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MINIMAL FISH PREDATION FOR THE PINK SHRIMP *PENAEUS NOTIALIS* IN SENEGAL (WEST AFRICA)

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ABSTRACT

The diet of potential fish predators (>20 cm total length) of Senegal's commercial pink shrimp *Penaeus notialis* was studied in 1986. Stomachs from 2657 fish, belonging to 32 species, were analyzed. They contained 3403 shrimp, with only 25 pink shrimp. Due to the large size of *P. notialis* in its marine phases and to the small number of large predators, the predation on this shrimp in the open sea is low. It is the small shrimps, especially *Parapenaeopsis atlantica*, that are the prey of coastal demersal fish. The current absence of fish predation on *P. notialis* in the Senegalese sea is generalized to the numerous fishing grounds of this species in West Africa. This is probably not the case for juveniles in estuaries and also in the sea when predatory species were slightly exploited. Related to the shrimp trawl activities, the decrease of the fish predation on pink shrimp in the sea could have permitted an increase of the shrimp catches, human predation replacing fish predation.

The exploitation of pink shrimp *Penaeus notialis* (Perez-Farfante, 1967) by specialized trawlers is one of the main marine fishing activities for many coastal countries of West Africa.

The species lives in the sea, on muddy bottoms, from the coast to 65 m depth. During 3 mo juveniles grow in estuaries and the maximal longevity is of 20 mo (Lhomme, 1981). In Senegalese waters, there are two fishing grounds (Fig. 1), one in the north and a more important one in the south (spreading also in the north of Guinea Bissau). The harvest from the south has been more than 1700 mt yr^{-1} since 1973, while the harvest from the north has been less than 1000 mt yr^{-1}. According to the distribution of the fishing effort, the strongest concentrations of *P. notialis* are found between 25 and 45 m (Lhomme, 1981). Pink shrimp stocks have been exploited since the end of 1960. The demersal fish species living on the shrimping grounds are currently overexploited (Caverivière et al., 1989).

Penaeus notialis belongs to the community of eurybathic or thermocline species, as defined by Fager and Longhurst (1968) and modified by Caverivière and Rabarison Andriamirado (1988). This small group has affinities with species of the coastal sciaenid community and, to a lesser extent, with the deeper water species of the sparid community. Eurybathic community includes many selacians that are able to adapt to rapid temperature and pressure changes. The small semi-pelagic fish species, *Brachydeuterus auritus* (Pomadasyidae), is also abundant on the shrimp fishing grounds; it is discarded by trawlers in Senegalese waters.

The feeding of demersal fish species off West African coasts has already been examined by several authors. Syntheses of these studies were made by Caverivière (1982, 1993a). The importance of crustaceans in fish diets is emphasized, especially for species of the coastal sciaenid community. In general, predominating prey groups are the small-crustaceans group, the shrimp group, and occasionally, for non-coastal fish species, the crab group. The pink shrimp, *P. notialis*, was very scarce in stomach contents reported by these earlier studies, however, few large fish were examined. Prey sizes are small com-

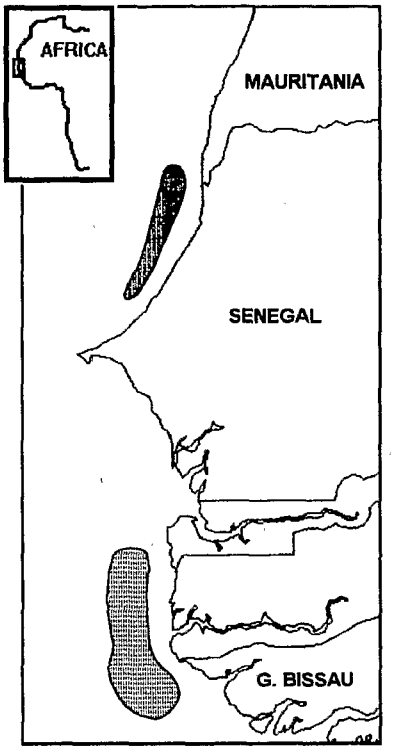

Figure 1. Location of the pink shrimp fishing grounds (in gray) in Senegalese waters.

pared to predator sizes, the average prey size should increase for a given species with the length of the predator studied.

The importance of the pink shrimp and associated fish species in the Senegalese fishing economy initiated a study of the fishery for shrimps, commercial fish species and discards (Caverivière and Rabarison Andriamirado, 1988). Parallel to this study, a study of the diets of fish caught in shrimp fishing grounds was begun to study the importance of fish predation on *Penaeus notialis*. For this purpose, large fish were oversampled. The present paper reports principal results of this last research.

Materials and Methods

The fish specimens for diet analysis came from two sources: (1) trawl surveys carried out in southern and northern Senegalese shrimp fishing grounds by the R/V Louis Sauger (January - February and July 1986), with a large vertical opening fish trawl working at 3.7 kn; (2) samplings of discards and commercial fish caught by the shrimp trawler Jasmin (south Senegal, December 1985 to August 1986) with a trawl speed about 3.0 kn. The escape of large individuals seems low, as suggested by catches of large white grouper *Epinephelus aeneus* and large barracuda *Sphyraena afra* (over 1.8 m in fork length) during 30 min tows (Caverivière, 1993b). Fish refuges do not exist on pink shrimp fishing grounds.

Stomachs were collected from fish exceeding 20 cm total length, i.e., potential predators of *P. notialis*. For some fish species, notably the croakers, *Pseudotolithus* spp., upon arriving on the deck the majority of fish stomachs were inverted which greatly reduced the number of available observa-

Table 1. Fish species sampled in the shrimp fishing grounds for diet analysis, with fish numbers, total prey and shrimp-prey numbers by species. The order is the systematic order. (Sc): species of the coastal sciaenid community. (Sp): sparid community. (Eu): eurybathic or thermocline species. (Pel): pelagic species.

Fish species		No. of sampled stomachs	No. of non-empty stomachs	No. of total prey	No. of shrimp-prey
SELACIANS					
Scyliorhinus stellaris	(Sp)	4	4	5	2
Sphyrna lewini	(Pel)	35	33	169	43
Mustelus mustelus	(Eu)	146	113	380	36
Leptocharias smithii	(Sc)	3	3	13	6
Paragaleus pectoralis	(Eu)	37	20	48	14
Squalus blainvillei	(Sp)	5	3	4	0
Rhinobatos rhinobatos	(Sc)	99	89	2141	1121
Raja miraletus	(Eu)	212	172	1138	825
Raja straeleni	(Sp)	31	28	241	134
Dasyatis margarita	(Sc)	36	21	95	5
Pteromylaeus bovinus	(Sc)	10	5	88	0
TELEOSTEANS					
Arius spp.	(Sc)	277	78	452	243
Cynoponticus ferox	(Sc)	110	73	146	7
Fistularia tabacaria	(Sc)	2	2	13	0
Galeoides decadactylus	(Sc)	143	94	397	196
Zeus faber mauritanicus	(Sp)	106	47	57	0
Epinephelus aenus	(Sp)	81	30	57	8
Pomadasys jubelini	(Sc)	141	52	573	14
Pomadasys peroteti	(Sc)	139	78	457	97
Plectorhynchus mediterranus	(Sp)	5	4	16	2
Umbrina canariensis	(Sp)	19	11	13	6
Pseudotolithus typus	(Sc)	53	35	130	113
Pseudotolithus Brachygnathus	(Sc)	22	6	12	2
Pseudotolithus senegalensis	(Sc)	398	234	657	388
Argyrosomus regius	(Sc)	117	61	201	14
Decapterus rhonchus	(Pel)	4	4	38	33
Alectis alexandrinus	(Sc)	55	38	163	37
Pomatomus saltatrix	(Pel)	9	6	19	0
Dentex canariensis	(Sp)	10	4	19	1
Pagellus bellottii	(Sp)	17	9	30	1
Sparus caeruleostictus	(Sp)	11	7	37	3
Trichiurus lepturus	(Eu)	320	215	382	52
Total (32 species)		2657	1579	8191	3403

tions. Stomachs plus intestines were taken from the seabreams, *Pagellus bellottii* and *Sparus caeruleostictus*, because their stomachs are very small.

Stomach contents were analyzed using numerical and ponderal methods, particularly the food coefficient Q (Hureau, 1966, 1970), and details were reported in a preliminary report (Rabarison Andriamirado and Caverivière, 1989). For a predatory species, the food coefficient is calculated to take into account both the occurrence and the importance of the weight of the species-prey.

Table 2. Fish species sampled (analysed stomach contents > 10) with more 10% shrimp in stomach and dominant shrimp-prey species. (Sc): species of the coastal sciaenid community. (Sp): sparid community. (Eu): eurybathic or thermocline species.

Fish species		Percent occurrence of shrimp prey	Dominant shrimp-prey species (according to food coefficient Q)
SELACIANS			
Sphyrna lewini	(Pel)	25.4	*Parapenaeopsis atlantica*
Paragaleus pectoralis	(Eu)	29.2	*P. atlantica, Penaeus notialis*
Rhinobatos rhinobatos	(Sc)	52.4	*P. atlantica*
Raja miraletus	(Eu)	72.5	*P. atlantica*
Raja straeleni	(Sp)	55.6	*Parapenaeus longirostris*
TELEOSTEANS			
Arius spp.	(Sc)	53.8	*Processa* sp., *Crangon crangon*
Galeoides decadactylus	(Sc)	49.4	*Crangon, Processa, Syciona*
Epinephelus aenus	(Sp)	14.0	*P. atlantica*
Pomadasys peroteti	(Sc)	21.2	*Palaemonidae* sp., *P. atlantica*
Umbrina canariensis	(Sp)	46.2	*Petites crevettes*
Pseudotolithus typus	(Sc)	86.9	*P. atlantica*
Pseudotolithus senegalensis	(Sc)	59.1	*P. atlantica*
Alectis alexandrinus	(Sc)	22.7	*Crangon crangon*
Trichiurus lepturus	(Eu)	13.6	*(Penaeus notialis), Processa* sp.

$Q = Cn \times Cp$ with $Cn = (n_i / n_t) \times 100$ $Cp = (p_i / p_t) \times 100$

ni = number of the species-prey i in stomach contents, nt = total number of the preys (all species) in stomach contents, pi = weight of the species-prey i in stomach contents, pt = total weight of the preys (all species) in stomach contents.

The emphasis of the present paper is on the size distribution of shrimp consumed by predators in relation to predator size and the size distribution of predators on the shrimp grounds. Carapace (cephalothorax) is frequently the only shrimp part found in stomach contents and allows species identification, length relationship could be used to change carapace length to total length. Major shrimp predators are defined by use of the food coefficient Q. We draw conclusions concerning the intensity of natural predation on the commercial penaeid species *P. notialis* on shrimp fishing grounds off Senegal's coast based on this information.

In this study, 2657 stomachs, belonging to 32 predator species were examined; 1579 stomachs contained food.

RESULTS

Of 8191 recorded prey, 3403 were shrimp (Table 1). Table 2 indicates fish with high shrimp consumption and the predominant shrimp species in their diets. These fish species belong particularly to the coastal sciaenid community. Selacians, especially rays, also eat shrimps. The shrimp-preys are mainly small coastal shrimps and *Parapenaeopsis atlantica* predominates. The size distribution of this shrimp species, compared to *P. notialis*, is represented in Figure 2. The most abundant demersal species in fish catches of shrimp trawlers are the croakers *Pseudotolithus* spp., the threadfin *Galeoides decadactylus* and

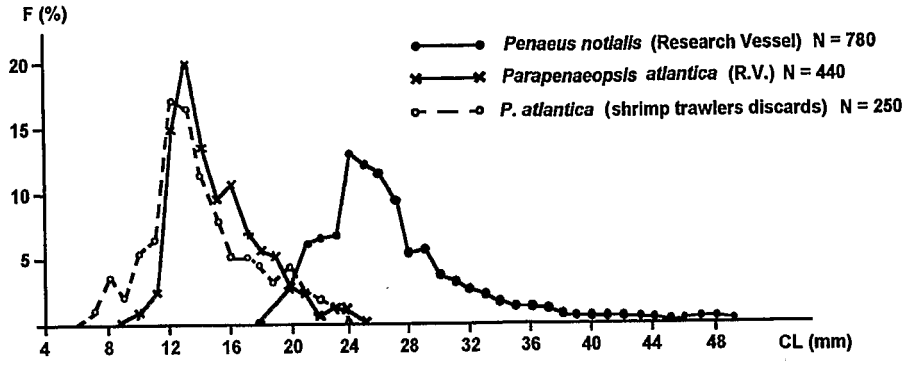

Figure 2. Size frequency distributions for *Penaeus notialis* and *Parapenaeopsis atlantica* collected on the Senegalese shrimping grounds. CL = Carapace Length

the catfishes *Arius* spp., all of which are high shrimp consumers. These results show the importance of shrimps as a food source for the coastal sciaenid community.

Only one individual of *P. notialis* was observed in each of 27 stomachs of 9 species (Table 3), this is a frequency of 3.0% for 899 analyzed food bolus belonging to these species. The size of the *P. notialis* ranged between 8.5 and 14 cm total length (TL) with an average size of 12 cm TL (~24 mm carapace length, CL, according to Garcia et al., 1970), that corresponds to immature individuals of only a few months (Lhomme, 1981). This last author estimates 26 mm CL (~13 cm TL) as the average size at migration to sea for the main southern Senegalese stock and 18 mm CL (~9 cm TL) as the average size for migrating northern stock. The size distribution of *P. notialis* on its fishing grounds (Fig. 2) shows that many pink shrimps are not subject to natural predation at sea, owing to their size and related factors (escape behavior for example). Predation only occurs on individuals that have just migrated. This occurs more often in the cold season that in the warm season due to the fact that the size at migration is slightly lower and pink shrimp growth is zero or low during the cold period.

Among important fish species, only the croakers *Pseudotolithus* eat pink shrimp within the fishing grounds. However, only individuals longer than 45 cm TL contained *P. notialis*. Fish of this size represented less than 4% of the croaker trawl catches from 1973 to the present.

It is generally believed that the size of the prey consumed is proportional to the size of the predator, even if this relationship can not always be formally established. Figure 3 put in parallel the distributions of size frequencies of predators (species of the coastal sciaenid community, eurybathic species and sparid community) and that of the shrimp-prey (totality of shrimp-preys). Average sizes calculated on these distributions are: average size of the shrimp-prey = 4.13 cm TL, average sizes of the fish-predators = 35.3 cm (sciaenid community) and 38.8 cm (eurybathic species and sparid community).

The ratio between average predator size and prey size is 8.5:1 in the first group and 9.4:1 in the second. On the whole, data suggest the existence of a link between the size of the fish and that of shrimp-prey. Different approaches were tried to statistically illustrate this relationship, but none has given truly satisfactory results. Figure 4 represents two test examples of placement in relationship between the size of predators *Pseudotolithus* spp. and *Raja miraletus* (grouped by 2-cm class size) and the average size of the shrimp in their stomachs.

Table 3. Fish predator species of *Penaeus notialis*. Number and size (total lengh) of the eaten *P. notialis*.

Fish predators	Stomachs analyzed	Number and size of eaten *P. notialis*			
		Cold season		Warm season	
		Number	Size (cm)	Number	Size (cm)
Sphyrna lewini	33	2	13	0	-
Paragaleus pectoralis	20	4	9-14	0	-
Rhinobatos rhinobatos	89	1	12	0	-
Raja miraletus	172	2	10.5-12	0	-
Raja straeleni	28	1	12	-	-
Cynoponticus ferox	73	3	11-13	-	-
Pseudotolithus typus	35	-	-	2	12
Pseudotolithus senegalensis	234	2	12-12.5	4	9-14
Trichiurus lepturus	215	5	8.5-13	1	12
Total	899	20		7	

The diagram in Figure 5 is a represention of the predation on shrimps (all species) by fish predators of the 12 species whose proportion of shrimps in their diet was greater than 20% (Table 2). To each class size of the predator, regardless of species, the maximal and minimal sizes of measurable shrimp-preys was determined. According to the length of the fish, these two sizes allowed a line trace and a curve that cut out the figure in three areas: an area where shrimp sizes are too small for the predator, a useful predation area, that increases with the size of the predator, an area where shrimp-prey are too large to be eaten.

Three other limits are also defined: the average migration size of *P. notialis* to sea (~9 cm TL) for the northern stock (the average migration size for the southern stock, ~13 cm TL, is also represented), the maximal size of the small shrimp-preys (*Parapenaeopsis atlantica, Processa* sp., *Alpheus* sp.), the average maximal size of shrimp predators within the fishing grounds (the average of the maximal sizes of the 14 selected predatory species), which is about 68 cm. This length could be compared with the modal size of the members of the sciaenid coastal community and the eurybathic and sparid community (Fig. 3 and the lower part of Fig. 5) which are much smaller (~ 24 cm and 35 cm, respectively).

These limits allow the definition of the potential predation areas, on *P. notialis* on the one hand and on small shrimp-preys on the other hand. One observes that the predation area on *P. notialis* is limited, which corresponds to the low percentage (3.0% for the nine predatory species) observed in stomachs. Predation on the small shrimps is far greater. The representation of the predation area on *P. notialis* is extremely small on the southern pink shrimp stock considering its average migration size (13 cm TL).

Discussion

The study of stomach contents of fishes caught in the Senegalese pink shrimp fishing grounds confirms what is already known in general concerning the feeding behavior of the demersal species forming a wide faunistic entity, that extends from Mauritania to

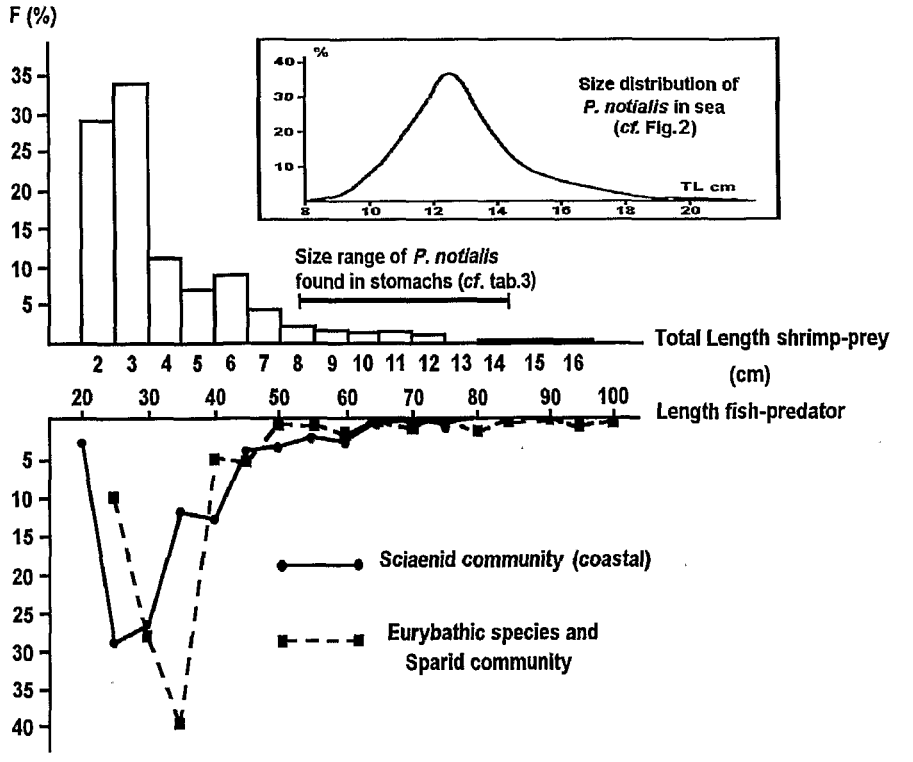

Figure 3. Size frequency distributions for the prey shrimp and their fish predators collected on the Senegalese shrimping grounds. Framed, the size frequency distribution of *Penaeus notialis* in sea (carapace lengths of the Fig. 1 grouped and transformed in total lengths), in the same x-scale than the lower shrimp-prey graph.

Angola (Caverivière, 1982, 1993a). Small crustaceans and shrimps are usually the predominant prey groups, particularly in the diet of coastal sciaenid community. In the Gulf of Guinea, the predominant shrimp-prey is *Palaemon hastatus* (Palaemonidae) and it is preferred over *Parapenaeopsis atlantica* (Penaeidae) by the croaker, *Pseudotholithus senegalensis* (Troadec, 1971). In Senegal, where *P. hastatus* appears scarce, *P. atlantica* becomes the dominant prey among shrimp species. Because of its geographical and size distributions (the latter almost entirely contained within the potential predation area for the majority of fishes) *P. atlantica* constitutes one of the most important foods for littoral fish species.

The predation on *P. notialis* is very low, only a small number of individuals which migrated recently from estuaries are concerned. It can be considered as negligible compared with the size of the population.

The sampling scheme was conducted much as recommended at a later date by Brewer et al. (1991) to estimate the predation on commercial shrimps of similar sizes to *P. notialis*. They recommend sampling species and individuals of large size which are potential predators and using fish trawls, which are more efficient than shrimp trawls in the sampling of these fishes. This sampling scheme was employed by Brewer et al. (1991) in order to

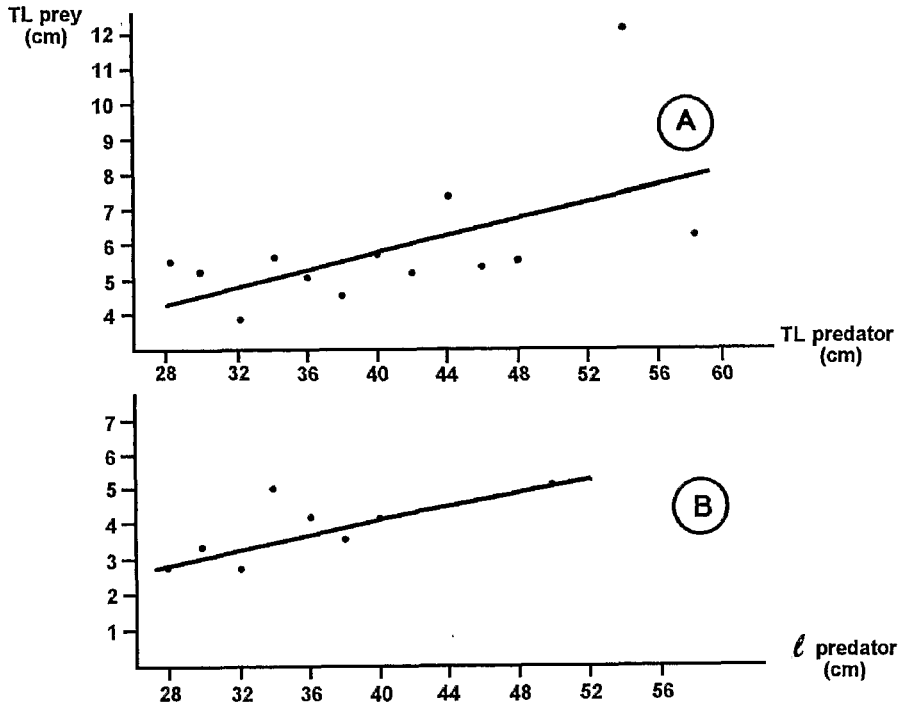

Figure 4. Predator sizes and average size of the corresponding shrimp-prey. A: *Pseudotolithus* spp. Linear regression: n= 13, r = 0.521, (P = 0.068). B: *Raja miraletus* (length between wing extremities). Linear regression: n = 8, r = 0.784*, (P = 0.021)

demonstrate, as in the present study, the relative importance of selacians on the predation of commercial shrimp (Penaeidae of *Penaeus* and *Metapenaeus* genera) in a bay of the Gulf of Carpentaria (Australia). However, they found very different results concerning the predation levels on the commercial shrimps (>15 cm total length): in that area the fish predation was clearly higher than human consumption. According to their bibliographical synthesis, their study differs from others concerning fish predation on large Penaeidae shrimp in open sea (Gulf of Mexico, Gulf of Guinea, Arabian Gulf). The low predation levels reported elsewhere can be considered a consequence of the small size of the fish sampled in relation to large size reached by commercial shrimps. Brewer et al. (1991) explain their results with the fact that only commercial shrimps are the object of a fishery in the studied area, and that fishery is seasonal; consequently large predators are numerous. Caverivière and Thiam (1995) showed that the percentage of large fish of commercial species decreased in the sea off Senegal between 1976 and 1986 due to exploitation, and the demersal species are now overexploited on the whole (Caverivière and Thiam, 1994). It is well known that large fish predators such as sharks, which were very abundant until World War II, are presently scarce.

The low predation level on pink shrimp *P. notialis* off Senegalese coasts can be generalized without risk to all pink shrimp stocks in West Africa. These stocks are located off

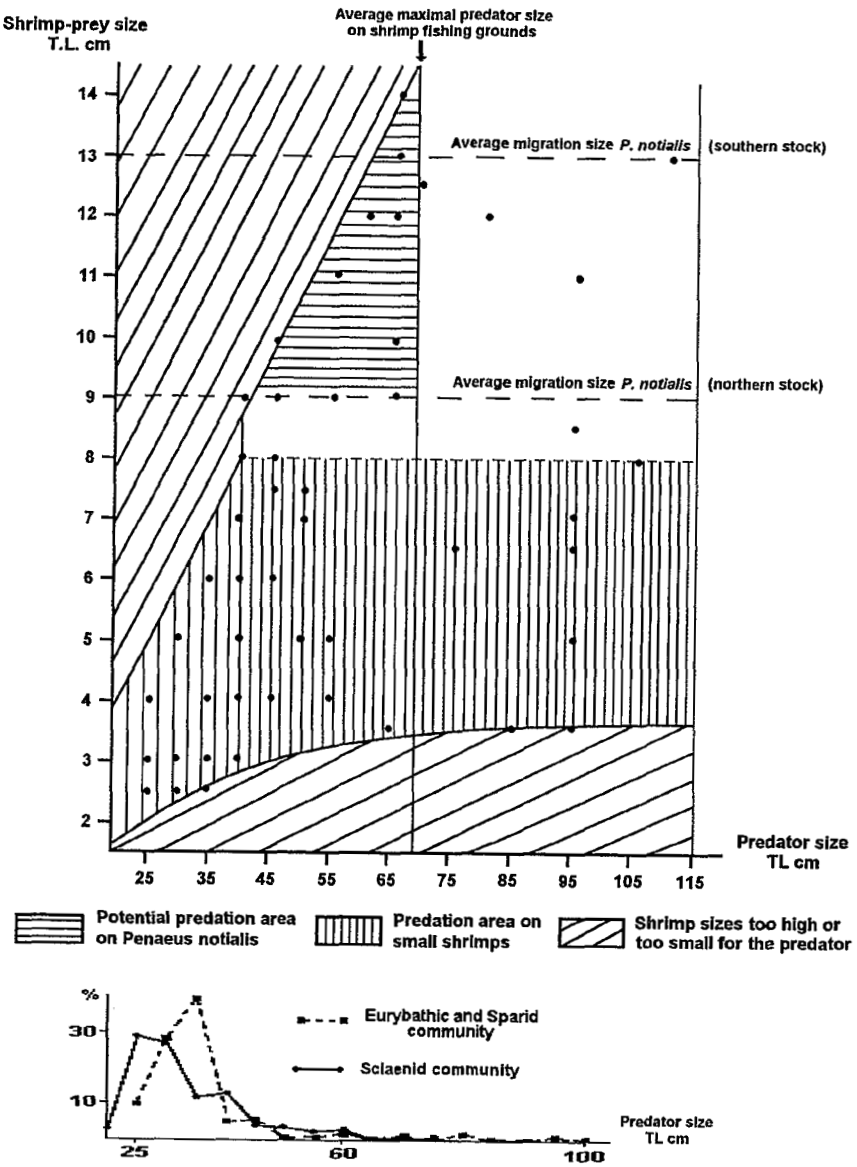

Figure 5. Fish predator lengths and minimal and maximal corresponding shrimp-prey lengths used to estimate predation areas on small shrimp species and on *Penaeus notialis* in Senegalese waters. The lower part of the figure shows the size frequency distribution (Fig. 3) for the fish predator of shrimp, in the same x-scale than the upper part.

many countries: Mauritania, Senegal, Gambia, Guinea-Bissau, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Gabon (Garcia and Lhomme, 1979). Indeed, faunistic entities are the same, and shrimp and fish stocks have experienced high exploitation rates for several years. Furthermore, there is in the Gulf of Guinea some dwarfism of demersal fishes in comparison with the sizes noticed to the north and to the

south of this area (Fontana, 1979; Caverivière, 1982). Sizes of the pink shrimp migration to sea in the Gulf of Guinea are close to those noticed for the northern Senegalese stock (Garcia and Lhomme, 1979).

The situation is probably different in estuaries and tidal rivers, where carnivorous fishes exist and pink shrimp are smaller. Crustaceans are the most common preys in the fish diets in the Ebrié Lagoon (Ivory Coast) and penaeid shrimps (*P. notialis* [Albaret, pers. comm.]) are preponderant along them (Albaret, 1994). This is similar to Senegalese estuaries, according to a current study conducted by Albaret. A senior researcher working on *P. notialis* fishery in Casamance River (Senegal) considers that the natural mortality of *P. notialis* has to be far higher in the estuary than at sea (Le Reste, pers. comm.). Minello and Zimmerman (1984) performed a study in Texas on the selection of the brown shrimp, *P. aztecus*, as prey to the spotted seatrout, *Cynoscion nebulosus*. They indicate, according to the occurrence of penaeid shrimp in stomach contents of estuarine fish predators, that fish predation is probably an important component of the shrimp mortality in estuaries.

The decrease of the fish predation level on *P. notialis* could be an explanation of the high *P. notialis* catches by shrimp trawlers on the Senegal-Guinea Bissau stock during the last 10 yrs. These catches have been around 5000 mt, whereas the Fox's surplus production model used by Lhomme (1981) for the 1967-1978 period showed a Maximum Sustainable Yield (MSY) around 2500 mt. Fishing activities, specially by shrimp trawlers, have reduced the number of elderly and large fish. Consequently, the predation on the short lifetime pink shrimp decreases because only the large fish are able to eat *P. notialis* at sea. Human consumption of shrimp predators reduces fish predation on adult pink shrimp, thus leaving more pink shrimp for human use, and thus accounting for the sustained harvests of pink shrimp at twice the calculated MSY. In Sierra Leone-Liberia (FAO, 1993), the first estimate of the pink shrimp MSY was 1870 mt for the 1969-1976 period. Later, the MSY was estimated to 6000-8000 mt for the 1985-1990 period, nevertheless with a poor adjustment, and the shrimp catches were widely higher than the first estimated MSY. Estimations at different time periods for the others pink shrimp stocks in West African waters do not exist.

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