



**Diet of the cassava croaker (*Pseudotolithus senegalensis*) (Valenciennes, 1833) (Sciaenidae) from the Senegalese coast, West Africa: effects of season, maturity stage, sex and location on diet**

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**ABSTRACT**

The current study was conducted at two sites; Joal and Mboro to evaluate the effects of season, sex, maturity stage, and location on the diet of the cassava croaker (*Pseudotolithus senegalensis*) (Valenciennes, 1833). The two study sites, located on Senegalese coast, were chosen for the estuary ecosystem and marine ecosystem, respectively. Prey diversity and feeding strategy were evaluated. Multivariate analysis was performed to test the influence of sex, season, location and maturity stage on this species' diet. The study extended from August 2015 to July 2016, and revealed that, of the 606 stomachs examined in both sites 577 (16.03%) contained food. Cumulative prey diversity curves reached a stable level at 225 stomachs in Mboro and 275 in Joal, and thus the sample size was large enough to describe the overall cassava croaker diet. IRI% index was used to describe the overall diet of the cassava croaker. Hence, a clear dominance of teleosts and crustaceans prey items in the stomach contents analyzed in both sexes, in both locations, in all seasons and at all maturity stages was monitored. In the diet, relevant differences were found between sexes, maturity stages, sampling seasons and locations. Those food shifts are probably related to morphological limitations and abilities associated with feeding habits of the cassava croaker. In Joal and Mboro, the trophic level of *Pseudotolithus senegalensis* was 4.04 and 4.15, respectively. Though the present findings showed that this species is a vigorous carnivorous predatory feeder, yet the wide range of prey items identified suggests an opportunist feeding behaviour. Moreover, this species also feeds on algae, organic debris and other invertebrates.

**INTRODUCTION**

Information on the niche, trophic dynamics and food chains of a species is often obtained from the analysis of stomach contents. The importance of life-history stages on the feeding habits of a species is essential for understanding how that species exploits food resources. These ecological studies provide essential information on fish and allow better elaboration for the appropriate management of their fishery. The ecological status of a given fish, and the determination of the direction of energy flow within an ecosystem, can be assessed from the study of prey diversity (Hyslop, 1980). The diversity of prey among predators most often depends on several ecological factors. Adequate representation of the diet of a fish species is often made difficult by changes on diet between individuals of different sizes and sexes

within the same species, different geographic locations and different seasons. Spatial differences in the diet of several teleost species (Orr & Bowering, 1997), ontogenetic shifts in fish feeding habits (Ribeiro & Molina-Ureña, 2009; Usmar, 2012) and dietary shifts according to maturity stage (Ba *et al.*, 2013) are often noted. Several authors have also reported differences in the diet between sexes (Matallanas, 1982) and seasons (Cortès *et al.*, 1996; Deus, 2003).

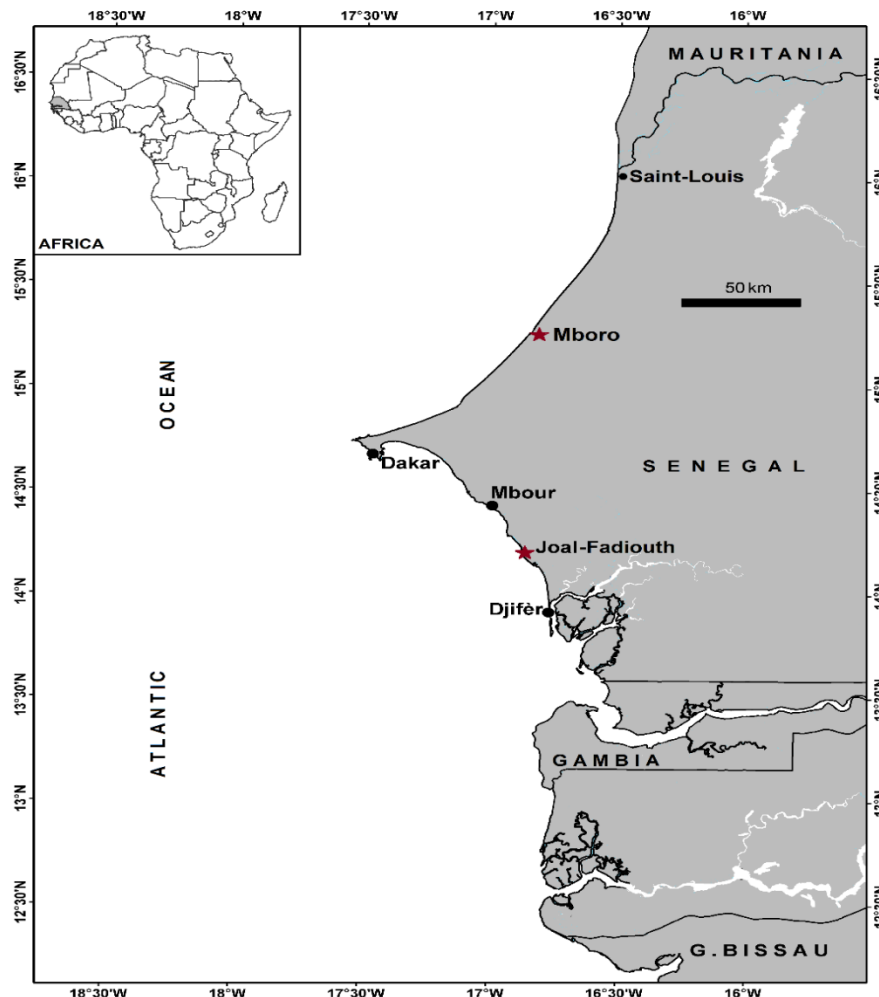
The Sciaenids constitute a large marine, demersal fish living in coastal waters over muddy, sandy or rocky bottoms. Smaller individuals were found in shallow waters, but rarely entering estuaries (Diouf, 1996; Edwards *et al.*, 2001). The species of genus *Pseudotolithus* commonly occur along the Atlantic coast of West Africa, residing in shallow waters over bottoms of sand or sandy mud (Gbaguidi, 2001; Sossoukpe, 2011; Sossoukpe *et al.*, 2013). The cassava croaker, *Pseudotolithus senegalensis* (Valenciennes, 1833), is widely present along the Gulf of Guinea in the coast of West Africa (Edwards *et al.*, 2001; Sidibé, 2003; Ngom, 2005). Early studies on food habits of the cassava croaker have been documented (Longhurst, 1964; Troadec, 1968; Anyanwu and Kusemiju, 1990; Tientcheu and Djama, 1994; Sidibé, 2003; Nunoo, 2013) declaring that *Pseudotolithus* species feed mainly on shrimps. Ample knowledge of aspects of feeding habits including diets, degree of diet overlaps and feeding strategies, of a fish population in the wild is imperative to comprehend their productive capacity and ecological role (Teixeira & Cortes, 2006). Such information is critical to the development of sustainable management plans and conservation. The Senegalese bar *Pseudotolithus senegalensis* (Valenciennes, 1833), the subject of this present study, is overexploited and is in a very critical phase (Sidibé *et al.*, 2002). A lack of data on the evolution of the population abundance of *P. senegalensis* has been noted over the past decade (Sidibé, 2010). This species is assessed as Endangered on the IUCN Red List (Nunoo & Nascimento, 2015). It is important to update the existing knowledge of the diet of this species, to provide new information and to compare existing data with those provided in the West African sub-region to better understand the ecology of this species and better preserve it. Therefore, the objectives of this study were to: (i) to describe the dietary composition and trophic level of the of the cassava croaker (*Pseudotolithus senegalensis*), (ii) identify the feeding strategy of this predator, and (iii) investigate whether there is a sexual, ontogenetic, seasonal and spatial shifts in the dietary composition of this species in the Senegalese coast. This information will contribute to the understand the ecological role of this species in Senegalese demersal marine communities.

## MATERIALS AND METHODS

### 1. Sampling method

Samples were collected monthly between August 2015 and July 2016 at two locations along the Senegalese coasts (Fig. 1) from the commercial catches taken by the small-scale fisheries. The sampling used size stratification to give the best representation of the different maturity stages of the population (around 30 individuals per month). All specimens fished by commercial pirogues were sampled once per month at each location. Specimens were measured for total length (TL in mm) and fork length (FL in mm) weighed (W in g). They

were sexed and assessed for sexual maturity. The maturity stage was evaluated; for males from the aspect of the testicle,s and for females from the aspects of ovaries according to the Fontana scale (**Fontana, 1969**). The TL50s were considered as the threshold for dividing males and females into two groups. The size at first sexual maturity (TL50) for males and females was calculated as a parameter of a logistic function fitting the relationship between the percentage of mature individuals and the total length (**Panfili *et al.*, 2006**).



**Fig. 1.** A map showing the sampling locations (with the red star markings showed Mboro and Joal sampling sites) of *Pseudotolithus senegalensis* off the coast of Senegal

## 2. Diet analysis

Stomachs were excised from each individual, and the inside flushed with 70% ethanol in order to collect any contents that might lodge or trap inside the stomach (**Cortés & Gruber 1990**). Samples were stored on ice in plastic bags and preserved in 70% ethanol. In the laboratory, the stomach contents of each teleost were filtered through a sieve, rinsed with water and weighed (g) after draining off excess water. Prey items were identified to the smallest taxonomic level possible using various identification guides (**Fischer *et al.*, 1981**; **Séret & Opic, 1981**; **Bellemans *et al.*, 1988**; **Carpenter & De Angelis, 2014**; **Carpenter & De Angelis, 2016a, 2016b, 2016c**), counted and weighed. Prey were identified where possible

from external morphology or with the use of a dissecting microscope whenever necessary, depending on the digestion stage of each item. Unidentified prey were placed in with the unidentified teleost or unidentified invertebrates.

### 3. Data analysis

Prey were grouped into major categories for comparison according to sex (male or female), stage of maturity, season (warm season, May to October; cold season, November to April) and location (Joal and Mboro). Two groups of males and females, corresponding to mature and immature stage, were categorized in relation to the size at first sexual maturity (TL50) estimated for mature males (TL $\geq$ 401 mm and TL $\geq$ 344 mm, respectively, in Joal and Mboro locations) and for mature females (TL $\geq$ 390 mm and TL $\geq$ 354 mm, respectively, in Joal and Mboro locations). Prey importance was evaluated by using the percentage by number (%N), mass (%W), frequency of occurrence (%F), and the index of relative importance (IRI) (Pinkas *et al.*, 1971), expressed on a percentage basis (%IRI) (Cortés, 1998). These values were calculated for each prey item, and the %IRI was calculated for higher taxa (e.g. teleosts, crustaceans and molluscs). The %IRI was calculated to facilitate comparisons between prey items (Saïdi *et al.*, 2009) as:

$$\%IRI_i = 100 \frac{IRI_i}{\sum_{i=1}^n IRI_i}$$

Prey diversity in the diet, which is a measure of trophic niche breadth, was calculated by Shannon–weiner ( $H'$ ) Index (Krebs, 1989).

$$H' = - \sum_{i=1}^s (P_i) \log_2(P_i)$$

where  $H'$  is diversity index of Shannon–Weiner,  $S$  is number previously assigned to the type of prey or groups, and  $P_i$  the proportion of the total sample belonging to each group. This index has adequate sensitivity to detect changes in species diversity and provide a general indication of the relative magnitude of trophic specialization (Berg, 1979).

To assess the adequacy of the number of samples gathered, cumulative prey curves were constructed. The order in which the stomachs were examined was randomized using a random number generator in the Excel software package. Then, the number of unique prey items was plotted against cumulative number of stomachs examined, following Ferry and Cailliet (1996). The use of cumulative prey curves is based on the assumption that if a curve reaches an asymptote, the diet would be adequately characterized because new prey types occur more and more infrequently.

Trophic level was calculated to determine the position of teleost within the food web (Cortés, 1999) and compare it to that of other regions. The trophic level was calculated as:

$$TL = 1 + \left( \sum_{j=1}^n P_j \times TR_j \right)$$

Where  $TR_j$  is the trophic level of each prey item, and  $P_j$  is the proportion of each prey item in the diet of teleost. The  $P_j$  value is obtained from the %IRI of each prey item and trophic level of each prey is obtained from **Cortés (1999)**.

Feeding strategy was determined with the method of **Amundsen *et al.* (1996)**, and modified according to the method of **Costello (1990)**, where prey-specific abundance ( $P_i$ ) is plotted against frequency of occurrence. Expressed as a percentage, prey-specific abundance is a given prey taxon's proportion in relation to all prey items observed in only those predator stomachs that contained the given prey taxon:

$$P_i = \left( \sum S_i / \sum S_{ti} \right) \times 100$$

Where  $P_i$  = the prey-specific abundance of prey  $i$ ;  $S_i$  = sum of prey  $i$ ; and  $S_{ti}$  = sum of all prey items found in only those predator stomachs that contained prey  $i$ . Data points, that cluster near the top of the y-axis, indicate specialized feeding by individuals within the population. A cluster, close to the origin, describes infrequent consumption of a prey type (i.e., prey types that are not an important part of the predator's diet). Data points that are scattered across the graph indicate that a population cannot be characterized as one that employs a single feeding strategy; a population may be specialized sometimes and generalized at the others. Data points, clustered in the upper right quadrant of the graph, indicate a population with a specialized feeding strategy, where a high percentage of the population consumes one or more specific prey types.

The interspecies dietary overlap value is sensitive to the taxonomic level at which the prey was identified, as for this paper the finest taxonomic breakdown available was used, i.e., prey identified to species whenever possible. Using the Simplified Morisita index ( $C_H$ ), the dietary overlap of the two maturity stages in turn of sexes and locations were compared (**Krebs, 1989**). The degree of overlap was determined according to the scale of **Langton (1982)** including: low overlap, 0-0.29; medium overlap, 0.30-0.59, and high overlap bigger than 0.60.

$$C_H = 2 \left( \sum P_{ij} P_{ik} \right) / \left( \sum P_{ij}^2 + \sum P_{ik}^2 \right)$$

Where  $P_{ij}$  is the proportion of prey category  $i$  used by size class  $j$ , and  $P_{ik}$  is the proportion of prey category  $i$  used by size class  $k$  (**Krebs, 1989**). The prey diversity of the two maturity stages of the cassava croaker were compared using the Shannon-Weiner Diversity Index ( $H$ ) (**Krebs, 1989**).

#### 4. Diet shifts

One-way multivariate analysis of variance (MANOVA) was applied to %IRI values to test differences in diet composition of each food category as a dependent variable for seasons, sexes, maturity stages and locations (**Cortés, 1997; Moura *et al.*, 2008**).

## RESULTS

### 1. Sample description

At Joal the total length of females ranged from 255 to 588 mm, while that of males ranged from 257, 33 to 479 mm in the Joal site. Whereas, at Mboro the total length of females ranged from 283 to 524 mm for, and from 302 to 490 mm for males. Of the 606 stomachs

examined at both sites, 577 (95, 21%) contained food. Of the 346 stomachs examined at the Joal site, 309 (89, 31%) contained food while of the 260 stomachs examined at the Mboro site, 245 (94, 23%) contained food. The vacuity indexes were estimated at 10, 69 and 5, 77 %, respectively, in Joal and Mboro. Of the 127 stomachs excised in the warm season, 106 (83.46%) contained food in Joal, while in the 89 stomachs excised in the cold season, 85 contained food (95.51%). In Joal, the percentage with stomachs containing food in the warm season was estimated at 83.40%, while in the cold season it was estimated at 96.25% (Table 1). In Mboro, these values were estimated at 92.9 and 96.2%, respectively, in the warm and cold season. During the whole season, 27 preys' species were identified as belonging to 7 taxonomic groups in Joal while 24 preys' species were identified in Mboro as belonging to 5 taxonomic groups, with a clear dominance of teleosts in both sites. In Joal, the vacuity index varied between the two seasons and 16.58% and 3.77% were recorded in warm and cold season, respectively. The cumulative prey curve for the samples of Joal (n = 282) and Mboro (n=220) appeared to approach an asymptote at 225 in Mboro and 275 in Joal, indicating that sample size was adequate for this study (Fig. 2). Therefore, the sample size was considered large enough to describe the overall diet in Joal and practically in Mboro.

## 2. Overall diet and feeding strategy

The relative importance of the different prey groups and species for *P. senegalensis* are given in Table (1) in both locations. At the Joal site, this species consumed a wide range of prey items belonging to seven major groups: teleosts, crustaceans, molluscs, algae, fishing nets, organics debris and plathelminthes, while in Mboro five groups of prey were found in the diet: teleosts. Crustaceans, molluscs, unidentified invertebrates and organics debris (Table 1). Considering identified preys, among the different prey categories found, teleosts were the most frequent in both sexes, in both locations, in all seasons and at all maturity stages (%IRI = 77.16 % and 82.29% of the total in Joal and Mboro, respectively ; Fig.3). Secondly, the diet of *Pseudotolithus senegalensis* consisted of benthic crustaceans (mainly Penaeidae, Aristeidae and Pandalidae shrimps and Portunidae crab, in Joal and mainly Penaeidae, Aristeidae shrimps and Portunidae crabs in Mboro). The other encountered dietary items could be considered as an incidental food prey (%IRI <2%) as shown in Table (1) and Fig. (3). They were composed of molluscs (%IRI = 0.08 and 0.07%), organic debris (%IRI = 0.12 and 0.01%) and unidentified invertebrates (0.13% in Mboro) as algae, fishing nets. Furthermore, unidentified teleosts were the most common prey item in stomachs analyzed in this diet study and represented 40.00 % 72.54 % (%IRI).

Diet breadth index calculated by Shannon-Weiner index ( $H = 1.18$  and  $1.20$  in Joal and Mboro, respectively) indicated a moderately spectrum of prey species in the diet of *P. senegalensis* at the sampling sites. The warm season samples recorded the highest prey diversity values ( $H' = 0.79$  and  $H' = 1.25$ ) at Joal and Mboro, respectively, while the cold season samples showed the lowest ( $H' = 0.32$  and  $H' = 0.88$ ), respectively.

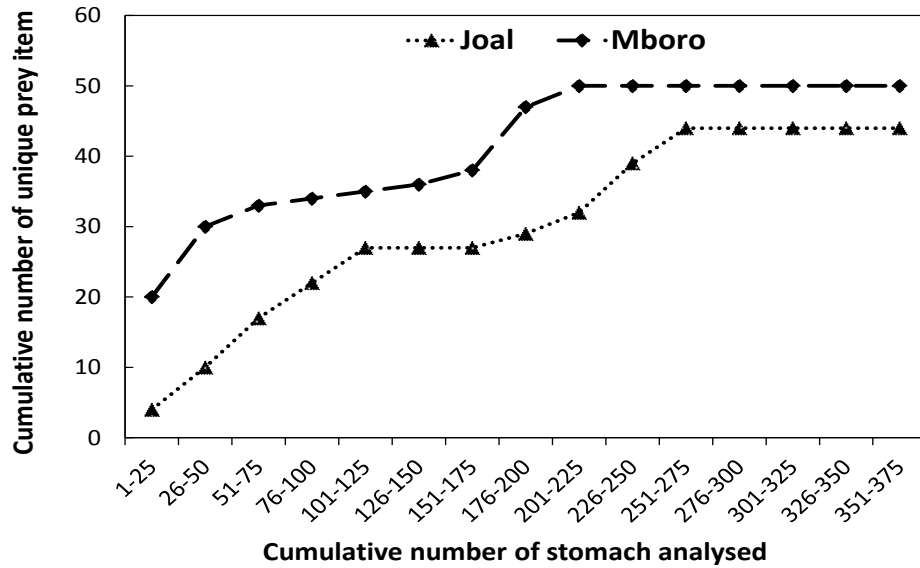


Fig. 2. Cumulative prey curve of identifiable prey items of *P. senegalensis* in Joal and Mboro.

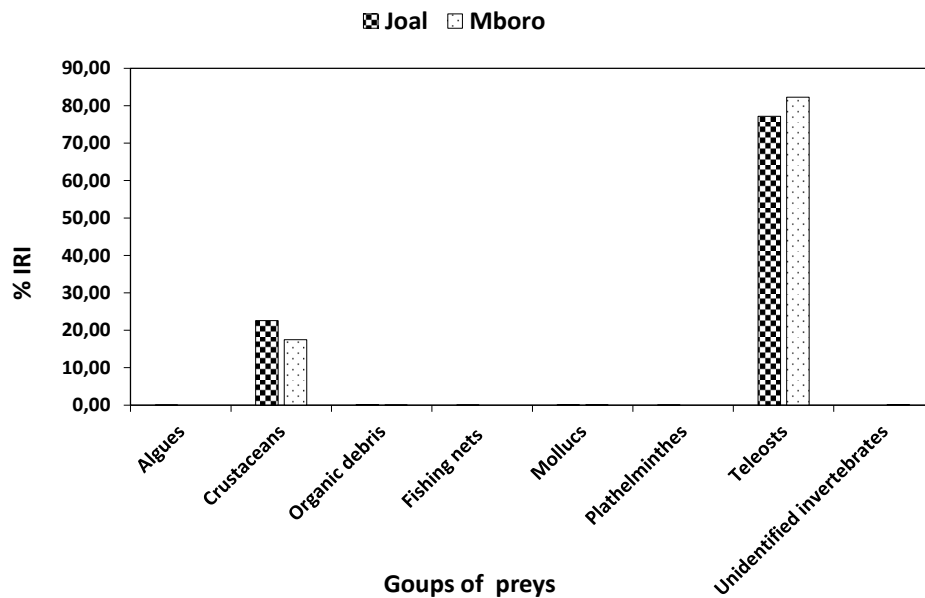


Fig. 3. Percentage of Index of Relative Importance of prey groups in the *P. senegalensis* diet according to the both sampling sites.

Table 1. Diet composition of *P. senegalensis*. %N, %W, %F and %IRI = percentages by number, mass, frequency of occurrence and index of relative importance of prey, respectively

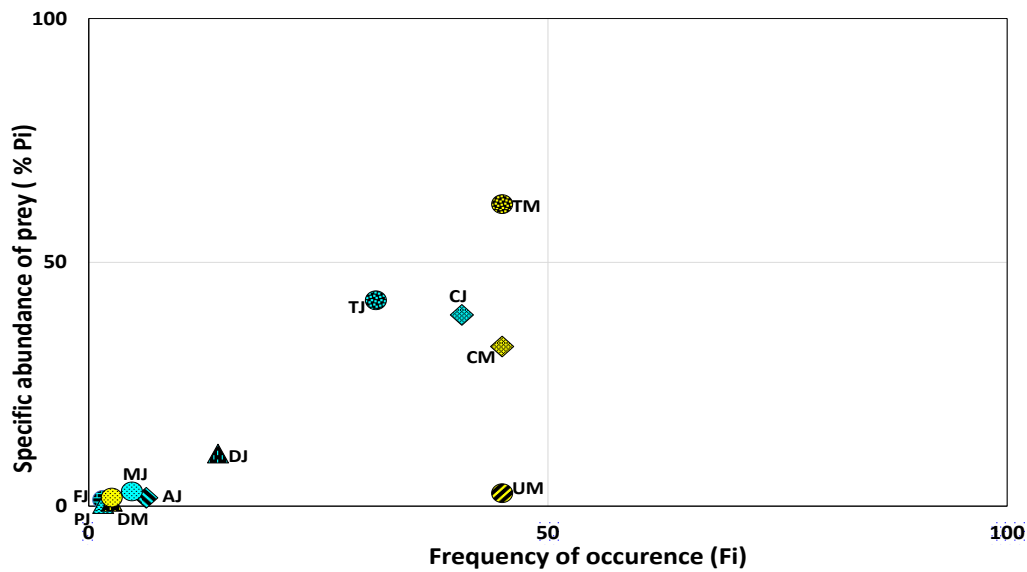
Taxon of the items	%N	%W	%F	IRI	%IRI
<b>Joal</b>					
Algae	2.65	0.05	1.74	4.69	0.12
Crustaceans	39.22	14.06	40.63	6525.36	96.27
Crangonidae	0.66	0.23	1	0.89	0.02
<i>Pontacaris lacazei</i>	0.66	0.23	1	0.89	0.02
Pandalidae	1.32	1.55	1.74	5	0.13

<i>Heterocarpus ensifer</i>	1.32	1.55	1.74	5	0.13
<b>Aristeidae</b>	3.97	5.32	2.61	24.25	0.64
<i>Aristeus varidens</i>	3.97	5.32	2.61	24.25	0.64
<b>Penaeidae</b>	24.5	10.99	30.44	540.12	14.25
<i>Parapenaeopsis atlantica</i>	5.3	4.62	6.96	68.98	1.82
<i>Penaeus notialis</i>	1.32	0.79	1.74	3.67	0.1
<i>Penaeus</i> sp.	0.66	0.45	0.87	0.97	0.03
Unidentified shrimps	17.22	5.13	20.87	466.5	12.3
<b>Portunidae</b>	0.66	0.09	0.87	0.66	0.02
<i>Callinectes pallidus</i>	0.66	0.09	0.87	0.66	0.02
<b>Organic debris</b>	6.62	0.14	1.74	11.76	0.31
<b>Fishing nets</b>	0.66	0	0.87	0.58	0.02
<b>Molluscs</b>	3.02	1.46	4.69	65.05	0.96
<b>Loliginidae</b>	0.66	0.28	0.87	0.82	0.02
<i>Loligo vulgaris</i>	0.66	0.28	0.87	0.82	0.02
<b>Patellidae</b>	0.66	0.01	0.87	0.58	0.02
<i>Patella</i> sp.	0.66	0.01	0.87	0.58	0.02
<b>Sepiidae</b>	0.66	1.45	0.87	1.84	0.05
<i>Sepia officinalis</i>	0.66	1.45	0.87	1.84	0.05
<b>Tellinidae</b>	0.66	0.01	0.87	0.58	0.02
<i>Tellina strigosa</i>	0.66	0.01	0.87	0.58	0.02
<b>Plathelminthes</b>	0.66	0.01	0.87	0.58	0.02
<b>Teleosts</b>	1.72	84.58	31.25	4546.18	65.92
<b>Clupeidae</b>	9.27	23.68	11.31	118.92	3.14
<i>Ilisha africana</i>	1.32	4.31	1.74	9.8	0.26
<i>Sardinella aurita</i>	1.32	2.77	1.74	7.11	0.19
<i>Sardinella maderensis</i>	1.99	5.35	2.61	19.14	0.5
<i>Sardinella</i> sp.	4.64	11.25	5.22	82.87	2.19
<b>Scianidae</b>	1.32	1.91	0.87	2.82	0.07
<i>Pseudotolithus</i> sp.	1.32	1.91	0.87	2.82	0.07
<b>Scrombidae</b>	0.66	1.83	0.87	2.17	0.06
<i>Scomberomorus tritor</i>	0.66	1.83	0.87	2.17	0.06
<b>Sparidae</b>	3.97	9.99	5.22	49.91	1.32
<i>Boops boops</i>	3.31	7.55	4.35	47.21	1.25
<i>Diplosus belloti</i>	0.66	2.44	0.87	2.7	0.07
<b>Unidentified Fishes</b>	40.4	42.46	36.52	3026.13	79.82
<b>Mboro</b>					
<b>Crustaceans</b>	32.74	20.20	45.00	2382.56	28.67
<b>Aristeidae</b>	1.69	3.15	1.98	9.6	0.32
<i>Aristeus varidens</i>	1.69	3.15	1.98	9.6	0.32
<b>Penaeidae</b>	3.39	6.16	3.96	12.85	0.42



<i>Parapenaeopsis atlantica</i>	0.85	1.43	0.99	2.26	0.07
<i>Penaeus atlantica</i>	0.85	3	0.99	3.81	0.13
<i>Penaeus notialis</i>	1.69	1.73	1.98	6.78	0.22
Unidentified shrimps	1.69	3.15	1.98	4.95	0.32
<b>Portunidae</b>	5.08	9.31	5.94	17.8	0.74
<i>Callinectes pallidus</i>	20.34	10.36	20.79	638.28	20.96
<i>Callinectes amnicola</i>	0.85	0.64	0.99	1.47	0.05
Unidentified Crabes	1.69	0.42	1.98	4.19	0.14
<b>Organic debris</b>	0.85	0	0.99	0.84	0.03
<b>Mollucs</b>	1.77	0.79	2.50	6.24	0.08
Bivalves Ind	2.54	0.71	2.97	9.67	0.32
Céphalopode Ind	0.85	0.69	0.99	1.52	0.05
<b>Teleosts</b>	61.95	69.38	45.00	5909.63	71.10
<b>Anguillidae</b>	0.85	0.1	0.99	0.94	0.03
<i>Anguilla anguilla</i>	0.85	0.1	0.99	0.94	0.03
<b>Clupeidae</b>	6.78	17.1	3.96	47.29	1.55
<i>S. maderensis</i>	2.54	8.42	1.98	21.72	0.71
<i>Sardinella sp.</i>	4.24	8.68	1.98	25.57	0.84
<b>Merlucciidae</b>	0.85	1.73	0.99	2.55	0.08
<i>Merluccius polli</i>	0.85	1.73	0.99	2.55	0.08
<b>Muraenesocidae</b>	0.85	0.09	0.99	0.93	0.03
<i>Cynoponticus ferox</i>	0.85	0.09	0.99	0.93	0.03
<b>Scianidae</b>	0.85	1.95	0.99	2.77	0.09
<i>Pteroscion peli</i>	0.85	1.95	0.99	2.77	0.09
<b>Sparidae</b>	5.93	8.91	5.94	88.16	2.9
<i>Boops boops</i>	5.93	8.91	5.94	88.16	2.9
<b>Trichiuridae</b>	1.69	0.24	0.99	1.92	0.06
<i>Lepidopus caudatus</i>	1.69	0.24	0.99	1.92	0.06
<b>Unidentified Fishes</b>	31.36	38.35	31.68	2208.5	72.54
<b>Unidentified invertebrates</b>	2.54	0.23	2.97	8.25	0.27

The plotting prey- specific abundance against frequency of occurrence confirmed that teleosts were the dominant prey. Amundsen metrics indicate that the population of *P. senegalensis* displayed a generalized feeding strategy. Although some prey items, including teleosts, crustaceans and mollucs, were consumed regularly, most prey types were infrequently observed in the stomachs of the cassava croaker (Fig. 4).



**Fig. 4.** Graphical representation of the feeding strategy of the cassava croaker: prey-specific abundance (% P) plotted against percentage frequency of occurrence (%F) (T: teleosts; C: crustaceans; M: molluscs; N: nematodes; A: annelids; U: unidentified invertebrates; D: organic debris; P: plathelminthes). The letters M and J in second position signify the two collection sites Mboro and Joal, respectively.

The trophic levels of *Pseudotolithus senegalensis*, calculated in this study at Joal and Mboro, were 4.04 and 4.15, respectively. A slight decrease in trophic level according to size or stage of maturity was noted in both sexes at both sites. The immature feed on small fishes and crustaceans thereby moving up in the Trophic Level whereas mature fishes feed on teleosts.

### 3. Diet shifts

At the Mboro site, the vacuity indexes were respectively estimated at 7.14 and 3.77 in warm and cold seasons. For the entire sample at each site, the vacuity index was estimated at 10.7 and 5.8, respectively at both Joal and Mboro. The effect of season, sex, geographic area and maturity stage on the diet of *P. senegalensis* are shown by the distribution of %IRI values of all prey according to these variables and have been summarized in Table (2).

There were significant differences in the diets of males and females (MANOVA:  $F = 3.896$ ,  $df. = 2$ ;  $P < 0.05$ ). Mean number of prey per stomach was  $0.68 (\pm 1.44)$  and  $0.65 (\pm 1.02)$ , respectively, for females and males in Joal while in Mboro, the mean number of prey per stomach was estimated at  $0.53 (\pm 0.89)$  and  $0.36 (\pm 0.68)$ , respectively, for females and males. Additionally, the value of %IRI for all prey items was much higher for females (71.89%) than for males (28.11%) at the Joal site, while the male's value of %IRI (55.82%) was higher than females (44.18%) in Mboro.

**Table 2.** The effect of season, sex, location and maturity stage on the diet of *P. senegalensis* according the %IRI values of diet groups with Manova test results and Index of Feeding Overlap (Simplified Morisita index) considering prey species.

		%IRI prey groups							MANOVA Test	SMI
		Crustaceans	Teleosts	Mollucs	Unidentified invertebrates	Organic debris	Fishing nets	Algues		
<b>Season</b>	Warm season	38.77	60.72	0.00	0.38	0.00	0.00	0.13	F = 3.882 ; P < 0.05	0.0015
	Cold season	6.78	89.73	2.04	0.00	1.43	0.02	0.00		
<b>Sex</b>	Females	19.42	77.42	2.08	0.10	0.85	0.03	0.10	F = 3.896 ; P < 0.05	0.0013
	Males	21.68	77.59	0.35	0.16	0.21	0.00	0.00		
<b>Location</b>	Joal	26.67	70.12	1.77	0.26	1.10	0.02	0.08	F = 30.468 ; P < 0.05	0.0029
	Mboro	11.65	88.35	0.00	0.00	0.00	0.00	0.00		
<b>Maturity stage Joal</b>	Imm** Females	17.46	80.76	0.00	0.22	1.56	0.00	0.00	F = 100.432 ; P < 0.05	0.0037
	Mat*** Females	0.00	71.44	23.83	0.00	0.00	1.51	3.22		
	Imm Males	35.87	63.60	0.22	0.00	0.31	0.00	0.00	F = 75.512 ; P < 0.05	0.1271
	Mat Males	55.41	31.34	0.00	7.20	6.05	0.00	0.00		
<b>Maturity stage Mboro</b>	Imm Females	0.00	100.00	0.00	0.00	0.00	0.00	0.00	F = 98.201 ; P < 0.05	0.1128
	Mat Females	36.77	63.29	0.00	0.00	0.00	0.00	0.00		
	Imm Males	0.00	100.00	0.00	0.00	0.00	0.00	0.00	F = 59.102 ; P < 0.05	0.0004
	mat Males	10.65	89.35	0.00	0.00	0.00	0.00	0.00		

\*SMI: Simplified Morisita indices; \*\*: immature; \*\*\*: mature

The value of % IRI was higher among immature in both sexes in Joal, accounting for 76.73 and 84.06%, respectively, for females and males in Joal for the overall prey items. At the Mboro site, the value of % IRI was higher among matures for both sexes accounting for 88.08 and 70.82%, respectively for females and males. The cassava croaker experienced an ontogenetic dietary shift, as evidenced by significant dietary differences between immature and mature females (MANOVA:  $F = 102.948$ ; d.f. = 2;  $P < 0.05$ ) and in males (MANOVA:  $F = 51.062$ ; d.f. = 2;  $P < 0.05$ ) (Table 2). Both seasons showed significant differences in the diet composition (MANOVA:  $F = 3.882$ ; df. = 1;  $P < 0.05$ ) (Table 2). The %IRI value for all prey items in the study was higher in the warm season (77.71%) than in the cold season (22.29%). Mean prey number per stomach was  $1.53 \pm 0.83$  and  $1.68 \pm 0.85$ , respectively, for warm and cold seasons. Joal and the Mboro revealed significant differences in the cassava croaker diet (MANOVA:  $F = 30.468$ ; d.f. = 1;  $P < 0.05$ ) (Table 2). The value of % IRI was higher in the Mboro (82.74%) than in Joal (17.26%). Mean number of prey per stomach was 1.47 ( $\pm 0.69$ ) and 1.64 ( $\pm 0.90$ ), respectively, in Joal and Mboro. The comparison of the %IRI values showed that teleosts were more present in the diet in Mboro, while the crustaceans were numerous in Joal.

Morisita index values calculated using %IRI per site indicated that, at the site of Joal the highest amount of overlap was observed in mature and immature males (0.1271), while at Mboro the females presented the highest value (0.1128). Niche overlap results in Table (2) show a very partitioning food of *P. senegalensis* according to sex, seasons and sizes. These groups did not consume the same prey type all the year.

## DISCUSSION

The food of the Senegalese cassava croaker in this study was similar to that of the species in other parts of the West Africa coast with a larger prey spectrum. The vacuity index, the number, weight and occurrence of item and diet Shifts highlighted in this study all give insight into the feeding pattern of *P. senegalensis*. Small sample sizes and large variations in food categories greatly influence the dietary importance of prey items (Hyslop, 1980). The curve of the 250 records of stomachs for the entire data set of both locations seemed to approach an asymptote; this study succinctly described the diet of *P. senegalensis* along the Senegalese coast. No studies had previously determined the number of stomachs needed to describe the cassava croaker diet.

*Pseudotolithus senegalensis* has been shown in this study to be a vigorous carnivorous predatory feeder as indicated by an overall estimated vacuity index of 8.58% for the overall sample. This result was confirmed by the high number of feeding activities (the relatively low percentage of empty stomach;  $<30\%$ ) reported for all maturity stages, sexes and locations. This finding was smaller than those reported by Troadec (1971) at the West African coast (18.2%), Tientcheu and Djama (1994) at the Cameroun coast (34%), and Blay *et al.* (2006) at the Ghanaian coast (12.6%). Low percentage of empty stomachs may reflect long period of feeding for the cassava croaker.

In the present study, the trophic level (4.04 and 4.15, respectively at Joal and Mboro) for *P. senegalensis* was close to its estimation (3.09) for the same species in the Nigerian coast (Anyanwu a& Kusemiju, 1990). The fishing activities had an impact on the trophic structure of the ecosystem and a “fishing down marine food web” effect was shown in West Africa (Laurans *et al.*, 2004). The trophic level changes observed in this study during ontogeny of *P. senegalensis* is very common in fishes (Vivekanandan *et al.*, 2005). However, the species seemed more overexploited in Nigeria compared to the Senegalese stock with a lower level in Nigeria.

The data presented here suggest that the cassava croaker feed on mostly demersal species (epibenthic crustacean, principally penaeids and fish), which is congruent with the assumptions of Troadec (1971), Tientcheu and Djama (1994), Blay *et al.* (2006) and Nunoo (2013). As a generalist, it is unlikely to strongly impact the population of any particular species preys, and in turn, is not likely to be strongly affected by fluctuations in abundance of a single prey species. Comparatively with previous studies in the West African coast, the current findings in the diet of the cassava croaker was most diverse. *P. senegalensis* appeared almost euryphagous in reference to the many types of prey found especially at Joal. This result contrasted with that found for this species in the region, which presented it as a stenophagous carnivore’s species with a very low prey spectrum (Troadec, 1971; Anyanwu & Kusemiju, 1990; Tientcheu & Djama, 1994; Sidibé, 2003; Blay, 2006; Nunoo *et al.*, 2013; Udoh & Ekpo, 2017).

Adequate representation of the diet of a species is complicated by differences in diet that occur within species among individuals of different sizes, sexes, geographical locations, and during different seasons (Wetherbee & Cortés 2004; Grubbs, 2010). In terms of diet overlap, immature and mature males and females appear to use the nursery habitat in the same way, with no apparent difference on diet. Nevertheless, in the present study, evaluated differences in the diet among different maturity levels of the *P. senegalensis* was performed according to the Shannon-Wiener prey diversity index. Many investigators have reported changes in diet of fish species as they grow (Fagade & Olaniyan, 1972). Teleosts and crustaceans remain a staple throughout the lifespan, however types and sizes of preys consumed may change Shannon-Wiener prey diversity index values, indicating that larger animals feed on more prey that is diverse. Those results indicate differences in the diet among the two trophic groups of *P. senegalensis*: immature males and females, and mature males and females. According to Vassilopoulou (2006), temporal variations in diet are due to ontogenetic transformation, mainly connected to morphological adjustments that accompany growth of a fish, as well as seasonal changes in food availability.

The differences in the diet among sexes and maturity stages may be associated with the formation of schools segregated by sex and size. These conclusions agree with previously published food habits studies for several populations of *Pseudotolithus* species (Nunoo *et al.*, 2013). For the whole sample, shrimps were more common in immature

individuals and teleosts and crabs were more consumed by mature individuals. The pattern could be associated with reproductive investment coupled with increased mouth gape and to the reduced vulnerability of the fish to predation while feeding (Nunoo *et al.*, 2013). Widening of dietary sources with the fish sizes constitutes another means of reducing competition between smaller and larger individuals. Onset of sexual maturity and the related change in the energetic needs due to reproduction such as gonad development, egg formation and gestation increases could trigger shifts in the feeding habits. The cassava croaker is a benthic and coastal species that feeds mainly on benthic prey. The presence of some pelagic species as *Sardinella* species in the diet could be due to a low availability of its preferred fish food in the benthic habitat as these may have migrated into surface waters and showed that *P. senegalensis* could conduct vertical movements (Nakamura *et al.*, 2011). These vertical migration patterns provide an opportunity for predatory fishes to encounter and consume prey that may only temporarily dwell in their foraging habitat (Goldman & Sedberry, 2010). Therefore creating an opportunity for diet overlap between bottom-feeding fishes and water-column-feeding fishes (Prete *et al.*, 2004).

Sexual differences observed in the diet of the Senegalese cassava croaker with fish food item have been relatively more important to females. *P. senegalensis* male exhibited a narrower food niche than large females. This may be due to the fact that males were probably limited to the food available around the nest since they display territorial behaviour and provide parental care for the eggs in the breeding season (Gkenas *et al.*, 2010). Furthermore, the lower ingestion of shrimps, algae and plathelminthes by males compared to females could explain the feeding dissimilarity between both sexes. As reported in several studies (McCord & Campana, 2003; Soares *et al.*, 2016), sexual differences in the diet were shown in this study. These differences are related to either sexual segregation resulting from sex-specific preferences in the food-searching sites, and the difference in the stomach size between males and females with the sexual dimorphism often seen in fish (McCord & Campana, 2003).

Several species have been shown to shift their diet across seasons and locations as a result of variations in the connectivity to floodplain habitats. Variation in diet of *P. senegalensis* with season in both study sites agree with the observations of several workers in different fish species (Ugwumba & Adebisi, 1992, Vassilopoulou & Papaconstantinou, 1993). The present study revealed seasonal variation in feeding activity of the cassava croaker indicating the highest amounts of food in the warm season in the Senegalese coast. Seasonal differences in diet presumably reflect seasonal migration of predators or of their prey. This is consistent with the observations of Nunoo *et al.* (2013), who exhibited that feeding of *P. senegalensis* and its congener *P. typus* was more intense during the major warm season than during any other season at the coasts of Benin. The present data are also consistent with the suggestions of Tyler (1971) who assumed that fish feeding rates decrease as water temperature drops. Seasonal migrations

of teleosts or of their prey and the changes in prey abundance (Muto *et al.*, 2001) between the warm and the cold season at the Senegalese coast could explain seasonal shifts observed in the diet of the cassava croaker. Changes in habitat quality and resource availability associated with seasonal variation in hydrology strongly influences ecological interactions in tropical areas (Lowe-McConnell, 1979). In benthic and demersal coastal communities, species composition is variable, because environmental conditions change seasonally (Jaureguizar *et al.*, 2006).

The geographic differences in diet are documented for many fishes. Habitat type and water depth have been found to influence diet composition and prey species usually associated with temperate/subtropical seagrass beds, sand flats, and muddy substrates (Cortés *et al.*, 1996).

This present investigation on the diet of *P. senegalensis* highlighted some differences in food habits of the species in two locations which was not previously addressed. Differences in the diet of the cassava croaker between Joal and Mboro, with the low Simplified Morisita index value, showed these habitats affected pattern of food selection and consumption for this species. The differences showed that they exploit almost local prey even if a similarity exist by referring to large groups. From Dakar to Saint Louis (Mboro), with the narrower plateau and a sandy coast characterized by the presence of a large canyon in Kayar, the ecological conditions are different compared to those south of Dakar (Joal) where upwelling is more regular during the year. These geographical particularities towards Mboro in the North play an important role in limiting the seasonal migration of demersal species towards the South. The variation of diet according to locations is exemplified by many species of teleosts (Lowe *et al.*, 1996). The nature of the estuarine ecosystem found at Joal and the marine type at Mboro probably explains the difference in the diet of this species. The estuaries are the seat of a strong enrichment, but the fishing pressure is stronger in Joal than in Mboro. The variation of diet according to locations is exemplified by many species.

## CONCLUSION

To sum up, this study is the first to provide detailed information on the diet of *P. senegalensis* at the Senegalese coast. Findings suggest the generalized feeding behaviour of this species at both study sites; namely, Joal and Mboro. In addition, *P. senegalensis* is found a tertiary consumer with a diet changing according to sex, maturity stage, season and location. The data demonstrated differences in the diet between specimens of different sexes, different maturity stages, and both locations. These changes in the diet show the adaptability of this predator to catch and consume large prey, availability of prey, density of prey and prey profitability. Further research is needed to better understand the factors influencing the diet of *P. senegalensis* with studies over a wider range

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