INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 17, No. 5, p. 23-33, 2020

RESEARCH PAPER OPEN ACCESS

Effectiveness of Catches from Various types of Gears for the estimation of Biodiversity in southwestern Côte d'Ivoire, West Africa

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Key words: Abiotic parameters, Artisanal fishery, Biodiversity, Fishing gears, Selectivity

http://dx.doi.org/10.12692/ijb/17.5.23-33 Article published on November 12, 2020

Abstract

Samples have been taken from fishery landings on the fishers' return to estimate fish and other aquatic animals diversity. Specimens were caught with various types of gears deployed in continental shelf waters of Côte d'Ivoire by the artisanal fishers residing at Sassandra (in the southwestern part of this country), some 272 kilometres away from Abidjan, the capital city. These gears include the drifting gillnet, stationary gillnet, bottom gillnet, beach seine,purse seine and longline. Here, we present the data collected from October 2017 to March 2019. The results indicated that overall species observed numbered 112 and comprised fish, crustaceans, cephalopods and gastropods. Fish were the most abundant species, accounting for 92.86 % of total species observed in the landings. An attempt was made at comparing our data with the catch data collected a year earlier by the local Office for Aquaculture and Fisheries Statistics (the "Bureau Aquaculture et Pêche", BAP - Sassandra). Confirmation of fish dominating the catches was obtained, as fish accounted for 95.13 % of total specimens landed and for 99.29 % of the yield, far exceeding Crustaceans, of which pink shrimp *Penaeus notialis* Pérez-Farfante, 1967 were the commonest. Clupeids, Carangids, Scombrids, Sciaenids, Polynemids and Haemulid species accounted for the main families among fishes, as they heavily contributed to taxon richness. The Shannon-Wiener diversity index (H' = 1.75) was relatively low, suggesting the predominance of at least one species in the catches, namely the Sardinellas.

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Introduction

Worldwide, various types of gears have been used and are currently being in use depending on the fisheries' size or the kind of target species or still in connection with the size of vessels and the broadness of the fishing grounds. No matter how efficacious each type of gear may be, it cannot be sparing of some effect on habitat and fish population, even on the overall ecosystem. For the living organisms are interrelated with one another regarding feeding and the environment in which they live; the kind of relationship carved out by the food web and/or the habitat. Therefore, Bundy *et al.* (2005) reasonably inferred that fisheries should extract yield at sustainable exploitation rates, with minimal disturbance to the trophic structure, and with no loss in species richness. That undoubtedly sounds well in practice as a goal to keep in focus, for this goal is attainable, as all gear types can be used responsibly and sustainably, provided they are carefully managed under the observance of responsible fishing practices. Despite those disadvantages, fishing with multiple gears can be effective in taking the best catches of various kinds of aquatic animals including fishes, cephalopods, crustaceans and gastropods, as a result of the combination of overall selectivity of those gears.

Estimation of the biodiversity in a given aquatic environment deserves an appealing concern to predict the impact of activities on such an environment. For example, according to Sumaila *et al.* (2014), a range of human activities in and around the ocean have an impact on the health of the ocean ecosystem and the health of fish stocks, which they believe presents an additional dimension to the challenge of sustainable fisheries. We too believe this is particularly true in West Africa, where the majority of artisanal fisheries are multi-species ones and the risk for species contamination owing to oil exploration activity is real. Additionally, the vast coastal ocean resources of the Gulf of Guinea have been heavily affected by the rapid development of human activity (Scheren *et al.*, 2002; O'Carroll *et al.*, 2019). Worldwide, the growing concerns over degradation and loss of habitat seem to have been given priority over the quality of the resources, that is, the different types and kinds of living organisms that form part of the whole ecosystem at stake.

In this respect, our approach offers the potential for tracking various population trends and sounds a promising way for fisheries managers to keep alert in advance to any possible changes, rather than awaiting the signs of a stock collapse before taking the appropriate measures.

The overall objective of the current study was to respond to the needs for resource management for sustainable artisanal fisheries through the evaluation of species richness and species diversity. A specific goal was to investigate monthly variations in sea surface temperature (SST) and in the abundance of the chlorophyll-A (i.e. a chemically active compound of the phytoplankton) and to determine whether or not there was any possible relationship between both abiotic parameters and species richness.

Materials and methods

Sampling procedure

Fishers customary go fishing using vessels known as canoes and powered by 40-hp motors in fishing grounds located on the continental shelf of Côte d'Ivoire. Fishers usually set most of the gears mentioned above at night and retrieve them the following day, early in the morning, sometimes at daybreak, most often before sunrise. Landings generally occur in the morning, though some other casual landings would take place in the afternoon. Specimens were purchased from wholesale fishmongers. Samples were put into a cool box, with sufficient ice onto them to keep them cool and finally taken to the laboratory where specimens were identified.

Identification of species from each sample

Identification was a key step to the study. It meant that each species should be assigned the right scientific name. Therefore, specimens have been identified using keys and manuals for marine species identification following Schneider (1992) and FAO (2016). Identification of species was carried out with accuracy, taking into consideration local names, FAO name and scientific name, to avoid any possible confusion inherent to resemblance between closely-related species.

Calculating the species diversity

To investigate how well both the number of species present and the dominance of species with one another could help evaluate the species diversity, we used the Shannon-Wiener index (Krebs, 1989) calculated as follows:

$$H' \approx \sum \left[\left(\frac{n_i}{N} \right) \times \ln \left(\frac{n_i}{N} \right) \right]$$

where n_i = number of individuals (i^{th} species) and N = total number of individuals, and ln = the natural log of the number.

Getting the abiotic parameters through satellite data from MODIS-Aqua

Sea surface temperature (SST) and chlorophyll-A (Chl-A) were the abiotic parameters we considered in this study. The SST and Chl-A data were obtained from the freely accessible NASA's Ocean Biology Processing Group Webpage where the data for the sea surface temperature and those for chlorophyll-A have been downloaded as mean values of Level 3 Network Common Data Format. These data were transferred into the SeaDAS software package, where they have been adjusted to the geographic coordinates of the continental shelf of Côte d'Ivoire.

Results

Table 1 shows the list of the species that made up the overall catches of the artisanal fishery from Sassandra, southwestern Côte d'Ivoire. All specimens listed in Table 1 numbered 112; they belonged to 55 families as they were assigned 4 zoological groups according to their kinds.

Table 1. Family, scientific name, local name and FAO name for the marine species landed by the artisanal fishery located at Sassandra, southwestern Côte d'Ivoire.

Family	Scientific name	Local name and FAO* name
Ariidae	*Arius parkii*	Mâchoiron / Guinean sea catfish
Belonidae	*Strongylura senegalensis*	Aiguille / Senegal needlefish
	Tylosurus crocodilus crocodilus	Crocodile / Aiguille / Hound needlefish
Branchiostegidae	*Branchiostegus semifasciatus*	Zèbre / Zebra tilefish
Carangidae	*Alectis alexandrinus*	Japon / Alexandria pompano
	Alectis ciliaris	Japon / African pompano
	Campogramma glaycos	Lirio / Vadigo
	Caranx crysos	Carangue / Blue runner
	Caranx hippos	Carangue / Japon / Crevalle jack
	Caranx latus	Carangue / Japon / Horse-eye jack
	Caranx senegallus	Carangue / Senegal jack
	Chloroscombrus chrysurus	Plat-plat / Atlantic bumper
	Decapterus rhonchus	Chinchard / Apolo / False scad
	Elagatis bipinnulata	Poisson-Banane / Rainbow runner
	Lichia amia	Liche / Leerfish
	Selene dorsalis	Musso / African lookdown
	Seriola dumerili	Sériole / Greater amberjack
	Trachinotus teraia	Arrè / Terai pompano
	Trachurus trachurus	Apolo / Atlantichorse mackerel
	Trachurus trecae	Chinchard / Cunene horse mackerel
Carcharhinidae	*Prionace glauca*	Requin Peau bleue / Blue shark
Centrolophidae	*Schedophilus pemarco*	Mademoiselle / Pemarco blackfish
Clupeidae	*Ethmalosa fimbriata*	Aoubé / Bonga shad
	Ilisha africana	Rasoir / Lame / West African ilisha

	Sardinella aurita *Sardinella maderensis* *Sardinella rouxi*	Sardine / Magni / Round sardinella Hareng / Magni / Madeiran sardinella Hareng / Yellowtail sardinella
Coryphaenidae	*Coryphaena hippurus*	Coryphène / Dolphinfish
Cynoglossidae	*Cynoglossus canariensis* *Cynoglossus senegalensis*	Sole / Canary tonguesole Sole / Senegalese tonguesole
Dactylopteridae	*Dactylopterus volitans*	Avion / Poisson volant /Flying gurnard
Dasyatidae	*Dasyatis margarita*	Raie perlée / Daisy stingray
Drepanidae	*Drepane africana*	Saint-Pierre / African sicklefish
Elopidae	*Elops lacerta*	Guinée / West African ladyfish
Engraulididae	*Engraulis encrasicolus*	Anchois / European anchovy
Ephippididae	*Chaetodipterus goreensis*	Chèvre de mer / African spadefish
Exocoetidae	*Exocoetus volitans* *Prognichthys gibbifrons*	Avion / Tropical two-wing flyingfish Poisson Avion / Bluntnose flyingfish
Gempylidae	*Promethichthys prometheus* *Ruvettus pretiosus*	Petit brochet / Promethean escolar Poulet / Oilfish
Gerreidae	*Eucinostomus melanopterus*	Friture argentée / Flagfin mojarra
Haemulidae	*Brachydeuterus auritus* *Parapristipoma octolineatum* *Pomadasys jubelini* *Pomadasys peroteti*	Friture / Lôcô-Lôcô / Bigeye grunt African striped grunt Carpe blanche / Sompat grunt Carpe blanche / Parrot grunt

Table 1 (Continued)

Family	Scientific name	Local name and FAO* name
Hemiramphidae	*Hemiramphus balao*	Aiguille / Aiguillette / Balao halfbeak
Istiophoridae	*Istiophorus albicans* *Makaira nigricans*	Socodjêkê / Atlantic sailfish Marlin / Blue marlin
Lethrinidae	*Lethrinus atlanticus*	Carpe grise / Atlantic emperor
Lutjanidae	*Lutjanus goreensis*	Carpe rouge / Gorean snapper
Megalopidae	*Tarpon atlanticus*	Tarpon / Atlantic tarpon
Mobulidae	*Manta birostris*	Diable de mer / Giant Atlantic manta
Mugilidae	*Liza falcipinnis* *Mugil cephalus*	Mulet / Sicklefin mullet Mulet / Flathead grey mullet
Mullidae	*Pseudupeneus prayensis*	Rouget / West African goatfish
Muraenesocidae	*Cynoponticus ferox*	Congre / Guinea pike conger
Muraenidae	*Lycodontys sp.* *Muraena sp.*	Murène Murène
Ophichthidae	*Echelus myrus* *Ophisurus serpens*	Poison-serpent / Painted eel Poisson-serpent / Serpent eel
Ophidiidae	*Brotula barbata*	Loche / Bearded brotula
Ostreidae	*Crassostrea gasar*	Huitre

Palinuridae	*Panulirus regius*	Langouste / Royal spiny lobster
Penaeidae	*Penaeus notialis*	Crevette / Pink shrimp
Polynemidae	*Galeoides decadactylus* *Pentanemus quinquarius* *Polydactylus quadrifilis*	Capitaine / Lesser african threadfin Friture moustachue / Royal threadfin Capitaine / Giant African threadfin
Portunidae	*Callinectes amnicola* *Callinectes marginatus*	Crabe / Bigfisted swimcrab Crabe / Marbled swimcrab
Priacanthidae	*Priacanthus arenatus*	Motard / Atlantic bigeye
Rachycentridae	*Rachycentron canadum*	Mafou / Cobia
Rhinobatidae	*Rhinobatos albomaculatus* *Rhinobatos rhinobatos*	Raie guitare / Whitespotted guitarfish Raie guitare / Common guitarfish
Rhynchobatidae	*Rhynchobatus lübberti*	Ange de mer
Sciaenidae	*Argyrosomus hololepidotus* *Pseudotolithus elongatus* *Pseudotolithus senegalensis* *Pseudotolithus typus* *Pteroscion peli* *Umbrina canariensis*	Courbine / Southern meagre Bobo / Sosso / Bobo croaker Bobo / Sosso / Cassava croaker Ombrine / Longneck croaker Friture blanche / Boe drum Ombrine / Canary drum
Scombridae	*Acanthocybium solandri* *Auxis rochei* *Auxis thazard* *Euthynnus alletteratus* *Katsuwonus pelamis* *Sarda sarda* *Scomber japonicus* *Scomber scombrus* *Scomberomorus tritor* *Thunnus albacares*	Thon blanc / Wahoo Auxide / Pokou / Bullet tuna Auxide / Cigare / Pokou / Frigate tuna Pokou / Little tunny Listao / Nescao / Skipjack tuna Assaf-Pokou / Atlantic bonito Maquereau / Chub mackerel Maquereau/ Assaf / Atlantic mackerel Thon blanc/West African Spanish mack Thon / Yellowfin tuna

Table 1 (Final)

Family	Scientific name	Local name and FAO* name
Scorpaenidae	*Scorpaena angolensis* *Scorpaena scorfa*	Crapaud / Angola rockfish Crapaud / Red scorpionfish
Scyllaridae	*Scyllarides herklotsii*	Cigale / Red slipper lobster
Sepiidae	*Sepia elegans* *Sepia officinalis*	Seiche / Elegant cuttlefish Seiche / Common cuttlefish
Serranidae	*Epinephelus aeneus* *Epinephelus goreensis*	Mérou / White grouper Mérou / Dungat grouper
Sparidae	*Pagellus bellottii*	Pageot / Red pandora
Sphyraenidae	*Sphyraena afra* *Sphyraena barracuda* *Sphyraena guachancho*	Barracuda/Brochet/Guinean barracuda Barracuda / Brochet / Great barracuda Brochet / Guachanche barracuda
Sphyrnidae	*Sphyrna lewini* *Sphyrna mokarran* *Sphyrna zygaena*	Requin marteau/Scalloped hammerhead Requin marteau / Great hammerhead Requin marteau / Smooth hammerhead
Squatinidae	*Squatina aculeata* *Squatina oculata*	Ange de mer / Sawback angelshark Ange de mer / Smoothback angelshark
Stromateidae	*Stromateus fiatola*	Mademoiselle / Butterfish

Tetraodontidae	*Lagocephalus laevigatus* *Sphoeroides pachygaster*	Crapaud / Smooth puffer Crapaud / Blunthead puffer
Trichiuridae	*Trichiurus lepturus*	Ceinture / Largehead hairtail
Xiphiidae	*Xiphias gladius*	Espadon / Swordfish
zeidae	*Zeus faber*	John dory

*FAO name for the species is indicated in Bold.

These groups comprised fish, crustaceans (shrimps, crabs, mantis-shrimps and crayfish), cephalopods (cuttlefish) and gastropods (oysters, sea snails). The species are from different realms in the water column according to their habitats. Some species are pelagic like the Clupeids [example: *Sardinella aurita* Valenciennes, 1847, *S. maderensis* (Lowe, 1839)], the Istiophorids [example: *Istiophorus albicans* (Latreille, 1804), *Makaira nigricans* Lacepède, 1802] and the Scombrids [example: *Auxis thazard* (Lacepède, 1800), *Thunnus albacares* (Bonnaterre, 1788)]. Other species that are semi pelagic include the Carangids [example: *Alectis alexandrinus* (Geoffroy Saint-Hilaire, 1817), *Trachurus trecae* Cadenat, 1949], the Mugilids [example: *Liza falcipinnis* (Valenciennes, 1836), *Mugil cephalus* Linnaeus, 1758] and the Polynemids [example: *Galeoides decadactylus* (Bloch, 1795), *Pentanemus quinquarius* (Linnaeus, 1758)]. Still, other species that belong to the Belonids [example: *Strongylura senegalensis* (Valenciennes, 1846),*Tylosurus crocodilus crocodilus* (Peron and Le Sueur, 1821)] or to the Sciaenids [example: *Pseudotolithus elongatus* (Bowdich, 1825), *Umbrina canariensis* Valenciennes, 1843] are demersal. In addition, some other species are either benthic or benthopelagic, as are the Dasyatids [example: *Dasyatis margarita* (Günther, 1870)], the Ophidiids [example: *Brotula barbata* (Bloch and Schneider, 1801)] and the Trichiurids [example: *Trichiurus lepturus* Linnaeus, 1758].

The total number of specimens comprised 104 fish species, 5 crustaceans, 2 cephalopods and 1 Gastropod, accounting for 92.86%, 4.46%, 1.79% and 0.89%, respectively, of all taxa observed in the fishery landings (Table 1). However, some sea snails whose full scientific name we could not ascertain were not listed in Table 1.

Table 2. Main families contribution to species richness (number of individuals) and to the yield obtained in 2016 at Sassandra, southwestern Côte d'Ivoire.

Family	Number of species in the family	Percentage Individuals	Percentage Yield
Clupeidae	5	80.58	81.78
Carangidae	16	6.24	3.00
Scombridae	10	1.17	3.23
Sciaenidae	6	1.27	1.93
Polynemidae	3	0.82	1.55
Haemulidae	4	0.44	0.68

Data derived from the 2016 fishery statistics collected by the Local Office for Aquaculture and Fisheries Statistics (the "Bureau Aquaculture et Pêche", BAP - Sassandra).

Table 2 shows the main families whose taking part in species richness was the most outstanding. Those families are composed of the Clupeids, the Carangids and the Scombrids, followed by the Sciaenids, the Polynemids and the Haemulid species, respectively. All six families accounted for 90.52% of captured specimens and 92.17% of the yield, according to statistics collected in 2016 by the BAP - Sassandra. However, the most prominent family was that of the Clupeids, as 80.58% of landed specimens belonged to that family. The less prominent family was composed of the Haemulid species, as that family accounted for 0.68% of the yield (Table 2). Besides, the Shannon-Wiener index was relatively low (H' = 1.75). Of all species landed, fish were the most abundant. Fig. 1 indicates that fish accounted for 95.13% of total specimens (Fig. 1A) and 99.29% of the yield in 2016 (Fig. 1B). With such higher percentages for Fish, it became obvious that Crustaceans, Cephalopods and Gastropods have poor percentages. Fig. 2 shows the SST and Chl-A variations throughout the study period. Overall, SST and Chl-A were inversely correlated. Following a phase of relatively low concentrations, from October 2017 to April 2O18, Chlorophyll-A level increased from May 2018 to July 2018. From then onward, Chl-A concentration decreased until March 2019. In contrast, SST remarkably decreased from May 2018 to September 2018, and then attained relatively higher values until March 2019.

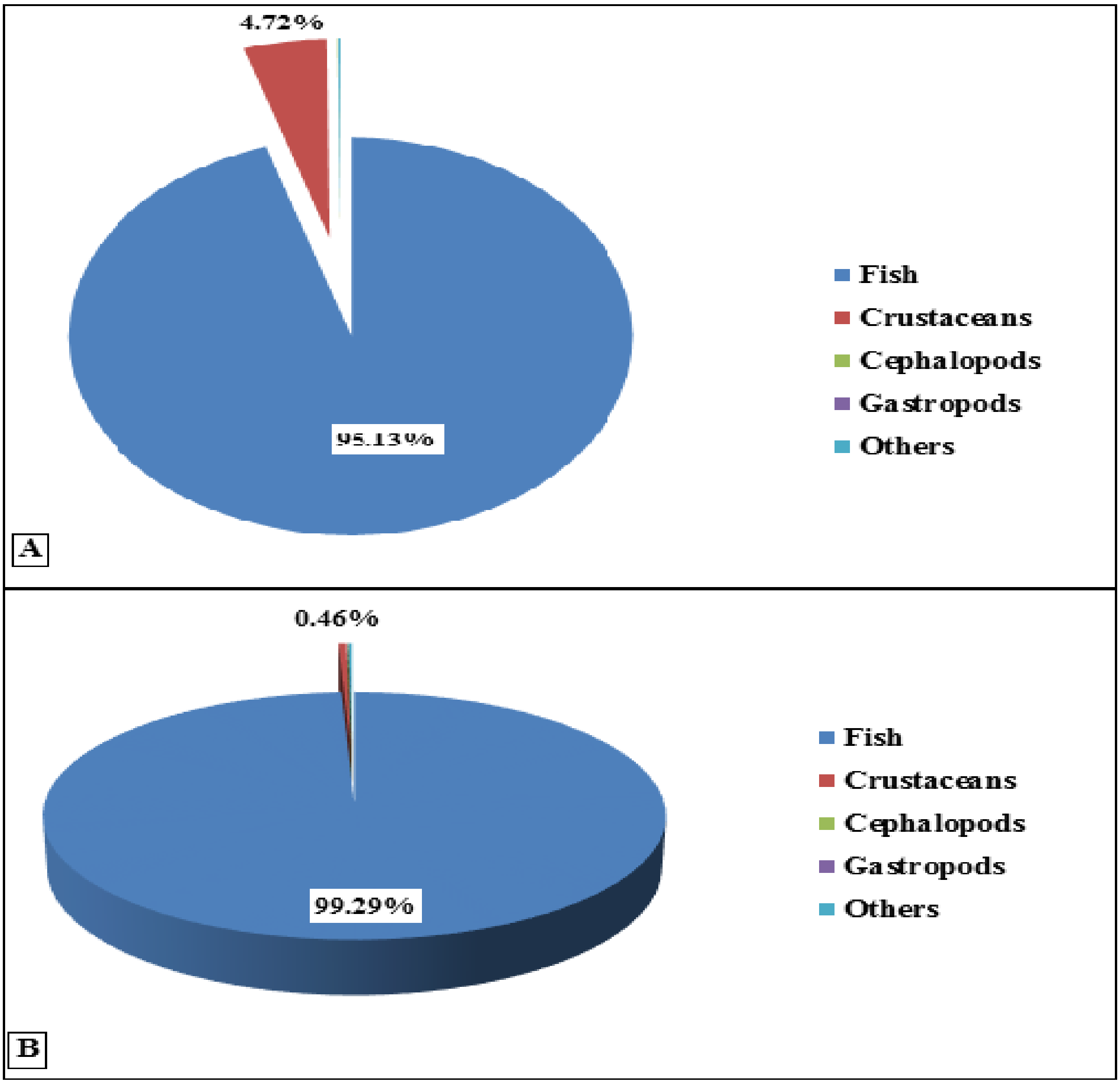

Fig. 1. The four zoological groups share in species richness in terms of number of specimens caught (A) and in the yield (B) derived from the fishery statistics collected in 2016 at Sassandra, southwestern Côte d'Ivoire.

Discussion

Numerous species have been observed in the catches taken by the artisanal fishers. The 112 species we observed include fish, crustaceans, cephalopods and gastropods. This number is similar to the 110 species observed during the CHALCI Trawling Campaign in Côte d'Ivoire (Écoutin, 1992). Such a species richness is favoured by environmental conditions, especially the ones reigning in the west on the continental shelf of Côte d'Ivoire, which are propitious to species expansion. According to Morlière and Rébert (1972), the area in continental shelf waters of Côte d'Ivoire that lies between Tabou and Sassandra is constantly under cooling conditions and is species disponibility favourable as a result. However, the 104 fish species we identified are not approximate to the 125 fish species of the Gulf of Guinea noted by Polidoro *et al.* (2017). Overall, the species observed are numerous and consequently sufficient enough to randomly or evenly distribute across various compartments in the water column to become either pelagic, semi pelagic, demersal, benthic, or benthopelagic species. Each realm in the water column virtually creates compartments that can be likened to biotopes. As there is scarcely any barrier between those biotopes, easy encroachment of some species into either biotope depending on their ecophysiological peculiarities is always possible.

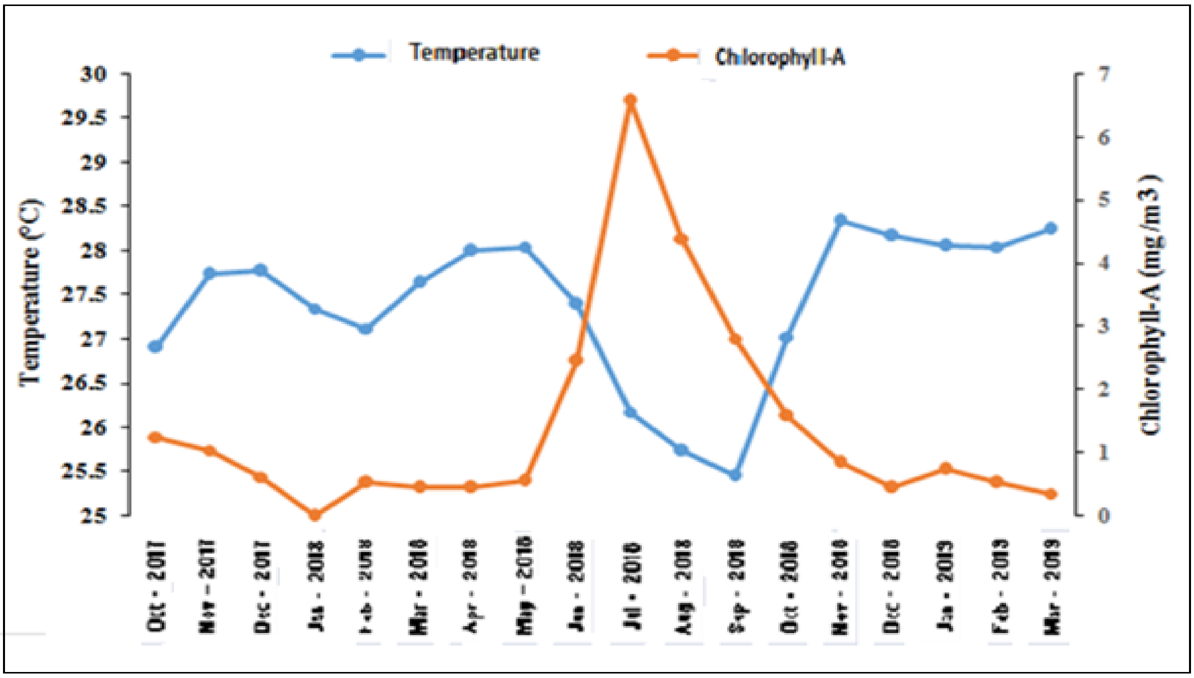

Fig. 2. Monthly average variations of the SST and Chl-A from October 2017 to March 2019 within the Ivorian Exclusive Economic Zone (Data derived from Satellite observations by MODIS-Aqua).

This inevitably creates an additional dimension to multiple-gear users' ability to capture various types and kinds of species. This ability may also be reinforced by the fact that all species generally do not occur at the same time in a given area, so as to avoid competition. For example, regarding feeding, some species would feed at dawn, others at sunset or during the night; still, some species would be bottom feeders while others would prefer feeding near the surface and so on. In any event, in most cases, the feeding behaviour of predatory species is dictated by prey distribution and prey occurrence as well as prey abundance and feeding behaviour. For species are generally caught in gears when in search of food or when chasing after prey in a given area. In this connection, the majority of species we observed are carnivorous species whose feeding behaviour is generally predatory. Yet, two fish species belonging to the Clupeidae family and known as the Sardinellas (i.e. *Sardinella aurita* and *S. maderensis*) dominated the catches, since they predominantly occurred in the landings. This is in accordance with the low value of the Shannon-Wiener diversity index. Still, this assertion is in line with FAO (2008) remark about Ivorian artisanal marine fishery, when commenting that small pelagics (e.g. the Sardinellas) generally account for 80% of the landings. This certainly cannot be attributable to a mere chance. Three factors are likely involved in causing the number of the Sardinellas to increase in the landings. These are, as follows: (i) Sardinellas might be key species to the ecosystem functioning, at least with regard to overall species' feeding habits. Many species prey upon the Sardinellas to enhance their feeding regimes. For example, some of the species that are known to be apex predators such as tunas and Billfishes rely on the Sardinellas as prey. Even Largehead hairtail *Trichiurus lepturus* and West African ladyfish *Elops lacerta* Valenciennes, 1846 are juvenile Sardinellas consumers. (ii) Sardinellas' schooling behaviour also has to do with these species' greater abundance in the catches. The more fishes move about in shoals, as the Sardinellas do, the greater their catchability to encircling gears like purse seines and beach seines or to drifting gillnets like the ones deployed by the fishers, which can attain as much as 2000-2500 m long (see Bard *et al.*, 2002), and (iii) Sardinellas' preferential habitat seems to be upwelling areas, where a superficial cool-water-layer permanently exists (Fréon, 1988). True to this author's assertion, fishers did catch plenty of fish, namely the Sardinellas, from May 2018 to September 2018, especially when the cool season, known as the main upwelling season, occurred from June to September. Cooling conditions generally make a way for the establishment of all-natural processes accounting for greater production of the phytoplankton and the expansion of most zooplankton species that comes along with it as a result of the bloom of phytoplankton, which Binet (1993) and Reyssac (1993) rightly noted. In fact, there is a correlation between the increase in chlorophyll-A and the abundance of phytoplankton, which Satellite imagery easily reveals, since phytoplankton blossoming is a remarkable event (Morales, 2014). But how does the increase in chlorophyll-A come to explain the species richness the current study deals with? Well, in the ocean, the first trophic level regarding the food web is the primary production, which is no other than the phytoplankton. And it is the quantity of chlorophyll-A which gives us information about how abundant the phytoplankton is. Therefore, the higher the quantity of chlorophyll-A, the higher the abundance of phytoplankton. According to Morales (2014), biomass production by the phytoplankton serves for the start to the food web in aquatic ecosystems. Hence, the phytoplankton is consumed by microscopic herbivorous animals known as the zooplankton, which in turn is fed upon by juvenile or small fishes, and so on, down to the apex predators such as sea birds or whales or still sharks, etc (Townsend, 2012; Morales, 2014). When the cool season occurs, the SST is low and all processes leading to food in profusion are being amplified as a result of the priming of the productivity of the aquatic ecosystem. For example, cold water reaching the surface brings nutrients into the euphotic layer, boosting the planktonic food web (Binet, 1995); thereby leading to a higher abundance of the majority of the living organisms, of which fishes, crustaceans, cephalopods and gastropods. Apparently, all sorts of organisms we could expect regarding the food web and the ecosystem functioning, spanning phytoplankton consumers to top predators (tunas, Billfishes, sharks, etc) are among the species listed in this study (see Table 1). Therefore, fishers may continue fishing while keeping in mind that they should limit their impact on the ecosystem to the extent possible to ensure and keep its functioning in a stable state.

Conclusion

Multiple gears utilization proved to be effective in catching diverse living organisms from different realms in the water column within the fishing grounds exploited by the artisanal fishers in southwestern Côte d'Ivoire. Additionally, the Sardinellas are likely to play a key role in the ecosystem functioning. The study also points to a particular event (e.g. the cool season, also known as main upwelling season) whose occurrence is food disponibility favourable and profitable to the various species whose abundance increases as a result. Therefore, fishers and fisheries managers should work at this natural process not be disturbed, in order to guarantee its functioning for the sake of the ecosystem and the viability of the fishing activity.

Acknowledgments

The author would like to thank the fishers and wholesale fishmongers whose leading role in catching or selling the species made them implicitly participants in this study. The author also would like to acknowledge the aid provided by the NOAA, Colorado, USA, through the data they placed for public use at their Web site, which the author freely downloaded. He would also extend his appreciation for the Office for Aquaculture and Fisheries Statistics (the "Bureau Aquaculture et Pêche", BAP - Sassandra) for their collaboration.

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