

Aspects of the Feeding Ecology of Some Selected Fish Species Assemblages of an Estuarine Mangrove Ecosystem in Ghana

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Abstract

Food and feeding habits of commercial fish species from Kakum River Estuary and Benya Lagoon were studied purposely to assess the range of food items available to the species in the brackish ecosystems. The quality of naturally available food resources within a brackish ecosystem influences the feeding habits of fish. Fish samples for the study were obtained with a cast net and were examined employing the frequency of occurrence method. The diet of the species from both the estuary and the lagoon were similar, with minor dissimilarities in the proportions of the recorded food items. While diatom, zooplankton, sand particles, detritus, and polychaetes occurred to be the most essential food items for grey mullets (*Mugilidae*) from the estuary, blue-green algae, polychaetes, and detritus was the preferred food for the species in the lagoon. The core feeding cycle of grey mullets in the Kakum River Estuary occurred during the diurnal period between the hours of 14:00 GMT and 18:00 GMT for all sampling dates. There was not much or no feeding during the nocturnal period except *Mugil curema* which feeding activity peaked at 2:00 GMT sampling. The peak feeding activity for *Liza dumerilli*, *Liza falcipinnis*, *Mugil bananensis*, and *Mugil curema* occurred at 14:00 GMT and 18:00 GMT while the peak feeding activity for *Mugil cephalus* occurred at 18:00 GMT during the day for all the sampling dates. *Liza dumerilli*, *Mugil cephalus*, and *Liza falcipinnis* occurred to be species with high feeding intensity at low tides.

Keywords: Fish species, Prey, Gut Content, Ecology, Habit, Consumed

Introduction

Food availability in brackish systems is one of the most essential aspects that influence the survival of fish. The quality of the available natural food resources within the ecosystem influences the food and feeding habits of fish. Research on food habits and the feeding ecology of fish is significant within their ecosystems since it shows the relationships built between feeding resources, and the flux of community energy (Allan et al., 2021), this permits predation effects on and competition among the fish community (Khan and Panikkar, 2009). Again, studies on the feeding of fishes lead to unceasing research since it establishes the foundation for the success of fisheries management program on culture and captured fisheries due to the dynamics of the aquatic

ecosystem. Numerous studies focused on trophic linkages in temperate brackish systems (Young et al., 2006), but few have analytically studied tropical and subtropical estuaries and their relationships (Cabral et al., 2018). Data on fish feeding habits among different age groups is necessary for fish stock assessment since it gives the trophic requirements at each developmental stage (Collie and Gislason, 2010). Bolnick et al. (2003) investigated the food regimes and patterns of feeding of fish communities to understand the ecological interaction as well as the community structure. Pallaoro et al. (2006) reported on variations in the stomach contents of demersal fishes from Passamaquoddy Bay and cited that the lower metabolic demands of fishes cause a reduction in their feeding intensity at lower temperatures. Dietary ecology and feeding habits were

attained by measuring the differences in trophic niche breadth and feeding intensity as well as resource use Hammerschlag et al. (2010). Nagelkerken et al. (2006) identified that, individual species are predicted to cause a shift in resource use according to the available food in the ecosystem. Heath et al. (2012) reported that seasonal variations in available resources and environmental conditions influence the feeding patterns of fish from freshwater and marine systems.

Most fish species found in brackish systems are oligophagous (Verdyck and Desender, 2003), which utilizes limited resources while other species are found to be polyphagous subsisting on wider spectra of items. Adaption of a broad trophic spectrum ensures a constant energy source that facilitates adequate utilization of available food resources and enables fish to easily move from one source to another in response to natural pulses in their relative abundance (Richardson and Danehy, 2007). Extensive research projects were done on the diet composition and trophic ecology of fishes from different aquatic systems such as lagoons, reservoirs, and lakes in Nigeria (Ferrareze et al., 2015). Despite the few studies on seasonal variation in the diets of fish populations inhabiting subtropical marine systems; little is known about changes in individual fishes and their resource use within populations (Bolnick et al., 2003). Individual-level variation in fish is called individual specialization, referring to individuals with is significantly narrower dietary niche than that of the population Bolnick et al. (2002, and 2003). However, during the day, opportunistic feeding takes place in mangroves systems

(Nagelkerken and van der Velde, 2004; Verweij et al., 2006). According to Armstrong and Witthames, (2012), the diet of fish has been a fundamental aspect governing fish growth, migration, and fecundity as well as condition factor. The fish feeding habits gives vital data on the bionomics of single species. Ahmed et al. (2015) stated that stomach content analysis of fish is a system for examining the diet of fish, and describes webs shared as well as food chains by different species of fish. An accurate measure of fish diets is a critical aspect of fisheries management according to Ovenden et al. (2015). Information on fish diet provides additional provision for practical management of the aquatic system, (Pitcher, 2001). Therefore, to understand the purpose of ecosystem habitation and to examine its food webs, there is a need to investigate the availability of prey since the type of feed and its accessibility is of higher importance for successful recruitment (Elliott et al., 2002). This research was conducted to study the feeding ecology of fishes in brackish systems and to assess the range of food items available to the species in the brackish ecosystems. This study provides useful information which could help define the predator-prey relationship occurring in brackish systems and identify the sustainability of food preferences of the species.

Materials and Methods

Site Description

The research was conducted in the Benya Lagoon and Kakum River Estuary in the Central Region of Ghana (Figure. 1). The

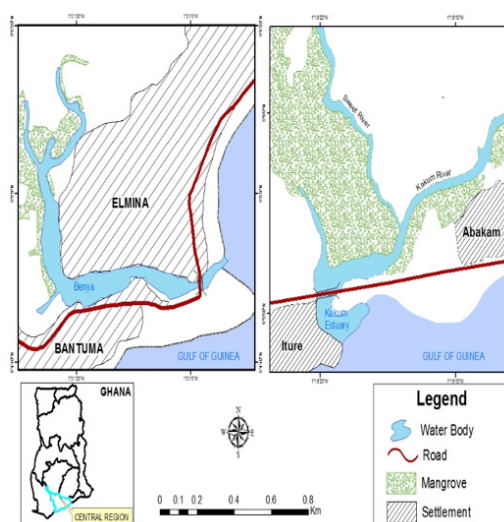


Figure 1 Map of Ghana and a plate showing the location of Kakum River Estuary and Benya Lagoon

estuary (001° 19' W, 5° 05' N) is located near Elmina which is about 5 km West of Cape Coast. It is formed by the Kakum River and the Sweet River which are twin river system, fringed by mangroves that are pristine in some areas and highly degraded in other areas, which forms a tributary with the Atlantic Ocean. Benya Lagoon is located at Elmina (001° 23' W, 5° 05' N), the lagoon is an open lagoon and approximately 3 km from the Kakum River Estuary. It is found in the western part of Cape Coast in the Central Region of Ghana.

Methods

Fishes were sampled from the Kakum River estuary and Benya Lagoon each month from November 2016 to April 2017. In both Kakum River Estuary and Benya Lagoon sampling was done within thirty (30) minutes during all sampling periods using a medium-mesh cast net of 20 mm stretched and a mini boat. In standardizing sampling effort, each sampling covered 1.5 miles. Casting was done following the tidal level of the water to get species occurring throughout low and high tides. On each water body ten castings were made during both day and night given a total of seventy castings on each sampling date in each month. Sampling was done at 06:00, 10:00, 14:00, 18:00, 22:00, 02:00, and 06:00 in each month to determine the diurnal periodicity. Species caught were preserved in 10% formalin and sorted out into various species by using identification keys (Froese and Pauly, 2012; Carpenter and DeAngelis, 2014). Fish species were identified to species level and individual fishes were measured for their total length (TL, cm) and body weight (BW, g) respectively to the nearest 0.1 cm and 0.01 g. As a measure of relative abundance or commonness of each species in the catch composition, an index of relative importance (%IRI), was used and it occurred that species used for this study were the dominant species of the two water bodies. The stomach contents of individual fish were weighed to the nearest 0.01g. The total prey items found were then identified to the lowest possible taxon and data obtained were quantified using numerical

methods such as percent by frequency of occurrence (%O), percent by number (%N), and percent by weight (%W) Hyslop (1980). Dietary breadth and gut repletion were calculated to determine the extent of dietary variety and the degree of gut fullness. Cumulative prey curves were constructed for each species to determine if an adequate number of stomachs had been collected to accurately describe diets (Cortés 1997). When the curves reach a stable asymptote, the number of stomachs analyzed is considered sufficient for describing dietary habits. Diet Breadth; a measure of the food spectrum as determined by Simpson's diversity index (Simpsons, 1949) Simpson's index:

$$D = 1 - \sum n(n-1) / N(N-1)$$

Where N = the total number of occurrences of all food items (in a stomach) and n = the number of occurrences of a food item. Prey items like plankton, were obtained using a microscope (Olympus CH-20, zoom 40X). The stomach contents were then grouped broadly into detritus, polychaetes, green algae, zooplankton, blue-green algae, and diatoms, as well as sand particles.

Results

Species composition of estuarine systems

Based on the calculated Index of Relative Importance (IRI) for number of fish, weight and frequency of fish caught from the estuary and the lagoon, the dominant species in the Kakum estuary were *Mugil curema*, *Liza falcipinnis*, *Liza dumerilli*, *Mugil bananensis* and *Caranx hippos* while *Mugil bananensis*, *Mugil curema*, *Liza falcipinnis*, *Sardinella aurita*, and *Eucinostomus melanopterus* were the most abundant species recorded from Benya Lagoon Figure 2. Comparatively, the dominant species composition of the fish community from both systems changed considerably.

Size range

The size range of the marine fish species

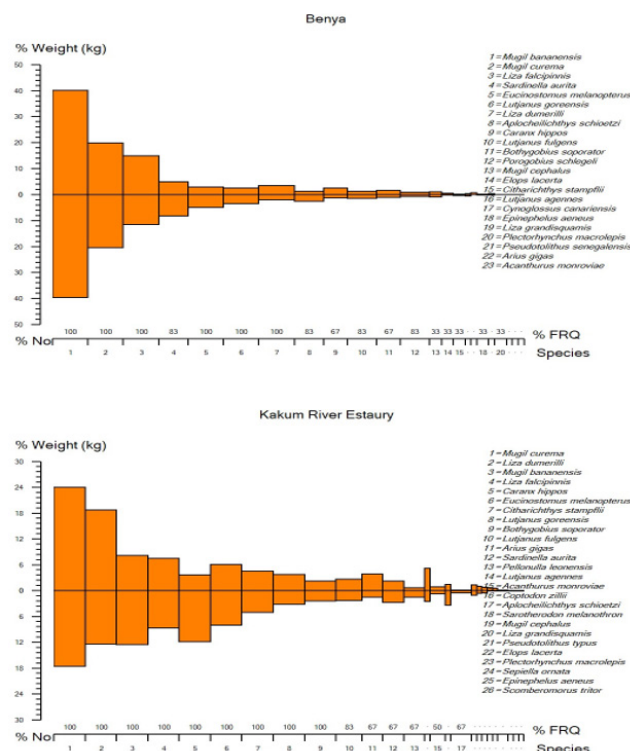


Figure 2 Index of Relative Importance of species from both Kakum Estuary and Benya Lagoon

selected for the stomach contents analysis for both the estuary and the lagoon Table 1. Larger specimens of each fish species were obtained from the estuary than in the lagoon.

Composition of stomach contents

Taxonomic groupings of stomach contents of the dominants fish species of both Kakum River Estuary and Benya Lagoon (Table 2). A total of 30 prey items were recorded from the guts of *Mugil cephalus*, *Mugil bananensis*, *Liza dumerilli*, *Liza falcipinnis*, *Mugil curema*, *Lutjanus goreensis*, *Lutjanus fulgens*, and *Lutjanus agennes* and *Sardinella*

aurita. Diatoms occurred to be the most prey items reordered followed by Zooplankton, Green algae, and Blue green algae. Benthic organisms Nematodes and Polychaetes were there least of the prey items identified from the guts of the species. Other particles such as sand particles, Detritus as well as filamentous green algae were also recorded.

Food Habits of Juvenile Marine Fishes

Food habits of the Family Mugilidae

Monthly data on stomach contents were put together to evaluate the general composition in the stomachs of the species from the

TABLE 1

The size range of marine species in Benya lagoon and Kakum River Estuary

Species	Kakum Estuary		Benya Lagoon	
	TL (mm)	BW (g)	TL (mm)	BW(g)
<i>Sardinella aurita</i>	71-176	28-496	59-109	187-953
<i>Liza falcipinnis</i>	51-200	152-769	53-143	15-285
<i>Liza dumerilli</i>	22-209	176-873	53-197	152-612
<i>Mugil bananensis</i>	44-154	19-356	53-73	185-972
<i>Mugil curema</i>	40-298	12-251	61-167	27-374
<i>Mugil Cephalus</i>	38-174	19-322	42-180	89-258
<i>Lutjanus fulgens</i>	51-160	30-658	4-104	10-170
<i>Lutjanus goreensis</i>	51-158	30-760	32-11	7-154
<i>Lutjanus agennes</i>	51-104	26-192	51-85	22-84

TABLE 2

List of taxonomic groupings of stomach contents of species of the Families Mugilidae, Clupeidae, and Lutjanidae from the estuary and the lagoon

Food items					
Zooplankton	Green algae	Blue-green algae	Benthic Organisms	Diatoms	Others
Crustaceans	Prasiola	Calothrix sp.	Nematodes	Gyrosigma sp.	Sand particles
Dinoflagellates	Schizomeris sp.	Lyngbya sp.	Polychaetes	Diatoma sp.	Detritus
Rotifers	Closterium sp.	Oscillatoria sp.		Cymbella sp.	Red algae
Crustaceans larvae	Spirogyra sp.	Agmellum sp.		Synedra sp.	Filamentous green algae
Annelid larvae	Pediastrum sp.	Chroococcus sp.		Suriella sp.	
Copepods	Stichococcus sp.	Anabaena sp.		Pinularia sp.	
				Navicula sp.	
				Melosira sp.	

family Mugilidae (Fig. 3). This was achieved after identifying differences among the size groups of the selected species as well as their stomach content throughout the period of study. The food items for the species from

both the estuary and the lagoon were similar with slight variation in the proportion of the identified food items. Diatom, detritus, sand particles, zooplankton, and polychaetes occurred to be the most essential food items

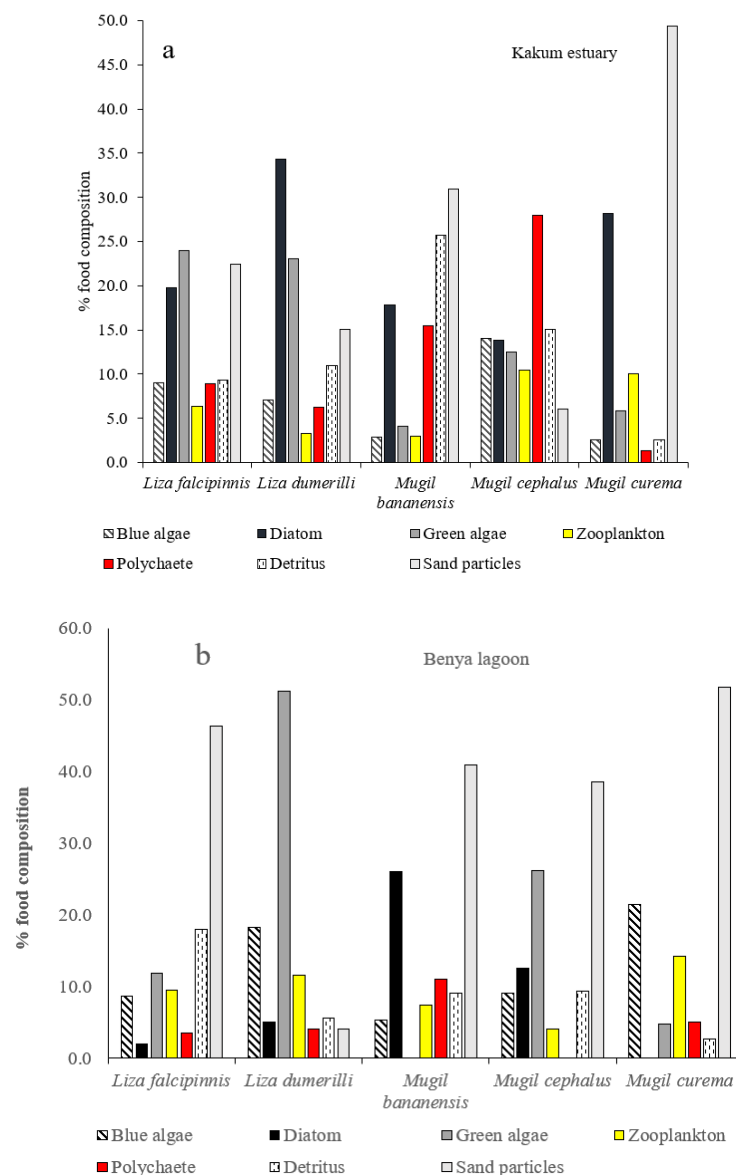


Figure 3 Composition of stomach content of grey mullets from Kakum River Estuary (a) and Benya Lagoon (b)

for the species from the estuary with diatom, Polychaetes, and sand particles forming the most important diet of all the species except in *Mugil bananensis* where green algae occurred to be the less food item. In the lagoon, the most important food items were detritus, blue-green algae, and polychaetes with the exception of polychaetes, green algae and diatom which respectively were absent in the diet of *Mugil bananensis*, *Mugil cephalus* and *Mugil curema*. Nematodes, fish scales, Red

algae, fish eggs, and a few organisms whose composition in the diet were less than 1.3% were not involved in the analysis.

Food Habits of the Family Lutjanidae

Monthly data on stomach contents of *Sardinella aurita*, *Lutjanus fulgens*, *Lutjanus goreensis*, and *Lutjanus agennes* were pooled to assess their total composition (Fig. 4). Diatom, Zooplankton, Detritus, fish, fish fry, crab, shrimp, and other food items were found

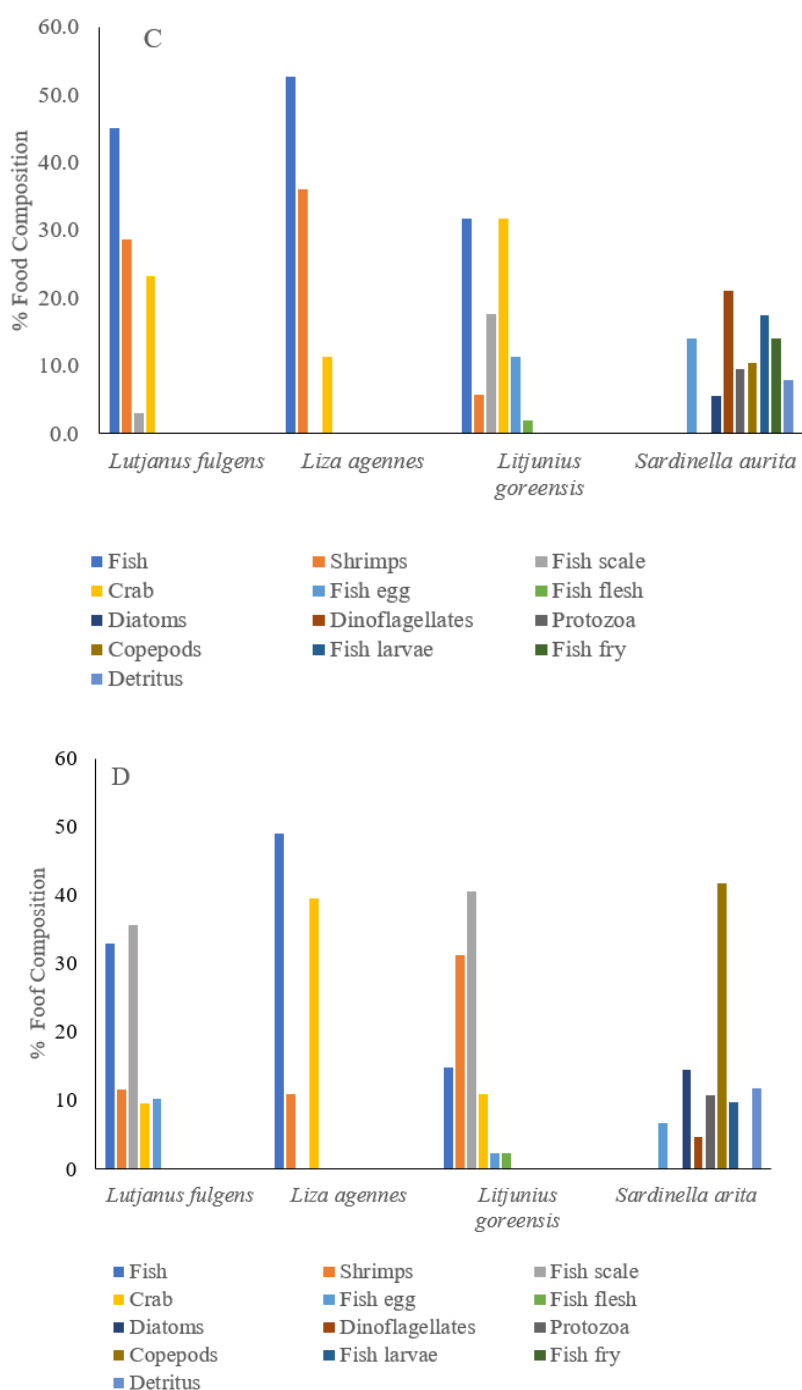


Figure 4 Composition of stomach content of *Sardinella aurita*, *Lutjanus fulgens*, *Lutjanus goreensis*, and *Lutjanus agennes* from Kakum River Estuary (c) and Benya Lagoon (d)

in the stomachs of *Lutjanus fulgens*, *Sardinella aurita*, *Lutjanus goreensis*, and *Lutjanus agennes* from both the estuary and the lagoon. In both the estuary and the lagoon, *Sardinella aurita* occurred to have consumed most of the organisms, while *Lutjanus agennes* consumed the least of the recorded items. Diatom, fish larvae, Copepods, dinoflagellates, fish fry, and detritus, were the essential food items for *Sardinella aurita* caught from both water bodies with occurring to be the lowest. Fish scale, fish egg, Crab, shrimp, and fish were the most consumed food items by *Lutjanus fulgens*, *Lutjanus goreensis*, and *Lutjanus agennes*. The remaining food items found in the diet of the species were less than 10%.

Feeding ecology

The dietary breadth and gut repletion index of the species from Kakum estuary is represented in Table 3. Simpson's index of diversity of the prey items ranged from 0.5 to 0.9 which is approximately 1. A wider food spectrum

was exhibited by *Lutjanus fulgens*, *Lutjanus goreensis*, *Sardinella aurita*, and *Lutjanus agennes* species from the estuary. The species had a broad diet however, *Liza dumerilli* (0.96) and *Mugil curima* (0.94) had the broadest spectrum of diet.

Gut Repletion Index (GRI) showed a moderate feeding intensity for *Liza falcipinnis*, *Mugil curema*, *Sardinella aurita*, *Liza dumerilli*, *Lutjanus agennes*, and *Mugil bananensis* representing 48.4%, 48.2%, 38.1 %, 33.3%, and 30.6% respectively. However, *Liza cephalus* (27%) and *Lutjanus goreensis* (13.1%) exhibited low feeding intensity.

Determination of the dietary breadth and the gut repletion index of the species from Benya lagoon are represented in Table 4. In the lagoon, the prey items from the species according to the Simpson's index of diversity ranged from 0.6 to 0.9 which is closer to 1. A wider food spectrum was exhibited by *Sardinella aurita*, *Lutjanus fulgens*, *Lutjanus goreensis*, and *Lutjanus agennes* species from the lagoon. The

TABLE 3

Dietary breadth (DB) and Gut Repletion Index (GRI) of the species from Kakum estuary

Fish species	Number of guts examined (%)	Non-empty guts (%)	GRI (%)	DB
<i>Sardinella aurita</i>	14.5	14.4	38.1	0.71
<i>Liza falcipinnis</i>	16.4	20.6	48.4	0.67
<i>Liza dumerilli</i>	15.5	15.3	38.0	0.96
<i>Mugil bananensis</i>	12.7	10.0	30.3	0.75
<i>Mugil curema</i>	21.8	27.3	48.2	0.94
<i>Mugil cephalus</i>	5.5	3.8	27.0	0.89
<i>Lutjanus fulgens</i>	5.5	1.9	13.1	0.89
<i>Lutjanus goreensis</i>	5.5	4.3	30.6	0.89
<i>Lutjanus agennes</i>	2.7	2.4	33.3	0.58

TABLE 4

Dietary breadth (DB) and Gut Repletion Index (GRI) of the species from Benya lagoon

Fish species	Guts examined (%)	Non-empty guts (%)	GRI (%)	DB
<i>Sardinella aurita</i>	18.0	23.1	35.0	0.97
<i>Liza falcipinnis</i>	14.4	8.8	16.7	0.81
<i>Liza dumerilli</i>	12.0	13.2	30.0	0.85
<i>Mugil bananensis</i>	12.0	19.8	45.0	0.85
<i>Mugil curema</i>	10.5	13.2	34.3	0.79
<i>Mugil cephalus</i>	4.5	2.2	13.3	0.91
<i>Lutjanus fulgens</i>	10.5	6.5	17.1	0.79
<i>Lutjanus goreensis</i>	9.0	4.4	13.3	0.62
<i>Lutjanus agennes</i>	9.0	8.8	26.7	0.60

species had a broad diet however, *Sardinella Aurita* (0.97) and *Mugil cephalus* (0.91) had the broadest spectrum of diet. *Mugil bananensis* (45.0%), *Sardinella aurita* (35.0%), *Mugil curema* (34.3%), *Liza dumerilli* (30.0%), and *Lutjanus agennes* (26.7%) respectively had high feeding intensity. The remaining species from the lagoon had a low feeding intensity of less than 20%.

Prey species accumulative curves

The cumulative curve of the five (5) species from both the estuary and the lagoon are shown in Figure 5. In a comprehensive term, the prey items consumed by the species *Mugil curema*, *Liza falcipinnis*, and *Mugil bananensis*

reached an asymptote, given the species diet to be adequately characterized in broad terms except for *Liza dumerilli* and *Mugil cephalus* which obtained an insufficient sampling size (Fig 5a). In Benya lagoon, the cumulative curve for *Mugil bananensis*, *Mugil curema*, and *Liza dumerilli* successfully reached a defined asymptote however, the prey curve for the remaining species *Liza falcipinnis* and *Mugil cephalus* failed to reach an asymptote as a result of insufficient sampling size (Figure 5b).

Diel feeding pattern

Changes over time in the average stomach fullness index of grey mullets from the Kakum

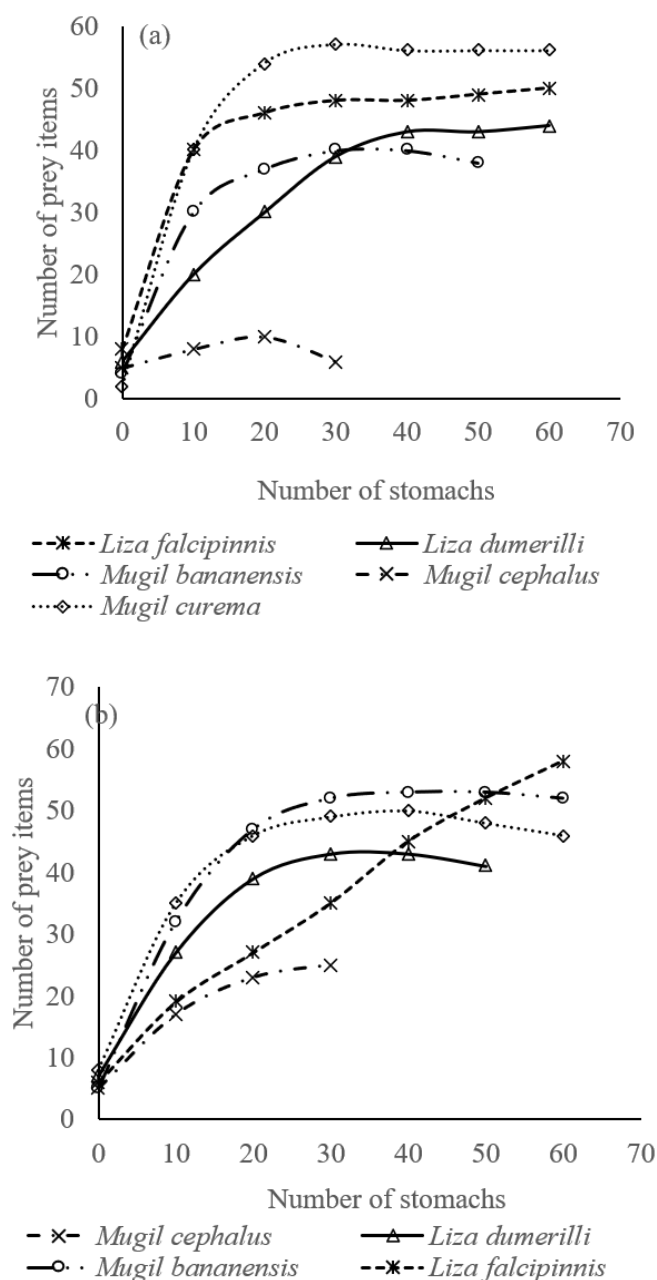


Figure 5 Randomized cumulative prey curves of grey mullet from Kakum estuary (a) and the Banya lagoon (b)

River Estuary throughout 24 hours are shown in Figure. 6. The fish's primary feeding cycle occurred during the diurnal period between the hours of 14:00 and 18:00 GMT for all sampling dates. There was not much or no feeding during the nocturnal period except *Mugil curema* whose feeding activity peaked at 2:00 GMT sampling. The peak feeding activity for *Liza dumerilli*, *Liza falcipinnis*, *Mugil bananensis*, and *Mugil curema* occurred at 14:00 and 18:00 GMT while the peak feeding activity for *Mugil cephalus* occurred at 18:00 GMT during the day for all the sampling dates. Diurnal feeding patterns were observed in all the species, with the primary eating window being between 08.00 and 12.00

GMT. However, each species has a different peak feeding hour.

Discussion

Stomach content analysis is more accurate for dietary analysis of fish species if the size of the sample is large (Amundsen, 2019). Sample sizes were relatively small for some selected fish species, and this was due to the low occurrence of species during sampling. Detailed literature on food habits of some species is inadequate and this affects the proper assessment of feeding activities of fish populations worldwide as well as those in the

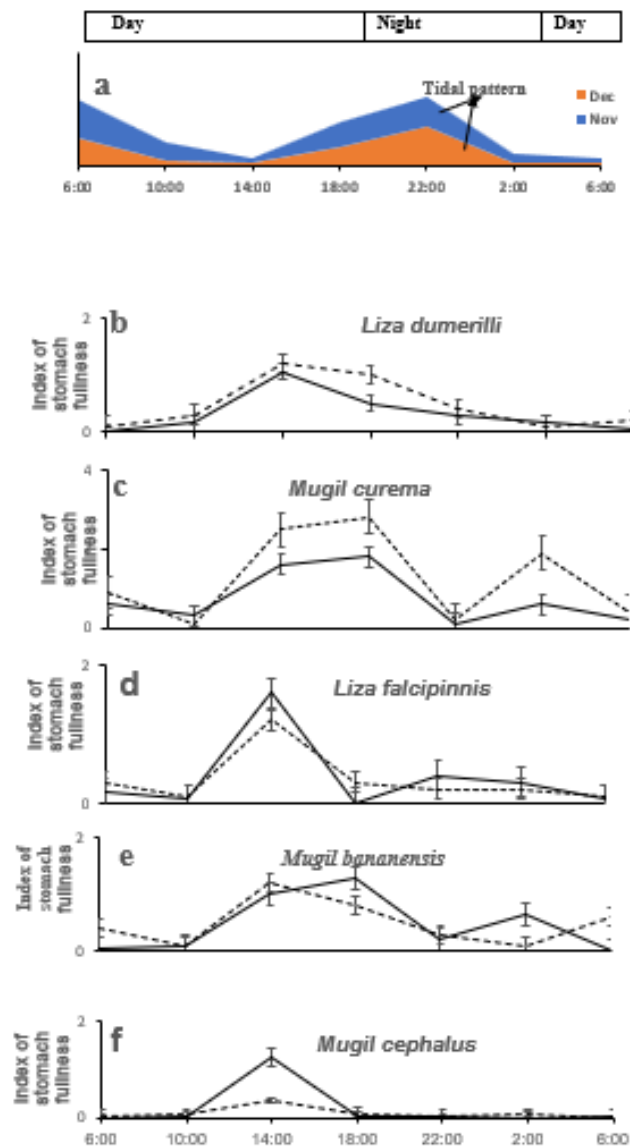


Figure 6 Feeding cyclicality and tidal pattern of grey mullets in Kakum River Estuary during 16-17 November 2016 (---) and 11-12 December 2016 (—). Vertical bars = $\pm$ SE

Benya Lagoon and the Kakum River Estuary. The species from the lagoon and the estuary shared a similar diet, yet minor changes occurred in the proportions of food items recorded. The results indicated that blue-green algae, diatom, detritus, green algae, fish scales, copepods, fish, fish larvae, nematodes, fish flesh, fish egg, protozoa, mollusc, sand, shrimp, crabs, shrimp appendages, annelids, dinoflagellates, and unidentified items were food consumed by the species examined. The results again suggest that possibly, the fish belong to three major eating groups, including the ones that mostly consumed plankton (planktophagous) and these were the Mugilidae, Lutjanidae, Carangidae, and Sciaenidae which occurred to be predatory fishes that specifically fed on extra macroscopic organisms in both water bodies.

In the lagoon and the estuary, the most common foods that the grey mullets consumed were sand particles, algae, detrital material, and diatoms. According to the current study, mullets (Mugilidae) mostly eat diatoms, organic detritus, and sand grains, which is in line with studies conducted in Ghana by Blay (1995) and other parts of West Africa (King, 1988). Because detritus is associated with bacteria and protozoa, it has nutritional value (Azam, 2007). Sand particles, however, were found in the stomachs of every mullet species under investigation and were the main food source found in the stomachs of *Mugil curema* from the lagoon and estuary, forming 49.8% and 21.8% occurrence respectively. The high dietary occurrence of sand and detrital materials might have been picked along with other food items. Ingested sand and debris are said to aid in the breakdown of food particles in the stomach's thick-walled pyloric acid, which functions as a gizzard (Dankwa, 2005). In contrast, the findings of this study support those of Blay (1995a), who examined the diet of young mullet from four different species (*Liza falcipinnis*, *Liza dumerilii*, *Mugil curema*, and *Mugil bananensis*) found in Ghana's Benya lagoon. Once more, grey mullets in the estuary consumed a greater variety of food items than those found in grey mullets in the lagoon.

These differences may be due to variations in the water's production and the variety of food items that the species prefer Bluhm, (2008). Unfavorable factors including salinity and temperature swings in both bodies of water may have hindered the growth of polychaete and nematode communities, which is why the grey mullet from the estuary did not eat them. Nematodes, fish, crab larvae, shrimp, fish scales, and partially digested food items were the main food sources for *Caranx hippos* in the estuary. A minor fraction of the food found in the stomachs of *Caranx hippos* consisted of nematodes. Research on the food and feeding linkages of brackish fish in the lagoon has shown that *Caranx hippos* primarily consumed fish from Lagos lagoon (Fagade and Olaniyan, 1974). According to the authors, the majority of the food that *Caranx hippos* consumed was juvenile clupeids, which primarily consisted of *E. fimbriata* and a few species of cichlids. When compared to *Caranx hippos* taken in the estuary, the outcome is different. Shrimps were the most popular meal among *Caranx hippos* in the estuary, which may have been caused by differences in the study regions and the availability of resources for the species to eat.

Captured from the lagoon and the estuary, *Lutjanus goreensis* was almost exclusively fed shrimp, crab, fish, shrimp appendages, fish eggs, and fish scales. While fish scales and shrimp were the usual foods provided by the species from the lagoon, *Lutjanus goreensis* from the estuary favored eating crabs and shrimp. *Lutjanus fulgens* were observed to ingest partially digested components, fish, shrimp, fish scales, fish eggs, and an unidentified dietary item. In the Kakum River Estuary, *Lutjanus fulgens* mostly consumed shrimp and fish, with fish scales and fish being the most desired food item in Benya Lagoon. Fish, shrimp, fish scales, and crabs were the principal foods consumed by *Lutjanus agennes* in both the estuary and the lagoon. In the estuary, fish and shrimp were the most popular foods consumed by this species, whereas in the lagoon, fish was the only food source.

Sardinella aurita was found to mostly consume detritus, copepods, dinoflagellates, diatoms, and protozoa in both the estuary and the lagoon. In this study, the most popular food item for *Sardinella aurita* from both water bodies was found to be copepods. The result is in line with studies conducted in 2002 by Stergiou and Karpouzi, who found that copepods are the main food source for sardines. Similar observations of debris in *Sardinella aurita*'s diet have been made by Madkour (2012). In addition to detritus, an annual average food composition of *Sardinella aurita* recorded zooplankton–phytoplankton ratio of 3:1, according to Nieland (1982). In the Northeastern Mediterranean, round *Sardinella* were found to have similar eating patterns (Stergiou & Karpouzi, 2002). In some aquatic environments, *Sardinella aurita* is classed as an omnivore with a preference for plankton materials, whereas in other systems, it is classified as a filter-feeder species that prefers animal prey (Nieland, 1982).

For the majority of the items, the highest level of prey identification was noted, and this is the primary factor that most likely has an impact on the species' niche breadth value. According to Greene et al. (2009), level prey identification may potentially devalue species dietary breadth, and this effect also influences the outcomes of IRI. Similarly, the degree of prey identification may overestimate those dietary overlap results (Greene et al., 2009). Concerning Gut Repletion Index (% GRI), a higher proportion of non-empty stomachs were observed in *Sardinella aurita*. This specifies a strong feeding activity which is a result of abundance of food items they consumed. Abdul et al., (2016) stated that high GRI indicates that fish are frequent feeders with higher energy requirements for a sustainable level of feeding intensity. High feeding intensity was detected in *Liza dumerrilli*, *Mugil bananensis*, and *Mugil curema* and *Liza falcipinnis* and *Lutjanus agennes* showed moderate feeding intensity. The low % GRI recorded in *Lutjanus fulgens*, *Lutjanus goreensis*, and *Mugil cephalus* might be attributed to their inability to change

diets due to the minimal abundance of food present in the system. Ogbeibu and Ezenuara (2005) detailed that seasonal variety in food items might influence the feeding intensity, food habits, and diet of fish. This then calls for monitoring of the population structure of the species and the brackish systems for sustainability. Once more, the link between feeding activity and nutrient storage may be the cause of the low GRI (%) (Vaitilingon et al., 2003). As documented by Dankwa et al. (2005) for many other fishes, tides may have affected the diurnal feeding activity of *Mugil cephalus* *Liza falcipinnis*, *Mugil bananensis*, *Mugil curema*, and *Liza dumerilli* from the estuary in the current study in addition to photoperiodicity. Whitfield, (2016), reported that tides and salinity, also influence the feeding capacity of mugilids and Dankwa et al. (2005) recorded higher feeding intensity in grey mullets during high tides. Such a relationship was not however, observed from species in the Elmina lagoon (Blay, 1995). *Liza dumerilli*, *Mugil cephalus*, and *Liza falcipinnis* occurred to be species with high feeding intensity at low tides. However, there was no fixed relation between the feeding activity and tides of *Mugil bananensis* and *Mugil curema*. Peak feeding activity of the species occurred at about the same time in both experimental periods. Some differences occurred in the peak feeding period amongst the species. Dissimilar grey mullet species have been reported to feed on diverse periods (De las Heras et al., 2015, Arechavala-Lopez et al., 2010). Variations in peak feeding periods of grey mullet species in the Kakum River Estuary may perhaps be a possible mechanism for avoiding competition (Cravo, 2021).

Conclusion

Many fish species from the lagoon and estuary had large stomach contents that included shrimp, crabs, and shrimp appendages, as well as blue-green algae, diatoms, detritus, green algae, fish scales, copepods, sand particles, and fish flesh and eggs. With higher feeding

activity recorded during the day and decreased feeding activity at night, the grey mullet showed a clear temporal feeding pattern. These feeding habits may be a tactic used by the fishes to maintain coexistence while avoiding interspecific competition.

Conflict of Interests

The authors declare that they have no conflicts of interests.

Reference

- Abdul, W. O., Omoniyi, I. T., Agbon, A. O., Adeosun, F. I., Olowe, O. S., and Adekoya, E. O. (2016). Food and feeding habits of some fish species in Ogun State coastal estuary, Ogun State, Nigeria. *Journal of Agricultural Science and Environment*, **16**(1); 61-74.
- Ahmed, Q., Yousuf, F., Sarfraz, M., Mohammad Ali, Q., Balkhour, M., Safi, S. Z., and Ashraf, M. A. (2015). *Euthynnus affinis* (little tuna): fishery, bionomics, seasonal elemental variations, health risk assessment and conservational management. *Frontiers in Life Science*, **8**(1); 71-96.
- Allan, J. D., Castillo, M. M., and Capps, K. A. (2021). Stream ecology: structure and function of running waters Nigeria. *Springer Nature*, **2**(35); 101-121
- Amundsen, P. A., and Sánchez-Hernández, J. (2019). Feeding studies take guts—critical review and recommendations of methods for stomach contents analysis in fish. *Journal of Fish Biology*, **95**(6); 1364-1373.
- Arechavala-Lopez, P., Uglem, I., Sanchez-Jerez, P., Fernandez-Jover, D., Bayle-Sempere, J. T., and Nilsen, R. (2010). Movements of grey mullet *Liza aurata* and *Chelon labrosus* associated with coastal fish farms in the western Mediterranean Sea. *Aquaculture Environment Interactions*, **1**(2); 127-136.
- Armstrong, M. J., and Witthames, P. R. (2012). Developments in understanding of fecundity of fish stocks in relation to egg production methods for estimating spawning stock biomass. *Fisheries Research*, **117**(9); 35-47.
- Azam, F., and Malfatti, F. (2007). Microbial structuring of marine ecosystems. *Nature Reviews Microbiology*, **5**(10); 782-791.
- Blay, J. Jr. (1995a.). Food and feeding habits of four species of juvenile mullets (Mugilidae) in a tidal lagoon in Ghana. *Journal of Fish Biology* **46**; 134–141.
- Bluhm, B. A., and Gradinger, R. (2008). Regional variability in food availability for Arctic marine mammals. *Ecological Applications*, **18**(sp2); S77-S96.
- Bolnick, D. I., Svanback, R., Fordyce, J. A., Yang, L. H., Davis, J. M., Hulsey, C. D., and Forister, M. L. (2003). The ecology of individuals: incidence and implications of individual specialization. *Am Nat* **161**; 1–28
- Bolnick, D. I., Yang, L. H., Fordyce, J. A., Davis, J. M., and Svanback, R. (2002). Measuring individual-level resource specialization. *Ecology* **83**; 2936–2941
- Cabral, A. C., Stark, J. S., Kolm, H. E., and Martins, C. C. (2018). An integrated evaluation of some faecal indicator bacteria (FIB) and chemical markers as potential tools for monitoring sewage contamination in subtropical estuaries. *Environmental Pollution*, **235**; 739-749.
- Capenter, K. L. and DeAngelis, N. (Eds) (2014). The complete guide Fish identification: A comprehensive field guide to the identification of the fishes of the world (2nd ed.). Network: Harpercollins Publishers
- Collie, J. S., and Gislason, H. (2001). Biological reference points for fish stocks in a multispecies context. *Canadian Journal of Fisheries and Aquatic Sciences*, **58**(11); 2167-2176.
- Cravo, M. M. (2021). Fish assemblages at Praia Salgada mangrove, Príncipe Island (Gulf of Guinea) (Master's thesis). University of Lisbon, Faculty of Sciences.
- Dankwa, H. R., Blay Jr, J., and Yankson, K. (2005). Food and feeding habits of grey mullets (Pisces: Mugilidae) in two estuaries in Ghana. *West African Journal of Applied*

- Ecology*, **8**(1).
- De las Heras, V., Martos-Sitcha, J. A., Yúfera, M., Mancera, J. M., and Martínez-Rodríguez, G.** (2015). Influence of stocking density on growth, metabolism and stress of thick-lipped grey mullet (*Chelon labrosus*) juveniles. *Aquaculture*, **448**(12); 29-37.
- Elliott, M., Hemingway, K., Costello, M. J., Duhamel, S., Hostens, K., Laropoulou, M., Marshall, S. and Winkler, H.** (2002). Link between fish and other trophic levels. In: Elliott, M and Hemingway, K. (2002). Fish in estuaries. Blackwall, Oxford, 12(89); 124-217
- Froese, R. and Pauly, D. (eds) (2012). FishBase. Revised from <http://www.fishbase.org>
- Fagade, S. O., & Olaniyan, C. I. O.** (1974). Seasonal distribution of the fish fauna of the Lagos Lagoon. *Bull. De I.I. F. A. N. T., Ser. A*, 36(1); 244-252.
- Ferrareze, M., Nogueira, M. G., and Casatti, L.** (2015). Differences in ichthyofauna feeding habits among lateral lagoons and the river channel in a large reservoir, Nigeria. *Brazilian Journal of Biology*, **75**; 380-390.
- Green, B. C., Smith D. J., Earley, S. E., Hepburn, L. J. and Underwood, G. J. C.** (2009). Seasonal changes in community composition and trophic structure of fish populations of five salt marshes along the Essex coastline, United Kingdom. *Estuarine, Coastal and Shelf Science*, **85**(2); 247-256.
- Hammerschlag, N., Ovando, D., and Serafy, J. E.** (2010). Seasonal diet and feeding habits of juvenile fishes foraging along a subtropical marine ecotone. *Aquat Biol.* doi: 10.3354/ab00251. **Vol. 9**; 279–290/b137862
- Heath, M. R., Neat, F. C., Pinnegar, J. K., Reid, D. G., Sims, D. W., and Wright, P. J.** (2012). Review of climate change impacts on marine fish and shellfish around the UK and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **22**(3); 337-367.
- Hureau J. C.** (1966). Biologie comparée de quelques poissons antartique (Nototheniidae). *Bull. Inst. Ocean ogr. Monaco* **68**; 1–244
- Hyslop E. J.** (1980). Stomach contents analysis – A review of methods and their application. *J. Fish Biol.* **17**; 411–429.
- Khan, M. F., and Panikkar, P.** (2009). Assessment of impacts of invasive fishes on the food web structure and ecosystem properties of a tropical reservoir in India. *Ecological Modelling*, **220**(18); 2281-2290.
- King, R. P.** (1988). New observations on the trophic ecology of *Liza grandisquamis* (Valenciennes, 1836) (Pisces: Mugilidae) in the Bonny river, Niger Delta, Nigeria. *Cybium* **12** (1); 23–36.
- Lévêque, C., Paugy, D. and Teugels, G. G.** (1992). Faune des poissons d’eauxouces et sumatres de l’Afrique de l’Ouest (Tome 2). Collection Faune Tropical No. 28, Vol. 1. Paris: ORSTOM et MARC.
- Madkour, F. F.** (2012). Feeding ecology of the round sardinella, *Sardinella aurita* (Family: Clupeidae) in the Egyptian Mediterranean waters. *International Journal of Environmental Science and Engineering*, **2**; 83-92.
- Nagelkerken, I., Dorenbosch, M., Verberk, W. C. E. P., Cocheret de la Morinie`re, E., and van der Velde, G.** (2000b). Importance of shallow-water biotopes of a Caribbean Bay for juvenile coral reef fishes: patterns in biotope association, community structure and spatial distribution. *Mar. Ecol. Prog. Ser.* **202**; 175–192.
- Nagelkerken, I., van der Velde, G., Verberk, W.C.E.P., and Dorenbosch, M.** (2006). Segregation along multiple resource axes in a tropical seagrass fish community. *Mar. Ecol. Prog. Ser.* **308**; 79–89.
- Nieland, H.** (1982). The food of *Sardinella aurita* (Val.) and *Sardinella eba* (Val.) off the coast of Senegal. *Rapportset procès-verbaux des reunions conseil international pour l’exploration de la mer*, **180**; 369-373.
- Ovenden, J. R., Berry, O., Welch, D. J., Buckworth, R. C., and Dichmont, C. M.** (2015). Ocean's eleven: a critical evaluation of the role of population, evolutionary and molecular genetics in the management of wild fisheries. *Fish and Fisheries*, **16**(1); 125-159.
- Pallaoro, A., Santic, M., and Jardas, I.**

- (2006). Feeding habits of the common two-banded sea bream, *Diplodus vulgaris* (Sparidae), in the eastern Adriatic Sea. *Cybium*, **30**(1); 19-25.
- Pitcher, T. J.** (2001). Fisheries managed to rebuild ecosystems Reconstructing the past to salvage the future. *Ecological applications*, **11**(2); 601-617.
- Richardson, J. S., and Danehy, R. J.** (2007). A synthesis of the ecology of headwater streams and their riparian zones in temperate forests. *Forest Science*, **53**(2), 131-147.
- Stergiou, K. I. and Karpouzi, V. S.** (2002). Feeding habits and trophic levels of Mediterranean fish. *Reviews in fish biology and fisheries*, **11**; 217-254.
- Verdyck, P., and Desender, K.** (2003). Mono- and oligophagous Phyllotreta (Coleoptera: Chrysomelidae) species: the relation between host plant range and genetic diversity. *Belgian journal of zoology*, **133**(1); 71-76.
- Verweij, M.C., Nagelkerken, I., Wartenbergh, S.L.J., Pen, I.R. and van der Velde, G.** (2006). Caribbean mangroves and seagrass beds as daytime feeding habitats for juvenile French grunts, *Haemulon flavolineatum*. *Marine Biology*. **149**; 1291-1299.
- Young, J. L., Bornik, Z. B., Marcotte, M. L., Charlie, K. N., Wagner, G. N., Hinch, S. G., and Cooke, S. J.** (2006). Integrating physiology and life history to improve fisheries management and conservation. *Fish and Fisheries*, **7**(4); 262-283.