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Research Article

Differences in fish assemblage between fisheries-dependent and independent data in Ghana coastal waters

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Abstract

This study aimed to identify the similarities in the catches of both experimental and commercial fishing efforts along the coast of Greater Accra, Ghana using trawls. Data for fisheries-independent (experimental, INFD) and fisheries-dependent (commercial, FID) catches were sourced monthly from June 2018 to May 2019. The obtained data was analyzed for non-metric multidimensional scaling (nMDS), diversity indices, similarity percentage, and cluster analysis using PRIMER 6 and PERMANOVA+ software. Sixty-seven fish species were obtained from both experimental and commercial catches. Species richness and Shannon-Weaver index (H') showed no significant difference between INFD and FID catches. SIMPER analysis revealed a high dissimilarity percentage (64.95%) between commercial and experimental catches, with *Selene dorsalis*, *Brachydeuterus auritus*, and *Galeoides decadactylus* contributing the most. The nMDS and cluster analyses showed two distinct groups which indicated that not all grounds are used as fishing grounds by fishermen. Based on the findings, certain areas within the experimental fishing sites should be designated as marine protected areas to safeguard the populations of marine fisheries resources in Ghana.

Introduction

Fishes are essential for the survival of fishing households, whose economy and welfare rely on the viability of fisheries resources. Mapping fish habitats is crucial for understanding marine resource abundance and distribution (Pennino *et al.*, 2014). However, there is limited quantitative scientific information on fishes, and data may not always be directly comparable due to habitat alterations between sampling times.

Spatial management of marine resources and accurate tracking of geographical and temporal fluctuations of commercially important fish species is crucial for effective management actions or policies for marine fisheries resources sustainability (Pennino *et al.*, 2016). To enhance the effective management of marine resources, fisheries-dependent (FID) and independent (INFD) data surveys are essential. INFD surveys provide direct observations for resource information, independent of the commercial fishery (NRC, 2000). These surveys present unrepresentative sampling, limited data collection, and rely on expensive at-sea research for reliable data (Pennino *et al.*, 2016). FID data is more comprehensive and reliable, but often has limited coverage, leading to biased and imprecise estimates (Hilborn and Walters, 2013). These surveys are efficient and low-cost strategies for effective fishery management. They provide valuable data at specific locations, including landed catch, effort expended, fishing gear type, and time spent. These surveys are crucial for a wide range of target species, gear types, landing sites, and distribution patterns (Lunn and Dearden, 2006). However, they lack specific details, have management constraints, and often involve intentional misreporting of catches (Pennino *et al.*, 2016).

Despite these challenges, FID surveys enhance the understanding of species distribution, particularly for ecologically significant endangered species in coastal countries like Ghana. The Ghanaian marine environment is rich in diverse and valuable fish species including anchovies, sardines, seabreams, sailfishes, and sharks (Akyempong *et al.*, 2013; Asiedu *et al.*, 2018). The fishing industry in Ghana comprises three sectors, namely; industrial, semi-industrial, and artisanal (Lazar *et al.*, 2017; Kassah and Asare, 2022). It employs 10% of the population and generates over $1 billion in annual revenue (Tall and Failler, 2012; Aikins, 2018; Asiedu *et al*., 2018). However, the industry faces challenges such as marine debris and illegal, unreported, and unregulated (IUU) fishing, which has resulted in reduced fish catches (Aplaku *et al.*, 2018). Despite this, scientific studies have primarily focused on commercial catches, with few studies (e.g. Koranteng, 1998) focusing on experimental catches as resources for managing marine fish stocks in Ghana. This study aims to compare experimental and commercial trawl catches to improve fish stock management in Ghana. It evaluates differences in fish species composition and similarities between experimental and commercial catches. The findings will help improve the conservation and management of fisheries resources in Ghana.

Materials and methods

Study area

For this study, INFD research concentrated on examining data from three distinct offshore stations with coordinates i) 05°40'32.91" N, 000°09'57.94" E; ii) 05°35'32.78" N, 000°04'12.38" E; and iii) 05°34'54.59" N, 000°02'31.64" W off the coast of Greater Accra, Ghana. For FID data, Tema Fishing Harbor was selected as the sampling location (Fig. 1).

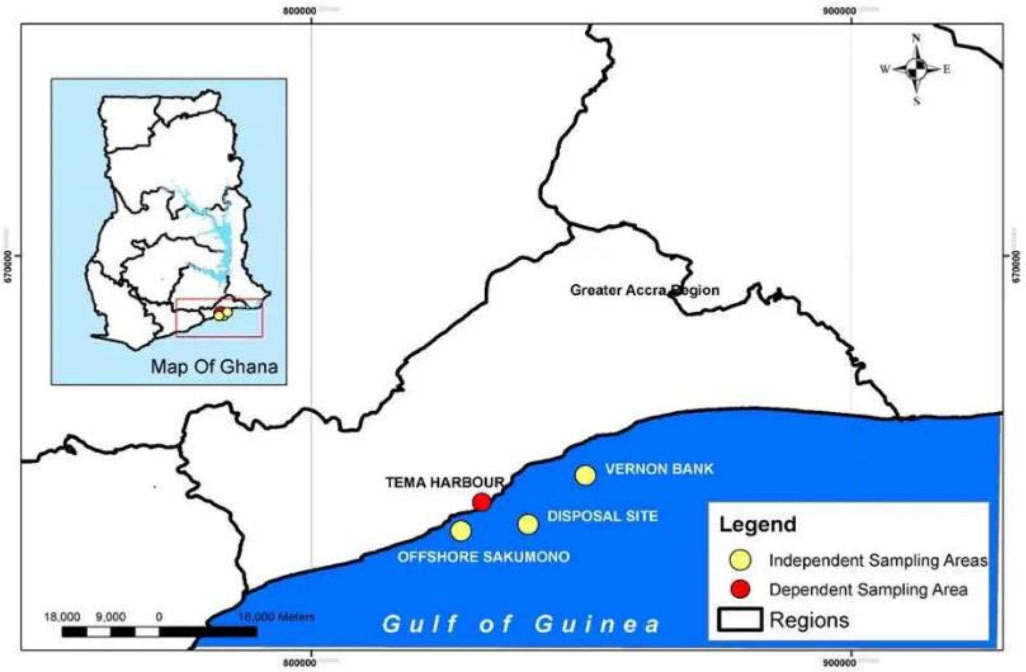

Figure 1: Map showing the sampling locations.

Data collection

Data for both experimental and commercial catches were sourced monthly from June 2018 to May 2019. For INFD data, sampling was conducted at the three offshore locations using a bottom trawl multifilament net of cod-end mesh size of 1 inch (diagonal stretch). This net was deployed at the various sampling locations of 21-35 m depth, using an inshore fishing vessel. The average trawling duration for the study was 45 min at an average vessel speed of 3.2 knots with each sampling area trawled once. The fish samples were sorted and identified to the species level. FID data were extracted monthly from the catches of inshore fishing vessels at the Tema Fishing Harbour. Fish samples were determined using the Schneider (1990) identification keys.

Univariate analysis

Univariate indices such as the species richness index (d), species evenness (J’), and Shannon-Weaver (H’) index provide a rapid and easy depiction of global patterns. The number of various species represented in an ecological community is referred to as species richness. Margalef index was to determine the d with the following expression (Margalef, 1958):

$d=(S-1)/\log N$

Where, s represents the number of species and N represents the total number of individuals.

According to the Shannon-Weaver index, the variety of a community is proportional to the amount of information in a code or message. It is calculated in the following way (Shannon and Weaver, 1963):

$H' = -\sum p_i \ln p_i$

To calculate the proportion of individuals in a certain species, we use the formula $p_i = n_i/N$. In this formula, p_i represents the proportion, n_i is the number of individuals in the species of interest, and N is the total number of individuals in the community.

Species evenness relates to how numerous each species is in a given environment. The evenness of the fish species (J') was calculated using Pielou's evenness index (Pielou, 1966) based on the expression:

$J' = H'/H'_{max}$

Where, H' is the Shannon-Weaver diversity index number and H'_{max} is the greatest conceivable value of H' (assuming all species were equally likely).

These indices were calculated using the PRIMER package (Clarke and Gorley, 2006). To compare diversity indices between fishing activities, an independent sample t-test was applied at a 95% confidence interval.

Multivariate statistics analysis

The square root was used to transform the fish abundance data. To determine the similarities in fish species composition among fishing types, and months, non-metric multidimensional scaling (nMDS) based on the Bray-Curtis similarity measure was used (Clarke and Warwick, 2001). The fishing activity and monthly variations in community patterns were ordinated using the canonical analysis of principal coordinates (CAP) model (Anderson *et al.*, 2008). Similarity percentage (SIMPER) analysis was used to determine changes in the species composition of the two fishing activities (Clarke, 1993). PERMANOVA tests were used to determine the impacts of the two fishing activities on fish composition with 9999 permutations and Monte Carlo correction (Anderson *et al.*, 2008). Scarce species contribute to increased noise and affect the overall variation, but they do not alter the interpretation. Therefore, in the present study, the species that constituted a small percentage less than 1% of the total fish assemblage were not added to the analyses. These analyses were performed using PRIMER version 6 and PERMANOVA+ (Clark and Warwick, 2001; Clarke and Gorley, 2006; Anderson *et al.*, 2008).

Results

Species abundance and composition

In this study, a total of eighty-eight fishes belonging to fifty-one families were identified. Sixty-seven fishes were recorded from the FID catches belonging to forty-one families. The dominant species were *Galeoides decadactylus, Selene dorsalis, Brachydeuterus auritus,* and *Chloroscombrus chrysurus*. *G. decadactylus, Cynoglossus senegalensis, B. auritus, Pseudotolithus senegalensis* and *C. chrysurus* were the only species recorded in all the sampling periods. *S. dorsalis, B. auritus, G. decadactylus,* and *Pteroscion peli* were the dominant species obtained from the INFD catches (Fig. 2). In all, sixty-seven fishes were recorded during the INFD sampling period belonging to forty-three families (Table 1). *G. decadactylus*, *C. senegalensis*, *B. auritus*, *P. senegalensis*, and *C. chrysurus* were the only species recorded in all the sampling periods.

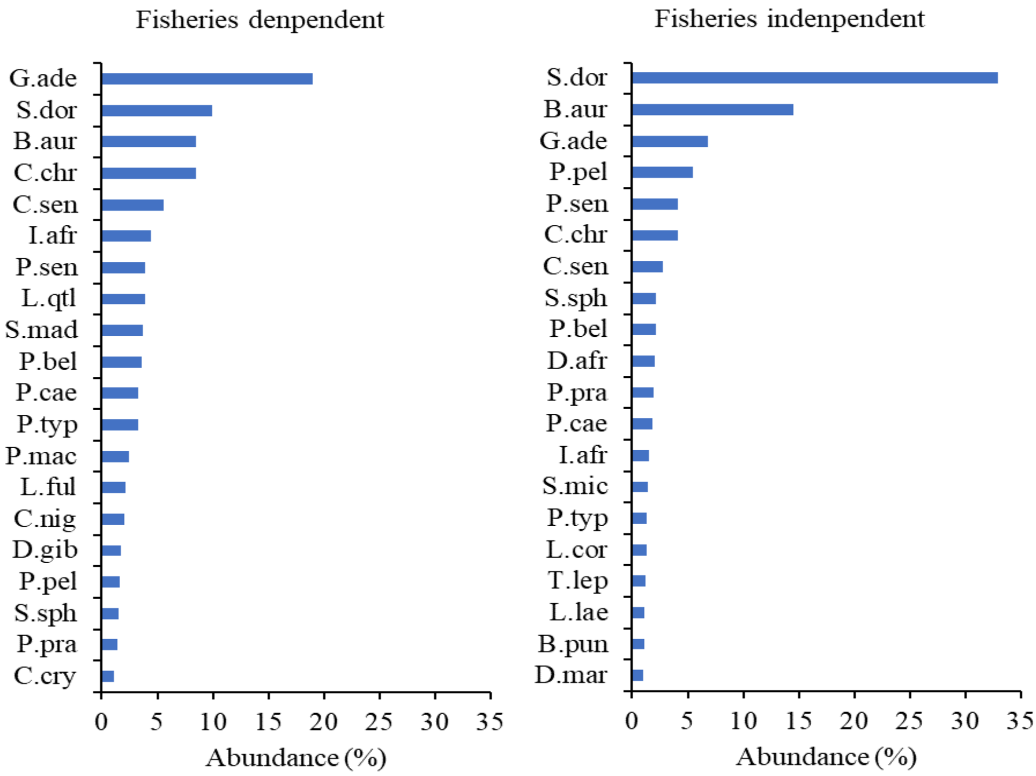

Figure 2: Abundance of fish species from fisheries dependent and independent samples (Figure includes fish species with more than 1% of total abundance) in Ghana coastal waters. See Table 1 for a key to species name abbreviations.

Table 1: List of fish species recorded by two fishing activities, including occurrence (Oc %) and abundance (mean and SD) in Ghana.

Family	Species name, and abbreviation		Fisheries dependent			Fisheries independent		
			Oc%	Mean	SD	Oc%	Mean	SD
Acanthuridae	*Acanthurus monroviae*	A.mon	8.3	0.67	2.31	41.7	1.92	2.81
Balistidae	*Alectis alexandrinus*	A.alx	0.0	0.00	0.00	50.0	1.42	2.07
Batrachoididae	*Balistes punctatus*	B.pun	8.3	0.08	0.29	91.7	6.33	6.04
Bothidae	*Bodianus speciosus*	B.spe	25.0	0.50	1.17	8.3	0.17	0.58
Bramidae	*Brachydeuterus auritus*	B.aur	100	36.92	46.72	91.7	84.33	128.17
Carangidae	*Canthigaster supramacula*	C.sup	0.0	0.00	0.00	8.3	0.42	1.44
	Caranx crysos	C.cry	58.3	4.92	7.51	8.3	1.67	5.77
	Chaetodon robustus	C. rob	16.7	1.08	3.45	41.7	1.17	1.47
	Dasyatis margarita	D.mar	8.3	0.08	0.29	75.0	5.67	7.45
	Decapterus punctatus	D. pun	41.7	1.50	3.12	16.7	5.33	17.85
	Scorpaena histrio	S.his	0.0	0.00	0.00	66.7	2.67	4.14
	Torpedo torpedo	T.tor	0.0	0.00	0.00	16.7	0.33	0.78
Chaetodontidae	*Chaetodipterus lippei*	C.lip	8.3	0.17	0.58	25.0	0.75	1.76
Clupeidae	*Holocentrus hastatus*	H.has	8.3	0.25	0.87	0.0	0.00	0.00
	Sarda sarda	S.sar	16.7	0.33	0.89	0.0	0.00	0.00
	Sardinella aurita	S.aur	25.0	0.50	1.17	0.0	0.00	0.00
Cyclopsettidae	*Stephanolepis hispidus*	S.his	0.0	0.00	0.00	66.7	3.33	6.87
Cynoglossidae	*Coris julis*	C.jul	16.7	0.17	0.39	25.0	0.42	0.90
Dactylopteridae	*Cynoponticus ferox*	C.fer	0.0	0.00	0.00	8.3	0.33	1.15

Table 1 (continued):

Family	Species name, and abbreviation		Fisheries dependent			Fisheries independent		
			Oc%	Mean	SD	Oc%	Mean	SD
Dasyatidae	*Dactylopterus volitans*	D.vol	41.7	3.83	8.62	33.3	1.08	2.57
Diodontidae	*Dicologoglossa hexophthalma*	D.hex	0.0	0.00	0.00	8.3	0.25	0.87
Drepanidae	*Diodon hystrix*	D.hys	0.0	0.00	0.00	25.0	0.58	1.16
Elopidae	*Drepane africana*	D.afr	25.0	0.58	1.24	83.3	11.67	13.55
Ephippidae	*Cephalopholis nigri*	C.nig	50.0	8.75	20.60	8.3	0.08	0.29
Exocoetidae	*Fistularia tabacaria*	F.tab	8.3	0.08	0.29	16.7	0.25	0.62
Fistulariidae	*Epinephelus aeneus*	E.aen	0.0	0.00	0.00	25.0	0.25	0.45
	Fistularia petimba	F.pet	16.7	0.25	0.62	16.7	0.67	1.78
Gerreidae	*Galeoides decadactylus*	G.ade	100	82.50	198.14	91.7	39.58	35.37
Grammistidae	*Rhinobatus albomaculatus*	R.alb	0.0	0.00	0.00	66.7	1.67	2.31
Gymnuridae	*Gerres melanopterus*	G.mel	83.3	2.92	3.63	8.3	0.08	0.29
Haemulidae	*Bothus podas africanus*	B.pod	0.0	0.00	0.00	25.0	0.42	0.90
	Pagrus caeruleostictus	P.cae	91.7	14.42	8.90	91.7	10.33	23.36
	Pentanemus quinquarius	P.qui	25.0	0.92	2.57	25.0	0.33	0.65
	Pomadasys incus	P.inc	8.3	1.17	4.04	0.0	0.00	0.00
Hemirampheide	*Gymnura micrura*	G.mic	0.0	0.00	0.00	8.3	0.17	0.58
Holocentridae	*Hemirampehus basiliensis*	H.bas	16.7	0.25	0.62	0.0	0.00	0.00
Labridae	*Batrachoides liberiensis*	B.lib	0.0	0.00	0.00	25.0	0.67	1.30
	Chromis lineatus	C.lin	0.0	0.00	0.00	33.3	2.42	6.01
	Umbrina canariensis	U.can	25.0	0.83	1.80	25.0	2.08	6.60
Lethrinidae	*Lagocephalus laevigatus*	L.lae	8.3	0.08	0.29	75.0	6.42	9.08
Lutjanidae	*Lethrinus atlanticus*	L.qtl	83.3	17.00	14.14	66.7	4.25	7.99
	Lutjanus agennes	L.age	16.7	0.75	2.05	0.0	0.00	0.00
	Lutjanus fulgens	L.ful	58.3	9.42	12.86	25.0	2.58	7.44
Monacanthidae	*Sphyraena sphyraena*	S.sph	66.7	6.42	12.98	41.7	12.67	27.13
Mugilidae	*Lutjanus goreensis*	L.gor	25.0	3.08	9.16	8.3	0.17	0.58
Mullidae	*Pseudotolithus typus*	P.typ	75.0	14.17	38.90	41.7	7.83	11.99
Muraenesocidae	*Cynoglossus senegalensis*	C.sen	100	24.00	38.94	100.0	15.83	10.99
Ophichthidae	*Mugil cephalus*	M.cep	8.3	0.08	0.29	0.0	0.00	0.00
Ostraciidae	*Ilisha africana*	I.afr	50.0	19.17	27.47	50.0	8.83	14.34
Polynemidae	*Fodiator acutus*	F.acu	8.3	0.50	1.73	0.0	0.00	0.00
	Pegusa cadenati	P.cad	0.0	0.00	0.00	16.7	1.25	3.11
Pomacentridae	*Chloroscombrus chrysurus*	C.chr	100	36.75	60.35	66.7	23.67	57.93
	Chromis limbata	C.lim	16.7	1.75	4.52	0.0	0.00	0.00
Priacanthide	*Pontinus accraensis*	P.acc	8.3	0.25	0.87	0.0	0.00	0.00
Rajidae	*Pteroscion peli*	P.pel	91.7	7.08	9.07	75.0	31.58	42.29
Rhinobatidae	*Raja miraletus*	R.mir	16.7	0.75	2.30	16.7	0.25	0.62
Rhinobatidae	*Xyrichtys novacula*	X.nov	0.0	0.00	0.00	8.3	0.08	0.29
Sargocentron hastatus	*Sardinella maderensis*	S.mad	58.3	16.17	29.04	8.3	0.25	0.87
Scaridae	*Sargocentron hastatus*	S.has	16.7	0.50	1.45	0.0	0.00	0.00
Sciaenidae	*Pricanthus arenatus*	P.are	25.0	0.50	0.90	0.0	0.00	0.00
	Pseudotolithus brachygnathus	P.bra	16.7	0.17	0.39	8.3	0.17	0.58
	Pseudotolithus senegalensis	P.sen	100	17.08	33.08	75.0	23.92	28.50
	Pseudupeneus prayensis	P.pra	83.3	6.00	3.93	91.7	11.17	9.16
	Trichiurus lepturus	T.lep	16.7	0.50	1.45	33.3	7.25	13.26
Scombridae	*Myrichthys pardalis*	M.par	0.0	0.00	0.00	8.3	0.08	0.29
	Rypticus saponaceus	R.sap	8.3	0.33	1.15	75.0	3.58	6.01
	Scarus hoefleri	S.hoe	8.3	0.08	0.29	41.7	1.83	3.69
Scorpaenidae	*Pomadasys jubelini*	P.jub	33.3	4.17	9.28	0.0	0.00	0.00
Scorpaenidae	*Scomberomorus tritor*	S.tri	8.3	0.08	0.29	0.0	0.00	0.00
Serranidae	*Caranx hippos*	C.hip	33.3	0.83	1.40	0.0	0.00	0.00
	Elops lacerta	E.lac	8.3	0.08	0.29	0.0	0.00	0.00
	Ephippion guttifer	E.gut	16.7	0.25	0.62	25.0	0.42	0.90
Soleidae	*Dentex gibbosus*	D.gib	100	7.33	5.16	33.3	1.25	3.41
	Parakuhlia macrophthalmus	P.mac	58.3	10.50	20.08	0.0	0.00	0.00
	Decapterus rhonchus	D.rho	25.0	0.33	0.65	16.7	0.17	0.39
	Dentex canariensis	D.can	0.0	0.00	0.00	33.3	1.58	3.06

Table 1 (continued):

Family	Species name, and abbreviation		Fisheries dependent			Fisheries independent		
			Oc%	Mean	SD	Oc%	Mean	SD
	Dentex congoensis	D.con	8.3	0.67	2.31	0.0	0.00	0.00
	Orcynopsis unicolor	O.uni	0.0	0.00	0.00	16.7	0.17	0.39
	Pagellus bellottii	P.bel	83.3	15.83	17.04	50.0	12.58	20.87
Sphyraenidae	*Sphoeroides marmoratus*	S.mar	0.0	0.00	0.00	41.7	1.92	3.00
Synodontidae	*Syacium micrurum*	S.mic	50.0	3.08	4.94	66.7	8.42	11.67
Tetraodontidae	*Brama brama*	B.bra	8.3	0.08	0.29	0.0	0.00	0.00
	Ephinepelus aenues	E.aen	16.7	0.33	0.89	0.0	0.00	0.00
	Lactoria cornuta	L.cor	0.0	0.00	0.00	91.7	7.33	7.28
	Selene dorsalis	S.dor	33.3	43.33	147.91	83.3	191.50	327.74
Torpedinidae	*Synodus synodus*	S.syn	25.0	0.50	1.17	33.3	1.25	2.45
Trichuridae	*Trachinotus ovatus*	T.ova	8.3	0.83	2.89	0.0	0.00	0.00
Rhinobatidae	*Zanobatus maculatus*	Z.mac	0.0	0.00	0.00	58.3	1.75	2.45

The red, yellow, and green color scales show the gradient from the minimum, medium, and maximum values of Oc, respectively.

Univariate analysis of diversity indices

The index of d for FID ranged from 1.87 in April 2019 to 6.60 in October 2018, with an average (SD) of 4.01±1.23. For INFD data, d ranged from 2.93 in November 2018 to 5.49 in September 2019, with an average of 4.39±0.72. The J' index for FID ranged from 0.52 in August 2018 to 0.85 in June 2018. For INFD data, it ranged from 0.41 in February 2019 to 0.85 in September 2018. The average of J' for FID and INFD were 0.74±0.11 and 0.71±0.14, respectively. The H' for FID ranged from 1.61 in August 2018 to 2.96 in October 2018. For INFD, the index ranged from 1.37 in February 2018 to 2.91 in July (Fig. 3). The average of H' for FID and INFD were 2.35±0.45 and 2.33±0.49, respectively. No significant differences were found between FID and INFD for three diversity indices ($p>0.05$).

Multivariate Statistics Analysis

The nMDS ordination based on the fish community showed a clear separation between the fishing activities. The first axis follows the period's gradient from INFD to FID which contributed to the biogeographic variation. In addition, the result of clustering of the fishing activities and months for similarities showed two main groups of INFD and FID with five subgroups. Group FID is divided into two subgroups (a=FID1-FID3, FID5-FID6, FID9-12; b=FID4 and FID7-FID8). The INFD group was divided into four subgroups (c=INFD9 and INFD6-INFD7; d=INFD2; e=INFD11 and INFD12; f=INFD1, INFD3-INFD5, INFD8, and INFD10; Fig. 4).

Among eight taxa in the bubble plots of MDS-ordination of the most occurrence fish species, five taxa occurrences tended to be more abundant in the INFD fishing activity (Fig. 5). Based on 24 points of data (two fisheries activities and twelve months), CAP demonstrated a clear temporal pattern of fish assembly. The first axis of CAP divided the clouds of samples in INFD (on the left) from those in FID (on the right). In contrast, the second axis distinguished the clouds of samples in months. A vector coverage of the predominant species with the CAP axis displayed that the vector of two species (G. mel *Gerres melanopterus* and D.gib *Dentex gibbosus*) pointed toward the sample cloud in the FID, B. aur *Brachydeuterus auritus* toward INFD in August, S. his *Scorpaena* *histrio* and A. alx *Alectis alexandrinus* toward INFD in April, May, and October, S. his *S. histrio*, B.pun *Balistes punctatus* and L.cor *A. notacanthus* toward to February, and T. lep *Trichiurus lepturus* and P. pel *Pteroscion peli* toward to June, July, and November (Fig. 6). PERMANOVAs and tests of dispersion were conducted between the FID and INFD. The one-way PERMANOVA test showed that species composition was significantly affected by fishing activities ($p<0.001$) (Table 2).

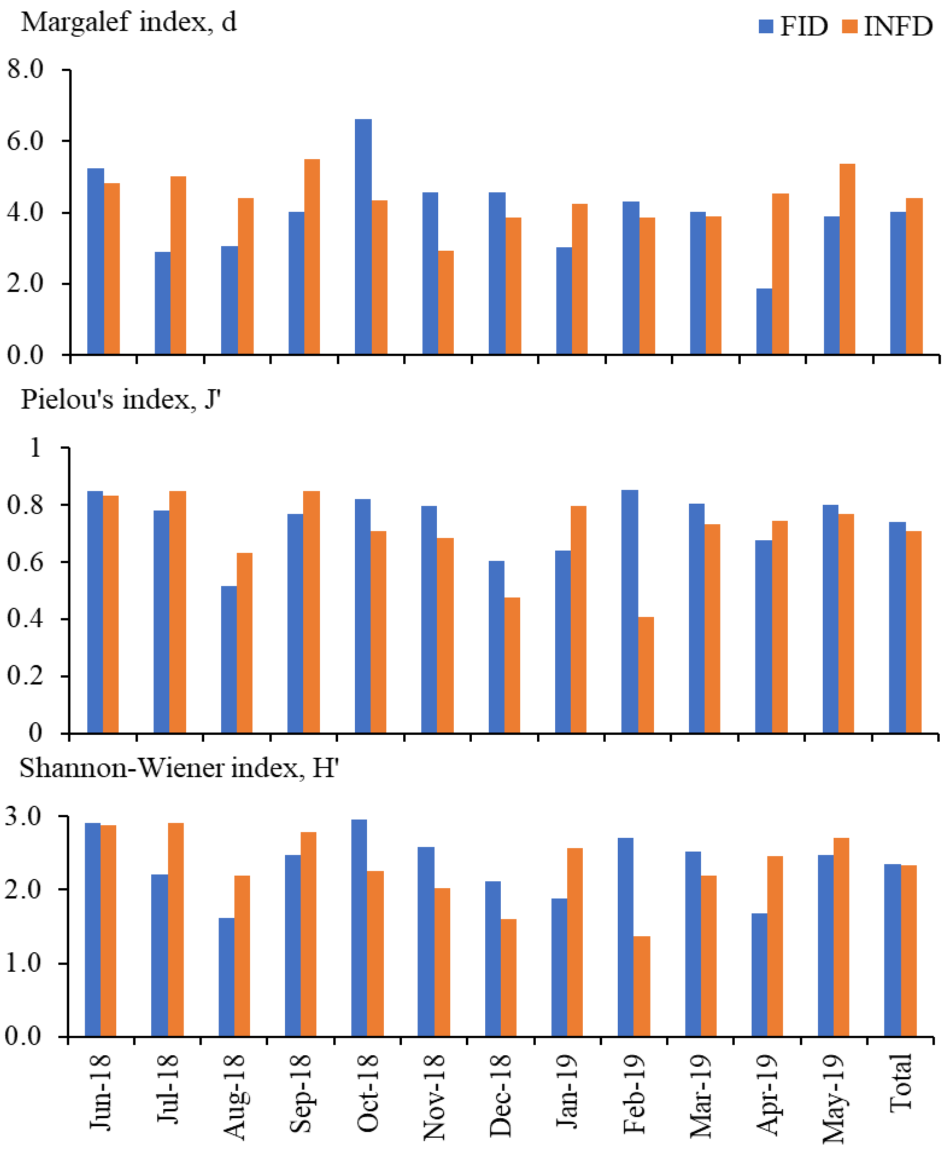

Figure 3: Monthly estimated diversity indices of fish species from fisheries dependent (FID) and independent (INFD) data in Ghana coastal waters.

The SIMPER analysis identified similarities and differences between two data sources. The similarity within the FID data was 46.52%, with *G. decadactylus* being the dominant species, which contributed about 11.0% of the average Bray-Curtis similarity and also achieved the highest Sim/SD of the group at 1.64.

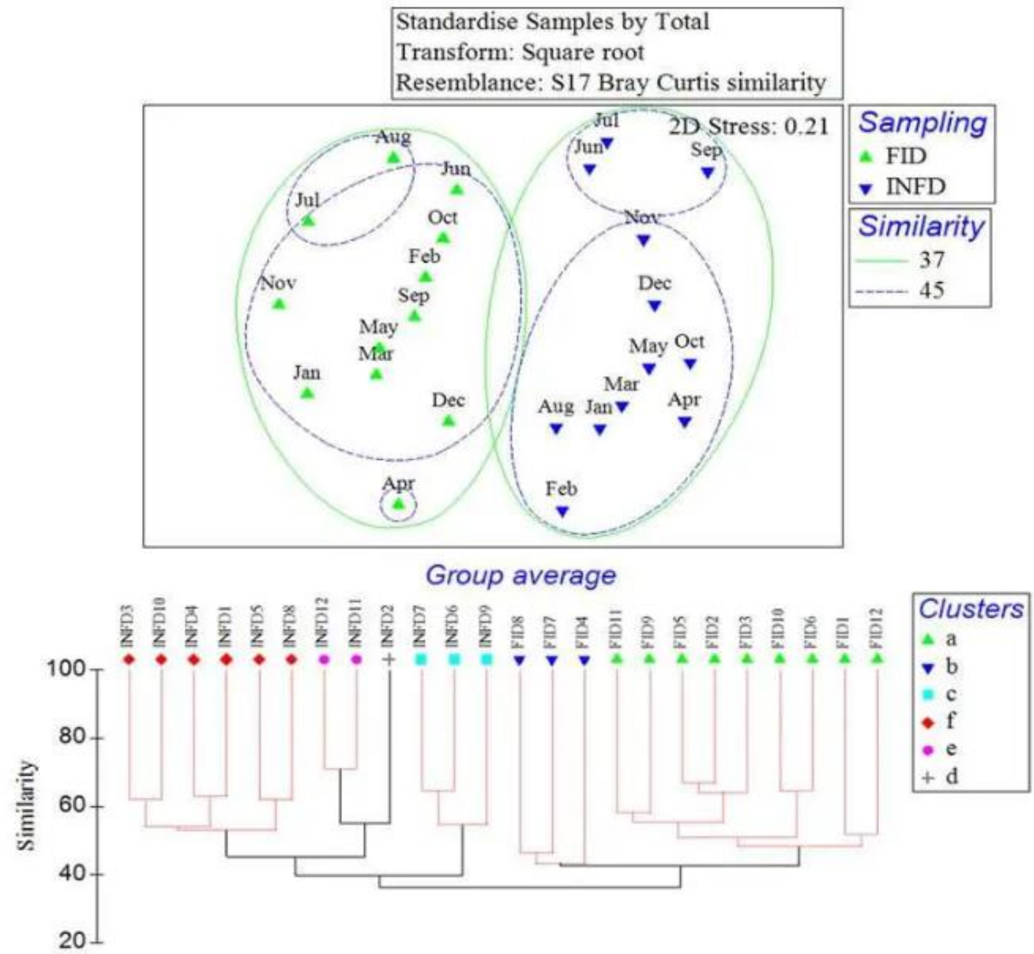

Figure 4: Up: nMDS-ordination based on Bray-Curtis similarity of fish species assemblage composition in two different fishing activities (FID fishing dependent and INFD fishing independent samples) and different months in Ghana coastal waters. Down: Cluster studies of fish species data from dependent and independent data sources, rs according to the SIMPROF test (*p*<0.05).

Other prominent species that are common (high Sim/SD) to FID data were *C. chrysurus* (Sim/SD=3.17, Contrib=9.27%), *C. senegalensis* (Sim/SD=3.08, Contrib=9.28%), *D. gibossus* (Sim/SD=1.92, Contrib=5.27%) and *Pagrus caeruleostictus* (Sim/SD=1.82, Contrib=7.28%). The similarity within the INFD data was 45.28% and dominated by *S. dorsalis*, which contributed to 12.0% of the average Bray-Curtis similarity and also achieved the highest Sim/Sd of the group at 1.01. Other prominent species that are common (high Sim/SD) were *C. senegalensis* (Sim/SD=1.74, Contrib=7.71%), *A. notacanthus* (Sim/SD=1.66, Contrib=3.69%), *B. punctatus* (Sim/SD=1.64, Contrib=3.74%) and *P. prayensis* (Sim/SD=1.54, Contrib=5.15%). The SIMPER analysis also identified dissimilarity between the two fisheries activities. The average dissimilarity between FID and INFD data was 64.93%. The most discriminating species (largest Diss/(SD) ratio) was *S. dorsalis* with a ratio of 1.29 and a contributing percentage of 7.19%. Other high contributing dissimilarity species were *B. auritus* with a Diss/SD ratio of 1.38 and a contributing percentage of 4.10%, *G. decadactylus* with a ratio of 1.23 and a contributing percentage of 4.01%, *C. chrysurus* with a ratio of 1.06 with a contributing percentage of 3.51%, and *Pagellus bellottii* with a ratio of 1.29 and a contributing percentage of 3.21% (Table 3). Significant spatial differences were observed between fish communities sampled from both FID and INFD data sources (ANOSIM: R=0.66, p<0.01).

Figure 5: The bubble plots of MDS-ordination based on Bray-Curtis similarity of fish species assemblage composition illustrate differences in different species by a combination of fishing activities (FID fishing dependent and INFD fishing independent samples) and month (the numbers) in Ghana coastal waters. See Table 1 for a key to species name abbreviations.

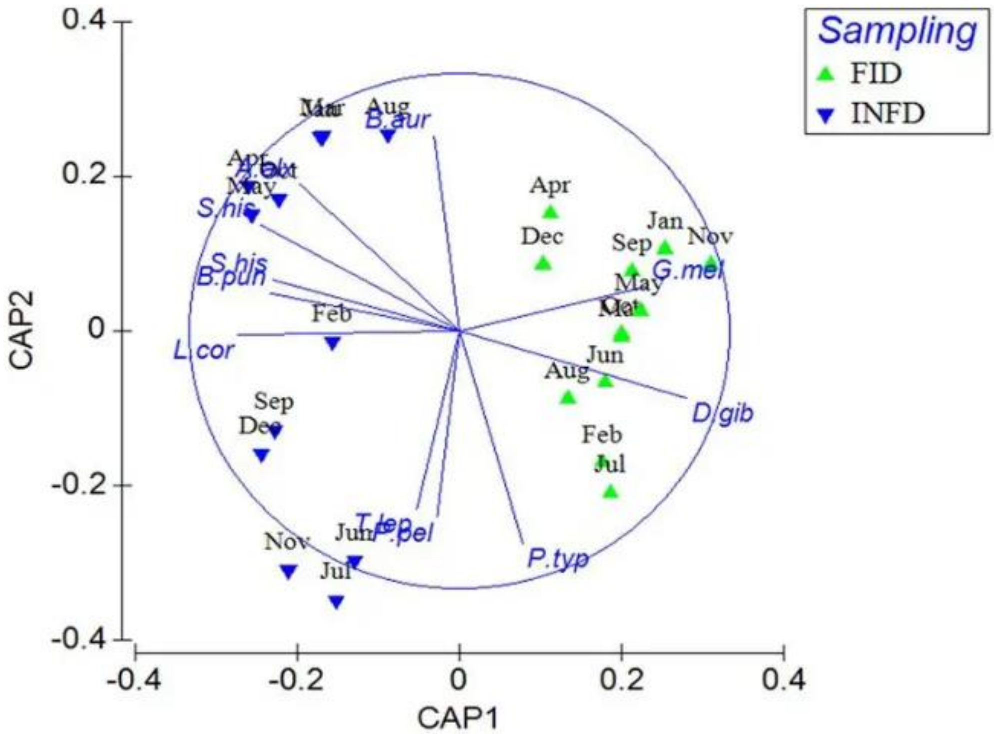

Figure 6: Canonical analysis coordinates (CAP) for fish communities with Spearman correlation (*r*>0.7) with CAP axis with required data transformed among samples from two fishing activities (FID fishing dependent and INFD fishing independent samples) and different months in Ghana coastal waters. See Table 1 for a key to species name abbreviations.

Table 2: PERMANOVA results for fish species assemblage models between fisheries dependent (FID) and fisheries independent (INFD).

Source	d.f.	MS	Pseudo-F	P(perm)
Fisheries activities	1	8963.7	6.30	0.001
Res	22	31303		

Table 3: SIMPER analysis between fisheries dependent (FID) and fisheries independent (INFD), where taxa represent 60% of the difference between the groups.

Species	Average Abundance	Average Abundance	Diss/SD	AvDis %	Cumulative AvDis %
	FID	INFD	Dissimilarity = 64.93		
Selene dorsalis	0.78	3.69	1.29	7.19	7.19
Brachydeuterus auritus	2.67	3.14	1.38	4.10	11.28
Galeoides decadactylus	3.04	2.56	1.23	4.01	15.30
Chloroscombrus chrysurus	2.47	1.26	1.06	3.51	18.80
Pagellus bellottii	1.85	0.94	1.29	3.21	22.01
Lethrinus atlanticus	1.98	0.70	1.50	3.17	25.18
Pteroscion peli	1.23	1.76	1.28	2.90	28.07
Sardinella maderensis	1.28	0.09	0.75	2.58	30.65
Ilisha africana	1.25	0.80	1.17	2.55	33.20
Lutjanus fulgens	1.30	0.19	0.96	2.46	35.66
Dentex gibbosus	1.40	0.23	1.79	2.41	38.07
Drepane africana	0.25	1.35	1.23	2.40	40.47

Table 3 (continued):

Species	**Average Abundance**	**Average Abundance**	**Diss/SD**	**AvDis %**	**Cumulative AvDis %**
	FID	**INFD**	**Dissimilarity = 64.93**		
Pagrus caeruleostictus	1.88	1.16	1.61	2.34	42.81
A. notacanthus	0.00	1.21	1.25	2.31	45.13
Pseudotolithus senegalensis	1.58	1.57	1.46	2.30	47.42
Cynoglossus senegalensis	2.10	2.07	1.40	2.19	49.61
Sphyraena sphyraena	0.81	0.77	0.97	2.15	51.76
Pseudotolithus typus	1.03	0.72	1.14	2.13	53.89
Syacium micrurum	0.68	1.09	1.26	2.01	55.90
Balistes punctatus	0.04	1.08	1.85	1.98	57.88
Parakuhlia macrophthalmus	1.08	0.00	0.71	1.97	59.85

Abundance (ind/m^3), average distance, dissimilarity (AvDis.%), and cumulative average dissimilarity of differences between the groups presented.

Discussion

The monthly variation in species diversity indices could be assigned to monthly fluctuation in physico-chemical parameters as alluded to by Segbefia *et al.* (2013). According to Okyere (2018), monthly changes in tides and dissolved oxygen influence diversity indices, particularly the Shannon-Weaver index of fish species. Habitat modification and adaptation, species interaction (e.g. prey-predator relationship), and fishing intensity could have affected the variation in diversity indices (Akongyuure *et al.,* 2017; Mensah *et al.,* 2018). In addition, the diversity of species from the experimental catches was relatively higher than the diversity of species observed from the commercial catches. Furthermore, many species that are economically insignificant for local fishermen are considered peripherally and are not collected. Therefore, this difference must exist. Furthermore, certain areas or patches are dangerous to the efficiency of their fishing gear, so fishermen avoid these fishing patches. The difference in species dominance might be a result of the fishing grounds visited by commercial fishermen, natural factors like weather, wind, and wave actions (González-Sansón *et al.*, 2022), as well as technical factors such as damage to the fishing gear, especially during hauling in of catches at rocky substrates (Barman *et al.,* 2021). Nonetheless, the first twenty fish species of commercial catches appear to be of high commercial value, while the experimental catches comprised a mixture of both high and low-valued fish species. This suggests that commercial fishermen land commercially important fish, which may have affected the species composition with a possibility of increasing discards at sea.

Tiralongo *et al.* (2021) posited that the landing of fish with high economic value correlates positively with an increase in discards at sea. The presence of less economically valued fish species from both experimental and commercial fishing activities suggests that trawl fishing gears are less selective than other fishing gears. The discard of inedible fish through sorting, at sea may have affected species diversity indices of commercial catches. The use of similar fishing methods, fishing gear, and possibly the depth at which the fishing gears were released during the experimental fishing period may have accounted for the similarity in species that dominated both experimental and commercial catches. Furthermore, the similarity in dominant species from both experimental and commercial catches may be reliant on the overlapping use of the aquatic ecosystem by these fish species (Munga *et al.,* 2014).

The catches obtained from the experimental fishing were similar in composition, as indicated by the closeness of survey points on nMDS and cluster analysis (Fig. 4), suggesting that the experimental fishing activity was consistently carried out at the same locations. Similarly, catches from the commercial survey by fishermen were biologically similar during the sampling period. Kirt and Vainik (2007) posited that data points on nMDS that are closer to each other are biologically similar. This finding also points to the repeated visitation of fishermen to these fishing grounds. In addition, it indicates that certain species are localized in these areas, especially *B. auritus, S. dorsalis,* and *G. decadactylus*. However, the overlap of some survey points within the experimental and commercial fishing surveys at a lower similarity percentage indicates the possible presence of commercial fishing activities within the locations of the experimental fishing survey, specifically experimental survey areas close to the nearshore. These nearshore areas are characterized by the presence of commercially important fishes such as *G.decadactylus, S. dorsalis,* and *B. auritus,* is significantly supported by the cluster analysis at a similarity percentage of 37.1 (Fig. 4). *G. melanopterus* and *D. gibbosus* were the main species that exhibited an association with FID at a correlation higher than 0.5. These species have been recorded in the catches of beach seine fishermen (Nunoo and Azumah, 2015). Furthermore, juvenile fishes have been recorded in wetlands along the coast of Ghana (Nortey *et al.,* 2016). This signifies that these juvenile fishes reside within the nearshore waters which makes them vulnerable to the fishing gear of fishermen (Clottey *et al.,* 2021). On the other hand, species such as *A. notacanthus, S. hispidus, B. auritus, P. bellottii,* and *A. alexcandrius* dominated the catches of the experimental fishing activities. This may be due to the fact that experimental fishing occurred at depths beyond the 30-meter zone. These fishes are mostly demersal and amphidromous and are found between 100 – 295 m depth (Froese and Pauly, 2024).

Fishes that distinguished the catches of the experimental survey from those of the commercial survey included *A. notacanthus, B. punctatus, L. laevigatus, S. histrio, S. hispidis, Z. maculatus* and *S. marmoratus*. Even though these fish are not economically viable for fishermen, the location and nature of the substrate deter fishermen from fishing in these sampling areas. For instance, *Z. maculatus* was obtained at the offshore stations which are known to harbor metallic parts of wrecked fishing vessels, while the farthest offshore locations are largely made of rocky substrate. These features, despite their unsuitable substrate, also reduce the efficiency of the fishing gear in capturing fish (Macfadyen *et al*., 2009; Gilman *et al.*, 2022; Yu *et al.,* 2023). For these given reasons, fishermen avoid these unsuitable locations during fishing expeditions (NOAA, 2015). This also shows that not all habitats are suitable fishing grounds for fishermen, and as such, can be designated as marine protected areas for the conservation of certain fish.

In conclusion, fish species from both experimental and commercial catches are similar due to the mobility of fishes and overlapping use of marine resources for foraging purposes among fish species. Dissimilarity analysis revealed that certain locations within the experimental fishing sites upon further scientific studies should be designated as marine protected areas. This will complement the already existing closed fishing season and hence, enhance the protection and management of Ghana's declining marine fisheries resources.

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Conflicts of interest

The authors declare no conflict of interest.

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