

A Survey of the Benthic Macrofauna and Fish Species Assemblages in a Mangrove Habitat in Ghana

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Abstract

In order to enhance ecological knowledge for coastal and mangrove ecosystem conservation in Ghana, the study documents the taxonomic groups of benthic macrofauna and fish assemblages in an urban mangrove swamp as its fundamental objective with emphasis on their composition, richness and diversity. This is because benthic and fish fauna of mangrove habitats are amongst the least studied biota in Ghana. Fish and benthos sampling was undertaken from five randomly selected pools within a mangrove stand during the wet and dry seasons using pole-seine net (7 m long and 1.5 m depth, with stretched mesh size of 5 mm) and an Ekman grab (15 cm × 15 cm dimensions), respectively. All samples were preserved in 10% formalin for laboratory analysis. The results indicated a more diverse macrozoobenthic community in the wet ($H^1 = 1.8$) than dry season ($H^1 = 1.5$). Overall, five out of a total of 13 genera found are intolerant to pollution and four moderately tolerant, while four comprising polychaetes and the midge *Chironomus*, are pollution tolerant. This suggests that the mangrove habitat is less polluted. A grand total of 917 fish specimens, belonging to 15 species and nine families, were encountered for both seasons (371 and 546 specimens for wet and dry seasons, respectively). The black-chinned tilapia, *Sarotherodon melanotheron*, was the dominant fish species in the wet season, accounting for 54.2% of the total fish caught, whilst the grey mullets, *Mugil babanensis* and *Mugil curema*, were the dominant species in the dry season, with a combined total of 51.4% of the fish population. However, over 70% of these dominant fish species from both seasons were juveniles providing a strong justification for the observation that the mangrove habitats are nursery grounds for fish inhabiting adjacent riverine, estuarine and inshore marine habitats. Considering this relevance of mangroves and the ongoing conversion attempts of mangrove habitats to other land uses, a concerted mangroves conservation effort is strongly advocated.

Introduction

The uniqueness of mangrove habitats as ecotones linking freshwater marshes to estuarine biomes has since been recognized especially from their physiographic attributes (Singkran & Sudara, 2005; George, *et al.*, 2009) to their role as refuge for benthic macroinvertebrates (George *et al.*, 2009; Olomukoro & Azubuike, 2009; George *et al.*, 2010), and habitat for fish fauna have been documented (Little *et al.*, 1988; Rehage & Loftus, 2007). Other exploratory studies have also revealed the

usefulness of mangrove habitats as nursery grounds for juvenile fishes from both freshwater and marine sources (Little *et al.*, 1988; Singkran & Sudara, 2005; Mwandya *et al.*, 2009), as biotope for benthic macrofauna, which play a vital role in the circulation and recirculation of nutrients in aquatic ecosystems (Gallep *et al.*, 1978), as well as serve as food for a wide range of fishes (Idowu & Ugwumba, 2005; Arslan *et al.*, 2007). Consequently, the need for conserving mangrove ecosystems with the ultimate goal of protecting their biota, ecological functions

and other socio-economic services is extremely important (Aheto, 2011). A better understanding of the fish community structure and benthic macrofauna assemblages in mangrove systems is relevant for understanding the functional role of mangroves, which could ultimately inform and shape management and conservation decisions (Scherer-Lorenzen, 2005), especially in face of the ongoing degradation of mangrove wetlands at local and global scales (Field, 1998; Bosire *et al.*, 2008).

Unfortunately in Ghana, benthic macroinvertebrate and fish biota of mangrove habitats are the least studied coastal ecosystem communities. Most of the studies have focused on communities of lagoons (Blay & Dongdem, 1996; Gordon, 2000; Lamptey & Armah, 2008; Okyere *et al.*, 2011a; Aggrey-Fynn *et al.*, 2011), estuaries (Blay, 1997; Okyere *et al.*, 2011a) and associated marshes (Okyere *et al.*, 2011b; Okyere *et al.*, 2012).

It is reported that the Kakum estuary mangrove system has the highest species diversity in Ghana made up of the red mangroves (*Rhizophora harrisonii*, *Rhizophora racemosa* and *Rhizophora mangle*), the black mangrove (*Avicennia germinans*) and the white mangrove (*Laguncularia racemosa*) (Sackey *et al.*, 1993). These species occur between the Kakum river estuary and the Kakum estuary salt marsh. Despite the functional role played by the mangrove habitats in terms of the provision of goods and other ecological services, very few published study exist on the mangroves and its adjoining biotopes as a whole. Aheto *et al.* (2011) assessed the structural parameters and above-ground

biomass of the mangroves. Blay (1997) looked at the occurrence and diversity of fish species entering the estuary while Okyere *et al.* (2011b) and Okyere *et al.* (2012) investigated the macrozoobenthic and fish communities of the salt marsh adjoining the mangroves. None of these studies extended to investigate the biotic communities of the mangrove habitat fringing the estuary.

The gaps existing between the aforementioned studies largely constrain knowledge on the macrobenthic biota and fish community structure of the habitat, which is a very relevant precursor to inform, shape and promote mangrove management and conservational efforts on the local scale. This study, therefore, aims at bridging this research gap by investigating the richness, diversity and composition of the benthic macroinvertebrate and fish communities in the Kakum estuary mangrove habitat in Ghana.

Materials and methods

Study site

The Kakum estuary mangrove system is located in the Central Region of Ghana (Latitudes 5°5'40" N and 5°6'05" N; Longitudes 1°19'10" W and 1°19'20" W) (Fig.1). The mangroves fringe the banks and catchments of the estuary of River Kakum, which discharges into the Atlantic Ocean. Occurring within the mangrove system are patches of marshes and sparsely distributed but interconnected pools through tidal exchanges. The pools serve as microhabitats within the mangrove swamp and provide refuge for a variety of fauna. Sampling was conducted in five large pools; three pools within the forested areas (designated Pools A-C) and two from the marshy areas (designated Pools D & E). These pools were

selected along the stretch of the mangrove forest from the mouth of the estuary (Pool A) to the inland end of the mangrove (Pool E). This was to enable analysis of possible transition in faunal assemblages from the seaward portions of the swamp to the inland end (Fig. 1). Seasonal sampling was undertaken during two field visits in March and April 2011 for wet season survey, and November 2012 to January 2013 for dry season survey. Pools D and E dried up during the dry season and were, therefore, not sampled for the latter.

Sampling of benthic and fish macrofauna

A 15 cm × 15 cm Ekman grab was used for the benthic sediment sampling; three replicates per pool were taken on each of the two field visits. The samples were screened in the field using a set of sieves of mesh sizes 4 mm, 2 mm and 0.5 mm, and the retained organisms preserved in 10% formalin for detailed examination in the laboratory. Prior to sorting out the organisms, the samples were dyed with eosin to enhance their visibility. The macrofauna found were identified with the aid of laboratory manuals

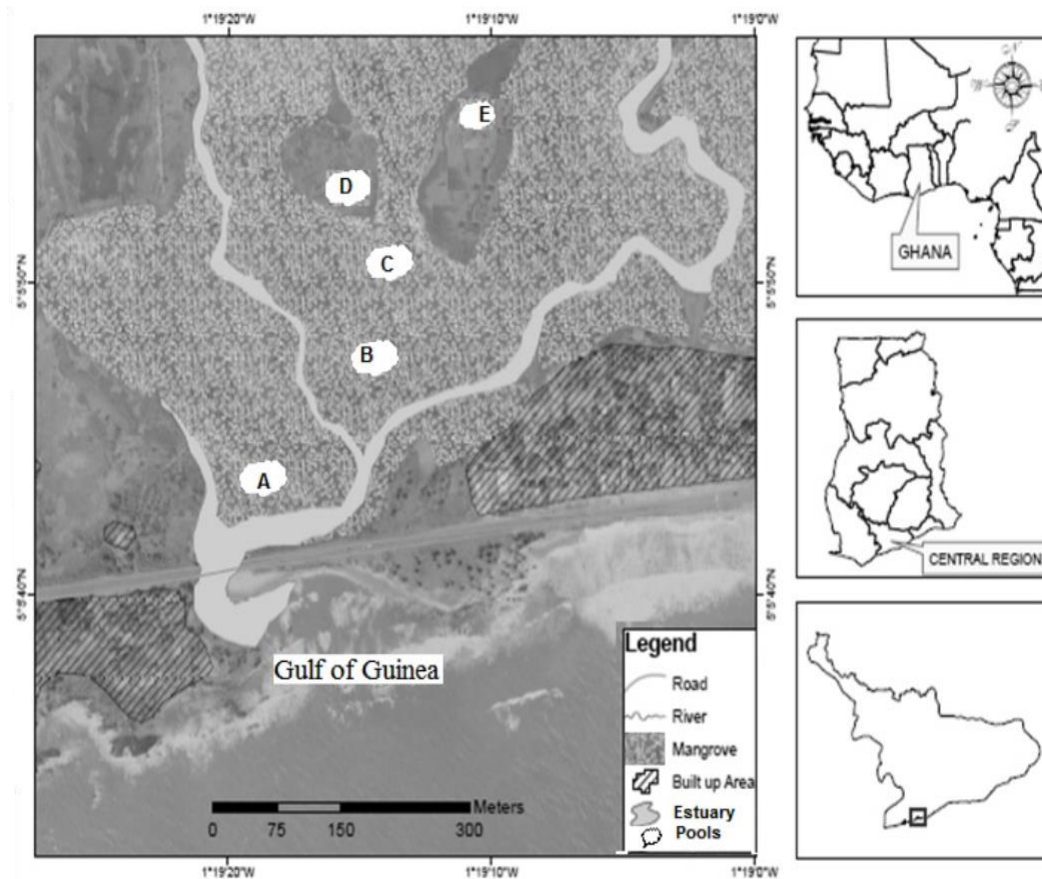


Fig. 1. Map of the study area showing sampled pools

(Thorp & Covich, 1991; Hauer & Lamberti, 2006). Counts of the different taxonomic groups were recorded for further analysis.

The fish were sampled with a pole-seine net measuring 7 m long and 1.5 m depth, with stretched mesh size of 5 mm. Samples from each pool were preserved in separate specimen jars containing 10% formalin and transported to the laboratory for examination. The fish samples were identified and sorted into their respective families and species using manuals and keys (Schneider, 1990; Holden & Reed, 1991; Dankwa *et al.*, 1999; Puagy *et al.*, 2003; Kwei & Ofori-Adu, 2005), and the number of individuals belonging to each species recorded. The total length (TL) of the finfish and carapace width (CW) of crab specimens were measured to the nearest 0.1 mm.

Macrozoobenthos and fish data analysis

The macroinvertebrate and fish data were, respectively, analysed for generic and species composition, richness, diversity and evenness. The richness was determined using Margalef index (d):

$$d = (s - 1) / \ln N \quad (1)$$

where s is the number of species in the sample, and N is the number of individuals in the sample while diversity was ascertained by the Shannon-Wiener index (H'):

$$H' = - \sum_{i=1}^s P_i (\ln P_i) \quad (2)$$

where s is the number of species in the pool and P_i is the proportion of individuals belonging to species i in the pool (Krebs 1999). The evenness component (J') of diversity was calculated from Pielou's index (Pielou, 1966):

$$J' = H' / H_{max} \quad (3)$$

where $H_{max} = \ln s$. The size range of the fish

specimens from each of the pools was also analyzed and tabulated. The invertebrates were classified based on their pollution tolerance following Ward (1992).

Results

Occurrence, richness and diversity of macrobenthic fauna

The zoobenthic organisms collected in both seasons (Table 1) were predominantly larvae of insects from eight genera belonging to seven families of six orders, most of which were found in only one or two of the pools sampled. Three polychaete genera (*Capitella*, *Nereis* and *Spio*) were encountered only during the dry season. The only crustacean genus encountered, *Echinogammarus*, of the order Amphipoda was present in all pools in both seasons while gastropods of the genus *Lymnaea* were found in two of the pools only in the wet season. Amongst the 13 invertebrate genera encountered in the mangrove habitat, five are pollution intolerant, four are moderately tolerant while four comprising the polychaetes and the midge *Chironomus* are pollution tolerant.

In the wet season, Pools A and B which were nearer to the seaward portion of the mangrove swamp had slightly higher number of invertebrate genera (five each) inhabiting them compared to Pools D and E in the marshy patches (four genera each) with Pool C recording the presence of only three genera (Table 1). This was reflected in the generic richness and diversity indices where Pools A and B had richer ($d = 1.5$ and 1.4 , respectively) and more diverse ($H' = 1.5$ each) macroinvertebrate genera than Pools D ($d = 0.9$, $H' = 1.3$) and E ($d = 0.8$, $H' = 1.3$) with least being recorded in Pool C.

TABLE I
Seasonal occurrence and diversity of benthic macrofauna taxa in five pools in the Kakum estuary mangrove habitat in Ghana (pollution tolerance classification in parenthesis)

Class	Order	Family	Wet season (Mar.-Apr.)					Dry season (Nov.-Jan.)					P	o	l	s
			Genus					Pools								
Overall			A	B	C	E	A	B	C	D	E	A	B	C	D	E
Gastropoda	Basommatophora	Lymnaeidae	Lymnaea (MT)	+	-	+	-	-	-	-	-	-	-	-	-	-
Crustacea	Amphipoda	Gammaridae	Echinogammarus (MT)	+	+	+	+	+	+	+	+	+	+	+	+	-
Insecta	Ephemeroptera	Oligoneuridae	Elassoneuria (NT)	-	-	-	+	+	+	+	-	-	-	-	-	-
	Baetidae	Cloeon (NT)	+	+	-	-	-	-	-	-	-	-	-	-	-	-
		Centropilum (NT)	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera	Chironomidae	Chironomus (T)	+	-	-	-	+	+	+	+	+	+	+	+	+	-
Megaloptera		Sialis	Sialis (NT)	-	+	-	-	-	-	-	-	-	+	+	-	-
Trichoptera		Hydropsychidae	Hydropsyche (NT)	-	+	-	-	-	-	-	-	-	-	-	-	-
Odonata	Coenagrionidae	Ischnura (MT)	-	+	+	+	+	+	+	+	-	+	+	+	-	-
Coleoptera		Elmidae	Stenelmis (MT)	-	-	-	+	+	+	+	-	-	-	-	-	-
Polychaeta	Phyllodocta	Nereidae	Nereis (T)	-	-	-	-	-	-	-	-	+	-	+	-	-
Spionida	Spionidae	Spio (T)	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Capitellida		Capitellidae	Capitella (T)	-	-	-	-	-	-	-	-	+	+	+	+	-
Total number of orders sampled				4	5	3	4	4	8	4	5	5	5	0	0	7
Total number of families sampled				3	5	3	4	4	9	4	5	5	5	0	0	7
Total number of genera sampled				5	5	3	4	4	10	4	5	4	5	4	0	7
Margalef's Richness (d)				1.5	1.4	0.6	0.9	0.8	1.8	0.9	1.1	1.3	1.1	1.3	1.4	1.4
Shannon - Wiener diversity (H')				1.5	1.5	1.1	1.3	1.3	1.8	1.3	1.3	1.4	1.3	1.3	1.4	1.5
Pielou's evenness (J')				0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.8	0.9	0.8	0.8	0.9	0.8

+ denotes present; - denotes absent; NT - Not tolerant to pollution; MT - Moderately tolerant to pollution; T - pollution tolerant

Comparatively, the overall community in the mangrove was richer and diverse in the wet season ($d = 1.8$, $H^1 = 1.8$) than in the dry season ($d = 1.4$, $H^1 = 1.5$). The closeness of the evenness index to 1.0 ($J^1 = 0.8$) in all pools and seasons indicates that the individuals are evenly distributed among the genera.

Composition of the benthic macroinvertebrate community

As illustrated in Fig. 2, the amphipods, *Echinogammarus*, were common in all pools in both seasons, generally constituting between 20% and 45% of the individuals in the pools while damselfly larvae (*Ischnura*: Odonata), which were also abundant in most pools made up between 20% and 40% of the benthos. The composition of the three Ephemeropteran (mayfly) genera *Elassoneuria*, *Cloeon* and *Centroptilum* varied between 10% and 35% in the various pools in which they occurred. The midge larvae (*Chironomus*: Diptera) were the least abundant benthos in the wet season constituting 6.6% of the macrofauna in only Pool A where they were sampled, but they became abundant in the dry season where their composition varied between 20% and 53% in the three existing pools. The polychaetes were also considerably represented (5%–20%) in the dry season.

Fish species occurrence, richness and diversity

A total of 917 fish specimens belonging to 19 species and 11 families including two species of marine crabs and two marine shrimps were sampled (Table 2). In both seasons, most of the species occurred in one or two pools especially (among Pools A, B

and C), except the black-chinned tilapia, *Sarotherodon melanotheron* (Cichlidae), which was caught in all pools and the mudskipper, *Periophthalmus barbarus* (Gobiidae), which was found in four pools in the wet season. Ten species were caught in the wet season while 15 species were caught in the dry season. Species richness and diversity were higher in the dry season ($d = 2.22$; $H^1 = 1.61$) than in the wet season ($d = 1.52$; $H^1 = 1.43$). Also, individuals were somehow evenly distributed among the species ($J^1 > 0.6$) in both seasonal communities.

Composition of the fish community

Result of the percentage composition of the different fishes encountered from the pools in the two seasons is presented in Fig. 3. The community in the wet season was dominated by the black-chinned tilapia *S. melanotheron* (54.2%) and the grey mullet *Mugil curema* (20.2%) with the eleotrid *Kribia nana* also occurred in considerably good numbers (6.7%). In the dry season, however, the four grey mullets *Mugil curema*, *Mugil bananensis*, *Mugil cephalus* and *Liza dumerilii*, together made up about 60% of the community while the banded lampeye *Aplocheilichthys spilauchen* constituted 22.5%. Each of the remaining 10 species were lowly represented (<4%).

Size range of fish species

The community consisted of fish from freshwater, brackishwater and marine sources (Table 3) of which majority were smaller individuals. Over 70% of the *S. melanotheron* caught measured 6.0–6.9 cm with the largest specimen measuring 7.6 cm while the four specimens of *Tilapia zillii* sampled measured 4.5 cm each. Similarly,

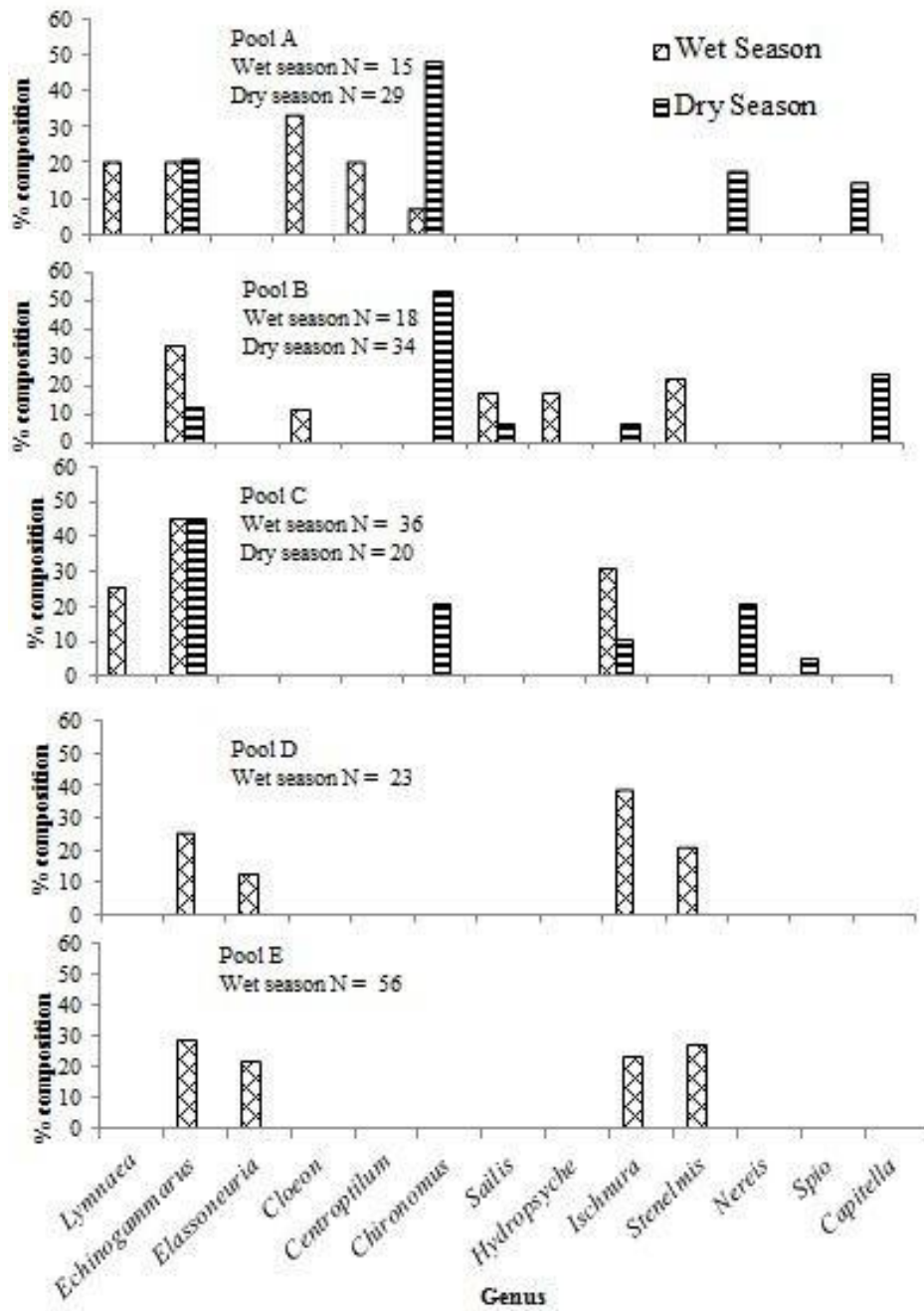


Fig. 2. Percentage composition of the different benthic macroinvertebrate genera collected from the five pools in the Kakum estuary mangrove in two seasons

TABLE 2
Seasonal occurrence and diversity of fish species in five pools in the Kakum estuary mangrove habitat in Ghana

Family	Species (Ecological range)	Wet Season (Mar-Apr)					Dry Season (Nov-Jan)							
		Pool					Pool							
		A	B	C	D	E	A	B	C	D	E			
FINFISH														
CICHLIDAE	<i>Tilapia zillii</i> (BW-FW)	-	+	-	-	-	+	-	-	-	-	-	-	-
CICHLIDAE	<i>Sarotherodon melanotheron</i> (BW-FW)	+	+	+	+	+	+	+	+	+	+	+	+	+
CICHLIDAE	<i>Oreochromis niloticus</i> (FW-BW)	-	-	-	-	-	+	+	+	+	+	+	+	+
CICHLIDAE	<i>Hemicarax bicolor</i> (MN-BW)	-	-	-	-	-	-	-	-	-	-	-	-	-
CARANGIDAE	<i>Kribia nana</i> (FW-BW)	+	+	+	+	+	+	+	+	+	+	+	+	+
ELEOTRIDAE	<i>Bostyrchus africanus</i> (MN-BW-FW)	-	-	-	-	-	+	+	+	+	+	+	+	+
ELEOTRIDAE	<i>Elops lacerta</i> (MN-BW-FW)	+	+	+	+	+	+	+	+	+	+	+	+	+
ELOPIDAE	<i>Periophthalmus barbarus</i> (BW-FW)	+	+	+	+	+	+	+	+	+	+	+	+	+
GOBIIDAE	<i>Awaous guineensis</i> (MN-BW-FW)	+	+	+	+	+	+	+	+	+	+	+	+	+
GOBIIDAE	<i>Sicydium crenilabrum</i> (FW-BW)	-	-	-	-	-	+	+	+	+	+	+	+	+
GOBIIDAE	<i>Mugil curema</i> (MN-BW-FW)	+	+	+	+	+	+	+	+	+	+	+	+	+
MUGILIDAE	<i>Mugil bananensis</i> (MN-BW-FW)	-	-	-	-	-	+	+	+	+	+	+	+	+
MUGILIDAE	<i>Mugil cephalus</i> (MN-BW-FW)	-	-	-	-	-	+	+	+	+	+	+	+	+
MUGILIDAE	<i>Liza dumerilii</i> (MN, BW, FW)	-	-	-	-	-	+	+	+	+	+	+	+	+
POECILIIDAE	<i>Aplocheilichthys spitauchen</i> (FW-BW)	-	-	-	-	-	-	-	-	-	-	-	-	-
CRUSTACEANS														
PORTUNIDAE	<i>Callinectes amnicola</i> (MN-BW)	+	+	+	+	+	+	+	+	+	+	+	+	+
PENAEIDAE	<i>Penaeus notialis</i> (MN-BW)	-	-	-	-	-	-	-	-	-	-	-	-	-
GRAPSIDAE	<i>Pachygrapsus transversus</i> (MN-BW)	+	+	+	+	+	-	-	-	-	-	-	-	-
ARISTEIDAE	<i>Plesiopeneus edwardsianus</i> (MN-BW)	+	+	+	+	+	-	-	-	-	-	-	-	-
Total number of families sampled		7	7	4	2	2	8	6	2	7	0	0	0	9
Total number of species sampled		8	9	4	2	2	10	12	2	10	0	0	0	15
Margalef's Richness (<i>d</i>)							1.52							2.22
Shannon - Wiener diversity (<i>H'</i>)							1.43							1.61
Pielou's evenness (<i>J'</i>)							0.6							0.6

+ indicates present; - indicates not found; FW-BW: Freshwater species occasionally entering brackishwater; BW-FW: Brackishwater species occasionally entering freshwater; MN-BW: Marine species occasionally entering brackishwater; MN-BW-FW: Marine species that primarily use estuarine mangrove

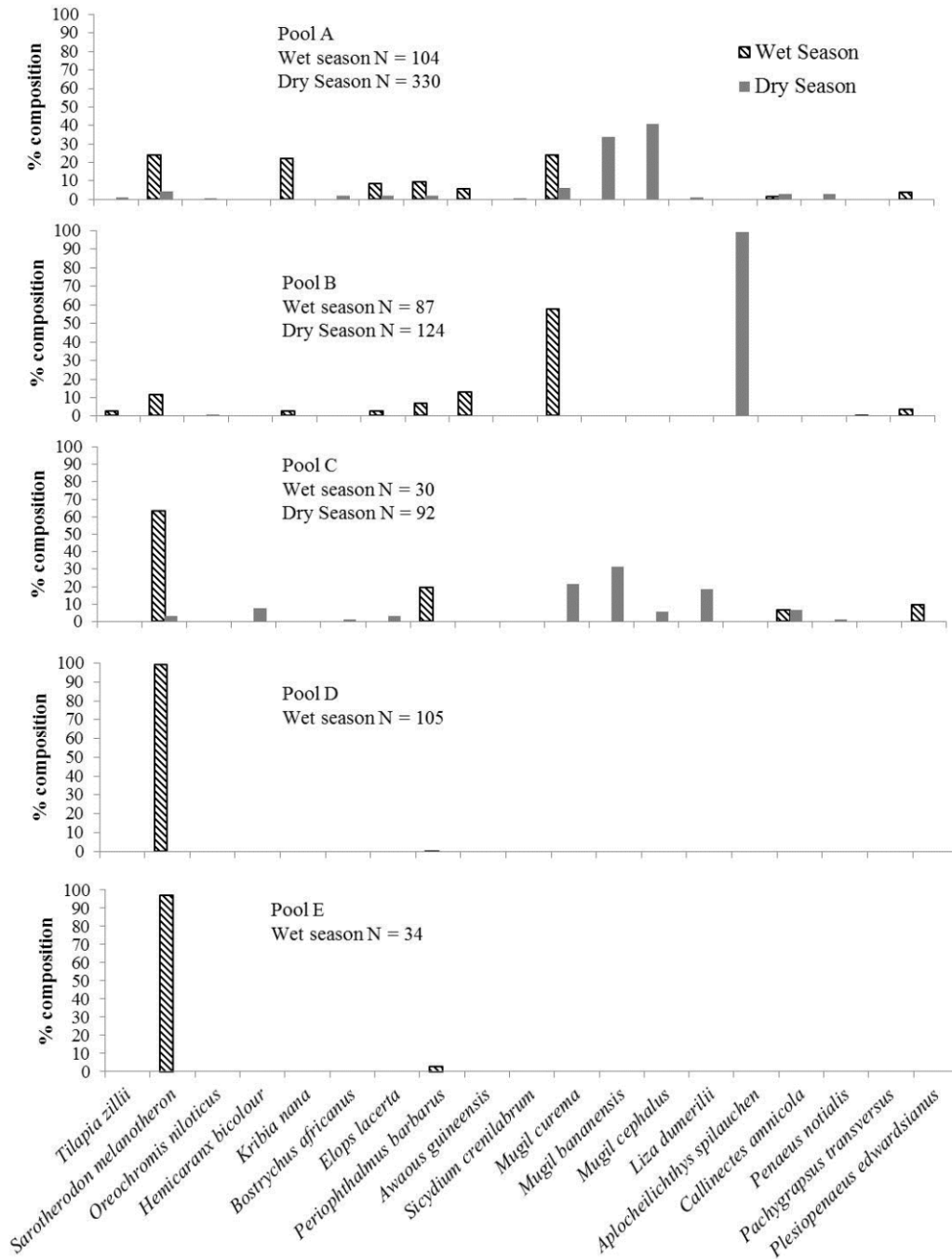


Fig. 3. Percentage composition of the different fish species sampled from the Kakum estuary mangrove habitat (Combined data from all five pools for each season)

over 90% of the grey mullets caught were within or below the class range of 6.0–6.9 cm, the West African lady fish *Elops lacerta* specimens had total length of 12 cm, or less, and the marine crabs *Callinectes amnicola* and *Pachygrapsus transverses* were less than 7 cm in carapace width.

Discussion

A multiplicity of factors including habitat physiographic attributes and microhabitat diversity influence the structure, distribution, diversity, and composition of the benthic macroinvertebrate communities (Galdean *et al.*, 2000, 2001; Callisto *et al.*, 2001; Aggrey-Fynn *et al.*, 2011). Although generic richness and diversity of benthos did not vary markedly among the sampled pools, the slight variability observed could be a reflection of microhabitat heterogeneity within the habitat, with conditions being somehow more favourable in the wet than the dry season, the pools nearer to the estuarine waters (Pools A and B) being slightly richer and diverse than those further away (Pools C, D and E). This is because a little more macrofauna were found in the former pools than the latter. In the same regard, microhabitat variability may have accounted for the obvious disparity in fish assemblages in the pools, where species richness and diversity were higher in Pools A and B ($d > 1.5$; $H' > 1.4$) but markedly poor in Pools D and E ($d < 0.3$; $H' < 0.3$) located in the marshy patches of the habitat.

Overall, 13 genera of benthic macrofauna belonging to 12 families found in the habitat were comparatively similar to the communities in other West African habitats where over 12 families of 19 species including polychaete and oligochaete

worms have been recorded (George *et al.*, 2009; Olomukoro & Azubuike, 2009; George *et al.*, 2010). The data showed marked variations in occurrence and diversity of the macrobenthic community in the wet and dry seasons. This finding supports earlier studies that confirm that macrobenthos abundance and diversity is influenced by seasonality (Oliveira *et al.*, 1997; Bispo & Oliveira, 1998; Gordon, 2000; Lamptey & Armah, 2008).

The Kakum habitat supports a considerably higher number of benthic macrofauna taxa than the adjoining salt marsh where Okyere *et al.* (2011b) found only chironomid larvae (Diptera) and oligochaete worms (Oligochaeta) in an 8-month study. In addition, the abundance of pollution intolerant invertebrates such as mayflies (Ephemeroptera) and moderately tolerant ones such as the damselfly (Odonata) is a possible indication of low levels of pollution in the mangrove swamp, compared to the salt marsh, which was highly dominated by the pollution tolerant chironomid larvae (Okyere *et al.*, 2011b). The occurrence and composition of fish species in brackishwater habitats in the tropics mostly has its driving force to be salinity (Little *et al.*, 1988). This is a major reason why most of the fish species observed in the dry season were from the marine and brackishwater origins (Table 2).

In the dry season, there is little or no rainfall and evaporation is a dominant factor that facilitates a net landward flux of saline water into mangrove habitats. However, occasional rainfall or runoffs is a controlling factor of the salinity budgets in these habitats (Benfer *et al.*, 2007). This may have accounted for the presence of freshwater fish species during the dry season. In the wet

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