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Research Paper

Diet of the Atlantic sailfish *Istiophorus albicans* (Latreille, 1804) caught in Coastal marine waters of Côte d'Ivoire, West Africa

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Abstract

Seasonal and size-related patterns in feeding habits of the Atlantic sailfish *Istiophorus albicans* in coastal marine waters of Côte d'Ivoire (a West African country) were investigated along with food composition. The study was carried out from December 2015 to November 2016. Fish size ranged from 150 cm to 195 cm LJFL (lower-jaw fork length). The fish were caught with gillnets deployed over the continental shelf by artisanal fishers. Of the stomachs examined, 32.65% contained at least one prey item while 21.43% contained Fish crystalline lens and Cephalopod crystalline lens as well as remaining Fish bones and Cephalopod beaks. Additionally, 45.92% of stomachs examined were empty or contained digestive fluids. No seasonal and size-related patterns were however found in the occurrence of non-empty stomachs, probably as a result of predominance of empty stomachs. The overall diet composition in terms of numerical importance was 86% Fish, of which flying gurnard, *Dactylopterus volitans* (Linnaeus, 1758) were the commonest (75.40%), far exceeding even all the Scombrids lamped together (1.84%). Prey size range was quite extended as it varied from smaller Cephalopod prey (3.1 – 3.8 cm ML, mantle length) to relatively larger Fish prey (43.5 cm SL, standard length), suggesting that the Atlantic sailfish could virtually feed on prey of various size.

Keywords: Ecosystem, Fish community, Living organism, Top predator, Trophic ecology

Introduction

Research effort devoted to fish nutrition has increased as studying the feeding habits and/or food composition of fishes proved to be an important way for gathering information on their ecosystems and the various relationships among species, based on feeding. For according to Bussy[1], in order to better understand the functioning of the fish communities and ecosystems it is appealing to study the trophic relations that interact or serve as fundamental bonds among the living organisms. In fact, for any living organism to occur in a given area – may it be a fish or other – it must get sufficient food when additional requirements such as good temperature conditions, salinity, pH, tranquillity etc … are met. As Kerrigan[2] put it, feeding is a fundamental mechanism through which the living organisms store up the energy necessary for their growth and reproduction.

The Atlantic sailfish *Istiophorus albicans* is listed in large predators fished by the artisanal fishers operating with canoes and drifting gillnets over the shelf of Côte d'Ivoire. Especially, this species is a top predator generally occupying different trophic positions in the pelagic ecosystems. The Atlantic sailfish is coastal and offshore, a fairly migratory fish whose body is elongate and much compressed, with an upper jaw prolonged into a rather slender spear[3]. Although this species occurs in West Africa, very few studies dealing with its feeding ecology are available.

Information on dietary sources can be gathered through studies based on trophic ecology of predators. These information can be obtained from several methods such as the stable isotope analyses (SIA) of animal tissues, or other methods based on the utilization of antibodies[4,5,6] or still the utilization of specific genetic markers[7,8,9] fitting for a given species. The latter two methods may be used as complement of the classical method of stomach contents analysis – which is less accurate compared with the preceding ones, and yet has its own advantages and is generally used at no great cost – as they help improve the results obtained from stomach contents analysis (SCA). Instead, stomach contents analysis has been successfully used as a technique to provide insight into the trophic ecology of various animal species worldwide, including fishes. Several authors, namely Elston et al[10] infer that examination of stomach contents remains one of the most reliable means of obtaining fine-scale taxonomic resolution of dietary items. The overall objective of the current study was to investigate the feeding habits of the Atlantic sailfish and search for any possible size-related and seasonal variation patterns.

Materials and Methods

Sampling procedure

Istiophorus albicans specimens were collected weekly from artisanal fishers operating with canoes and drifting gillnets in continental shelf waters of Côte d'Ivoire, from December 2015 to November 2016, on the fishers' return. These fishers always go fishing at Sea keeping sufficient ice on board their canoes to keep the fish in good conditions. A total of 98 fish were purchased. Specimens were transported each time to the laboratory and washed clean with ordinary water to get them rid of the sand and undesirable spots. Individual fish were measured with a measuring tape and their total weights were recorded using a scale. Length data, lower-jaw fork length (LJFL), were measured to the nearest centimeter, i.e. from the tip of the lower jaw to the fork of the caudal fin. Fish were also weighed to the nearest 0.1 g.

Analysis of stomach contents

Stomachs were removed from dissected fish. Stomach fullness was determined on a scale of 0 – 4. Scale 0 = empty stomach or stomach containing only digestive fluids or accumulated material such as otoliths, Fish bones, Fish and Cephalopods crystalline lenses or Cephalopod beaks. Scale 1 = filled to one quarter of stomach volume; scale 2 = half-filled stomach. Scale 3 = full stomach; more than three quarters of the stomach filled. And scale 4 = very full stomach, i.e. very distended stomach. Prey were sorted displaying each prey according to its kind. After stomachs were emptied, we measured them with a measuring board, stretching them out a little bit while measuring them. Measurable, intact and indigested prey items were measured to the nearest 1 mm. Each prey item was weighed to the nearest 0.01 g. Stomach contents were identified to the lowest possible taxon using the keys and description of[11,12,3].

Data analysis

The diet of the Atlantic sailfish was assessed using an Index of Relative Importance (IRI) calculated for all prey taxa[13], from percent number (%N), percent mass (%W), and percent frequency of occurrence (%O) of prey items identified from stomach contents. Combined stomach contents from all fish were used to calculate the percentages. The stomach contents of captured sailfish would have been influenced by the digestion process. Therefore, stages of digestion of the food items were recorded. Yet, we used the measured wet weight of the prey summed across all fish and not reconstituted mass to calculate percent weight. The IRI was calculated as follows:

$$IRI = (\%N + \%W) \times \%O$$

$$IRI\% = (IRI / \sum IRI) \times 100$$

The Vacuity Index (VI%) was also calculated as the number of empty stomachs expressed as a percentage of the total number of stomachs examined. Relationships between any pair of variables were determined using the Statistica 7.1 software, as simple linear regression was necessary to examine the correlations between these variables. The level of significance was set at $p < 0.005$.

Results and Discussion

Figure 1 shows the size range of all Atlantic sailfish specimens sampled. Fish size ranged from 150 to 195 cm LJFL, far exceeding the size of any potential prey. Figure 1 also shows histograms with various amplitudes, which suggest heterogeneity in the size of the specimens caught by the artisanal fishers.

Size of the specimens that were sampled and size of their stomach are evidence that the Atlantic sailfish are large fish. Therefore, the Atlantic sailfish may be highly favored by size and swimming speed, which undoubtedly enable them to get the most out of feeding and trophic adaptability, as they can take advantage of any type of species they view as potential prey. In fact, sailfish are ranked among the fastest fish ever known, as they reach 110 $km.h^{-1}$ swimming across the ocean[14]. And swimming speed could possibly play an important role in the predation. However, this assertion conflicts the results obtained by Dominici et al[15] who noted that sailfish did not rely on rapid swimming for prey capture. Field observation and close underwater observations of predator – prey interactions made it possible for[15] to present the first direct evidence of how the rostrum is used by sailfish to capture schooling sardine (i.e. *Sardinella aurita*). According to these authors, prior to the critical stages of an attack sailfish swam directly behind and at similar speeds to their prey (i.e. sardine schools). It admits of no doubt, only the bill or rostrum is used as predatory weapon. Instead, the bow waves generated by these aquatic predators are likely to be detected by prey[16,17]. Then how do Atlantic sailfish manage through stealth and rapid motion[15] to successfully capture prey? Well, the relatively smooth and elongated rostrum of billfishes may reduce water disturbance, thereby delaying detection of approaching sailfish by prey[17].

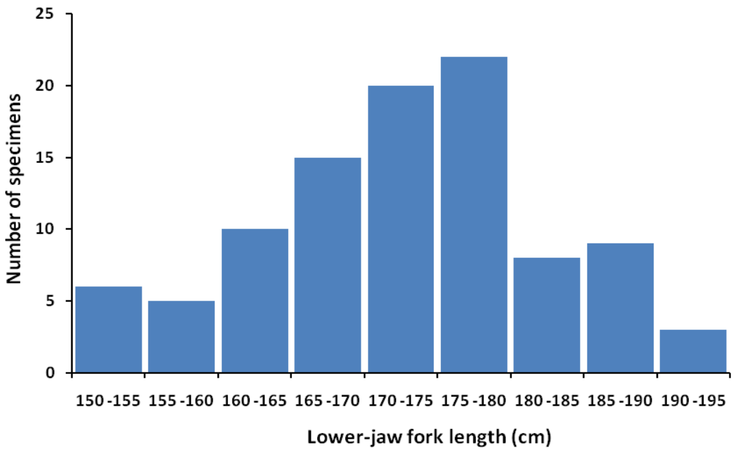

Figure 1: Size distribution of Atlantic sailfish specimens caught with gillnets by artisanal fishers from Côte d'Ivoire

In addition, prey species consumed by the Atlantic sailfish are listed in Table 1, with regard to the family, occurrence, weight, number, and relative importance index. Flying gurnard *Dactylopterus volitans* have the highest IRI value (38.85%). They are followed by frigate tuna *Auxis thazard* (IRI% = 12.86). Besides these prey, contribution of the other prey to the feeding regime of the Atlantic sailfish seems to be scarce. However, when prey are considered by name of the group they belong to, the diet is largely dominated by Fish (IRI% = 85.45), while Cephalopods contributed 14.55% in terms of relative importance. All prey species we identified in the present study inhabit various portions of the Ocean. Some, like the Flying gurnard, are known for inhabiting coastal waters at depths to about 80 m (FAO[3]). Others, like the Mirrorwing flyingfish *Hyrundichthys speculiger*, are notorious for inhabiting surface waters of open Ocean as well as neritic and inshore areas[3]. Still others, like sardinellas *Sardinella aurita*, are coastal and pelagic[3], just as some of the Scombrid species listed in Table 1 are. This actually indicates that though pelagic and oceanic, the Atlantic sailfish would also come close to shore to feed on relatively small schooling fishes.

Table 1: Frequency of occurrence (O), weight (W), number of prey (N) and Index of Relative Importance (IRI) for prey species found in the stomachs of the Atlantic sailfish specimens. %O = frequency of occurrence as a percentage of all prey species, %W = percentage mass, %N = number of a particular prey species as a percentage of the total number of prey items.

Family	Species	O%	W%	N%	IRI%
Belonidae	*Tylosurus crocodilus crocodilus*	2.98	5.77	0.40	0.77
Clupeidae	*Sardinella aurita*	4.48	5.11	0.40	1.03
Dactylopteridae	*Dactylopterus volitans*	10.45	13.47	75.40	38.85
Exocoetidae	*Hirundichthys speculiger*	2.98	2.46	0.58	0.38
Scombridae	*Auxis rochei*	2.99	5.64	0.23	0.73
	Auxis thazard	13.43	22.07	0.81	12.86
	Euthynnus alletteratus	4.48	1.40	0.23	0.31
	Scomber japonicus	2.99	2.86	0.17	0.38
	Scomberomorus tritor	2.98	9.70	0.29	1.25
Unidentified					
Carangids		2.99	4.21	0.11	0.54
Cephalopods		19.40	3.93	14.00	14.55
Fish		26.87	17.27	7.26	27.58
Scombrids		2.98	6.11	0.12	0.78

Success in the Atlantic sailfish predation lies in their foraging behavior. Atlantic sailfish use their rostrum to strike their prey in a wider range of motions fitting for a multi-plane striking behavior enabling them to either tap on individual prey or to slash through the schooling prey during predation and feeding, as reported by[15] for this species. It seems that the more prey move in schools, the more sailfish feel at ease to capture them. Things really happen this way because Atlantic sailfish undoubtedly exert strong influences over their prey species. According to[15], sailfish typically hunt in groups to drive large schools of their prey to the surface for easier capture. Such a foraging behavior really is extremely advantageous and profitable to the predator (sailfish), since the prey are lined up on every side. This predation behavior certainly proves helpful in making the sailfish capable of consuming even schooling prey that may seem smaller. For example, Varghese et al[18] found that relatively smaller prey constituted bulk of Indo-Pacific sailfish *Istiophorus platypterus* diet and that even large specimens consumed small prey. The relationships between large predators and small prey species can be viewed as a driving force to the ecosystems functioning as they generate subsequent complex trophic relations among the living organisms. In this respect, tropical marine ecosystems are believed to be the centre for generally complex trophic relations as a result of both strong and weak predator – prey interactions[19,20,10].

Moreover, Figures 2 and 3 show prey size variation in connection with predator size and predator stomach length, respectively. Size range of prey is quite extended, varying from relatively small Cephalopod prey (3.1 – 3.8 cm ML) to relatively larger Fish prey (43.5 cm SL) as the Atlantic sailfish grow (Figure 2) and their stomachs get wider and longer (Figure 3). In both cases each Figure shows a slightly decreasing trend of prey size when we refer to the correlation curve. Figure 3 also shows that the Atlantic sailfish possess huge stomach that can measure between 43 and 65 cm in length, and correlation was observed between stomach length and specimens' size ($r = 0.8066$; $p = 0.0000$; $y = -44.5864 + 0.5789*x$). This and the overall trending in Figures 2 and 3 could possibly indicate selectivity of the sailfish for prey size. In such a case larger sailfish would show a tendency to consume both smaller and larger prey but smaller sailfish would only feed on relatively large and medium sized prey.

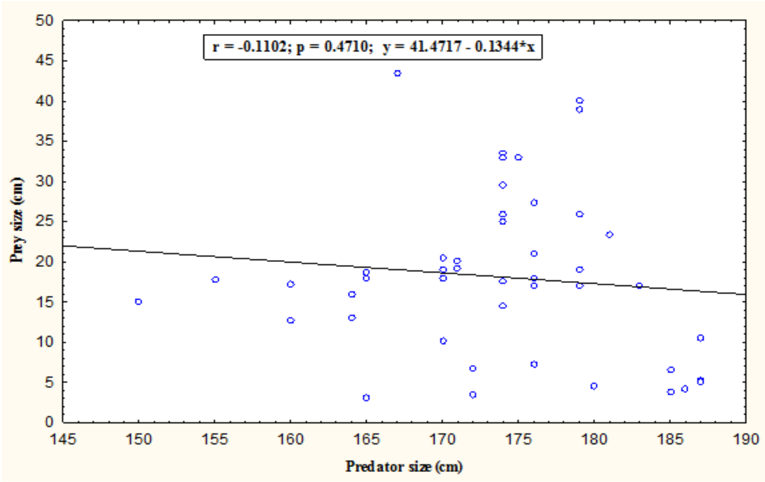

Figure 2: Relationship between prey size and predator size

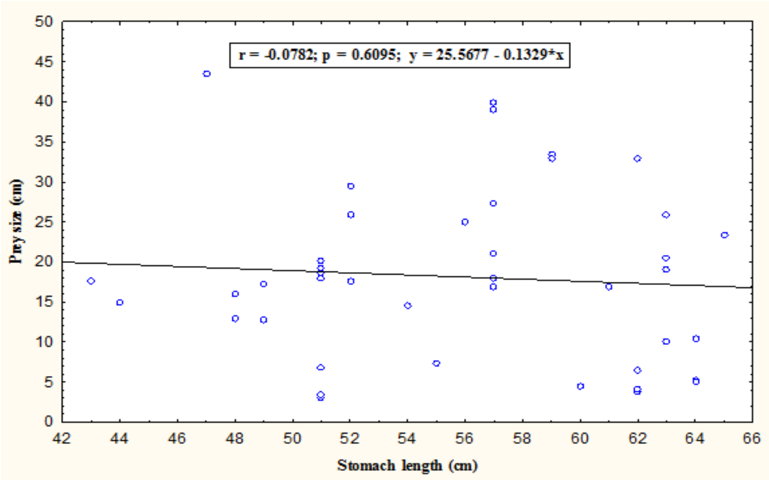

Figure 3: Relationship between prey size and predator's stomach length

Sailfish predation behavior can be likened to a mean to ingest the maximum available prey in order to fill their stomach as faster as possible. And sailfish are well-equipped with a fitting stomach in this regard. For we did count 160 and 180 individuals flying gurnard at different digestion stages measuring 5-7 cm SL inside stomachs of 60 and 65 cm in length that belonged to sailfish specimens of 180 and 187 cm LJFL, respectively. In both stomachs the majority of flying gurnard had some flesh remaining with head and tail disarticulated. Some were almost completely digested and yet recognizable to their orange-colored remaining stomachs. Furthermore, the high vacuity index (45.92%) found in the current study may indicate that the last meal had been fully digested and that many of the fish had not fed recently. In addition, the lack of any significant size-related variation in the occurrence of prey species and the lack of significant seasonal pattern in feeding could be attributable to the high number of empty stomachs, which did not allow for examination of a large number of stomachs containing prey.

Conclusion

The study attempts to offer an ecological understanding of the food composition of the Atlantic sailfish *Istiophorus albicans* based on stomach contents analysis. We observed that few prey species constituted the diet, essentially attributable to the large number of stomachs containing digestive fluids and remaining materials such as Fish bones, Fish crystalline lens, Cephalopod crystalline lens, and Cephalopod beaks. Based on the results obtained, we reached the conclusion that stomach contents analysis proved to be less effective in permitting to thoroughly identify prey items; especially when it comes to identification of the remaining materials, which other methods such as stable isotope analyses of animal tissues easily permit.

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