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Characterization of Livebait Fishing by Pole-and-Line Tuna Vessels in Hann Bay, Senegal, West Africa

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Abstract: Senegal has a large coastline that faces the Atlantic Ocean and most developed fishing industnes in West Africa. The fishing industry supplies food for domestic consumption and is a signifIcant source of foreign exchange. Senegal's highly developed tuna fishery, one of West Africa's largest, is dominated by the commercial sector. The present study provides information about pole and line fishery. This work focused on data from Fisheries Protection and Surveillance Directorate (FPSD) reports of fishery observers on foreign-flagged tuna vessels from 2015 to 2019, representing more than 330 live bait fishing operations. Masters of pole-and-line tuna vessels or representatives of the Thiaroye shipowners and fishermen working on the sea concerned were investigated. The existence of a fleet consisting of pole-and-line tuna vessels of some 15 foreign and domestic vessels based in the port of Dakar targeted these species of tropical tuna. The bait fishery was carried out by the artisan fishermen of Thiaroye sur mer, authorized by the Maritime Fisheries Directorate (MFD), but without a formal procedure manual. These fishermen were very uneducated and did not have a professional organization that could defend their interests. The percentage of livebait needed to catch tuna varied from 8.7% in 2015 to 3.2% in 2019 for foreign vessels. Due to the lack of observers on Senegalese pole-and-line tuna vessels, there was a loss of information on these livebait fishing activities. The quality of the bait was a function of the intrinsic characteristics of the species, in particular its resilience to storage conditions in the tanks, its frenetic behaviour or not once rejected.

Keywords: Live Bait, Pole-and-Line, Tuna, Hann Bay, Senegal

1. Introduction

The Republic of Senegal has one of the largest and most developed fishing industnes in West Africa. Senegal's 700 km coastline borders on waters that, because of seasonal coastal upwelling, contains some of West Africa's richest fishery resources [1]. Senegal's geographical position, whose exclusive economic zone (EEZ) is influenced by the Canary Current and upwelling phenomena [2, 3] and with harbour infrastructures offer opportunities to the fishing operations of pole-and-line tuna vessels. There is a long tradition of offshore fishing targeting tropical tuna with cane as a fishing gear, according to statistics from the Dakar-Thiaroye Oceanographic Research Centre (CRODT), landings in 2012 reached nearly 21544 tons of fish. Whereas the annual average is about 15500 tons between 1999 and 2017. A fishing fleet of some 15 foreign and domestic vessels based in the port of Dakar are targeting these tropical tuna species. These vessels are of varying sizes and capacities and also develop different fishing methods. Fisheries represent one of the most important sectors in Senegal's economy. The fishing industry supplies food for domestic consumption and is a signifIcant source of foreign exchange. Built as a priority in the achievement of the objectives of the Emergent Senegal Plan (ESP), the fisheries sector has managed to maintain its position as a pillar of the national economy despite the many structural and cyclical constraints that beset it. Its role is strategic in economic, food and social security, in terms of job creation, wealth, and balance of trade. It contributes 7.1% to primary sector GDP in 2017 [4]. Fishery products play a

key role in the diet of populations, with a 70% contribution to the nutritional intake of proteins of animal origin. Maritime fishing, which amounted to 524,851 tons in 2018, is thus divided between two types of fisheries: industrial fishing totally oriented towards export (with a share of 24% of landings) and artisanal fishing which alone provides 76% of the groundings [5]. The fisheries resources of the waters under Senegalese jurisdiction constitute a national heritage. As regards the typology of fishing licences, it is defined by the Maritime Fishing Code, which establishes the categories of industrial fishing licences. It highlights the type of offshore pelagic fishing licence, with the option of pole-and-line fishing, targeting tropical tuna. Offshore pelagics are represented by three families: Scombridae, Istiophoridae and Xiphiidae.

Tuna are the most important species caught by Senegalese fIshermen. Tuna and Skipjack tuna are large pelagic fish that always migrate from one water to another whose habitat is suitable in terms of biology, oceanographic conditions, and meteorology [6]. Tropical tunas, albacore, patudo and listao are fish species considered highly migratory [7]. In the Atlantic Ocean, they are managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT). These offshore resources have been the subject of numerous studies carried out notably in Senegal [8-13]. The research focused on the biology, ecology and ethology of the main species, but also on the fisheries that exploit these stocks. Tuna are caught throughout tropical and temperate waters by one of three principal methods: purse seine, longline and pole-and-line [14]. If conducted properly, the most environmentally desirable aspect of the pole-and-line method is the very low levels of bycatch [15, 16].

Pole-and-line fishing gear has the advantage of being the most effective, selective fishing gear for tuna and environmentally friendly, and has a low bycatch [17]. As the name implies, pole-and-line fishing involves the use of fishing poles and lines with hooks. The method is generally used to catch tuna, but also sometimes other large pelagic species one fish at a time. It is a very selective fishing method with very low levels of bycatch and generally only catching the target species. The method is dependent on the availability of small pelagic fish (bait fish) released live into the sea to attract tuna schools within range of a vessel's fishing gear. Therefore, pole and line fishing gear is highly recommended for catching tuna [18].

The objective of this study is to characterize live bait fishing for sardines, ethmaloses, mackerel, anchovies and horse mackerel. Characterization of this fishery is a necessary activity for pole-and-line tuna operations targeting tropical major tuna.

2. Material and Methods

2.1. Description of the Study Area

Hann Bay is located on the eastern façade of the Cape Verde Peninsula between the tip of Cape Manuel and the village of Mbao (Figure 1). This part of the shoreline has two major morphological categories [19]. The rock categories that are limited to the south of Dakar characterized by carved cliffs, consisting of a succession of rocky capes (Cape Manuel) and coves of very small extension (Anse Bernard). There are also the sandy categories encountered south of Cape Verde and characterized by the presence of dune formations (Thiaroye to Bargny). The geographical location of Hann Bay has encouraged the establishment of infrastructures such as the port and industrial units. It houses more than 60% of the country's industrial fabric. Thus, Hann Bay has become a vast dumping ground for domestic and industrial waste water and refuse, causing a major ecological problem for Senegal, which is detrimental to fishing, tourism and life [20].

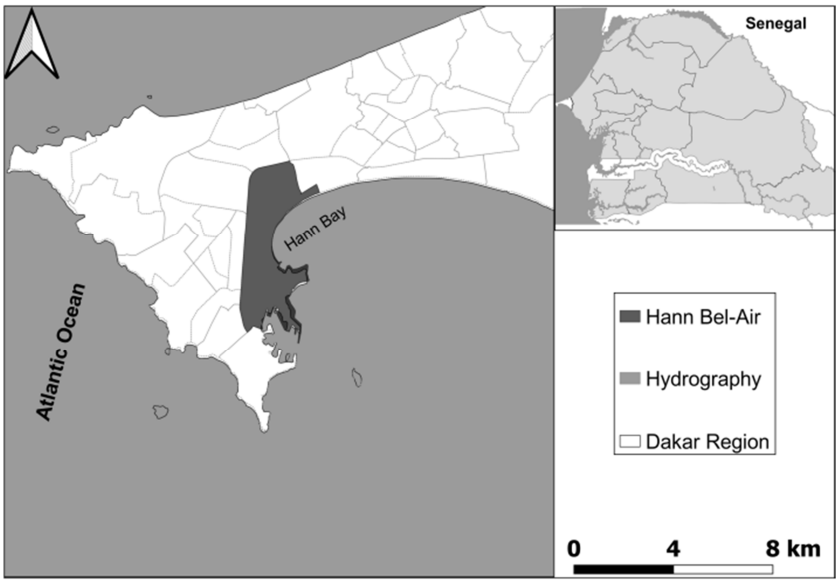

Figure 1. *Location map of the study area, Hann Bay in Senegal.*

2.2. General Information on Pole-and-Line Tuna Vessels in the Atlantic Ocean

The first experience of fishing with livebait in northern Atlantic waters dates back to 1948 when French fishermen introduced this gear fishing albacore and bluefin tuna at the ports of the Bay of Biscay, having imported it from the Pacific Ocean [21]. This new fishing gear rapidly spread throughout all the ports of the Basque Country in the 1950s [22]. The fishing gear also spread to other areas of the Atlantic Ocean, where major fisheries for temperate (bluefin and albacore) and tropical species (mainly bigeye in the waters of Madeira and the Azores) were started for part of the livebait fleet. At the end of this decade, some European baitboats (French and Spanish) started fishing close to the African coasts (Senegal and Congo), using local ports as their base. At the end of the 1960s, this gear spread to other areas of the eastern tropical Atlantic, targeting yellowfin and skipjack tunas. One of the areas of the Atlantic that has experienced the greatest growth is the Gulf of Guinea, with Tema (Ghana) as the base. In the western Atlantic, live bait fishery was developed in the 1970s in Brazilian waters [23, 24].

2.3. Characteristics of Pole-and-Line Tuna Vessels Based in Dakar

Pole-and-line vessels had variable characteristics that were officially validated by the competent authorities of Senegal and transmitted to international institutions such as FAO and regional fisheries management organizations such as ICCAT for tuna atlantic. These vessels were equipped with tanks of varying numbers and capacities, which served as tanks, and equipped with mechanisms for renewing and aerating seawater to maintain live bait under the conditions required for their use. The tanks were also used to store tuna caught in a frozen brine solution at -18°C. These were vessels with Dakar as their home port all year round, flying the Senegalese flag and belonging to Senegalese companies. These vessels, eight of which were foreign (one French and seven Spanish) were freezers using brine for the conservation of their catches. For the purposes of monitoring activities, any foreign industrial fishing vessel authorized to operate in Senegalese waters embarked on board at least one observer for the collection of fisheries statistics and the monitoring of activities. Moreover, for fishing vessels flying the Senegalese flag, the boarding of an observer was not systematic. It could be planned for scientific and control reasons. This collection and control function was not continuous, so it was unreliable. Due to the lack of observers on board Senegalese vessels, the available data were weak. The data was collected from the armaments, when the boat arrived at the dock, with high biases and risks of loss of information.

2.4. Data Collection and Analysis

Quantitative research methods with different investigative tools were used in this study. Consultations and analyses were carried out on official documents related to the subject, such as the lists of vessels authorized from 2015 to 2019, provided by the Maritime Fisheries Directorate (MFD) and the statutory instruments. Live bait collection sheets in the reports of fishery observers embarked by the Fisheries Surveillance and Protection Directorate (FSPD), of the 08 foreign pole-and-line tuna vessels based in Dakar from 2015 to 2019 were processed. They represented more than 110 tides and nearly 330 live bait operations. All data entered on this sheet were transcribed into Excel. However, some data showed incongruities, but they were still usable, after correction. An initial survey of the 14 fishing masters of Senegalese and foreign pole-and-line tuna vessels, or their fleet owners, was carried out. A second survey carried out among 07 captains on the ten canoes authorized to the traditional village of Thiaroye on sea was conducted.

2.5. Fishing Gear

The livebait fishery was conducted with a rotating seine of varying size. The rotating seine net is a device consisting of several layers of nets with variable meshes, equipped with floats allowing to retain on the surface the top rope and ballast to quickly drop the bottom rope. The principle of the purse seine is to encircle a school of fish directly spotted at sea. The mesh of the nets may vary from one net to another depending on the owner's choice or the fisherman's fishing objective. The length and width of the net also varies according to the means of the fisherman. Whatever the size and mesh of the gear, fishermen use the same fishing techniques for purse seines or encircling nets. With a landing net, operated by means of a winch of the pole-and-line tuna vessel, the fish caught and retained in the seine bag were placed in a tank. The tanks had been previously washed and prepared for live bait. The tanks were filled with seawater, aerated and renewed by an appropriate device. Arrangements were made not to enter the port, avoiding the polluted waters of this space due to the waste and water discharged from the boats on the plan. These polluted waters could harm fish life in the tanks.

3. Results

3.1. Live Bait Fishing Boats

Small craft that participated in fishing operations during the period 2015-2019 were listed in Table 1. Most of these canoes were registered in the Dakar region and several of them had numbered fishing licences in Dakar and Thiaroye. It happened that some pirogues only have the payment receipt, the permit having not yet been established.

Table 1. *Canoes used by pole-and-line tuna vessels for live bait from 2015 to 2019.*

N	Name of the boat	Registration	Licence	Year	N	Name of the boat	Registration	Licence	Year
1	IBRAHIMA DIOP	DK4602TH	Undetermined	2015	21	BAYE BIRAHIM GUEYE	DK0075	QUIT	2017
2	MOMAR GUEYE	DK2185TR	1294DK		22	FATMA NIANG	DK3607TR	1812TR	
3	MAREME DIOP	DK4078TR	Undetermined		23	SEYDINA MOUHAMED	DK0058TR	Undetermined	
4	DEBBO BA	DK0350TR	0192DK		24	BABACAR SY	DK2587TR	Undetermined	
5	DIOKINE GUEYE	DK4602TH	1886DK		25	ADJIA MAIMOUNA FAYE	DK0904TR	2774TR	
6	MAIMOUNA FAYE	DK0349TR	1289TR		26	ANTA DIOP	DK0761TR	3942TR	2018
7	SERIGNE MBAYE SALL	DK0349TR	Undetermined		27	ALIOU NIANG	DK4208TR	3945TR	
8	NGONE DIOP	DK5514TR	2460TR		28	ABDOULAYE DIOP	DK0761TR	Undetermined	
9	ANTA DIOP	DK3847TR	1297TR		29	DIOKINE GUEYE	DK3608TR	3186TR	
10	ALHADJI KANE	DK2588TR	2742TR		30	FATMA NIANG	DK3607TR	1812TR	
11	PAUL NAHIA INGE	DK3446TR	4182TR		31	IBRAHIMA GUEYE	DK3607TR	Undetermined	
12	SERIGNE BABACAR	DK2587TR	0850TR		32	SAMBA ISSA GUEYE	DK5045TR	5023TR	
13	NDEYE FATOU DIALLO	DK4536TR	1771TR	2016	33	FATMA NIANG	DK3607TR	5034TR	
14	ABLAYE DIOP	DK0761TR	1257DK		34	SEYDINA MOUHAMED	DK0058TR	2676TR	2019
15	SERIGNE BABACAR SY	DK4019TR	1885DK		35	MOMAR GUEYE	DK2185TR	1294TR	
16	ABSAMBA DIOP	DK0576TR	1989DK		36	SERIGNE BABACAR SY	DK2587TR	3186TR	
17	MAIMOUNA FAYE	DK0349TR	2015DK		37	ELHADJ KANE	DK2587TR	Undetermined	
18	SERIGNE MANSOUR SY	INSTANCE	QUIT		38	ALIOU GUEYE	DK0056	2676TR	
19	KHADY DIATOU NDIAYE	DK3500TR	1550TR	2017					
20	BARA DIOP	DK0576TR	1446TR						

3.2. Livebait and Proportion of Total Catch

Livebait caught by the pole-and-line vessels along the Senegalese coast consisted of small pelagic fishes including juveniles of round sardinella (Sardinella aurita), flat sardinella (Sardinella maderensis), anchovy (Engraulis encrasicolus), black horse mackerel (Trachurus trachurus) and yellow (Trachurus mediterranus) and mulets (Mugil sp). These species of relatively small size, constituted an important fishing potential along the West African coasts and more particularly on the Senegalese coast where they represented more than 70% of the catch. In this study (Figure 2), tuna catch rate was highest with livebait catches (2018 and 2019) and was lowest with it (2015, 2018 and 2019).

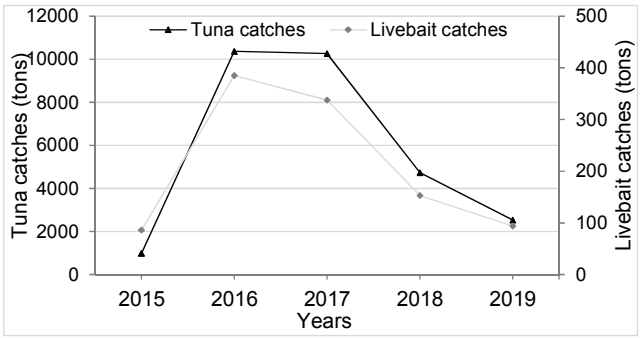

Figure 2. *Evolution of tuna and live bait catches by year.*

3.3. Temporal Evolution of Livebait Catches

According to observer reports that were sorted and processed from 2015 to 2019, the amount of livebait needed to catch tuna declined during this period from 8.7% to 3.2% (Figure 3). A slight upward trend was noted between 2018 and 2019, moving from 3.2% to 3.7%. On the whole, percentage of bait over the past four years had fluctuated widely with a gradual decline observed from 2015 to 2019. Overall, the trend in the percentage of bait required for tuna fishing from 2015 to 2019 was on a downward trend.

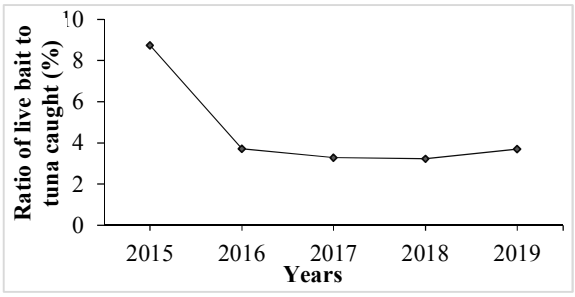

Figure 3. *Evolution of the tuna/live bait catch ratio in Senegal.*

3.4. Live Bait Used by Vessel from 2015 to 2019

From 2015 to 2019, it was noted that vessels were catching fewer and fewer live bait for tuna fishing (Figure 4). In 2015, the vessel Corona Del Mar had 23.5% live bait relative to the weight of tuna caught, while in 2016, 2017 and 2018, this percentage was roughly equal to 5%. It was during the years 2015 and 2019 that the percentage of live bait used by vessels was greater than 10%. Some vessels had not used live bait in 2015, while the lowest amounts of live bait used by these boats were obtained in 2018.

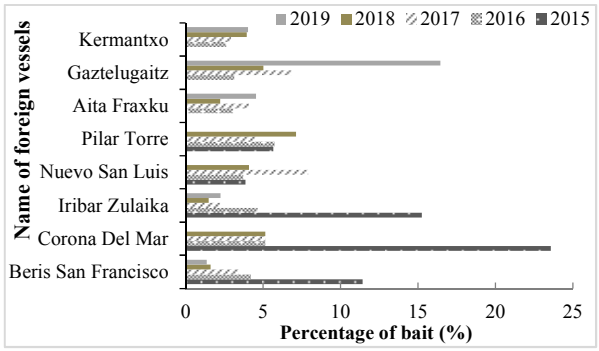

Figure 4. *Amount of bait required for tuna fishing for foreign vessels from 2015 to 2019.*

3.5. Quality of Livebait According to Caners

The quality of the bait was a function of its intrinsic characteristics, including its resilience to storage conditions in tanks, its behaviour once discharged to the target fish. It also depended on the target species. It emerges from the investigations with fishing patterns that the anchovies, were very little resistant to the conditions of conservation in the vats beyond a few days. Moreover, when they were put in polluted waters like those of the port, they died quickly; this corresponded to a waste of time and biodiversity. The sardines behaved frantically when launched, which was a favourable factor for the tuna fishery, which was a major predator. The size between 10 and 12 cm was favourable to the Skipjack fishery. The horse mackerel, set to the hook, were more apt to catch the big fish like the albacore or the patudo. The mules had a better resilience, even with the polluted waters of the port. They resisted storage conditions in the tanks. On the other hand their behaviour at the launch was not frenetic, therefore did not attract the tuna sufficiently.

3.6. Education Level and Organization of Livebait Harvesters

The analysis of figure 5 showed that 88% of the actors had not exceeded the level of primary education and that less than 1% had the university level. These characteristics of fishing communities showed their vulnerability and the weakness of the ability to formulate and argue for their interests in negotiations with other competing socio-professional categories in the value chain of the fishery concerned. The town of Thiaroye on the sea was the focus of most of the canoes that fished for live bait. Our field surveys showed that fishers were not organized within a statutory framework. This lack of organization weakened the assumption of their interests in the negotiations with the owners of pole-and-line tuna vessels.

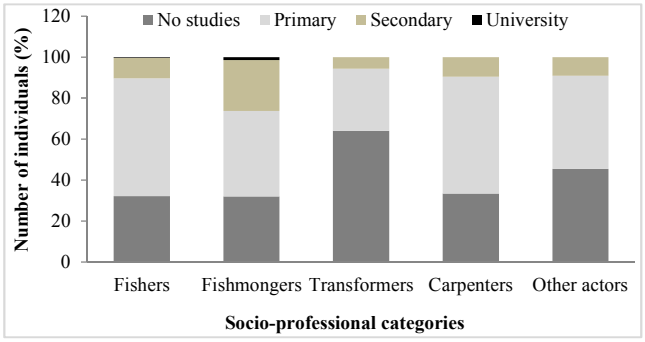

Figure 5. *Instruction level of actors by occupation.*

3.7. Livebait-Tuna Catches Relationship

Figure 6 showed that larger the livebait catches, larger the tuna catches. The relationship between the use of live bait and catches was y = 30.434x - 651.26 with r square = 0.97 and the correlation of determination = 97%. The meaning of the equation above was that every addition of 1 kg of livebait would affect 30.43 kg of fish caught, where livebait had an effect on catch of 97%, while the remaining 3% were influenced by other variables outside the regression model.

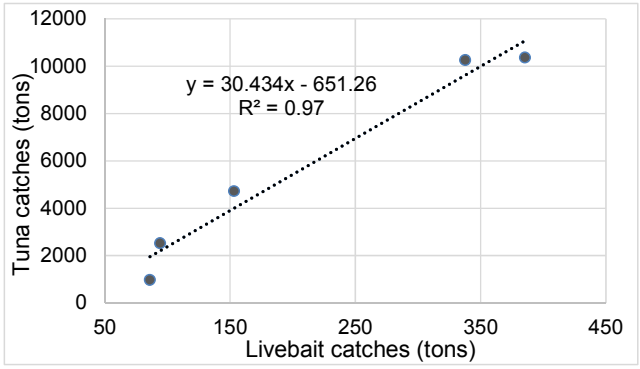

Figure 6. *Regression of relationship of using livebait with the tuna catches.*

4. Discussion

The fishing of tropical tuna with cane was among the most respectful of the marine environment. Rod fishing had very little negative impact on marine ecosystems [25]. It was better suited to receive environmental certification such as eco-labelling. It was recognized that on the tuna industry market, the price of tuna caught on cane was higher than that of other fishing gear such as seine and longline. This demonstrated the importance of this type of fishery.

In the present study, 28883.679 tons of tuna were caught by height (08) vessels with pole-and-line using livebaits. It is known that catch rate decreases as hook size increases [26, 27]. Hook size was positively correlated with the mouth width and fish length.

As regards the characteristics of pole-and-line tuna vessels based in Dakar, these were vessels of average size of 35 m, which operated in the waters under the jurisdiction of Senegal and neighbouring countries. Some of these vessels were glaciers before freezing because of changes in fishing strategy, resource scarcity and market demand in the tuna industry. The average gross registered tonnage (GRT) was about 200, but it varied from year to year. The crew consisted of about 25 people, mainly of Senegalese nationality, which represented a considerable work force potential. The vessels were equipped with tanks that were used to store tuna caught in a -18 or -25°C frozen brine solution. The tanks were also used to keep the bait alive under specific conditions suitable for their future use on the high seas. Feeding habits and mouth size of the target species should also be taken into consideration when selecting baits in longline fishing [28]. The live bait was caught in Hann Bay, which because of its configuration was sheltered from the prevailing marine currents. This was a spawning area, thus providing conditions for large populations of juvenile small pelagic populations [29]. However, for several years, the Bay was experiencing domestic and industrial pollution, but also fishing practices that negatively impacted the environment. The processes of urbanization and demographic pressure had absorbed the land reserves that allowed fishermen to diversify their

activities. Clean-up and implementation of good fishing practices in Hann Bay were issues to be considered for sustainable fishing [30]. Bait fishing was carried out by the artisanal pirogues authorized by the DPM, on behalf of tuna vessels. These were canoes registered mostly in Thiaroye. The crew of a canoe for a fishing operation was of the order of 15 to 20 people, for a duration of 3 to 5 days. As a result, the live bait fishery used significant labour. On the other hand, there was no validated formal procedure for organising fishing activity, with a view to setting up mechanisms for continuous improvement and optimum exploitation. The low level of education of artisanal fishermen and the lack of professional organizations were limiting factors in optimizing bait fishing for these pole-and-line tuna vessels. The percentage of live bait needed to catch tuna varied from 8.74% in 2015 to 3.23% in 2019. This situation demonstrated efforts to improve practices and optimize the use of live bait on pole-and-line tuna vessels. Administrative follow-up measures were taken to improve the knowledge and management of live bait fishing activities. However, there was no specific fishing licence for live bait. The quality of the bait was a function of the intrinsic characteristics of the species, including its resilience to storage conditions in tanks and its frenetic or not-released behaviour. According to the target tuna species, the live bait had to be adequate. For the large albacores, a bait hook with a fish of more than 15 cm was required, while the feathers or hooks were baited with the juveniles of live sardinella for the Listaos.

The small fish that were caught to use as livebait in the tuna pole-and-line fishery were likely to be an important food source for seabirds, small carcharhinid sharks, whale sharks and dolphins. It was, therefore, possible that collection of bait fish may indirectly affect various marine predators by reducing their food resource. The lack of a procedure manual for the capture of bait and a system for monitoring and evaluating fishing activities was a reality. However, mechanisms to reduce the waste of livebait were not implemented. Losses could be significant when conditions for catching and storing bait in tanks were not adequate.

5. Conclusion

This work is a contribution to improving the knowledge of the field of bait fishing living in the Bay of Hann in Senegal. These baits mainly target sardines, ethmaloses, mackerel, anchovies and horse mackerel. This is a necessary step for pole-and-line tuna operations, targeting tropical tuna. This fishing is carried out by fishermen craftsmen from Thiaroye on sea, authorized by the competent authorities, on behalf of pole-and-line tuna vessels. The authorities have taken initiatives to monitor live bait fishing. Fishermen engaged in this type of fishery have a very low level of education. The sustainable management and labelling of the pole-and-line tuna fishery can only be envisaged through the establishment of formal procedures aimed at optimising fishing with live bait. It is now clear that the government agencies, responsible for managing fisheries resources, have a better understanding of livebait fishery resources and mechanisms are in place to obtain information that will allow sustainable exploitation of livebait resources. Although fishers are supportive in providing data and share information with relevant authorities to facilitate sustainable exploitation of bait resources the real challenge now would be to effectually manage this important fishery.

Our recommendations are to take the necessary measures to ensure that the fishing effort of catching vessels are commensurate with the tuna fishing With a view to the development of sustainable artisanal tuna fishing in Senegal and other African countries, we recommend to set up a tuna access allocation system that gives priority to those who fish in the most sustainable way. We recommend also to authorities to draw up, in consultation with the fisheries sector stakeholders, a sustainable development plan for Senegalese tuna fisheries, including artisanal, and submit this plan to ICCAT in order to have better access to resources and quotas to match.

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