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RELATIONSHIPS BETWEEN DIET AND ENVIRONMENTAL PARAMETERS FOR CASSAVA CROAKER IN CONTINENTAL SHELF WATERS OF CÔTE D'IVOIRE

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ABSTRACT

Identifying the dietary niche of aquatic predators is essential to understanding the structure of aquatic ecosystems. Dietary analysis is key to formulation of a feeding strategy and the breadth of a predator's diet. The objective of this study was to evaluate the diet of cassava croaker (*Pseudotolithus senegalensis*) off the Ivorian coast, characterised by different hydrological regimes, as an entry point for this species' acclimation. Diets and feeding intensities of cassava croaker were evaluated through analysis of the stomach contents of fish collected monthly, off the Ivorian continental shelf water, during January 2014 to December 2015. A total of 1, 238 fish stomachs were analysed, 551 (44.50%) emptied and 687 (55.50%) contained preys. Six different prey species belonged to three groups, namely crustaceans, fishes and cephalopods and were identified as cassava croaker stomach contents. The preponderance index indicated that crustaceans were the main food of cassava croaker. Crustaceans dominated 85% frequency of occurrence. The diets varied significantly with fish size; young ones (months after) preyed on crustaceans; whereas larger fishes (LS > 20.45 cm) preyed on both crustaceans and fishes.

Keys Words: Crustaceans, Ivorian coast, *Pseudotolithus senegalensis*

RÉSUMÉ

La compréhension des relations trophiques dans les populations de poissons est limitée en raison d'une connaissance insuffisante du régime alimentaire des principales espèces. Cette étude porte sur *Pseudotolithus senegalensis* qui est une des espèce marine a un intérêt économique en Côte d'Ivoire. Le but de cette étude était d'analyser la variabilité qualitative et quantitative du régime alimentaire de cette espèce en fonction de la taille et des saisons marines. Le régime alimentaire de *Pseudotolithus senegalensis* a été examiné mensuellement dans les eaux du plateau continental ivoirien de janvier

2014 à décembre 2015. Sur un total de 1 238 estomacs analysés, 551 étaient vides (44,50 %) et 687 contenaient des proies (55,50 %). L'indice de prépondérance a été calculé. Six proies ont été identifiées et regroupées en trois entités à savoir les crustacés, les poissons et les céphalopodes. Le régime alimentaire de *Pseudotolithus senegalensis* est dominé par les crustacés fréquence d'occurrence de 85 %. Le régime alimentaire *P. senegalensis* varie considérablement avec la taille. Les juvéniles se nourrissent de crustacés tandis que les plus adultes (LS > 20,45 cm) se nourrissent de crustacés et de poissons.

Mots Clés : Crustaceans, Ivorian coast, *Pseudotolithus senegalensis*

INTRODUCTION

Identifying the dietary niche of aquatic predators is essential to understanding the structure of aquatic ecosystems and for identifying the feeding regime of commercial fishes, to identify habitats or sites of higher fish multiplication for successful commercial capture (Amundsen *et al*., 1996; Smith *et al*., 2011).

The Ivorian coast is a habitant for many economically important fish species such as *Pseudotolithus senegalensis*; one of the Ivorian coast demersal resources. It forms part of the trawl fishery catch in the Ivorian coast and belongs to the family Sciaenidae. It inhabits soft muddy sandy bottoms, at depths of 15-70 m (Seret, 2011). *Pseudotolithus senegalensis* is widely distributed along the coast of tropical West Africa, particularly from Senegal to Angola (Edwards *et al*., 2001).

Pseudotolithus senegalensis is highly valued as fish-food in Côte d'Ivoire (Tia, 2014), and contributes 9% to the fishery trawler of the Ivorian continental shelf (FAO, 2008). In West Africa and Côte d'Ivoire in particular, little information is available on this species on biology and population dynamics (Sylla *et al*., 2016; Tia *et al*., 2017).

Due to long term exploitation of fishery resources of the Ivorian coast, the feeding habit of *P. senegalensis* in the coast could have changed. The objective of this study was to evaluate the diet of cassava croaker (*Pseudotolithus senegalensis)* off the Ivorian coast, as an entry point for acclimation of this species'.

MATERIALS AND METHODS

Study area. This study was conducted in the Ivorian continental shelf, which covers approximately 11,000 Km^2 and extends to about 570 Km length (Pottier and Anoh, 2008). It is influenced by four marine's seasons; two cold and two warm seasons (Soro *et al*., 2009). A minor cold season occurs from December to January; while the main cold season lasts from July to September. The major warm season extends from February to June; while the minor warm season occurs from October to November. The period from July to October corresponds to the Great upwelling; while a minor upwelling is usually observed between January and February (Soro *et al*., 2009).

Collection of specimens. A total of 1,238 specimens of *P. senegalensis* were collected during January 2014 to December 2015, from commercial catches at the fishing harbor from the industrial bottom trawlers and artisanal at the autonomous port of Abidjan. The samples were packaged under ice and transported to the research laboratory for preservation in a deep freezer at -20 °C prior to analysis for the diet of the cassava croaker.

Environmental variables. The environmental variables considered for dietary analysis included sea surface temperature (SST) and sea surface chlorophyll a concentration (the latter as an indicator of productivity). The data so obtained were derived from satellite imagery (http://oceancolor.gsfc.nasa.gov). Mean

values of the Sea Surface Temperature (SST)' data are used over the years

Stomach content analysis. In the laboratory, fish specimens were weighed to the nearest 0.1 g, after blotting dry with filter paper. Total length (TL) and standard length (SL) were measured to the nearest 0.1 cm, using an icthyometer. Then each specimen was dissected and the stomach removed. The stomach contents were emptied into a petri dish for each sample with a few drops distilled water added to agitate them prior to examination microscopically. Two variables were estimated, namely frequency of occurrence and relative prey abundance (Amundsen *et al*., 1996). The frequency of occurrence is the number of stomachs in which each specific prey type is represented, expressed as a frequency (or percentage) of the total number of stomachs with prey. according to Amundsen and Sánchez-Hernández (2019).

Coefficient of emptiness. The coefficient of emptiness (Cv) was computed as the percentage of emptiness or voids relative to the total number of stomachs examined (Equation 1):

$$Cv = \frac{N_v}{N_t} \times 100 \quad \text{..... Equation 1}$$

Where:

Nv = Number of empty stomachs; Nt = Total number of stomachs examined.

Numerical method. The number of stomach in which each food item was recorded and expressed as a percentage of number of stomach containing food. This method provides information on the various types of food organism the fish fed upon.

$$F_i = \frac{N_e}{N_t} \quad \text{..... Equation 2}$$

Where:

Ne = the number of stomachs containing a prey category; Nt = the total number of stomachs containing at least one prey.

Weight percentage (P). It involves determining the percentage of the mass of a food category I (Pi) relative to the total mass (Pt) of the stomach contents (Amundsen *et al*., 1996).

$$P = \frac{P_i}{P_t} \times 100 \quad \text{..... Equation 3}$$

Where:

Pi = percentage of mass of a food category; I and Pt = the total mass of preys into each stomachs by category.

Index of preponderance (IP). For evaluating the relative importance of all food items, the index of preponderance (Amundsen *et al*., 1996) was used:

$$IP = \frac{P_i F_i}{\sum P_i F_i} \quad \text{..... Equation 4}$$

Where:

Pi = percentage of mass of a food category I; Fi = percentage of number of stomach containing food.

Statistical analyses. The PRIMER5 software (Plymouth Marine Laboratory; Clarke and Gorley, 2001) was used to calculate the Analysis of Similarities (ANOSIM) and the Similarity of Percentages (SIMPER). One-way Analysis of Similarities (ANOSIM) were carried out to test for significant differences in the diet and feeding intensity between different groups that were delimited beforehand. Similarity of Percentages

(SIMPER) was used to investigate which genera were responsible for these differences.

The abundance of prey in stomach contents was used to determine the similarity between different classes. The gradual consolidation of size classes according to the similarities of the stomach contents was performed by the method of classification (Clarke and Gorley, 2015). The hierarchical classification ancestry (HCA) was to group the closest species as a dendrogram, whereby the length of the branches represents the average or total distance between species and groups of species.

One-way Analysis of Similarities (ANOSIM) tests was used to determine whether, overall, the diets of *Pseudotolithus senegalensis* were influenced significantly by habitat, body size and/or season. The magnitude of the associated Global R-statistic values was employed to explore the extent to which dietary composition was influenced overall by each of those factors.

R-statistic values ranged from 0 (same regime) to 1 (different regime) (Somerfield *et al.*, 2021). The null hypothesis for ANOSIM tests that the dietary compositions were not significantly different were rejected at P>0.05. If R> 0.75 then the groups were considered different and then well separated; if R >0.75 > 0.5 then the groups are different; if R<0.5 then the groups are not clearly separated and 0.5 > if R < 0.25 then the groups are barely visible.

Similarities percentages (SIMPER) were used to determine the percentage of similarity or dissimilarity and the level of contribution of each prey in the diet. The higher the percentage of similarity the more than 50%, more prey was consumed in much the same way (Clarke and Warwick, 2001).

RESULTS

Seasonal variation of chlorophyll a and sea surface temperature. From the SeaWiFS data (Figs. 1 and 2), a high concentration of chlorophyll-a was recorded during the cold seasons; and low concentrations during the hot season. In the short cold season, the concentration of chlorophyll a varied from 1.63 mg m^{-3} in February to 1.91 mg m^{-3} in January. However, in extreme cold, the concentration of chlorophyll-a varied from 1.25 mg m^{-3} in September to 0.78 mg m^{-3} in October 2014 (Fig. 1). Moreover, in 2015, the concentration of chlorophyll-a varied from 1.01 in February to 1.14 mg m^{-3} in January in small cold season. In the long cold season, the chlorophyll-a concentrations recorded varied from 1.25 mg m^{-3} in September to 0.85 mg m^{-3} in October (Fig. 2). Figures 1 and 2 showed that the maximum chlorophyll-a coincided with the lowest Sea Surface Temperature (SST). Figure 3 illustrates the variation of chlorophyll-a during the minor cold season; while Figure 4 illustrates the variation of chlorophyll during the major cold season.

Vacuity index and diet composition. A total of 1,238 *Pseudotolithus senegalensis* stomachs were analysed of which 551 contained no prey; which gives a vacuity index of 44.50%.

Analysis of stomach content of *P. senegalensis* showed that the diet of this specie consisted mainly of shrimps, including fishes, cephalopods and crabs. *Pseudotolithus senegalensis* fed on the same species of shrimps, cephalopods and crabs.

The preponderance index (IP) of different species are given in Table I. The shrimps, *Penaeus notialis*, constituted the most important prey species in samples, making up 89.92 % of total IP.

Fishes contributed secondarily at dietary with 8.44%. Other dietary items included *Octopus vulgaris* and *Callinectes amnicola,* which had 0.49% IP, possibly considered as an incidental prey.

Seasonal variation. The seasonal variation in dietary items was determined by the preponderance index in cold and warm seasons. *Peneaus notialis* was the most

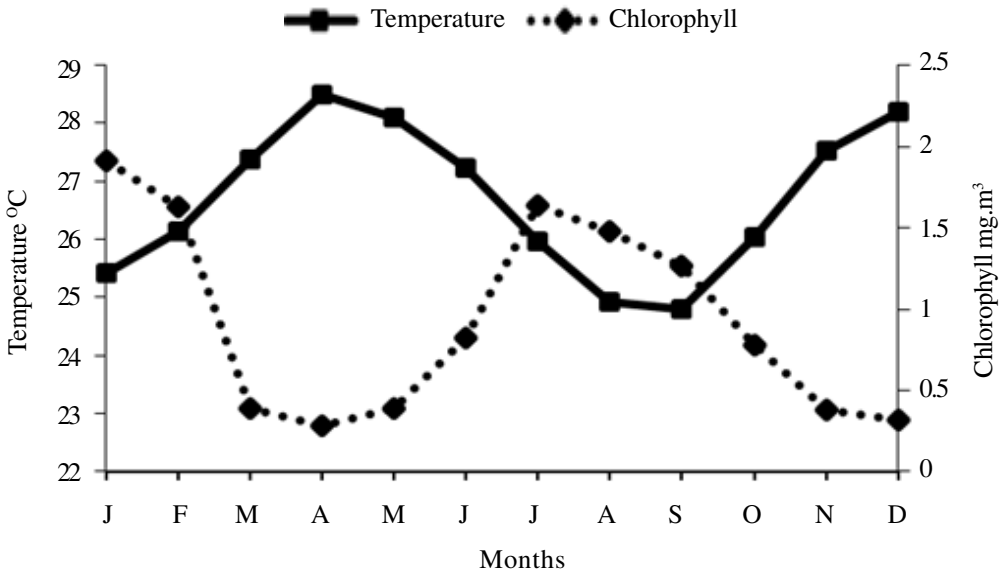

Figure 1. Seasonal variations of chlorophyll (Chl-a) and Sea Surface Temperature (SST) extracted from a point at the upwelling area in 2014.

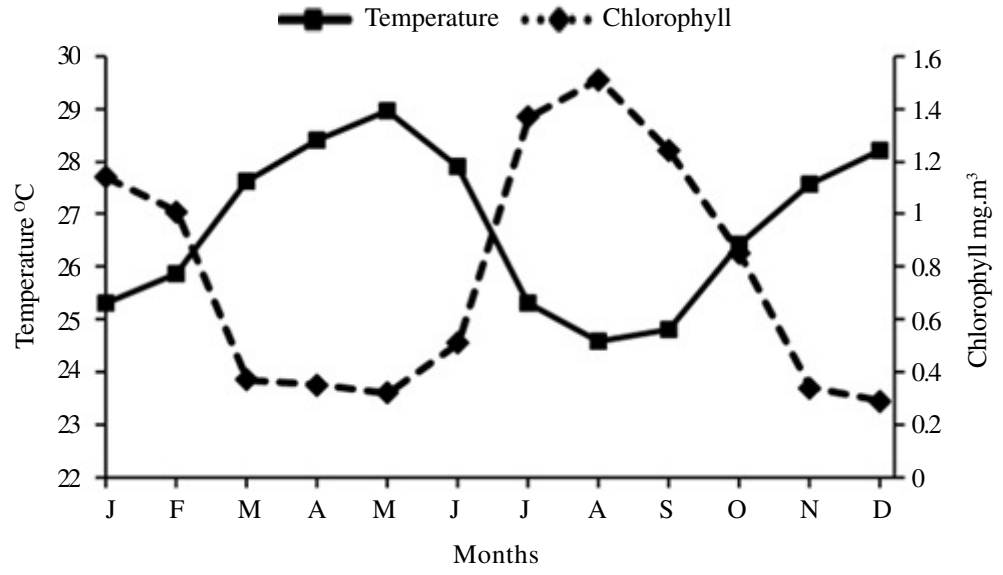

Figure 2. Seasonal variations of chlorophyll (Chl-a) and Sea Surface Temperature (SST) extracted from a point at the upwelling area in 2015.

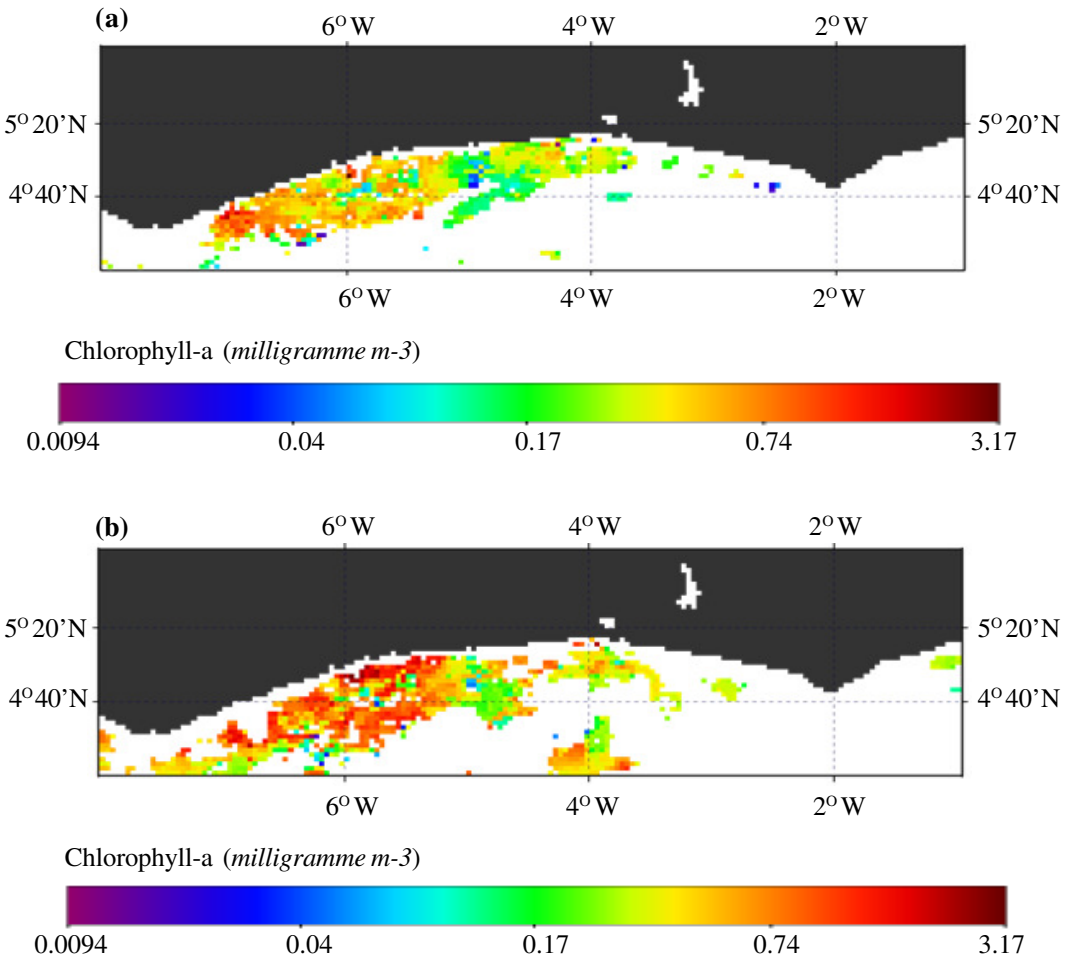

Figure 3. MODIS Aqua Chlorophyll-a composites during minor cold season. (a) : January 2014; (b) : February 2015.

TABLE 1. Preponderances index of dietary items of *Pseudotolithus senegalensis* in the Ivorian continental shelf

Preys	Ip
Penaeus notialis	89.92
Octopus vulgaris	0.47
Callinectes amnicola	0.02
Scyllarides sp.	0.00
Fish	8.44
Detritus	1.15
Total	100.00

prominent dietary item, followed by fishes and *Octopus vulgaris* in cold and warm seasons, respectively. *Callinectes amnicola* was the least prominent dietary item in both seasons (Table 2).

Composition and contribution of prey in the diet. Bray-Curtis similarity between groups of size *P. senegalensis* was 53.35 and 68.66%, respectively; for autumn and summer. One prey was common to the different size classes in all seasons, with contributions of 91.51% in autumn and 97.05% in summer. The Bray Curtis similarity between different seasons was

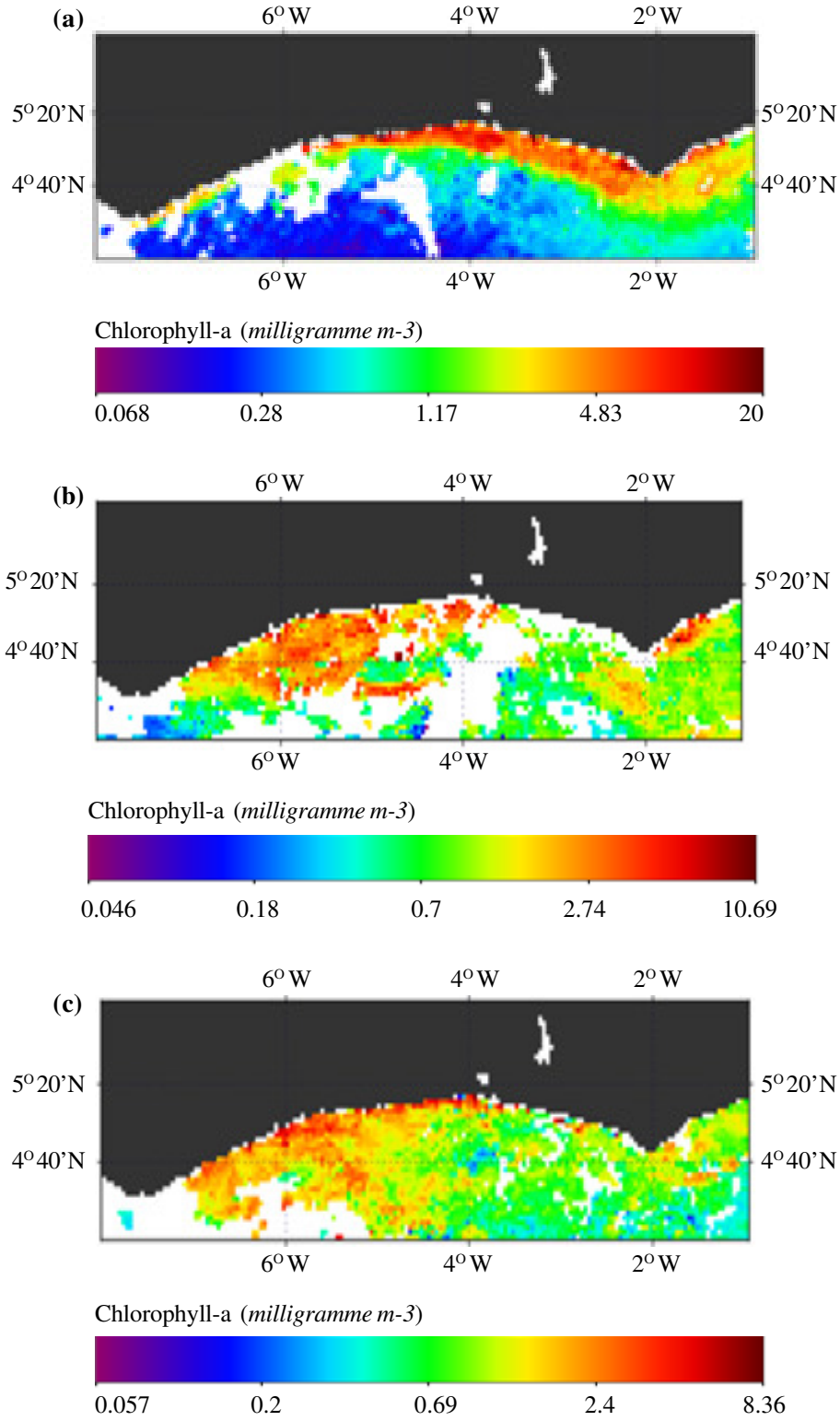

Figure 4. MODIS Aqua Chlorophyll-a composites during Great cold season. (a) : July 2014 ; (b) : August 2014; and (c): September 2015.

66.99%. Three preys were common to the different season; these were *Peneaus notialis* with a contribution level of 40.80%, animal debris for 29.51% and fishes for 22.21%.

Diet similarity *Pseudotolithus senegalensis* according to size group. In the Ivorian shelf water, the dendrogram showed two groups to 50% (Fig. 5). Group 1 was composed of specimens that were of standard length, low to 30 cm; and the second group included specimens with standard length >30 cm.

The ANOSIM (Analysis of Similarity) was calculated (R= 0.185). This value was less than the critical value of 0.30; implying that there was no significant difference in diet within size classes. However, the intra-class test (Pairwise tests) indicated overall R-value of 0.185 whatever the season. Class 1 had a mean of 91.66% similarity with one prey dominate diet, *Penaeus notialis* contributing 99.42%. Class 2 displayed food similarity of 54.59% with two preys; these included *Penaeus notialis* and fishes contributing 89.97 and 8.85% to the diet, respectively.

Class 3 displayed food similarity of 62.72% with two preys. These differed from others by their level of contribution to diet. They were

TABLE 2. Seasonal variation in dietary items of *Pseudotolithus senegalensis* in the Ivorian continental shelf

Preys	Cold season	Warm season
	— — — Ip — — — —	
Penaeus notialis	91.82	75.28
Octopus vulgaris	0.32	0.53
Callinectes amnicola	0.01	0.02
Scyllarides sp.	0.00	0.00
Illex coindetti	0.00	0.00
Fish	6.91	20.64
Detritus	0.94	3.51
Total	100.00	100.00

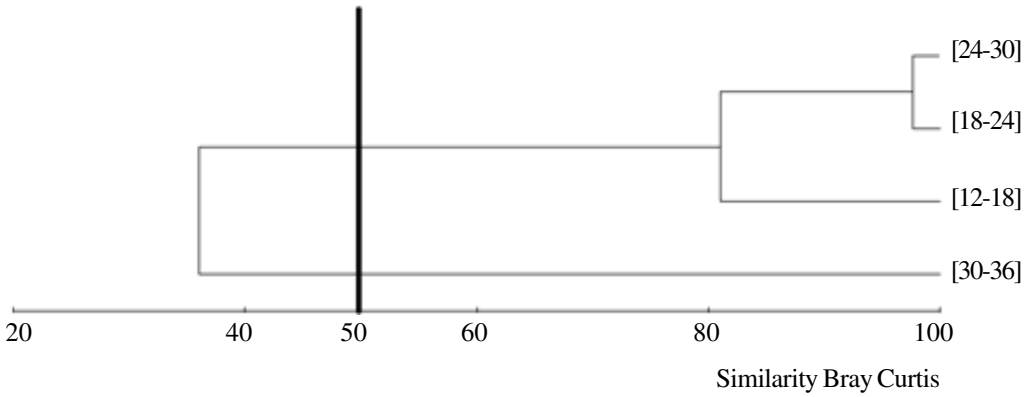

Figure 5. Dendrogram of sizes class of *Pseudotolithus senegalens* is in function seasons based on Bray-Curtis similarity after a square root transformation in numerical percentage prey consumed in the Ivorian continental shelf.

crustaceans *Penaeus notialis* (86.71%) and fishes (12.81%), all of which contributed to 99.52% to the diet.

The SIMPER analysis. Dietary similarity between size classes were determined in this study. The result showed that Classes 1 and 2 presented a mean of 74.39% similarity food with a less diverse diet. Three preys dominate the diet, they are *Penaeus notialis* (47.59%), fishes (38.15%) and detritus (12.36%); for the Class 1 and Class 3 displayed food similarity of 74.03% with three preys dominate; *Penaeus notialis* (41.85%), fishes (36.13%) and *Octopus vulgaris* (13.70%).

Classes 2 and 3 had similar types estimated at 74.1% with a most diverse diets. Four preys were in common and dominated the diet, namely *Penaeus notialis* contributing to 43.84%, fishes contributing to 29.90% and *Octopus vulgaris* and detritus contributing to 13.74 and 12.45%, respectively. Food similarity between Classes 1 and 4 was estimated at 39.16% for two preys, namely *Penaeus notialis* and detritus with contributions of 49.34 and 50%, respectively.

For Classes 2 and 4, a mean relating to food similarity was 41.37% for three preys. These were *Penaeus notialis* at 31.87%, fishes at 17.33% and detritus at 50%.

Classes 3 and 4 had food similarity estimated at 34.92% for three preys; namely *P. notialis* (29.51%) fishes (15.01%) and detritus (50%).

DISCUSSION

Seasonal variation of chlorophyll a and Sea Surface Temperature. Upwelling events are indicated by low Sea Surface Temperature values and high chlorophyll-a concentrations (Abbas *et al.,* 2012). In MODIS images during January to February and July to September, the maximum chlorophyll-a coincided in time with the lowest SST during two years 2014 to 2015. The upwelling event explains the marked high variations of chlorophyll-a. Because the deep water brought to the surface is often rich in nutrients, coastal upwelling supports the growth of seaweed and plankton. The plankton is the productive base of both marine and freshwater ecosystems, providing food for animals as *Pseudotolithus senegalensis* (Djagoua *et al.,* 2006).

Vacuity index and diet composition. The high vacuity index value for *Pseudotolithus senegalensis* could be explained by the regurgitation phenomenon due to stress of the fishing. This phenomenon occurs in other fish such as *Trachinotus teraia* (Sylla *et al.*, 2008).

The food items of *P. senegalensis* consisted of mainly crustacean (*Peneidae shrimps*). Other food item included fish, *Octopus vulgaris*, Callinectes *Amnicola, Scyllarides* sp. and detritus. Crustaceans (*Panaeus notialis*) were the first prey for all individuals. The dietary items and feeding habits showed that *P. senegalensis* was a predatory fish. There are two types of predatory fish.

Piscivorous predatory fish is the fish species that constitutes its major dietary items; and non-piscivorous predatory fish which has other macroscopic animals other than fish as its major dietary items. In the present study, *P. senegalensis* had crustaceans as their major dietary items. Hence, it can be inferred to be a non-piscivorous predatory fish. Another fish such as *Plagioscion squamosissimus*, which eats shrimp during the season of its high abundance, includes shrimp-eaters group as identified as predatory species (Cardoso *et al*., 2019). Our results are confirmed by Blay (2006) and Nunoo *et al.* (2013), who reported the importance of shrimps in the food regime of *Pseudotolithus senegalensis*.

Seasonal variation. Crustaceans' abundance in the *P. senegalensis* food chain in the cold seasons was due to upwelling as the outstanding hydrological condition. This phenomenon induces shrimp' abundance in the Ivory continental self. According to Sankaré and Amalachy (2014), shrimp (*Penaeus*

notialis) species are abundant in the lagoon around the sea. This abundance depends on the marine season.

Composition and contribution of prey to diet. The relative proportions of prey that dominated the diet of the species included *P. notialis* which decreased; while fishes and *Octopus vulgaris* increased.

Diet similarity according to size group and SIMPER analysis. Differences in the composition of diets across maturity generally corroborated results with previous work (Blay, 2006; Nunoo *et al.,* 2013). Generalist carnivors, such as the cassava croaker, commonly undergo ontogenic shifts in diet as they progress through their life cycle. In general, fish predatories begin their life cycle of consuming plankton like cladoceran, copepods and small crustaceans (*Peanaeus notialis*); and shift to fish and cephalopod through adult (Speed *et al.*, 2022). According to Speed *et al.* (2022), large individuals exploit a broader range of prey more than smaller ones due to the larger mouth gap of the former. Widening of dietary sources with sizes constitutes another means of reducing competition between smaller and larger individuals.

The overall ANOSIM R = 0.185 has shown that there is no significant difference between the diet of different size class. The level of dietary overlap between classes is the perfect size; reflecting a high degree of similarity in the use of available food resources. The results of similarity of the diet showed that different strategies are used by *P. senegalensis* to reduce competition.

A study of food similarity between the different size classes showed that the similarity was high in cold seasons and low in warm seasons. High food similarity observed in cold season could be explained by higher trophic resources during this period in the Ivorian continental shelf. The concentration of chlorophyll-a at cold season months is important and a good parameter to estimate productivity and prey abundance.

CONCLUSION

The analysis of stomach contents showed that *Pseudotolithus senegalensis* feeds mainly on *Peneaus notialis*, fishes, *Octopus vulgaris*, *Callinectes amnicola*, *Scyllarides* sp. and detritus. It is clear that *P. senegalensis* are non-piscivorous predatory because crustaceans constitute a large part of its diet. There was no evidence of seasonal changes in the diets of *P. senegalensis*, except for item consumed less frequently.

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