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Does the mechanised trawl target the non-targets from the commercial fishing grounds of northern Maharashtra, eastern Arabian Sea India

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Abstract

The trawl net is one of the most destructive type of mobile gears that dragged over the bottom gathering wide range of marine organisms in addition to the targeted resource as by catch. In this juncture, an attempt has been made to document the non-target resources that are caught by the multiday shrimp trawlers operating in the commercial trawl fishing grounds off New Ferry Wharf landing centre of Maharashtra for a period of two years from January 2013 to December 2014. The study revealed that the average annual non-target catch constituted about 78.59% of the total trawl catch. The average annual catch rate was 178.64 kg/h of which the target catch is 39.6 kg/h and the non-target catch is 139.04 kg/h with the target: non-target catch ratio of 1:4. The study also highlight that the by catch consisted of 52.44% of juveniles of commercially important fish species with the catch rate of 73.3 kg/h. The discarded by catch was found to be 33.25% of the total catch and 42.19% of the total by catch with the catch rate of 59.3 kg/h. The trawl non-targeted diversity recorded a total of 145 species belonging to 112 genera, 73 families and 30 orders. Species that contributed more than 5% in terms of abundance (n/h) *Charybdis callianassa* (15.64%), *Coilia dussumieri* (11.98%), *Miyakella nepa* (7.29%), and *Thalamita crenata* (5.28%) and in biomass (kg/h) were *Lagocephalus lunaris* (7.57%), *Harpadon nehereus* (7.37%), *Coilia dussumieri* (6.82%) and *Otolithes cuvieri* (5.75%). The abundance-biomass curve depicts that irrespective of the seasons Maharashtra trawl fishing grounds are heavily stressed with negative w-static value. Bray-Curtis similarity coefficient reveals that high similarity in species composition was found between monsoon and post-monsoon season (77.47%). Findings of the study recommends fishery managers to suggest measures such as restriction on fleet size, fishing days per trip, regulatory juvenile catch limit, the establishment of suitable market chain for permissible by catch landings, sustainable harvest of fishery resources and participation of fishermen in the decision-making process thereby sustaining the stocks of Maharashtra fishing grounds forever.

Keywords: Biodiversity, discard catch, juvenile by catch, low-value by catch, trawl fishery, and target species

1. Introduction

Indian marine fish production is mainly contributed by the mechanized fishing sector contributing 82.6% of which mechanized multiday trawlers, accounting 46.5% of the marine fishery catch 2018 [1]. In the State of Maharashtra, trawl fishery contributed 57% of the total state marine fish production during 2018 [1]. Despite having higher contributions, trawl fishery harm the commercial fishing grounds due to the indiscriminate harvest of juveniles of commercially important fishes, low-value marine resources and posing severe damage to benthic ecology ultimately affects the structural and functional biodiversity [2-7]. Globally, trawl fishery accounts for a higher by catch rate of which shrimp trawl recorded high discard to catch ratio ranging from 3:1 to 15:1 to any other fisheries [8, 9, 10]. In India, an increase in the trend of utilization of low-value by catch (LVB) further encourages the catching of non-targeted fishery resources including juveniles of commercially important fishes by trawlers [11, 12]. The fishery managers are able to take the decision on a gap in technology improvement, sustainable harvest of fishery resources and to get maximum economic yield [13]. In this view, a continuous monitoring and maintenance of timeline database is very much needed to ascertain the fishing pressure exerted by commercial trawlers [14, 15]. In Maharashtra, New Ferry Wharf (NFW) landing centre alone accounts for 33% of the total trawl landings of the State during 2018 [16].

Faunal diversity and profiling of the trawlers fishery grounds operating off Sassoon Dock and Versova fishing landing centre were recorded by various researchers [17, 18]. However, detailed study on trawl profiling of commercial fishing grounds of NFW trawlers is not studied so far. Studying the obtained bottom trawling target and non-targeted catch is very important for the better understanding on the sustainability of the fish stock. Hence, the study also addressed and fulfils the importance for ecosystem conservation and the paucity of scientific data set about the non-target still exists for Maharashtra state of India. With this aim, this paper forms baseline information on the qualitative and quantitative database on trawl by catch diversity, by catch rates and its temporal variations in species composition caught by multiday shrimp trawlers of New Ferry Wharf (NFW) landing center in the commercial fishing grounds of Maharashtra coast, India.

2. Material and Methods

2.1 Study area

The samples were collected from multi-day trawlers of New Ferry Wharf (NFW) landing center, Mumbai from January 2013 to December 2014. The fishery months of the Maharashtra coasts were divided into four season's *viz.*, monsoon, MoN (August to September); post-monsoon. Po MoN (October to December); winter, Win (January to February) and Pre-monsoon, Pr-MoN (March - May) to study the temporal variation in trawl by catch among various seasons. The fishing area of these trawlers extends from south of Saurashtra coast to Ratnagiri covering an area between 17^0 -21^0 N latitude and 71^0 -73^0 E longitude. Sampling stations of commercial trawl fishing grounds of NFW trawlers were shown in the depth contour map during the study period (figure 1).

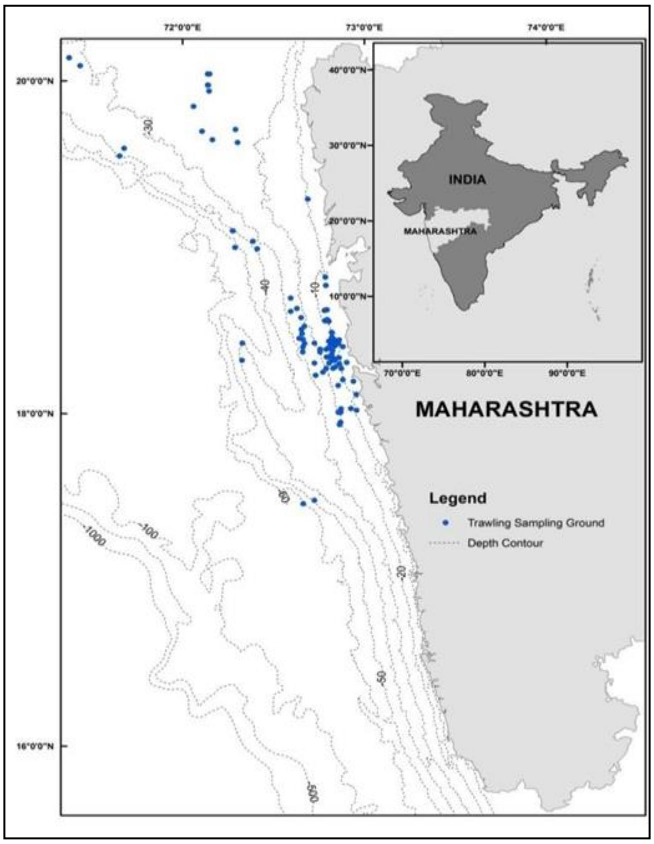

Fig 1: Blue dots indicates trawl sampling grounds of this study with depth contour.

2.2 Craft and Fishery details

The trawlers operated ranged between 10-15 m (OAL) with an engine capacity of 95-160 hp and crew capacity of 8 to 10 people. The trawlers engaged for the shrimp exploitation restrict their operation between 10-40 m depth at the beginning of the fishing season i.e., from September to December and explore up to 80m depth at the end of the fishing season (April and May). The duration of a fishing trip is between 7 to 15 days. Shrimp trawlers use flat rectangular otter boards made of wood planks reinforced by a steel frame of 55-80 kg. Fishing hours vary from 140 hours to 320 hours per trip with 30 to 45 hauls and trawling for 3 to 4 hours in each haul. All the shrimp trawlers are fitted with mechanical winches and metal rope diameter of 15mm. The trawl nets used were 40-60 m in length with a 10-25 mm cod-end mesh size. Maharashtra State Government has observed trawl ban from 1st June to 15th August every year that restrict the multiday trawlers venturing into sea, due to this reason catch data for that period is not available.

2.3 Sampling procedure

Random samples of by catch were collected on a weekly basis from the commercial trawlers operating from NFW landing centre that comprising of samples from 10 to 12 hauls per month. Samples collected from each haul represent the total catch of the haul and preserved in ice on-board and brought to the lab for the recording of species composition and diversity of the trawl by catch. The trawl by catch biomass was calculated by multiplying the quantity in the subsample from each haul and then raised to a factor based on the subsample to total by catch weight ratio [19]. The above data was standardized to 60 minutes haul due to variability in the trawling operation hour. Catch rate (abundance and biomass) of the individual species in each subsample for each haul are expressed as numbers per hour (n/h) and kilogram per hour (kg/h) respectively.

2.4 Statistical analysis

Temporal variation in species composition of trawl by catch was analysed through multivariate analysis using PRIMER v.6 (Plymouth Routines in Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory [20, 21]. The Bray–Curtis similarities were performed to understand the similarity profile in the species distribution of the commercial trawl fishing grounds between each months and seasons in the form of hierarchical cluster analysis (Dendrogram plot) tested with similarity profile routine, SIMPROF [22]. The Abundance-Biomass Comparison (ABC) curves were plotted in order to find level of trawling pressure experienced by the trawl fishing grounds of Maharashtra. SIMPER analysis was used to identify the species that contributed to the similarity or dissimilarity within seasons.

3. Results and Discussion

3.1 Trawl by catch diversity

In this study, a total of 145 species from 112 genus, 73 families and 30 orders were recorded as non-target or by catch from multiday shrimp trawls operated from NFW landing centre, Mumbai, during the period of January 2013 to December 2014. A total of 3561 kg of subsamples from 236 hauls operated at depth range of 10 to 60 m were analysed. The by catch composition consists of 76 species of teleosts, 6 species from elasmobranchs, 14 crabs, 11 cephalopods, 4 stomatopods, 22 gastropods, 8 bivalves, 1 species of box jellyfish (*Chiropsoides buitendijki*), 1 species of sea snake (*Enhydrina schistose*), 1 species of sea urchin (*Salmacis bicolour*) and 1 species of sand dollar (*Dendraster* sp.) (Table 1). Groupwise percentage abundance (nh^{-1}) of trawl by catch is dominated by teleosts contributing 55.67%, followed by crabs (20.02%), stomatopods (10.30%), cephalopods (5.57%), gastropods and bivalves (4.29%), elasmobranchs (2.26%) and miscellaneous (1.89%). Out of 73 families recorded in by catch, 25 families contributed to 94.59% of total by catch abundance. The most abundant families are Portunidae (16.56%), Engraulidae (12.98%), Squillidae (10.30%), Sciaenidae (9.37%) Calappidae (5.29%), Tetraodontidae (4.88%), Harpadontidae (4.61%), Trichiuridae (3.91%), Leiognathidae (3.17%), Gobiidae (3.01%), Sepiidae (2.46%), Bregmacerotidae (2.37%), Cynoglossidae (2.04%), Loliginidae (1.85%), Rostellariidae (1.77%), Clupeidae (1.62%), Ariidae (1.35%), Onychoteuthidae (1.17%), Nemipteridae (1%) and Carcharhinidae (0.99%). In biomass (kgh^{-1}) of trawl by catch, the maximum was contributed by teleosts (71.39%) followed by cephalopods (5.87%), stomatopods (5.84%), elasmobranchs (5.62%), gastropods and bivalves (5.50%), crabs (4.54%) and miscellaneous (1.24%). Out of 73 families, 25 families contributed 91.02% of their biomass in trawl by catch. Among these 25 families, Sciaenidae contributed the maximum amount of biomass (17.03%) followed by Tetraodontidae (7.57%), Engraulidae (7.56%), Trichiuridae (7.53%), Harpadontidae (7.37%) Squillidae (5.84%), Portunidae (4.46%), Ariidae (4.42%), Rostellariidae (3.87%), Sepiidae (3.72%), Carcharhinidae (3.55%), Cynoglossidae (2.98%), Nemipteridae (1.89%), Polynemidae (1.33%), Calappidae (1.31%), Apogonidae (1.3%), Loliginidae (1.25%), Gobiidae (1.12%), Pristigasteridae (1.05%) and Clupeidae (1.02%). Out of 145 species, 25 species contributed to 71.48% of the total biomass and the rest of the species contributed to 28.52%. The most dominant species that caught in shrimp trawl as by catch in numbers (n/h) and in biomass (kg/h) are given in table 1.

Table 1: Trawl by catch species diversity, mean catch rates and species wise percentage contribution from trawl fishing grounds of Maharashtra waters

Species	Mean biomass (kg/h) ± (S.E)	Mean number (n/h)±(S.E)	% n/h	% kg/h
Lagocephalus lunaris	27.22±11.14	1181.74±483.80	4.88	7.57
Harpadon nehereus	26.51±9.31	1117.91±392.44	4.61	7.37
Coilia dussumieri	24.52±6.61	2901.98±782.58	11.98	6.82
Otolithes cuvieri	20.67±6.08	877.03±258.06	3.61	5.75
Miyakella nepa	14.04±3.58	1765.55±450.60	7.29	3.9
Tibia curta	13.90±2.75	429.22±84.97	1.77	3.87
Johnius borneensis	13.49±2.21	362.34±59.29	1.5	3.75
Trichiurus lepturus	13.14±4.20	428.80±137.07	1.77	3.65
Scoliodon laticaudus	12.75±3.79	240.72±71.46	0.99	3.55
Charybdis callianassa	11.59±2.26	3791.08±737.86	15.64	3.22
Cynoglossus arel	9.26±2.88	334.99±104.17	1.38	2.58
Sepia pharaonis	7.22±1.26	48.16±8.38	0.2	2.01
Lepturacanthus savala	7.08±1.17	284.87±47.22	1.17	1.97
Rastrelliger kanagurta	6.34±1.73	176.77±48.19	1.02	1.77
Otolithes ruber	6.08±3.74	143.73±88.54	0.59	1.69
Osteogeneiosus militaris	4.87±0.76	138.68±21.68	0.57	1.36
Filimanus heptadactyla	4.77±1.10	79.25±18.36	0.32	1.33
Thalamita crenata	4.50±1.59	1279.18±452.32	5.28	1.25
Protonibea diacanthus	4.45±1.09	237.53±58.42	0.98	1.24
Plicofollis tenuispinis	4.37±0.57	20.53±2.66	0.08	1.22
Harpiosquilla harpax	4.25±0.92	582.08±126.11	2.4	1.18
Johnius glaucus	4.20±1.38	188.14±61.61	0.77	1.17
Johnius macrorhynus	4.19±0.74	149.01±26.15	0.61	1.17
Trypauchen vagina	3.83±1.92	694.00±347.71	2.86	1.06
Nemapteryx caelata	3.76±0.42	91.45±10.18	0.37	1.05
Epinephelus diacanthus	3.64±1.04	61.68±17.64	0.25	1.01
Sepiella inermis	3.63±0.37	332.23±33.73	1.37	1.01
Rhynchobatus djiddensis	3.34±2.03	32.72±19.93	0.14	0.93
Johnius dussumieri	3.27±0.40	165.87±20.36	0.68	0.91
Otolithoides biauritus	3.16±0.65	44.22±9.08	0.18	0.88
Bufonaria echinata	3.11±0.52	199.18±33.04	0.82	0.87
Uroteuthis (P) duvaucelii	2.97±0.66	143.16±31.57	0.59	0.83
Nemipterus japonicus	2.91±0.29	141.71±13.96	0.58	0.81
Saurida tumbil	2.58±0.54	101.57±21.38	0.43	0.72
Pampus argenteus	2.55±0.46	36.26±6.54	0.15	0.71
Sepia aculeata	2.54±0.43	216.80±36.68	0.89	0.71
Muraenesox cinereous	2.51±0.96	123.92±47.29	0.51	0.7
Nemipterus randalli	2.45±0.43	68.28±11.99	0.28	0.68
Johnius belangerii	2.42±0.84	50.84±17.75	0.19	0.21
Decapterus russelli	2.41±1.47	100.57±20.35	0.5	0.76
Lactarius lactarius	2.38±0.65	197.80±54.05	0.82	0.66
Charybdis feriata	2.36±0.64	51.92±14.03	0.21	0.66
Ilisha filigera	2.20±0.45	26.04±5.35	0.12	0.61

Plicofollis dussumieri	2.12±0.04	49.91±0.98	0.21	0.59
Upeneus moluccensis	1.74±0.45	45.83±11.97	0.19	0.48
Cistopus indicus	1.73±0.41	20.06±4.71	0.08	0.48
Quollastria ornata	1.59±0.73	57.62±24.89	0.56	0.44
Alepes djedaba	1.54±0.42	55.01±15.01	0.23	0.43
Loliolus hardwickei	1.47±0.19	303.70±39.06	1.25	0.41
Leiognathus daura	1.46±0.73	284.42±142.01	2.06	0.26
Thryssa dussumieri	1.46±0.29	68.4±13.36	0.28	0.41
Cynoglossus macrostomus	1.44±0.41	160.46±45.53	0.66	0.4
Brevitrygon imbricata	1.43±0.44	17.87±5.50	0.07	0.4
Nemipterus bipunctatus	1.42±0.59	32.00±13.28	0.13	0.4
Escualosa thoracata	1.19±0.71	270.58±160.98	1.12	0.33
Priacanthus harmer	1.16±0.70	52±15.89	0.08	0.19
Megalaspis cordyla	1.15±0.25	29.50±6.46	0.12	0.32
Sardinella longiceps	1.12±0.29	55.43±8.27	0.13	0.31
Harpiosquilla raphidea	1.12±0.33	12.88±3.82	0.05	0.31
Nuchequula blochii	1.02±0.24	226.05±52.78	0.93	0.28

Note: species landed more than 1 kg/h was included in the table 1.

3.2 Temporal analysis of trawl catch rates

The average annual total catch rate (target and non-targeted catch) was 178.64 kg/h of which the highest catch rate was during the period of September (236.48 kg/h) and the lowest during March (120.14 kg/h). The average annual target catch rate was 39.6 kg/h where the highest was during the period of September (90.79 kg/h) and the lowest during April (20.20 kg/h). The average annual by catch rate was 139.04 kg/h with a highest catch rate during December (179.79 kg/h) and the lowest during March (91.99 kg/h) as shown in the figure 2. The average annual percentage of target and non-target catch to the total catch was about 21.4% and 78.6%, respectively. On an average, the target catch shows a wide fluctuation between 14.09% (April) and 38.39% (September) to the total catch. The lowest by catch percentage was observed in the month of September (61.61%) and the highest (85.91%) in April. The target: non-target ratio ranges between 1:6 in April and 1:1.6 in September with an annual average of 1:4. The average annual discarded by catch was found to be 33.25% of the total catch and 42.19% of the total by catch. The discarded by catch rate fluctuated between 50.62 kg/h (January) and 83.05 kg/h (December) with an average catch rate of 59.3 kg/h. The discarded by catch composition consisted of 52.5% finfish including teleosts and elasmobranchs, 16.9% stomatopods, 15.9% gastropods and bivalves, 10.9% crabs and 3.8% miscellaneous by weight. The by catch consisted of 52.44% of juveniles of commercially important species with an average catch rate of 73.3 kg/h/year for juveniles. The highest was observed during December (95.43 kg/h) and the lowest during March (40 kg/h) is shown in the figure 3.

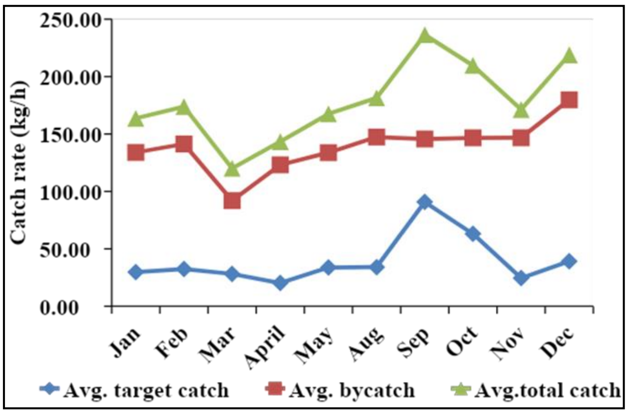

Fig 2: Temporal variation in catch rates of trawl catch

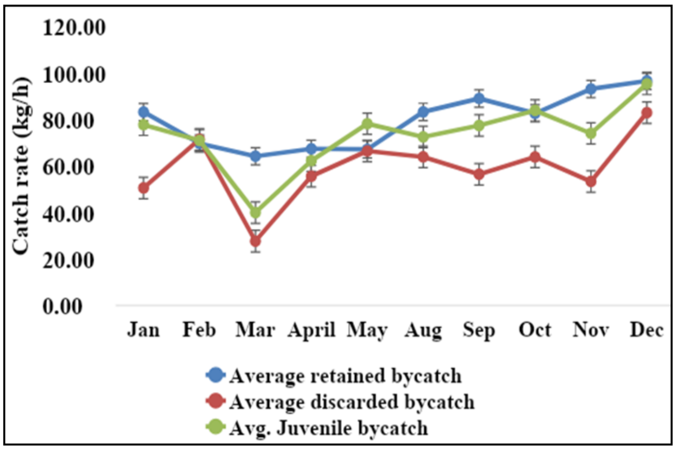

Fig 3: Temporal variation in the catch rates of retained by catch, discarded by catch and juvenile by catch landed by the trawl gear in the study period

3.3 Temporal analysis of trawl by catch species composition

Similarity in species composition between the seasons was analysed using Bray-Curtis similarity coefficient and dendrogram plot shown in the figure 4. High similarity (77.47%) in species composition was found between monsoon and post-monsoon and low similarity (67.33%) was observed between winter and monsoon. Season-wise SIMPER in the species contribution in trawl by catch within season during the study period was found to be 72.10% similarity is shown in the Table 2.

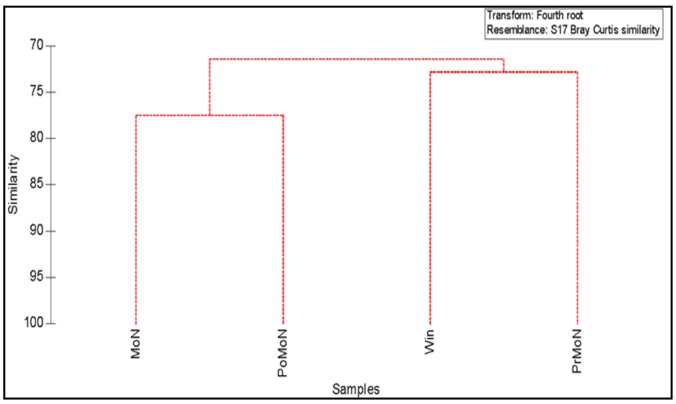

Fig 4: Dendrogram plot for trawl by catch between seasons.

Table 2: Seasonal similarity percentages (SIMPER) within different seasons in the species contributions of trawl by catch for the study period

Species	Average Abundance (%)	Average Similarity (%)	Average Contribution (%)	Cumulative Contribution (%)
Average similarity: 72.10				
Charybdis callianassa	7.68	2.35	3.26	3.26
Coilia dussumieri	7.03	2.06	2.85	6.11
Miyakella nepa	6.22	1.82	2.52	8.64
Harpiosquilla harpax	4.74	1.38	1.92	10.55
Sepiella inermis	4.24	1.33	1.84	12.39
Tibia curta	4.42	1.3	1.8	14.2
Loliolus hardwickei	4.13	1.28	1.78	15.97
Johnius borneensis	4.26	1.27	1.76	17.74
Otolithes cuvieri	4.91	1.26	1.75	19.49
Lepturacanthus savala	4.04	1.24	1.72	21.21
Cynoglossus arel	4.05	1.17	1.63	22.84
Thalamita crenata	5	1.14	1.57	24.41
Trichiurus lepturus	4.16	1.12	1.55	25.96
Bufonaria echinata	3.68	1.11	1.54	27.51
Bregmaceros mcclellandi	4.27	1.1	1.52	29.03
Johnius dussumieri	3.55	1.1	1.52	30.55
Sepia aculeata	3.71	1.09	1.51	32.06
Nemipterus japonicus	3.43	1.07	1.49	33.55
Scoliodon laticaudus	3.73	1.07	1.49	35.04
Leiognathus daura	4.17	1.07	1.48	36.51
Protonibea diacanthus	3.73	1.05	1.45	37.97
Johnius macrorhynus	3.43	1.04	1.44	39.41
Harpadon nehereus	4.75	1.03	1.43	40.84
Rastrelliger kanagurta	3.48	1.01	1.4	42.25
Osteogeneiosus militaris	3.35	1	1.39	43.64
Johnius glaucus	3.48	1	1.39	45.03
Uroteuthis (P) duvaucelii	3.34	0.97	1.35	46.37
Nemapteryx caelata	3.07	0.97	1.34	47.71
Stolephorus commersonnii	3.25	0.92	1.27	48.99
Lactarius lactarius	3.41	0.89	1.23	50.22

3.4 Analysis of fishing pressure on commercial trawl fishing ground

The Abundance Biomass Comparison curve depicts W value which is a quantitative measure of the difference between biomass and abundance curve. The ABC curve for trawl fishery of the present study is heavily stressed as W static value is negative for all the four seasons is given in the Figure 5. This leads to a higher abundance in species as compared to the corresponding biomass indicating growth overfishing, occurring throughout the year.

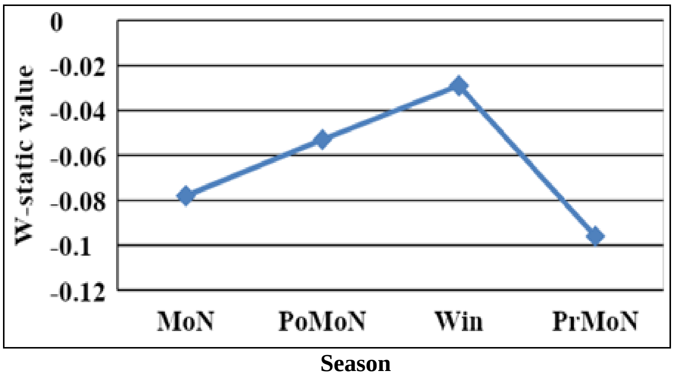

Fig 5: Abundance biomass comparison with season wise W-static value.

4. Discussion

The studies on the diversity and the species composition in trawl by catch conducted by various researchers along the West coast of India [17, 18, 23, 24, 25]. A by catch assessment in Uran, Navi Mumbai reported 101 species that consists of juveniles and sub-adults of fin fishes (29), crustaceans (22) and cephalopods (3) [24]. Faunal species diversity of Mumbai trawl fishing ground reported to have teleost [73], elasmobranch (4), shrimps (13), crabs (9), cephalopods (5), mantis shrimps (4) and shellfishes (11) [18]. Trawl by catch along north Andhra Pradesh coast recorded 248 species with teleost contributing 87.49%, followed by invertebrates (11.48%), elasmobranchs, turtles and sea snakes (<0.5%) [9]. Shrimp trawl by catch studies off Cochin identified 281 species consisting of juveniles of commercially important fishes and shellfishes where the by catch consisted of 40% juveniles [25]. Dineshbabu identified 205 species/groups of which 147 were finfishes, 4 bivalves, 7 cephalopods, 21 crabs, 3 stomatopods, 3 lobsters and several miscellaneous groups in the study period 2008-2011 in shrimp trawls as by catch along Mangalore coast. Of which 34% by weight and 63% by number were juveniles of 45 commercially important species [12]. Putting together, the juvenile landings of commercially important species are exploited heavily in all fishing grounds accounting for growth overfishing along the West coast of India. The average discarded by catch was found to be 33.25% of the total catch with average catch rate of 59.30 kg/hr in our study. Similarly, Bhendekar observed discards percentage of multiday and single day trawlers operating along Mumbai coast was found to be in the range of 7-33% and 4-30% respectively [17]. CMFRI studies reported the decreasing trend in the discards at sea in Mangalore and Calicut is due to high raw material demand from fish meal/ fish oil plants in Mangalore, Karnataka driven by aquaculture and poultry feed factories between 2008 and 2011 [26, 27]. In our study also, 43.7% of discard consists of crabs, gastropods, bivalves and stomatopods that could similarly be utilized as raw material for low cost fish meal preparation in order to decrease the discard trends in the sea of Mumbai trawlers. Similarly, a study in Goa waters states that shrimp trawls discard 36% of it's by catch back to the sea due to lack of commercial value and non-edibility [28]. India's national average discarded by catch was found to be 22% of the total catch from major fishing harbours such as Mangalore, Calicut, Munambam, Sakthikulangara, Kasimedu, Veraval and Vishakhapatnam that accounts for more than 50% of the multiday trawl landings of the country [23]. From these findings, it is clear that shrimp trawlers from Mumbai discard the highest amount of by catch as compared to the national average discards. In our study, the reasons for discard of by catch in multiday trawlers were attributed to non-availability of space for storage, fear of spoiling of high valued/ large fish and non-edibility nature of the catch. Similarly, in Andaman waters, Thomas observed the same reason for the discards by trawlers of that coast and discards percentage was found to be 74.47% higher than our study [6].In our study, 52.44% of by catch consists of juveniles of commercially important species and occurrence of opportunistic species (gastropods, bivalves, sea urchin, jellyfish) indicating that shrimp trawl in Mumbai waters are destructive. The abundance of juveniles throughout the seasons clearly shows the behaviour of year-round spawning and recruitment patterns of tropical fish. Trawlers of west coast mostly sweep the shallow waters with 10 – 50m depth which is found to be highly productive resulting in increased food availability supporting juvenile population[29-31]. Continuous removal of juveniles of commercially important species results in reduction in their mean size that leads to growth overfishing [32, 33]. This was evident from our study through all seasons. In our study, there is a continuous removal of predators such as *Plicofollis tenuispinis* (4.37 kg/h), *Protonibea diacanthus* (4.45 kg/h), *Scoliodon laticaudus* (12.75 kg/h), *Sepia pharoanis* (7.22 kg/h), *Trichiurus lepturus* (13.14 kg/h), *Osteogeneiosus militaris* (4.87 kg/h), *Lepturacanthus savala* (7.08 kg/h), *Johnius borneensis* (13.49 kg/h) and *Harpadon nehereus* (26.51 kg/h), irrespective of seasons these have wide diet spectrum feeding on squilla, crabs, gastropods and 20 families of finfishes throughout the year that paves way for aggregation/increase in population of non-commercial/non edible species in trawl grounds [34]. The economic loss of juvenile fishing in trawl catch as estimated by Najmudeen and Sathiadhas (2009) [35] in Kerala coast was US $ 0.511 million per annum [35]. Sugumar estimated the commercially important cephalopod juvenile landings of *Uroteuthis (P) duvaucelli* (912 t), *Sepia elliptica* (254 t), *S. pharaonis* (142 t), *Sepiella inermis* (199 t) and *Cistopus indicus* (189 t) by multiday trawlers of New ferry wharf landing centre[3].Sugumar also estimated the juvenile landings of four commercially important marine Ariids in multiday trawlers of Mumbai waters was found to be *Nemapteryx caelata* (423 t), *Plicofollis dussumieri* (220 t), *P. tenuispinis* (93 t) and *Osteogeneiosus militaris* (182 t) and economic loss found to be 13.15 cores per annum[4]. The target: non-target ratio in the present study is ranging between 1:6 in April and 1:1.6 in September with an annual average of 1:4. This result is in consensus with that of Bhathal where the ratio was reported to be 1:4 for Indian trawl fisheries[36]. Similarly, Haque reported the ratio in *Acetes* shrimp targeted fishery as 1:9 for India and Bangladesh [37]. In case of Southeast and Southwest regions of India, the by catch ratios were 1:2.6 and 1:4.6, respectively [38]. Non-edible by catch to target catch ratio of multiday trawlers along Mangalore coast was 1:3.93 [5]. The non-target catch percentage during trawl fishery in India was found to range between 56 – 82% [13]. In the present study, the non-target catch constituted about 78.59% of the total trawl catch. However, Chakraborty reported 68.7% of by catch to total catch in Mumbai waters [39]. The 10% increase since last 3 decades is due to more number of trawlers venturing into the sea. This is supported by the report that estimated the optimum fleet size (2,778) for shrimp targeted trawlers based on 22 years of time series data in Maharashtra waters. However, the operating fleet size (5613 trawlers) in Maharashtra accounts for the rising percentage of by catch in shrimp trawlers [40, 41]. The high catch rate found in the present study can be attributed to the presence of wide continental shelf with even topography upto 100 m depth provides more trawling area along northern Maharashtra. Similar to our study, Bhendekar also reported that higher catch rate of trawl by catch is due to more trawling hours and wide continental shelf of Mumbai coast not-so-high engine power [17]. Various workers also evidenced that the higher trawl catch rate is due to increased trawling hours [42, 43]. The decrease in catch rate of by catch from 200 kg/h[44]in 2007 to 139.04 kg/h (present study) indicates that fishery potential of trawl fishery ground in Maharashtra waters are experiencing high fishing pressure. This was evidenced from report by CMFRI which indicates that stocks of 25 species are 28% less abundant, 56% declining, 4% depleted and 4% in collapsed state, in Maharashtra [40, 41].Bhagirathan analysed the similarity percentages in species composition of trawl catch before and after trawling using SIMPER analysis and found that similarity in species contribution found to be high in heavily trawled area than lightly trawled area, similar to our study [45]. This means in the long run species diversity contributing to the catch in the Maharashtra waters will start coming down as the trawling pressure increases. Similarly, in Gulf of Mannar biosphere reserve due to heavy trawl pressure in the seagrass beds, seagrass diversity is reduced from 15 species [46] to 3 species [7]. Bhagirathan further analysed the impact of bottom trawling of Veraval coast using Abundance biomass curve comparison to found the relation between trawling and stress on fauna. It was found to be lightly trawled grounds are less or moderately stressed and heavily trawled grounds are under high pressure. In their study, 15-25 m depth are moderately stressed and 26-40 m depth is heavily stressed [45]. It was implied that with increase in depth, the trawl intensity increases. In our study, we observed that Mumbai waters of 10-40 m depth are experiencing high trawling pressure in all the four seasons. Similarly, in our study the abundance curve is above the biomass curve that depicts our fishing grounds are experiencing high fishing pressure.

5. Conclusion

Thus, in our present study, commercial fishing ground of northern Maharashtra coast undergone high fishing pressure throughout the study period. This leads to indiscriminate fishing of juveniles of commercially important fishes and on the other side increased catch of non-edible resources that play an important role in energy transfer from one trophic level to another level. Trawl fishing of non-valuable resources that encourages more discards has emerged leading to ecological imbalance in the system and in the long run it affects mean size of the catch and question the sustainability of the fishery resources of the northern Maharashtra fishing grounds. In order to avoid or have a control over the present situation, the following recommendations such as restriction on fleet size, restriction on fishing days per trip, strict enforcement of use of mesh size in cod-end to 35 mm and above by trawlers, entry permit of boats to sea should be closed once their catch limit on by catch is reached. Regulatory juvenile catch limit should be implemented to avoid growth overfishing. Establishment of suitable market chain for permissible by catch landings. Awareness among fishers on destructive nature of trawl fishing, sustainable harvest of fishery resources and participation of fishermen in the decision-making process are put forward thereby sustaining the stocks of Maharashtra fishing grounds forever.

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