THE INFLUENCE OF COMPETITION FOR BAIT IN LONGLINE CATCHABILITY

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ABSTRACT

In this paper, results of the bottom longline analysis demonstrate that bait consumers' fauna significantly influences the catchability coefficient and the crustaceans, that are non-susceptible to catch, showed great influence in that variation. Moreover, the demonstration of the existence of significant associations among the species captured and non-captured suggests the possibility of correlating the capture composition and the variation of the catchability coefficient.

Key words: longline; catchability; hook; competition; bait; Brazil

A INFLUÊNCIA DA COMPETIÇÃO POR ISCAS NA CAPTURABILIDADE DE ESPINHEL

RESUMO

Nesse trabalho, resultados das análises com espinhel de fundo demonstram que a fauna de consumidores de isca influencia significativamente o coeficiente de capturabilidade desse aparelho de pesca, e os crustáceos, organismos não susceptíveis à captura, apresentam grande influência nessa variação. Além disso, a demonstração de existência de associação entre as espécies capturadas e não-capturadas sugere a possibilidade de correlacionar a composição das capturas e a variação do coeficiente de capturabilidade.

Palavras-chave: espinhel; capturabilidade; anzol; competição; isca; Brasil

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INTRODUCTION

The capture of a fishing operation is proportional to the stock density and this relation could be expressed as: $\Delta C = q\Delta f\ N/A$ or $\Delta C/\Delta f = q\ N/A = qD$, where ΔC denotes operation catch; $\Delta C/\Delta f$ is the catch per unit of effort (CPUE); Δf is the fishing intensity or fishing effort; q is the catchability coefficient; N is the stock size; A is the stock distribution area; and D is the stock density.

BEVERTON and HOLT (1957) and GULLAND (1969) discussed the necessity of standardizing fishing effort to make constant the catchability coefficient, through determination of variations due to the effective fishing time, fishing power, fleet distribution, etc, and RICHARDS and SCHNUTE (1986) argued this relation could be more complex than presented previously, because the catchability coefficient is a function of other factors like gear action area, behaviour of the captured fish, seasonality, and others. Moreover, although longline requires a simpler standardization, its CPUE depends much more on fish behaviour and their reaction to the gear than that of mobile fishing gears, and several factors should influence its catchability coefficient (SKUD, 1978).

LØKKEBORG and BJORDAL (1992) and BJORDAL and LØKKEBORG (1996) extensively reviewed the factors that affect longline catchability, which can be grouped into three categories: the first one is about baits, their attraction, palatability and durability; the second concerns fishing gear, hook size and shape, cables and fishing strategy and the third category includes natural factors such as fauna and environmental conditions (TUTUI, 2000).

The gear saturation time can be defined as the moment when all baits were consumed, with or without capture. In operations with the same number of hooks, the variation on that time will be a function of the gear catchability coefficient. Moreover, if there are no differences in the bait used and the technological characteristics of the gear, that variation will be a response to differences in the faunistic composition of bait consumers and competition for baits.

Even so, that fauna is composed of species susceptible and non-susceptible (mainly saprophytic crustaceans) to capture, and the possible interrelations among them can vary by place and period of the year. Therefore, this paper intends to demonstrate that correlation exists among the species of that fauna, being possible to correlate the catch composition and the variation of the catchability coefficient.

MATERIAL AND METHODS

In the Southeast and South coast of Brazil, two bottom longline surveys were conducted using a commercial fishing boat, which released 188 sets and 187,908 hooks, one in spring (between August 28 and October 25, 1996), and another one in autumn (between April 11 and June 16, 1997), and in both cruises the sets were at the same locations (Figure 1). The sets were distributed along 18 transects perpendicular to the coastline, with a distance between then of approximately 52 nautical miles. In each transect, 4 to 6 sets were accomplished at six depth strata: 100 -149 m, 150 - 199 m, 200 - 249 m, 250 - 299 m, 300 - 399 m and 400 - 500 meters. In steep bottom areas, the sets were released with a 100 m depth interval.

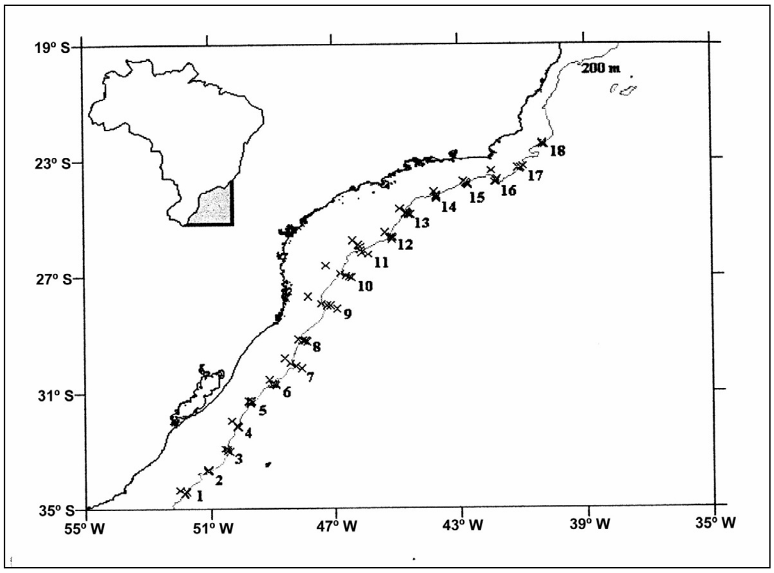

Figure 1. Distribution of sets in the studied area and transect´s number

The fishing gear was similar to the one used by the commercial fleet: each set had 1,000 hooks baited with squid and interval of one hour between release and retrieval. The state of each hook was registered along the retrieval, using four categories: lost, without bait, with bait, with capture. In this last case, a specific code was used to identify the species. Only 0.22% of hooks were lost, and that category was discarded for further analyses. To capture the saprophytic fauna during the autumn cruise, three traps were disposed in the extremities and in the middle of the gear, using the same bait of the hooks.

Although the relative frequency of empty hooks and hooks with capture was varied along the study area (Figure 2), the empty hooks variation was more marked, and it must be caused by zones with distinct bait consumers composition, considering three zones: southern zone (transects 1 to 6 of the spring cruise and 1 to 7 of the autumn cruise), central zone (transects 7 to 11 of the spring cruise and 8 to 11 of the autumn cruise) and northern zone (transects 12 to 18 of both cruises).

Significance differences in the mean relative frequencies of empty hook and hooks with capture between zones and seasons were tested using Scheirer - Ray - Hare two-way analysis of variance for ranked data. The Kolmogorov-Smirnov test was used to assess normality and the Bartlett test for variance homogeneity (SOKAL and ROLHF, 1995).

That analysis of variance needs balanced data, a condition not met in this paper. The number of sets varied from 18 (central zone in the autumn) to 33 sets (northern extremity in the autumn), a randomisation of sets was accomplished to balance the treatments (zones and cruises). Even so, since the results can depend on the selected sets, this procedure was replicated 100 times, being considered significant the factor which presented significant values ($p < 5\%$), in at least 95% of the cases. An *a posteriori* non-parametric comparison similar to the Tukey test was applied to determine what zones were significantly different and used the Dunn's method for standard error (SOKAL and ROLHF, 1995; ZAR, 1996).

The Shannon index of diversity was calculated for each set from the equation:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where p_i is the proportion of individuals found in the i^th^ species. In a sample the true value of p_i is unknown but is estimated as n_i / N, where n_i is the number of individuals found in the i^th^ species and N is the total number of individuals (MAGURRAN, 1988). The variation of the diversity was tested in relation to the zone and cruise with the same analyses proposed for the empty hook and hooks with capture.

The presence or absence of saprophytic organisms captured by the traps was analysed as a function of the selected zones, using a contingency table and the residues method proposed by Haberman, *apud* EVERITT (1977). The relative frequencies of empty hooks, hooks with capture and diversity as a function of presence or absence of the saprophytic species were compared using the Mann-Whitney non-parametric test.

Finally, the association of the saprophytic species captured by the traps with the main fish species captured by the longline was tested. The chosen taxonomic groups of fish were those with relative frequency of capture higher than 1% and a relative frequency of occurrence superior to 10%. The Schluter interspecific association test for multiple species was used, and after the negative result, an association test by using contingency table analysis was accomplished among fishes and saprophytics (LUDWIG and REYNOLDS, 1988).

RESULTS

Figure 2 shows an inverse relationship between empty hooks and hooks with capture, explained by the high dependence of both variables, with significant correlation (Spearman's correlation coefficient $r_s = -0.8962$; $p=0.001$). Based on those information, the option was to analyse only the variation of the empty hooks, due to the hypothesis of the saprophytic organisms influence.

The distribution of the H's values obtained by the Scheirer-Ray–Hare test for the comparison of the relative frequencies of empty hooks among cruises, zones and the interaction of them, no significant value was obtained in the comparison between cruises ($\chi^2_{0.05;1}=3.84$; $p=0.05$), while in the comparison among zones ($\chi^2_{0.05;2}=5.99$; $p=0.05$) all observed values were significant and in the interaction ($\chi^2_{0.05;2}=5.99$; $p=0.05$) only 2% of the results were significant. The *a posteriori* non-parametric comparison demonstrated that the central zone differed significantly from southern extremity (Q=6.6427; $p<0.01$) and northern extremity too (Q=5.3196; $p<0.01$).

The H's values distribution obtained in the comparison of the relative frequency of hooks with capture among cruises, zones and in the interaction of them, the comparison between cruises ($\chi^2_{0.05;\,1}$=3.8415; p=0.05) only 4% of the H's values obtained were significant; among zones ($\chi^2_{0.05;\,2}$ =5.9915; p=0.05) 52% of the values were significant and in the interaction ($\chi^2_{0.05;\,2}$=5.9915; p=0.05) 74% of the values were significant.

The comparison of diversities between cruises ($\chi^2_{0.05;\,1}$=3.8415; p=0.05) was not significant; only 2% of the values were significant among zones ($\chi^2_{0.05;\,2}$=5.9915; p=0.05) and again no significant values were obtained in the interaction ($\chi^2_{0.05;\,2}$=5.9915; p=0.05).

Table 1 shows the relative frequencies of capture and occurrence for the main species, by zone and cruise. Although these species occur at the three zones, the relative frequencies of capture and occurrence differ, showing four groups: ***1***. species which frequencies decreased from south to north (*Polyprion americanus* and *Helicolenus lahillei*); **2**. species which frequencies decreased from north to south (*Epinephelus niveatus*, *Gymnothorax* sp. and *Pseudopercis numida*); ***3***. species which frequencies were greater at the extreme zones (*Squalus* spp., *Pagrus pagrus* and *Mustelus* spp.); and ***4***. species which frequencies were greater at the central zone (*Urophycis cirrata* and *Lopholatilus villarii*).

Table 1. Relative frequencies of catch (number of individuals) and occurrence (number of sets) for the main species, by zone and cruise

	Spring						Autumn					
	Southern extremity		Central zone		Northern extremity		Southern extremity		Central zone		Northern extremity	
	catch	occurrence	catch	occurrence	catch	occurrence	catch	occurrence	catch	occurrence	catch	occurrence
Epinephelus niveatus	0.26	12.90	0.62	15.79	3.65	34.38	0.16	13.33	0.27	16.67	1.88	42.42
Gymnothorax sp.	0.26	22.58	0.56	26.32	3.42	50.00	0.33	16.67	0.70	38.89	1.47	39.39
Helicolenus lahillei	4.95	58.06	33.97	36.84	2.30	18.75	17.99	66.67	7.44	27.78	3.66	30.30
Lopholatilus villarii	5.99	32.26	13.44	57.89	16.25	50.00	3.98	23.33	14.06	72.22	13.85	51.52
Mustelus spp.	2.15	32.26	0.17	5.26	1.62	34.38	2.45	16.67	-	-	0.59	15.15
Pagrus pagrus	4.02	16.13	0.39	5.26	0.77	9.38	3.69	13.33	0.16	5.56	0.26	15.15
Polyprion americanus	3.87	48.39	0.51	21.05	-	-	3.26	46.67	-	-	0.26	6.06
Pseudopercis numida	0.20	6.45	1.63	31.58	6.08	53.13	0.42	13.33	1.40	33.33	1.62	48.48
Squalus spp.	41.36	87.10	11.81	36.84	32.60	62.50	7.90	30.00	2.10	33.33	8.78	42.42
Urophycis cirrata	28.74	64.52	34.14	63.16	26.65	43.75	57.36	73.33	70.15	77.78	64.26	57.58

The central zone was the only one to present significant adjusted deviations in the comparison of the absolute values of the contingency table analysis through the residues method (d=2.76; $p < 0.05$). Therefore, the occurrence of saprophytic crustaceans was smaller in the central zone than those in the southern and northern extremities, showing that crustaceans' fauna distribution was similar to the relative frequency distribution of empty hooks (Figure 2).

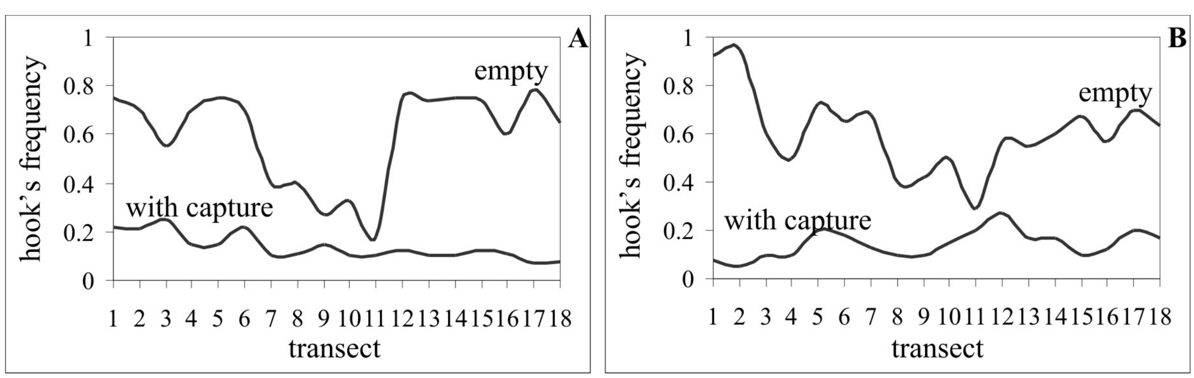

Figure 2. Trends in the relative frequency of empty hooks and hooks with capture, by transect. A: spring; B: autumn

The possible relation between presence or absence of the saprophytic crustaceans and the relative frequency of empty hooks, mentioned in the previous result, can be better explored by comparing the relative frequency of empty hooks and hooks with capture in function of the presence or absence of saprophytic crustaceans.

The differences between the relative frequency of empty hooks is function of the saprophytic crustaceans' occurrence. When such differences were tested through the Mann-Whitney non-parametric test, the occurrence of saprophytic crustaceans was observed to alter significantly the relative frequency of empty hooks ($Z= - 2.73$; $p < 0.01$). It means that more empty hooks occur in presence of the saprophytic crustaceans than in its absence. On the other hand, the analysis result of the variation of relative frequency of hooks with capture in function of the saprophytic crustaceans was not significant ($Z=0.51$) demonstrating that this variable does not influence the capture frequency.

A new test to demonstrate the differences in the diversity in function of the saprophitic crustaceans occurrence was performed to verify if that difference is significant. The Mann-Whitney non-parametric test result demonstrated diversity is significantly larger ($Z=2.3754$; $p < 0.05$) in the absence of saprophytic crustaceans than in their presence.

Given the diversity difference, the existence of association among the crustaceans and fishes species was tested. The catch of the traps was composed of decapods Brachyura of the genus *Chaeson* and family Majidae and isopods of the genus *Cirolana* and *Bathyinomus*. The occurrence of these crustaceans were correlated with the occurrence of the main fish species caught: *Epinephelus niveatus*; *Helicolenus lahillei*; *Lopholatilus villarii*; *Mustelus canis* and *M. fasciatus*; *Pagrus pagrus*; *Pseudopercis numida*; *Polyprion americanus*; *Squalus megalops* and *S. mitsukurii*; *Urophycis cirrata*.

In the Schluter test for general interespecific association, the result was not significant ($W=70.6135$) and the result of the association test between fishes and crustaceans (2x2) (Table 2) demonstrates that all crustaceans' taxonomic groups present some degree of association with the selected fish species.

Table 2. Results of the association between fishes and crustaceans 2x2. The sign represents the association type (* p<0.05; ** p<0.01).

	Chaeson ramosae	*Libinia* sp.	*Cirolana* spp.	*Batinomius giganteus*
Epinephelus niveatus	- 3.27	- 0.50	+ 4.98 *	- 2.78
Helicolenus lahillei	+ 16.88 **	+ 0.02	- 1.28	+ 7.72 **
Lopholatilus villarii	- 6.35	+ 3.92 *	- 0.52	- 4.75 *
Mustelus spp.	- 1.24	- 1.07	+ 2.37	- 0.22
Pagrus pagrus	- 0.96	- 0.82	+ 3.00	- 0.15
Polyprion americanus	+ 10.30	- 1.33	- 3.34	+ 2.21
Pseudopercis numida	- 3.51	- 0.27	+ 2.45	- 2.41
Squalus spp.	- 2.38	- 0.67	0.00	- 0.71
Urophycis cirrata	+ 1.47	+ 0.24	- 0.95	+ 2.24

DISCUSSION

The southeastern and southern bottom longline fleet concentrate their operations between 22º S and 26º S and south of 28º S, with little performance between 26º S and 28º S (ÁVILA DA SILVA and MOREIRA, 2003; HAIMOVICI *et al*., 2003) and, if the capture probability of a fishing operation could be interpreted as the interaction between resource abundance and fishing effort (ARREGUÍM-SÁNCHES, 1996), it can be supposed the extreme areas have a larger catchability. Besides, it is known that in areas of larger occurrence of saprophytic crustaceans, that fleet use a smaller immersion time, as fishing strategy, showing the empiric understanding of the influence of those organisms to the capture.

Variations in the relative frequencies of empty hooks and hooks with capture as a function of the zone and cruise indicate that the central zone differs from the extremities, considering its smaller gear catchability. In spite of the samplings with traps, to catch saprophytic crustaceans, only happened in the autumn cruise, the diversity analyses and the table 1 suggest that the bait consumers' fauna is similar in the spring cruise, being reasonable to consider that the results obtained in the analyses involving saprophytic crustaceans are similar for that cruise.

Such difference can be related to two factors:

a) Fauna composition in the central zone is different from those in the extremities, where capture was probably larger and with smaller amount of empty hooks. Even so, the abundance of fish species must be smaller because the comparison of the relative frequencies of hooks with capture is not different from the other zones, or

b) The high rate of empty hooks in the extremities is not due to a smaller capture probability but to the occurrence of a bait consumers fauna non-susceptible to the capture. In addition, this fauna is less frequent in the central zone.

The comparison of the saprophytic crustaceans' occurrence by zone and the comparison of relative frequency of empty hooks to the presence or absence of those organisms demonstrate the importance of the crustaceans in the variation of the relative frequency of empty hooks and consequently in the gear catchability. Even so, it is not possible to discard the first factor, because both can affect catches simultaneously. With respect to the bottom longline catches in the study area, ÁVILA DA SILVA *et al*. (1999) presented four main groups of fish, associated to many different fishing areas, defined by geographical position and depth. In this case, the central zone represents the bordering area among the areas suggested by those authors, explaining the largest differences among captures of the extremities than between these and the central zone (Table 1). On the other hand, the period of the year did not explain the formation of the fish groups suggested by ÁVILA DA SILVA *et al*. (1999), and table 1 does not suggest what factor could have influenced the variation of the catch composition, but only the relative abundance of species. Moreover, those observations assume that variation of relative frequency of the hooks without bait cannot be influenced by differences in the catch composition.

Besides, differences in diversity were not observed among zones and cruises or interaction between these two variables, supposing that the diversity does not explain the variation in the number of hooks without bait. The results of the diversity comparison in function of the occurrence or absence of saprophytic crustaceans demonstrate significant difference, although it is not conclusive, because it should be considered that the larger occurrence of saprophytic crustaceans can increase the competitive pressure for baits reducing the capture of less competitive species, consequently decreasing the capture diversity. In spite of the impossibility of determining the real diversity of organisms susceptible to capture with or without the presence of saprophytic crustaceans, that result points out to their great influence on the gear catchability coefficient.

All results discussed confirm the hypothesis that the bait consumers' fauna influences the variation of the longline catchability coefficient, corroborating two conclusions of SINODA (1981), that the number of captured fish of a species depends on the presence of other species, and that proportion of capture of two species competing for baited hook varies in function of the interference intensity of each species.

Therefore, precautions are necessary in the CPUE analysis of those fisheries and in the studies of gear selectivity through the technological and bait variations, mainly due to the fact that organisms with larger influence in that variation are not susceptible to capture. The example of Bjordal, *apud* BERTRAND (1988), demonstrates that differences in the efficiency between two forms of hooks tend to zero when the capture probability increases, masking a possible differentiation in the catch sizes.

Finally, the environmental effects were not addressed in this work, what could be an important source of variation in the abundance of any species. Even so, the spring cruise began in the southern extremity of the study area, with the first sets in winter, greatly influenced by the Subtropical Convergence and under its effects of climatic and fishing stocks alterations (SEELIGER *et al*., 1997; HAIMOVICI *et al*., 1994). This would explain the high importance of the genus *Squalus* in that zone and cruise (Table 1), showing those environmental alterations did not affect significantly the gear catchability in that situation.

Therefore, it can be considered that catch composition is representative of the whole bait consumers' fauna and it can vary due to environmental factors, being reasonable to suppose that it is possible to correlate that same catch composition to gear saturation time, obtaining a fishing effort correction in fisheries with little variation of the technological and bait factors.

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