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Comparative Analysis on Feeding Habits of Two Estuarine Fishes in Aby Lagoon, Southeastern Côte d'Ivoire

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ABSTRACT

The present study focused on the feeding of two estuarine fish species *Monodactylus sebae* and *Citharichthys stampflii* in Aby lagoon to detect similarity and differences in feeding habits. The diets of both species were examined during March 2012 and February 2013. Fish were sampled monthly using gillnets of different mesh sizes. Main Food Index (MFI) was used to express diet and nonparametric statistical tests were applied. Total number of analyzed stomachs was 67 for *M. sebae* from 55 to 170 mm Total Length (TL) and 53 for *C. stampflii* ranging from 68 to 172 mm TL. Results indicated that *C. stampflii* share a general diet based on fishes and shrimps while *M. sebae* fed aquatic insects, plankton, Annelids and terrestrial arthropod (Arachnida) in addition. The overlap index indicated that the diets of both species are not overlapping, although they fed on fish and crustaceans. Seasonal variations of diet showed a similarity for each species. Juveniles fed mostly small prey while adults fed on larger prey such as fish, however, no significant difference was observed. It may concluded that *M. sebae* can be categorised as omnivorous with piscivorous tendancy while *C. stampflii*, strictly piscivorous.

INTRODUCTION

The lifecycles of many coastal fish species are closely associated with estuaries, lagoons and salt marshes (Laffaille *et al.*, 2001).[1] Several marine species perform tidal feeding migrations from estuaries and lagoons, where they find abundant potential prey items (Elliott *et al.*, 2002).[2] The natural habitats offer a great diversity of organisms that are used as food by fish, which differ in sizes and taxonomy groups. Food is the main source of energy and plays an important role in determining the abundance of population, rate of growth and condition of fishes. The food and feeding habits of fish vary with time of day, season, species and size of the fish with different food substances present in the water body and its ecological factors (Royce, 1972).[3]

Estuarine fishes *Monodactylus sebae* (Cuvier, 1829) and *Citharichthys stampflii* (Steindachner, 1894) as regular components of the icthyofauna in coastal Aby lagoon (Charles-Dominique, 1993; Koffi *et al.*, 2014).[4-5] *M. sebae* is very common in estuaries and lagoons where reproduction takes place, marshes and lower courses of rivers, sometimes ascending over long distances into freshwater (Froese and Pauly, 2000).[6] *C. stampflii* occurs in coastal waters and brackish water of estuaries and lagoons, also ascending rivers and entering freshwater (Froese and Pauly, 2000).[6] Koffi *et al.* (2014)[5] reported that *M. sebae* is estuarine resident and *C. stampflii* is estuarine dependant marine fish in Aby lagoon. Both species feed on common base of food resources formed by small benthic-pelagic fishes and invertebrates (Froese and Pauly, 2000).[6] Therefore, the coexistence of both species poses an important research question related to trophic niche overlap.

Evidence from a variety of systems indicate that the same food resource may be shared by numerous species and that each specie may successively exploit several different resources during the year (Knöppel, 1970).[7] However, other reports indicate the opposite (Moyle and Senanayake 1984; Winemiller, 1989)[8-9]. No reports are available on dietary breadth, overlap and feeding strategy of both estuarine fishes in west African. However, Accurate description of fish diets and feeding habits also provides the basis for understanding trophic interactions in aquatic food webs (Paugy and Lévêque, 2006).[10] The present study aims to provide information on the diet composition, food overlap and feeding strategy among both species inhabiting in Aby lagoon.

MATERIALS AND METHODS

Samples area

Aby lagoon system is located in South East of Côte d'Ivoire (5°05'- 5°22' N, 2°51'-3°21'W), and forms a natural border between Côte d'Ivoire and Ghana (Figure 1). It's extends over 30 km of the coastline and covers an area of 424 km², with a mean depth of 3.5 m and width of 5.5 km (Seu-Anoï *et al.*, 2011).[11] The vegetation is dominated by mangrove forest and palm tree plantation. Aby lagoon complex is lined with mangroves and communicates with the sea by the Assini channel. It is supplied with freshwater inputs by the river Bia in the northwest and Tanoe in the East. Hydrological seasons of Aby lagoon are characterized by two rainy seasons (Mai-July and October-November) and two dry seasons (August- September and January-April) (Konan *et al.*, 2014).[12]

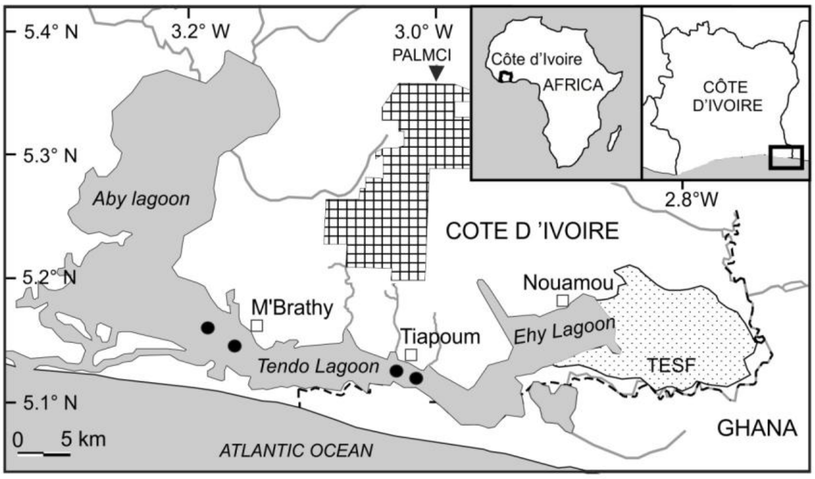


Figure 1: Map of Aby lagoon showing different sampling sites (•).

Sampling and laboratory examination

Fishes were collected monthly in Aby lagoon from March 2012 to February 2013 using gillnets of different mesh sizes (8, 10, 14, 20, 25 and 35 mm). Sampled fish were taken to the laboratory where they were identified by referring to Paugy *et al.* (2003)[13] and TL were measured. Stomachs were removed and contents preserved in 5% formalin solution for later identification. Stomach contents were examined using a binocular dissecting microscope and each food item was identified to the lowest possible taxonomic level following Moor & Day (2002)[14] and Tachet *et al.* (2010).[15]

The relative importance of each food category in the diet was expressed after Hyslop (1980)[16] as percentage of numerical abundance (N), frequency of occurrence of food items in stomachs (F) and weight (W). The frequency of occurrence (F) was the percentage of the total number of stomachs in which the particular prey species occur: %F = (FOi/FOt) x 100; where FOi is the number of stomachs in which the item species occurs, and FOt is the total number of stomachs analysed (Hyslop, 1980)[16]. MFI (Zander, 1982)[17] was calculated to get a better grasp of the importance of food items for each species, using the following equation :

$$MFI = [W (N + F) / 2]^{1/2}$$

This index was improved by Rosecchi and Nouaze (1987)[18] where MFI was summed and for each prey item was expressed as the ratio of the total, following the classification: main prey: MFI > 50%; secondary prey: 10% ≤MFI< 50% and accessory prey: MFI < 10%.

According to Lawson *et al.* (2013)[19], three size group of *M. sebae* identified: small (50-80), medium (90-140) and large (150-160) mm TL. In the present study, to analyze ontogenetic changes, *M. sebae* were classified into two groups based on their total length as follows: small-(TL <90 mm) and large (TL ≥ 90 mm). For *C. stampflii*, the smallest individuals are TL <120 mm and largest are TL ≥120 mm (Dias *et al.*, 2005; Sánchez-Gil *et al.*, 2008).[20-21]

Data analysis

Food overlap between species has been calculated, using the overlap measure of Horn (1966).[22]

$$C_\lambda = \frac{2\sum_{i=1}^{S} X_i Y_i}{\sum X_i^2 + \sum Y_i^2}$$

Where S is the total number of food categories and *Xi* and *Yi* are the proportion of total diet of species *X* and *Y* taken from a given category of food *i*. Food overlap values superior than 0.60 are considered to be biologically significant (Zaret and Rand, 1971).[23]

To assess the feeding strategy along the studied period, the modified Costello (1990) graphical method (Amundsen *et al.*, 1996)[24] was used. In this method, the prey-specific abundance (%Pi) (y-axis) was plotted against the frequency of occurrence (F) (x-axis). The prey-specific abundance (Pi) has been expressed as:

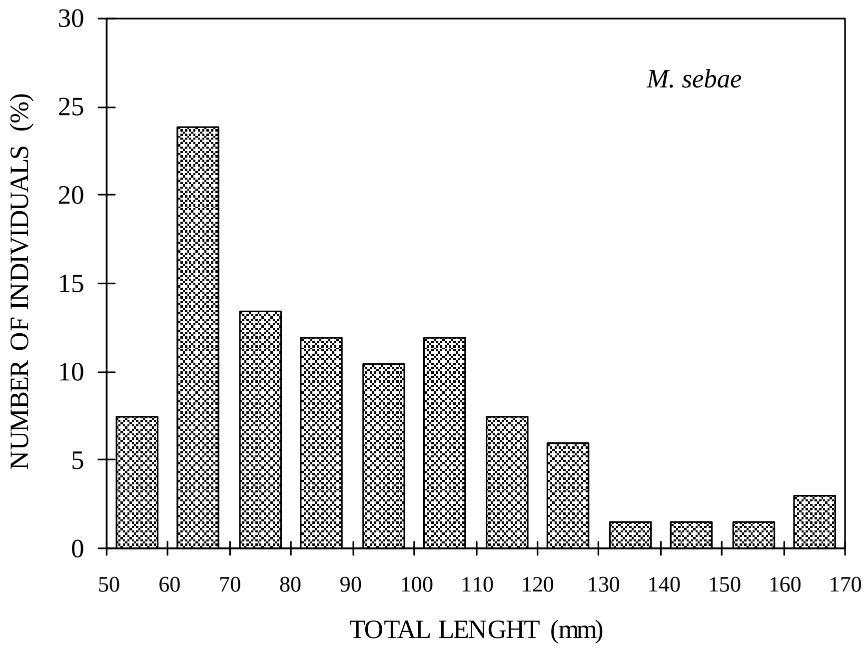
$$\%Pi = \frac{\sum Si}{\sum Sti} * 100$$

Intraspecific seasonal and ontogenic changes in diet were evaluated using the non-parametric Kolmogorov-Smirnov two sample test (D). The diets among both species were compared by a chi-square analysis.

RESULTS

Lenght-frequency distribution

Figure 2 presents histograms of length frequency distribution of *M. sebae* and *C. stampflii*. A Total of 67 specimens of *M. sebae* were analysed and ranged from 55 and 170 mm TL, with the overall mean was 88.6 mm; smaller (TL <90 mm) and larger individuals constituting average 57 % and 43% % of total catch respectively. The length groups [60 - 70[and [70 - 80[were dominant in the catch (23.89% and 13.43%, respectively) and the histogram exhibited binomial distribution. The total number of *C. stampflii* was 53 and samples ranged from 68 and 172 mm TL with the mean length was 134.6 mm. Larger individuals (TL ≥120 mm) dominated samples (83%) and one mode were recorded. The most dominant length groups were [130 - 140[and [140 - 150[, with a numerical percentage of 16.98 and 30.19, respectively. From these histograms, we can also see that the biggest length groups are poorly represented in the catch of *M. sebae* as opposed to *C. stampflii*.



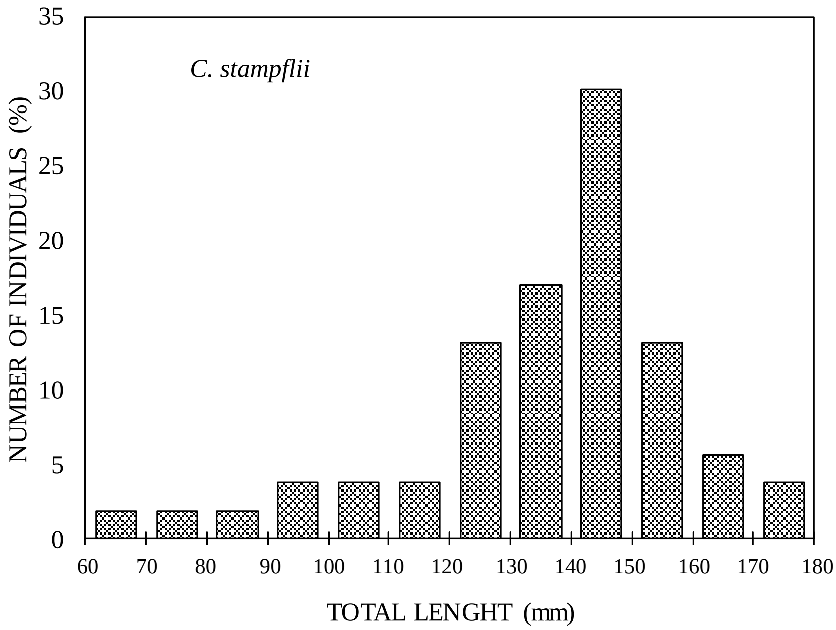


Figure 2: Percentage length–frequency distribution of *M. sebae* and *C. stampflii* in Aby lagoon

General diet composition

A total of 3 and 13 distincts items preys were respectively found in stomach for *C. stampflii* and *M. sebae* **(Table 1)**. The diet of *M. sebae* was composed mainly of fish (MFI = 60.33%) with an important contribution of *Pellonula leonensis*. Insects pertained four families and Chironomidae are mostly common items in stomachs (F = 17.65). By numeric proportion, Cyclopidae comprised 92.28%, with *P. leonensis* and *Chironomus* sp. as other important items in stomach contents**.** Although numeric percentage of Plankton was high, contrary to the Frequency of occurence.

The main components in the diet of *C. stampflii* were fish (MFI = 98.88%). Regarding crustaceans, only shrimps *Atya* sp. were found in stomachs. The fish preys, *P. leonensis* are the most common (F = 92.11). MFI values indicated that *P. leonensis* and *Hemichromis fasciatus* were the main preys for both species. In *M. sebae*, insects and crustaceans were secondary preys, and others were accessory, whereas shrimp is an incidental prey in *C. stampflii*. Chi-square analysis detected significantly differences in fish preys (Chi-square = 46.66; ddl = 1 ; $p<0.05$) and crustaceans (Chi-square = 21.67 ; ddl = 1 ; $p<0.05$) between both species.

Table 1: Frequency of occurence (F), numeric percentage (N), weight percentage (W) and Main Food Index (MFI) of the taxa in stomach contents of *M. sebae* and *C. stampflii* captured in Aby lagoon.

			M sebae					*C stampflii*				
Items preys		**Preys number**	**F**	**N**	**W**	**MFI**	**%MFI**	**F**	**N**	**W**	**MFI**	**%MFI**
Fish						**41.08**	**60.33**				**97.31**	**98.88**
	Pellonula leonensis	P1	38.35	3.3	54.36	33.65		92.11	76.49	90.2	87.2	
	Hemichromis fasciatus	P2	5.88	0.58	17.15	7.44		4.63	16.75	9.56	10.11	
Insects						**15.04**	**22.09**					
	Chironomus sp.	P3	17.65	1.47	1.49	3.77		–	–	–	–	
	Ceriagrion sp.	P4	8.82	0.78	4.12	4.45		–	–	–	–	
	Elmis sp.	P5	5.88	0.32	5.22	4.02		–	–	–	–	
	Potamanthus sp.	P6	4.41	0.45	3.23	2.8		–	–	–	–	
Crustaceans						**7.34**	**10.78**				**1.1**	**1.12**
	Atya sp.	P7	5.88	0.32	10.22	5.63		3.26	6.75	0.24		
	Asellus sp.	P8	2.94	0.19	1.9	1.72		–	–	–	–	
Plankton	Cyclopidae	P9	1.47	92.28	0.14	**2.5**	**3.76**	–	–	–	–	
Annelids						**1.5**	**2.2**					
	Nereis sp.	P10	2.94	0.13	0.03	0.21		–	–	–	–	
	Tubifex sp.	P11	1.47	0.06	0.03	0.15		–	–	–	–	
	Hirudo medicinalis	P12	1.47	0.06	1.69	1.14		–	–	–	–	
Arachnids	Tetragnathidae	P13	1.47	0.06	0.42	**0.57**	**0.84**	–	–	–	–	
Other	Sand	P14	1.37	–	–	–						

Seasonal variation in diet composition

The food composition in relation to season is presented in Table 2. Results indicated that *P. leonensis* and *H. fasciatus* were the main preys (MFI>50%), aquatics insects were secondary preys. Crustaceans were secondary preys (%MFI=18.65) in stomach of *M. sebae* in rainy season while they represented incidental preys in dry season. Cyclopidae and Tetragnatidae were not observed during rainy season while *Tubifex* sp. and *H. medicinalis* were present. For *C. stampflii*, Shrimps *Atya* sp. and *Asellus* sp. were not observed in stomach content during dry season.

No significantly differences in diet of *M. sebae* according both seasons (Kolmogorov-Smirnov test, D=59.78 ; p>0.05), as well as *C. stampflii* (D=99.32 ; p>0.05). On the other hand the feeding pattern was not significantly different between *M. sebae* and *C. stampflii* in rainy season (Chi-square = 115.11, ddl = 5, p < 0.0001) and dry season (Chi-square = 15.48, ddl = 5, p < 0.0001).

Table 2: Seasonal food composition of *M. sebae* and *C. stampflii* in Aby lagoon.

		M. sebae				*C. stampflii*			
		Dry		Rainy		Dry		Rainy	
Items preys		**MFI**	**%MFI**	**MFI**	**%MFI**	**MFI**	**%MFI**	**MFI**	**%MFI**
Fish		**52.41**	**60.66**	**35.68**	**58.91**	**99.88**	**100**	**97.69**	**98.64**
	Pellonula leonensis	36.42		31.29		93.17		90.94	
	Hemichromis fasciatus	15.99		4.39		6.71		6.75	
Insects		**22.02**	**25.49**	**12.33**	**20.36**				
	Chironomus sp.	6.46		2.24					
	Ceriagrion sp.	6.69		3.59					
	Elmis sp.	1.14		6.29					
	Potamanthus sp.	7.73		0.21					
Crustaceans		**8.19**	**9.48**	**7.85**	**13**			**1.35**	**1.36**
	Atya sp.	4.08		7.58		–	–	1.35	
	Asellus sp.	4.11		0.27					
Plankton	Cyclopidae	–	–	**3.44**	**5.68**				
Annelids		**3.78**	**4.37**	**0.21**	**0.35**				
	Nereis sp.	0.31		0.21	0.35				
	Tubifex sp.	0.41		–					
	Hirudo medicinalis	3.06		–					
Arachnids	Tetragnathidae	–		**1.05**	**1.73**				

Food in relation to fish size

The contribution of each size classes, expressed as percentages of total MFI are given in **table 3**. Total number of analyzed stomachs in small and large specimens was for *M. sebae* was respectively 38, 29 and 9, 39 individuals for *C. stampflii*.

Results indicate that no items were main preys (MFI<50%) in smallest specimens of *M. sebae*; fish and insects were secondary preys while crustaceans, plankton and annelids were accessory. But the larger specimens fed mainly fish preys, *P. leonensis* and *H. fasciatus* (MFI=62.34%). Kolmogorov-Smirnov test indicated no significantly differences in diet of small and large specimens of *M. sebae* (D= 58,20 ; p> 0.05), and both size classes of *C. stampflii* (D=80.06 ; p> 0.05). Similarly, Chi-square test revealed no difference between fish prey and crustaceans in both species.

Table 3: Size-dependent variation in diet composition of *M. sebae* and *C. stampflii* in Aby lagoon. MFI = Main Food Index.

		M. sebae				*C. stampflii*			
		Dry		Rainy		Dry		Rainy	
Items preys		**MFI**	**%MFI**	**MFI**	**%MFI**	**MFI**	**%MFI**	**MFI**	**%MFI**
Fish		**52.41**	**60.66**	**35.68**	**58.91**	**99.88**	**100**	**97.69**	**98.64**
	Pellonula leonensis	36.42		31.29		93.17		90.94	
	Hemichromis fasciatus	15.99		4.39		6.71		6.75	
Insects		**22.02**	**25.49**	**12.33**	**20.36**				
	Chironomus sp.	6.46		2.24					
	Ceriagrion sp.	6.69		3.59					
	Elmis sp.	1.14		6.29					
	Potamanthus sp.	7.73		0.21					
Crustaceans		**8.19**	**9.48**	**7.85**	**12,97**			**1.35**	**1.36**
	Atya sp.	4.08		7.58		–	–	1.35	
	Asellus sp.	4.11		0.27					
Plankton	Cyclopidae	–	–	**3.44**	**5.68**				
Annelids		**3.78**	**4.37**	**0.21**	**0.35**				
	Nereis sp.	0.31		0.21	0.35				
	Tubifex sp.	0.41		–					
	Hirudo medicinalis	3.06		–					
Arachnids	Tetragnathidae	–		**1.05**	**1.73**				
Other	Sand	–		–	–				

Diet overlap and feeding strategy

Overlap indices of general dietary of both species was 0.56 and showed some variations according to season and size class of specimens. This index was 0.53 and 0.59 for rainy and dry seasons respectively, then 0.31 and 0.42 for juveniles and adults, respectively. Dietary overlap indices revealed that *M. sebae* and *C. stampflii* had no biologically significant interspecific overlap.

Analysis of feeding strategy, based on the Amundsen's method, showed that both species had a different feeding strategy, with varying degrees of specialization and generalization on different prey types (Figure 3). When compared with *C. stampflii, M. sebae* had a higher opportunism in its feeding strategy, showing occasional consumption of prey such as Atya sp., Chironomus, Nerieis sp. etc. In terms of prey importance, *P. leonensis* (P1) was the most important with *H. fasciatus* being low abundance in the diet of *C. stampflii*.

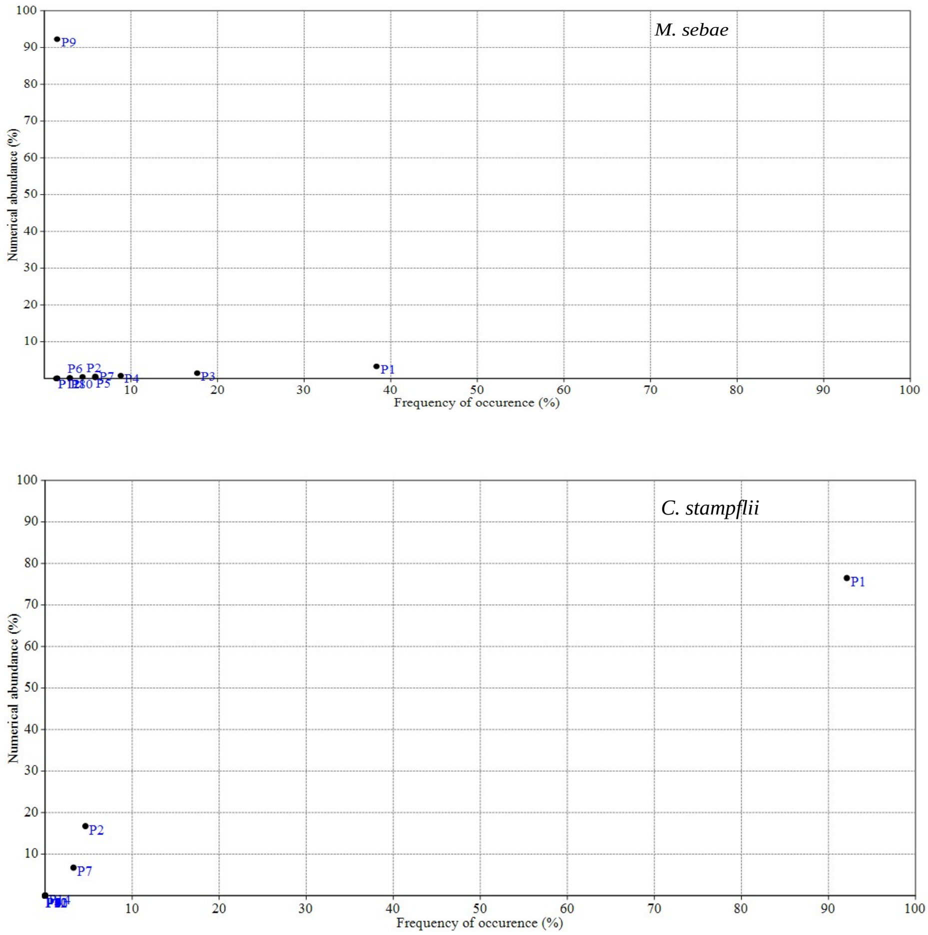


Figure 3: Feeding strategy diagram of *Monodactylus sebae* and *Citharichthys stampflii* in Aby lagoon. The black dots represent different food items; see Table 1 for items number.

DISCUSSION

The results indicated that small individuals dominated samples of *M. sebae* (89±27 mmTL) while large ones dominated captures of *C. stampflii* (140±16 mmTL). The dominance of large individuals could be related to differences in habitat preference according to size (Chande and Mhitu, 2005)[25]. One of the possible explanation could be swimming ability; larger individuals can resist adverse conditions. Presence of adult and large numbers of juveniles may be related to migratory nature of both species and suggest that the Aby lagoon serves as a veritable spawning, breeding or feeding ground for some fish (Lawson *et al.*, 2013).[19]

The present study showed that *M. sebae* fed on 13 prey items composed mainly fish (*P. leonensis* and *H. fasciatus*), followed by insects and crustaceans. This reflects an omnivorous diet with a piscivorous tendency. Feeding habits of *M. sebae* in other ecosystems has shown similar results. For example, Faye *et al.* (2012)[26] indicated an omnivorous diet with piscivorous tendency, composed of fish, plant materials, insects, crustaceans, zooplankton, mollusks in a tropical estuary (Senegal). On the other hand, an omnivorous diet of same species based in plant material, diatoms, detritus was found in the cross river estuary, Southeast Nigeria (Udoh and Ekpoh, 2017)[27]. The absence of fish preys in the diet of these individuals contrasts with the results of the present study. These results may be related to the availability of food resources in the environment (Paugy and Lévêque, 2006).[10] *M. sebae* seems to be opportunistic adapting to the resources of the environment. This difference may be linked to a spatial variability in food availability in relation to habitat (Gning *et al.*, 2010).[28] Indeed Kouadio *et al.* (2008)[29] showed the existence of uneven distribution of structure and taxa richness of invertebrate assemblages along Aby lagoon with both salinity and seasons. The analysis of stomach contents of *C. stampflii* showed 3 prey items, *P. leonensis*, *H. fasciatus* and Atya sp., indicating a piscivorous diet in Aby lagoon because of shrimps was accessory prey. Similarly, a carnivorous diet composed of polychaetes and crustaceans was found in *Citharichthys spilopterus* from Louisiana estuary (Toepfer and Fleeger, 1995).[30]

Seasonal variation showed no significant differences in diet with seasons. However, plankton and terrestrial prey such as Tetragnatidae appeared in stomachs of rainy season in *M. sebae*. Our observations suggest that the low predation on aquatic insects and plankton in rainy season is compensated by an increase in consumption of allochthonous matter (Aracnhids). This is in agreement with arguments of Welcomme (1985)[31] about the temporal diet plasticity of tropical fishes. However, in contrast to other reports that indicate the importance of allochthonous food throughout the year, the results showed that allochthonous foods are important only in rainy season. As an implication, alteration of terrestrial environment can have a negative effect on food resource for fishes. Similar results were obtained in *C. stampflii* where shrimps were only obtained in stomachs of rainy season.

Ontogenic variations in diet were also observed in both species. *P. leonensis* and *H. fasciatus* are secondary prey in juveniles of *M. sebae*, whereas they become predominant in adults. Some preys such as zooplankton are only observed in stomachs contents of juveniles. Similar observations were observed in *C. stampflii* for fish preys. Also, shrimps were abundant in stomachs of juneniles while they are consumed occassionally by adults. As specimens become larger, invertebrates play lesser role in their diets and fish adopt a more piscivorous feeding behavior narrowing their food spectra. A similar result has been found for species of genus *Monodactylus* and *Citharichthys* by other authors (Toepfer and Fleeger, 1995; Gning *et al.*, 2008)[30-32] and other species (Scharf *et al.*, 2000; Pessanha and Araujo, 2014).[33-34] A transition from invertebrates to fishes in diet is probably driven largely by the constraints of mouth size on prey capture ability (Wainwright and Richard, 1995).[35] It is in agreement with the optimum foraging theory, which states that with an increase in size, predators tend to consume heavier prey, thus maximizing the energetic gain relative to capture effort (Duarte and Garcia, 1999).[36]

In the present study, the similarity index indicated a low overlap between general and seasonal diets of both species. This overlap is even lower in juveniles than in adults. Dietary overlap is affected by food availability, competition, and the size of the fish, among other factors. Though fish may broaden their dietary breadth when food resources are scarce, food items may remain sufficiently partitioned for competition to be avoided (Keast and Fox, 1990).[37] The reduction of diet overlap in small individuals may be a consequence of a general reduction in predation on fish preys. Insignificant intraspecific dietary overlap between both species reflects a food resource partitioning in the lagoon. Resource partitioning may also occur in size, since small individuals are feeding small preys while large individuals are feeding bigger preys. The feeding strategy suggested a marked variation in the diet of both fishes. Individuals of *M. sebae* had a more diverse diet in terms of prey richness, whereas *C. stampflii* seemed to concentrate mainly on fish preys, mainly *P. leonensis* and *H. fasciatus*. Such differences suggest *C. stampflii* are more mobile and active within Aby lagoon than *M. sebae* due to their larger size class and body morphology. Indeed Monodactylidae are fishes deep-bodied, strongly compressed while Paralichthyidae are fishes with flat and asymetric bodies (Paugy *et al*, 2003).[13]

CONCLUSION

The present study showed clear difference in diet composition among both species. Interspecifc differences in diet composition result from variations in the proportion of fish prey, crustaceans and others. These results indicate a more piscivorous habit in *C. stampflii* compared to *M. sebae*. Ontogenetic changes in diet of both species towards larger preys as fishes grow have also played a fundamental role to reduce interspecifc competition.

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