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Measuring indices of fish community structure in Fisheries Management Area 713 (FMA 713), Indonesia

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Abstract. *Wiyono ES, Zainuddin M, Syamsuddin ML. 2024. Measuring indices of fish community structure in Fisheries Management Area 713 (FMA 713), Indonesia. Biodiversitas 25: 1857-1866.* Understanding the dynamic of the fish community structure over time and space is a fundamental interest and an important component of fisheries science and management. To optimize the utilization of catch species in Fisheries Management Area 713 (FMA 713), the second productive area in Indonesian Waters, we measured the indices of fish community structure in the area. The study analyzed e-log-book fish data introduced by the Ministry of Marine Affairs and Fisheries, Republic of Indonesia (MMAF RI). We studied the composition, productivity, diversity, interaction, and cluster indices to describe the fish community in the study area. The result analysis confirmed that fish composition differed between seasons and reached its highest amount during the west monsoon (WM) season. However, the highest productivity occurred during the east monsoon (EM) season. The diversity of the diversity indices in the study area reached its highest during the WM season and lowest during the second transition (ST) season. In general, there is no significant interaction between most of the catch species. Since the fish community is dynamic seasonally, the fishermen's fishing ground also indicated seasonal movement. During WM and EM seasons, the fishing ground tends to concentrate in the coastal area of Kalimantan. Still, during the transition season, the fishing ground tends to scatter. Therefore, to utilize the fish community results, optimizing fishing was proposed.

Keywords: Fish community, fish community indices, FMA 713, monsoon season

INTRODUCTION

Located in the territorial waters of the Makassar Straits, the Flores Sea, Bone Bay, and the Bali Sea, Fisheries Management Area 713 (FMA 713) is one of Indonesia's finest pelagic fishing areas. Based on the data, the potential of marine resources and fisheries in FMA 713 was estimated to reach 1,073,147 tons/year, with the potential for large pelagic fish of 162,506 tons/year and the potential for small pelagic fish of roughly 248,302 tons/year (MMAF RI 2022). The potential fish stocks in FMA 713 can be Indonesia's second-largest fish production area, with 12.43% of the total national production (Koeshendrajana et al. 2019). This area also comprises one of the migration routes for large pelagic fish originating from the Pacific Ocean. Within this area is the ARLINDO flow, a route for fish to enter Indonesian waters from the Pacific Ocean and the Indian Ocean (Gordon 2005). Additionally, FMA 713 also contains intense potential fishing grounds, specifically upwelling and eddies in the South Makassar Strait (Atmadipoera and Widyastuti 2015; Nuzula et al. 2017; Istnaeni et al. 2023), distribution of thermal fronts in the Makassar Strait (Zainuddin et al. 2020), along with upwelling and downwelling in Bone-Bay, Flores (Gordon 2005; Hidayat et al. 2022; Napitupulu 2022).

A potential fishing grounds habitat is an area with high biological productivity and is important for catching pelagic fish schools (Zainuddin et al. 2006, 2023; Mugo et al. 2020; Wiadnya et al. 2023). The potential fishing grounds' dynamic spatial and temporal movements make it possible to monitor pelagic fish migration patterns (Etnoyer et al. 2004; Bell et al. 2022; Hong et al. 2023). The potential fishing grounds for tuna and skipjack are believed to be strongly influenced by front, eddy, and upwelling dynamics (Zainuddin et al. 2006, 2023). Data from one area of FMA 713 shows a utilization rate of only 46% for the production of large pelagic fish (Zainuddin et al. 2017); therefore, if the potential of fish resources in the area is optimized, the production contribution nationally is expected to reach 15 to 20%. The primary reason for the less optimal pelagic fish catch in the waters of FMA 713 is caused by limited actual and accurate scientific information on fish abundance, fish migration patterns, and fishing season, besides the impact of climate change on the fish stock (Bell et al. 2022; Hong et al. 2023). These particular conditions mean the fisher fishing activities are conducted speculatively, resulting in a catch that tends to be erratic, and in the long run, it is feared that it will diminish the fish resources (Daris et al. 2022).

Therefore, to ensure the sustainability of fishing activities in the long term, it is essential to assess fishing activities to be employed as a reference in the fisheries management process (Bell et al. 2022; Hong et al. 2023; Hasan et al. 2023). The valuable information required in fisheries management is spatial and temporal changes in fish communities due to fishing activities. Assessing changes in biodiversity is an ecological significance because of the importance of designing conservation strategies. For this purpose, the data from commercial fisheries can be used to analyze the biodiversity of catch species (Bell et al. 2022; Hong et al. 2023).

Moreover, managing tropical fisheries is more complicated (Herdiana et al. 2024); the catch species are dynamic spatial-temporally and are highly uncertain regarding catch landing (Halim et al. 2018). As there has been a failure to implement conventional fisheries management in tropical areas, it is necessary to consider an ecological approach by initiating appropriate criteria for the catch species biodiversity (McQuatters-Gollop et al. 2019). However, studies that could explain the biodiversity of catch species and the interaction between catch species and fishing gear are scarce.

Therefore, to assist resource managers in better understanding the performance of pelagic fish biodiversity, we analyzed the characteristics of catch species in multispecies-multigears used in FMA 713, Indonesia, based on the time series about e-logbook commercial landing data. Since the fisheries activity exhibited clear seasonal variations in fishing activity and catch species, the characteristics were investigated on a seasonal basis using several indices of the structure of the species community. The aim of this study is to define the characteristics of the community structure in FMA 713, Indonesia, between seasons. More precisely, the objective is to study the seasonal dynamics of composition, diversity, seasonal patterns, and the extent of the similarity of catch species between seasons in tropical fisheries. We subsequently use these results to recommend management strategies for fisheries management in an area.

MATERIALS AND METHODS

Source of data and pre-processing

The data used in this paper are from the electronic logbooks (e-logbooks). Since 2019, Indonesia has been committed to implementing electronic fishing logbooks for fishing vessels that operate in territorial waters and on the high seas. The program aims to enhance the quality and quantity of data to develop strong policies in fisheries management, strengthen the traceability system for Indonesian fisheries products, promote compliance among fishers, and prevent illegal, unreported, and unregulated (IUU) fishing. To describe the pelagic fish biodiversity in FMA 713 (Figure 1), we examined e-logbook data from 2020-2021 belonging to the Directorate General of Capture Fisheries, Ministry of Fisheries and Marine Affairs, Republic of Indonesia. The e-logbook data content is the fishing activity of vessels that contain fish catch per species per fishing day and fishing grounds. There are about 7 types of fishing gear used by fishermen. The most commonly used gear is purse seine, followed by hand line, gillnet, bouke ami, trammel net, trolling line and longline. These gears catch 56 fish species. Prior to the analyses, roughly 255 sets of data were tidied up, sorted and clustered both into fishing gear and fishing season.

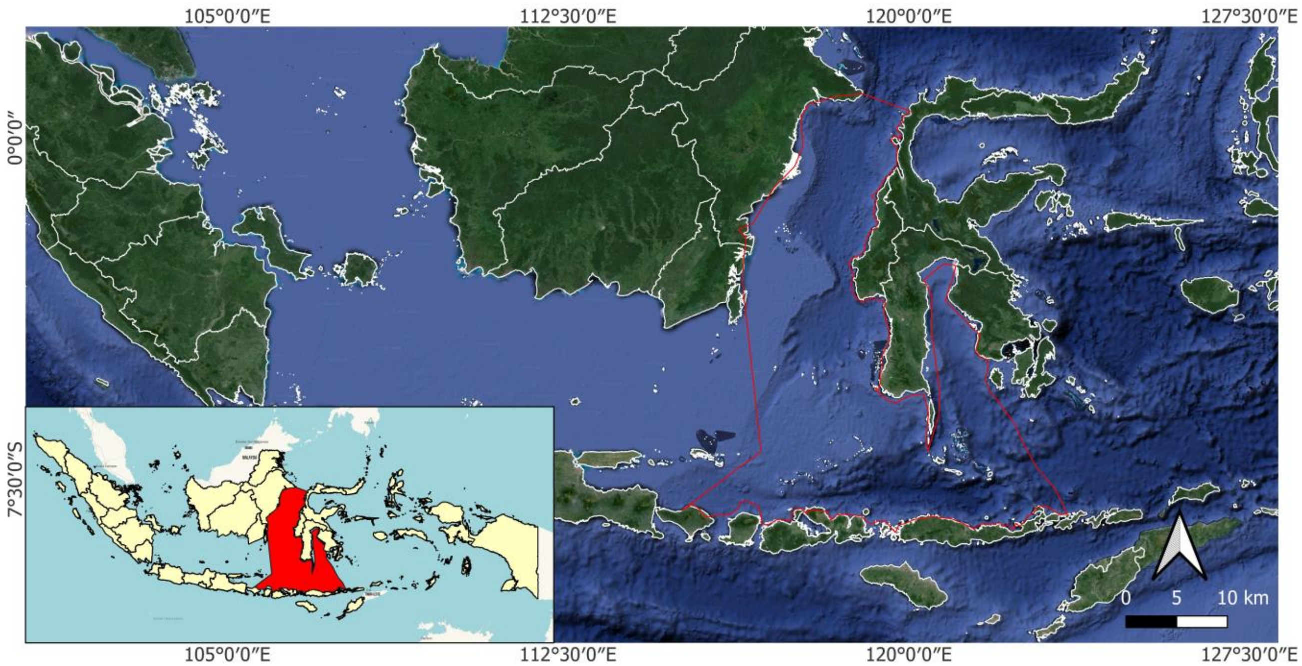

Figure 1. Study area in Fisheries Management Area 713 (FMA 713), Indonesia

Data analysis

Several indicators that can measure the general features of the fish community were selected to investigate the characteristics of the pelagic fish community found in FMA 713 throughout the year. Using the available data, we focused on selecting indicators at the community level without consideration of the individual levels.

As the monsoon wind influenced the Indonesian water (Picaulima et al. 2020), we grouped our set data into the monsoon season (Table 1). The Indonesian monsoon is a part of the East and Southeast Asian monsoon. The Indonesian season was defined based on the wind direction over the region (Setiawan and Habibi 2010). During December, January, and February, wind blows west to the northwest over the Southern Hemisphere and causes the northeast monsoon season. On the contrary, during June, July, and August, the east monsoon wind blows east to west, causing the east monsoon season (Purwanto et al. 2021).

Data on catch per trip was used to analyze species' seasonal abundance (productivity) (Wiyono and Ihsan 2018). This was performed each season based on the catch and trip data relating to the gears. Since fishing trips varied between fishing gears and seasons, the fishing effort was computed by the number of fishing trips. The high catch per trip indicates that fish in a certain season was abundant and vice versa.

The Shannon Diversity Index (Magurran 1988) was used to evaluate the seasonal variation of species diversity (Sihombing et al. 2017; Wahyuningsih 2022; Hasan et al. 2023). The diversity index is a mathematical function that combines wealth and evenness in a single size. Although there are several methods, the most commonly used diversity indexes are the Shannon and Simpson Diversity Index. Shannon's index stresses the evenness of components, while Simpson's index places greater emphasis on the component of wealth. As a result, these indices can exhibit considerable variation in their response to changes in species composition. Species diversity combining species richness and diversity provides valuable information to assess spatiotemporal variability (Luo et al. 2023). The index was calculated using catch species (kg) by season as follows:

$$H'_m = -\sum_{i=1}^{S} p_{i,m} \ln p_{i,m}$$

Where:

H'_m : the Shannon Diversity Index of catch species in monsoon season m

$p_{i,m}$: the proportion of species i in monsoon season m relative to the total species catch

S : the number of species caught.

A high index indicates that the catch species was distributed evenly among species. On the contrary, a low index indicates that the catch species is dominated by a single or a few target species.

Furthermore, to understand the interaction between catch species, we employed Pearson's correlation coefficient to describe the degree of correlation between species (Lezama-Ochoa 2017). Correlation coefficients are statistical analyses that are typically exploited to indicate a predictive relationship and measure how strong a relationship is between two variables. This research defines a positive correlation, meaning two catch species interact in the same season. A negative correlation denotes that two species have not interacted in the same season. A correlation coefficient close to 1 suggests that the interaction of two catch species in the same season is to a large degree. However, if close to 0, it implies a low degree of evidence concerning the interaction of two catch species in the same season (Koya et al. 2018).

The similarities in catch species were described using cluster analysis (van Tongeren 1995). The seasonal species composition was computed to describe similarity patterns among catch species (SPSS Chicago, IL, US); if catch species are clustered into one group, it signifies that the catch species have a similar fishing season. On the contrary, if catch species fall outside the group, it indicates they are in different fishing seasons. The distinctive catch species similarity patterns between seasons were described by hierarchical clustering analysis based on the centroid and squared Euclidean distance interval methods (Wiyono et al. 2020).

RESULTS AND DISCUSSION

Species, catch composition and catch abundance.

The fishermen caught more than 50 species in FMA 713 (Table 2), and the catch species in FMA 713 demonstrated dynamic seasonality. The highest total catch was found during the east monsoon season (44.8%), while the lowest was observed during the west monsoon season (15.4%). Although the highest total catch species was discovered during the east monsoon season, the highest number of species (38) was observed during the second transition, followed by the west monsoon season (37), first transition (33) and east monsoon (31). In general, catch species were dominated by four species and observed to be caught throughout the year. Sardine, shortfin scad, Indian scad, and spotted sardine contributed over 70% of the total catch (Figure 2). The species catch was determined to be evenly distributed during the east monsoon season, but during the other season, it had changed. During the west monsoon season, the sardines and spotted sardines dominated the species catch. However, during the transition, monsoon catch species were dominated by sardine, shortfin.

Table 1. Monsoon season in Indonesia

Season	Period
Northwest monsoon	Dec-Jan-Feb
First transition	Mar-Apr-May
Southeast monsoon	June-July-Aug
Second transition	Sept-Oct-Nov

The abundance of each species also varied seasonally. Comparing seasons, the total catch per trip on FMA 713 during the east monsoon season (18,870 kg), observed the highest productivity among seasons. Given that the wind during the east monsoon season was friendly, the number of fishing trips during the east monsoon season increased and resulted in the highest total catch (Table 2). The lowest amount of total catch was found during the second transition monsoon (9,853 kg), although the season had already changed, and many fishing trips were taking place at sea. However, the abundance of fish had already reduced, although it was still relatively high. In contrast, during the west monsoon season, catch species productivity increased; due to the challenging season, the number of fishing trips decreased. Nevertheless, the catch species was relatively high.

Species diversity

In general, catch species in FMA 713 were relatively similar and overlapped between seasons. Although approximately 57 fish species were captured, the compositions of the landing were dominated by only four particular species, specifically sardine, shortfin scad, Indian scad, and spotted sardine. The Shannon Diversity Index analysis of catch species composition demonstrated that the diversity of species of most monsoon seasons is changing and varies seasonally (Figure 3). The results of the analysis reveal that the diversity of catch species was highest during the west monsoon-first transition season from December to May (0.9), followed by the east monsoon season (0.8) and the second transition season (0.7).

Species interaction

This study used correlation analysis to describe the interaction between catch species in the study area. The correlation studies about the catch species rates revealed that most did not show significant statistics ($p>0.05$), and most of the major species catch revealed a positive relationship with other species, with only a few negative correlations (Table 3).

The sardine correlation only presents a significant positive correlation with the yellowfin tuna species ($p < 0.05$). Conversely, spotted sardine only exhibited a significant positive correlation with mackerel scad ($p< 0.05$). Sardine catches negatively correlated with spotted sardine, little tuna, bigeye scad, torpedo scad, mackerel scad, bigeye tuna, yellow strip scad, and narrow-barred Spanish mackerel. Indian scad and spotted sardine typically have a negative correlation pattern similar to the sardine pattern. Sardine, Indian scad, and spotted sardine negatively correlate with tuna species. However, the correlation pattern of shortfin scad was noted to be relatively different.

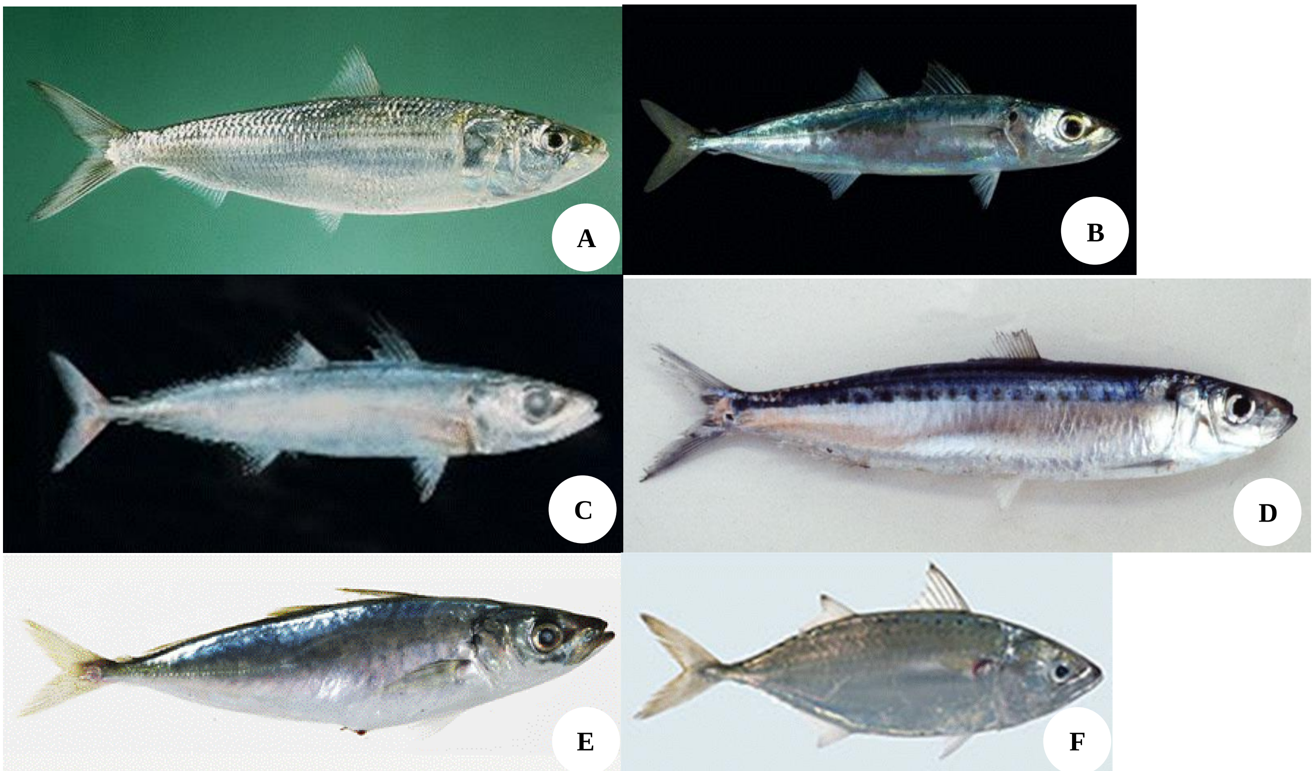

Figure 2. Main fish catch in the study area, FMA 713, Indonesia. A. Sardine (*Sardinella longiceps* Valenciennes 1847); B. Shortfin scad (*Decapterus macrosoma* Bleeker 1851); C. Indian scad (*Decapterus russelli* Rüppell 1830); D. Spotted sardine (*Amblygaster sirm* Walbaum 1792); E. Japanese scad (*Decapterus maruadsi* Temminck and Schlegel 1843); F. Short mackerel (*Rastrelliger brachysoma* Bleeker 1851). Sources: https://www.fishbase.se/search.php

Table 2. Catch composition (kg) of FMA 713, Indonesia between seasons

Common name	Family	Genera	Scientific name	West monsoon		First transition		East monsoon		Second transition	
				Total (kg)	Average	Total (kg)	Average	Total (kg)	Average	Total (kg)	Average
Needlefish	Belonidae	*Tylosurus*	*Tylosurus crocodilus*	-	-	150	3.3	-	-	-	-
Bigtooth pomfret	Bramidae	*Brama*	*Brama orcini*	-	-	-	-	-	-	387	5.1
Mottled fusilier	Caesionidae	*Dipterygonotus*	*Dipterygonotus balteatus*	40	1.0	-	-	-	-	-	-
Blackfin scad	Carangidae	*Alepes*	*Alepes melanoptera*	-	-	10	0.2	-	-	500	6.6
Streaked seerfish	Carangidae	*Alepes*	*Alepes djedaba*	650	15.9	215	4.7	-	-	7,330	96.4
Cleftbelly trevally	Carangidae	*Atropus*	*Atropus atropos*	-	-	-	-	-	-	4	0.1
Shadow trevally	Carangidae	*Carangoides*	*Carangoides dinema*	-	-	15	0.3	-	-	-	-
Tille trevally	Carangidae	*Caranx*	*Caranx tille*	-	-	-	-	-	-	40	0.5
Indian scad	Carangidae	*Decapterus*	*Decapterus russelli*	49,555	1.208.7	151,155	3,286.0	339,586	3,691.2	99,830	1,313.6
Rainbow sardine	Carangidae	*Decapterus*	*Decapterus macarellus*	4,070	99.3	-	-	3,330	36.2	-	-
Redtail scad	Carangidae	*Decapterus*	*Decapterus kurroides*	2,650	64.6	4,581	99.6	11,410	124.0	800	10.5
Japanese scad	Carangidae	*Decapterus*	*Decapterus maruadsi*	23,790	580.2	22,243	483.5	75,075	816.0	21,395	281.5
Shortfin Scad	Carangidae	*Decapterus*	*Decapterus macrosoma*	66,636	1,625.3	239,149	5,198.9	303,012	3,293.6	168,185	2,213.0
Torpedo scad	Carangidae	*Decapterus*	*Decapterus russelli*	500	12.2	18,150	394.6	-	-	-	-
Shrimp scad	Carangidae	*Megalaspis*	*Megalaspis cordyla*	-	-	17,001	369.6	400	4.3	-	-
Barred queenfish	Carangidae	*Scomberoides*	*Scomberoides tala*	-	-	-	-	60	0.7	65	0.9
Bigeye tuna	Carangidae	*Scomberoides*	*Scomberomorus lineolatus*	171	4.2	740	16.1	2,224	24.2	1,139	15.0
Narrow-barred mackerel	Carangidae	*Scomberoides*	*Scomberomorus commerson*	186	4.5	675	14.7	16	0.2	176	2.3
Bigeye scad	Carangidae	*Selar*	*Selar crumenophthalmus*	12,348	301.2	22,594	491.2	14,550	158.2	11,730	154.3
Oxeye scad	Carangidae	*Selar*	*Selar boops*	740	18.0	100	2.2	-	-	-	-
Yellow stripe scad	Carangidae	*Selaroides*	*Selaroides leptolepis*	100	2.4	900	19.6	-	-	245	3.2
Copper shark	Carcharhinidae	*Carcharhinus*	*Carcharhinus brachyurus*	-	-	1,500	32.6	-	-	-	-
Nervous shark	Carcharhinidae	*Carcharhinus*	*Carcharhinus cautus*	-	-	100	2.2	528	5.7	127	1.7
Silky shark	Carcharhinidae	*Carcharhinus*	*Carcharhinus falciformis*	-	-	-	-	-	-	350	4.6
Dorab wolf-herring	Chiricentridae	*Chirocentrus*	*Chirocentrus dorab*	60	1.5	-	-	-	-	-	-
Goldstripe sardinella	Clupeidae	*Sardinella*	*Sardinella brachysoma*	8,035	196.0	14,152	307.7	22,600	245.7	3,800	50.0
Sardine	Clupeidae	*Sardinella*	*Sardinella longiceps*	151,640	3,698.5	157,768	3,429.7	278,512	3,027.3	256,767	3,378.5
Common dolphinfish	Coryphaenidae	*Coryphaena*	*Coryphaena hippurus*	-	-	-	-	75	0.8	30	0.4
Spotted sardine	Dorosomatidae	*Amblygaster*	*Amblygaster sirm*	201,055	4,903.8	49,690	1,080.2	193,618	2,104.5	24,580	323.4
Rainbow sardine	Dussumieriidae	*Dussumieria*	*Dussumieria acuta*	100	2.4	-	-	1,120	12.2	3,000	39.5
Commerson's anchovy	Engraulidae	*Stolephorus*	*Stolephorus commersonii*	380	9.3	205	4.5	-	-	500	6.6
Black marlin	Istiophoridae	*Istiompax*	*Istiompax indica*	-	-	-	-	300	3.3	-	-
Indo-Pacific sailfish	Istiophoridae	*Istiophorus*	*Istiophorus platypterus*	230	5.6	-	-	564	6.1	75	1.0
Blue Marlins	Istiophoridae	*Makaira*	*Makaira mazara*	20	0.5	-	-	-	-	-	-
Shortbill spearfish	Istiophoridae	*Tetrapturus*	*Tetrapturus angustirostris*	-	-	-	-	-	-	1	0.0
False trevally	Lactariidae	*Lactarius*	*Lactarius lactarius*	200	4.9	-	-	-	-	-	-
Longfin mako	Lamnidae	*Isurus*	*Isurus paucus*	100	2.4	-	-	2,274	24.7	-	-
Opah	Lampridae	*Lampris*	*Lampris guttatus*	540	13.4	-	-	-	-	-	-
Moonfish	Menidae	*Mene*	*Mene maculata*	960	23.4	1,804	39.2	-	-	-	-
Bullet tuna	Scombridae	*Auxis*	*Auxis rochei*	5,691	138.8	2,100	45.7	37,350	406.0	17,000	223.7
Frigate tuna	Scombridae	*Auxis*	*Auxis thazard*	3,250	79.3	-	-	10,550	114.7	27,470	361.4
Indian mackerel	Scombridae	*Euthynnus*	*Euthynnus affinis*	10,326	251,9	39,905	867.5	14,833	161.2	17,040	224.2
Mackerel scad	Scombridae	*Euthynnus*	*Euthynnus lineatus*	8,670	211.5	2,950	64.1	1,792	19.5	235	3.1
Skipjack tuna	Scombridae	*Katsuwonus*	*Katsuwonus pelamis*	11,694	285.2	3,560	77.4	34,655	376.7	12,096	159.2
Little tuna	Scombridae	*Rastrelliger*	*Rastrelliger kanagurta*	25,091	612.0	18,860	410.0	29,173	317.1	16,882	222.1

Short mackerel	Scombridae	*Rastrelliger*	*Rastrelliger brachysoma*	2,375	57.9	7,105	154.5	337,925	3,673.1	10,750	141.4
Striped bonito	Scombridae	*Sarda*	*Sarda orientalis*	-	-	600	13.0	1,400	15.2	-	-
Albacore	Scombridae	*Thunnus*	*Thunnus alalunga*	-	-	38	0.8	-	-	100	1.3
Big eye tuna	Scombridae	*Thunnus*	*Thunnus obesus*	-	-	1,070	23.3	-	-	187	2.5
Bigeye tuna	Scombridae	*Thunnus*	*Thunnus obesus*	-	-	-	-	40	0.4	-	-
Longtail tuna	Scombridae	*Thunnus*	*Thunnus tonggol*	5,040	122.9	14,170	308.0	5,790	62.9	39,059	513.9
Yellowfin tuna	Scombridae	*Thunnus*	*Thunnus albacares*	330	8.0	143	3.1	13,162	143.1	6,729	88.5
Great barracuda	Sphyranidae	*Sphyraena*	*Sphyraena barracuda*	-	-	-	-	-	-	155	2.0
Scalloped hammerhead	Sphyrnidae	*Sphyrna*	*Sphyrna lewini*	267	6.5	-	-	-	-	-	-
Savalai hairtail	Trichioridae	*Lepturacanthus*	*Lepturacanthus savala*	1,055	25.7	-	-	-	-	60	0.8
Swordfish	Xiphiidae	*Xiphias*	*Xiphias gladius*	90	2.2	-	-	94	1.0	25	0.3
Number of species				37		33		31		38	
Total catch				598,635		793,398		1,736,018		748,844	
Total Trip				41		46		92		76	
Catch/trip				14,601		17,248		18,870		9,853	

Table 3. Correlation matrix between species

	SDN	SFS	INS	SPS	SHT	SCD	LTN	INM	LTT	BLT	SJT	BES	GSS	FGT	YFT	RTS	TPS	SSD	MSD	SSF	RBS	BET	YSS	NSM
SDN	1.0																							
SFS	0.6	1.0																						
INS	0.6	0.9	1.0																					
SPS	0.0	-0.1	0.3	1.0																				
SHT	0.7	0.7	0.9	0.5	1.0																			
SCD	0.7	0.7	0.9	0.6	.990**	1.0																		
LTN	-0.6	0.2	0.0	-0.5	-0.4	-0.4	1.0																	
INM	0.2	0.2	0.6	0.9	0.8	0.8	-0.4	1.0																
LTT	0.4	-0.1	-0.3	-0.8	-0.4	-0.5	-0.1	-0.8	1.0															
BLT	0.9	0.6	0.8	0.4	0.9	0.9	-0.6	0.6	-0.1	1.0														
SJT	0.8	0.5	0.8	0.6	.955*	.956*	-0.6	0.8	-0.3	.960*	1.0													
BES	-0.4	0.5	0.2	-0.3	-0.1	-0.1	.957*	-0.2	-0.2	-0.4	-0.4	1.0												
GSS	0.3	0.8	0.9	0.5	0.8	0.9	0.1	0.7	-0.7	0.6	0.7	0.4	1.0											
FGT	0.7	0.0	-0.1	-0.4	0.0	0.0	-0.6	-0.4	0.8	0.4	0.2	-0.6	-0.4	1.0										
YFT	.953*	0.6	0.8	0.2	0.9	0.9	-0.6	0.5	0.1	.990**	0.9	-0.4	0.5	0.5	1.0									
RTS	0.4	0.8	0.9	0.5	0.9	0.9	-0.1	0.8	-0.6	0.7	0.8	0.2	.978*	-0.3	0.7	1.0								
TPS	-0.5	0.3	0.0	-0.5	-0.3	-0.3	.995**	-0.4	-0.1	-0.5	-0.6	.975*	0.2	-0.6	-0.5	0.0	1.0							
SSD	0.4	-0.2	-0.4	-0.6	-0.4	-0.4	-0.4	-0.7	.957*	0.0	-0.2	-0.5	-0.7	0.9	0.1	-0.6	-0.4	1.0						
MSD	0.0	-0.2	0.1	.988*	0.4	0.5	-0.5	0.9	-0.8	0.3	0.6	-0.4	0.3	-0.4	0.2	0.4	-0.6	-0.5	1.0					
SSF	0.9	0.8	0.9	0.1	0.9	0.9	-0.3	0.4	0.0	0.9	0.8	-0.1	0.7	0.4	.953*	0.8	-0.2	0.0	0.0	1.0				
RBS	0.8	0.1	0.0	-0.5	0.0	0.0	-0.5	-0.4	0.9	0.4	0.2	-0.6	-0.4	.997**	0.5	-0.3	-0.5	0.9	-0.4	0.4	1.0			
BET	-0,5	0,3	0,0	-0,6	-0,4	-0.4	.979*	-0.6	0.1	-0.6	-0.7	0.9	0.0	-0.4	-0.5	-0.1	.983*	-0.2	-0.7	-0.3	-0.4	1.0		
YSS	-0.5	0.2	-0.2	-0.7	-0.5	-0.5	.969*	-0.6	0.1	-0.7	-0.7	0.9	-0.1	-0.4	-0.6	-0.3	.964*	-0.1	-0.7	-0.3	-0.3	.993**	1.0	
NSM	-0.7	0.0	-0.2	-0.6	-0.6	-0.6	.975*	-0.6	0.0	-0.8	-0.8	0.9	-0.1	-0.5	-0.7	-0.3	.956*	-0.2	-0.6	-0.5	-0.5	.969*	.985*	1.0

Note: *: correlation is significant at the 0.05 level (2-tailed); **: correlation is significant at the 0.01 level (2-tailed); SDN: sardine; LTN: little tuna; SSD: shrimp scad' MSD: mackerel scad; SFS: shortfin scad; INM: Indian mackerel; FGT: frigate tuna; SSF: streaked seerfish; INS: Indian scad; LTT: longtail scad; YFT: yellowfin tuna; RBS: rainbow sardine; SPS: spotted sardine; BLT: bullet tuna; RTS: redtail scad; BET: bigeye tuna; SHT: short mackerel; SJT: skipjack tuna; TPS: torpedo tuna; YSS: yellowstripe scad; SCD: scad; BES: bigeye scad; GSS: goldstripe sardinella; NSM: narrow-barred Spanish mackerel

Based on the catch species between seasons, the result of the cluster analysis illustrated that the catch species in the study area can be classified into three separate clusters (Figure 4). The first cluster included short mackerel and spotted sardines. This group was characterized by equal catches during the east and second transition monsoon seasons. The second cluster consisted of sardine, Indian scad, and shortfin tuna, the best three catch species in FMA 713. This cluster was marked by the similarity of catch species in the three best species. The third cluster was populated by other catch species, which contributed approximately 30% of catch species. This cluster was characterized by relatively small catch species with no pattern.

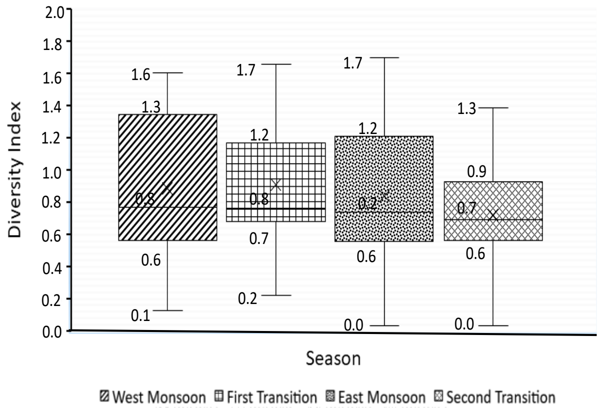

Figure 3. Seasonal catch species diversity

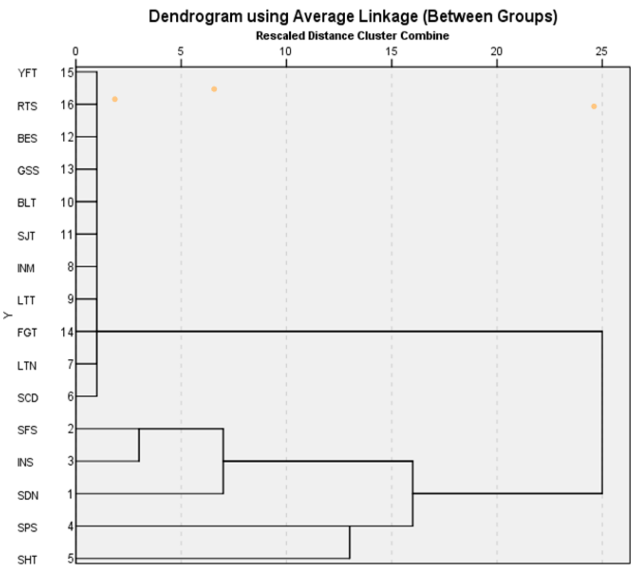

Figure 4. Catch species similarity between seasons. Notes: SDN: sardine; LTN: little tuna; SHT: short mackerel; SJT: skipjack tuna; SFS: shortfin scad; INM: Indian mackerel; FGT: frigate tuna; SCD: scad; INS: Indian scad: LTT: longtail tuna; YFT:yellowfin tuna; BES: bigeye tuna; SPS:spotted sardine; BLT: bullet tuna; RTS: redtail scad; GSS: goldstripe sardinella

Fishing ground dynamics

The fishermen's decisions concerning the allocation of fishing gear for both the fishing grounds and fishing season in the waters of FMA 713 were observed to be dynamic (Figure 5). The allocation of fishing gear in a certain fishing ground changed seasonally following the season. During the west monsoon season, which coincides with the rainy season, the fishing gear allocation was relatively small; it scattered along the coast of Kalimantan until the Flores Sea. After the west monsoon season finished, the allocation of fishing gear was increased, and the fishermen moved to the coast of Kalimantan. During the east monsoon season (June, July, and August), when the rain is less, the allocation of fishing gear significantly increased, concentrated in the coastal waters of Kalimantan and scattered across several areas. After encountering the peak season for the allocation of fishing gear, the fish catch declined, the number of fishing gear decreased, and the fishing gear belonging to the fishing grounds was scattered in the waters of the surrounding area.

Discussion

The Fisheries Management Area (FMA 713) of Indonesian waters, which includes the Makassar Strait, Bone Bay, Flores Sea, and Bali Sea, is thought to contain a potential resource of 162,506 tons of large pelagic fish and 248,302 tons of small pelagic fish resources (MMAF RI 2022). The waters of the Makassar Strait are recognized as one of the most productive areas in Indonesian waters. Fishermen capture the fish throughout the year using variate fishing gear, for instance, purse seines, drift gill nets, hand lines and troll lines. The study examined catch species based on the e-logbook fishing data to optimize fish stock utilization in the waters. The analysis shows that the composition and productivity per trip of catch species in FMA 713 varied among seasons. The species composition values, which are higher in the west monsoon season than the other seasons, indicate that species composition is more diverse in the west monsoon season, which coincides with the rainy season. Conversely, catch species productivity was highest during the east monsoon season, during the dry season in June, July, and August. These phenomena may be influenced by the seasonal dynamics concerning the oceanography factor and/or fishermen's behavior in allocating their gears seasonally.

A recent study conducted in Makassar Strait, part of FMA 713, stated that the oceanographic parameters in this area, governed by the monsoon season, fluctuate seasonally. The surface ocean current flows northward during the Northwest Monsoon (NWM) season, whereas during the Southeast Monsoon (SEM) season, the surface current flows southward. Those transport volumes are dominated by thermocline depth, which peaks during the SEM season ss (Setiawan and Abdullah 2010; Purwanto et al. 2021). Using satellite data (Terra/MODIS), Zainuddin et al. (2015) clarified the seasonal dynamic of the sea surface temperature (SST) and chlorophyll-a (Chl-a) in their study area; it was revealed that the SST and Chl-a ranges were correlated with fish abundance (Safruddin et al. 2019).

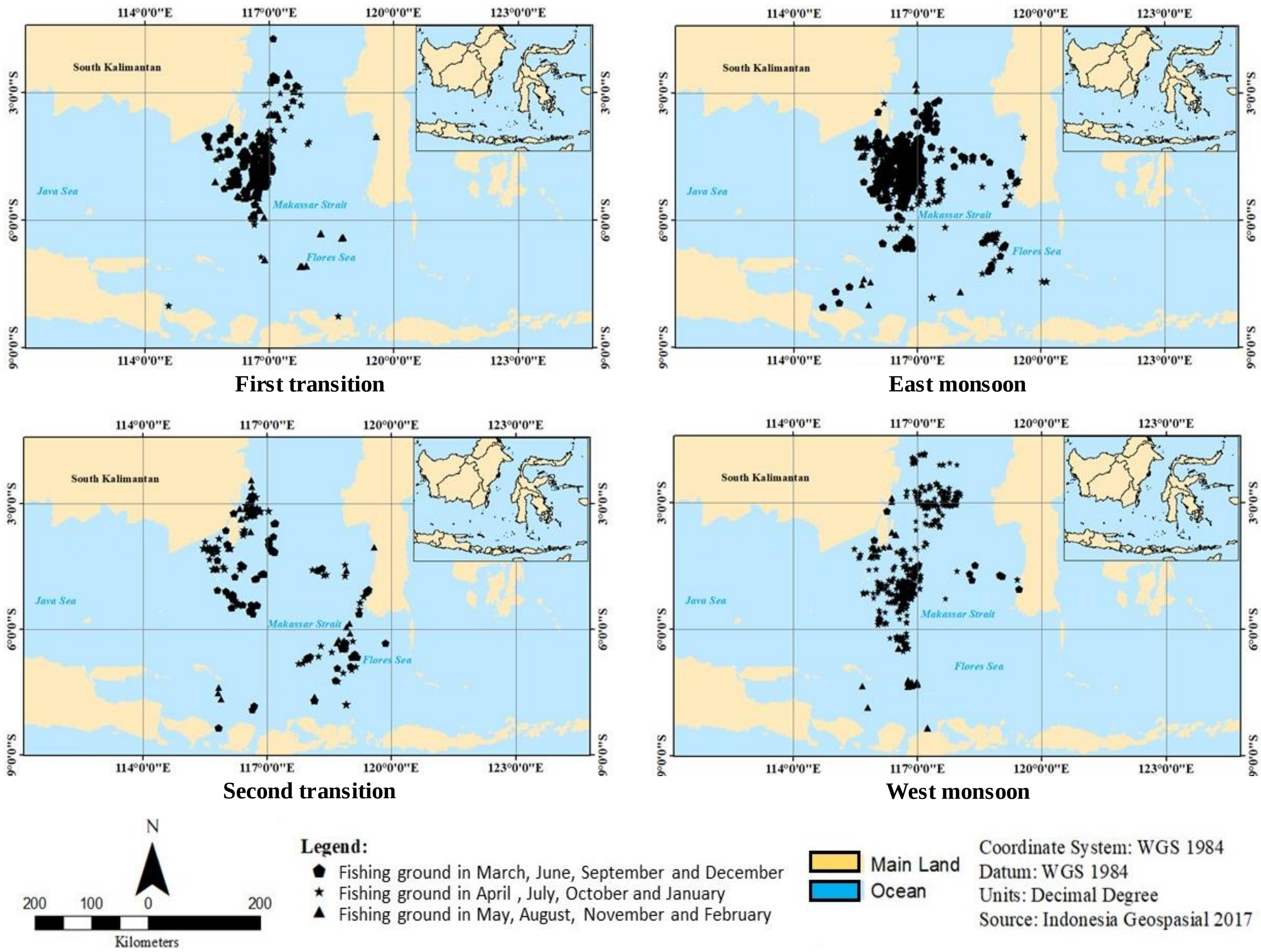

Figure 5. The dynamic of fishing grounds between season

During the west monsoon season in January-February, the SST reached 29-30°C in the study area when the concentration of Chl-a is relatively higher and tends to spread extensively with concentration levels exceeding 0.4 mg/m^3. The SST began to increase in March and reached 29-30°C. From February to March, the waters have the lowest relative Chl-a concentrations of roughly 0.16 and 0.18 mg/m^3. From April to May, the SST occurred at approximately 30-31°C, and the Chl-a density improved again. In June, when the SST begins to decrease, and the concentration increases, fish productivity, indicated by catch per fishing effort, increases.

As the composition of the catch species changed seasonally, it significantly influenced the community diversity of the population. Several factors, such as the number of food supplies, competition between species, disturbances and environmental conditions, also influenced community diversity. Fish diversity may decline in situations associated with the pressure related to fishing, resulting in a reduced diversity value (Hossain et al. 2012). The results of this study revealed that the Shannon Diversity Index of catch species varied from 0.5 to 0.7, indicating that the catch species is only dominated by a few species. Although several fishing gear construction and operation methods could capture several non-target species, the fishermen's preference to capture target species with a higher landing volume and longer fishing seasons caused their Shannon index values to be low. In addition, the smallest monthly variation in the value of the Shannon Diversity Index indicated that the fish composition does not change seasonally.

Two species or more are associated with each other and interact because of their dependency on one another or because, similarly, they are affected by a different factor. Depending on their relationship and response to the external factor, they may be positively or negatively associated. This study's result proved that most species' correlation was insignificant ($p>0.05$). This implies that most species do not interact significantly; the caught species in the study area generally do not depend on each other. Although the correlation between catch species is not statistically significant, the analysis revealed that most catch species have a positive correlation. Furthermore, the seasonally can be separated into three specific groups. Ts and one group were characterized by non-dominant target species. This result signified that the catch species was inconsistent but dominated only a few species targets.

Due to the characteristics of fish, fishermen allocate their fishing gear seasonally to maximize their catch. The migration of fishing grounds is influenced by the changing catch composition in each fishing ground. During the west monsoon season, the catch is dominated by sardine and spotted sardine, and the fishing grounds are concentrated on the Kalimantan to Flores Sea coast. Following a challenging transition period, fishing gear allocation shifted to the coastal waters of Kalimantan. During the east monsoon season, there was a notable increase in fishing gear allocation, which was concentrated on the Kalimantan coast. Prior to the second transition season, fishing gear decreased and became scattered throughout FMA 713.

This study's results demonstrate the dynamic nature of fishing activities. Fishermen move from one fishing ground to another in order to catch fish. However, excessive fishing efforts and overcapacity operations often lead to the capture of more fish than necessary to offset costs. To address this issue, stricter catch restrictions should be implemented using a quota system. The catch of fish per fishing vessel should be restricted to the quota established by the government to prevent overfishing.

In conclusion, the implication for management is that in situations where data is limited, fisheries' logbook data can be extremely useful for monitoring fish resources. This research aims to utilize logbook data for fish resource management through simple data analysis. The primary advantage of using logbooks is the ability to monitor fisheries at a relatively low cost. The main obstacles to completing data collection using the logbook method are limited funds and enumerator personnel. To address this issue, it is essential to provide training to enumerators and increase the state budget. Involving NGOs and universities could also be an alternative to improve the quality of fish data collection.

Our results suggest that season did not have a significant effect on the indices of the fish community structure, both the composition and diversity index. This is for the reason that only four species out of 57 catch species dominated the catch. Conversely, catch species productivity was determined to be different between seasons and reached its highest during the east monsoon season. Given that the catch species were dominated by a few species, catch similarity was characterized by the main catch species. In light of rapid fish consumption and climate change, understanding the underlying ecological processes will assist us in better protection and conservation action plans for fisheries. The government should provide baseline information to understand ecological roles and develop management to plan fish conservation in the future.

This study's results also demonstrate the dynamic nature of fishing activities. Fishermen move from one fishing ground to another in order to catch fish. However, excessive fishing efforts and overcapacity operations often lead to the capture of more fish than necessary to offset costs. To address this issue, stricter catch restrictions should be implemented using a quota system. The catch of fish per fishing vessel should be restricted to the quota established by the government to prevent overfishing.

Fish community composition could be applied as an alternative management method by proposing the following conservation measures in the area: (i) conservation of economically important fish species, (ii) mapping of potential fishing grounds for potential target species, (iii) scheduling the fishing season activity, (iv) habitat restoration for endangered and important species, and (v) restrictions on fishing gear that comprises a small mesh size such as purse seine.

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