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ASSESSING IMPACT OF STINGRAY GILL NET FISHERY TO BYCATCH POPULATION AROUND BIDONG ISLAND, MALAYSIA

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Abstract: This study assessed the bycatch composition around Bidong Island, Malaysia, and factors affecting its assemblages. Bycatch samples were collected monthly from January to December 2018 with supplementary samplings in February and October 2019. A total of 648 individuals of bycatch from 15 fish species were collected, which accounted for 84.2% of the total catch. The most dominant species were *Alectis indica, Rachycentron canadum* and *Epinephelus areolatus*. The abundance of bycatch varied significantly between seasons ($P<0.05$), whereas the species richness of the bycatch was not affected by season, depth and interaction of season and depth ($P>0.05$). The most abundant bycatch was found at a depth of 20 m in moderate rainy and rainy seasons. The non-metric multidimensional scaling ordination clearly separated the three major groups of the community structure of bycatch based on depth, but not season. It is therefore concluded that season affected bycatch abundance, and conversely, depth influenced the community structure of the bycatch from stingray gillnet.

Keywords: Rays, depth, seasonal, discarded species, South China Sea.

Introduction

Unselective capture, or bycatch, incidentally contributes to devastating ecological impacts, such as decline in global capture fisheries production and the death of other marine species with no commercial value (Lewison *et al.,* 2004; Davies *et al.,* 2009). A total of 9.1 million tonnes of bycatch are collected annually, in which 0.8 million tonnes of this amount came from gillnet fisheries (The Food and Agriculture Organisation [FAO], 2020). Bycatch can be classified into three categories: (i) normal bycatch, (ii) cryptic bycatch and (iii) ghost fishing. Normal bycatch occurs when non-targeted species are accidentally captured in the fishing gear during the hauling process, regardless of whether they are alive or dead (Kumar *et al.,* 2016; Fazrul *et al.,* 2015; Leland *et al.,* 2013). Cryptic bycatch refers to living organisms that developed injuries after being entangled in fishing gears and then died following release or escape (Kumar *et al.,* 2016; Fazrul *et al.,* 2015; Reeves *et al.,* 2013). The final type of bycatch, ghost fishing, is where the lost or intentionally discarded fishing gears continue to cause fatality to marine organisms without any human control (Sullivan *et al.,* 2019; Fazrul *et al.,* 2015; Campbell & Sumpton, 2009). The Malaysian fisheries sector produced a total of 1.86 million metric tonnes of fish in 2019, including 263,093 tonnes from deep-water fisheries and 1,189,416 tonnes from coastal fisheries (The Department of Fisheries [DOF], 2020). Based on these statistics, the negative impact of bycatch from coastal fisheries would have a greater impact on the Malaysian fisheries production compared with deep-water fisheries.

Studies on bycatch related to modern fishing gears in deep waters are quite established, but not for small-scale fisheries or artisanal fisheries in shallower waters (Selgrath *et al.,* 2018). Most of the bycatch studies only focus on modern fishing gears, such as trawls (Cashion *et al.,* 2018; FAO, 2018; Keledjian *et al.,* 2014) and purse seines (Cashion *et al.,* 2018; FAO, 2018). Bycatch from artisanal fisheries is often neglected, and to date, only a few studies related to it have been conducted (Alava *et al.,* 2019; Cashion *et al.,* 2018; Kumar *et al.,* 2016; Coelho *et al.,* 2015; Fazrul, 2015; Keledjian *et al.,* 2014; Moore *et al.,* 2010). The coastal area is plankton-rich and an ideal feeding ground for juveniles of deep-water fish species; thus, these areas need to be protected, and any fish landing needs to be recorded (Hastings *et al.,* 2017). Data on bycatch in the shallow or coastal areas are crucial for the future planning of sustainable fisheries, and overexploitation by artisanal fisheries can lead to a decline in deep-water catches and reduced biodiversity (Selgrath *et al.,* 2018).

There are various types of gillnets targeting the capture of a specific species. For example, crab gillnets, pelagic fish gillnets, stingray gillnets, prawn gillnets and cephalopod gillnets (Chumchuen & Krueajun, 2021; Fazrul *et al.,* 2015; Pérez-Jiménez & Mendez-Loeza, 2015; Lim *et al.,* 2014; Dharmadi *et al.,* 2009; White *et al.,* 2006). Gillnets are made of many types of materials, such as nylon, rope, monofilament, multifilament and multi-monofilament (Ayaz *et al.,* 2006; Walker *et al.,* 2005). Stingray gillnets are used to catch various species of rays in many parts of the world (Oliver *et al.,* 2015). Li *et al.* (2018) reported that this fishing equipment is efficient in capturing rays. Although it is a globally accepted fishing method, the deployment of the stingray gillnet is banned in Malaysia because of the harm it poses to the turtle population. Many artisanal fishers do not abide to the correct mesh size of gillnets allowed for fishing as stated in the Fisheries Regulation 1990. Due to the usual practice of leaving gillnets at sea for days, any trapped turtles in these unattended nets will die before getting rescued (Yassin, 1997; Sunardi *et al.,* 2013; The Straits Times, 2016; Yaacob, 2019). Consequently, local fishers are still finding efficient fishing methods to catch rays without using a stingray gillnet in coastal areas.

Nonetheless, its illegal usage is still reported as artisanal fishers have long believed that fisheries resources are renewable and everlasting, which is why scientific data collection on bycatch is urgently needed to prove otherwise (Ali *et al.,* 2011; Wong & Yong, 2020). Identifying habitats for conservation is a top priority for ecologists and conservationists globally (da Silva *et al.,* 2021). The death of non-commercial species caused by fishing can have a variety of consequences for biodiversity and ecosystems. The impact and consequences of discarding practices are still being debated (Damalas *et al.,* 2010). Non-target species may be severely reduced long before effective management practises can be enacted, according to some experts. This is due to the fact that fisheries are driven by valuable target species, which are frequently examined, whereas low or non-commercially valuable species are left unmonitored (Damalas *et al.,* 2010). The highly selective fishing patterns are important in fisheries management to reduce bycatch, protect species and rebuild ecosystems (Kolding *et al.,* 2015). The importance of coastal areas as nursery grounds for marine species can also be highlighted through a bycatch study (Le Pape & Bonhommeau, 2015). Various habitat variables, including substrate qualities, area, season, depth, temperature and salinity were linked to fishery-related abundance indices (Damalas *et al.,* 2010). For all species, depth was the most relevant factor (Damalas *et al.,* 2010). Identification of species-habitat relationships can help us better understand their distribution and migration patterns, as well as the significance of the environmental factors (Damalas *et al.,* 2010). Along this depth gradient, the fauna is also known to shift (Zintzen *et al.,* 2012). According to Abesamis *et al.* (2018), total fish species richness, abundance or biomass decreases gradually or rapidly as depth increases. Other research has found peaks in fish species richness or abundance, as well as a major shift in species composition, at specific depths (Abesamis *et al.,* 2018). The study of seasonal fluctuations in species' relative abundance is one of the fundamental goals of the fish ecology community. According to Castillo-Rivera's (2013) research, salinity, depth and turbidity which are all affected by seasonal variations in rainfall and freshwater intake, play a significant role in determining species abundance. Therefore, the aim of this study was to examine the impact of depth and season on the community structure of bycatch.

Materials and Methods

Study Area

This study was conducted around Bidong Island in Terengganu waters off the east coast of Peninsular Malaysia, where three different depths were examined: 10 m, 15 m and 20 m. Three sub-stations were set up as net transects centred to Bidong Island, based on the different depths, which were 10 m for stations A1, B1, C1; 20 m for stations A2, B2, C2 and 30 m for stations A3, B3, C3 (Figure 1). The depths at each of the sampling stations were measured using the SIMRAD EK15 scientific echo sounder with a frequency of 200 kHz. The latitude and longitude for the sub-stations are shown in Table 1. The stations were chosen as they were the common areas frequented by local fishers to catch stingrays. The seasonal division for this study was based on Fazrul *et al.* (2015), where seasons were divided based on the quantity of rainfall: (1) the dry season from January to April, (2) the moderate season from

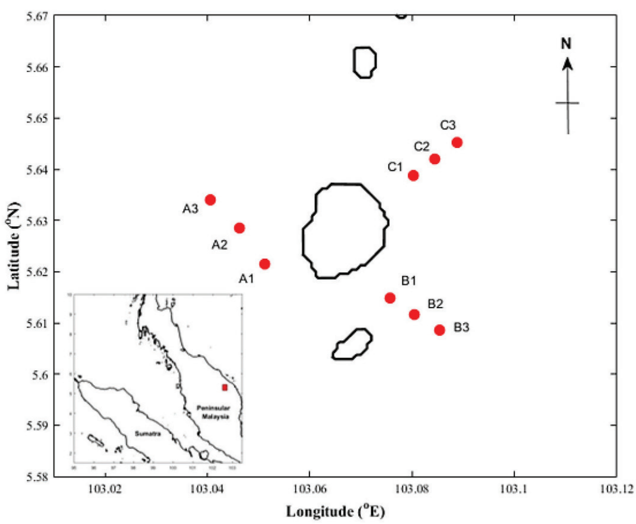

Figure 1: The sub-stations in a line transect setting at the sampling site

Table 1: The latitude and longitude of the sampling sub-stations

Station	Latitude	Longitude
A1	5°37'17.4" N	103°3'4.4388" E
A2	5°37'42.42" N	103°2'46.32" E
A3	5°38'2.22" N	103°2'26.4012" E
B1	5°36'53.6472" N	103°4'32.9232" E
B2	5°36'42.0804" N	103°4'50.0484" E
B3	5°36'30.5388" N	103°5'7.6956" E
C1	5°38'19.3308" N	103°4'48.7632" E
C2	5°38'31.056" N	103°5'3.9444" E
C3	5°38'42.9324" N	103°5'20.0472" E

May to August and (3) the rainy season from September to December in 2018.

Collection of Samples

Samples were collected monthly from January to December 2018 using stingray gillnets with supplementary samplings in February 2019 and October 2019 to complement existing data based on seasonal, species and depth factors for the same months in 2018. At each sub-station of each depth contour, a net with a depth of 2 m, length of 2,100 m and stretch mesh size of 26 cm was set at 06.00 hours, left overnight for 24 hours and hauled on board the next morning (Figure 2). Altogether, 6,300 m of netting was deployed at each depth and overall 18,900 m from all three depths were hauled for each sampling month. The catch per unit effort (CPUE) was calculated as follows:

$$\text{CPUE} = \frac{\text{Total fishing hours} \times \text{Total number of gillnets}}{\text{Number of bycatch}}$$

After being boarded, the specimens were measured, labelled and frozen.

Laboratory Method

All the bycatch fish species from the stingray gillnets were preserved with 10% formalin and deposited at the Science Fisheries Collection of Faculty of Fisheries and Food Sciences, Universiti Malaysia Terengganu, for future reference (Fazrul *et al.,* 2015). The bycatch species were classified into two groups: (1) discarded or non-valuable bycatch (D) and (2) retained or valuable bycatch (R), with each species determined based on local practice.

Data and Statistical Analysis for Bycatch

Monthly data at each depth contour were analysed for (1) community parameters; Shannon–Weiner's diversity index (H') and species richness and (2) relative abundance. Two-way analysis of variance (ANOVA) was used to compare the abundance of bycatch or species richness between the three depth contours and seasons (Fazrul *et al.,* 2015). The bycatch data, both numbers of individuals and numbers of species were log (X+1) transformed to reduce non-normality prior to analysis.

A non-metric multidimensional scaling (nMDS) ordination were plotted using the PRIMER statistical package version 5.0 to assess the extent of each individual grouping based on depth and season. A Bray-Curtis similarity based on log X+1 transformation was used to examine the difference in bycatch community assemblages between all the depths and seasons. Analysis of similarity (ANOSIM) was used to determine whether the bycatch assemblage of each depth and season differed significantly. Once the difference is detected, a similarity percentage (SIMPER) was used to examine which bycatch species contributed most to the grouping.

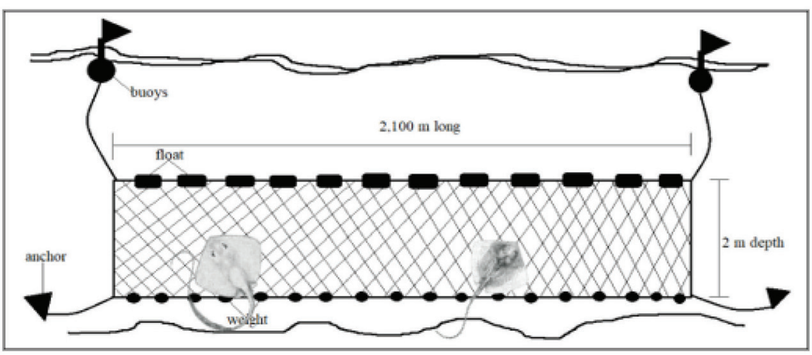

Figure 2: The characteristic of the stingray gillnet used during sampling

Results

It was found that 84.2% of the bycatch were caught by stingray gillnets set in different depths and seasons. The ratio of stingrays and bycatch varied between depths and seasons. However, the bycatch proportion remained higher than that of stingray catches for all depths and seasons (Table 2 and Table 3).

Altogether, 648 individuals of bycatch were caught together with stingrays by stingray gillnets. The bycatch comprises 15 species. The three main families of the bycatch were Carangidae, Serranidae and Rachycentridae. *Alectis indica*, *Rachycentron canadum* and *Epinephelus areolatus* were the three most dominant bycatch species (Table 4). Their abundance and utilisation status, either discarded or retained, are shown in Table 4.

The calculated catch per unit of effort (CPUE) of bycatch was 3.33 per 10 panel-hour. The results of the ecological attributes of the bycatch collected from stingray gillnets in Terengganu waters are presented in Table 5.

Table 2: A comparison between the number of stingrays and bycatch collected by stingray gillnets at different depths

Depth	Number of Individuals of Bycatch (%)	
	Stingrays	**Bycatch**
10 m	16 (7.7%)	191 (92.3%)
15 m	29 (12.9%)	196 (87.1%)
20 m	77 (22.8%)	261 (77.2%)
Total	122 (15.8%)	648 (84.2%)

Table 3: A comparison between the number of stingrays and bycatch collected by stingray gillnets in different seasons

Season	Number of Individuals of Bycatch (%)	
	Stingrays	**Bycatch**
Dry	67 (19.8%)	272 (80.2%)
Moderate	45 (17.6%)	210 (82.4%)
Rainy	10 (5.7%)	166 (94.3%)
Total	122 (15.8%)	648 (84.2%)

Table 4: Bycatch compositions collected by stingray gillnets in Terengganu waters, Malaysia (D = discarded, R = retained), (LC = least concern, DD = data deficient, NT = near threatened, VU = vulnerable, CR = critically endangered)

Species	Common Name	Status	Status in IUCN	%	No. of Individuals
Carangidae					
Alectis indica	Mirror fish/Indian threadfish	R	LC	12.2	79
Alectis ciliaris	African pompano	R	LC	9.4	61
Gnathanodon speciosus	Golden trevally	R	LC	6.9	45
Ariidae					
Arius maculatus	Spotted catfish	R	DD	8.2	53

Chanidae					
Chanos chanos	Milkfish	R	LC	4.9	32
Carcharhinidae					
Carcharhinus leucas	Bull shark	R	NT	4.9	32
Hemiscylliidae					
Chiloscyllium griseum	Grey bamboo shark	R	VU	5.2	34
Serranidae					
Epinephelus areolatus	Areolate grouper	R	LC	11.7	76
Epinephelus bleekeri	Dusky tail grouper	R	DD	3.1	20
Epinephelus coioides	Orange-spotted grouper	R	LC	1.4	9
Lutjanidae					
Lutjanus argentimaculatus	Mangrove red snapper	R	LC	6.2	40
Rachycentridae					
Rachycentron canadum	Cobia	R	LC	11.9	77
Rhinidae					
Rhynchobatus australiae	White spotted wedge fish	R	CR	5.9	38
Scombridae					
Scomberomorus lineolatus	Streaked seerfish/ Streaked Spanish mackerel	R	LC	7.3	47
Thunnus tonggol	Bluefin longtail tuna	R	DD	0.8	5

Table 5: Summary of ecological indices of bycatch in different depths and seasons collected by stingray gillnets

Depth	Season	Total Abundance	Total Species	Species Richness (d)	H’
10 m	Dry	87	6	0.3135	0.3219
	Moderate	56	5	0.1554	0.1296
	Rainy	48	5	0.3850	0.3039
15 m	Dry	69	5	0.1659	0.2081
	Moderate	80	4	0.2098	0.2594
	Rainy	47	4	0.2148	0.1820
20 m	Dry	116	7	0.4506	0.5830
	Moderate	74	6	0.4964	0.5709
	Rainy	71	9	0.6190	0.6484

Impacts of Depth and Season

The results of the analysis of variance (ANOVA) indicated that seasonal factors significantly affected ($P<0.05$) the abundance of bycatch from stingray gillnet fisheries (Table 6). However, there was no significant difference in species richness of bycatch between seasons, depths and the interaction of the two ($P>0.05$).

Bycatch Assemblages in Different Depth and Season

The result from nMDS plots showed that the bycatch was clustered into three major groups based on the depths of 10 m, 15 m and 20 m (Figure 3). Analysis of similarity (ANOSIM) confirmed the difference between these three groups (P = 0.1%, Global R = 0.301). The similarity percentage (SIMPER) identified two main species of bycatch that contributed the most to the grouping of the 10 m depth community, *Alectis indica* and *Arius maculatus* (Table 7). *Rachycentron canadum* and *Lutjanus argentimaculatus* contributed to the formation of the catches from the 15 m depth. For the 20 m depth, *Alectis ciliaris* was the major contributor to the formation of this group.

The results from the nMDS ordination showed that there was no separated grouping based on season (Figure 4). Analysis of similarity (ANOSIM) confirmed that there was no difference among seasons in terms of fish assemblage (P > 0.5, Global R = -0.026).

Table 6: The results of the two-way analysis of variance of the effects of depth and season on the abundance of bycatch collected by gillnets

Sources	Abundance				Species Richness			
	df	F	MS	P-value	df	F	MS	P-value
Depth (h)	2	1.442	0.048	2.62×10^{-1}	2	0.416	0.026	6.66×10^{-1}
Season (s)	2	3.922	0.131	3.90×10^{-2}	2	0.167	0.010	8.47×10^{-1}
h × s	4	0.660	0.022	6.28×10^{-1}	4	0.449	0.028	7.72×10^{-1}

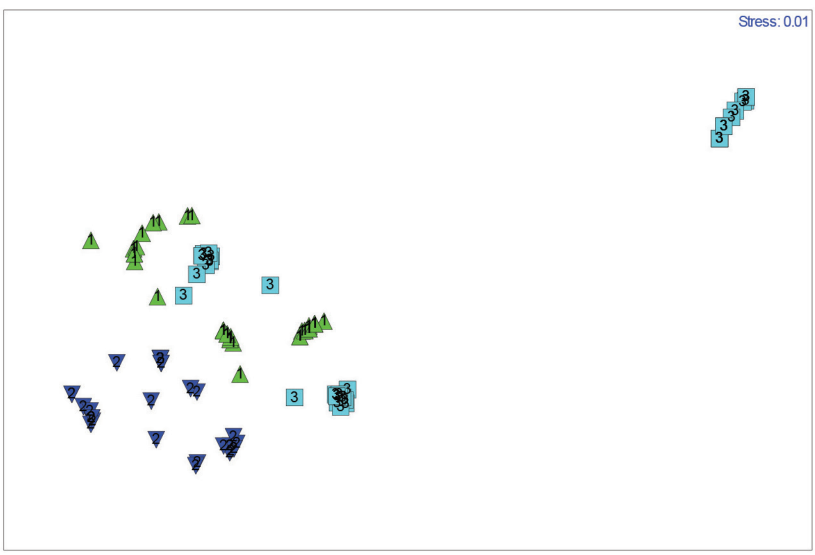

Figure 3: The nMDS ordination for the assemblages at three different depths (1 = 10 m, 2 = 15 m, 3 = 20 m) of bycatch collected by stingray gillnets

Table 7: The SIMPER results for bycatch assemblages in different depths based on nMDS plots

Depth	Species	% Contribution
10 m	*Alectis indica*	36.63
	Arius maculatus	34.88
	Epinephelus areolatus	17.74
15 m	*Rachycentron canadum*	33.69
	Lutjanus argentimaculatus	28.94
	Scomberomorus lineolatus	27.86
20 m	*Alectis ciliaris*	30.36
	Epinephelus areolatus	16.57
	Gnathanodon speciosus	15.32

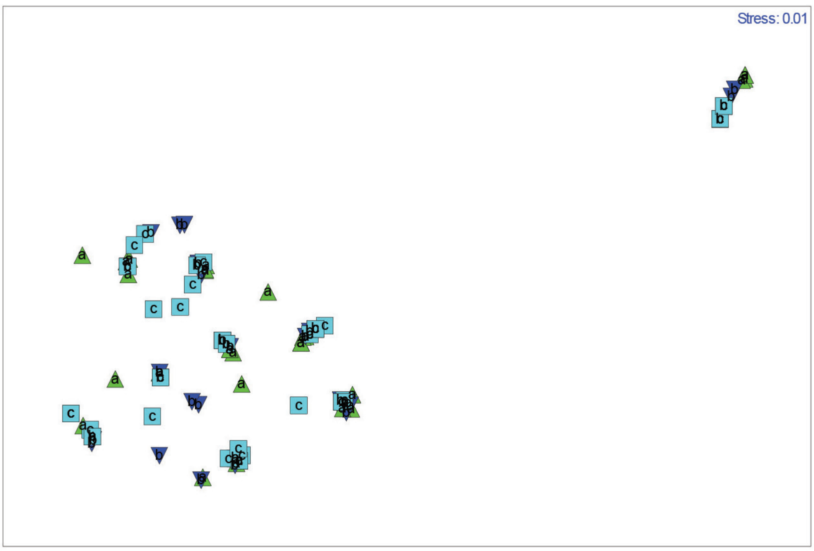

Figure 4: The nMDS plot for assemblages at different seasons (a = dry season, b = moderate rainy season, c = rainy season) of bycatch collected by stingray gillnets

Discussion

It was found that the stingray gillnets used by fishers in Terengganu waters were ineffective in discriminating the stingray species for capture. The use of gillnets with a mesh size shorter than the length at first sexual maturity of a population is said to improve growth, and also reduce the mortality of potential spawners (Wolff *et al.,* 2015). In contrast, another study reported that gillnets with mesh sizes bigger than the length at first sexual maturity produces similar outcomes (Garcia *et al.,* 2012). Gillnets are the most selective gear; however, it is biased in terms of the abundance and distribution of size structure and species capture (Akongyuure Amisah & Agyemang, 2017; Li *et al.,* 2015). Yet, only seasonal changes affected the abundance of the bycatch species. The ratio of abundance of stingrays and the cumulative bycatch species for all depths and seasons were starkly different at

15.8% (stingrays) and 84.2% (bycatch species). The bycatch is higher at any depth and seasonal change compared with stingray catches.

Stingray gillnets; main aim to capture stingrays and other species caught by the gillnets are considered bycatch based on local perception (Fazrul *et al.,* 2015). Bycatch (non-target species) is divided into two categories, namely those discarded and retained (Hamid & Kamri, 2021; James *et al.,* 2016). For example, the white spotted wedge fish is not a target for stingray gillnets and is indeed considered a bycatch. Furthermore, from a total of 648 individuals of bycatch, 15 species were identified, of which all of them were considered as retained species. According to the Red List of the International Union for Conservation of Nature (IUCN, 2019, 2021), all retained species were categorised as Least Concern (LC) and Data Deficient (DD) and were determined to have local commercial value based on the IUCN Use and Trade Classification Scheme.

The outcomes obtained in this study showed that a variety of marine species were caught by the gillnets. Aside from stingrays, 648 (84.2%) bycatch individuals were caught by stingray gillnets. It is observed that most of them are demersal and pelagic reef-associated species. Fish, mainly demersal species, are the most diverse bycatch collected at different depths and in different seasons, yet no crabs, shrimp and molluscs were caught. Most of the bycatch are targeted species with high commercial value in Malaysia, such as *E. areolatus, E. bleekeri, E.coiodes* and *L. argentimaculatus* (DOF, 2018). Quantitatively, the abundance of bycatch around Bidong Island was affected by the season rather than depth. The species richness of the bycatch was not influenced by both depth and season. A previous study stated that the bycatch abundance and species richness are different based on habitat and season (Fazrul *et al.,* 2015). Fazrul *et al.* (2015) and Hossain *et al.* (2016) stated that the abundance of bycatch was influenced by season, habitat and also the interaction of both habitat and season.

In terms of assemblages based on nMDS ordination, the responses of bycatch assemblages were different at each depth. Three major groups were classified at the different depths. The species of the bycatch at each depth were distinguished by the similarity of percentage shown in Table 7. However, for different seasons, there was no separation for the species assemblages observed. The data analysis of each sampling based on depth or season were distributed all over the plot with a grouping trend. This may lead to the conclusion that bycatch species assemblages collected by stingray gillnet fisheries at different depths are generally different. It is observed that the composition of bycatch is different at each depth (10 m, 15 m and 20 m). The species composition and size distributions of organisms vary considerably over very small distances (Skiftesvik *et al.,* 2015). The species caught are commonly distributed in tropical sea areas. The bycatch composition in this study varied with depth as indicated by the separated groupings of bycatch at different depths. The species that appeared at a depth of 10 m do not appear at 15 m and 20 m. Hence, it can be seen that there are distinct identifiable communities associated with the shelf, slope and abyssal plain, and the species composition changes with depth (Zintzen *et al.,* 2012). The potential factors of the presence of particular groups of organisms at a location are numerous, such as the topographic complexity, presence of oxygen minimum zones, changes in sediment grain size, the degree of physical disturbance or the spatial and temporal variations in food availability (Zintzen *et al.,* 2012). Based on a study by Abesamis *et al.* (2018), multiple factors such as depth, the availability of light, habitat, food, gradients in temperature and fishing pressure, could influence the structure of fish assemblages. Species richness and abundance declined with increasing depth regardless of storm damage on most trophic groups of fish (Abesamis *et al.,* 2018). There are differences in the taxonomy and trophic structure of the shallow and mesophotic fish assemblages, as well as in the degree of the orientation of the fishery. Significant changes of species composition occurr at certain depths based on species richness or abundance (Abesamis *et al.,* 2018). Seasonal factors affect only the abundance of bycatch, but not the community structure. Based on a study by Prayoga and Arthana (2009), during the southeast monsoon, the CPUEs of bigeye scad and indian scad are high, which is contrast during the northwest monsoon, and *Goldstripe sardinella* has a high CPUE production in the early southeast monsoon. Each habitat in the coastal mosaic has its own dynamics, and species in the same community may play diverse roles (da Silva *et al.,* 2021). The impacts of habitat heterogeneity on ecosystem functioning and filtering mechanisms, on the other hand, are still poorly understood, especially when seasonal fluctuations are taken into account (da Silva *et al.,* 2021). Seasonality, which is influenced by rainfall patterns, causes significant variations in environmental conditions and habitat structure in coastal locations, which has a direct impact on the shape and structure of fish assemblages (da Silva *et al.,* 2021). Based on a study by da Silva *et al.* (2021), seasonally, the dynamics of estuarine and coastal sandy beaches alter, with increased wave action during the rainy season, resulting in a constant remineralisation process of organic matter and a bigger quantity of nutrients in the water column being available, attracting new species to this habitat. Due to the substantial functional redundancy among fish species, seasonal changes in species composition appear to have no effect on the functioning of these habitats, according to a few studies.

There are reasons for fishers to discard or retains their catches. Usually, fish with a market value in a particular area will be kept for personal consumption (Goncalves *et al.,* 2007; Cabral *et al.,* 2003; Alverson *et al.,* 1994). Moreover, fishermen will retain some of the species that have commercial value (Fazrul *et al.,* 2015). It is crucial to highlight the bycatch composition from stingray gillnets to serve as the baseline data for future management. All findings from this study will help the authorities manage fish stocks and establish sustainable fisheries.

Conclusion

The total number of bycatches from stingray gillnets represents 84.2% of the total catch and all of them are of the finfish species. The season affected the abundance and the depth influenced the community structure of bycatch from stingray gillnets in the study area. The results of this study will contribute to the education of fishers in terms of sustainable utilisation of fisheries resources in the specific target area and other information on the usage of selective fishing gear suitable for aquatic resources.

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