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Quantitative Assessment and Temporal Fluctuation of a Multiday Shrimp Trawl Bycatch off Digha Coast, West Bengal, India

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Abstract

Bycatch is one of the main issues affecting marine fisheries globally, and attempts have been made to understand the issue of bycatch at different scales. In India the bycatch issues in trawling have been reported widely. However, there are only scarce reports from northeast coast of India. The current study was carried out between July 2018 and March 2019 to assess the faunal composition, quantity of trawl bycatch and its seasonal fluctuation from a commercial multiday shrimp trawl (targeting shrimps and lobsters) operated along inshore areas off the Digha coast, West Bengal, India. Out of 145 finfish and shellfish species recorded, 130 species (104 species retained and 26 species discarded) were classified as bycatch. Sciaenids, crabs, shrimp, clupeids, Bombay duck, mollucsc, and elasmobranchs made up the bulk of the catch. The only species identified throughout the study period was *Coilia dussumieri*, but *Harpadon nehereus* was the most prevalent species that contributed to the weight as a single species. Gobies, angler fish, puffer fish, tripod fish, some crab species, stomatopods, octopus, gastropods, bivalves, and juveniles of high commercial value fishes were among the species that were discarded. Target catch, retained bycatch and discards constituted 9.4%, 54.8%, and 35.8% respectively of the overall catch. Use of bycatch reduction strategies, nets with better selectivity and seasonal ban on trawling is suggested for sustaining trawl fisheries along the coast.

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Introduction

Trawling is the most predominant fishing method contributing more than fifty percent to the marine fish landings in India. Despite the most common and effective fishing method for capturing demersal fish, its non-selectivity raises serious environmental issues and causes significant harm to the marine ecology and biodiversity (Kaiser, Collie, Hall, Jennings & Poiner, 2002). One of the main issues associated with trawling is indeed the incidental capture of non-target species, known as “bycatch.” The catch that is returned to the water is referred to as “discards,” and the retained catch of non-target species is referred to as “incidental catch” (Kumar & Deepthi, 2006). Until and unless they are effectively controlled, bycatch and discards can escalate to severe challenges in sustainable fisheries at all levels. The third assessment of global marine fisheries discards (Pérez Roda et al., 2019) reported annual discards from global marine capture fisheries between 2010 and 2014 as 9.1 million tonnes, compared to 7.3 million tonnes in 2005 (Kelleher, 2005) with bottom trawls contributing about 41.9-45.5% (Pérez Roda et al., 2019).

Owing to the multispecies fishery, the Indian shrimp trawl fishery is reported to have high catches of non-target species (Gibinkumar, Sabu, Pravin & Boopendranath, 2012). Bycatch associated with Indian trawls along the Indian coast has been studied by various researchers (George, Suseelan, & Balan, 1981; Gordon, 1991; Pillai, 1998; Kurup, Thomas & Anand, 2004; Zacharia, Krishnakumar, Muthiah, Krishnan & Durgekar, 2005; Bijukumar &

Deepthi, 2009; Gibinkumar et al., 2012; Dineshbabu et al., 2013; Madhu, Raphael & Meenakumari, 2015; Purusothaman, Jayaprabha & Murugesan, 2016; Madhu, Raphel, Jeevan, Antony & Edwin, 2017; Chattopadhyay, 2017; Samanta et al., 2018; Jenishma et al., 2019) and have reported the bycatch ranging from 20% to 90% of the total catch depending on location, season and fishing techniques. However, excepting Chattopadhyay (2017), none of these reports are from West Bengal.

The State of West Bengal, with a coastal length of 158 km and a continental shelf area of 17,049 sq. km (CMFRI-DoF, 2020), is spread in two districts namely South 24-Parganas and Purba Medinipur. Purba Medinipur has an open coast on the south-eastern part of West Bengal. The marine fish landings in the state ranged from of 1.52 lakh tonnes to 1.63 lakh tonnes in the last decade which is about 4.0-4.37% of the total marine fish catch of the country (Anon, 2020). A total of 4,014 mechanised vessels are operating in the state, out of which trawlers contribute about 50% (CMFRI-DoF, 2020) and mechanised vessels account for nearly 90% of the total marine landings in the state (CMFRI, 2021). However, the marine fisheries sector of the state is facing several challenges like overfishing, stock depletion, uneven distribution of fishing efforts, fishing conflicts, high fluctuations of environmental parameters, and issue of bycatch and discards (Dutta, Chakraborty & Hazra, 2016; Kar et al., 2017). Despite these, works addressing such issues, particularly bycatch and discards have been inconsequential. Precise and timely assessment of bycatch and discards would provide necessary data for sustainable fisheries management in the state. The present study, first of its kind along the coast of West Bengal was aimed to quantify and evaluate temporal fluctuations in catches from a multiday shrimp trawler along the Digha coast of West Bengal, India.

Materials and Methods

The study was carried out in the inshore areas of the Bay of Bengal along the coast of Digha (Latitude 21.6800° N and Longitude 87.5500° E), Purba Medinipur is the Bay of Bengal on southeastern part of West Bengal.

A commercial multiday shrimp trawler (16.8 m overall length; 320 hp) with a trawl net of 35.05 m head rope and 42.67 m foot rope length, and codend mesh (diamond shape) size of 20 mm, rectangular-flat type (wooden with iron frame) otter board (length 1.91 m, width 0.91 m, breadth 0.04 m; 105 kg each) was used for the experiments. The Geographical Position System (GPS) on-board (Garmin®2013) was used to navigate the different sampling locations of the study area.

Sampling was carried out once a month from July 2018 to March 2019 using the trawler operated at a depth ranging between 9.0 m and 30.0 m (Fig. 1). A total of 36 hauls with an average duration of 3 hours and at a towing speed between 2.5-3.5 knots, were taken for bycatch analysis. Sample collection was done following the method given by Devaraj (1983), which ensures adequate representation of the subsample for studying bycatch composition. The collected sub-samples from the sorted catch were then cleaned, weighed and temporarily preserved in an icebox for further analyses. On-board data about fishing activities were also collected with the help of a structured log sheet, designed for the purpose with fishing details like date of fishing, location of the shooting, depth of shooting, shooting time, hauling time, towing duration, and also details about the target, incidental catch and discards. To ensure a realistic representation of the catch, samples were obtained prior to discards being thrown back.

The samples collected were brought to the laboratory for further analyses. The wet weight of each taxa, group, total catch, retained bycatch and discards was recorded to the nearest gram using an electronic balance and were segregated into different groups.

The samples were preserved in 5% neutralised formalin after weighing. The fauna was identified up to the specific/generic level using Fischer and Whitehead (1974), Fischer and Bianchi (1984), Jayaram (2002), and Raje et al. (2007). Taxonomic nomenclature was followed as per the WoRMS Editorial Board (2020).

The entire duration of study was divided into three seasons of pre-monsoon (January to March), post-monsoon (July to September), and winter (October to December) to evaluate the seasonal variation in the bycatch species composition using group average hierarchical cluster analysis ideal for identifying similarities and patterns within complex datasets. The group that contributed more than 1% to the monthly aggregate abundance data were chosen for the cluster analysis, whereas the groups that contributed less than 1% were collectively placed as

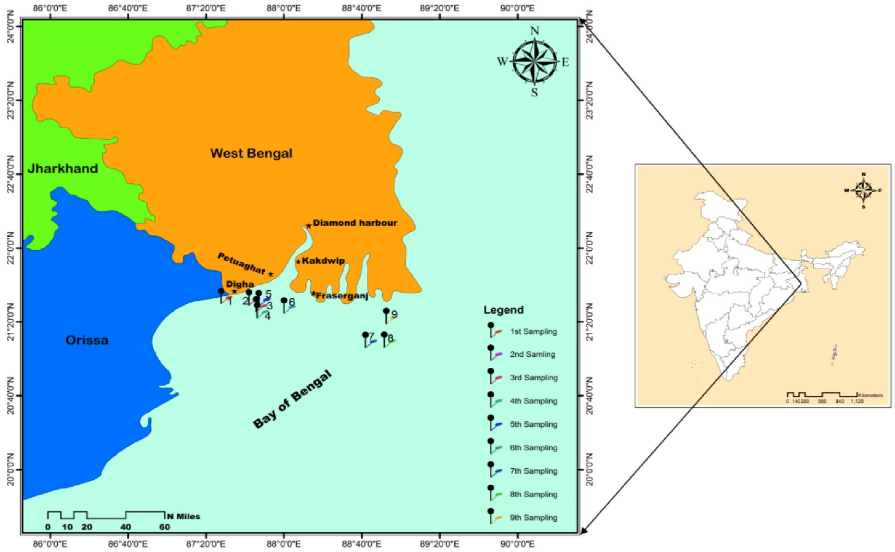

Fig. 1. Map showing the study area and sampling locations

miscellaneous group. The abundance data were normalised using the square root transformation function to down weigh the effect of high abundant groups (Velip & Rivonker, 2015). A lower triangular matrix was calculated using the Bray-Curtis Similarity Coefficient (Bray & Curtis, 1957) and dendrogram plots were constructed to determine dissimilarity among the seasons in Primer 7 software (Clarke & Gorley, 2015).

Results and Discussion

The marine fisheries of West Bengal has enormous potential for commercial fishes due to the influx of nutrients laden water in the Bay of Bengal through creeks and canals of the two coastal districts (Dutta et al., 2016). The number of marine and estuarine fish species reported from West Bengal varied between 168 and 402 (Manna & Goswami, 1985; Talwar, Mukherjee, Saha, Paul & Kar, 1992; Goswami, 1992; Chatterjee, Talukdar & Mukherjee, 2000; Kar et al., 2017; Yennawar, Mohapatra & Tudu, 2017).

In the study, a total of 145 species comprising finfishes and shellfishes belonging to 108 genera, 59 families, and 24 orders were recorded by trawling, off the Digha coast (Table 1). Target catch constituted 14 species of shrimps and prawns (penaeids and non-penaeids) belonging to four families and one species of lobster. The bycatch comprised 130 species which included 98 species of teleosts belonging to 39 families, five species of elasmobranchs belonging to three families, six species of crabs belonging to two families, four species of cephalopods belonging to three families, seven species of gastropods belonging to six families, two species of bivalves of one family and eight species of stomatopods belonging to one family (Fig. 2). Among the families, major contributors were Engraulidae, Sciaenidae, Cynoglossidae, and Carangidae with 12, 10, 9 and 8 species respectively. *Coilia dussumieri* was the only species recorded throughout the study period. Similar to Bombay duck, this species exhibits discontinuous distribution and contributed to about 4-8% of the total landings of West Bengal (Joseph & Jayaprakash, 2003; Pradhan & Mahapatra, 2018). Earlier, *C. dussumieri* formed a bycatch in bag net fishery; however, there has been a significant increase in its landings by trawls too in recent years. *Harpadon nehereus*, *Scoliodon laticaudus*, *Panna microdon*, *Trichiurus lepturus*, *Portunus sanguinolentus*, *Charybdis callianassa*, *Matuta planipes* and *Sepiella inermis* were recorded most frequently in the bycatch during the present study. *Panna microdon* was the dominant species that contributed to the landings in the family Sciaenidae and *Stolephorus indicus* was the dominant species among the clupeids. *Charybdis callianassa* was the most abundant species among the crabs and *Sepiella inermis* was the most abundant among the cephalopods.

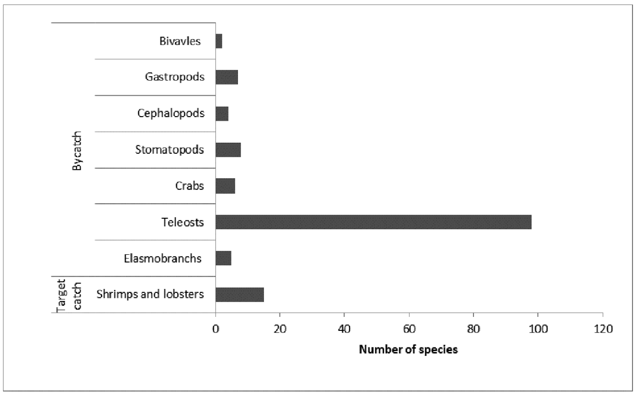

Fig. 2. Number of species recorded in different groups caught

While most of the species recorded in the bycatch were enlisted as either not evaluated (NE) or least concern (LC) in the IUCN Red List category, it is worthwhile to mention here that three Near Threatened (NT) species (*Scoliodon laticaudus, Harpadon nehereus, Scomberomorus commerson*), two Vulnerable (V) species (*Tenualosa toli, Gymnura poecilura*) and one Critically Endangered (CR) species (*Glaucostegus granulatus)* were recorded in the present study (IUCN, 2020).

Discards included a total of 27 species, mostly contributed by two species of goby (*Trypauchen vagina* and *Paratrypauchen* sp.), one species of angler fish, two species of puffer fish, one species of tripod fish, three species of crabs (*Charybdis callianassa, Matuta planipes, Charybdis lucifera*) eight species of stomatopods, one species of octopus, seven species of gastropods and two species of bivalves which have low or no economic value along this coast. The most commonly discarded species were *Charybdis callianassa*, *Matuta planipes*, *Miyakella* sp. and *Turricula javana.* Discards also included the juveniles of commercially important fish species, prominent being *Panna microdon*, *Johnius borneensis*, *Stolephorus indicus* and *Stolephorus commersonnii*. We could notice as many as juveniles of 24 commercially important species (Table 1) belonging chiefly to elasmobranchs, engraluids, sciaenids and flatfish groups. It is a matter of concern for sustainable fisheries, as catching of excessive juveniles may lead to growth overfishing by not allowing them to grow and reproduce. However, discard of these species was inconsistent and was depended upon the season, availability of target and other commercial important catch, improper sorting and skill, and eye estimation of workers involved in sorting.

All the species recorded in the present study could be categorised under 16 groups of finfish and shellfish based on their wet-weight contribution to the total catch (Fig. 3). The present study revealed that maximum bycatch was contributed by sciaenids (11.7%), followed by crabs (10.5%), clupeids (10.3%), Bombay duck (7.6%), molluscs (7%) and elasmobranchs (6.6%) (Fig. 3). Other groups encountered in relatively lesser quantity included pomfrets (2.2%), polynemids (1.0%), ribbonfish (1.2%), flatfish (3.1%) and miscellaneous including other perches like scombrids, serranids, puffer fish, eels, mullets and flatheads (23.2%). Target catch constituted shrimps (9.9%) and lobsters (0.7%).

The number of species reported in the trawl bycatch along the Indian coast varied between 121 and 281 (Sujatha, 1995; Gibinkumar et al., 2012; Mahesh et al., 2014; Purusothaman et al., 2016; Behera, Ghosh, Muktha, Kumar & Jishnudev, 2017; Samanta et al., 2018). A comparative analysis of bycatch studies in different parts of India is depicted in Table 2. The variations in the number and composition of species recorded by different authors may be attributed to spatial and temporal fluctuations, prevailing fishing depth, region-specific commercial and edible value, and the target species that they have considered. However, the overall faunal composition, which is typically the most abundant group of fishes from estuaries and coastal waters, recorded in the present study is comparable with those recorded in the West Bengal landings (BOBP, 1990; Anon, 2016; Kar et al., 2017; and bycatch recorded in West Bengal (Chattopadhyay, 2017), and other parts of India (Purusothaman et al., 2016; Madhu et al., 2017; Samanta et al., 2018; Mahesh et al., 2019).

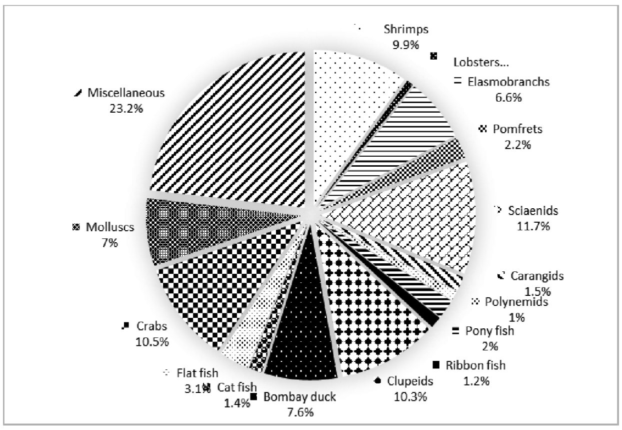

Fig. 3. Overall wet-weight percentage of different groups

Table 1. Faunal composition of a multiday shrimp trawl catch recorded during July, 2018 to March, 2019 off Digha coast, West Bengal.

Taxonomic Classification	Sl. No.	Scientific name	Common Name
Target catch (shrimps, prawns and lobsters)			
Class: Malacostraca			
Order: Decapoda			
Family: Hippolytidae	1.	*Exhippolysmata ensirostris* (Kemp,1914)	Hunter shrimp
Family: Solenoceridae	2.	*Solenocera choprai* (Nataraj, 1945)	Ridgeback shrimp
	3.	*Solenocera crassicornis* (Milne-Edwards, 1837)	Coastal mud shrimp
Family: Penaeidae	4.	*Mierspenaeopsis sculptilis* (Heller, 1862)	Rainbow shrimp
	5.	*Parapenaeopsis stylifera* (Milne-Edwards, 1837)	Kiddi shrimp
	6.	*Metapenaeus brevicornis* (Milne-Edwards, 1837)	Yellow shrimp
	7.	*Penaeus monodon* (Fabricius, 1798)	Giant tiger prawn
	8.	*Metapenaeus lysianassa* (De Man, 1888)	
	9.	*Metapenaeus affinis* (Milne-Edwards, 1837)	Jinga shrimp
	10.	*Ganjampenaeopsis uncta* (Alcock, 1905)	Uncta shrimp
	11.	*Metapenaeus ensis* (De Haan, 1844)	Greasyback shrimp
Family: Palaemonidae	12.	*Macrobrachium rosenbergii* (De Man, 1879)	Giant river prawn
	13.	*Nematopalaemon tenuipes* (Henderson, 1893)	Spider prawn
	14.	*Exopalaemon styliferus* (H. Milne Edwards, 1840)	
Family: Palinuridae	15.	*Panulirus polyphagus* (Herbst, 1793)	Mud spiny lobster
Bycatch			
Elasmobranchs			
Class: Chondrichthyes			
Order: Carcharhiniformes			
Family: Carcharhinidae	16.	**#Scoliodon laticaudus* (Müller & Henle, 1838)	Spadenose shark
Order: Rhinopristiformes			
Family: Glaucostegidae	17.	****Glaucostegus granulatus* (Cuvier, 1829)	Granulated guitarfish
Order: Myliobatiformes			
Family: Gymnuridae	18.	***Gymnura poecilura* (Shaw, 1804)	Long tailed butterfly ray
Family: Dasyatidae	19.	*#Himantura alcockii* (Annandale, 1909)	Pale-spot whipray
	20.	*#Brevitrygon imbricata* (Bloch & Schneider, 1801)	Bengal whipray
Teleosts			
Class: Actinopteri			
Order: Clupeiformes			
Family: Engraulidae	21.	*Stolephorus waitei* (Jordan & Seale, 1926)	Spotty-face anchovy
	22.	*#Stolephorus commersonnii* (Lacepède, 1803)	Commerson's anchovy
	23.	*#Stolephorus indicus* (van Hasselt, 1823)	Indian anchovy
	24.	*#Thryssa malabarica* (Bloch, 1795)	Malabar thryssa
	25.	*#Thryssa dussumieri* (Valenciennes, 1848)	Dussumier's thryssa
	26.	*#Thryssa hamiltonii* (Gray, 1835)	Hamilton's thryssa
	27.	*Thryssa mystax* (Bloch & Schneider, 1801)	Moustached thryssa
	28.	*Thryssa vitrirostris* (Gilchrist & Thompson, 1908)	Orangemouth anchovy
	29.	*#Coilia dussumieri* (Valenciennes, 1848)	Goldspotted grenadier anchovy
	30.	*Coilia neglecta* (Whitehead, 1967)	Neglected grenadier anchovy
	31.	*#Setipinna taty* (Valenciennes, 1848)	Scaly hairfin anchovy
	32.	*Setipinna phasa* (Hamilton, 1822)	Gangetic hairfin anchovy

Taxonomic Classification	Sl. No.	Scientific name	Common Name
Family: Dussumieriidae	33.	*Dussumieria acuta* (Valenciennes, 1847)	Slender rainbow sardine
Family: Pristigasteridae	34.	*#Raconda russeliana* (Gray, 1831)	Raconda
	35.	*Ilisha megaloptera* (Swainson, 1839)	Bigeye ilisha
Family: Chirocentridae	36.	*Chirocentrus nudus* (Swainson, 1839)	Whitefin wolf-herring
	37.	*Chirocentrus dorab* (Forsskål, 1775)	Dorab wolf-herring
Family: Clupeidae	38.	*Anodontostoma chacunda* (Hamilton, 1822)	Chacunda gizzard shad
	39.	*Tenualosa ilisha* (Hamilton, 1822)	Hilsa shad
	40.	***Tenualosa toli* (Valenciennes, 1847)	Toli shad
	41.	*Escualosa thoracata* (Valenciennes, 1847)	White sardine
	42.	*Sardinella gibbosa* (Bleeker, 1849)	Goldstripe sardinella
Order: Aulopiformes			
Family: Synodontidae	43.	*#Saurida tumbil* (Bloch, 1795)	Greater lizardfish
	44.	**#Harpadon nehereus* (Hamilton, 1822)	Bombay duck
Order: Syngnathiformes			
Family: Fistulariidae	45.	*#Fistularia petimba* (Lacepède, 1803)	Red cornetfish
Order: Lophiiformes			
Family: Lophiidae	46.	*Lophiodes* sp.	
Order: Tetraodontiformes			
Family: Tetraodontidae	47.	*Lagocephalus lunaris* (Bloch & Schneider, 1801)	Lunartail puffer
	48.	*Takifugu oblongus* (Bloch, 1786)	Lattice blaasop
Family: Triacanthidae	49.	*Triacanthus biaculeatus* (Bloch, 1786)	Short-nosed tripodfish
Order: Anguilliformes			
Family: Muraenesocidae	50.	*Muraenesox cinereus* (Forsskål, 1775)	Daggertooth pike conger
	51.	*Muraenesox bagio* (Hamilton, 1822)	Common pike conger
Family: Muraenidae	52.	*Strophidon sathete* (Hamilton, 1822)	Slender giant moray
Order: Gadiformes			
Family: Bregmacerotidae	53.	*#Bregmaceros mcclellandi* (Thompson, 1840)	Unicorn cod
Order: Pleuronectiformes			
Family: Soleidae	54.	*Synaptura commersonnii* (Lacepède, 1802)	Commerson's sole
Family: Cynoglossidae	55.	*Symphurus woodmasoni* (Alcock, 1889)	
	56.	*Cynoglossus lingua* (Hamilton, 1822)	Long tongue sole
	57.	*Cynoglossus macrostomus* (Norman, 1928)	Malabar tonguesole
	58.	*Cynoglossus arel* (Bloch & Schneider, 1801)	Largescale tonguesole
	59.	*Cynoglossus bilineatus* (Lacepède, 1802)	Fourlined tonguesole
	60.	*Cynoglossus cynoglossus* (Hamilton, 1822)	Bengal tongue sole
	61.	*Paraplagusia bilineata* (Bloch, 1787)	Doublelined tonguesole
	62.	*#Cynoglossus* sp.	
	63.	*Paraplagusia* sp.	
Order: Siluriformes			
Family: Ariidae	64.	*Osteogeneiosus militaris* (Linnaeus, 1758)	Soldier catfish
	65.	*Arius maculatus* (Thunberg, 1792)	Spotted catfish
	66.	*Nemapteryx caelata* (Valenciennes, 1840)	Engraved catfish
Order: Mugiliformes			
Family: Mugilidae	67.	*Mugil cephalus* (Linnaeus, 1758)	Flathead gray mullet
	68.	*Chelon parsia* (Hamilton, 1822)	Goldspot-mullet

Taxonomic Classification	Sl. No.	Scientific name	Common Name
Order: Scorpaeniformes			
Family: Platycephalidae	69.	*Grammoplites scaber* (Linnaeus, 1758)	Rough flathead
	70.	*Platycephalus indicus* (Linnaeus, 1758)	Bartail flathead
Order: Synbranchiformes			
Family: Mastacembelidae	71.	*Macrognathus aral* (Bloch & Schneider, 1801)	One-stripe spinyeel
Order: Perciformes			
Family: Stromateidae	72.	*Pampus chinensis* (Euphrasen, 1788)	Chinese silver pomfret
	73.	*Pampus argenteus* (Euphrasen, 1788)	Silver pomfret
Family: Drepaneidae	74.	*Drepane longimana* (Bloch & Schneider, 1801)	Concertina fish
Family: Leiognathidae	75.	*Deveximentum insidiator* (Bloch, 1787)	Pugnose ponyfish
	76.	*Deveximentum ruconius* (Hamilton, 1822)	Deep pugnose ponyfish
	77.	*Nuchequula blochii* (Valenciennes, 1835)	Twoblotch ponyfish
	78.	*Leiognathus equula* (Forsskål, 1775)	Common ponyfish
Family: Trichiuridae	79.	*Trichiurus lepturus* (Linnaeus, 1758)	Largehead hairtail
	80.	*#Lepturacanthus savala* (Cuvier, 1829)	Savalai hairtail
	81.	*Eupleurogrammus muticus* (Gray, 1831)	Smallhead hairtail
Family: Polynemidae	82.	*Polynemus paradiseus* (Linnaeus, 1758)	Paradise threadfin
	83.	*Eleutheronema tetradactylum* (Shaw, 1804)	Fourfinger threadfin
Family: Sillaginidae	84.	*Sillago sihama* (Forsskål, 1775)	Silver sillago
	85.	*Sillaginopsis panijus* (Hamilton, 1822)	Flathead sillago
Family: Terapontidae	86.	*Terapon jarbua* (Forsskål, 1775)	Jarbua terapon
	87.	*Terapon theraps* Cuvier, 1829	Largescaled terapon
Family: Carangidae	88.	*#Alepes djedaba* (Forsskål, 1775)	Shrimp scad
	89.	*Alectis ciliaris* (Bloch, 1787)	African pompano
	90.	*Parastromateus niger* (Bloch, 1795)	Black pomfret
	91.	*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad
	92.	*Decapterus russelli* (Rüppell, 1830)	Indian scad
	93.	*#Scomberoides commersonnianus* (Lacepède, 1801)	Talang queenfish
	94.	*#Scomberoides* sp.	
	95.	*Atropus atropos* (Bloch & Schneider, 1801)	Cleftbelly trevally
Family: Serranidae	96.	*Epinephelus latifasciatus* (Temminck & Schlegel, 1842)	Striped grouper
Family: Lobotidae	97.	*Lobotes surinamensis* (Bloch, 1790)	Tripletail
Family: Sciaenidae	98.	*#Panna microdon* (Bleeker, 1849)	Panna croaker
	99.	*Chrysochir aureua* (Richardson, 1846)	Reeve's croaker
	100.	*Otolithoides pama* (Hamilton, 1822)	Pama croaker
	101.	*Pterotolithus maculatus* (Cuvier, 1830)	Blotched tiger-toothed croaker
	102.	*Johnius glaucus* (Day, 1876)	Pale spotfin croaker
	103.	*Johnius belangerii* (Cuvier, 1830)	Belanger's croaker
	104.	*Johnius carutta* (Bloch, 1793)	Karut croaker
	105.	*#Johnius borneensis* (Bleeker, 1851)	Sharpnose hammer croaker
	106.	*Johnius* sp.	
	107.	*Johnius* sp.	
Family: Gobiidae	108.	*Trypauchen vagina* (Bloch & Schneider, 1801)	
	109.	*Paratrypauchen* sp.	
Family: Priacanthidae	110.	*Priacanthus hamrur* (Forsskål, 1775)	Moontail bullseye

Taxonomic Classification	Sl. No.	Scientific name	Common Name
Family: Scombridae	111.	**Scomberomorus commerson* (Lacepède, 1800)	Narrow-barred Spanish mackerel
	112.	*Rastrelliger kanagurta* (Cuvier, 1816)	Indian mackerel
Family: Sphyraenidae	113.	*Sphyraena obtusata* (Cuvier, 1829)	Obtuse barracuda
Family: Lactariidae	114.	*Lactarius lactarius* (Bloch & Schneider, 1801)	False trevally
Family: Nemipteridae	115.	*Nemipterus bipunctatus* (Valenciennes, 1830)	Delagoa threadfin bream
Family: Haemulidae	116.	*Pomadasys maculatus* (Bloch, 1793)	Saddle grunt
Family: Mullidae	117.	*Upeneus moluccensis* (Bleeker, 1855)	Goldband goatfish
	118.	#*Upeneus vittatus* (Forsskål, 1775)	Yellowstriped goatfish
Crustaceans			
Class: Malacostraca			
Order: Decapoda			
Family:Portunidae	119.	#*Portunus sanguinolentus* (Herbst, 1783)	Threespot swimming crab
	120.	*Charybdis callianassa* (Herbst, 1789)	
	121.	*Portunus pelagicus* (Linnaeus, 1758)	Blue swimming crab
	122.	*Charybdis feriata* (Linnaeus, 1758)	Crucifix crab
	123.	*Charybdis lucifera* (Fabricius, 1798)	Yellowish brown crab
Family: Calappidae	124.	*Matuta planipes* (Fabricius, 1798)	Flower moon crab
Stomatopods			
Order: Stomatopoda			
Family: Squillidae	125.	*Diogenes alias* (McLaughlin & Holthuis, 2001)	
	126.	*Clibanarius longitarsus* (De Haan, 1849)	
	127.	*Miyakella nepa* (Latreille, 1828)	
	128.	*Oratosquilla* sp.	
	129.	*Oratosquilla interrupta* (Manning, 1995)	
	130.	*Quollastria* sp.	
	131.	*Harpiosquilla* sp.	
	132.	*Squilla mantis* (Linnaeus, 1758)	Spottail mantis shrimp
Molluscs			
Cephalopods			
Class: Cephalopoda			
Order: Sepiida			
Family: Sepiidae	133.	*Sepiella inermis* (Van Hasselt, 1835)	Spineless cuttlefish
	134.	*Sepia aculeata* (Van Hasselt, 1835)	Needle cuttlefish
Order: Octopoda			
Family: Octopodidae	135.	*Octopus* sp.	
Order: Myopsida			
Family: Loliginidae	136.	*Uroteuthis duvaucelii* (D'Orbigny, 1835)	Indian squid
Gastropods			
Class: Gastropoda			
Order: Neotaeniogolssa			
Family: Tonnidae	137.	*Tonna dolium* (Linnaeus, 1758)	Spotted tun
Order: Neogastropoda			
Family: Turridae	138.	*Turricula javana* (Linnaeus, 1758)	Javanese turrid
Family: Buccinidae	139.	*Busycotypus canaliculatus* (Linnaeus, 1758)	Channeled whelk
Family: Babyloniidae	140.	*Babylonia spirata* (Linnaeus, 1758)	Spiral Babylon
	141.	*Melo melo* (Lightfoot, 1786)	Indian volute

Taxonomic Classification	Sl. No.	Scientific name	Common Name
Order: Littorinimorpha			
Family: Naticidae	142.	*Natica vitellus* (Linnaeus, 1758)	Calf moon snail
Family: Bursidae	143.	*Bufonaria crumena* (Lamarck, 1816)	
Bivalves			
Class: Bivalvia			
Order: Venerida			
Family: Veneridae	144.	*Paphia rotundata* (Linnaeus, 1758)	
Order: Arcida			
Family: Arcidae	145.	*Tegillarca granosa* (Linnaeus, 1758)	Granular ark

*Near threatened (NT) species; **Vulnerable (V) species; *** Critically endangered species (CR); #Part of the retained catch but discarded only when caught in small sizes

Apart from hilsa shad, the major marine resources landed in West Bengal are sciaenids, Bombay duck, catfish, anchovies and penaeid prawns (Mini et al., 2017). Sciaenids, contribute to about 6-12% of total landings of West Bengal and are one of the principal group in demersal fish landings of the State (Anon, 2016). Sciaenids sustain one of the most significant demersal fisheries along the Indian coast, though they are caught in large numbers as bycatch. Pravin and Manohardoss (1996) and Samanta et al. (2018) also reported maximum share of sciaenids in the bycatch of shrimp trawl along the coast of Mumbai and Veraval, respectively. Catfishes, chiefly comprised of the *Arius* spp., another important resource in the state which is consistently landed along this coast. In the present study, their contribution is less as they are also caught by gillnetters, which is not accounted for here. Total catch recorded from the selected hauls by the trawl during the study period was 9,064 kg, out of which target catch (shrimps and lobsters) constituted 9.4%, retained bycatch represented 54.8% and discards formed 35.8% of the total catch (Fig. 4), thus forming 90.6% as bycatch. Overall, bycatch recorded in the present study is comparable with Pillai (1998), Gibinkumar et al. (2012) and Velip and Rivonker (2015) who have reported 90%, 87.15±5.77% and 89.6% as bycatch along the coasts of Vishakapatnan, Cochin and Goa, respectively. The present study clearly showed that the bycatch percentage was high along the Digha coast. *Harpadon nehereus* was the most dominant species contributing to the weight as a single species. The higher percentage of bycatch might be due to the consideration of only the shrimps and lobsters as target catch while the rest formed the bycatch. Other researchers have taken shrimps, lobsters, flat fish, crabs, squids and sciaenids (Velip & Rivonker, 2015); shrimps, and commercial-sized fishes (Zacharia, Krishnakumar, Durgekar, Anoop & Muthiah, 2006) as target catch. Most of the species in retained bycatch are also commercially important and marketed. Dinesh babu et al. (2013) and Mahesh et al. (2017) have used the term ‘low-value bycatch’ (LVB) for non-edible portion of landed bycatch which is mainly consisted of juveniles of fishes, and the term ‘discards’ for the discarded portion of bycatch. Pravin and Manohardoss (1996) have taken small-sized fishes, juveniles of commercially important fishes, small prawns, crabs, squilla, jelly fish, sea snakes as low-value bycatch (LVB) off Veraval. And hence it can be concluded that the variation in percentage would vary considerably (George et al., 1981; Pillai, 1998; Dineshbabu, Thomas & Vivekanandan, 2014; Madhu et al., 2017; Jenishma et al., 2019; Azeez et al., 2024). Fluctuations in the

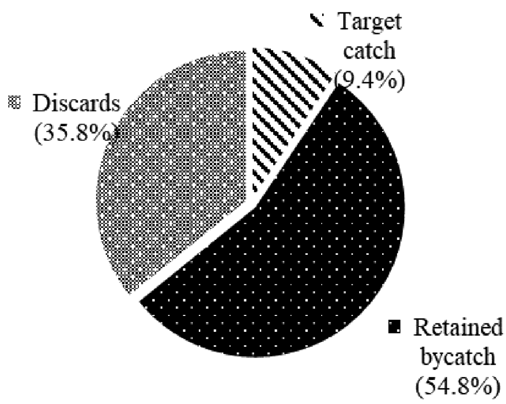

Fig. 4. Overall wet-weight percentage of target catch, retained catch, and discards

Table 2. A comparative analysis on shrimp trawl bycatch studies in different parts of India

Auth Study area	or	Target catch	Bycatch	Discards
Gibinkumar et al. (2012)	Shrimps	• 281 species (191 fishes, 11 shrimps, 3 lobsters, 13 crabs, 11 cephalopods, 44 molluscan shells, 2 echinoderms, 2 jelly fishes, 2 stomatopods, 1 sea snake and 1sea turtle) • Quantity: 87.15 ± 5.77% of the total catch	-	Cochin, Southwest coast
Velip and Rivonker (2015)	Prawns, crabs, solefishes, sciaenid and, squids	• 103 species (7 elasmobranchs, 90 teleosts, 3 crustaceans and 3 molluscs) • Quantity: 68% of the trawl catch	• 89% of the species discarded into the sea comprised of juveniles of target and trash species • 71 species (24 teleosts, 27 crustaceans, 13 molluscs, 4 echinoderms, 2 reptiles and 1 cnidarian) • Quantity: 36% of total bycatch	Goa, Southwest coast
Behera et al. (2017)	Shrimps	• 248 species (teleosts, invertebrates, elasmobranchs, turtles and seasnakes) • Quantity: Mean catch rate 75.693 to 176.596 kg h^{-1}.	-	Off northern Andhra Pradesh, Western Bay of Bengal
Samanta et al. (2018)	Shrimps, prawns and lobster	• 127 species (7 elasmobranches, 82 finfishes, 8 crabs, 4 mantis shrimps, 24 molluscs) • The maximum catch was contributed by sciaenids (35%), sharks and rays (10%), anchovies (10%), Bombay duck (6%) and otherdemersal species. • Quantity; 11.82 to 20.65 kg h^{-1},	• Jelly fish, molluscs, stomatopods and juveniles of fish	Mumbai, Northwest coast
Jenishma et al. (2019)	Shrimps	• 83 species (44 finfishes, 13 shrimps, 10 gastropods, 4 crabs, 3 cephalopods 3 stomatopods, 3 elasmobranch, 1 lobster, 1 hermit crab, and 1 jellyfish). • Quantity: 32% (retained) of the total catch	• juveniles of commercially important fishes and marine debris • 60% of the total catch	Mumbai, Northwest coast
Present study	Shrimps, prawns and lobster	• 130 species (98 teleosts 5 elasmobranchs, 6 crabs, 4 cephalopods, 7 gastropods, 2 bivalves and 8 stomatopods) • Quantity: 54.8% (retained) of total catch	• Gobies, angler fish, puffer fish, tripod fish, crabs, stomatopods, octopus, gastropods, bivalves, juveniles of commercially important fish species.	Off Digha coast, West Bengal

quantity of discards have been attributed to various reasons such as seasonal variations in temperature and salinity, an extension of distribution of small pelagic to deeper waters (Behera et al., 2017), temporal variations in biotic factors, diversity of species (Mahesh et al., 2014), scraping the bottom vigorously and thus harvesting a large assemblage of epifaunal organisms, which clog the net resulting in hauling of discards in higher quantities (Kurup et al., 2004), use of small mesh size (Kurup, Premlal, Thomas, & Anand, 2003) and difference in fishing depth (Zacharia, et al., 2006). Higher percentage of discards in the present study could be attributed to smaller mesh size (20 mm) (Madhu, Raphael, &

Meenakumari, 2015), operation of trawl net in inshore waters which invariably produces more bycatch than the deeper waters >30 m (Zacharia, Anoop, Durgekar & Krishnakumar, 2006).

The hierarchical cluster analysis technique was used in the present study to determine the similarity in species composition and abundance during the study period. The hierarchical cluster analysis of the weights of different fish groups revealed multiple clusters based on their similarities (Fig. 5). Elasmobranchs and pomfrets shared 85.88% similarity, sciaenids and miscellaneous group at 81.43%, clupeids and Bombay duck at 84.32%, and carangids with polynemids and catfish at 78.61%. Crabs combined with carangids, polynemids, catfish, and other groups at 73.41% similarity, while ribbonfish share 49.64% similarity with elasmobranchs and pomfrets. The final comprehensive cluster, which incorporated the highest similarity cluster (65.47%)

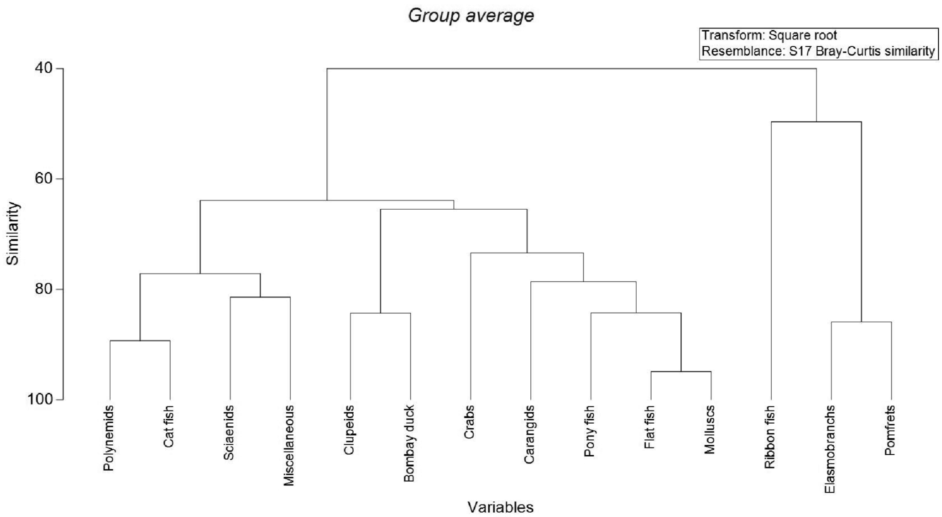

Fig. 5. Dendrogram showing similarity in the weight and bycatch composition in the trawl catch during the study period

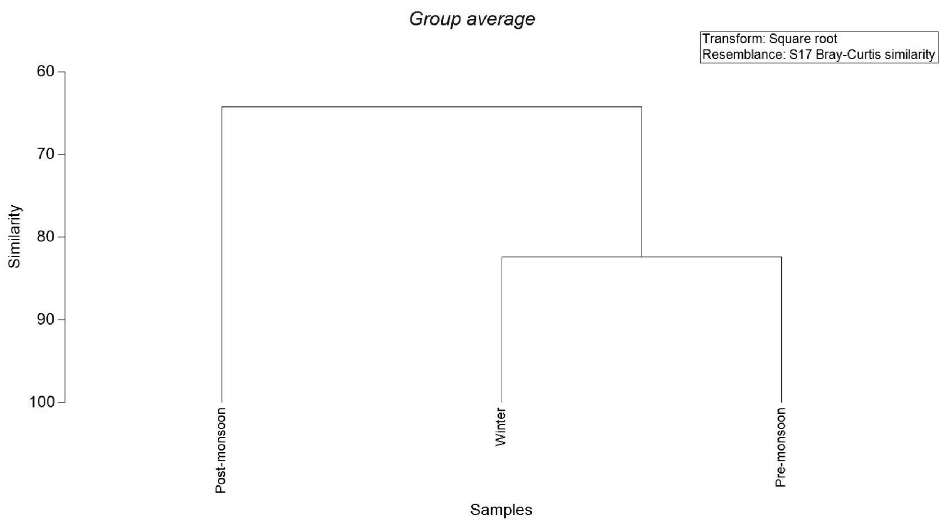

Fig. 6. Dendrogram showing similarity in bycatch weight in the trawl catch among the seasons

Table 3. List of prominent species and their seasonal abundance

Sl. No.	Species name	Seasonal abundance
1.	*Scoliodon laticaudus*	Post-monsoon
2.	*Stolephorus commersonnii*	Post-monsoon
3.	*Coilia dussumieri*	Post-monsoon, winter
4.	*Setipinna taty*	Post-monsoon, winter
5.	*Harpadon nehereus*	Post-monsoon, winter
6.	*Drepane longimana*	Post-monsoon
7	*Deveximentum insidiator*	Post-monsoon, Pre-monsoon, winter
8.	*Polynemus paradiseus*	Post-monsoon, winter
9.	*Panna microdon*	Post-monsoon, Pre-monsoon, winter
10.	*Johnius borneensis*	Post-monsoon, Pre-monsoon, winter
11.	*Charybdis callianassa*	Post-monsoon, Pre-monsoon, winter
12.	*Exhippolysmata ensirostris*	Post-monsoon
13.	*Mierspenaeopsis sculptilis*	Post-monsoon, winter
14.	*Parapenaeopsis stylifera*	Post-monsoon, Pre-monsoon, winter
15.	*Stolephorus waitei*	Pre-monsoon
16.	*Nuchequula blochii*	Pre-monsoon
17.	*Portunus sanguinolentus*	Pre-monsoon, winter
18.	*Charybdis feriata*	Pre-monsoon
19.	*Matuta planipes*	Pre-monsoon, winter
20.	*Miyakella nepa*	Pre-monsoon, winter
21.	*Sepiella inermis*	Pre-monsoon, winter
22.	*Uroteuthis duvaucelii*	Pre-monsoon
23.	*Thryssa dussumieri*	Winter
24.	*Stolephorus indicus*	Winter
25.	*Coilia neglecta*	Winter
26.	*Cynoglossus macrostomus*	Winter
27.	*Cynoglossus cynoglossus*	Winter
28.	*Arius maculatus*	Winter
29.	*Turricula javana*	Winter
30.	*Ganjampenaeopsis uncta*	Winter
31.	*Nematopalaemon tenuipes*	Winter

and other important clusters, had an overall similarity of 40%. The clusters produced at high similarity levels (over 80%) indicate that the groups are closely related, implying possible ecological or biological similarities. As the similarity threshold drops, more complex clusters form, integrating numerous species groupings. For example, merging carangids with polynemids and catfish implies a broader range of weight similarities. The final cluster, with 40% similarity, encompasses all groups, reflecting the overall structure of the fish population in the examined ecosystem and offering a macroscopic view of weight distribution across groups.

The seasonal data analysis (Fig. 6) revealed that winter and pre-monsoon had a high similarity (82.39%), suggesting that fish weights in these periods are more alike, potentially due to stable environmental conditions or consistent fishing practices. The lower similarity (64.22%) when combining post-monsoon with winter-pre-monsoon clusters indicates greater variation in fish weights during the post-monsoon season, possibly due to changes in water temperature, food availability, or migratory patterns. Seasonal variations in bycatch composition and patters have been well documented (Madhu et al., 2017; Azeez et al., 2024). The list of prominent species in bycatch and their seasonal abundance recorded during the current study is presented in Table 3. Variability of clusters formation and seasonal association of various fish species can be attributed to trophic interaction, habitat sharing, environmental conditions as it varied between seasons, and other trophic dynamics (Hernández, González, Villarroel & Acuña, 2010; Velip & Rivonker, 2015; Behera et al., 2017; Kumar, Benakappa, Kumar Naik, & Rawat, 2020).

Although the current study is limited to one commercial vessel and consists of fishery-dependent data, the baseline data obtained in the present study about faunal composition and bycatch assessment are likely to aid in the development of bycatch management techniques. Effective implementation of trawl net selectivity and the use of bycatch reduction devices have been suggested not only to minimise the damages to the ecosystem but also for sustainable marine fisheries of the State.

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