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Diet and Food Ethology of Largehead Hairtail *Trichiurus Lepturus* Linnaeus, 1758 (Perciformes, Trichiuridae) in Coastal Waters of Cote d'Ivoire

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Abstract This study aims to evaluate the food ecology of *Trichiurus lepturus*. 876 specimens of *Trichiurus lepturus* were collected monthly from January 2018 to December 2018 in Abidjan fishing port and their stomachs contents examined. The number of stomachs non-empty examined in this study is 176 stomachs out of the 876 obtained. The index of preponderance (%PI) showed that *T. lepturus* had a carnivorous diet piscivorous tendency. Twelve items grouped into three categories, Fishes (PI = 97.99%), Crustaceans (PI = 2.10%) and Molluscs (PI = 0.002%) were the major feed. Juveniles (Total Length (TL) < the length at first maturity (L_{50}= 48.02 cm)…) consumed crustaceans (PI = 59.18%) as main preys and fishes (PI = 40.18%) as secondary preys. In adults (Total Length (TL) > the length at first maturity (L_{50}= 48.02 cm) …), Fishes (PI = 97.59%) were the main preys eaten. According seasons, *T. lepturus* feeds Fishes (PI = 89.02 %) and Crustaceans (PI = 10.98%) during miner warm season and mayor cold season Fishes (PI = 94.26%) and Crustaceans (PI= 5.65%). They only feed on Fishes (PI = 99.91%) during the miner cold season (mcs) and mayor warm season (PI= 99.1%) (MWS). Bray-Curtis similarity showed no significant difference ($p > 0.05$) between diet of juveniles and adults of *Trichiurus lepturus* in all seasons.

Keywords: *largehead hairtail, Trichiurus lepturus, feeding habits, coastal waters, Cote d'Ivoire, West Africa*

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1. Introduction

Trichiurus Lepturus Linnaeus, 1758, is a benthopelagic species widely distributed in all tropical and subtropical seas at maximum depths of 350 m [1]. This species was specifically investigated in a number of studies such as systematics [2], biology [3,4,5,6,7] , ecology [8,9,10] and dynamics [11,12] In addition to the scientific interest, *T. lepturus* makes a very important economic contribution in several countries [13], particularly in China and Japan, where it is considered overexploited with the highest catch volumes [14]. *T. lepturus* also plays an important ecological role as a top predator in the ecosystem in controlling populations of mid and lower trophic level fishes, cephalopod species and crustaceans [13,15]. In many West African countries such as Cote d'Ivoire, this species has not always been targeted by fishermen [16,17]. However, during its last ten years, it has gradually achieved the status of a dominant marine resource. This species has taken an important part in the feeding habits of the local population in Cote d'Ivoire and it is highly traded fresh, smoked and dried in the markets. However, due to the absence of formal regulations and the lack of information on its ecology and on its biology, the stock of this species could be irrationally exploited in Cote d'Ivoire. The present study therefore, aims to provide further information on the nourishment and abundance of natural food needed by *T. lepturus* according to sizes and seasons in order to propose appropriate sustainable management measures for this species.

2. Materials and Methods

2.1. Study Area and Sampling Strategy

Specimens of *T. lepturus* are caught by the industrial and artisanal fishery in the Gulf of Guinea. This oceanic area belongs to the Central East portion of the Atlantic Ocean which covers West Africa, from Morocco to Congo [18]. The maritime area of Cote d'Ivoire which belongs to the Atlantic Ocean extends from Cape of Palmes (8 ° W) in the West to Cape of three-Pointes (2 ° 30'W) to the East, over a length of approximately 600 km [19] Figure 1. The whole sample consisted in 876 specimens with size ranging from 38-104 cm in total length were taken between January to December 2018 at the fishing port of Abidjan. The specimens were identified using the keys of FAO [14]. The total length (TL) was recorded individually to the nearest 1 cm, and total body weight (TW) and eviscerated body weight (EW) to the nearest 0.1 g. Organisms were dissected to determine the sex by macroscopic investigations and remove the stomach. The stomach and stomach contents, were weighed to the nearest 0.001 g, which was preserved by immersing in 5% formaldehyde. The contents of stomach each of the dissected specimens was poured into a Petri dish, and the weight of food belonging to each taxon were noted.

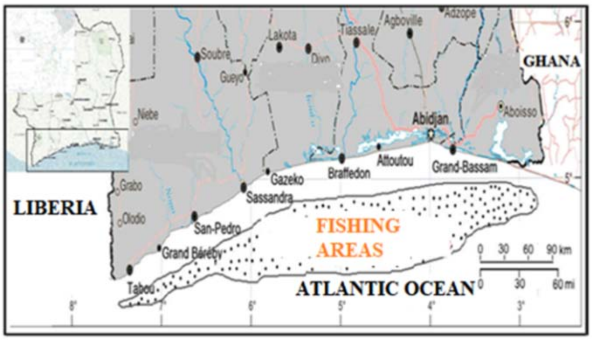

Figure 1. Fishing areas of fishing location (•) of different fisheries in the Coastal of Cote d'Ivoire (West Africa).

2.2. Data Analysis

(1) Feeding intensity

The feeding intensity of the specimens was assessed based on the volume of food contained in the stomach, and classified as full, ½ full, or empty stomach. The importance of various food components in the stomach was calculated by the preponderance index (PI) as described in [18]. This was estimated by incorporating the: 1) percentage of the number of each food item to the total number of all food items identified (%N); 2) frequency of occurrence of each food item in the total number of stomachs examined (%F) and 3) percentage of wet weight of each food item to the total weight of all food items identified (%W). The preponderance index was computed as given below:

$$PI = (F + W) / \sum (F + W)$$

The different categories of prey will be classified according to the classification scale proposed by [20], modified by [21].

Main prey: PI>50%; Important prey: 25 <PI≤50; Secondary prey: 10≤ PI ≤25%; Accidental prey: PI <10%

The different PI values were analyzed were grouped by size into two categories: juveniles (38 to 48 cm Tl) and adults (48 to 104 cm Tl). The influence of the seasonal variation of the oceanographic conditions, samples were grouped in four categories (1-mcs: miner cold season; 2-Mcs: major cold season; 3- mws: miner warm season; 4- Mws: major warm season). In addition to the above percentages, the vacuity index (VI) has been calculated. It allowed to appreciate the trophic intensity of the fish. The vacuity index was computed as given below:

$$VI = \frac{Number\ of\ empty\ stomachs}{Number\ of\ total\ stomachs} \times 100$$

We evaluated the diet similarity between juveniles and adults fishes, the similarity these different seasons. Using the Bray-Curtis similarity index, we performed a cluster analysis on the standardized and transformed %PI to describe this variations in PRIMER 5.2.

(2) Feeding strategy

The analysis proposed by [21], was used to interpret the stomach contents data Figure 2. This method is a modification of the traditional method of [22]. The analysis is based on a two dimensional representation of prey specific abundance and frequency of occurrence of the different prey types in the diet. It allows to analyze the prey's importance, feeding strategy, and inter and intra-individual components of niche breadth to be analyzed by a two-dimensional representation of prey abundance (PI) and frequency of occurrence (F) [21]. Prey is more important than if PI x F is high. According to its authors, the interpretation of the diagram (prey importance, feeding strategy and niche breadth) can be obtained by examining the distribution of points along the diagonals and axes of the graph. The diagonal from the lower left to the upper right corner provides a measure of prey importance (b), with dominant prey at the top, and rare prey at the lower end. The vertical axis represents the feeding strategy of the predator in terms of specialization or generalization.

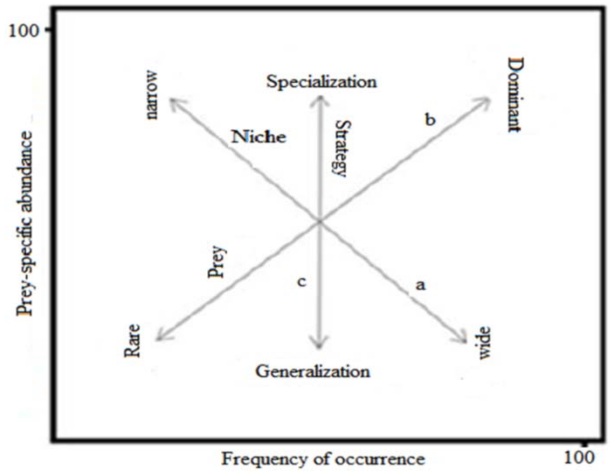

Figure 2. Feeding strategy diagram for *T. lepturus* [20,21], January 2018 to December 2018.

Predators have specialized on prey positioned in the upper part of the graph, whereas preys positioned in the lower part have been eaten only occasionally (generalization) (c). Finally, in terms of niche breadth. It can be wide or narrow (a).

3. Results

3.1. Vacuity Index

A total of 876 stomachs from specimens ranging from

38 to 104 cm of total length was examined. 176 were non-empty compared with 700 empty stomachs. The vacuity index calculated were 79.90%. During the major warm season, 238 empty stomachs out of 294 were recorded. The vacuity index observed were 80.95%. In the short warm season, 112 empty stomachs out of 136 examined with a vacuity index of 82.35% were noted. During the great cold season, 206 stomachs out of the 306 harvested were empty and vacuity index recorded were 67.32%. In the short cold season, 102 empty stomachs were observed on 140 stripped stomachs examined. Vacuity index calculated during this season were 72.85% Figure 3.

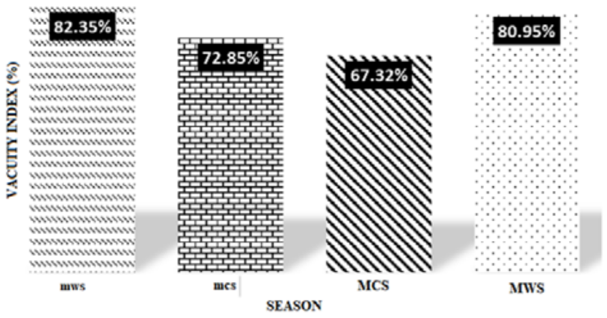

Figure 3. Variation of vacuity index of *T. lepturus* sampled between January 2018 to December 2018 and based on the different marine seasons (mws = miner warm season; mcs = miner cold season; MCS = Mayor cold season; MWS = Mayor warm season).

3.2. General Composition of Diet

Twelve (12) food items were obtained after analysis of 176 non empty stomachs of *T. lepturus* these food items were categorized into three major groups: Fishes, Crustaceans and Molluscs Table 1. Based on preponderance index (IP), Fishes (PI= 97.99%) including the fish detritus, *B. auritus* and *E. encrasicolus*, were the primary food items. They are followed by Crustaceans (PI= 2.10%) including *P. longisrostris* and Crustaceans detritus, and Molluscs (PI = 0.002%). According occurrence values, fish detritus (%F = 48.86) was the most important part of *T. lepturus* diet. Among food items, Fishes constituted by *Brachydeterus auritus* (%F= 11.363), *Engraulis encrasicolus* (%F = 14.772) and Crustaceans constituted by *Parapenaeus longirostris* (%F= 26.136) were a most important preys eat by *T. lepturus* (Figure 4). Along all diet groups, fish detritus (%F=48.86) and shrimps detritus (%F=14.77) are the regular prey of *T. lepturus*. According weight percentage, *Sphyraena guachancho* (%W=19.42), *Brachydeterus auritus* (%W=16.04) and fish detritus (%W=33.65) were dominating the diet of *T. lepturus*. Preponderance index showed that Fish items with 97.29%, are the main prey eating by *T. lepturus*. All other food items found in stomach with PI <10%, are accessory prey.

Table 1. General diet composition of *Trichiurus lepturus* an Cote d'Ivoire coastal sampled between January 2018 to December 2018. %W: percentage weight, %F: frequency of occurrence, % Fc: frequency of occurrence corrected, %PI: preponderance index, % PIc: preponderance index corrected

Foods items/groups	%W	%F	%FC	%PI	%PIC
FISHES					
Carangidea					
Caranx senegalus (Cuvier, 1833*).*	2.844	1.136	0.833	0.141	0.141
Clupeidae					
Sardinella aurita (Lowe, 1838)	5.811	2.272	1.666	0.579	0.579
Engraulidae					
Engraulis encrasicolus (Linnaeus, 1758)	8.871	14.772	10.833	5.752	5.752
Haemulidae					
Brachydeterus auritus (Valenciennes, 1832)	16.043	11.363	8.33	8.001	8.001
Sciaenidae					
Pteroscion peli (Bleeker, 1863)	5.82	3.409	2.5	0.87	0.87
Sphyraenidae					
Sphyraena guachancho Cuvier, 1829	19.425	2.272	1.666	1.937	1.937
Trichiuridae					
Trichiurus lepturs Linnaeus, 1758	1.5	1.136	0.833	0.074	0.074
Sparidae					
Pagellus belottii Steindachner, 1882	0.608	4.545	3.333	0.121	0.121
Fishes detritus	33.652	48.863	35.833	72.172	72.172
CRUSTACEANS					
Peneidae					
Parapenaeus longirostris (Lucas, 1846)	3.979	26.136	18.11	4.582	4.582
Shrimps detritus	1.066	14.772	10.236	0.693	0.693
MOLLUSCS					
Cephalopodes	0.107	2.272	1.666	0.01	0.01
TOTAL					
FISHES	94.578	89.772	65.833	97.299	97.299
CRUSTACEANS	5.045	40.909	28.346	2.106	2.106
MOLLUSCS	0.107	2.272	1.666	0.002	0.002

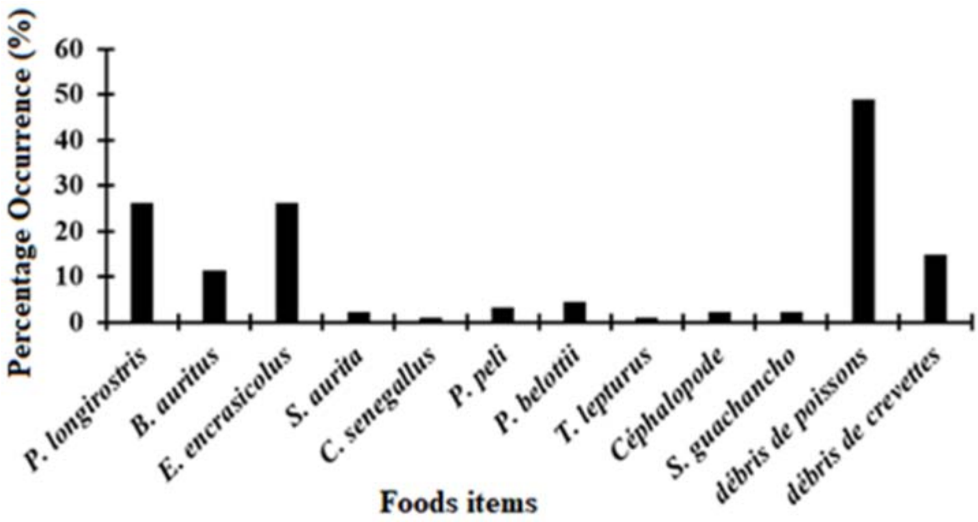

Figure 4. Occurrence percentage of food items in gut contents of *T. lepturus* sampled along Cote d'Ivoire Coastal between January 2018 to December 2018.

3.3. Variation of the Feeding According Size Classes and Seasonal

Analysis of food items in relation to body size, as presented in Figure 5. Juveniles with total length (TL) < 48.02 cm, ate mostly crustaceans consisting mainly of shrimp detritus (PI = 59.18%) as main preys. In adults, total length (TL) >48.02 cm have as preferred prey, Fish with a PI = 97.59 %. Seasonal variation in the diet composition of *T. lepturus* for the period was studied by analyzing the data for December 2018 to January 2018 (Figure 6). In the miner cold season (January to February), fishes (89.02 %) were the dominant food items found in the gut, followed by crustaceans (10.98%). Among fishes, unidentified fish remains (63.76%) formed the mayor category, following by *Brachydeterus auritus* (6.68%), *Sphyraena guachancho* (4.55%), *Engraulis encrasicolus* (3.71 %), crustacean's detritus (1.54 %) and *P. longirostris* (13.55%) was the key prey followed by other shrimps. During Mayor warm season (March, April, May and June), the maximum PI was for fishes (99.06%), followed by crustaceans (0.92%), and molluscs (0.02%). In the Mayor cold season (July, August, September and October), fishes dominant the item (94.25%), followed crustaceans (5.65%) and the contribution of molluscs to the diet was negligible (0.1). Among fishes unidentified fish remains (40.87%), *Brachydeterus auritus* (20.88%), *Engraulis encrasicolus* (25.72%), *Sphyraena guachancho* (2.18%), *sardinella aurita* (6.56%) comprised major part of the diet. While *P. longisrostris* (3.73%). Constituted the crustacean component. During miner warm season (November to December) fishes dominated item (99.91%) and the contribution of crustaceans (0.09%) and molluscs (0%) to the diet was negligible. This was followed by unidentified fish (90.45%), *P. longirostris* (3.65%) and *T. lepturus* (5.04%). Bray-Curtis similarity showed normal distribution and no significant difference (p>0.05) was observed between seasons.

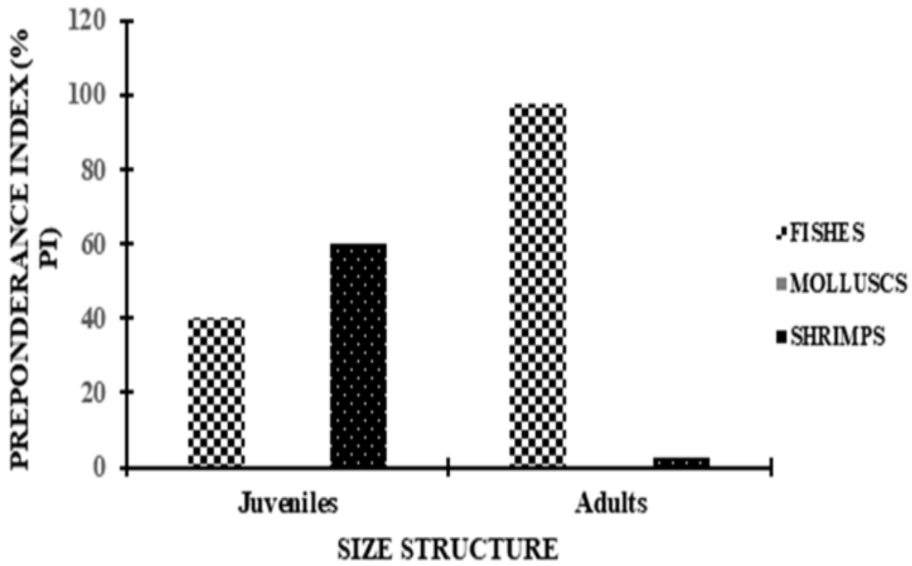

Figure 5. Feeding according different size classes of *Trichiurus lepturus* sampled between January 2018 to December 2018

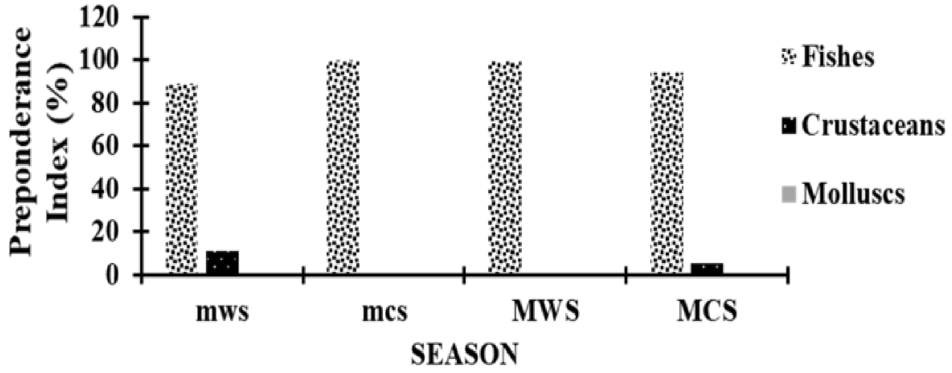

Figure 6. Seasonal variation in diet composition of *Trichiurus lepturus* sampled between January 2018 to December 2018 and based on the % PI of main prey categories

3.4. Feeding Strategy

Analysis of feeding strategy, based on the [21] method Figure 7, showed that Molluscs, are consumed only occasionally (rare). In terms of prey importance, Fishes and Crustaceans were the most important. Fishes being more abundant in the diet of the *T. lepturus*. Fish detritus, partially digested unidentified remains is the most dominant prey followed by *E. encrasicolus* and *B. auritus*. But a fringe of this population consumes, in addition to fish as preferred prey, crustaceans as secondary prey, with an abundance of *P. longirostris*.

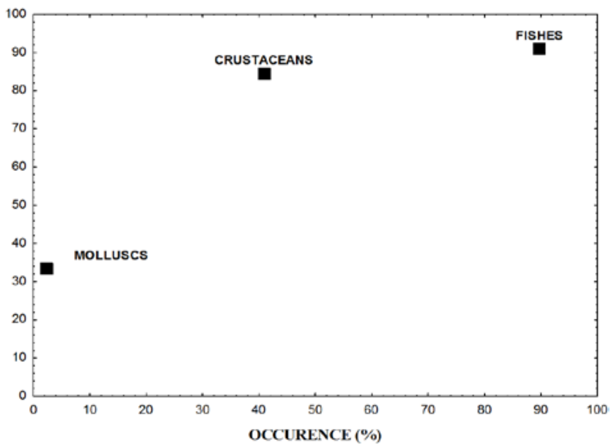

Figure 7. Feeding strategy for *Trichiurus lepturus* sampled between January 2018 to December 2018

4. Discussion

4.1. Vacuity Index

The study of the diet of *T. lepturus* revealed a very high rate of empty stomachs. The presence of high percentage of empty stomachs is characteristic of piscivorous fishes [10,23]. Work going in the same direction showed Higher proportion of empty stomachs in *T. lepturus* were reported, in particular the work of [24] Arabian sea and northern bay of Bengal.

Those from [25], in southwest Indian coasts and the work of [10], Northwest Indian coasts. The vacuity index was important value during the different season. But is maximum during the months following the upwelling period, miner warm season (November to December) and major warm season (March to Jun). Is the peak period of landing of *T. lepturus* at the Abidjan fishing port. Thus, there is a clear indication that the abundance of specimens in the period is consequent to the abundance of prey items at this time precisely.

4.2. General Composition of the Diet

12 food items were obtained after analysis the general diet of *T. lepturus*. Three groups of prey, fishes, shrimps and molluscs. The most abundant groups are the fishes that follow crustaceans consumed by part of population and molluscs that are rarely eaten. The study also reveals that the species is a carnivore both an optional cannibal. However, the cannibalism in the present study was comparatively very low (%W= 1.5) and similar to the cannibalism of same species in South-western of Indian coast [24], and south-western of Taiwan (%W= 0.5) [13]. Other studies have shown very high values of cannibalism. This is the case of the work of [26], with percentage weight (%W =25.2) for the China, those from [27], in the Brazil with percentage weight (%W = 40.2) and 21.6% in the South China Sea [28]. However, cannibalism it the important factors to regulate population size. According to [29], cannibalism has frequently been suggested as a strategy to transfer energy from smaller to larger individuals. It increases when the population was abundant [25].

4.3. Variation of the Feeding According Size Classes and Seasonal

Results of similarity test (Bray-Curtis) suggest were significantly variation between juveniles and adults feeding of *T. lepturus*. The juveniles feeding of crustaceans and fishes whereas adults feeding fishes. Studies in the Indian Ocean show that juveniles feed on euphausiids and clupeids and also fish larvae off the coast of India [30]. The differences between these studies and ours can be explained by the low number of *T. lepturus* juveniles sampled in our study environment. In addition, the diversity of prey may vary depending on the study areas, it must also be taken into account. Also, according to the work of [31], these changes in feeding behavior are most often linked to ontogenetic, anatomical and morphogenetic changes in fish during their growth. These changes have most of the consequences, the change in the choice of prey. They thus have an increased preference for large prey that may provide them with more energy for growth and reproductive ability [32,33]. The diet of *T. lepturus* varies significantly with the specimen's size. This difference could be explained by the inability of juveniles to capture preys whereas adults who have larger mouths with higher movement speed can capture larger prey. According to [34] studies, the largest predatory fish can hunt their preys before catching them.

The study of seasonal variations in PI shows changes in the diet of *T. lepturus*. This diet has similarities despite the slight variations observed between different seasons. This variation varies according to the abundance of the prey observed. Fish has been the essential prey encountered in their stomachs. Among the fish, unidentified fish, *B. auritus* and *E. encrasicolus* were the main foods. *P. longirostris* was the main group of prey among crustaceans. The presence of crustaceans in the diet is significant only during the miner warm season (mws) and the major cold season (MCS). The miner warm season and the major cold season coincide with the period when the proportion of juveniles is the highest of the population. This fringe of the population feeds, in addition to the certainly small fish, crustaceans mainly of the species *P. longirostris*. Previous studies carried out in the Egyptian Mediterranean have clearly shown that *T. lepturus* feed mainly of the prey *E. encrasicolus* [35]. In the East China Sea, *T. japonicus* was the main prey [36]. However, they differ from the observations of [10], based on work done in the North-West Indian coasts. According to this work, *T. lepturus* feed mainly prey to shrimp, mainly *Acetes sp*. However, fish also contributed significantly to the diet in this same environment.

4.4. Feeding Strategy

A benthopelagic species, *T. lepturus* is a carnivore that mainly targets fish and to a lesser extent, crustaceans. Amundsen's method, showed that a *T. lepturus* mixed feeding strategy, with varying degrees of specialization and generalization on different prey types. Fishes were the most important prey follow crustaceans which are consumed by a fringe of the population and molluscs as occasional prey. Many studies found that *T. lepturus* main prey is fish [25]in South-west of Indian; [15] in South China sea; [27], in Northerm Rio de Janeiro. In contrast this study differs from the observations of [10] in Northerm Rio de Janeiro where *T. lepturus* have for main prey the crustaceans, *Acetes sp*., but fish contributed significantly to the diet in this ecosystem.

5. Conclusion

The study indicates that *Trichiurus lepturus* is a carnivore and its principal food in the Cote d'Ivoire coastal water is fish. Fishes such *Engraulis encrasicolus* and *Brachydeterus auritus* also formed its food during different seasons. Crustacean (shrimp) resources such as *parapenaeus longirostris* also constituted the diet of juveniles significantly. The study also indicates the role of feeding intensity with spawning and the important role of *T. lepturus* in the ecosystem. This information is very important for developing an ecosystem based approach for fishery management along Cote d'Ivoire coastal.

Acknowledgments

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List of Abbreviations

CRO: Oceanological Research Centre
DRAV: Aquatic Living Resources
Mcs: Major cold season
mcs: miner cold season
Mws: major warm season
mws: miner warm season

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