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CHARACTERISTICS AND SPECIES COMPOSITION OF THE BOTTOM-SET GILLNET FISHERY IN THREE COMMUNITIES ON THE CENTRAL COAST OF GHANA

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Abstract

The bottom-set gillnet fishery was studied along Ghana's central coast to describe its distinctive characteristics over 18 months, from February 2017 to July 2018. Canoe sizes and the stretch mesh sizes of gears were measured to define the crafts and gears employed. Fishing operations were described through field observations. Fish catches were assessed to determine the species composition. The findings indicated a multispecies fishery with landings dominated by the spotted box crab Calappa rubroguttata at Apam and Egyaa No.1 (45.0% and 35.2% respectively), and the cassava croaker (20.9%) at Cape Coast. Bycatch was dominated by cnidarians (corals) (52.2%) and crustaceans (39.9%). The lengths of the canoes ranged from 6 m to 12 m LOA with a mean width of 1.48 ± 0.28 m, and mesh sizes were in the range of 7.6 cm to 15.2 cm. The common soak time in the fishery was between 18 hours and 24 hours. Loss of fishing gear during fishing, which contributes to ghost fishing, was common in the fishery. To reduce the negative ecological impacts of the fishery on the marine environment, it was recommended that fisheries regulations on the use of set gillnets in the marine sector should be enforced. Again, gear-specific studies should be regularly carried out to provide and update information for the effective management of specific fisheries in Ghana. It was also recommended that there should be a stakeholder engagement on whether a review of the Ghana Fisheries Regulations on the use of gillnets should be considered based on prevailing fishing practices and the state of the fisheries resources. Furthermore, the possible occurrence of a coral garden off the Apam coast suggested by the findings of the study should be further investigated to ensure its protection if confirmed.

Keywords
Canoe size, mesh size, soak time, bycatch, ghost fishing, and Ghanaian fisheries.

Introduction

Humans have been fishing for generations and have progressed from subsistence fishing to artisanal and commercial fishing. Artisanal fisheries provides about half of global fish production and employ about 99% of the world's fishers (Basurto et al., 2017). It was characterized by vessels less than 15 m long, mechanized or manual fishing gears, low relative catch per vessel, relatively low technology, and limited extent of fishing area, as well as the use of numerous fishing techniques and gear designs (Halim et al., 2019). In Ghana, artisanal fisheries is the highest contributor to domestic fish production, accounting for 56.63% of total domestic production in 2020 (Fisheries Commission, 2021). The contribution to total GDP, according to Sowah et al. (2022), was about 3%. The artisanal fisheries sector consists of six sub-sectors in terms of gears operated, and they include the *Ali* fishery, *Poli*/*Watsa* fishery (purse seine), drift gillnet fishery, set gillnet fishery, hook-and-line fishery, and the beach seine fishery (Afoakwah et al., 2018; Dovlo et al., 2016). Beach seines are operated on gently sloping sandy shores and exploit pelagic and demersal fish resources. The hook-and-line gear comprises a long rope with several hooks baited with small, low-priced fish, and the fishery exploits mostly demersal fish. *Poli*/*Watsa* nets have small mesh sizes and are used to encircle schools of fish in mid-water. Set gillnets are deployed either in mid-water, near, or at the bottom (Akyeampong et al., 2013). The *Ali* net, drift gillnet, and set net all have a component of gillnet. As reported by Dovlo et al. (2016), beach seine and set nets are predominant among the Ewe fishers; purse seine and hook and line are the most common among Ga fishers. The Central Region was more associated with set gillnet, hook and line, and purse seine. Except for beach seine, all the other gears are used in the Western Region, with purse seines and set gillnets being the most common.

Bottom-set gillnets are used in coastal waters to harvest demersal fish resources around the world. At most places where the fishery was well established, the gear was used to target specific species, and several other species may be retained or discarded (Zeng et al., 2018). The effectiveness of the gear was determined by the mesh size, mesh shape, hanging ratio, net length, net color, the material used for constructing the net, the twine thickness of the material, and the soak time (Parsa et al., 2014). Hanging ratio was the length of the rope on which a net panel was mounted, divided by the actual length of stretch netting on the rope. The soak time was the duration from the setting of the net to withdrawing it from the water. The use of bottom-set gillnet has been associated with ecological issues, such as bycatch and ghost fishing, and the management of the fisheries in many countries has mainly been centered on solving these ecological issues. In Ghana, the bottom-set gillnet fishery was very vibrant along the central and western coasts, however, not much has been reported

on its management.

Not many studies have been reported on most of the gear-specific fisheries along the Ghanaian coast by way of characterization. Kraan (2006) reported on the social and cultural features that characterize the beach seine fishery. Catch composition, species diversity, and abundance of beach seine landings, were investigated by Aggrey-Fynn and Sackey-Mensah (2012). Nunoo and Azumah (2015) also studied the selectivity properties of beach seine, and Okyere (2022) reported on the socio-economic response of the beach seine fishery to upwelling variability. Except for the beach seine fishery, there was paucity of detailed information on the characteristics of other gear-specific fisheries in the Ghanaian artisanal sector. Conversely, characterizing a fishery should be the first step toward its effective management. It makes available necessary information for management decisions that ensure the sustainable exploitation of the fisheries resource. In this regard, the study was aimed at characterizing the bottom-set gillnet fishery in terms of gear used, its operations, species exploited, and bycatch to provide useful information to enhance sustainable management of the fishery.

Materials and Methods

Study Site

The study was conducted along the coast in the Central Region of Ghana (Figure 1). The Central Region was noted for the use of set gillnet among the four coastal regions of the country. The region recorded the highest number of canoes operating set gillnet in the marine canoe frame surveys from 1997 to 2013 (Akyeampong et al., 2013). The specific sampling sites for this study were Apam (5°17'05"N, 0°44'13"W) in the Gomoa West district, Egyaa No.1 (5°10'60"N, 1°6'0"W) in the Mfantsiman Municipality, and Cape Coast (5°6'19"N, 1°14'47"W) in the Cape Coast Municipality (Figure 1). The bottom-set gillnet fishery was vibrant in all three fishing communities.

Data Collection

Data were collected monthly for 18 months from February 2017 to July 2018. Data collection was done through field observations, fishing craft measurements, interviews, and sampling of fish catch to determine catch composition.

Description of fishing gear characteristics and operations

Canoes totaling 48, used in the bottom-set gillnet fishery were randomly selected from the three study sites. Randomization was done by selecting of canoes arriving at shore in multiples of three. The embossed number on the canoes were recorded to avoid repeated measurements. Using a tape measure, their length overall (LOA) and width were measured to the nearest 0.1 m. Canoe owners/Fishermen totaling 60, 20 from each community, were interviewed using a structured questionnaire on their fishing operations, specifically on soak time, crew, and gear. Further observation of crew was done by counting the crew on board canoes arriving from sea. At each study site, 25

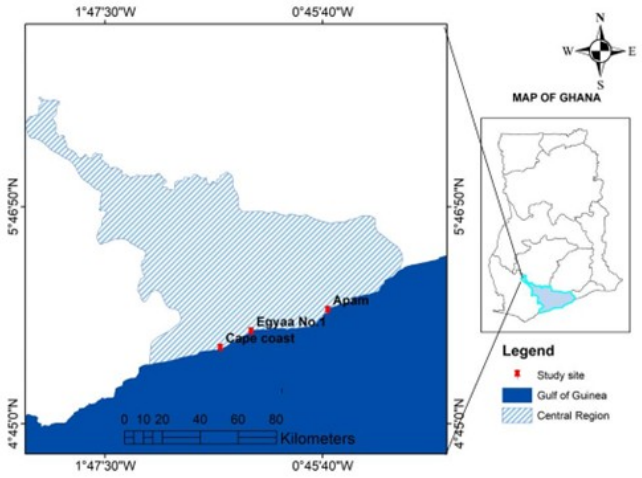

Figure 1. Map of study area showing sampling sites.

fishing gears were selected randomly and their stretched mesh size was measured to the nearest 0.1 cm using a measuring rule.

Determination of the catch composition

The species composition of catch was recorded monthly for three canoes at each study site. The catches were sorted, species identified, and recorded. Identification of the fish species was done using identification guides by Carpenter and De Angelis (2014), Carpenter and De Angelis (2016) and Schneider (1990). Catch also comprise corals and they were identified using Ramos et al. (2009).

Determination of bycatch composition

In the current study, bycatch was defined as organisms that were of no value to the fisherman and thus discarded. The proportion of catch considered to be of value to the fisherman was referred to as the retained catch. Bycatch was sorted and the number of individuals of each species was recorded.

Data analysis

Data collected were analyzed in IBM Statistical Package for Social Science version 21, Excel 2013, and Plymouth Routines in Multivariate Ecological Research version 6 (PRIMER v6). Data was described using descriptive statistics. Differences in canoe size, soak time, and catch composition among sites were tested for significance with ANOVA at a 95% confidence interval. Species abundance data were fourth root transformed. Species richness was measured using Margalef's richness index. Species similarity among the study sites was determined using the Bray Curtis similarity index. A K-Dominance curve was generated from the species percentage cumulative abundance plotted against species rank to visualize and compare the diversity profiles of the three sampling sites. A hierarchical cluster analysis was performed to reveal the relationship in species occurrence among the three study sites.

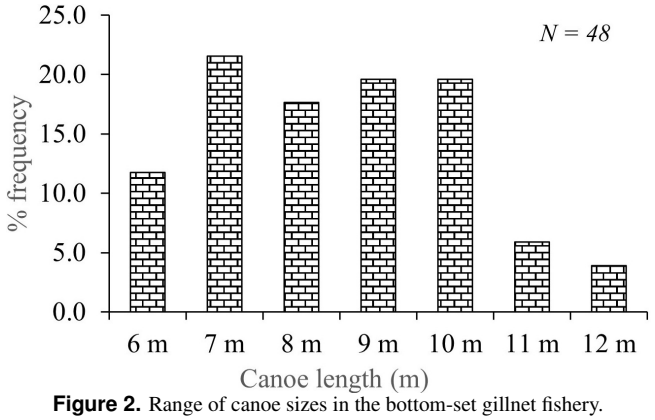

Figure 2. Range of canoe sizes in the bottom-set gillnet fishery.

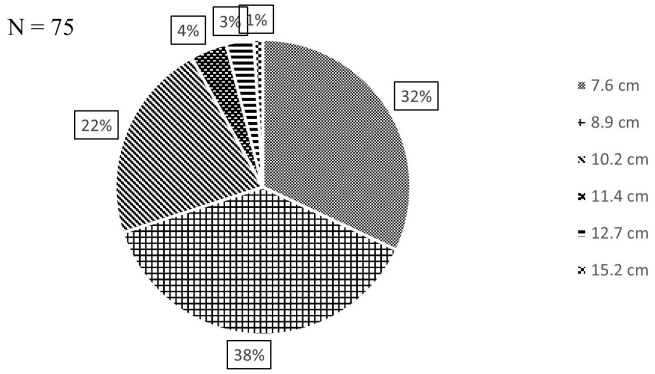

Figure 3. Stretch mesh sizes encountered in the bottom-set gillnet fishery.

Results and Discussion

Results

Fishing gear characteristics

Canoe sizes in the bottom-set gillnet fishery ranged from 6m – 12m LOA (Length Overall) with a mean width of 1.48 ± 1.76m. Mean canoe size at Cape Coast and Apam was 8.70 ± 1.76m and 9.77 ± 1.21m LOA, respectively. At Egyaa No.1, the mean canoe size was 7.79 ± 1.03m LOA. Variation in canoe sizes was not statistically significant at Apam and Cape Coast ($p = 0.126$). Sizes of canoes however varied significantly ($p = 0.002$) between Egyaa and Apam. The fishery was dominated by 7 m LOA canoes, followed by 9m and 10m LOA canoes (Figure 2). Gillnets encountered in the fishery were of monofilament nylon material. The stretch mesh size of fishing gears measured were in a range of 7.6cm and 15.2cm, and they were dominated by 8.9cm stretch mesh size (Figure 3). Most fishermen (62.5%) used single mesh size gears to fish. The rest, however, combined different mesh sizes for their gears. Combinations were of two (25%), three (8.3%), and more (4.2%) mesh sizes.

Fishing Operations

Soak Time

Soak time ranged between 5 hours to 72 hours. Few fishermen (4% in each case) set gears for 5 – 8 hours, 25 – 48 hours, and 49 – 72 hours. Also, 7% and 19% of respondents respectively indicated setting gears for 9 – 12 hours and 13 – 17 hours. The majority (63%) set their gears for 18 – 24 hours before hauling in the catch. Variation in soak time among the three communities was statistically not significant ($F = 2.38$, $p = 0.116$). Soak time in the fishery depended on distance to the fishing ground, quantity of fuel available for the trip, and mesh size of fishing gear. Soak time increased with increasing mesh size. The quality of the catch was observed to decrease with increasing soak time. The catch quality was assessed by appearance, color, and smell, where bulging eyes, blotted stomach, brown gills, lighter than usual general body color, and offensive smell characterized spoilage.

Other Operations

A high number of fishermen (78.6%) confirmed losing their gear during fishing operations. The crew on board ranged from two to four in all the communities; nonetheless, it was dominated by a crew of three (50%). Crews of two and four accounted for 32.8% and 15.5% of respondents, respectively. There was no significant variation in crew among sites ($F = 2.35$, $p = 0.104$). All three sites observed fishing holidays on Tuesdays; however, it was not strictly observed in the bottom-set gillnet fishery. Fishermen in the fishery go to sea on fishing holidays either to set their net or to haul in their nets and land the catch. Setting a net and landing the catch on the same day, according to respondents, was prohibited on a fishing holiday.

Catch Composition and Species Occurrence

A total of 16,651 individual aquatic organisms, made up of 151 species from 77 families, were recorded in the study. This comprised 95 bony fish species from 46 families, and 17 crustacean species from 9 families. Elasmobranchs encountered were 10 species from 5 families and dominated by Rhinobatos irvinie (Family: Rhinobatidae). The others were 13 gastropod species from 4 families, 9 cnidarian species from 6 families, four echinoderms from 4 families, and two cephalopods from two families. The main gastropod landed was Cymbium glans (Family: Volutidae). Crustaceans dominated the catch at Apam and Egyaa No.1 in terms of abundance (4,907; 55.5%, 4757; 73.9% respectively) and weight (685.38 kg; 33%, 442.89 kg; 32% respectively) (Figure 4), and the most abundant species was the spotted box crab Calappa rubroguttata (Family: Calappidae) (3,978; 45.0% at Apam and 2,265; 35.2% at Egyaa No.1 respectively). Bony fishes were the most dominant taxonomic group in landings at Cape Coast by abundance (817; 59.2%) and by weight (170.74 kg; 64%), (Figure 4) and the main species was Pseudotolithus senegalensis (Family: Sciaenidae) (288; 20.9%).

A significantly high proportion of the monthly catch was retained by abundance and weight, respectively, at Egyaa No.1 ($t = 4.468$; $p = 0.001$, $t = 6.194$; $p = 1.1 \times 10^{-6}$) and Cape Coast ($t = 5.699$; $p = 3.2 \times 10^{-6}$, $t = 6.052$; $p = 1.2 \times 10^{-6}$) (Figure 4). The retained catch was also significantly high at Apam ($t = 5.507$; $p = 5.5 \times 10^{-6}$) by weight. Bycatch differed significantly by abundance and weight among the three study sites ($F = 9.17$, $p = 0.005$), with the highest recorded at Apam and the lowest at Cape Coast (Figure 5).

The occurrence of bycatch species also differed significantly

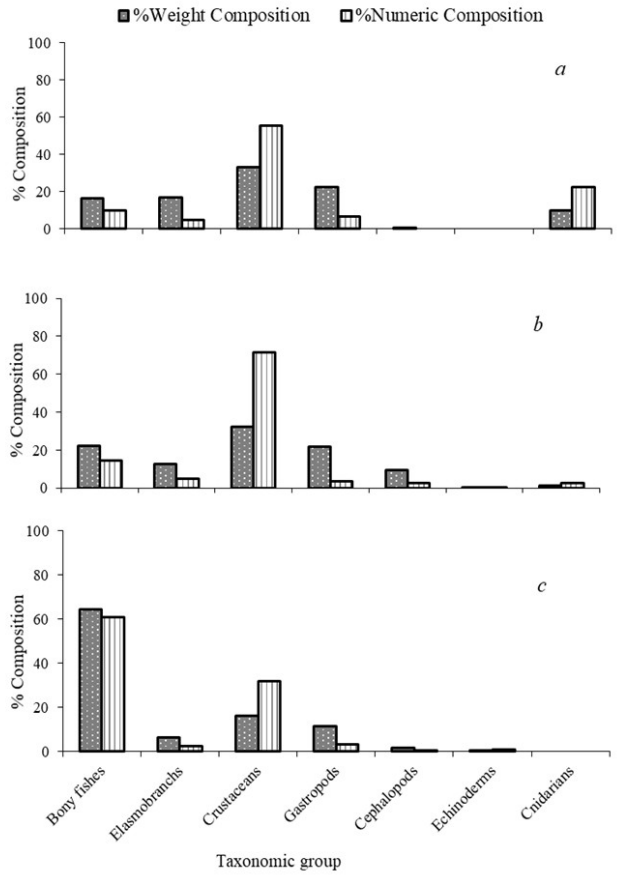

Figure 4. Summary of the composition of organisms landed at Apam (a), Egyaa No.1 (b), and Cape Coast (c).

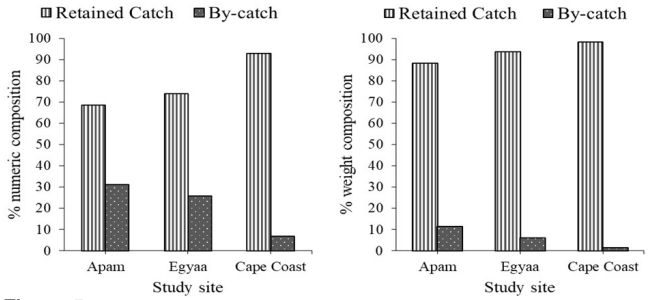

Figure 5. Variation in retained catch and bycatch at Apam, Egyaa No.1, and Cape Coast during the study period.

among taxonomic groups by numeric composition (F = 4.09, p = 0.0009) and weight (F = 2.34, p = 0.0356). Twenty-eight species from 22 families were encountered as bycatch in the study, and they were dominated by cnidarians (corals) (52.2%) and crustaceans (39.9%) (Table 1). Cnidarians dominated at Apam and crustaceans at Egyaa No.1 and Cape Coast (Figure 6). The main crustacean species in the bycatch were spiny spider crabs (*Maja brachydactyla*), hermit crabs (*Pagurites cadenati*), and sponge crabs (*Dromiidea* sp) (Table 1).

Species Richness and Similarity

Species was richest in Apam landings (18.32), followed by Egyaa No.1 (17.65), and the least was recorded at Cape Coast

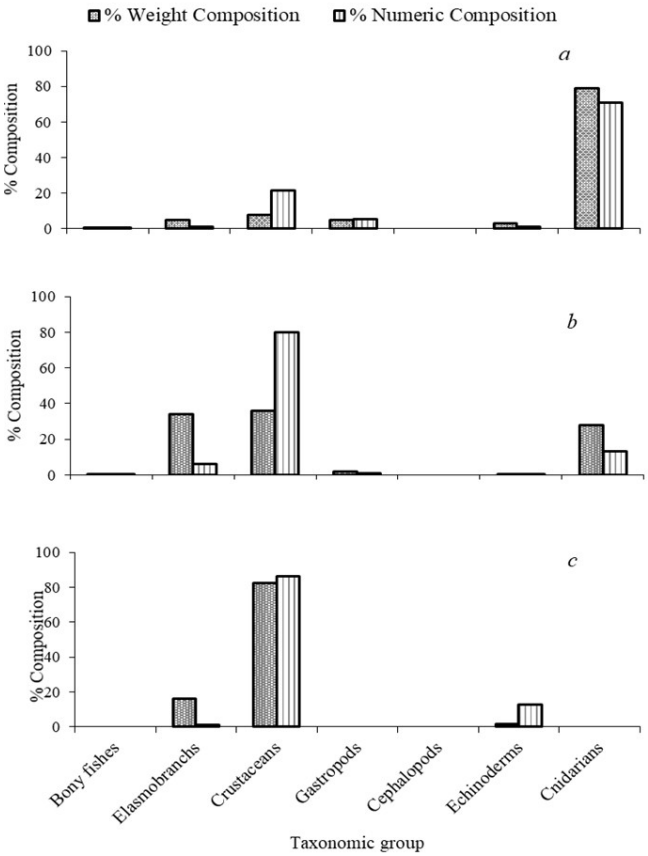

Figure 6. Composition of bycatch in the landings at Apam (a), Egyaa No. 1 (b), and Cape Coast (c).

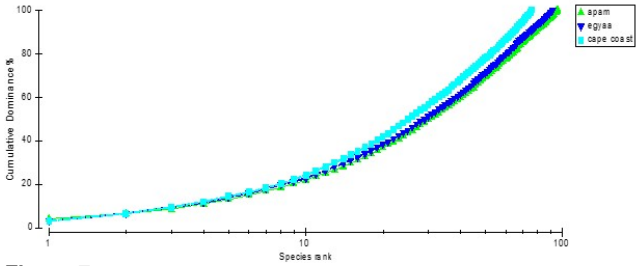

Figure 7. K-dominance curve showing the diversity profile of the three study sites.

(15.74). Species composition was most diverse in Apam, this was closely followed by the diversity of fish species landed at Egyaa No.1 (Figure 7). There was also a high resemblance observed (68.8%) between species landed at Apam and Egyaa No.1 compared to between Apam and Cape Coast (55.5%), and Cape Coast and Egyaa (54.9%). A hierarchical cluster analysis identified two statistically distinct clusters with Apam and Egyaa forming one cluster and Cape Coast forming another cluster (Figure 8).

Discussions

The canoe sizes measured showed that the bottom-set gillnet fishery in the Central Region of Ghana uses medium-sized canoes, though with some modifications. In Catalogue of small-scale fishing gear of Ghana, (Doyi, 1984) described medium-sized canoes to be 6 m to 11 m long, and 0.70 m

Table 1. Species considered as bycatch in the bottom-set gillnet fishery

Group	Family	Species	Apam	Egyaa	Cape Coast
Bony fishes	Diodontidae	Diodon halocanthus	0.03	-	-
	Ostraciidae	Acanthostracion guineensis	-	1.2	-
Elasmobranchs	Torpedinidae	Torpedo mackayana	0.11	0.54	-
		Torpedo torpedo	0.21	-	-
		Torpedo marmorata	-	0.23	-
	Zanobatidae	Zanobatidae maculatus	0.72	5.67	24.55
Crustaceans	Majidae	Maja brachydactyla	5.12	51.12	22.42
	Paguroidae	Paguristes cadenati	11.39	19.17	5.26
	Portunidae	Cronius ruber	0.1	2.76	-
	Squillidae	Squilla calmani	0.03	0.46	-
	Dromiidae	Dromidae sp	4.7	5.83	24.89
Gastropods	Melongenidae	Pugilina morio	0.32	0.46	-
	Muricidae	Bolinus cornetus	3.28	1.1	-
		Hexaplex duplex	1.91	0.33	-
Echinoderms	Oreasteridae	Oreaster clavatus	0.52	0.99	14.12
	Cidaroidea	Phyllacanthus imperialis	0.43	0.34	-
	Astropectinidae	Astropecten vappa	0.1	-	8.76
	Clypeasteridae	Arachnoides placenta	0.1	-	-
Cnidarians (Corals)	Gorgoniidae	Iciligorgia schrammi	5.3	3.5	-
		Gorgonia mariae	5.09	-	-
		Gorgonia flabellum	7.16	1	-
	Chrysogorgiidea	*No species listed*	8.1	-	-
	Plexauridae	Plexaura flexuos	10.3	-	-
	Faviidae	*No species listed*	8.3	-	-
	Acroporidae	Montipora sp	9.85	2.5	-
	Poritidae	Porites profundus	6.4	3.1	-
		Porites sp	7.86	0.9	-
Poriferans	Demospongia	Auxinelaa verrucosa	1.61	-	-
		Hymeniacidon sanguinea	0.96	-	-

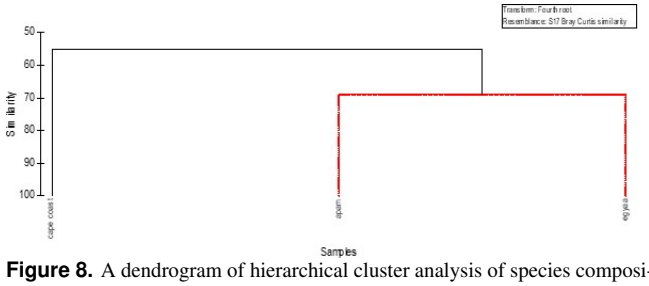

Figure 8. A dendrogram of hierarchical cluster analysis of species composition in Cape Coast, Apam, and at Egyaa No.1.

to one meter wide. The canoes measured in the fishery were wider than the width documented by the author for medium-sized canoes. The increase in width could be to create more space for the gear, as the number of net panels used by fishermen has increased over time in a bid to increase catch. The significant variation in canoe size observed between Apam and Egyaa No.1 may be ascribable to the canoes in Apam being used for multi-gears, compared to Egyaa No. 1, where the canoes are used mainly for bottom-set gillnet. Apam was a multi-gear landing site, Egyaa No.1 on the other hand was a single-gear landing site, using only the bottom-set gillnet. Cape Coast was also a multi-gear landing site, explaining why canoe sizes did not differ significantly between Apam and Cape Coast.

Fishing gears encountered were all made of monofilament netting, making the gears illegal according to Ghanaian fishing laws. According to section eight (8) of the Fisheries Regulation of Ghana (LI 1968), the use of monofilament nets in the marine waters of Ghana was prohibited. This offense was liable on summary conviction to a fine of not more than one hundred and fifty penalty units (152.14 USD), or to a term of imprisonment of not more than 12 months, or both. The switch to monofilament nets may be due to their perceived higher catch efficiency, lower relative cost, and ease of use (Smith et al., 2022). Compared to the legal minimum mesh size of 5 cm for multifilament nets in marine waters, the large mesh-size nets used in the bottom-set gillnet fishery may cause the gear, though made of monofilaments, to be less efficient and hence less damaging to the aquatic environment. As reported by Simasiku et al. (2017), the efficiency of monofilament nets decreases with increasing mesh size. The loss of gillnets at sea, as was the case in the current study, is a matter of ecological concern and was caused by storms, other

vessels, and the presence of rocky bottoms. Lost gillnets continue to fish, a phenomenon referred to as ghost fishing. Some studies have also reported lost gears to interfere with fishing, which leads to further loss of gears Richardson et al. (2019). Enforcement of regulations on submerged stationary fishing gears in Ghanaian waters Fisheries Commission (2002) and Fisheries Commission (2010) could reduce ghost fishing and its negative ecological impacts in the coastal waters of Ghana. Also, the widespread use of large mesh size monofilament gillnets in the bottom-set gillnet fishery calls for a stakeholder engagement on whether a review of the Ghana Fisheries Regulations should be considered.

The characteristics of the main gear observed in the current study were in line with descriptions of the lobster net given by earlier authors (Dovlo et al., 2016; Marquette et al., 2002). Combinations of different mesh sizes in a gear could be used to increase diversity in fish sizes in landings. Gillnets of different mesh sizes have different selection windows, with some overlapping. The crew per canoe in the current study was in line with the crew for lobster nets as reported by Dovlo et al. (2016) and Marquette et al. (2002).

Soak time is the duration of time from deployment of the fishing gear to its retrieval from the water. Increased soak time allowed in the fishery for gears of large mesh sizes may be ascribable to ensuring enough time for net saturation Savina et al. (2016). Though increased soak time maximized catch, it also resulted in a reduction in catch quality, which led to a reduction in the market value of the catch (only good enough to be processed into fermented fish). A reduction in the market value of landings reduced the profit of the fishermen. Findings in the current study confirmed findings made by Savina et al. (2016). Soak time was determined in the bottom-set gillnet fishery by available fuel, mesh size of fishing gear, and distance to the fishing ground. Setting a net and waiting at sea to retrieve it results in a reduced soak time; on the other hand, soak time increases when the fisherman returns to shore after setting the net and retrieves it on another sea trip. The quality of landings should be an important factor in determining soak time if profits are to be optimized in the bottom-set gill net fishery.

The fishery was multispecies, as shown by the richness of species landed at all three study locations. This was in line with observations made by Cosgrove et al. (2016), where the authors reported bottom-set gillnet fisheries as multispecies fisheries, with other species caught apart from the target species, either retained or discarded. The multispecies nature of the bottom-set gillnet fishery may have resulted from poor species selectivity of gillnets, which led to the catching of a wide range of species. According to Lucchetti et al. (2020), though gillnets are size-selective, they are very poor in species selectivity making them to catch various species. Also, they are selective when fish are caught by enmeshing and almost no selectivity when fish are caught by entangling. The dominant bycatch species which were made up of corals and crustaceans were entangled in the gear.

The resemblance in species landed at Apam and Egyaa showed a possibility of the same or similar fish assemblage off the Apam and Egyaa coast. Differences in species composition of landings among the three study locations could be explained by several factors. Firstly, it could be attributed to body morphology. The capture of the dominant species landed, the spotted box crab Calappa rubroguttata could have been aided by its body extensions like limbs and claws. Modifications in fins may also aid the capture of some of the fin fish species in the gillnets (Lucchetti et al., 2020). Secondly, the relative abundance of size classes of various fish species on the fishing grounds could determine the number of each fish species retained in gillnets. The dominance of the spotted box crab in the landings could be attributed to its mode of capture and its possible abundance in the fishing grounds. Finally, differences in species composition of landings among the three study locations may be explained by the time the gears were set. Fishermen in the current study set their gears during the day and draw them out of the water the next day. A gear set during the day will first catch day feeders before catching nocturnal feeders later at night. Due to different feeding behaviors in different species, therefore, the time of the day a gillnet was set plays a role in determining species composition and species dominance in gillnet catches. Similar findings were made by Li et al. (2011).

Differences in the quantity of bycatch recorded at the three study sites could be attributed to the level of concentration of target fish species in the respective fishing grounds. Low bycatch has been reported in areas of high concentration of target fish and high bycatch rates in diverse assemblages (Pons et al., 2022). Bycatch was recorded at all three study locations. Though not significant, this could have a negative impact on the community structure. Aquatic species considered as bycatch which include non-target species and branched organisms also contribute to shaping the community structure of aquatic ecosystems, and major fisheries ecological impacts may occur due to their removal (Gilman et al., 2014).

The dominance of coral species (cnidarians) in bycatch at Apam, their occurrence also at Egyaa No.1, and their complete absence at Cape Coast, coupled with the resemblance in species landed at Apam and Egyaa suggested a possible coral garden off the Apam coast, stretching towards the Egyaa coast. A coral garden was a relatively dense aggregation of colonies or individuals of coral species. All cnidarians recorded were gorgonian and scleractinian corals, which was a characteristic of coral gardens (Buhl-Mortensen et al., 2017). The high number of hermit crabs recorded at Apam, compared to the other sites, also further confirms the possible presence of a coral habitat in the area. Hermit crabs are known to have a great diversity of symbiotic associations, and they exhibit one of the highest associates with corals (Colombara et al., 2017; Fujii, 2017; Igawa and Kato, 2017). The coral garden suggested by the results of the study could be further investigated to confirm its presence.

Conclusion

The bottom-set gillnet fishery in the Central Region of Ghana was a multispecies fishery with the spotted box crab, Calappa rubroguttata, as the dominant species landed. Cnidarians (corals) and crustaceans were the most abundant species in the bycatch from the fishery with the most dominant crustacean being spider crabs (Maja brachydactyla). Canoes of 7 m to 10 m LOA dominate the sizes of canoe used and gears were made of monofilament netting with a dominant stretch mesh size of 8.9 cm (89 mm). The fishery contributes to ghost fishing in Ghanaian coastal waters as nets lost are mostly not retrieved. It was recommended that fishing regulations on set gillnet use in Ghana should be enforced to reduce the negative impacts of ghost fishing on the marine environment. Again, gear-specific studies should be regularly carried out to provide and update information for the effective management of specific fisheries in Ghana. Also, there should be a stakeholder engagement on whether a review of the Ghana Fisheries Regulations on the use of gillnets should be considered. However, scientific information that should back a fisheries regulation review on the use of gillnets must be from all other fisheries that use gillnets. Furthermore, the possible occurrence of a coral garden off the Apam coast suggested by the findings of the study should be further investigated to ensure its protection if confirmed.

Acknowledgments

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