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(Research Article)

The feeding regime of the Spanish mackerel (*Scomber colias* Gmelin, 1789) under ordeal by time: A change to the detriment of prey-species of the genus *Sardinella*

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Abstract

Sardinellas are amongst the principal fishery resources of the Ivorian coastal areas, being the prey of predatory fishes, of which tunas. A close observation of the trophic ecology and fisheries data in the scientific literature permitted to gain insights into previously-held relationship between the Spanish mackerel and the Sardinellas regarding feeding. We recall past facts accounting for the disappearance of both species from the landings, following the scarceness of the round Sardinella (*Sardinella aurita*). This study was carried out to investigate the current relationship between both species, selecting a fishery for its heavy catches for Sardinellas. Samples of *Scomber colias* were taken each week of July and August from that fishery in 2022. A total of 115 specimens were collected at the landing stage of Sassandra (Southwestern Côte d'Ivoire). The fish were measured and weighed, and stages for sexual maturity of their gonads were estimated. The results indicated that specimens ranged in size from 20.4 to 35.5 cmFL while their stomachs measured between 1.8 and 9.6 cm. Stomach contents weights ranged from 0.05 to 36.5 g. The stomach contents analysis showed a feeding regime made up mainly of small organism-prey, of which the mantel shrimp *Scyllarides herklotsii*, the pink shrimp *Farfantepenaeus notialis*, the spiny lobster *Nephropsis atlantica*, juvenile fish species of the Myctophidae family, juvenile Cephalopods (squids), and almost no fish of the genus *Sardinella*. The occurrence of a large proportion of empty stomachs (whose weight was <2.0 g) was noticeable, since the Spanish mackerel mainly fed on small prey.

Keywords: Predatory fishes; Prey-species; Sardinellas; Sassandra; Spanish mackerel; Trophic relationship

1. Introduction

If the various needs of terrestrial species or those living in the oceans and seas were to be ranked according to priority order, the need for food would certainly be put at the first place before the others. For, as Kerrigan [1] put it, feeding is a fundamental mechanism through which the living organisms gather for themselves the necessary energy they need for growth and reproduction. Therefore, seeking food can be viewed as a must to any particular species, compelling them to spending their energy and time in an effort to place themselves under feeding-dependency relationships with other species within the same ecosystem. In this connection, feeding can be regarded as a key-mechanism to the ecosystem functioning, governing, as Bussy [2] believes, the trophic relationships across species and the transfer efficiency of energy flows in the food web. Therefore, studying the feeding regime of a particular species constitutes an efficient way for gaining insights into a thorough understanding of possible interactions that may occur within an ecosystem. Yet, intricate peculiarities pertaining to each ecosystem sometimes make it possible to observe astounding differences in the feeding regimes among individuals of the same species, especially when those individuals are sampled in areas with different ecological characteristics. It seems that things generally turn out to working fine as if each living

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organism adapted their feeding regime to the type of available food the environment offers in accordance with the change of season. Pezennec and Bard [3] likened the Ivorian coastal waters to the other coastal marine waters of the world, especially those where seasonal upwellings occur, as they are a suitable place for the development of diverse pelagic fishes, following the favourable ecological and environmental conditions established by cooling. In particular, in Côte d'Ivoire, some small pelagic fishes, of which two species known as the Sardinellas, the round Sardinella (*Sardinella aurita* Valenciennes, 1847) and the flat Sardinella *Sardinella maderensis* (Lowé, 1839), proved to be the principal fish.

Historical record of events relating to fisheries research tells of possible relationship between the Spanish mackerel and the Sardinellas as regards feeding; the former being a predator to the later. In addition, Binet [4] recalled the scarceness of the round Sardinella (*Sardinella aurita*), which was shortly thereafter followed by the disappearance of both species (i.e. *Sardinella aurita* and *Scomber colias*) from the landings. The feeding regime of the Spanish mackerel suffered as a result of steady fluctuations in abundance and poor state of Sardinellas resources, of which the ones in 1972 were prominent. The facts were noticed by researchers from the former ORSTOM (present-day French Research Institute for Sustainable Development, IRD) who were prominent to acknowledge the truthfulness of the trophic relationship between the Spanish mackerels and the Sardinellas. For those researchers, it was obvious that the Spanish mackerels were predators to the Sardinellas [5]. They vanished from the landings **from** 1973 up to 1985, following the poorness of the state of the Sardinella resources, and appeared again in high proportions within the catches at a time when the Sardinellas increased in abundance [3].

The overall objective of the current study was to show how relevant the trophic relationship between the Spanish mackerels and the Sardinellas is in an attempt to gaining insights into the role some pelagic fishes may play within the marine ecosystems. The study enables us to define the scope of the subject in time and space, addressing a relationship that was initially like a dependence of the Spanish mackerels on the Sardinellas, and seemingly changed over time. A specific goal was to investigate prey composition of the diet of the Spanish mackerel and to determine whether or not there were any Sardinella species therein.

2. Material and methods

2.1. Sampling procedure and other steps prior to stomach contents analysis

Spanish mackerels (*Scomber colias*) were collected from a marine artisanal fishery in Southwestern Côte d'Ivoire. The fish were caught in gillnets that were set by the **fishers** onboard canoes powered by 40-hp motors. Measuring and weighing devices were used to estimate metrics to know the size and weight ranges of specimens. Those fish ranged in size from 20 to 36 cmFL (centimetre fork length), with **weights** between 72.0 and 871.5 g. The fish were placed in a platter, while being measured to the nearest centimetre using a ruler or a caliper, and weighed to the nearest gram with a scale, prior to dissection. Fork length measurements were taken as the distance from the snout tip to the fork of caudal fin. Measurements also included the body depth, head length, specimens´ mouth height, specimens´ mouth width, and initial length of stomachs (i.e. when the stomachs were not stretched out). While in the platter, specimens were dissected using scissors. Stomachs were removed from the belly of dissected specimens as were gonads (i.e. testes and ovaries) from the body cavity. Stages for sexual maturity of specimens were estimated prior to stomach content analysis. Total weights of stomachs were taken using a scale.

2.2. Stomach contents analysis

Prey-items were removed from the stomach envelop and sorted according to their kinds. Some prey-items were measured and weighed, either individually or collectively. In addition, not all prey-items were recognizable with the naked eyes. Therefore, we used a hand lens to observe the prey-items of that kind, as it magnifies them and facilitates recognition. Identification of prey-items was carried out using a Field Manual fitting for West African marine commercial species identification [6] and a Manual intended for fishery purposes, yet useful for species identification [7].

3. Results and discussion

Table 1 indicates metrics estimates to know the size and weight ranges of specimens. The fish ranged in size from 20.40 to 35.50 cmFL, with a mean value of 28.68 ± 3.78 cmFL. Weight of specimens varied between 72 g (0.07 Kg) and 871.5 g (0.87 Kg). An estimate of the waist measurement using a measuring tape showed that **individuals´ waists** varied between 9.40 cm (for smaller fish) and 29.10 cm (for larger specimens). Distance from the snout tip to the posterior limit of operculum measured between 5.50 and 9.20 cm, with a mean value of 7.67 ± 0.88 cm. The Spanish mackerels can open their mouth as to get the vertical distance separating the tips of their upper and lower jaws vary between 2.80

cm (minimum) and 5.50 cm (maximum). When their mouth is open, the horizontal distance separating the bases of maxillae can vary between 1.50 (for smaller fish) and 4.30 cm (for larger specimens). With an initial length that can be equal to 1.80 up to 9.60 cm, the stomach in Spanish mackerels can stretch out to reach lengths about 16 cm, when containing prey-items of various sizes, especially larger ones; thereby allowing the stomach envelop to bear 36.50 g of total stomach contents, as shown in this study (Table 1).

Table 1 Data obtained from measurement and weighing of specimens of the Spanish mackerel sampled from July to August 2022 at the landing stage of Sassandra (Southwestern Côte d'Ivoire)

Variable	**Weight (Kg)**	**Fork length (cm)**	**Body depth (cm)**	**Head length (cm)**
Minimum	0.07	20.40	9.40	5.50
Maximum	0.87	35.50	29.10	9.20
Mean	0.32	28.68	15.69	7.67
SD	0.15	3.78	3.01	0.88
Variable	Specimen´s mouth height (cm)	Specimen´s mouth width (cm)	Initial length of stomach (cm)	Total weight of stomach contents (g)
Minimum	2.80	1.50	1.80	0 – 0.5
Maximum	5.50	4.30	9.60	36.50
Mean	4.25	3.21	5.06	3.89
SD	0.49	0.48	1.58	4.81

SD = standard deviation; Fork length = measurement taken from the snout tip to the fork of caudal fin; Body depth = an estimate of the waist measurement using a measuring tape; Head length = the distance from the snout tip to the posterior limit of operculum; Mouth height = the vertical distance separating the tips of the upper and lower jaws of the fish; Mouth width = the horizontal distance separating the bases of maxillae. Note: measurements of the Fork length, Head length, Mouth height, Mouth width and Stomach length were taken using a ruler.

Figure 1 shows additional characteristics of sampled-fish. The specimens collected have a relatively larger size-range made up of fish of 18 up to 36 cmFL in length, with individuals measuring between 24 and 34 cmFL being the commonest (Figure 1A). Those fish accounted for 81.74% of total individuals sampled. In contrast, there is a predominance of empty stomachs (Figure 1B). Such empty stomachs were the ones with total contents weight <2.0 g; they accounted for 46.96% of total stomachs observed. Besides these, stomachs filled with digestive fluids slightly contained various items (fish bones, fish crystalline lens, cephalopod beaks, cephalopod crystalline lens). They were also numerous (51.30%), compared with the other stomachs containing solid prey-items that were still intact and not yet digested (1.74%). Additionally, Figure 1C shows sexual maturity stages of sampled-fish. All specimens apparently reached maturity. Maturity stages 4 and 5 prevailed in male fish, with a percentage for each stage corresponding to 19.13% of male fish. Yet, in female fish, the ovaries at stage 5 were commonest (40.67% of female fish), far exceeding the ovaries at the other stages (Figure 1C).

Figure 2 shows photos of the stomachs of some specimens, along with the type of prey-items. The stomach is relatively small, depending on size of the fish and whether the fish has yet ingested some prey-items (Figure 2A). Overall, the prey consumed by the Spanish mackerels are relatively small (Figures 2B and 2C). Prey-items belong to each of the four zoological groups (e.g. Fish, Cephalopods, Crustaceans, and Insects). Three crustacean species were identified. These are the mantel shrimp *Scyllarides herklotsii* (Herklots, 1851), the pink shrimp *Farfantepenaeus notialis* (Pérez-Farfante, 1967) and the spiny lobster *Nephropsis atlantica* (Norman, 1882). In addition, two fish of the Myctophidae family were identified, measuring 4.4 and 5.8 cm in length (standard length, SL), and weighing 1.0 and 2.5 g, respectively. Cephalopods (squids) ranged in size from 1.0 to 3.0 cm (mantle length, ML); with a mean length of 2.3 cmML while their weight varied between 0.5 and 2.0 g (mean weight = 1.3 g). In pink shrimps, the distance from the eye to the anterior limit of telson varied between 0.8 and 1.5 cm (mean = 1.2 cm); while their mean weight was 0.04 g. As prey-items were small, they would rapidly and easily get digested, making overall stomach contents be transformed into digestive fluids (Figure 2D). Yet, the stomach is capable of getting outstretched when filled with larger prey (Figures 2E and 2F). Figure 2G, which shows the prey-items removed from the stomach shown in Figure 2F, reveals among the stomach contents a fish known as the round sardinella (*Sardinella aurita*) and some pink shrimps (*Farfantepenaeus notialis*). That fish-prey measured 16 cm in length, which clearly shows the amazing size-increasing ability of the stomach in Spanish mackerels.

Moreover, of all stomachs observed, only one stomach (0.87% of total stomachs) contained a fish-prey of the genus *Sardinella*.

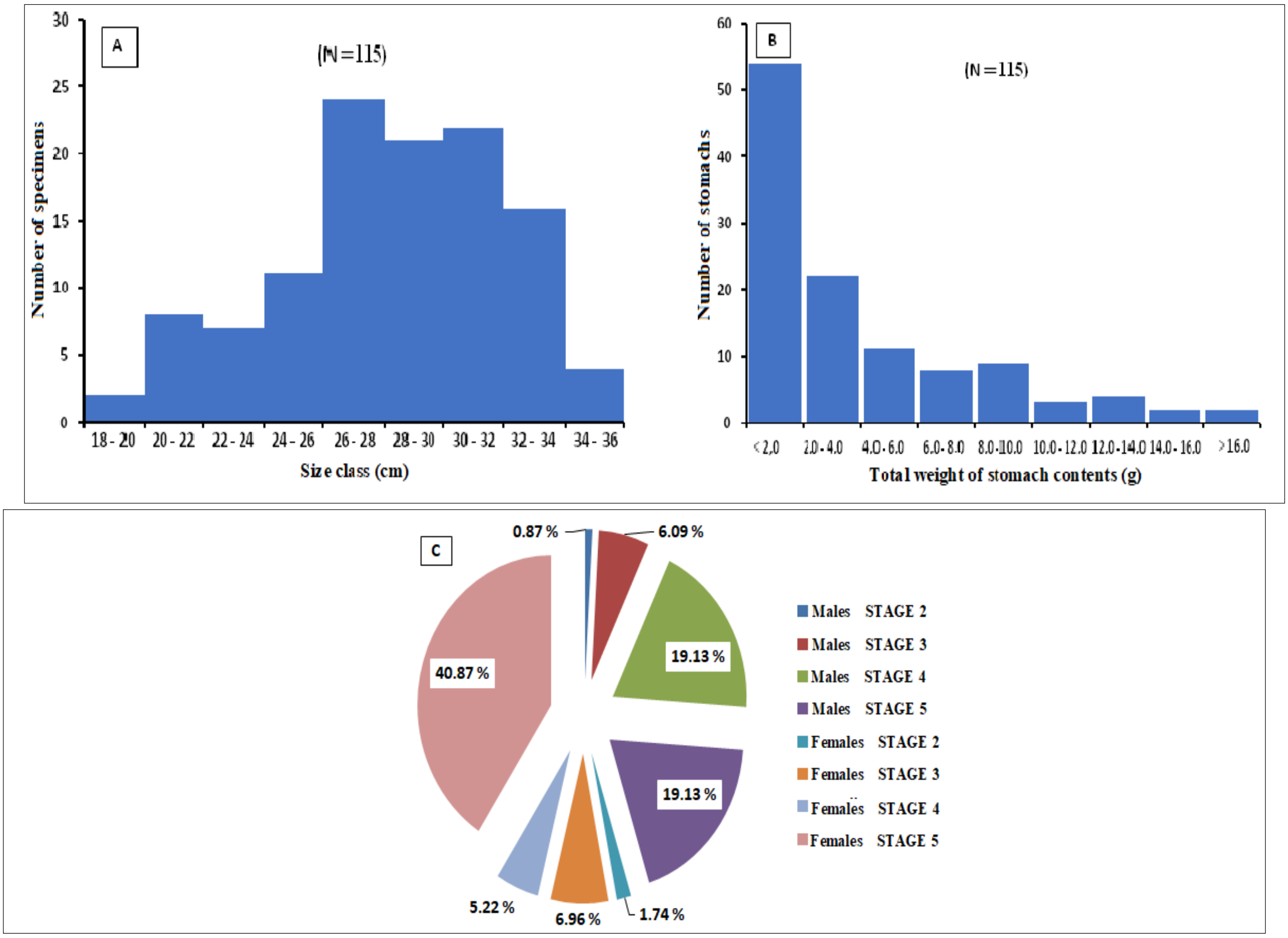

Figure 1 Characteristics of sampled-specimens of the Spanish mackerel (*Scomber colias* Gmelin, 1789) from the marine artisanal fishery of Sassandra, Southwestern Côte d'Ivoire. (A): Size frequency distribution of specimens; (B): Specimens´ stomach contents frequency distribution; (C): The proportion of sexual maturity stages in collected-specimens.

Apparently, the Spanish mackerels seem to be well-equipped with features pertaining to their predatory nature, physical appearance, and their stomach´s size-increasing ability, which they use to their full advantage. Individuals exhibited variation in morphological features, which shows they certainly derived from various groups of fish as a result of sampling or the fishing gear´s selective capacity. In fact, gear selectivity enables fish of a certain size relating to fork length, body depth, head length, specimens´ mouth height, specimens´ mouth width as well as length of stomachs, and even different stages of gonads to occur within the catches. Huse et al. [8] rightly acknowledged selectivity as a key-factor on which exploitation of fish stocks is dependent. In particular, when it comes to studying the feeding regime of a particular species, it is worth having specimens of various sizes within the samples. Yet, the larger individuals are, the wider can their mouth be when in open position; which enables them to seize prey of various sizes, including larger prey. For the mouth´s capability to open wider is generally correlated with fish size, enabling them to capture a wide range of prey types with various sizes, as shown in fishes other than tuna [9, 10]. Actually, carnivorous fishes like the Spanish mackerels do chase after prey whose size match with their own mouth´s size, thereby increasing their hunting success and opportunistic predator skills. In addition, the Spanish mackerel´s stomach is extensible in length and width and generally fit the size and shape of ingested prey, in connection with that, giving the stomach contents the advantage of including various prey types lying on top of one another, especially when the stomach is filled.

The predominance of female and male fish at the maturity stages 4 and 5 suggests that reproduction was certainly under way within the stock of specimens caught by the artisanal fishers. This certainly has to do with the high proportion of empty stomachs we observed. For in some fish species, of which the Spanish mackerels are probably no exception, when the reproductive period occurs the digestive tract is highly compressed by the increasing gonads, causing the feeding activities to lessen. This remark is in line with the observations by Boëly and Fréon [11] who rightly noticed that food intake in most fishes generally lessens as a result of occurring reproductive period. This undoubtedly opens the way for an increasing number of empty stomachs among sampled-fish.

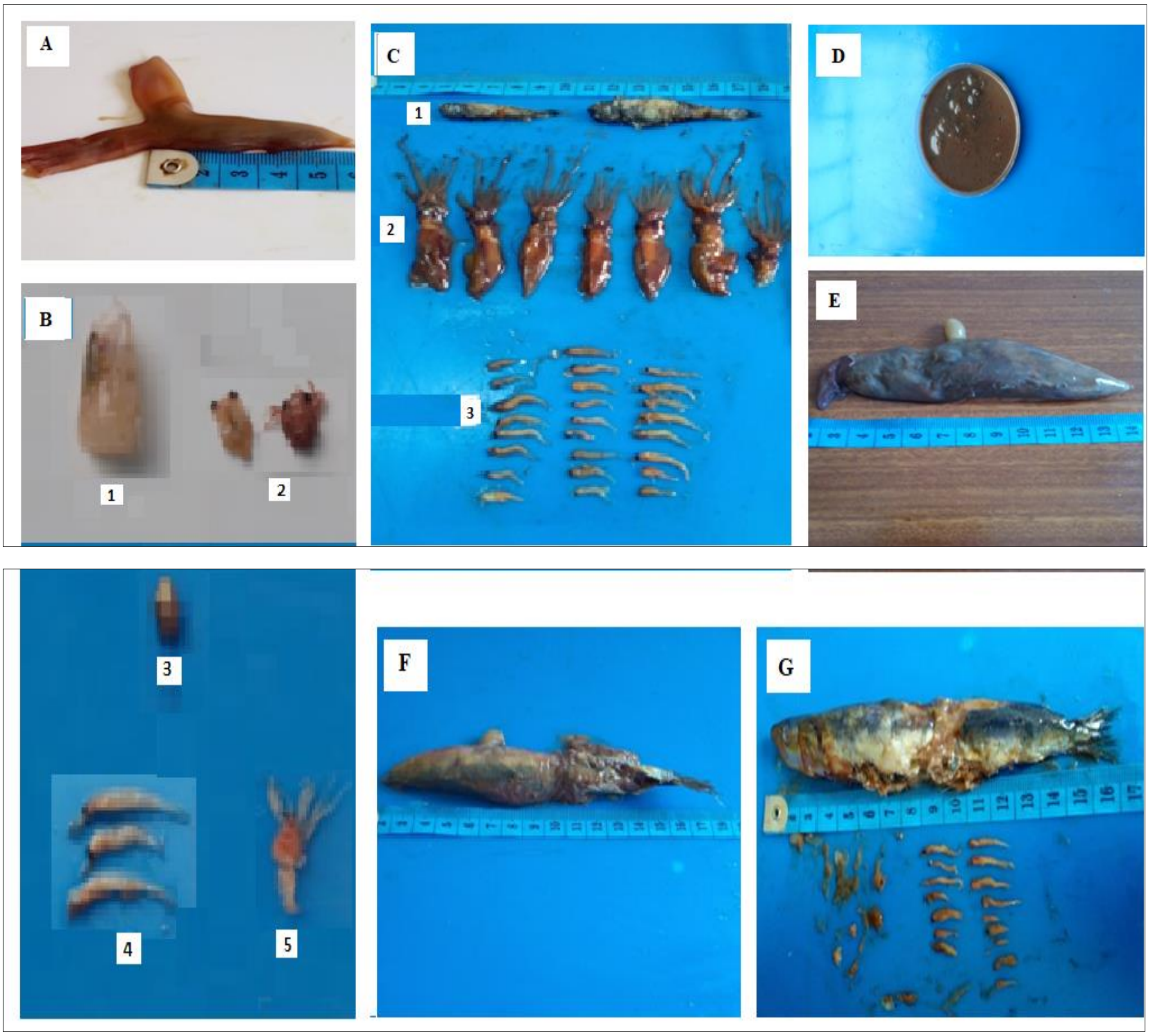

Figure 2 Photographs showing a relatively empty stomach (A) and the prey-items observed in the stomachs of the specimens of *Scomber colias* (B, C, E, F and G), with digestive fluid (D) as a result of complete digestion of suchlike prey. Note (B): 1 = Posterior part of an un-identified insect; 2 = Juvenile mantel shrimps *Scyllarides herklotsii* (Herklots, 1851); 3 = An un-identified insect; 4 = Some pink shrimps *Farfantepenaeus notialis* (Pérez-Farfante, 1967); 5 = Juvenile spiny lobster *Nephropsis atlantica* (Norman, 1882) ; (C) : 1 = Some un-identified juvenile fish of the Myctophidae family; 2 = Some un-identified Cephalopod species (Squids); 3 = Some pink shrimps *Farfantepenaeus notialis*; (D) : Digestive fluid; (E) and (F) = Photos showing the same filled-stomach, with prey-species inside it; which most likely were (G) : the fish known as the round Sardinella, *Sardinella aurita* Valenciennes, 1847; and some pink shrimps *Farfantepenaeus notialis*.

The Spanish mackerels are known to feed opportunistically on various available prey sorts within the ecosystem. The current study showed that their feeding regime was made up of the mantel shrimp *Scyllarides herklotsii*, the pink shrimp *Farfantepemaeus notialis* and the spiny lobster *Nephropsis atlantica*, including few fish and scarcely any Sardinella species. Such a composition of the feeding regime of the Spanish mackerel (*Scomber colias*) could likely be in variance with findings by authors elsewhere, possibly due to the fact that predatory fishes generally adapt their feeding regime to the readily available prey types. The scarceness of prey-species of the genus *Sardinella* was not a mere chance. In fact, how could we explain the low proportion of Sardinellas in the diet of the Spanish mackerel? Well, at least three reasons could be given, as follows: (i) This was certainly due to the fact that the Spanish mackerels would tend to show a preference for prey whose low swimming speeds work to their advantage. (ii) Predatory-fishes living in marine waters are very sensitive to the change and perturbations that are likely to occur within the food web [12, 2]. In addition to direct perturbations relating to human presence in a given area (e.g. pollution, incidental capture of a particular type of fish, maritime traffic), there are indirect effects of human activities causing the poorness of the state of some fishery resources as a result of overfishing [2]. The former steady fluctuations in abundance and poor state of Sardinellas resources in the 1970s caused the Spanish mackerels to leave the Ivorian shelf waters, acting as a shared experience among them and, some thirteen years later on down to this day, adapt their feeding regime to heavy consumption of food or prey other than Sardinellas; certainly reinforcing their social bonds as predators and group-living fish [13]. (iii) Third reason is, the current study showed that the prey-species of the genus *Sardinella* occurred incidentally in the diet of the Spanish mackerels, since they are no longer being heavily consumed by them as it was formerly believed. We assume that the above-mentioned situation resulted in a change to the ecological relationship (formerly shaped by absolute predation) between the Spanish mackerel and the Sardinellas. For the study area is propitious to the development of Sardinellas resources [14, 15, 16]; yet, the feeding regime of the Spanish mackerel barely showed Sardinellas as prey.

4. Conclusion

This study showed that the feeding regime of the Spanish mackerel was made up mainly of small organism-prey, with almost no pelagic fish of the genus *Sardinella*. The Spanish mackerel certainly feed on the most readily available and abundant prey whose swimming speeds are low, compared to that of the Sardinellas. The stomach of the Spanish mackerel is quite smaller when empty. It would however get larger when outstretched accordingly to match with good-sized prey-items. The current study also revealed the consequences of overfishing on the trophic relationship between a predatory fish (*Scomber colias*) and its former prey (the Sardinellas), as it calls on fisheries managers to closely observe the admonition by FAO [17] against the over-exploitation of the Sardinellas stocks that is under way.

Compliance with ethical standards

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Disclosure of Conflict of interest

All the authors declare that there are no conflicts of interest/ Competing Interests connected with the publication of their manuscript.

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