (TL in mm) depending on species. Taxa other than teleosts were measured for their total length (sharks), disc width (rays), snout-vent length (sea snakes), carapace length or width (crustaceans) and mantle length (cephalopods).

The number of individuals and the biomass of each species from each trawl haul were calculated by multiplying the subsample by a raising factor based on the subsample to total bycatch weight ratio[14]. The catch rates of numbers (n h^{-1}) and biomass (kg h^{-1}) of each species were standardized to account for seasonal differences.

The entire duration of study was divided into two seasons i.e. pre-fishing ban (December-mid April) and post-fishing ban (June-November). The taxa (those which contributed more than 0.5% to a monthly aggregate abundance) data were selected for cluster analysis. Abundance data were normalized using the square root transformation function, converted into a lower triangular matrix using the Bray–Curtis Similarity Coefficient[15] and dendrogram plots were constructed using the group average function in ‘Plymouth Routines in Multivariate Ecological Research’ (PRIMER) v.6 ‘data analysis sofware[16]. The significance of the cluster groups ($p < 0.05$) was tested by similarity profile (SIMPROF) analysis. Abbreviations used to represent species are given in the Appendix. The significant differences between seasons in the mean biomass, the number of species in the overall catch, the mean number of individuals and biomasses of the 10 most abundant by-catch species for both teleosts and invertebrates were analysed by using a single factor analysis of variance (ANOVA).

Results

A total of 330.036 kg of by-catch was processed from 53 trawl subsamples which consisted of 27, 854 individuals from 248 taxa (89 families), of which 216 species were identified upto species (Table 1). The contribution of teleosts, invertebrates, elasmobranchs, turtles and sea snakes to the total by-catch biomass was 87.49%, 11.48%, <0.5%, <0.5% and <0.5% respectively. Numbers of individuals in the by-catch were also dominated by teleosts (86.83%), with invertebrates (13.05%), elasmobranchs (<0.1%), turtles (<0.1%) and sea snakes (<0.1%) contributing fewer individuals.

The eight most speciose families accounted for 41% of the species. These were Portunidae, Carangidae, Penaeidae, Sciaenidae, Apogonidae, Engraulidae, Synodontidae and Leiognathidae (Table 1). Scombridae contributed nearly 39.21 % to the total by-catch biomass, mainly due to the large contribution by *Rastrelliger kanagurta*. Carangidae and Mullidae also contributed significantly to the biomass: 6.75 and 6.94 %, respectively. Leiognathidae was the most numerically dominant family, contributing 31.09% of the by-catch because of large contribution of *Photopectoralis bindus* (16.92%). *Photopectoralis bindus* was the most numerically abundant (16.92%) of all the by-catch species. Teleost species with the highest mean catch rates were *Decapterus russelli*, *Upeneus vittatus*, *Rastrelliger kanagurta*, *Secutor insidiator*, *Photopectoralis bindus* and *Lagocephalus lunaris* (Table 1).

A total of 60 invertebrate species from 27 families was recorded from the by-catch subsamples. Portunidae and Penaeidae were the most speciose, represented by seven and thirteen species each respectively. Portunidae contributed the most to the invertebrate by-catch: 6.56 % of the total biomass, and 31.18% by weight and 28.12% by number of the invertebrate component. *Portunus sanguinolentus* was the most numerically abundant among all invertebrates (Table1), and accounted for 5.85 % of the total invertebrate biomass.

Table 1: Percentage occurrence and mean catch rates of by-catch species from Visakhapatnam waters

By-catch group	Species	Family	Mean biomass (kg/h) ± (S.E)	Mean number (n/h) ± (S.E)
Teleosts	*Pennahia anea*	Sciaenidae	5.200±0.350	50.302±8.179
	Johnius carutta	Sciaenidae	3.136±0.122	114.615±.635
	Pennahia macrophthalmus	Sciaenidae	2.293±0.173	40.365±2.240
	Nibea maculata	Sciaenidae	4.652±0.244	72.543±2.582
	Kathalla axillaris	Sciaenidae	3.811±0.878	111.446±46.195
	Johnius sp.	Sciaenidae	1.408±0.385	29.263±6.140
	Decapterus russelli	Carangidae	65.253±7.040	1642.642±589.4
	Selar boops	Carangidae	2.830±0.329	29.473±4.353
	Alepes sp.	Carangidae	2.259±1.044	41.077±12.864
	Thryssa hamiltoni	Clupeidae	3.347±0.245	108.145±2.935
	Thryssa mystax	Clupeidae	1.966±0.114	157.336±12.126
	Stolephorus indicus	Clupeidae	13.174±1.961	3052.153±550.033
	Dussumieria acuta	Clupeidae	4.355±0.503	116.820±6.607
	Ilisha megaloptera	Clupeidae	1.205±0.010	40.367±1.846
	Upeneus sulphureus	Mullidae	7.941±0.189	382.057±36.844
	Upeneus vittatus	Mullidae	105.190±5.023	4186.052±29.49
	Upeneus mollucensis	Mullidae	8.236±0.285	201.688±21.148
	Saurida undosquamis	Synodontidae	13.119±0.131	1200.921±29.28
	Saurida tumbil	Synodontidae	11.206±0.115	609.790±42.33
	Nemipterus randalli	Nemipteridae	19.722±0.401	1605.836±44.37
	Nemipterus japonicus	Nemipteridae	2.530±0.128	429.523±20.69
	Priacanthus hamrur	Priacanthidae	29.393±0.833	903.475±53.24
	Priacanthus tayenus	Priacanthidae	3.090±0.123	67.642±2.57
	Rastrelliger kanagurta	Scombridae	371.055±121.055	4651.784±2290.78
	Rastrelliger faughni	Scombridae	2.321±0.801	19.280±7.07
	Secutor insidiator	Leiognathidae	208.044±12.831	8004.363±454.24
	Photopectoralis bindus	Leiognathidae	118.220±3.007	10757.207±521.08
	Leiognathus elongatus	Leiognathidae	4.757±0.307	1590.198±19.98
	Pentaprion longimanus	Leiognathidae	14.151±0.645	1088.802±65.682
	Gazza minuta	Leiognathidae	11.887±0.674	332.277±43.064
	Leiognathus equulus	Leiognathidae	8.788±0.575	134.132±28.919
	Eubleekeria splendens	Leiognathidae	3.213±0.192	186.080±20.87
	Trichiurus lepturus	Trichiuridae	20.920±0.203	476.076±50.04
	Lepturacanthus savala	Trichiuridae	38.213±39.467	2255.442±125.31
	Apogon poecilopterus	Apogonidae	1.0360.286	420.637±95.63
	Apogonichthyoides taeniatus	Apogonidae	1.523±0.227	500.575±9.638
	Apogon sp.	Apogonidae	1.331±0.136	466.251±14.07
	Ostorhinchus fasciatus	Apogonidae	1.334±0.116	224.352±7.768
	Lagocephalus lunaris	Tetraodontidae	10.21±17.806	199.825±49.702
	Lagocephalus inermis	Tetraodontidae	5.727±1.469	210.463±87.463

	Pseudotriacanthus strigilifer	Triacanthidae	1.676±0.218	79.516±4.303
	Platycephalus indicus	Platycephalidae	5.893±0.329	310.579±45.456
	Cynoglossus sps	Cynoglossidae	2.876±0.290	25.773±.919
	Fistularia petimba	Fistulariidae	0.930±0.280	55.294±13.294
	Sphyraena sp.	Sphyraenidae	7.254±0.267	59.987±5.226
	Eel		3.089±0.432	42.372±2.838
	Valenciennea sexguttata	Gobiidae	2.942±0.379	30.301±5.178
	Pomadasys maculata	Haemulidae	2.504±0.381	59.867±6.135
Invertebrates	*Uroteuthis duvaucelii*	Loliginidae	6.946±0.304	599.194±10.929
	Sepia aculeata	Sepiidae	1.782±0.204	58.209±6.913
	Sepiella inermis	Sepiidae	3.797±0.062	159.248±5.965
	Sepia prashadi	Sepiidae	6.895±0.228	177.782±17.341
	Sepia sp.	Sepiidae	2.043±0.278	20.505±2.618
	Charybdis natator	Portunidae	1.681±1.560	307.901±2.211
	Portunus sanguinolentus	Portunidae	5.846±0.071	638.791±13.221
	Metapenaeus monoceros	Penaeidae	1.216±0.107	60.601±6.004
	Oratosquillina pentadactyla	Squillidae	1.731±0.133	169.578±2.553
Elasmobranchs	*Himantura imbricata*	Dasyatidae	2.021±0.321	15.123±6.231
	Torpedo panthera	Torpedinidae	1.230±0.125	23.023±8.213
	Torpedo sinuspersici	Torpedinidae	1.120±0.102	15.213±6.314
	Narke dipterygia	Narkidae	1.021±0.103	16.213±6.781
	Narcine brunnea	Narkidae	1.001±0.36	10.213±5.213

Note: Species landed in by-catch with a mean biomass greater than 1 kg/h are included

Table 2: Comparison of mean catch rate between prefishing ban and post fishing ban for total bycatch, total teleosts and important species

Groups	**Mean biomass (kg/h) ± SE**		**Mean number (n/h) ± SE**	
	Prefishing ban	Postfishing ban	Prefishing ban	Postfishing ban
Total bycatch	75.693 ± 2.840	176.596 ± 23.670	4549.7679±355.960	10375.93±766.109
Total teleosts	81.972± 10.640	162.322± 25.101	3679.001± 130.017	8458.674± 257.801
Finfishes				
Upeneus vittatus	16.039±0.204	83.8309±0.196	96.51±11.860	745.35±20.178
Nemipterus randalli	0.533±0.166	1.855±0.190	21.84±7.250	61.43±7.910
Lepturcanthus savala	1.668±0.452	7.563±0.560	34.607±11.720	2903.17±227.720
Photopectoralis bindus	1.484±0.023	21.87±1.410	161.59±2.560	2081.64±62.400
Stolephorus indicus	1.439±0.185	12.69±0.318	268.17±53.950	1969.43±125.390
Priacanthus hamrur	0.159±0.004	4.965±0.661	5.704±0.223	155.25±7.530
Thryssa setirostris	0.193±0.068	2.21±0.211	9.567±1.855	233.064±27.710
Leiognathus equulus	1.536±0.253	0.178±0.113	20.625±10.560	1.418±0.094
Invertebrates				
Portunus sanguinolentus	0.033±0.001	0.968±0.113	0.349±0.050	4.759±1.350
Metapenaeus monoceros	0.15±0.015	0.073±0.015	10.399±0.44	1.148±0.340
Metapenaeus barbata	0.015±0.002	0.973±0.014	5.99±0.147	50.257±1.515
Octopus membranaceus	0.188±0.016	10.068±0.110	8.039±2.990	73.7±5.713
Sepia aculeata	0.238±0.027	0.23±0.017	7.207±0.610	4.07±0.280

Five elasmobranch species were identified in the subsamples. *Himantura imbricata* was the most abundant and contributed 64% of the total number of elasmobranchs caught. Total of 32 sea turtles were accidentally captured as bycatch in trawl net from 28 trawl hauls. The most common was olive ridley turtle (*Lepidochelys olivaceae*). This accidental capture was mostly from September to March. Most of the captures occurred within 5 km of the shoreline and at a depth of less than 10m.

Mean catch rates of total by-catch differed significantly between seasons with higher catch rates in post fishing ban (PSFB) period for biomass (F = 4.65; P < 0.05) and number (F = 4.43; P < 0.05) (Table 2). However, the mean number of species did not differ significantly between pre and post fishing ban period (F = 3.123; P > 0.05).

Teleosts showed a similar pattern to the total by-catch. The mean catch rates differed significantly between pre fishing ban period (PFB) and post fishing ban period (PSFB) with higher catch rates in PSFB for biomass (F = 10.55; P < 0.001) (Table 2) and number (F = 9.12; P < 0.001). However, the mean number of teleost species did not differ significantly between two seasons (F = 4.956; P > 0.05). The mean catch rates of invertebrate by-catch did not differ significantly between PFB and PSFB for biomass (F = 0.145; P > 0.05) and number (F = 0.4268; P > 0.05), nor was there any difference in the mean number of invertebrate species (F = 0.8531; P > 0.05) between seasons.

Of the 10 most abundant teleost species, eight had mean catch rates (by biomass and number) that differed significantly between seasons. The catch rates of *Upeneus vittatus*, *Nemipterus randalli*, *Lepturacanthus savala*, *Photopectoralis bindus*, *Stolephorus indicus*, *Priacanthus hamrur* and *Thryssa setirostris* were higher during PSFB (Table 2), while for *Leiognathus equulus*, the catch rate was higher during PFB (Table 2). For the 10 most abundant invertebrate species, five differed significantly in their catch rates (by biomass and number) between seasons. Four species (*Portunus sanguinolentus*, *Metapenaeus monoceros*, *Metapenaeus barbata* and *Octopus membranaceus)* had higher catch rates during post fishing ban period (PSFB) while *Sepia aculeata* had higher catch rates in pre fishing ban period (PFB) (Table 2).

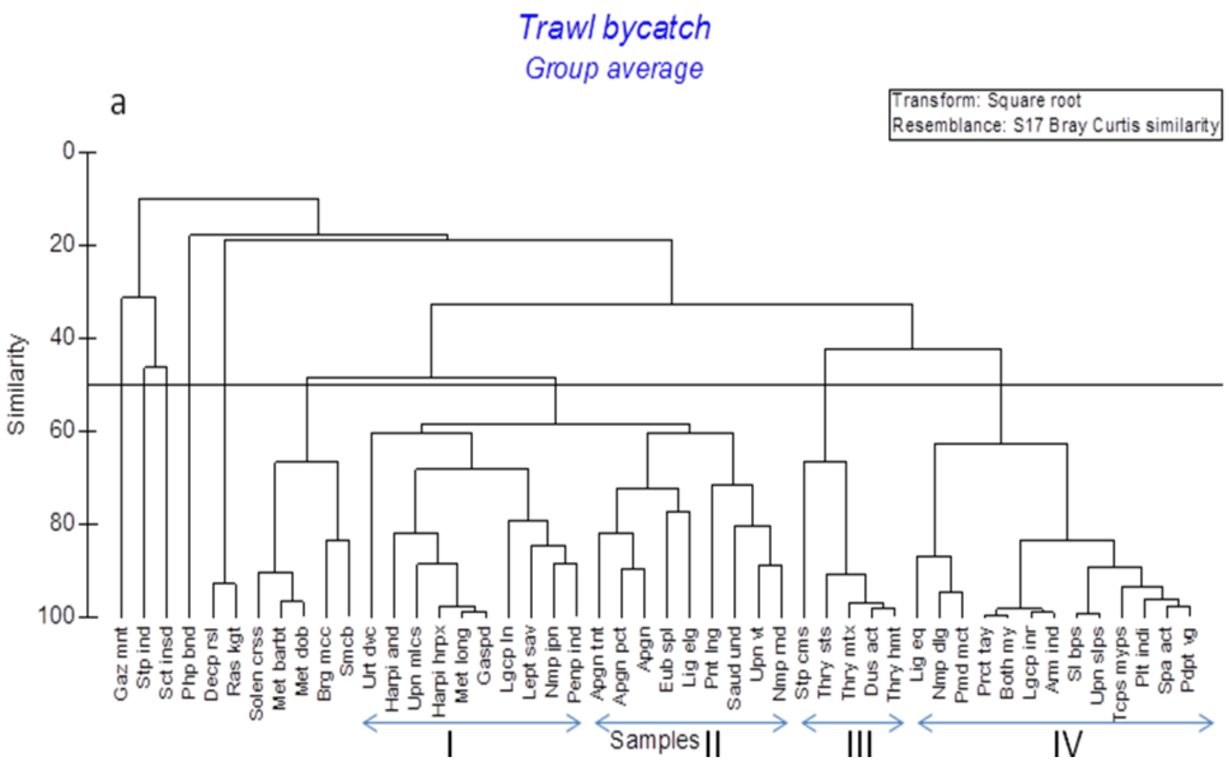

Figure 1 (a) Dendrogram showing clustering of species during pre fishing ban period

Cluster analysis of bycatch revealed the presence of four major clusters in pre-fishing ban and post fishing ban seasons. In the pre fishing ban season (Fig. 1a); cluster I comprised of *Leiognathus equulus, Nemipterus delagoe, Pomadasys maculate, Priacanthus tayenus, Bothus myriaster, Lagocephalus inermis, Ariomma indica, Selar boops, Upeneus sulphureus, Trachinocephalus myops, Platycephalus indicus, Sepia aculeate and Podopthalmus vigil*; cluster II comprised of *Uroteuthis duvaucelii, Harpiosquilla annandeli, Upeneus mollucensis, Harpiosquilla harpax, Metapenaeus longipes*, Gastropods, *Lagocephalus lunaris, Lepturacanthus savala, Nemipterus japonicas and Penaeus indicus*; cluster III comprised of *Apogonichthyoides taeniatus, Apogon poecilopterus, Apogon sp., Eubleekeria splendens, Leiognathus elongates, Pentaprion longimanus, Saurida undosquamis, Upeneus vittatus and Nemipterus randalii* and cluster IV comprised of *Thryssa setirostris, Thryssa mystax, Dussumieria acuta, Thryssa hamiltoni, Stolephorus commersoni* and *Metapenaeus dobsoni*.

During the post-fishing ban period (Fig. 1b), cluster I was composed of *Lagocephalus lunaris, T. lepturus, N. japonicas, Apogon sp., Harpiosquilla annandeli, Stolephorus commersonii, Thryssa hamiltoni, Solenocera crassicornis, N. delagoe and Bregmaceros macclellandi*; cluster II was composed of *M. granulosa*, unidentified red prawns, *Apogonichthyoides taeniatus, Apogon poecilopterus, Sepiella inermis, Pennahia anea, Alepes kleinii, Johnius dussumieri, Metapenaeus barbata, Kathalla axillaries, Thryssa mystax, Upeneus sulphureus* and *Gazza minuta*; cluster III was represented by *Decapterus russelii, Pentaprion longimanus, Upeneus vittatus and Saurida undosquamis* and cluster IV comprised of *Saurida tumbil, Nemipterus randalli, Priacanthus hamrur, Platycephalus indicus*, small crabs, *Charybdis sp., Upeneus mollucensis, Octopus membranaceus, Lagocephalus inermis and Uroteuthis duvaucelii.*

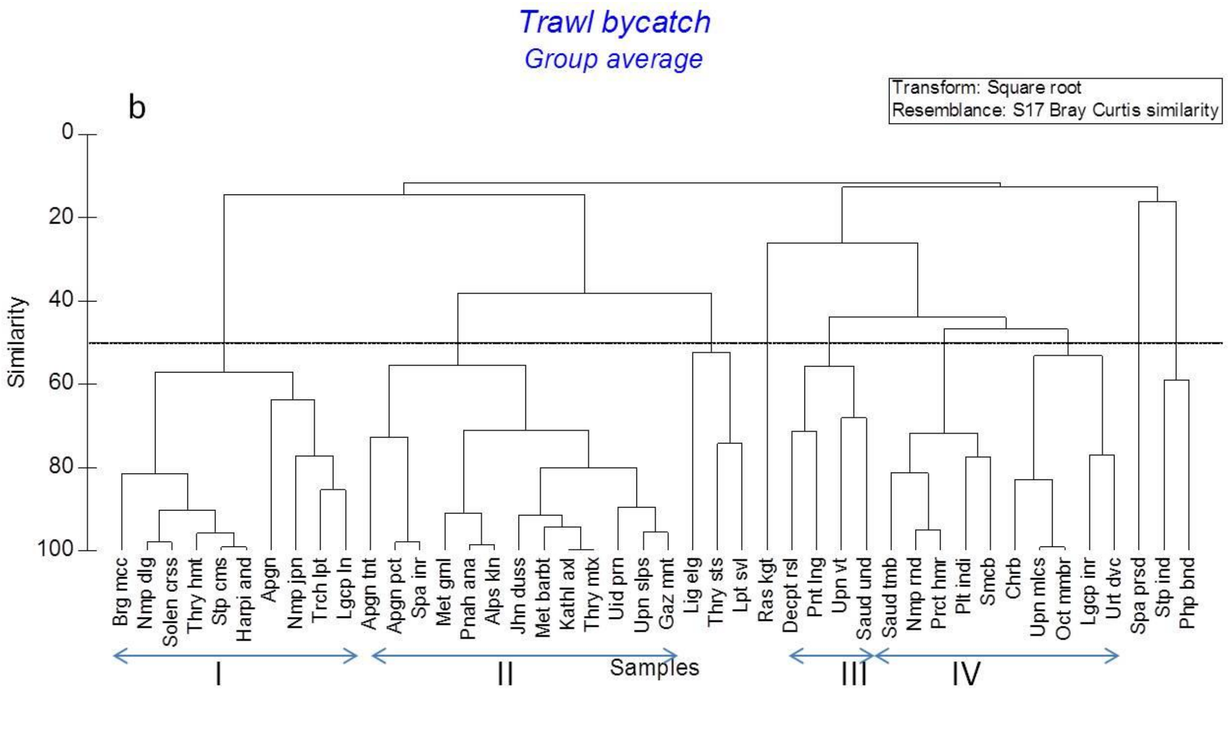

Figure 1(b) Dendrogram showing clustering of species during post fishing ban period

Discussion

The present investigation on the catch composition of shrimp trawl revealed that teleosts constituted 86.83 % by number and 87.49 % by biomass of total by-catch. A total of 155 teleost species representing 60 families and 60 invertebrate species representing 27 families were recorded. *Photopectoralis bindus* was the most numerically abundant (16.92%) of all by-catch species, whereas *Portunus sanguinolentus* was the most numerically abundant among invertebrates. Portunidae and Penaeidae were the most speciose among invertebrates, represented by seven and thirteen species respectively. Similar opinion was expressed and reported on family Portunidae (13 species) to be the most speciose family in crustacean by-catch landed from trawl fishery along north Tamilnadu coast[17]. In an earlier study from Visakhapatnam waters, 65 species of finfishes, 20 species of crustaceans and 6 species of mollusks have been reported from low value by-catch[18]. Higher occurrence of teleosts in trawl by-catch with 228 species of finfishes was also observed in an earlier study at Vishakhapatanam[19].

Scombridae, because of large contribution by *Rastrelliger kanagurta*, contributed nearly 39.21% to the total by-catch biomass, indicating the presence of small pelagic species in trawl. The occurrence of large amounts of small pelagic resources in trawls is a recent phenomenon attributed to the response of fish to seawater warming [20]. With warming of seawater, small pelagics such as oil sardine and Indian Mackerel extend their area of distribution to deeper waters.

Similar, to the present study[21], earlier authors have observed more than 70% of turtle captures in shrimp trawls at distances of 5 km from shore during October to May along Odisha coast. This incidental capture of endangered species as by-catch in shrimp trawls is a matter of great concern for the future. It is to be noted that along Odisha coast, more than 1,00,000 dead olive ridley turtles have been reported since 1994, mainly due to fisheries-related mortalities, resulting in possible decline in their population[22].

Present study revealed a significantly larger biomass and abundance of by-catch during post fishing ban seasons as compared to pre fishing ban seasons. Several other tropical shrimp trawl studies have also reported temporal variation in by-catch assemblages[10, 13]. The monsoon trawl ban helped in the recoupment and regeneration of favorable benthic prey items, and this could support higher by-catch biomass in post ban period[23]. The seasonal variations in temperature and salinity could also have contributed to this variation in faunal assemblage structure. Temporal variations in biotic factors viz., peak spawning season, spawning stock biomass and recruitment strength might also have influenced the by-catch biomass and abundance[24]. In our study, *Stolephorus indicus, Thryssa setirostris, Upeneus vittatus, Nemipterus randalli, Priacanthus hamrur, Photopectoralis bindus, Lepturacanthus savala, Leiognathus equulus, Portunus sanguinolentus, Metapenaeus monoceros, Metapenaeus barbata, Sepia aculeata and Octopus membranaceus* accounted for the major differences in biomass and numbers between seasons.

The fact that shrimp trawl fishery has an important impact on the benthic community structure is evident from the density and biomass changes in invertebrate by-catch. Selective trawl harvesting of species may alter benthic faunal composition. The organisms most affected by shrimp trawling include epibenthic species of mollusks, echinoderms, crustaceans, sponges, hydrozoans, bryozoans and fish[25, 26]. Studies have shown that by-catch alters the character of species assemblages[4, 27, 28]. Such shifts potentially alter the prey/predator relationships, increase the food for scavengers and modify the benthos ecosystem structure and function[4]. In light of the above, by-catch management assumes paramount importance for formulating fisheries management measures.

In the pre fishing ban period, cluster I comprised of predatory fish species with other benthic and pelagic species. These predatory species are known to feed on other species observed in this cluster suggesting the existence of predator and prey relationship. Cluster II comprised of mostly epibenthic species except *Lepturacanthus savala* suggesting sharing of habitat. Two species viz., *Nemipterus japonicus and Penaeus indicus* exhibited a prey-predator relationship[29]. Cluster III comprised of mostly demersal carnivores suggesting sharing of habitat[30]. Cluster IV comprised of a mixture of benthic and pelagic species indicating bentho–pelagic coupling of food chains or trophic interactions owing to the shallow depth of coastal waters[31].

During post fishing ban season, species associations were attributed to feeding aggregations. Coastal waters serve as nurseries for a variety of marine species[32]. They support a high density of juveniles[33] and contribute significantly to recruitment[34]. Cluster I comprised of predatory fish species (*N. japonicus, T. lepturus, L. lunaris and N. delagoe*) with other benthic and pelagic species. These predatory species are known to feed on other species observed in this cluster [29, 30] suggesting the existence of a prey–predator relationship. Cluster II comprised of carnivores and planktivorous species, and their association also suggested a prey–predator relationship[30]. Cluster IV comprising of benthic and demersal carnivores[30] use this habitat for their feeding and spawning. *Platycephalus indicus* and small crabs exhibit a prey–predator relationship, as *P. indicus* is known to feed on small crabs[30]. Hence this cluster is attributed to both habitat use and predator-prey relation.

In 1999, Government of Andhra Pradesh imposed a fishing ban for 45 days (April 16th to May 31st), as a conservation measure and it is in practice till date. A cursory analysis of data indicates an increase in catch and catch rates after the ban period, when compared to the pre-ban period. However, it is difficult to assess whether this increase is due to the impact of ban alone, as the fishery undergoes seasonal changes with respect to the efficiency of trawlers, duration of fishing and range of exploited area[35].

Additionally, biotic and abiotic factors could also play a role on this. It is generally believed that closure of fishery for a period of time manifest in an increase in landings by allowing the stocks to rebuild [36, 37,38,39]. However, it is not possible to revive depleting resources entirely by imposing closed season without a restriction on the number of operating fishing vessels[36, 40]. By-catch reduction in the trawl fishery at Visakhapatnam can be achieved by reducing the effort, by increasing the cod end mesh size and by increasing the seasonal closure of the fishery. This, in turn, will preserve the ecosystem structure and function and maintain biodiversity.

Acknowledgement

The authors express their gratitude to the Director, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, India

References

1. Dinesh T. V. and Chandrashekher U. R., Trends and composition of trawl by-catch and its implications on tropical fishing grounds off Goa, India. *Regional Studies in Marine Science,* 2 (2015), 65–75.
2. Kelleher, K., Discards in the World's marine fisheries. An update, *FAO Fish. Tech. Pap.* No. 470 (2004), pp. 134.
3. FAO., The State of World Fisheries and Aquaculture1998. FAO, Rome, Italy,(1999) (accessed January 2016).
4. Alverson, D. L., Freeberg, M. H., Murawski, S. A., Pope, J. G., A global assessment of fisheries bycatch and discards. *FAO Fish. Tech. Pap,* 339 (1994), 1–233.
5. Alverson, D. L., Global assessment of fisheries bycatch and discards: a summary overview. In: *Pikitch, E.K., Huppert, D.D., Sissenwine, M.P. (Eds.), Global Trends: Fisheries Management, Am. Fish. Soc. Symp.,* 20(1997) pp. 115–125.
6. FAO, United Nations Food and Agriculture Organisation, 2002. FAO Statistical Database. Available from http://apps.fao.org/default.htm (accessed January 2016).
7. Biju K. A. and Deepthi, G. R., Trawling and by-catch: Implications on marine ecosystem. *Current Science*, 90 (2006), pp. 922-931.
8. Gibinkumar,T.R., Sabu, S., Pravin, P. and Boopendranath, M.R. Bycatch Characterization of Shrimp Trawl Landings off Southwest Coast of India. *Fishery Technology* 49 (2012), pp. 132 -140.
9. Srinath, M., An appraisal of exploited marine fishery resources in India. In: Mohan Joseph, M. and Jayaprakash, A. A. (Eds.), *Status of exploited marine fishery resources of India*. CMFRI, Cochin, (2003), p. 254-285.
10. Tonks, M. L., Griffiths, S.P., Heales, D.S., Brewer, D.T. and Dell., Species composition and temporal variation of prawn trawl by catch in the Joseph Bonaparte Gulf, northwestern *Australia, Fisheries Research,* 89 (2008), 276-293.
11. Aswathi, N., R. Sathyadhas, Narayana K.R. and Shyam, S. S., Marketing and utilization of marine bycatch: problems and prospects, *J. Fish. Econ. Dev*. XII (2011): 1-8.
12. Heales, D., Brewer, D.T., Wang, Y-G., Subsampling multi-species trawl catches from tropical northern Australia: does it matter which part of the catch is sampled? *Fisheries Research,* 48 (2000), 117–126.
13. Stobutzki, I. C., Miller, M.J., Jones, P. and Salini, J.P., By-catch diversity and variation in a tropical Australian penaeid fishery; the implications for monitoring. *Fisheries Research,* 53(2001), 283-301.
14. Stobutzki, I.C., Miller, M.J., Heales, D.S. and Brewer, D.T., Sustainability of elasmobranchs caught as by-catch in a tropical prawn (shrimp) trawl fishery. *Fisheries Bulletin*, 100 (2002), 800–821.
15. Bray, J.R., Curtis, J.T., An ordination of the upland forest communities of Southern Wisconsin, *Ecol. Monograph*, 27(1957), 325–349.
16. Clarke, K. L., Gorley, R. N., Primer v6.1.10: user manual/tutorial PRIMER-E, Plymouth Routines in Multivariate Ecological Research, Plymouth (2006).
17. Pillai, S.L., Kizhakudan, S. J., Radhakrishnan, E. V. and Thirumilu, P., Crustacean bycatch from trawl fishery along north Tamil Nadu coast. *Indian J. Fish*., 61(2014), 7-13.
18. Rao, P. Y., Veni, D. N. K. and Sirisha, I. R. Trawl net by-catches off Visakhapatnam with special reference to Finfish. Advances *in Applied Science Research*, 4 (2013) pp. 363-371
19. Sujatha, K., Finfish constituents of trawl by-catch off Visakhapatnam, *Fish. Technol.* 32 (1995): 56-60.
20. Vivekanandan, E., Climate Change and Indian Marine Fisheries. *CMFRI Spl. Publ.*, 105 (2011), 97.
21. Tripathy, B. and Rajasekhar, P. S., Natural and anthropogenic threats to Olive ridley sea turtles at rushikulya rookery of Orissa coast, India. *Indian journal of Marine Sciences*, 38(2009), 439-443.
22. Gopi, G.V., Pandav, B. and Choudhury, B.C.C., Incidental captures and mortalities of olive ridley sea turtles in industrial trawl fisheries in the coastal waters off Orissa, India. *Chelonian conservation and biology,* 5(2006):276-280.

23. Thomas, V. J., Sreedevi, C., and Madhusoodana, K. B., Variation on the infaunal polychaetes due to bottom trawling along the inshore waters of Kerala (southwest coast of India). *Indian Journal of Marine Sciences,*53(2006), pp 249-256.
24. Vivekanandan, E., The trawl fisheries of the western Bay of Bengal “The Trawl Fisheries of the Western Bay of Bengal. APFIC Regional Expert Workshop on Tropical Trawl Fishery Management, (2013), Phuket, Thailand .
25. Collie, J. S., Escanero, G.A. and Valentine, P.C., Effects of bottom fishing on the benthic mega fauna of Georges Bank. *Mar. Ecol. Prog. Ser.,* 155(1997), 159-172.
26. Jennings, S. and Kaiser, M. J., The effects of fishing on marine ecosystems, *Advances in marine biology*, 34(1998), pp. 201-352.
27. Blaber, S.J.M. and Wassenberg T.J., Feeding ecology of the piscivorous birds, *Phalacrocorax varius, P. melanoleucos* and *Sterna bergii,* in Moreton Bay, Australia: diets and dependence on the trawler discards. *Marine Biology.* 101(1989), 1-10.
28. Wassenberg, T.J., Hill, B.J., The effect of trawling and subsequent handling on the survival of the by-catch of prawn trawlers in Moreton Bay, *Australia Fisheries Research*, 7(1989), 99–110.
29. Abdurahiman, K. P., Nayak, T. H., Zacharia, P.U., Mohamed, K.S., Trophic organisation and predator–prey interactions among commercially exploited demersal finfishes in the coastal waters of the southeastern Arabian Sea, *Estuar. Coast. Shelf Sci.,* 87(2010), 601–610.
30. Froese, R. and Pauly, D. Fishbase World Wide Web electronic publication. www.fishbase.org (2014).
31. Alvarez, I., Catalan, I. A., Jordi, A., Palmer, M., Sabatés, A. and Basterretxea, G., Drivers of larval fish assemblage shift during the spring-summer transition in the coastal Mediterranean, *Estuar. Coast. Shelf Sci.,* 97(2012), 127–135.
32. Sheaves, M., Baker, R., Nagelkerken, I. and Connolly, R.M., True value of estuarine and coastal nurseries for fish: Incorporating complexity and dynamics. *Estuaries and Coasts*, 38(2014), 401- 414.
33. Orth, R. J., and Montfrans, J.V., Utilization of a seagrass meadow and tidal marsh creek by blue crab *Callinectes sapidus*. Seasonal and annual variations in abundance with emphasis of post-settlement juveniles. *Mar. Ecol. Prog. Ser.* 41(1987), 283–294.
34. Camp, A.L., Ryer, C.H., Laurel, B., Seals, K., Effect of nursery habitat on density dependent habitat selection in juvenile flatfish. *J. Exp. Mar. Biol. Ecol*. 404 (2011), 15–20.
35. Rao, G.S., The fishery closed season - An obsession, *Souvenir,* Visakhapatnam Regional Centre of Central Marine Fisheries Research Institute, Visakhapatnam, (2001), 13-17.
36. Bailey, C., Lessons from Indonesia's 1980 trawl ban, *Mar. Policy* 2 I (1997): 225-235.
37. Pipitone, e., Badalamenti, F. D., Anna, G. and Patti, B., Fish biomass increase after a four-year trawl ban in the Gulf of Castellammare (NW) Sicily, Mediterranean Sea, *Fish. Res.* 48 (2000), 23-30.
38. Sreedevi, C. and Kurup, B. M., Temporal variations in polychaete population in 0–50 meters along coastal Kerala, S. India. Sixth Asian Fisheries Forum, Kaohsiung, Taiwan, Asian Fisheries Society, Book of Abstracts (UnitA), (2001), p. 230.
39. Dinmore, T.A., Duplisea, D.E., Rackham, B.D., Maxwell, D. L., and Jennings, S., Impact of a large-scale area closure on patterns of fishing disturbance and the consequences for benthic communities. *ICES J. Mar. Sci.,* 60 (2003): 371-380.
40. Kurup, B. M., Marine and coastal fisheries of Kerala (S. India) – status, sustainability issues and polices. In Proceedings of Kerala Environment Congress (ed. Babu Ambat), Centre for Environment and Development, Thiruvananthapuram,(2005), pp. 74–88.