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Original Research Article

Contribution to a better knowledge of bycatch of fixed gillnets of shrimps (*Farfantepenaeus notialis*) in the Casamance estuary in Southern Senegal

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This study was carried out in Ziguinchor (Senegal) in southern Senegal where the coastal shrimp *Farfantepenaeus notialis* is exploited by a small-scale fishery whose activities have been mainly oriented for several years. Data were collected downstream Casamance Estuary from 26 July to 31 August 2016 at two landing sites: from July 26 to August 12 in Boudody and then from August 16 to 31 under the bridge Emile Badiane. During this period, the landings of 61 fishermen were studied. Those fishermen were selected at random or through contacts established by the Ziguinchor Regional Fisheries and Surveillance Service. The collection was carried out three times a week with fishermen returning from fishing between 9 PM and 10 AM. Juvenile fish are the main bycatch of this type of fishing gear (86.85%), followed by crustaceans (13.13%) and cephalopod molluscs (0.02%). Most of these captures (89.54%) are discarded, 10.46% are retained. Some 39 species constitute the bycatch of fixed net used in shrimp fishery downstream Casamance estuary. There are four species regularly found in fishermen's nets, 1 quite frequently, 5 of them are retrieved occasionally and 29 are erratic. *Ethmalosa fimbriata*, accounting for almost 60.74% of catches, is the main bycatch species found in fixed net. 64% of species caught belong to the category of minor concerns and 10% are labelled as threatened species (vulnerable and endangered). Out of those 39 species, 13 are estuarine of marine origin and 13 are marine estuarine and 21 of them are predatory species of the second trophic level. Bycatch discards account for 140 kg. Some species, mainly juvenile fish, discarded by fishermen are salvaged for human and / or animal consumption. Others are kept by fishermen and are eaten.

Key words : bycatch - fixed nets - artisanal shrimp fishery - *Farfantepenaeus notialis*, downstream estuary of Casamance, Senegal.

INTRODUCTION

Peneid Coastal shrimps were traditionally exploited by artisanal fishing along the West African coast. This exploitation has increased since the 1950s with the development of a more advanced and specialized industrial fishery (Thiaw, 2010).

Shrimp is on one hand exploited at sea by industrial fishery and on the other hand in estuary or lagoon by small-

scale fishing (Le Reste and Collart-Odinetz, 1987). In Senegal, small-scale fishing takes place in estuarine environments, including the mouth of the Senegal River, the Sine-Saloum-Gambia complex and the Casamance River (Caverivière and Thiam, 2002). In Casamance estuary, especially downstream, shrimp fishery is mainly carried out using fixed nets (Le Reste, 1993). These are nets attached to

each side of the canoe anchored in the channel and capturing the shrimp migrating towards the sea (Le Reste, 1992). In Casamance, fishing mainly targets *Farfantepenaeus notialis* (Le Reste and Diallo, 1994). However, non-target species are also captured by these fixed nets (Charles-Dominique and Ndiaye, 2003). Those species represent the bycatch (Saila, 198; Eayrs, 2009). They are either retained or discarded by fishermen (Thiam, 2013). They are therefore a major concern for fisheries management (Hall et al., 2000).

This scientific paper aims to contribute to a better knowledge of the fixed net bycatch targeting the coastal shrimp, *Farfantepenaeus notialis*, downstream Casamance estuary.

Abbreviations

he-ph: Herbivore feeding predominantly on phytoplankton or microphyte
 p1-zo : First-tier predator feeding predominantly on zooplankton
 p1-bt : First-tier predator predominantly benthivorous (molluscs, worms)
 P1-ge : General level predator
 p1-mc : Macrophage or generalist first-tier predator (crustaceans, insects)
 p2-ge : Second-tier general predator (fish, shrimps, crabs)
 p2-pi : Second-tier predator predominantly piscivorous

MATERIALS AND METHODS

The study area

This study was conducted in the marine influence zone of the Casamance estuary, downstream Ziguinchor (Figure 1). Salinity in that area is like that of seawater (Debenay et al., 1986). The area is mostly covered by a large mangrove. Suspended sand is responsible for the water turbidity which is the main feature of this area (Le Reste et al, 1986). Between the point of Saint Georges and Ziguinchor, the river's bottoms are composed of heterogeneous sediments (Diouf et al., 1986).

This part of the estuary is also characterized by a semi-diurnal tide whose amplitude decreases from downstream to upstream (Brunet-Moret, 1970). This amplitude is 169 cm at the mouth and is 52 cm in Ziguinchor. In general, the depth of the channel decreases from downstream to upstream.

The average surface water temperature in Casamance Estuary varies between 22 °C in January and February, and 28 °C from May to September, with a peak of 38.7 °C (Pagés et al., 1987).

Fixed shrimp gillnet

As its name suggests, fixed shrimp net is anchored

permanently in the channel with two vertical stakes fixed to 2 dugouts or 2 long poles, about 5-meter-long, with floats fixed at their end to ensure the floatation of the fishing gear. The canoes used are 7 to 8-meter-long and one meter high. The mesh size of the net is around 11 mm (DPM, 2014). Shrimp net fishing is carried out at night in the channel at low tide.

Systematic identification of caught species

For better identification of the species, different identification keys were used. These are the FAO species identification sheets for the eastern central Atlantic (Fischer et al., 1981), the guide for the rapid determination of the Senegalese mullet (Diouf, 1991), the simplified identification guide of Mugilidae (Djadji et al., 2010). In addition to identification sheets, databases such as the IUCN 2016 website, Fishbase, a catalog of marine life were consulted.

Sampling strategy

This study was conducted in Ziguinchor (Senegal) from July 26 to August 31, 2016 in two landing sites: from July 26 to August 12 in Boudody and from August 16 to 31 under the bridge Emile Badiane. During this period, landings of 61 fishermen were studied. These fishermen were selected at random or through contacts established by the Ziguinchor Regional Fisheries and Surveillance Service. Data were collected three times a week with fishermen returning from fishing between 9 pm and 10 am. Bycatch species were sorted and identified by canoe. For kept species, only the total number of individuals per species was determined during each data collection. Fishermen used 20-liter empty cans to retrieve discarded species and emptied them on a sorting table. Individuals of discarded species were collected, measured, weighed and totted up. In case of a small collection (less than or equal to 100 individuals), all individuals were measured. When the size of the collection was important (more than 100 individuals), at least one quarter (1/4) of the individuals were measured:

- the total length of fish (TL) or the fork length (FL), if there is any, was measured to the nearest centimeter using a one meter long graduated board;
- the carapace length (CL) of crustaceans, especially crabs, was measured to the nearest millimeter using a mechanical caliper. The total length of Mantis Shrimp was measured to the nearest centimeter using a graduated board;
- the mantle length (ML) was measured for cephalopod molluscs, to the nearest centimeter using a one meter long graduated board.

After measurement, all discarded individuals were weighed using an electronic scale with a 2Kg weighing capacity.

Based on scientific publications and reports (Albaret, 1994, Albaret et al., 2005, Ecoutin et al., 2014; Sadio, 2015) as well as databases (IUCN Red List 2016, Fishbase and



Figure 1: Location map of the study area

Sealifebase), the ecological and trophic categories as well as the status of the different species were determined.

Data analysis

After the measurements, the total number of individuals of each species was calculated when it was a small size sample. In large samples, individuals which were not measured, had their seize estimated. This makes it possible to determine the total number of individuals discarded per species and per sample according to the following formula:

$$\text{Nb. R} = \frac{\text{Nb.E of i species} \times \text{PNE of species i}}{\text{PE of species i}}$$

We can infer that: $\text{Nb. T} = \text{Nb. R} + \text{Nb. E}$

Nb. R = number of unmeasured individuals of species i;

Nb. E = number of individuals measured of species i;

PNE = weight of unmeasured individuals of species i;

PE = weight of measured individuals of species i;

Nb. T = the total number of individuals discarded from the species i

Relative frequency and frequency of occurrence were calculated.

Relative frequency (% F)

It is the ratio of the total number of individuals of species i to the total number of individuals (abundance) multiplied

by 100.

$$\% F = \frac{F_i}{F_t} \times 100$$

F_i = number of individuals of species i and F_t = total number of individuals of all species

Occurrence frequency (% C):

It equals the percentage of a given species records. The Occurrence frequency by species was computed using the scale proposed by Charbonnel et al. (1995): permanent (100% to 75%), frequent (75% to 50%), occasional (50% to 25%) or rare (25% to 0%).

$$\% C = \frac{E_i}{E_t} \times 100$$

E_i : the number of landings where species i is found and E_t : the total number of landings.

All the data collected (body measurements, weight of discarded individuals, number of individuals by species) were processed using the Excel spreadsheet and R statistical software (R Development Core Team 2017).

RESULTS

In this study we were able to identify 12,535 individuals from bycatch all taxa included.

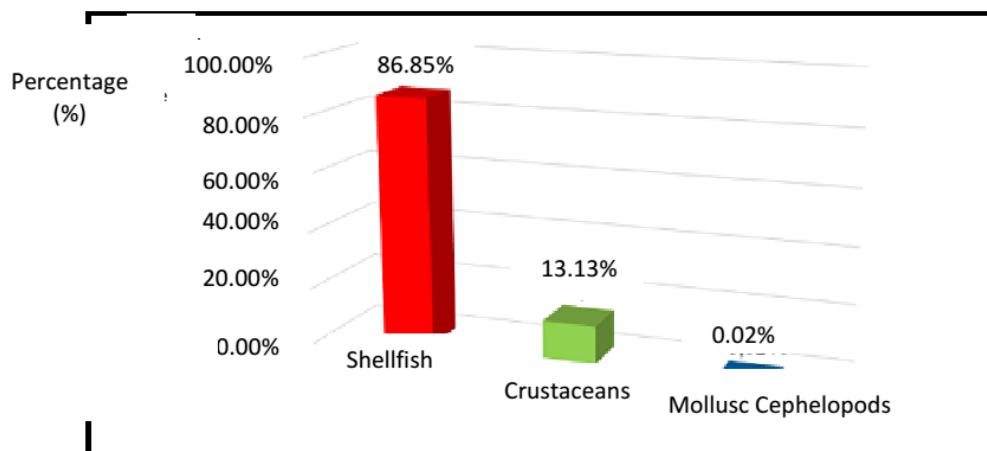


Figure 2. Percentage of each taxon in bycatch

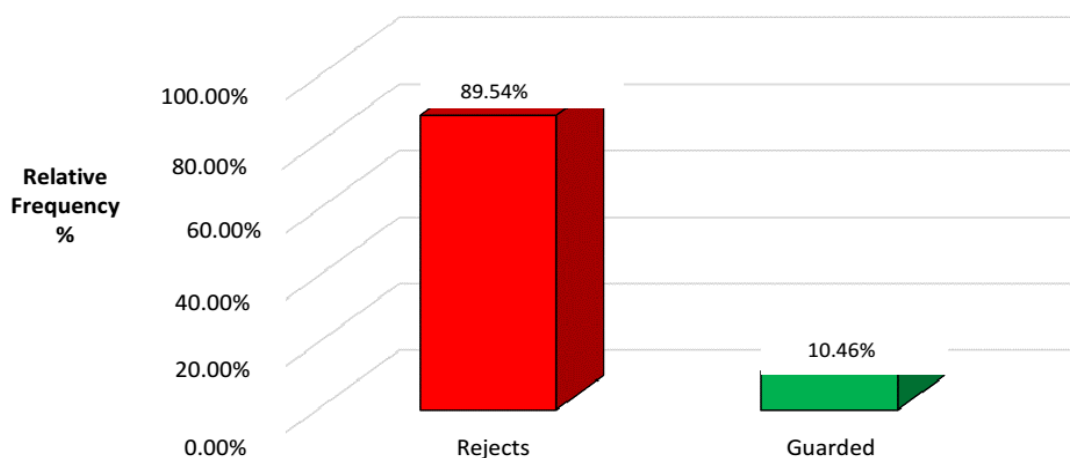


Figure 3: Relative frequency of discarded and guarded catch

The results reveal the presence of three taxa in the bycatch (Figure 2). These are mainly fish (86.85%), crustaceans (13.13%) and cephalopod molluscs (0.02%) accounting for a small percentage.

Number and relative frequency of discarded and retained catches

The total number of discarded catches is 11,244; the relative frequency is 89.54% (Figure 3). The share retained amounts to 1,311 individuals i.e. 10.46% of the total catch (Figure 3).

During the inventory of bycatch species in the small-scale shrimp fixed-net fishery landings downstream Ziguinchor from July 26 to August 31, 2016, researchers were able to identify 11 orders, 26 families and 39 species (Table 1). *Clupeidae Ethmalosa fimbriata* is the species most represented in bycatch. This species represents 60.74%

of the total population; the other species account for 39.26%.

In bycatch researchers found 4 permanent species, one frequent species, 5 occasional species and 29 species that are weakly represented in catches.

Status of the different species according to the IUCN Red List (2016)

According to the IUCN Red List (2016), the various species found in bycatch belong to 6 categories: *endangered (EN)*, *vulnerable (VU)*, *nearly threatened (NT)*, *minor concern (MC)*, *Data Deficient (DD)* and *Not Evaluated (NE)*. The analysis of the results shows that species of minor concern are best represented (Figure 3). This group encompasses 25 species and account for 64% of caught species. The vulnerable category represents 8%, the category in danger 2%, almost threatened 5%, data insufficient 13% and not

Table 1 . Species present in bycatch and their importance

Types of species	Orders	Families	Genres and Species	% C	% F
Regular species in catches	Decapodes	Portunidae	<i>Callinectes sp</i> #	78.69	13.12
	Elopiformes	Elopidae	<i>Elops lacerta</i> #	81.97	3.45
	Clupéiformes	Clupeidae	<i>Ethmalosa fimbriata</i> #	93.44	60.74
		Sciaenidae	<i>Pseudotolithus elongatus</i> #	91.8	12.74
Frequent species at a moment	Perciformes	Gerreidae	<i>Eucinopterus melanopterus</i> #	67.21	2.24
Occasional species	Clupéiformes	Pristigasteridae	<i>lisha africana</i> -	44.26	2.99
			<i>Liza falcipinnis</i> #	39.34	0.4
		Mugilidae	<i>Liza grandisquamis</i> #	42.62	0.72
	Perciformes	Polynemidae	<i>Pentanemus quinquarius</i> #	34.43	0.47
Rare species	Anguilliformes	Ophichthidae	<i>Echelus myrus</i> -	1.64	0.01
		Belonidae	<i>Strongylura senegalensis</i> -	4.92	0,03
	Beloniformes	Hemiramphidae	<i>Hemiramphus brasiliensis</i> -	4.92	0.02
	Clupéiformes	Clupeidae	<i>Sardinella maderensis</i> -	4.92	0.2
		Carangidae	<i>Caranx hippos</i> #	8.2	0.19
			<i>Caranx senegallus</i> #	13.11	0.14
		Cichlidae	<i>Hemichromis fasciatus</i> *	3.28	0.02
			<i>Sarotherodon melanotheron</i> *	13.11	0.41
			<i>Tilapia guineensis</i> #	13.11	0.21
		Drepaneidae	<i>Drepane africana</i> *	1.64	0.01
		Gobiidae	<i>Gobionellus occidentalis</i> -	9.84	0.07
			<i>Awaous lateristriga</i> -	1.64	0.01
		Haemulidae	<i>Plectorhinchus macrolepis</i> *	1.64	0.01
			<i>Pomadasys jubelini</i> #	19.67	0.16
		Monodactylidae	<i>Monodactylus sebae</i> -	16.39	0.24
		Mugilidae	<i>Liza dumerili</i> #	14.75	0.17
		Polynemidae	<i>Polydactylus quadrifilis</i> *	1.64	0.01
		Sciaenidae	<i>Pseudotolithus senegalensis</i> *	1.64	0.01
		Scombridae	<i>Scomberomorus tritor</i> -	4.92	0.06
		Sphyraenidae	<i>Sphyraena guachancho</i> *	1.64	0.01
	Perciformes	Trichiuridae	<i>Trichiurus lepturus</i> -	4.92	0.04
	Pleuronectiformes	Cynoglossidae	<i>Cynoglossus senegalensis</i> *	1.64	0.01
		Paralichthyidae	<i>Citharichthys stampflii</i> -	3.28	0.04
	Sepioloides	Sepiidae	<i>Sepia officinalis</i> -	3.28	0.02
	Siluriformes	Ariidae	<i>Arius latiscutatus</i> #	22.95	0.44
	Stomatopodes	Squillidae	<i>Squilla mantis</i> -	1.64	0.01
	Tétraodontiformes	Tetraodontidae	<i>Lagocephalus laevigatus</i> -	14.75	0.09
			<i>Sphoeroides spengleri</i> -	4.92	0.02

% C frequency of occurrence , % F relative frequency in catches , * : fully guarded species , - : total rejected species , # : species of which some individuals are kept and others rejected according to their size

evaluated account for 8%.Threatened, vulnerable and endangered species that are present in this study account for 10% of bycatch (Figure 3).

Distribution of different species in ecological and trophic categories

Figure 4 illustrate the distribution of the different species in the ecological and trophic categories. There are 13 estuarine species of marine origin (Em) and 13 estuarine

marine species (ME). Marine bycatch species (Ma) are represented by 6 species, 5 species are ranked as strictly estuarine species (Es). Estuarine forms of continental origin (Ec) and occasional marine (Mo) are weakly represented with only 1 species of fish for each category.

Depending on the diet, 8 trophic categories are found in bycatch. The analysis of the results (Figure 5) reveals that in the bycatch, the second-level predators (15 species) and the second-level predators which are mainly piscivorous (6 species), are the best represented, i.e 21 species out of 39.

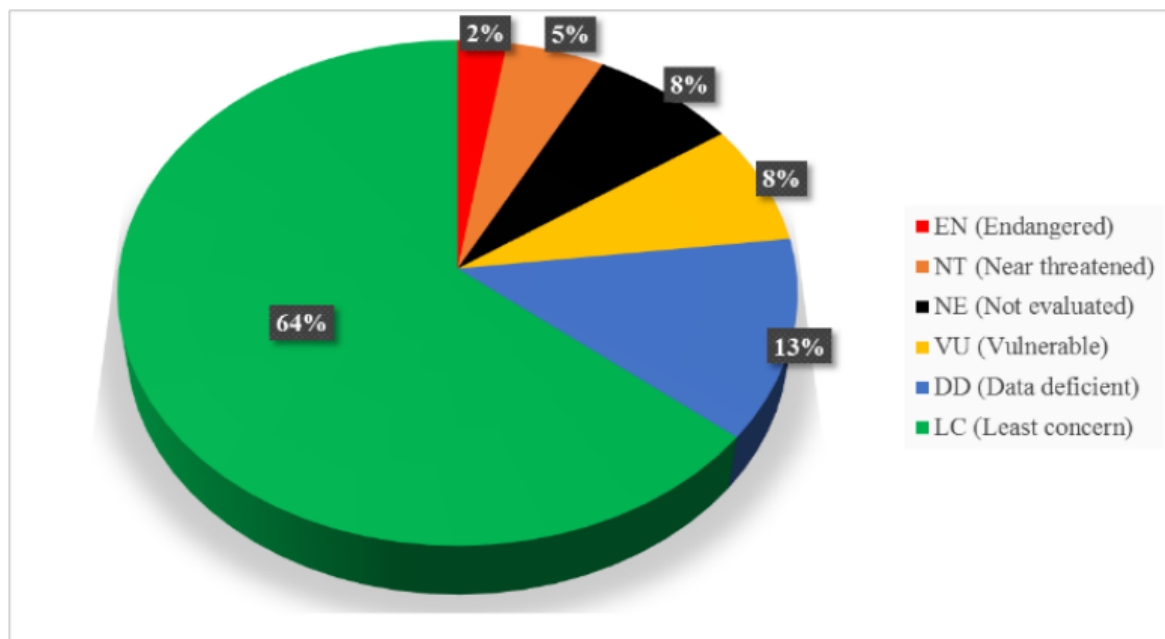


Figure 4: Proportion of different species based on IUCN status (2016)

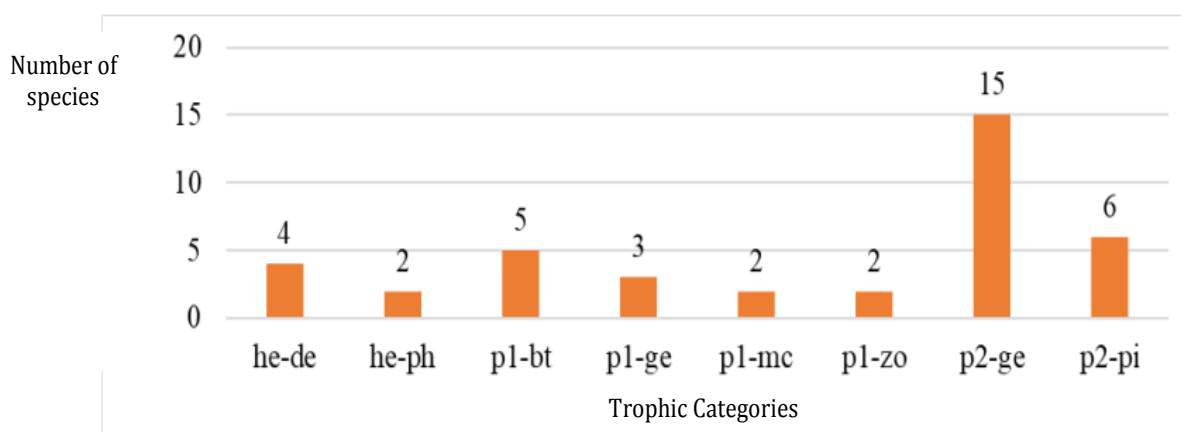


Figure 5 : Trophic category distribution of the 39 species

Twelve (12) species out of the 39 identified belong to the first level predator category (p1-zo, p1-bt, p1-mc and p1-ge); 6 out of 39 species are herbivores (he-de and he-ph).

Characteristics of discarded bycatch

Discarded catches mainly consist of 5 species (Table 2). They represent 97.6% of the discarded catch with a total weight of 134.59 kg. The crustacean *Callinectes sp* frequency is 13.99% with a total weight of 28.5 kg. The minimum size is 3 cm and the maximum is 14 cm. Fish such as *Ethmalosa fimbriata*, *Pseudotolithus elongatus*, *Ilisha africana* and *Elops lacerta* have respectively the following frequencies 66.35%, 10.82, 3.34% and 3.10%. Weights are 81.38; 10.71, 7.32 and 6.68 kg respectively for *E. fimbriata*,

P. elongatus, *E. lacerta* and *I. africana*. The minimum and maximum sizes observed range between 2 and 18 cm for *E. fimbriata*, 3 and 21 cm for *P. elongatus*, 5 and 27 cm for *E. lacerta*, 3 and 18 cm for *I. africana*. The size authorized by the fishing code (Senegal) for crustaceans *Callinectes sp* is 7 cm and 12 cm. For *E. fimbriata* and *P. elongatus* fish, the authorized size is between 18 and 20 cm. The characteristics of the different discarded species are shown in Table 2.

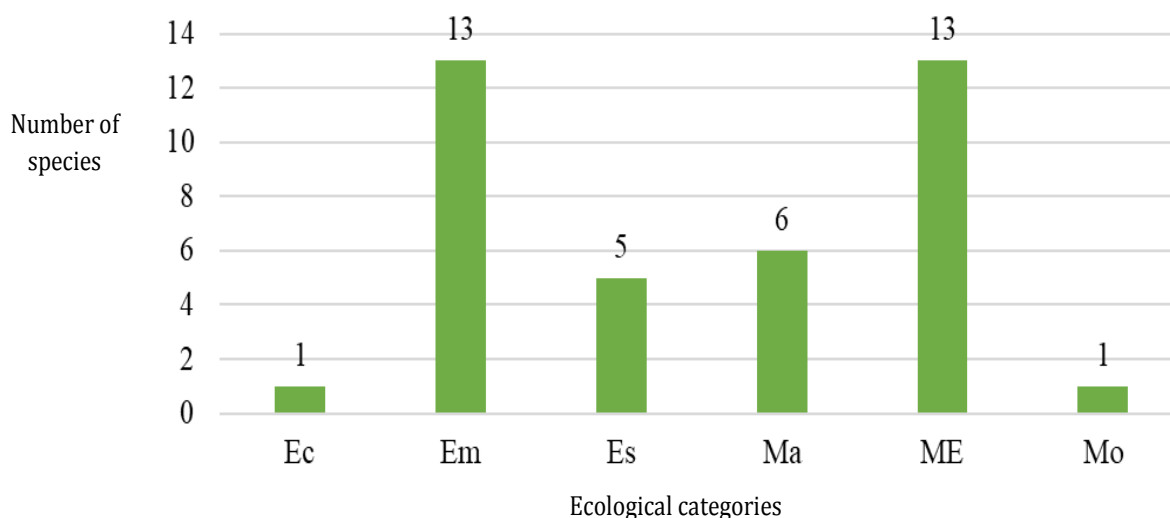
Size structure of the fish population

The analysis of the population size structure of fish (Figure 6) shows that the smallest individual caught measures 2 cm (species) while the largest measures 65 cm (species) for a

Table 2. Characteristics of the 5 main species rejected

Species	% F	Weight (Kg)	Lenght min (cm)	Length Max (cm)	Length authorized by the fishing code
<i>Callinectes sp</i>	13.99	28,50	3(n = 23)	14(n = 4)	≤ 7 cm / ≤ 12 cm
<i>Elops lacerta</i>	3.10	7.32	5 (n = 1)	27(n = 1)	
<i>Ethmalosa fimbriata</i>	66.35	81.38	2(n = 2)	18(n = 3)	≤ 18 cm
<i>Ilisha africana</i>	3.34	6.68	3(n = 1)	18(n = 3)	
% F total = 97.6		Poids total (kg) = 134.59			

(% F = relative frequency, min = minimum, max = maximum, ≤ = less or equal)

**Figure 6 :** Ecological categorization of the 39 species caught

mode equal to 10 cm. This mode corresponds to 21.8% of the total population of the stand; 74.01% of individuals are less than or equal to 10 cm tall.

Discards are mainly composed of 4 species of fish (*Ethmalosa fimbriata*, *Pseudotolithus elongatus*, *Ilisha africana* and *Elops lacerta*) and 1 species of crustacean (*Callinectes sp*) (Figure 7 and 8).

For fish, especially *Ethmalosa fimbriata*, the analysis of the results (Figure 7) shows that the size range is from 2 to 18 cm for a mode equal to 10 cm (27.7% of the population). For *Pseudotolithus elongatus*, it varies between 3 and 21 cm for a mode equal to 8 cm (18.01%). Regarding *Ilisha africana*, the size range is from 3 to 18 cm for a mode equal to 10 cm (20.53%). Finally for *Elops lacerta*, it varies between 5 and 27 cm for a mode equal to 8 cm (31.67%). For the crustacean *Callinectes sp* (Figure 12), the size range is from 3 to 14 cm for a mode equal to 6 cm (23.01%).

Use of bycatch

The results of the survey highlighted two (2) possible use of bycatch. When the quantity landed is not important, bycatch is usually retained by fishermen for family

consumption; but when that quantity is important, a share of the catches is sold on the spot to the market and the other part is consumed.

There are three (3) possible uses of discarded bycatch:

- Species that are edible and small in size are picked up by women or men to prepare a local dish called "Pépéssou"¹
- Species that are not suitable for human consumption are salvaged by ranchers and are used as feed for pigs, especially poultry and turkey.

- Species that are not recovered and discarded on the bank are eaten by birds (piscivorous birds: Pelicans and Herons).

There is a specific use for other species. This is the case of the following species:

- *Arius latiscutatus*: kept individuals are often smoked before being resold on the market.
- *Callinectes sp*: discarded individuals are resold at 25 CFA Francs per stack of two individuals.
- *Elops lacerta*: discarded individuals are used as bait for fishing.

¹ « Pépéssou : it's a soup made from small fish

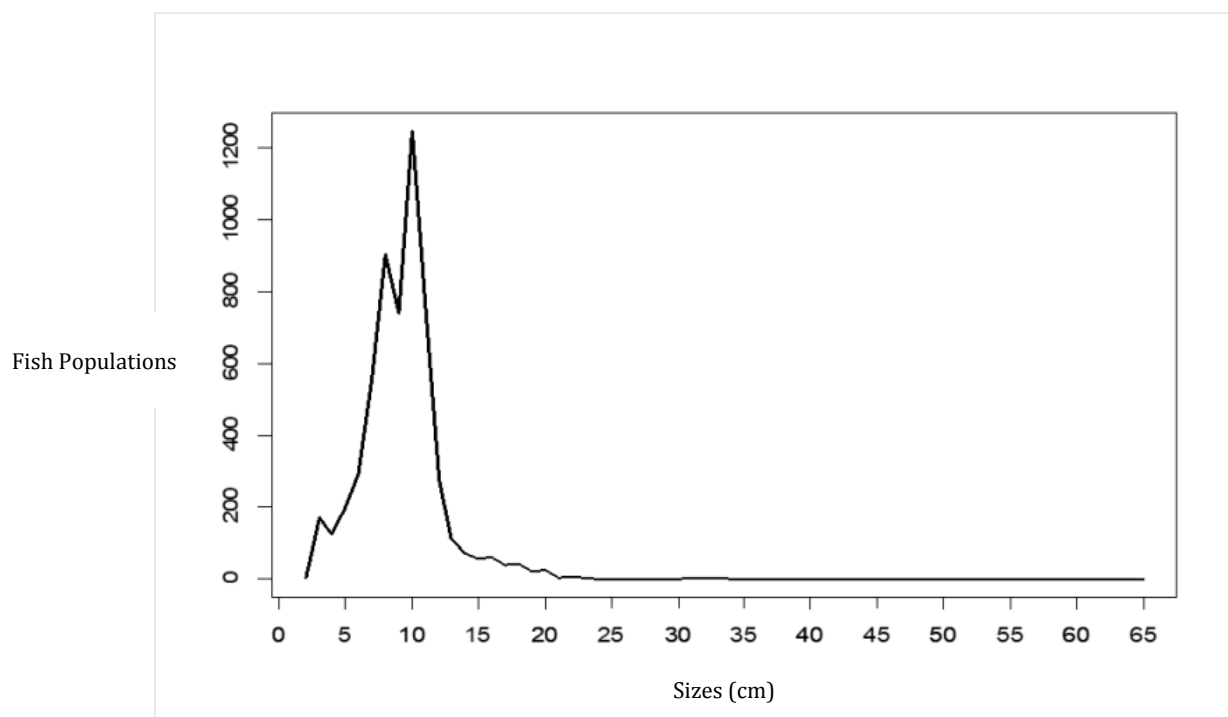


Figure 7 : Size structure of the fish population

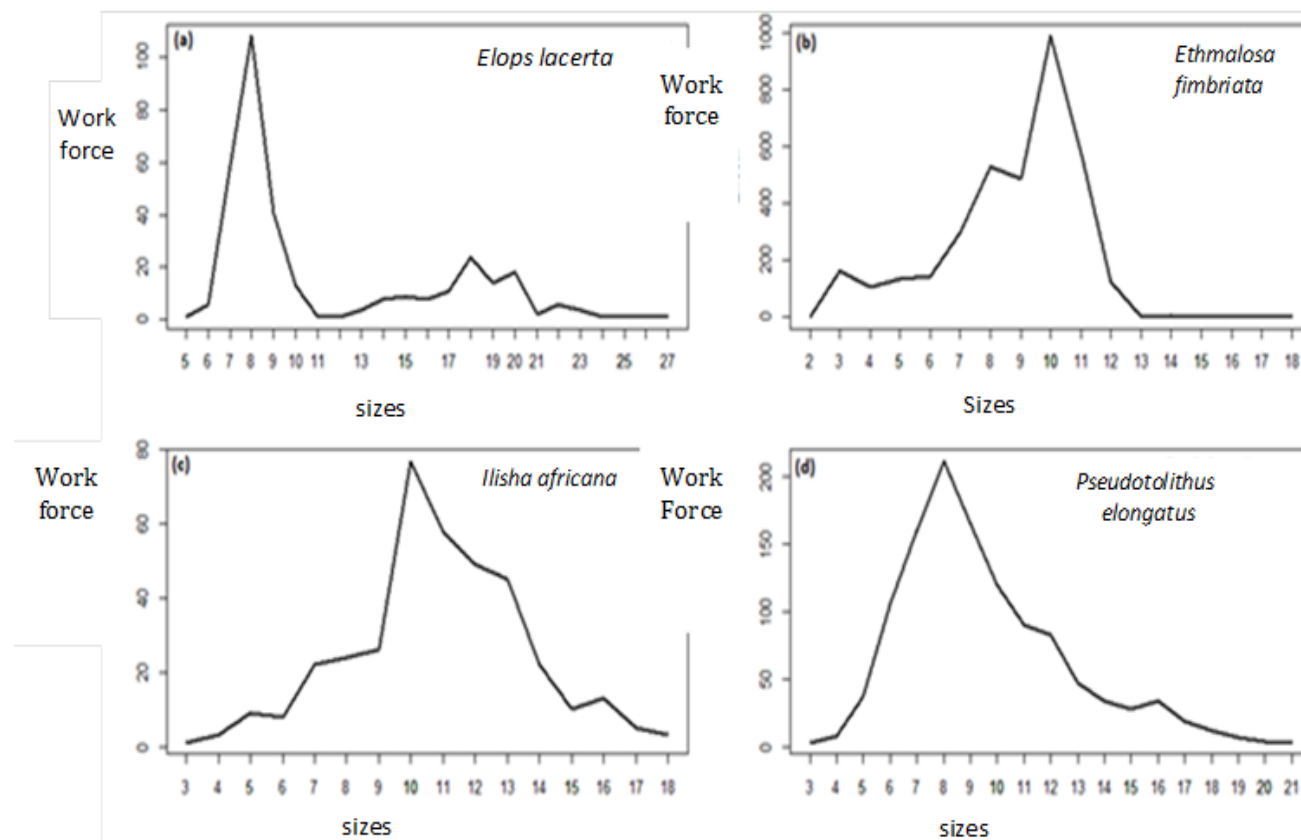


Figure 8 : Size structure of the 4 main species of discarded fish (a): *Elops lacerta*, (b): *Ethmalosa fimbriata*, (c): *Ilisha africana*, (d): *Pseudotolithus elongatus*, n: the total number of individuals measured.

- *Ethmalosa fimbriata* and *Eucinostomus melanopterus*: are highly valued and the individuals kept are roasted near the bank by shrimp fishermen.

DISCUSSION

This study reveals that bycatch in the small-scale shrimp fishery in the Casamance estuary is mainly composed of fish. These results could be explained by the fact that the mangrove estuary complex is known as a nursery, a protection and breeding area for many exploited fish populations (Diouf, 1996; Vidy, 2010). Other studies in Senegal related to small-scale shrimp fishing (Emanuelsson, 2008) and industrial fishing (Caverivière and Andriamirado, 1988, Thiam and Fall, 2010) have also buttressed the fact that fish are more abundant in bycatch. In other countries, Portugal (Monteiro et al., 2001; Costa et al., 2008), Nigeria (Ambrose et al., 2005, John and Ambrose, 2016), similar findings were obtained.

We found *Ethmalosa fimbriata*, a pelagic species, in large numbers in the bycatch studied. Its common presence in large quantities is related to the results of Charles-Dominique (1982) who demonstrated that this coastal species, spend part of its life cycle in estuaries, lagoons, rivers and deltas. Moreover, it is the most abundant species in the Casamance estuary (Diouf, 1996).

The specific composition of bycatch in our study is different from Emanuelsson's findings (2008) with fixed nets. This situation could be explained by the difference in the duration, period and fishing areas of shrimp nets studied. Studies of bycatch (Sarah et al., 2007; Randriaril et al., 2008) and distribution and abundance of juveniles (Vidy, 2010) in fisheries would buttress this fact. The numerous observations made in 2005-2006 on board shrimp trawlers made it possible to carry out, on one hand, bycatch estimates and discards, and on the other hand, the inventory of species representative of accompanying fish by areas and periods of fishing.

4 species were regularly recorded in the catches of shrimp fixed nets during the whole study period (about 02 months). These species are: *Ethmalosa fimbriata*, *Pseudotolithus elongatus*, *Callinectes sp*, *Elops lacerta*. These species are close to the coastal shrimp *F. notialis* in behavior and diet.

Indeed, among crabs of the genus *Callinectes*, *C. amnicola* is generally the most abundant in estuaries (Charles-Dominique and Hem, 1981) and is omnivorous (Arimoro and Idoro, 2007). *Elops lacerta*, is found in estuaries at juvenile and immature stages (Hié Daré 1982; Albaret, 2003) and is classified by Albaret (1994) as estuarine marine (ME). Its diet is mainly composed of fish, but it can occasionally eat shrimps and mysids (Séne, 1997).

Ethmalosa fimbriata is an estuarine species of marine origin (Em) (Albaret, 1994). Juveniles feed on zooplankton (Gning et al., 2008) and adults feed on phytoplankton (Séne 1997, Gning 2008); the presence of these juveniles downstream Casamance estuary is probably related to the

abundance and diversity of zooplankton in this area (Diouf and Diallo, 1987). Juveniles of *E. fimbriata* live in the estuary until maturity before migrating to the sea (Albaret, 1994). However, fixed nets are only active at night, at the height of ebb tide and mainly during periods of high water and they capture shrimp migrating towards the sea (Le Reste, 1993). This can also explain the permanent presence of *E. fimbriata* in *F. notialis* shrimp catches by fixed nets. Ndiaye (1985) and Lhomme (1994) indicate that shrimps feed on cyanophyceae, diatoms, phanerogamous debris, hydroids, nematodes, molluscs, fish larvae and other small crustaceans. Thus, the juveniles of *E. fimbriata* which feed on zooplankton share with shrimp *F. notialis* some prey such as diatoms and molluscs. *Pseudotolithus elongatus* is a species found in estuaries or near and at the outlet of lagoons (Sidibé, 2010); it is classified by Albaret (1994) as estuarine species of marine origin (Em). Studies carried out by Caverivière and Andriamirado (1997) and Sidibé (2003) reveal that this species feeds mainly on shrimp and to some extent on fish.

Most of the bycatch fit into the minor concern category according to IUCN (2016). However, in the present study, we found a vulnerable species *Pseudotolithus senegallus* and an endangered species *Pseudotolithus senegalensis*; they are Sciaenidae of great economic value found on the market in the sub-region. Both species are threatened by overexploitation (Nunoo, 2015; Nunoo and Nascimento, 2015).

In bycatch, there are many species with marine affinity (Em and ME) and predators of second trophic level (p2-ge and p2-pi). The presence in large numbers of species with marine affinity could be related to a good adaptation of the latter to the physicochemical conditions downstream of the estuary. In fact, salinity is lower in this zone than upstream (Albaret, 1987). The abundance of second level predator species may be explained by their predation on shrimp and juveniles of other fish (Albaret et al., 2005). This is the case of *Pseudotolithus elongatus* (p2-ge) which feeds on shrimps and fish (Caverivière and Andriamirado, 1997; Sidibé, 2003).

Bycatch is mainly composed of discards, which are mainly represented by 5 species. They are *Ethmalosa fimbriata*, *Callinectes sp*, *Pseudotolithus elongatus*, *Ilisha africana* and *Elops lacerta*. According to the results of a study on industrial fishing carried out by Caverivière and Andriamirado (1988), the 5 species most abundant in discards during the same (warm) season in comparison to our study are *Brachydeuterus auritus*, *Pteromylaeus bovinus*, *Ilisha africana*, *Arius latiscutatus*, *Arius heudoloti* and *Galeoides decadactylus*. Therefore the results of that study differ from ours. This difference could be due, on one hand, to the source of the data; indeed, our data come from the estuarine fishery, whereas those from Caverivière and Andriamirado (1988) come from industrial fishing that operates in deeper areas. This difference could be explained by the short duration of the study (about 2 months).

School of estuarine fish is mainly dominated by individuals of small size (less than 15 cm). These results are

confirmed by Albaret et al. (2005), who indicate that in fish, the size of small individuals is less than 15 cm. The abundance of small-sized individuals in discards could be on one hand related to a clogging effect of these individuals on the bottom of the fixed nets, because the mesh size authorized by the Senegalese legislation (Senegal's fishing code) is 24 mm of stretched mesh (<http://www.jo.gouv.sn/spip.php>). However, according to Charles-Dominique and Ndiaye (2003), the real size of the mesh used by fishermen is 22 mm of stretched mesh. On the other hand, this abundance finds its explanation in the fact that our study was carried out during the rainy season in Casamance when the reproduction of many marine species takes place (Albaret, 1986; Pandaré et al., 1986; Pandaré et al., 1997). Research carried out by Vidy (2010) in Sine Saloum inverse estuary, revealed that there were more juvenile fish during the rainy season. A study carried out by Pandaré et al., 1990 reached the same conclusion. Research conducted by Tiéhoua et al. (2016) in Côte d'Ivoire (in Ebrié Lagoon) suggested that *P. elongatus* reproduces all year round with the rainy season as the most favorable one. In the same vein, an investigation carried out by Diouf (1996) illustrated that in Sine Saloum, the reproductive activity is more important during the hot and dry season and in the rainy season; similar results were obtained in Casamance by Pandaré (1990) and Pandaré et al. (1997).

Our results also indicate that the discarded bycatch is composed of juveniles. Furthermore, an analysis of the size structure of the main discarded species reveals that the bycatch is mainly composed of juvenile fish. These results are buttressed by other studies, such as those of Albaret (1987), which reveal that in Casamance, *Ethmalosa fimbriata* reaches its first sexual maturity (L50) between 14 and 15 cm for females, and 13 to 14 cm for males. In the same vein, the size of first sexual maturity calculated by Panfili et al. (2004) in Sine Saloum is 17.3 cm for males and 15.3 cm for females. According to Diouf (1996) in Sine Saloum, *Pseudotolithus elongatus* reaches first sexual maturity at 29 cm for females and 28.5 cm for males; *Ilisha africana*, reaches its at 13.6 cm for females and the smallest male captured measured 10.5 cm. On another note, according to Tiéhoua et al. (2016) in Côte d'Ivoire (in Ebrié lagoon), the size of first sexual maturity of *P. elongatus* is 21.06 cm for females and 20.21 cm for males. As far as *Elops lacerta* is concerned, the abundance of small-sized individuals in the catch could be explained by the presence of this species in estuaries only at juvenile and immature stages (Hie Daré, 1982, Albaret, 2003). Finally, for crabs of the genus *Callinectes*, according to Arimoro and Idoro (2007), in Nigeria the average carapace length of mature females of *C. amnicola* is 8.95 cm; the smallest male and the smallest female that are observed at the development stage V measure respectively 8.2 cm and 9 cm.

Bycatch species which are kept are intended for human consumption while those discarded may be used for human consumption and / or for animal consumption. These results are confirmed by Eayrs (2009) who states that

bycatch have a commercial value in artisanal fishery and are often used for human or animal consumption. This applies to *Ilisha africana*, which can be marketed or used in fish farming as fishmeal in Nigeria (Ambrose et al., 2005). In Senegal, especially in Casamance, the results of a study carried out by Emanuelsson (2008) reveal that *Callinectes sp* is often used as an aromatic powder or stew. *Ethmalosa fimbriata* can be cooked or discarded fresh at night.

CONCLUSION

This study on bycatch of shrimp fixed nets has enable us to have a better knowledge of species which are not targeted by the small-scale shrimp fishery of *F. notialis*. *Callinectes sp*, *Elops lacerta*, *Ethmalosa fimbriata* and *Pseudotolithus elongatus* are regularly discarded.

Bycatch is composed mainly of species of *minor concern*. However we can also identify 4 endangered species (VU and EN). Depending on the different ecological and trophic categories, bycatch is mainly composed of species of marine affinity and second-level predators. Discards are mainly juveniles, especially juvenile fish. The bycatch is used for multiple purposes: the species kept are intended for human consumption; discards can be used for human and / or animal consumption.

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Conflict of interests

The authors declare that they have no conflicting interests.

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