Indian J. Fish., 70 (2): 19-27, 2023
doi:10.21077/ijf.2023.70.2.120576-02
Available online at: epubs.icar.org.in/index.php/IJF

Comparative footprint studies of single and multiday trawl fishing along Ratnagiri coast, Maharashtra, India

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Abstract

Trawl fishing is widely recognised as the most productive and industrious fishing method in the world. Due to the importance of trawl fisheries along the Ratnagiri coast of Maharashtra, the present comparative study was undertaken on single and multiday trawl fishing in the region. In this study, monthly variations in fishing depth, catch per hour (CPH), discard per hour (DPH), spatio-temporal species distribution and spatial prediction of catch-discard of 136 trawl hauls were analysed. Single and multiday trawlers were operated from 15°53’24’’N to 18°00’36’’N latitude and 72°55’55’’E to 73°25’48’’E longitude within a depth range of 10 to 64 m in the Arabian Sea. For the multiday trawlers, maximum CPH of 68.30 kg h^{-1} was recorded in October 2015, while single day trawlers recorded CPH of 42.70 kg h^{-1} in November 2015. Average DPH for multiday and single day trawlers were recorded as 7.66 and 3.84 kg h^{-1} respectively. The study found that CPH and DPH were significantly ($p<0.05$) higher in multiday trawlers than single day trawlers. Based on spatial mapping, high fishing pressure was observed in the area south-west off Ratnagiri. Our results highlighted the need for suitable strategies for conservation and management of fisheries resources to achieve long-term sustainability in the region.

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Keywords:
Catch, Discard, Diversity, GIS mapping

Received : 25.01.2022
Accepted : 01.06.2023

Introduction

India stood at fourth position in capture fisheries after China, Indonesia and Peru with 5.49% contribution of the total global capture fisheries production (96.4 million t) during 2018 (FAO, 2020). During 2017-18, the marine fish production was 3.69 million t which contributed around 29.35% of the total fish production of India and supported nearly 3.79 million fisher population (CMFRI, 2018; HBFS, 2019;). The north-west coast of India constituted around 28.57% of the entire coastline and contributed 32.14% (2017-18) of the total landing. Maharashtra coast alone contributed 9.94% of the total landing of which 99.2% came from mechanised crafts (CMFRI, 2017). The main fishing gears that supported the fishery in Maharashtra were trawl net (57%), bag net (20%), purse seine (18%), and gillnet (5%). Trawlers accounted for 82.3% of the demersal, 35% of the pelagic, 91% of the cephalopod catches and 38.8% of the revenue from the marine fisheries catch of Maharashtra (CMFRI, 2017; Devi *et al.*, 2018).

Trawling is one of the most productive and industrious fishing method in the world, which “annually covers an area equivalent to perhaps half of the world’s continental shelf” and contributes about 23% of the global catch (Watling and Norse, 1998: Cashiona *et al.*, 2018). Around 83,000 trawlers are operating in the tropical parts of Asia-Pacific (FAO, 2014). Out of 35,228 trawlers in India, Maharashtra accounted for 5,613 trawlers, and Ratnagiri District alone has around 36% trawlers (CMFRI, 2012). Due to easy maneuverability and non-selective nature, trawl fishing has extensively operated all along the coast and exploited large quantities of near-bottom species (Gabriel *et al.,* 2005). In the early 1970s, the single day trawler was the most common and cost-effective method of fishing. However, at a later stage, multiday fishing was introduced in inshore waters, and during 2017, multiday trawlers alone contributed to 54% of the total marine landings in Maharashtra (CMFRI, 2017). Over the years, the rapid expansion of industrialised fishing efforts has adversely impacted the natural recruitment and sustainability of the fishing industry. Apart from disturbing the ecology of the inshore waters, it also contributed to economic losses of around 50 billion US dollars annually (Anticamara *et al.*, 2011; FAO, 2014).

Such excessive pressure of trawling depleted entire fishery stocks with catch per hour (CPH) declining from 198 kg h^{-1} to 33.7 kg h^{-1} along the west coast of India (Poliakov, 1962; Rao, 1967; Dineshbabu, 2013). It has been reported that intensive shrimp trawling with multiday fishing in Maharashtra, India, has been attributed to overexploitation of the resources and reduced commercially important resources (Deshpande, 1960; Deshmukh, 2013). Hassan and Sathiadhas (2009) compared the single day and multiday trawlers of Kerala, and recommended that multiday trawlers are not advisable for the long-term sustainable exploitation of open-access marine fisheries. Hence, a proper monitoring and surveillance programme should be initiated to understand and record the fishing activities around the coast of Maharashtra.

Globally, the use of Geographical Information System (GIS) as an improved satellite-based surveillance system for fisheries development has been growing rapidly for over a decade. However, in India, GIS application in fisheries is restricted to inland water bodies and aquaculture (Dineshbabu *et al.,* 2016). Though the application of GIS in the marine fisheries sector in India is still very limited, in recent times, it is becoming a very useful tool for analysis of various spatial and temporal fishing activities (Meaden and Do, 1996; Jalali *et al.,* 2015). In the present study, GIS-based monitoring tools and other statistical analysis was used to monitor, evaluate and compare the fishing efforts and catch composition by single and multiday trawlers off the Ratnagiri coast during 2015-2016.

Materials and methods

Fisheries description and study area

For the study area, the cruise path traditionally operated by trawl fishermen off Ratnagiri coast (15°53’24”N to 18°00’36”N latitude and 72°55’55”E to 73°25’48”E longitude) has been considered (Fig. 1). The data were collected from the commercial single and multiday bottom (fish and shrimp) otter trawls targeting fish and shrimp, operated from Ratnagiri (Mirkarwada) Landing Centre, during September 2015 to May 2016. The fishers of Ratnagiri used wooden trawlers with Fiber Reinforced Plastic (FRP) coated deck. Length overall (LOA) of multiday trawlers varied from 18-20 m with 90-110 hp engine capacity while that of single day trawlers varied from 13.64 m-15.5 m with 87-90 hp engine capacity. Both trawlers used the same type of trawl gear to harvest fish and shrimp. For analysis and interpretation, fishing vessels that operated for more than a day were classified as multiday units, while the ones that fished for a day were considered as single day units (Devi *et al.*, 2018).

Data collection and GIS mapping

Onboard information such as fishing geo-locations, recorded from an onboard fitted GPS, total catch (kg) and discard (kg), catch and discard per hour, fishing depth, fishing duration, trawling speed and number of hauls per day were collected fortnightly from single and multiday trawlers. In the present study, total catch means the catch that landed at the landing centre, and total discard means the catch that was discarded back to the sea. The fish and shellfish samples taken from unsorted trawl catch were preserved in ice and stored in the fish hold. During laboratory analysis, all the samples were identified up to species level (Fischer and Bianchi, 1984; Jayaram, 2002). The catch and discard data files were made in CSV (comma-separated values) format for GIS software and analysed in Microsoft Excel 2013. The spatio-temporal data collected was used as input for the GIS study as described by Dineshbabu *et al.* (2012).

Fishing season in Maharashtra is of nine months, from September to May. Fishing activities are banned from 01 June to 31 July along the west coast of India, as per the orders of the Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. Moreover, rough sea condition also prevents fishing activities during this period. On an average, both the single and multiday trawlers operated for 3 h at 3-3.5 knot speed for each trip and made three trips in a day. The number of geo-referenced trawl hauls from which data were collected for single and multiday trawlers during summer (March to May), post-monsoon (September to November) and winter (December to February) seasons were 48, 40 and 48, respectively.

Base map features were digitised from Hydrographic Survey Maps 212 (1970) and 213 (1972) by on-screen digitisation in Arc Map 10.1 at 1:50,000 scale. The Universal Transverse Mercator (UTM) projection system was used as the projection system and World Geodetic System (WGS) 1984 was used as the geographical coordinate system with the WGS 84 datum. These database files were later used in the Ratnagiri geo-database, in Arc GIS 10.1. The predictive maps about total catch and total discards were prepared using inverse distance weighted (IDW) in Geo-statistical Analysis Arc GIS10.1. The unsampled fishing area was analysed using the IDW model, where weights are inversely proportional

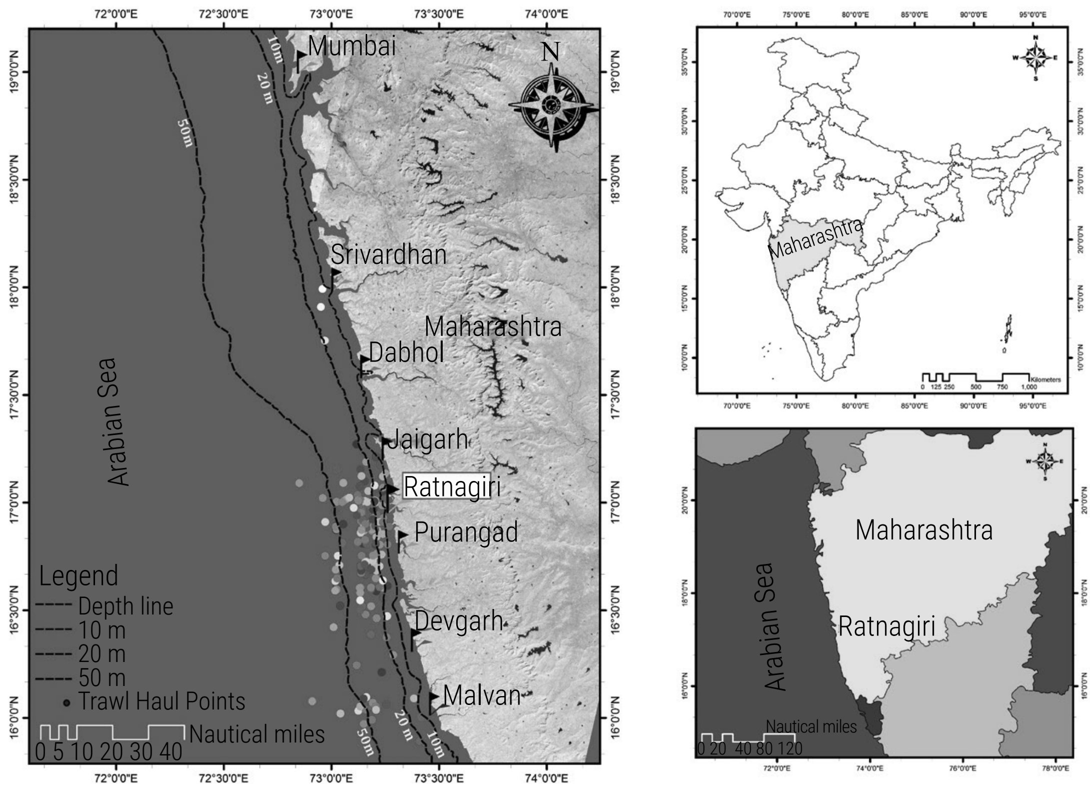

Fig. 1. Map of the study area along the Ratnagiri Coast, showing trawl hauling points

to a power of distance and weighted average values of all fishing points of a certain range (10 to 20) were taken, and the unsampled area was projected on the map (Burrough, 1986; Infantina *et al.*, 2016).

Results and discussion

Trawl fishing is widely recognised as one of the most important fishing methods in marine fisheries and is also responsible for placing the Asia-Pacific region as the world's largest fish producer (FAO, 2014; Singh *et al.*, 2017; Suuronen *et al.*, 2020). In the present study, a total of 136 trawl fishing hauls, both single and multiday trawlers, were studied from September 2015 to May 2016. The commercial fishing trawlers studied during that period were operated from 15°53'24"N to 18°00'36"N and from 73°25'48"E to 72°55'55"E from Mirkarwada Landing Centre off Ratnagiri coast. It was found that based on fishery resources availability and manoeuvrable capacity of fishing vessels, multiday trawlers travelled between 8.09 to 68.57 nautical miles and single day trawlers travelled between 3.24 to 21.59 nautical miles. The rich fishing grounds in terms of catch for multiday trawlers were recorded at a depth of 22-30 m from Ratnagiri to Devgarh in the south-west direction and similarly single day trawlers operated mostly at a depth of 7-22 m off Ratnagiri to Ganpatipule in the north, and Pawas and Puarngad in the south direction with the overall depth of operation ranging from 10 to 64 m (Fig. 2). The maximum fishing effort was between 22 to 30 m depth and was generally carried out parallel to the coast, towards south and north off Ratnagiri coast. Trawl fisheries in Asian tropical waters generally operate at depths from 10 to 150 m, but are often restricted to a maximum depth of about 70 m (FAO, 2014). Dineshbabu *et al.* (2012), also analysed the fishing operation along the west coast of India from the Konkan-Malabar coast during 2007-2010 and found that the most intensive fishing effort was at 30 m depth off Mangalore to Panaji, followed by 100 m depth off Malpe to Karwar. Kunjir *et al.* (2007), stated that trawlers along the Ratnagiri coast operated up to depth zone of 50 m. Bhendekar *et al.* (2016), recorded the depth of trawl operation between 5 to 40 m in a similar study conducted during September 2013 to February 2014 along the Mumbai coast. In accordance to the present study, Devi *et al.* (2018), reported that multiday trawlers of Maharashtra (Mumbai) coast operated within the depth range of 10 to 105 m with a distance range of 6.5 to 215 nautical miles from the shore. The availability of this spatial information related to fishing operations will support the decision-making process regarding regulation of fishing effort.

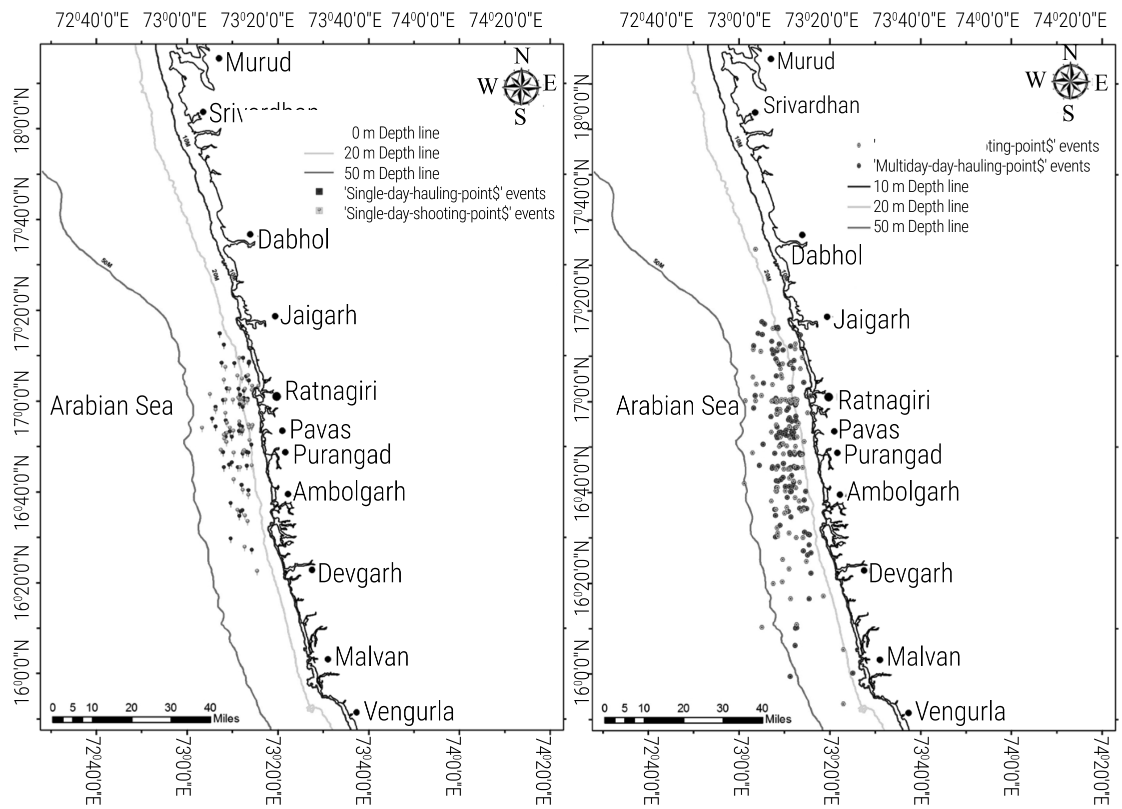

Fig. 2. Fishing depth and trawling intensities of single and multiday trawlers

Month-wise variation of total catch, discard, fishing depth and travelled distance from single and multiday trawler is given in Table 1. In all the months, multiday trawlers harvested more catch than single day. During October 2015, the overall maximum harvest was recorded (17.7 t) in multiday fishing followed by May 2016 (13.6 t). In single day fishing, the maximum harvest was recorded in November 2015 (9.98 t) followed by May 2016 (9.88 t). Maximum discard per hour by multiday trawlers was 13.7 kg during November and for single day trawlers it was 9.3 kg in January. Jellyfish comprised more than 80% of the discards during October-November from both single and multiday trawlers. From January to May 2016, squilla (mantis shrimp) was the major discarded resource in both single day and multiday trawlers.

Table 1. Monthly variations in total catch, discard, fishing depth and travelled distance of single and multiday trawlers of Ratnagiri

Months	Multiday				Single day			
	Total catch per month (kg)	Total discard per month (kg)	Fishing depth (m)	Distance from landing centre (Nm)	Total catch per month (kg)	Total discard per month (kg)	Fishing depth (m)	Distance from landing centre (Nm)
Sep-15	10584	936	36.37	30.5	3588	156	29.12	9.58
Oct-15	14760	2952	37	34.76	7176	624	39.93	12.61
Nov-15	10944	2016	39.5	28.41	9984	1950	32.5	10.45
Dec-15	8752	1512	27.31	15.04	6786	234	29.37	6.41
Jan-16	9468	1620	34.89	22.54	2160	1260	30.12	16.06
Feb-16	7968	1152	33	17.34	4992	1638	23.18	16.19
Mar-16	9504	1152	29.28	6.85	6084	546	39.81	7.08
Apr-16	11290	1872	31.62	12.14	7358	390	28.12	8.3
May-16	12276	1368	25.75	11.2	9880	364	27.87	15.58

Data related to total fish harvest during post-monsoon, winter and summer season is illustrated in Fig. 3. Our study revealed that post-monsoon and winter were the best seasons for multiday trawlers ($p<0.05$) and during the same period, summer was the best for single day trawlers ($p<0.05$) of Ratnagiri. Production differences are significantly more wider ($p<0.05$) in the post-monsoon and summer seasons than the winter season. This indicated that multiday fishing can achieve higher production during those two seasons. Selvaraj *et al.* (2007) observed that fishery was predominant during the pre-monsoon season and the highest CPUE of 307 kg h^{-1} was recorded along the Gujarat coast and moderately high catch rates were also recorded in the deeper waters off south-west coast of Mumbai in the summer and post-monsoon seasons. Monthly variation in catch per hour (CPH) and discard per hour (DPH) by single and multiday trawlers are illustrated in Fig. 4. The CPH was maximum during October 2015 for multiday trawlers (68.30 kg h^{-1}) and for single day trawlers it was in November 2015 (42.70 kg h^{-1}). The average catch per hour for single and multiday fishing was 28.3 and 49.9 kg h^{-1} respectively. Dineshbabu (2013) reported that catch rate of trawlers along eastern Arabian Sea fluctuated between 30-50 kg h^{-1} during 1990-2007. He further mentioned that catch rates increased from 2008 and reached up to 75 kg h^{-1} during 2012, and attributed this to the introduction of high speed engines in trawling. Relatively higher average catch (55.2 kg h^{-1}) was also reported by Gajbhiye *et al.* (1994), during 1980-1992 from the Ratnagiri coast. Similar to the present study, Kharatmol *et al.* (2018), reported the average CPH by single and multiday trawlers to be 38.24 and 44.75 kg h^{-1} respectively off Mumbai coast, Maharashtra. Similar to the present study, highest CPH for multiday (73.27 kg h^{-1}) and single day trawlers (22.70 kg h^{-1}) off Mumbai coast was recorded in October and December respectively. Kharatmol *et al.* (2018), indicated that October and November were the peak fishing months for trawl fishing and fishing intensity reduced in April and May, due to dominance of low value catch along the Mumbai coast. The present study also paves the way for further studies in these areas to determine the average CPH and species diversity in different fishing periods.

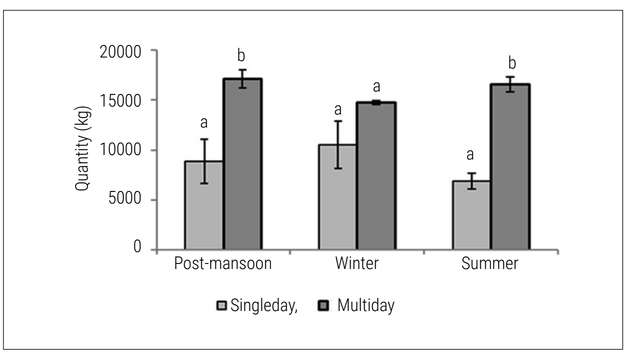

Fig. 3. Seasonal fish harvested (kg) by single and multiday trawlers of Ratnagiri
**a* and *b* denote significant difference between single and multiday fish harvest

Bycatch and discard are the major issues in trawl fishing, and non-targeted bycatch is either discarded back into the sea or retained in the catch for subsequent use in fishmeal preparation. In the current study, the average discard per hour (DPH) of a single day trawler progressively increased after the fishing season started and peaked in January 2016 and then showed subsequent decline. No similar trend was observed in case of DPH of multiday fishing and maximum discard was recorded in October 2015 and for the rest of the months the discards were more or less similar. The average discard per hour for single and multiday fishing was 3.84 and 7.66 kg h^{-1} respectively. The study shows that CPH and DPH was significantly ($p<0.05$) higher in multiday fishing compared to single day. To have a comparative difference of the discard in single and multiday fishing, monthly variations in the percentage of total discard from total harvest of single and multiday trawlers is illustrated in Fig. 5. It was found that the overall discard percentage from single and multiday fishing was 12.3±3.88 and 13.0±0.95% respectively. However, a significantly ($p<0.05$) higher percentage of discard was recorded in single day fishing in January 2016 followed by February 2016, and this is mainly due to low-value mantis shrimp caught by single day trawlers. However, the discard percentage was almost uniform in the case of multiday fishing.

Similar to the present study, Dineshbabu *et al.* (2013, 2014), reported 10-22% discards from the total onboard samples collected from the trawlers at Veraval, Mangalore,

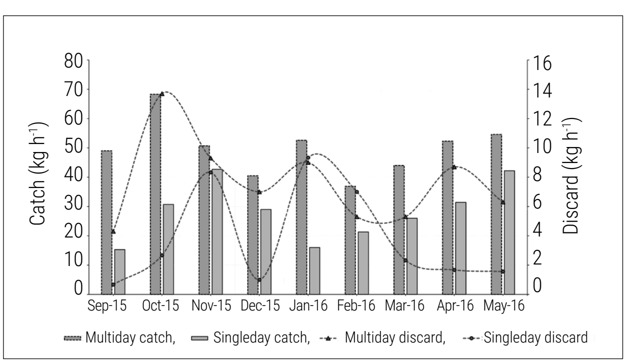

Fig. 4. Monthly variation of catch and discard per hour from single and multiday trawlers

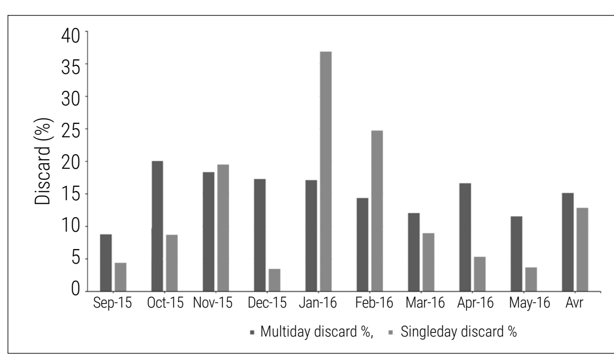

Fig. 5. Monthly variations in percentage of total discards from single and multiday trawlers

Calicut and Visakhapatnam fishing harbours during 2008. Further, Dineshbabu *et al.* (2014), mentioned that total estimated discard during 2011 from the trawlers of Mumbai, Visakhapatnam and Chennai, were 22, 15 and 1%, respectively. Kharatmol *et al.* (2018), estimated that DPH from the multiday and single day trawlers to be within the range of 5.33 to 16.00 kg h^{-1} and 3.00 to 7.67 kg h^{-1}, respectively and found that discards rate was relatively less in single day trawlers. Singh *et al.* (2017) also found less discard rate in single day trawlers. Results from their studies indicated that single day trawlers were better in terms of reducing discard rates. Zacharia *et al.* (2006), had highlighted the implications of trawl discards on marine ecosystem along the south-west coast of India and reported higher proportion of discards (33.9 to 35.1%) from the Karnataka coast. The large-scale discards from trawl fishing, is not only ecologically hazardous but also weakens the fishing industry economically. Hence there is an urgent need for a comprehensive estimation of bycatch and discards of trawlers from all coastal states of the country for developing policies so that wastage in the form of bycatch and discards can be reduced (Aswathi *et al.,* 2011). In the present study, geo-spatial tracking system was generated using fishing coordinates off Ratnagiri coast and predictive maps of geo-spatial variations in the catch and discard for both single and multiday trawlers were made. The predictive values of catch and discard for the trawlers are shown in Fig. 6 and 7. Maximum catch (150-250 kg $haul^{-1}$) was predicted between 15°46’220”N-16°48’024”N to 72°19’056”E-73°39’510”E in the south-west direction and 17°28’218”N-18°05’311”N to 72°18’011”E-73°06’540”E in north-west direction from the multiday trawlers. The maximum catch (140-200 kg $haul^{-1}$) from single day trawlers was predicted near to Malvan Estuary in the south-west direction. The predicted maximum discard from multiday trawler was 35-75 kg $haul^{-1}$ found near to Devgarh region and for single day trawlers it was 25-48 kg $haul^{-1}$ observed in between Jaigarh to Dabhol off Ratnagiri coast. In the present study, GIS based spatial predictive result of the single and multiday trawlers indicated that maximum catch and discard values were towards southern direction near to ecologically sensitive estuarine area (Malvan Estuary), for both types of trawlers. These results of resource mapping of the Economic Exclusive Zone (EEZ) are very important especially for developing countries (Caddy and Garcia, 1986). The information on the spatio-temporal distribution of fishing effort along with catch composition and discard

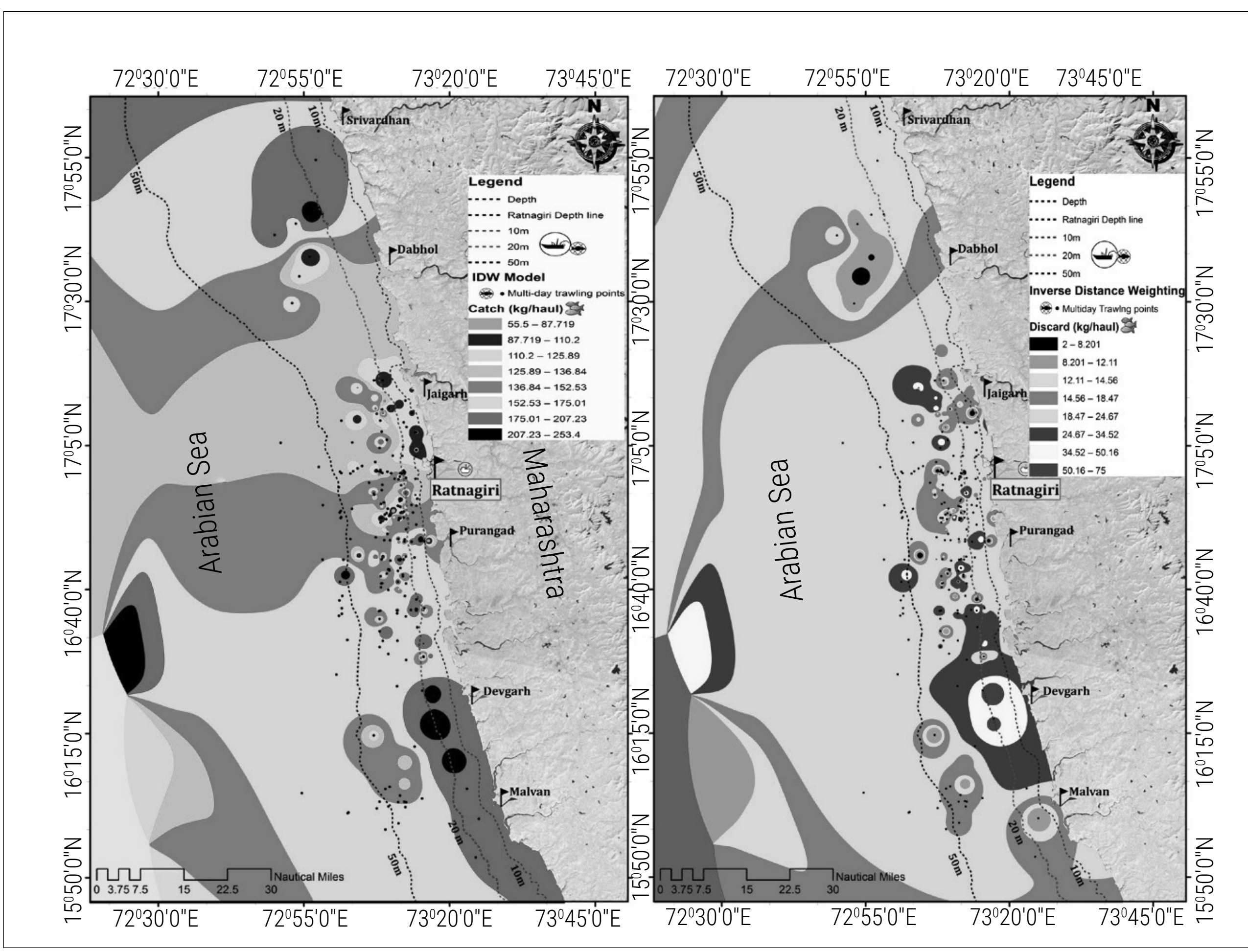

Fig. 6 Predictive map of total catch and discard from multiday trawlers

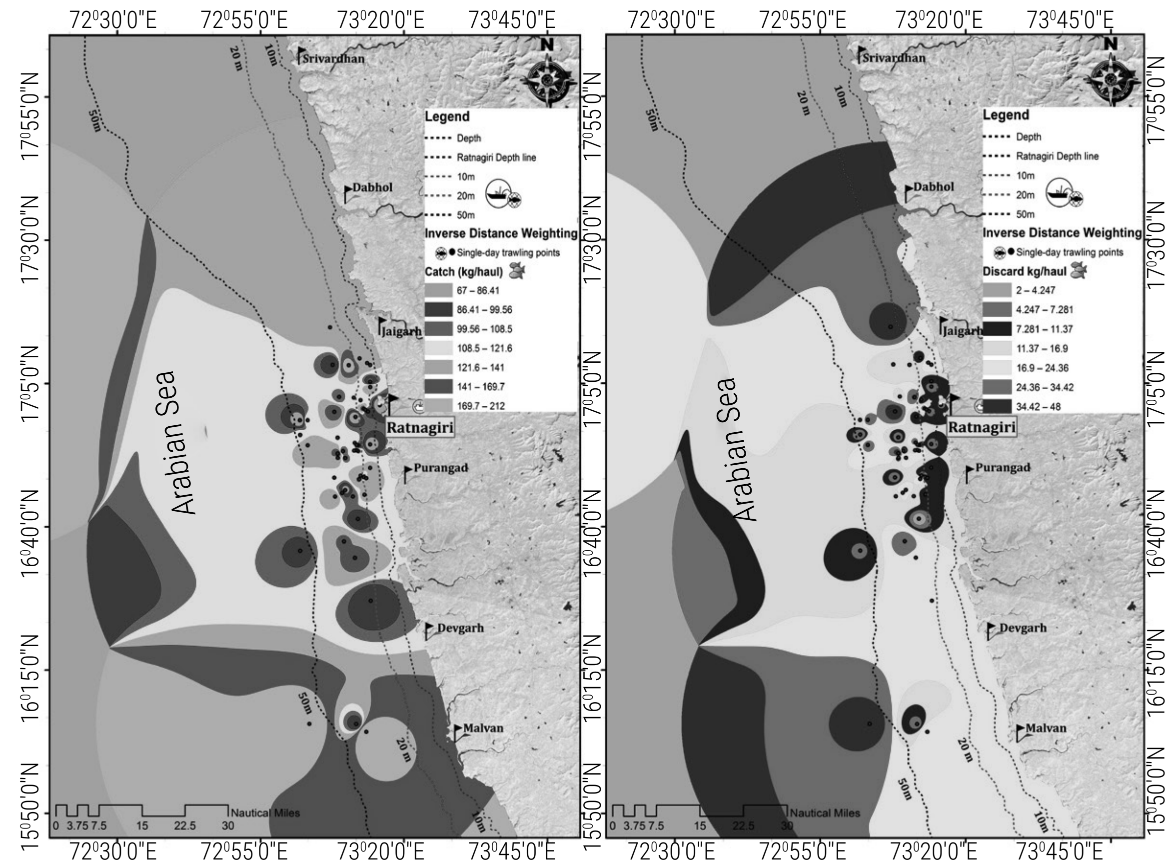

Fig. 7. Predictive map of total catch and discard from single day trawlers

volumes can improve the knowledge of the trawl fisheries in Indian waters and help in the conservation of marine fisheries resources, also ensuring the safety of fishermen (Kroodsma *et al.*, 2018).

The percentage contribution of different species landed by single and multiday trawlers during the study period is illustrated in Fig. 8. In the present study, a total of 134 species were identified in catches from multiday and single day trawlers during September 2015 to May 2016. The catch-wise major species landed by trawlers along Ratnagiri coast consisted of grouper (*Epinephelus diacanthus),* white fish *(Lactarius lactarius)*, croakers *(Johnius dussumieri, Otolithes cuvieri*), pony fish *(Photopectoralis bindus)*, scad *(Alepes djedaba),* ribbonfish *(Lepturacanthus savala, Trichiurus lepturus*), lizard fish *(Saurida tumbil)*, tongue sole *(Cynoglossus bilineatus, Cynoglossus macrostomus)*, pomfret *(Pampus argenteus)*, wolf-herring *(Chirocentrus dorab),* shrimp (*Metapenaeus affinis*, *Parapenaeopsis stylifera*), mantis shrimp/squilla *(Oratosquilla nepa)*, crab (*Portunus sanguinolentus*), cuttle fish and squid [*Sepiella inermis, Uroteuthis (Photololigo) duvaucelii*].

During post-monsoon, it was found that grouper, ribbonfish, croakers, wolf-herring, shrimps and squid were the major groups landed by multiday trawlers while single day trawlers landed mainly grouper, white fish, croakers and shrimps. Comparative temporal distribution of species landed by single day and multiday trawlers, is illustrated in Fig. 9. It was found that total number of species landed by multiday trawlers (114) were much higher than the single day trawlers (77) which may be due to larger and deeper scouting area of multiday trawlers. The fish species diversity from the catch increased after the fishing season started and peaked in November and again declined (Fig. 9).

Relatively higher species diversity has been reported from the west coast of India *viz.* 281 species off the south-west coast of India during 2004-06 (Gibinkumar *et al.*, 2012), 106 to 154 during 2008-09 from west coast of India (Dineshbabu *et al.*, 2012) and 121 species from Mumbai coast during 2013-14 (Bhendekar *et al.*, 2016). Notably, species diversity from 2004-06 to 2016-17 has decreased in the study region. However, during 2016-17, relatively higher species diversity was recorded off Maharastra coast (CMFRI 2017). This

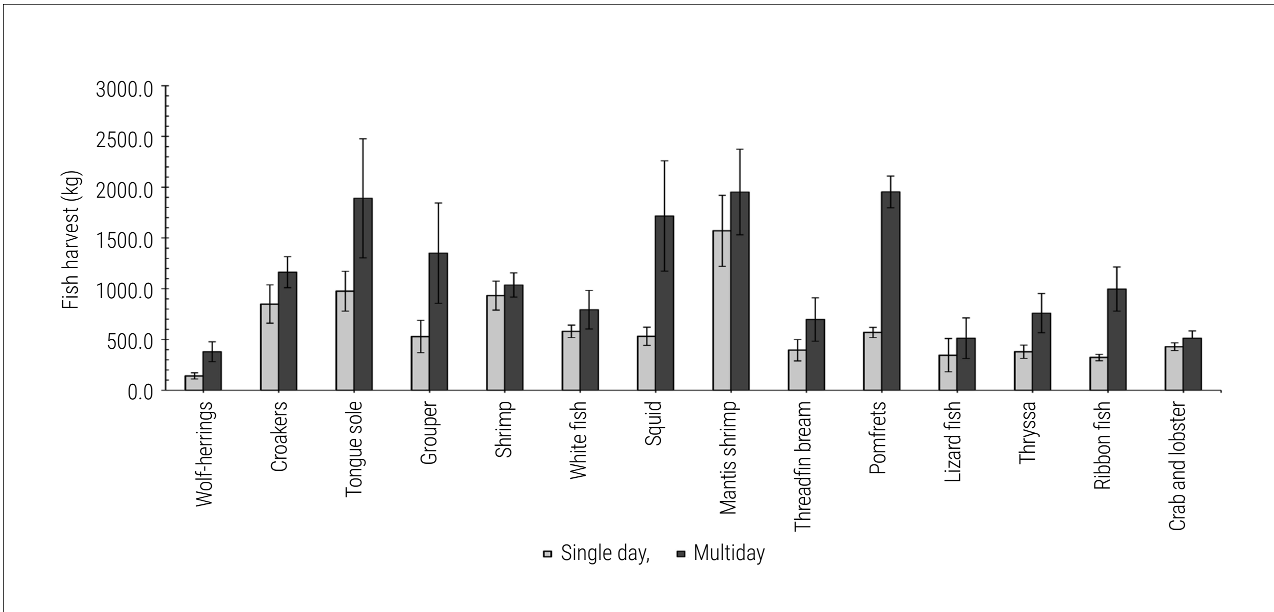

Fig. 8. Percentage contribution of different species under single and multi day trawling

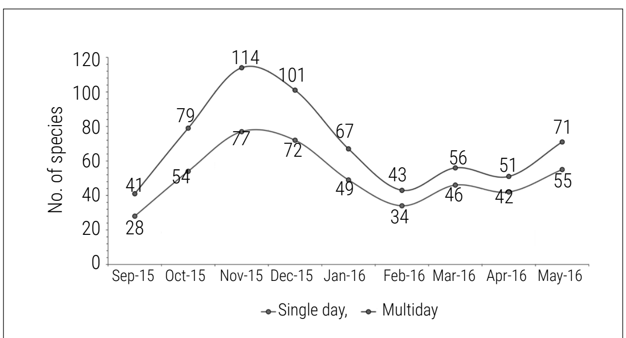

Fig. 9. Temporal distribution of species harvested by single and multiday trawling`

progressive decrease of species diversity in trawl catch indicates higher trawling pressure in these areas. Hence, the results presented highlight that trawl fishing pressure is higher in the south-west direction and suitable conservation and management policies need to be formulated on a priority basis to achieve long-term sustainability of the marine resources in the study region. Spatial and seasonal restrictions on fishing effort can be promoted in selected areas to conserve fisheries resources. The geo-database generated by the present study would be helpful for researchers, academicians, policymakers and fishery managers to gather exact geo-spatial information on fishing activities for use as inputs in formulating management/conservation plans for the region.

Acknowledgements

The authors are thankful to the Director, ICAR-CIFE, Mumbai for providing necessary facilities to carry out the study. Authors also wish to thank staff of College of Fisheries, Ratnagiri for their support and help during data collection. The help and support provided by the owner and crew members of the trawler group “Chamunda Prasad” of Mirkarwada Landing Centre, Ratnagiri is thankfully acknowledged.

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