Diet of *Elagatis bipinnulata* (Guoy & Gaimard, 1824) in Côte d'Ivoire (Gulf of Guinea)

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Doi: 10.19044/esj.2019.v15n3p131 URL:http://dx.doi.org/10.19044/esj.2019.v15n3p131

Abstract

The rainbow runner, *Elagatis bipinnulata*, which belongs to the *Carangidae* family, is regularly encountered in the landing of artisanal fishing in Abobo-Doumé (Republic of Côte d'Ivoire). The object of this work is to study the diet of *Elagatis bipinnulata* according to the marine seasons and the size of the various specimens (immature and mature). About 900 fish measuring between 43 and 93 cm (fork length - FL) were examined from September 2015 to August 2017. On the 900 examined stomachs, 541 were empty, which is giving a vacuity coefficient of 60.11%. A feeding index (IRI: index of relative importance of food item) combining three methods percentage occurrence, numerical method and weight method) was used. The identification of the items found in the stomach contents revealed that the principals food items were fish (%IRI=48.85) and crustaceans (%IRI=45.78). Cephalopods (%IRI=4.17), fish detritus (%IRI=1.2) and crustaceans (*Portunus puber*) (%IRI=0.55) are accidental food. The diet of the species does not change according to the seasons and the size of fish.

Keywords: *Carangidae*, artisanal fishing, feeding, Côte d'Ivoire

Introduction

Elagatis bipinnulata has a circumtropical distribution, occurring in the Atlantic from Bermuda and Massachusetts (USA), southward to northeastern Brazil (FAO, 2002). It is a pelagic fish, normally found near the surface, over reefs, or occasionally over the islands slope (Pinheiro *et al.*, 2011). In the East Atlantic, this species is found in the Canary Islands, from Dakar to Angola and particularly in the gulf of Guinea (Collette and Nauen, 1983).

Elagatis bipinnulata belongs to the Carangidae family and occupies an important place in the landings in Côte d'Ivoire. This species is part of "false fish", a local name to designate a category of fish refused by the canneries, but sold at the local market of Abidjan (N'da *et al.*, 2007). It is very appreciated by the population because of its great commercial value. It has been shown that there are local markets with high demand for these discards from tuna purse seiners in the main landing ports in West Africa i.e. Abidjan, Tema and Dakar (Amandè *et al.*, 2016a). However, the proportion of this species in partnership with the thonidés minor ones, mainly captured by gillnet and trawls is difficult to evaluate in the statistics of fishing and tonnage resulting in Côte d'Ivoire (Amande, 2007) and (SCRS, 2017). It thus represents a great interest for the fishermen who develop more and more fishing techniques intended for a more profitable activity.

However, very few data exist on the biology and the ecology of this species in the East Atlantic in general, and on its diet in particular. In Côte d'Ivoire, information available for this species is only of a general nature. This species is fished with tunas. Works carried out in other marine areas around the world explain that *Elagatis bipinnulata* is associated with the devices of fish concentration (DCP) (N'da *et al.*, 2007). Indeed, according to these authors, this species find its prey around the floating objects. In the central Colombian Caribbean, *E. bipinnulata* also feeds more during the dry season rather than the rainy season. García *et al*., (2014), Wang *et al.* (2013) worked on the biology of the reproduction and the diet. This study determined the laying period and the diet of the species caught around DCP or under natural or artificial floating objects.

The main aim of this work is to study the trophic behavior of *Elagatis bipinnulata* and to describe its variability according to the marine seasons and class sizes of the specimens.

Method and Study Area

Study area

Samplings of *E.bipinnulata* to obtain through of this work were fished in the exclusive economic zone of Côte d'Ivoire (EEZ) by artisan fishers. This zone belongs the Gulf of Guinea.

The Gulf of Guinea (Fig. 1) is located in West Africa, in the large marine ecosystem that represents coastal regions. It is bounded to the north by the West African coast, south by the Equator, west by the Cape Palmas (8°W) and east by 2°30 E (Pezennec and Bard, 1992). The climate is Guinean and a series of sandy beaches forms a wide arch open to the Atlantic Ocean. Its major feature is the presence of four marine seasons determined by the temperature variation during the year (Pezennec and Bard, 1992). So, the two cold seasons (a great from July to October and a small from January to February) are characterized by a resurgence of cold salty ocean water (above 35 ‰ salinity) and low temperatures between 23 and 25°C. There are also two hot seasons (a high from March to June and a small in November and December), and are defined by ocean water with a salinity lower than 35‰ and a high temperature between 28 and 30°C (Golé Bi *et al.*,2005).

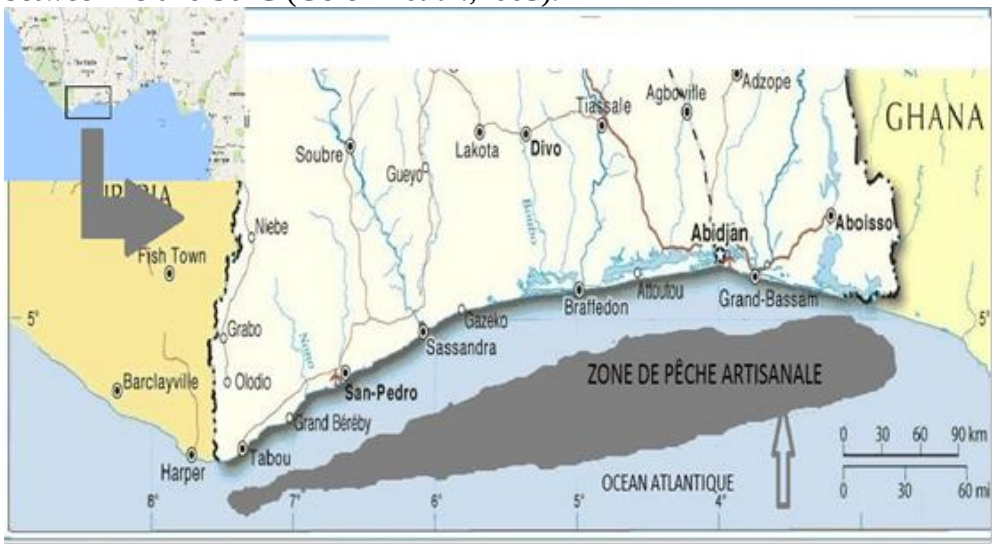

Figure 1: Fishing zone of Côte d'Ivoire artisanal fisheries (Aquamaps, 2016)

Strategy of sampling and analysis of the stomachs contents

Sampling was carried out monthly (September 2015 to August 2017) at the landing site of Abobo-Doumé located at the fishing port of Abidjan during the landings by artisan fishers.

Samples were randomly collected and several measurements were taken: the fork length (FL) with a tape measure and to the nearest centimeter, total weight (W) and eviscerate weight (We) determined with a precision scale

of 0.1g. After gutting, sex and stages of maturation were determined for each individual. The stomachs were transported at the Center of Oceanology Research (CRO). At the laboratory, each stomach was dissected and the content rinsed with water on a series of sieve of mesh 1000µm, 500µm, 250µm and 100µm, before an examination with the naked eye or binocular magnifying glass according to the size of the individuals preys. The various preys were sorted, counted, weighed using the numerical balance (SCOUT) and identified. For digested fish, otolith were collected then observed with the binocular magnifying glass for the identification of their form. After the observation of their form the otoliths, we were basing ourselves on studies carried out by Campana (2004), Veen et Hoedemakers (2005) and Tuset *et al.* (2008) to determine the different species of consumed fish. Several indices were used to quantify the importance of different prey items in the diet of *E.bipinnulata.*

Vacuity Coefficient (VC):

$$\mathrm{VC\%} = \frac{\text{a number of empty stomachs}}{\text{a number of examined stomachs}} \times 100 \quad (1)$$

Frequency of occurrence (F):

$$\mathrm{F\%} = \frac{\text{a number of stomach containing Itemi}}{\text{a number of examined full stomachs}} \times 100 \quad (2)$$

Percentage in a number of the preys (Cn):

$$\mathrm{Cn\%} = \frac{\text{Total number of the Itemi}}{\text{Total number of all Items}} \times 100 \quad (3)$$

Percentage in weight of the preys (W):

$$\mathrm{W\%} = \frac{\text{Weight of the Itemi}}{\text{Total weight of the preys}} \times 100 \quad (4)$$

The diet was determined using the index of relative importance (IRI) from (Pinkas *et al* 1971) .This index combines the occurrence (F), numerical (N) and weight (W) percentages:

$$IRI=F*(N+W) \quad (5)$$

Prey species were sorted in decreasing order according to IRI and the cumulative IRI was calculated.

Statistical analysis

Using the program Statistica version 7.1, the Spearman's rank correlation coefficient was used to see if there is or not a relation between the diets (probability criticizes retained: p<0, 05). The computed values on the basis of IRI made it possible to check the link between the diets of the class sizes and the marine seasons in order to illustrate the differences and the

resemblances in diet between the populations of *Elagatis bipinnulata.* According to Scherrer (1984), diets are exactly the same if RS=1, independent if RS=0, and rigorously inverse if RS=-1. The Kruskal-Wallis test was carried out with the software R, on the vacuity of coefficients according to the sex to determine the significant differences ($p<0.05$).

Results

Vacuity coefficient of the stomach

The vacuity coefficient gives an outline on the repletion of fish. A total of 900 stomachs were examined during this study period from September 2015 to August 2017, and 541 were empty. The VC calculated is 60.11%.

Monthly variation of the vacuity coefficient according to the sex

Figure 2 shows the monthly variation of the VC. The vacuity coefficient of the two distinct populations (male: M and female: F) not being statistically different (Kruskal-Wallis test between M and F, $p = 0.1 > 0.05$), they were combined (M+F). The vacuity coefficient of M+F undergoes ranged from 21.47% to 39.96%. The highest mean are observed: in November, April, July and September with respectively 35.92%, 36.48%, 39.62% and 38.96. And the lowest values were recorded in October (22.22%) and January (21.47%).

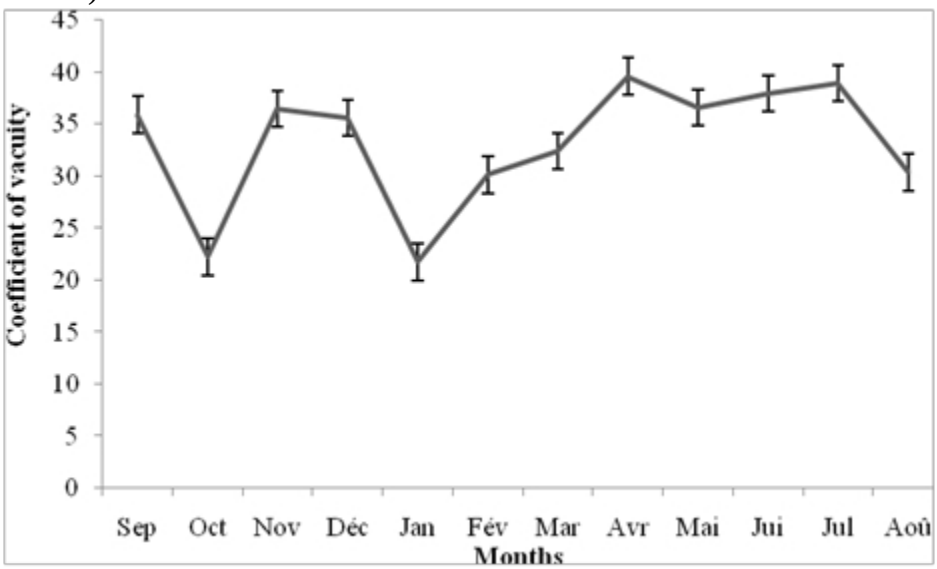

Figure 2: Monthly evolution of the vacuity coefficient of *Elagatis bipinnulata*.

Variation of the vacuity coefficient according to the marine seasons

Figure 3 shows the evolution of the vacuity coefficient of *Elagatis.bipinnulata* according to the marine seasons. The specimens fished

during the hot seasons recorded the highest means of the vacuity coefficient (small hot season with 36.07% and great hot season with 30.03%).

The smallest values of vacuity were recorded during the great cold seasons (27.62%) and the small cold seasons (25.94%). The highest means of the vacuity coefficient were recorded in the hot season than the great season.

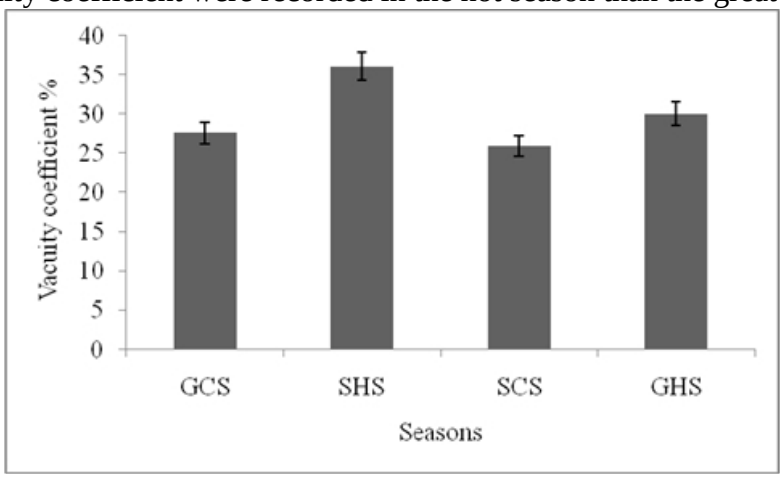

Figure 3: Seasonal evolution of the vacuity coefficient of *Elagatis bipinnulata*. GCS=great cold season; SHC=Small hot season; SCS=small cold season; GHS=great hot season.

Variation of the vacuity coefficient according to their size

The collected specimens measure between 40 to 93 cm (fork length) (Figure 4). Two classes of sizes were established according to the size of the first sexual maturity (L50). Specimens of small size (40<LF<60; N=240) make up the group of immature or class 1. Those of big size (60<LF<93; N=301) are the group of mature or class 2. The graphical representation of the vacuity coefficient according to the two classes of size gives 44.36% for class 1 and 55.64% for class 2. The analysis of this result shows that class 2 is higher than the class 1.

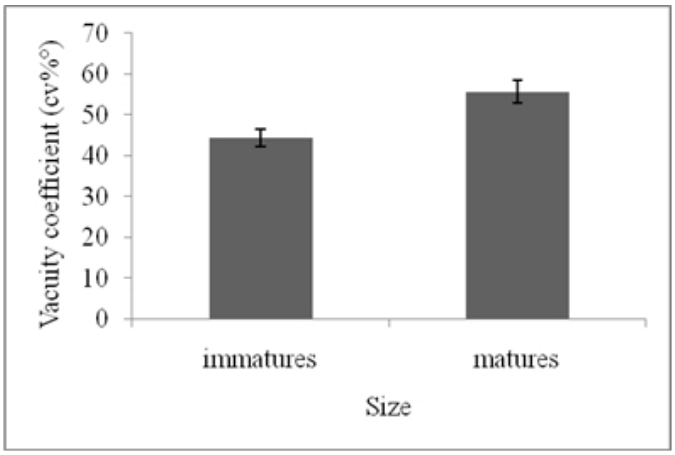

Figure 4: Evolution of the vacuity coefficient according to the sizes for *Elagatis bipinnulata*.

General profile of the diet

On all the 900 stomachs of *Elagatis bipinnulata*, 359 contained food. Ten categories of food were identified and divided in three groups (Table I). They are fish, crustaceans and cephalopods. The group of fish is composed of 7 species from 4 families: *Scombridae* (2 species), *Carangidae* (3 species), *Clupeidae* (1 species) and *Trichiuridae* (1 species). This group is also constituted of fish not identified due to their very advanced stage of digestion. The crustaceans group includes the shrimps *Penaeus nottialis* and the *Brachyoures* (crab). A single species of cephalopod was found in the food bowl of *E. bipinnulata*. According to the classification with IRI (Table II), fish (%IRI=48.85) and crustaceans (%IRI=45.78) are the preferential preys. This analysis shows that of all the combinations of preys present in the stomach of this species, the shrimp *Penaeus notialis* is the most higher (%IRI=45.23), followed by *Clupeidae* (%IRI=20.61) and additional preys: *Carangidae* (*Decapterus macarellus, Selene dorsalis, Caranx sexfasciatus* respectively %IRI=8.26; 2.6; 1.78), *Scombridae*: *Katsuwonus pelamis*, cephalopods such as *Sepia officinalis* (%IRI=4.17), leftovers of fish (1.2%) and crustaceans *Portunus puber* (IRI=0.55%).

Table I: Percentages of the food indices of *E. bipinnulata* resulting from marine artisanal fishing of the Ivory Coast from September 2015 to August 2017. Cn: numerical percentage; W: percentage by weight; F: percentage of occurrence; IRI: percentage of index of relative importance

			Cn (%)	Cp (%)	Ep (%)	%IRI
Group	**Family**	**Species**				
Fish	*Scombridae*	*Katsuwonus pelamis*	8.09	12.39	9	7.49
		Auxis thazard	6.96	8	4	2.43
	Carangidae	*Caranx sexfasciatus*	6.85	7.61	3.03	1.78
		Selene dorsalis	3.92	5.19	7.03	2.6
		Decapterus macarellus	5.82	9.58	13.2	8.26
	Clupeidae					
		Sardinella maderensis	10.98	18.49	17.22	20.61
	Trichiuridae	*Trichiurus lepturus*	7.16	8.17	9.13	5.68
Crustaceans	*Macroures*	*Panaeus notialis*	30.37	9.22	28.13	45.23
	Brachyoures	*Portunus puber*	1.9	4.46	2.13	0.55
Cephalopods		*Sepia officinalis*	9.95	10.07	5.13	4.17
Fish Leftovers			8	6.82	2	1.2
Total						
Fish Leftovers			8	6.82	2	1.2
Fish			49.78	69.43	62.61	48.85
Crustaceans			32.27	13.68	30.26	45.78

Variation of the diet according to the marine seasons

The diet was analyzed according to four marine seasons with knowing the great cold season, the small hot season, the small cold season and the great hot season (Figure 5). In great cold season, fish (%IRI=49.39) and crustaceans (%IRI=42.92) constitute the preferential preys. Cephalopods (%IRI=6.43) and the fish leftovers (%IRI=1.26) are additional preys. During the small hot season, fish (%IRI=48.96) and crustaceans (%IRI=41.2) are the preferential preys. Cephalopods (%IRI=4.88) and the fish leftovers (%IRI=4.9) are secondary preys. In small cold season, the diet is focused on fish (%IRI=56.26) which constitute the principal preys. Crustaceans (37.07%) are significant in the bolus, but constitute secondary preys compared to fish. The cephalopods and the leftovers of fish are accessories preys.

During the great hot season, consumption is dominated considerably by fish (66.58%) which constitute the principal preys. Crustaceans (17.99%) and cephalopods (10.59%) are secondary preys, while fish leftovers (0.08%) constitute additional preys with an IRI lower to 10%. The Spearman's correlation coefficient calculated from the percentages of IRI of the various seasons is significant (RS=0.79, with $p=0.001<0.05=p$).

There is a similarity of the diets during the small cold season and the small hot season.

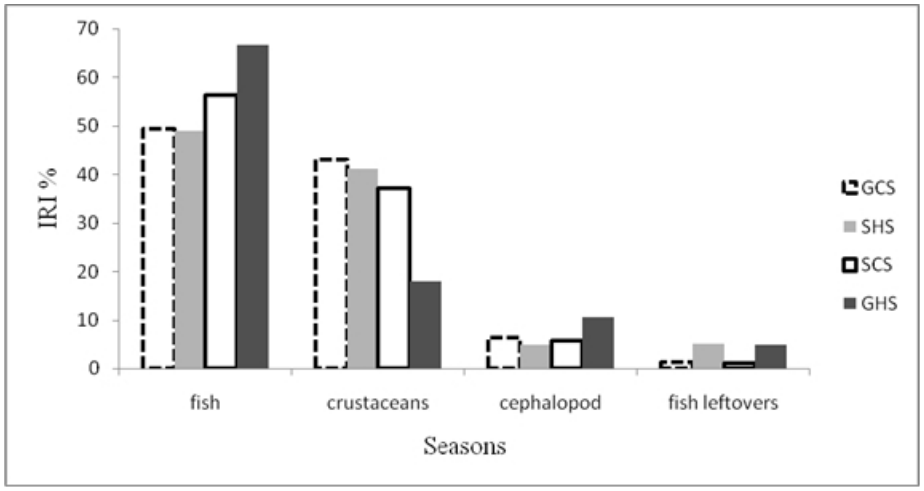

Figure 5: Composition of the diet of *Elagatis bipinnulata* according to the marine seasons. GCS=great cold seasons; SHS=small hot season; SCS=small cold season; GHS=great hot season.

Variation of the diet according to the size

For the juveniles specimens (40<LF<60 cm), fish constitute the preys mainly consumed (%IRI=65.15). Among those, *Sardinella maderensis* (15.39%) is the principal one, followed by *Decapterus macarellus* (IRI=11.64%) and *Katsuwonus pelamis* (%IRI=10.95). The incidentally

consumed food are crustaceans (%IRI=24.94) then cephalopods (%IRI=7.88) and the fish leftovers (Figure 6).

Regarding adults (60<LF<93 cm), consumption is mostly dominated by fish (%IRI=71.44), crustaceans (%IRI=18.67) being considered as secondary prey. Other foods represented by cephalopods (%IRI=8.74), fish remains (unspecified) (%IRI=1.15) are ingested incidentally. The Spearman's correlation coefficient calculated from the percentages of IRI of juveniles and adults was significant (RS=0.82) with p=0.01.

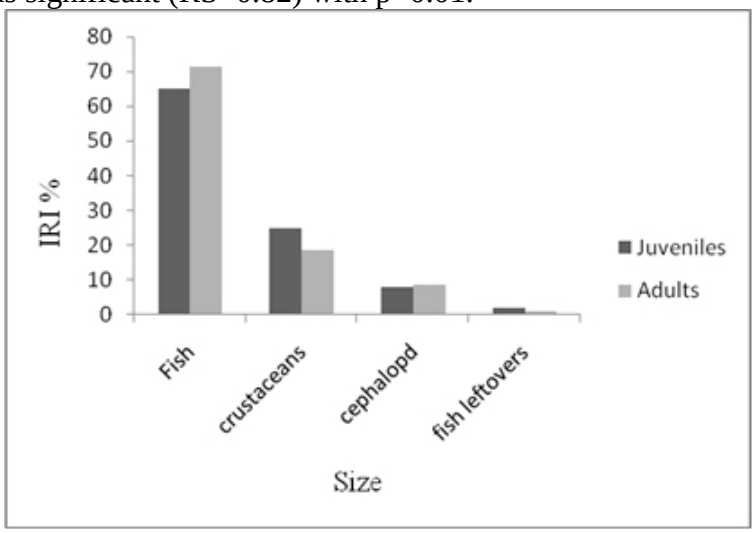

Figure 6: Composition of the diet of *Elagatis bipinnulata* according to the size.

Discussion

The vacuity coefficient of the whole analyzed samples landed at Abobo-Doumé is 60.11%. This strong proportion of empty stomachs could be due to the stress that the fish undergo during captures (Diaha *et al*., 2010). Indeed, the high proportions of empty stomachs observed are often a consequence of the fishing method which would support the regurgitation of food ingested during the capture. It is the case for other species such as *Trachinotus teraia* in the Ebrié lagoon in Ivory Coast (Sylla *et al.*, 2008; Heithaus *et al*., 2008).

This important VC suggests for the periods of high percentages, the fish are not nourishing themselves veritably. The food activity would then be influenced by the conditions of the medium and the physiological state of fish (Diaha *et al*., 2010).

The study of the reproduction of *Elagatis bipinnulata* revealed that the spawning period proceeds during hot season, where the VC is also high. The seasonal variations of this coefficient show that this fish presents a different food behavior according to studied months.

Indeed, *E. bipinnulata* eats more in cold season which corresponds to an importance food activity for the constitution of energy reserves in order to use them during the reproduction. The vacuity rate of *E. bipinnulata* is higher during the hot seasons than during the cold seasons, reflecting a trophic activity significantly greater during recent seasons.

These results are contrary with those obtained by Garcia *et al.* (2014) in Colombia. These authors think that *E. bipinnulata* eats more in hot season than cold season. These results are also contrary with those obtained in the tropical Atlantic Ocean (Vaske *et al.*, 2006). These authors found that *E. bipinnulata* eats night and day during all seasons. The VC is higher for the adults specimens than for the juveniles, which shows the trophic activity of juveniles is much more significant than of the adults. Our results are similar to those described in the central Pacific Ocean (Wang *et al*., 2013). They estimated the vacuity coefficient increases with the age of the fish.

The analysis of the stomach contents of *Elagatis bipinnulata* shows this fish is a predator. It feeds fish, shellfish, of cephalopods and fish leftovers. The food profile of the studied preys is identical to that highlighted by (Wang *et al*., 2013). In this study, authors indicated that this species feeding from fish, shellfish and cephalopods. *E. bipinnulata* is an opportunist depredator, means its diet varies both in space and time. Also in the tropical Atlantic Ocean (the archipelago of Saint Peter and Saint Paul) the rainbow runner mainly feeds flying fish of small size as *Cypselurus cyanopterus* and *Exocoetus volitans* in the Pacific Ocean. *E. bipinnulata* feeds on at least 22 species like preys (Bocanegra, 2007). A fish minority could not be identified because of their very advanced digestion stage. However, the analysis of the flesh, fishbone, and other parts hard, allowed determine that these fish belong to teleosteens.

The food of *E. bipinnulata* does not vary much according to the marine seasons. The rainbow runner in the Atlantic selects what it can eat according to the size. The bolus of juveniles is primarily made up of shellfish, while that of adults is predominantly dominated by fish. The food of *E. bipinnulata* is in connection with the physical state of the animal. Which would mean that in a youthful state, this fish is not able to capture larger preys of size? It contents to nourish itself with animals easier to capture. Which means that *E. bipinnulata* does not capture large pelagic fish such as the blue marlin (*Makaira nigricans*), marlin black (*Istiompax indica*), Atlantic Sailfish (*Istiophorus platypterus*), silky shark (*Carcharhinus falciformis*) described respectively by Shimose *et al.* (2006), Shimose *et al*. (2008) and Bocanegra (2007).

Conclusion

Elagatis bipinnulata is a predatory fish. It nourishes mainly fish, and incidentally of cephalopods and fish remains. The fish species *Decapterus*

macarellus is mostly consumed during the great hot season, while the species *Sardinella madernesis* is preferred during the great cold season.

Moreover, the crustaceans *Panaeus notialis* is consumed during the great cold season, the small hot season and the small cold season.

The immature specimens prefer *Decapterus macarellus* whereas *Sardinella maderensis* is privilege both by juveniles and adults, as well as the crustacean species *Panaeus notialis.*

Acknowledgements

Thanks to the laboratory of department of the alive aquatic resources of oceanographic research centre (CRO) who made its infrastructure available to us and facilitated the access to the fishing abobo-doume in Côte d'Ivoire.

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