

SELECTIVITY OF BOTTOM GILLNET OF SOUTHEASTERN BRAZIL*

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ABSTRACT

Gillnet is one of the most widespread types of fishing gear on the Brazilian coast, greatly used by the small-scale fleet due to its low cost and easy handling. This study aimed to estimate the selectivity of gillnets by using length-converted catch curves for the main Osteichthyes species landed at Santos (SP) by gillnet fleet. Only landing data (length and weight) and production data were used, which are useful and easy to obtain, especially in countries with low budget for scientific research. The length at first capture ($L_{c50\%}$) was compared to the length at first maturity (L_{50}) showing that only *Micropogonias furnieri* had a $L_{c50\%}$ very close to L_{50} ; *Menticirrhus americanus* e *Macrodon atricauda* presented a characteristic celomatic cavity expansion during their pre-spawning period, which increases their maximum perimeter and changing the gear selectivity for both species; and *Scomberomorus brasiliensis* had the widest selection range, but all landed individuals already had length higher than the L_{50} . This method, combined with other biological data gathered from the literature, could be a good tool for fishery management. We suggest that temporal closed fishing areas and/or periods of gillnet usage suspension, and revision of technological aspects should be considered by management plans.

Key words: Catch curve; fishery management; biological aspects; first catch length

SELETIVIDADE DAS REDES DE EMALHE DE FUNDO DO SUDESTE DO BRASIL

RESUMO

A pesca de emalhe é uma das artes mais difundidas no litoral brasileiro. É amplamente utilizada, principalmente pela frota artesanal, pelo fácil manuseio e baixo custo de aquisição e manutenção. O objetivo deste trabalho foi estimar a seletividade das redes de emalhe, pelo método da curva de captura linearizada convertida para comprimento, para as principais espécies de Osteichthyes desembarcadas em Santos-SP pela frota de emalhe. Para tanto, foram utilizados apenas dados de desembarque (comprimento e peso) e de produção, pois são úteis e mais acessíveis, especialmente em países com poucos recursos para pesquisa. Comparando o comprimento de primeira captura ($L_{c50\%}$) com o de primeira maturação (L_{50}) observou-se que apenas *Micropogonias furnieri* teve um $L_{c50\%}$ muito próximo ao L_{50} ; *Menticirrhus americanus* e *Macrodon atricauda*, apresentaram aumento da cavidade celomática no período pré-desova, o que aumentou seu perímetro máximo alterando a seletividade do aparelho para estas espécies; e *Scomberomorus brasiliensis*, teve a maior amplitude de seleção, porém todos os indivíduos desembarcados já tinham comprimento superior ao L_{50} . Esta metodologia, utilizada em conjunto com outros dados biológicos levantados na literatura pode ser uma ferramenta apropriada para o manejo pesqueiro. Sugere-se que os planos de manejo considerem a adoção de proibição temporária da pesca de emalhe em áreas e/ou períodos, e a revisão de aspectos tecnológicos.

Palavras chave: Curva de captura; manejo pesqueiro; aspectos biológicos; comprimento de primeira captura.

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INTRODUCTION

Fishery management should focus on catching larger fish and allowing the smaller ones to escape, which ensures population reproduction and renewal (ARMSTRONG *et al.*, 1990). However, recent studies have demonstrated the need to protect the larger fish of exploited populations, so as to maintain the genetic health of these populations (MILTON *et al.*, 1998; ZHOU *et al.*, 2010).

Greater knowledge on the catch efficiency of gillnet fishery and its selectivity parameters is essential in order to ascertain the impact of this activity on exploited resources (FABI *et al.*, 2002). Combined with biological data, this can provide the optimum mesh size for attaining sustainable fisheries. The same is true for species that, despite not being a significant part of the gillnet catch, are important for environmental health and are also exploited by other fisheries. Thus, knowing more about them contributes towards better management and maintenance of the environment and exploitation, within a sustainable perspective.

Gillnets are very size-selective gear, thus specific mesh sizes tend to catch fish of a limited size range. The selectivity of a specific gear can be understood as the likelihood that a particular species and size of fish will be caught by the gear (KITAHARA, 1971). The gillnet selectivity curve results on the anatomical and physiological characteristics of the fish, as well as technical characteristics (for example, the ranging ratio), so that the gillnet selectivity can be estimated through indirect methods.

The selective properties of gillnets are typically estimated using indirect methods that are conceptually more complex than the direct methods. The first one does not require knowledge population size for each length group, the data came from experimental catch for length class and for different mesh sizes. The second just is utilized when the population size for each length group is known (HOVGARD and LASSEN, 2000). The methodology used in this work is an indirect model, but utilizes commercial data, which is easier and cheaper to be gathered. This methodology was chosen because of its independence from the mesh size. Methods that

are mesh size-dependent are more common, but in this case, because of the fishing dynamics (the use of three mesh sizes, see ALVES *et al.* 2009), it is difficult to determine which mesh each fish was caught in.

Several fleets catches the same resources in Southern Brazil, specially the groundfishes, and the gillnet fishery has been an important fleet in landed weight of this group in São Paulo State (TOMÁS, 2007). Thus, a better comprehension of the impact over the groundfishes is necessary.

This study estimated the selectivity of gillnets and compared it to biological data, aiming discuss the need to reduce the use of some mesh sizes during specific reproductive peaks, so as to avoid catching juveniles or fish at first maturity.

MATERIAL AND METHODS

The data were gathered between January 2004 and December 2006 from the Santos Public Fishing Terminal, Santos (SP). The landed production data were gathered from Fisheries Institute (throughout of ProPesq[®] databank, INSTITUTO DE PESCA, 2007). Taxonomic identification was based on the literature (FIGUEIREDO and MENEZES, 1978; 1980; MENEZES and FIGUEIREDO, 1980; 1985; 1998). Among the data gathered, the following were identified as some of the main species in the gillnet landings: southern kingfish (*Menticirrhus americanus*; N = 2,714), weakfish (*Micropogonias furnieri*; N = 3,048), Jamaican weakfish (*Cynoscion jamaicensis*; N = 1,274), Atlantic bumper (*Chloroscombrus chrysurus*; N = 129), king weakfish (*Macrodon atricauda* later *M. ancylodon*; N = 884) and Spanish mackerel (*Scomberomorus brasiliensis*; N = 424).

Data on total length (L_t , in mm) and total weight (W_t , in g) were gathered from samples and used to calculate the non-linear length-weight relationship ($W_t = aL_t^b$), using least-squares regression on a log-transformation of the equation (R DEVELOPMENT CORE TEAM, 2006), and size class distribution. With the numerical frequency by length class (nc), total weight (TSW) of these data, the total landed weight (TLW) and the parameters "a" and "b" of the equation above, it was estimated the weight corresponding to the each length class. For each

class, the weight multiplied by the frequency resulted in the adjusted sample weight (ASW_c), which was used for weighting (pondered) the TLW_c from the equation: TLW_c = ASW_c × (TLW/TSW). Finally, there was obtained the frequency of TLW_c (N_c) by the reason TLW_c/nc.

By using the weighted (pondered) size class distribution, the total instantaneous rate of mortality (Z) was estimated through the length-converted catch curve method (PAULY, 1983; 1984a; b) (equation 1). For this estimation the von Bertalanffy growth curve parameters of the species were obtained from the literature (Table 1). For calculating the selectivity, it was necessary to estimate, for each size class, the total number of individuals exposed to fishery (2) and the relative frequency (3).

$$(1) \ln(N_{cp} \div \Delta t_c) = c + d \times t_c, \text{ being } Z = -d$$

$$(2) NT_c = \Delta t_c e^{c+Zt_c}$$

$$(3) S_{cp} = N_{cp} / NT_c$$

Where:

NT_c = total number of individuals exposed to fishery for each size class;

Δt_c = length of time for which an individual belongs a size class;

e = exponential constant;

c = linear coefficient;

d = angular coefficient;

Z = total instantaneous rate of mortality;

t_c = age that corresponds to the size in the middle of the class;

S_{cp} = relative frequency of total number of individuals retained by the fishing gear, according to size class;

N_{cp} = total number of individuals retained by the fishing gear.

Table 1. Biological parameters utilized in analyses.

Species	Parameters			
	L _∞ (mm)	K year ⁻¹	L ₅₀ (mm)	Gender
<i>M. americanus</i>	463 ¹	0.29 ¹	126 ⁷	U
			140 ⁸	U
<i>M. furnieri</i>	689 ²	0.31 ²	+188 ⁹	F
			+*292 ¹⁰	F
			*243 ¹⁰	M
			275 ²	F
			250 ²	M
			224 ⁷	MI
<i>C. jamaicensis</i>	400 ³	0.41 ³	203 ⁸	U
			+195 ³	F
			154 ¹¹	F
			185 ¹²	M
<i>M. atricauda</i>	562 ⁴	0.17 ⁴	150 ⁷	U
			167 ⁸	U
			+*290 ⁴	F
<i>S. brasiliensis</i>	1.244 ⁵	0.22 ⁵	190 ⁷	U
			+280 ¹³	F
<i>C. chrysurus</i>	451 ⁶	0.22 ⁶	+*153 ⁶	U

¹ SMITH and WENNER (1985); ² VAZZOLER (1971); ³ CASTRO *et al.* (2005); ⁴ CARNEIRO and CASTRO (2005); ⁵ NÓBREGA (2002); ⁶ MASUMOTO and CERGOLE (2005); ⁷ VAZZOLER *et al.* (1989a); ⁸ VAZZOLER *et al.* (1989b); ⁹ TUTUI *et al.* (2004); ¹⁰ CARNEIRO *et al.* (2005); ¹¹ VAZZOLER and BRAGA (1983); ¹² COELHO *et al.* (1995); ¹³ LIMA (2004).

(+) value taken; (*) rounded value; (U) Unsexed; (MI) Mixed; (F) Female; (M) Male.

The length at first capture ($L_{c50\%}$), defined as the length at which at least 50% of the individuals have full likelihood of being caught when encountering the gear, was compared to the length at first maturity (L_{50}), i.e. the length at which at least 50% of the individuals are able to reproduce for the first time, obtained from the literature. The aim of this relationship was to estimate the percentage of immature fish landed.

This study took a capture likelihood of 0.5 as the $L_{c50\%}$ and a full likelihood of retention (1) as the optimum length of capture (L_m).

RESULTS

The $L_{c50\%}$ values from the samples of *M. americanus*, *C. jamaicensis*, *M. atricauda* and *S.*

brasiliensis were, respectively, 49.2; 27.4; 10.1 and 95.7% higher than L_{50} , and just 0.0; 3.6; 10.3 and 0.5% of the individuals were below L_{50} . For *M. furnieri*, the $L_{c50\%}$ value was just 1.4% higher than L_{50} , and 32.3% of the sample was below L_{50} (Table 2 and Figure 1).

In this study the probability of 0.1 in both sides of the curve was considered for describe the estimated selection range. So the selection range and L_m (optimum length of capture) obtained were: 240-470 mm and 284 mm for *M. americanus*; 250-750 mm and 377 mm for *M. furnieri*; 220-400 mm and 276 mm for *C. jamaicensis*; 290-460 mm and 355 mm for *M. atricauda*; 420-780 mm and 688 mm for *S. brasiliensis*; and, 200-430 mm and 264 mm for *C. chrysurus*. *Micropogonias furnieri* and *S. brasiliensis* had the widest selection ranges.

Table 2. Biological and fishery parameters estimated.

Species	Parameters			
	Wt = a Lt ^b	Z year ⁻¹	$L_{c50\%}$ (mm)	L_m (mm)
<i>M. americanus</i>	Wt = $8.10^{-6} Lt^{3.027}$	1.17	262	284
<i>M. furnieri</i>	Wt = $2.10^{-5} Lt^{2.908}$	1.18	295	377
<i>C. jamaicensis</i>	Wt = $2.10^{-5} Lt^{2.904}$	2.60	249	276
<i>M. atricauda</i>	Wt = $3.10^{-5} Lt^{2.799}$	1.57	320	355
<i>S. brasiliensis</i>	Wt = $4.10^{-5} Lt^{2.682}$	1.44	547	688
<i>C. chrysurus</i>	Wt = $5.10^{-6} Lt^{3.088}$	0.78	227	264

DISCUSSION

Studies on selectivity have disseminated over the past decades after the publishing of a model that is easy to apply, developed by HOLT (1963). However, this model has been more used in developed countries, due its demands of experimental data, which are notoriously expensive. In other countries the option is to apply models based on the catch, such as that by PAULY (1983; 1984a; b), which, despite its limitations, generate selectivity estimations which are similar to those obtained with the model by Holt, as will be discussed in the following.

The practice of on board discarding (small sized species and/or with low price markets) limits the estimates of specific size ranges, thereby making fishery management less effective (KARAKULAK and ERK, 2008).

The data of this study were from gillnet mesh sizes (between opposites knots - stretched mesh) of 70, 110 (less used) and 130 mm (ALVES *et al.*, 2009). Even though this methodology does not consider the mesh size, the results obtained are similar to those of REIS and PAWSON (1999), who obtained an optimum length for *M. americanus* of 268 mm in a 70 mm mesh size, i.e. close to what was observed in the present study for the same species.

For the southern stock of *M. furnieri*, REIS and PAWSON (1999) calculated an L_m value of 241 mm. This contrasts with the value in the present study and may have been due to different stocks (HAIMOVICI and IGNÁCIO, 2005; VOLPEDO and CIRELLI, 2006). SOUZA (2007) obtained an L_m of 500 mm for a set of samples from 1997 to 2000.

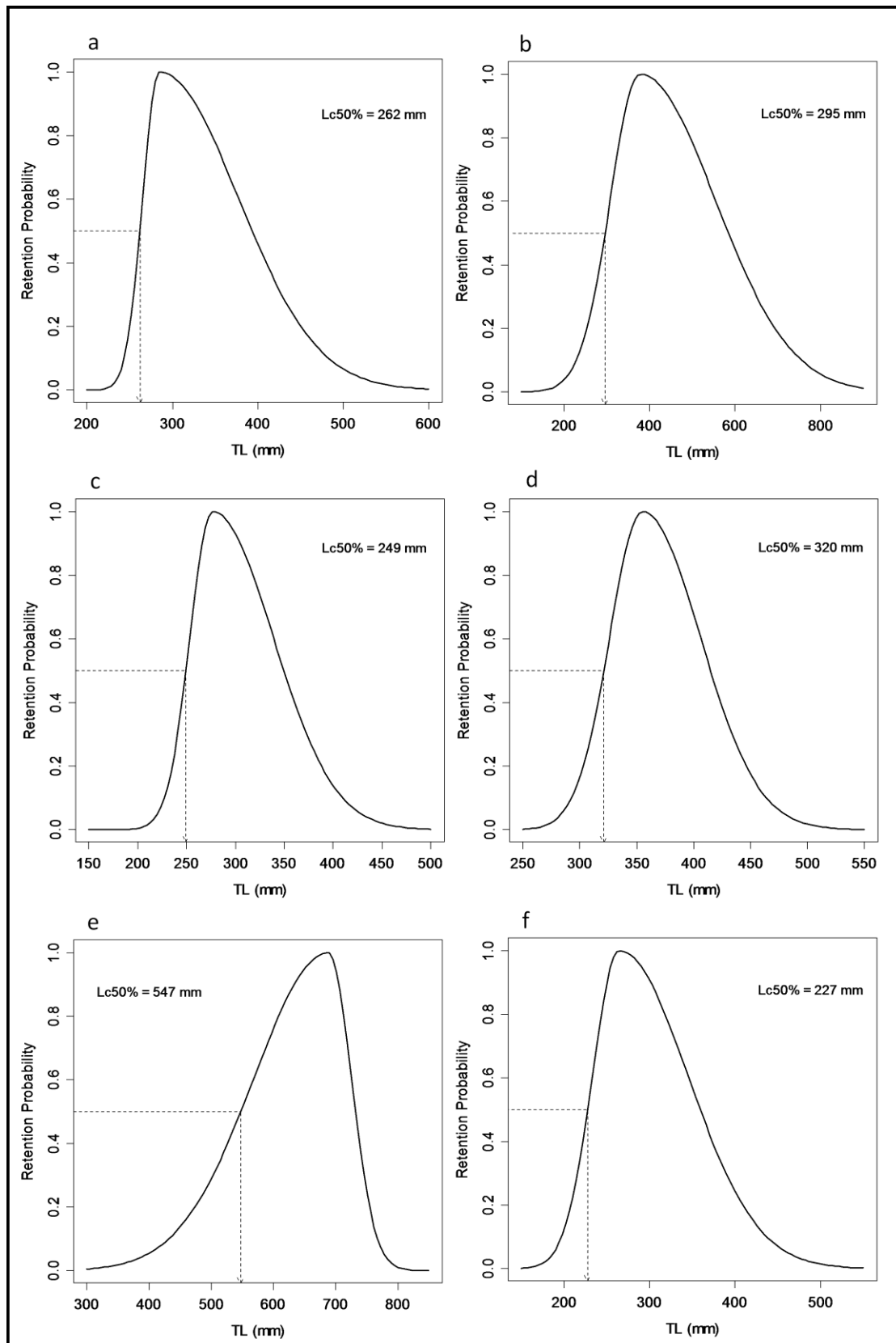


Figure 1. Bottom gillnet selectivity curves for the Santos fleet (SP, Brazil): (a) *M. americanus*; (b) *M. furnieri*; (c) *C. jamaicensis*; (d) *M. atricauda*; (e) *S. brasiliensis*; (f) *C. chrysurus*.

For *C. jamaicensis*, the estimated $L_{c50\%}$ value was closer to that of SOUZA (2007) (262 mm), thus indicating small changes in the exploitation pattern, but higher than the L_{50} value of 195 mm estimated by CASTRO *et al.* (2005). The latter authors, however, pointed out that this resource had been exploited since the 1960s by pair trawl and later by several other fleets on the São Paulo coast, due to stock depletion of their target species.

For *M. atricauda*, HACKETT *et al.* (2000) obtained an $L_{c50\%}$ of 305 mm, which was close to the value found in the present study. This similarity can be explained by the use of a 70 mm mesh size by the gillnet fleet, with the aim of capturing this resource, which is more abundant near the 20 meter isobath (CARNEIRO *et al.*, 2005). These authors discuss a fail point in the management of this resource, consisting of reduction of the L_{50} by approximately 40 mm (from 300 to 259 mm) over recent decades. This is worrying and shows inefficient management. CADIMA (2000) emphasized this and stated that the biological reference limit-points were critical. These can be understood as the maximum values of fishing mortality or the minimum biomass values, which must not (or in this case, should not) be exceeded, because the excess could put at risk the self-renovation capacity of the stock. This L_{50} decrease indicated that, for this stock, the exploitation was not at a suitable level, and was now closer than what the Code of Conduct for Responsible Fisheries (FAO, 1995) recommends. This code has a precautionary approach, and states that gaps caused by lack of data for estimating parameters and assessing the stock should not be used as a justification for not applying regulatory measures for conserving targeted species, depending on the case, as well as for associated and non-targeted species and their environment.

Similarly to *M. americanus*, *M. atricauda* presents considerable variation in the perimeter of the first dorsal fin, where the feminine gonads develop, which increases the likelihood that females will be caught in the pre-spawning period at first maturity. This shows that effective management must take into account the length, as well as the perimeter of the fish.

The smallest lengths observed for *M. atricauda* were within the 180 and 200 mm size class, which is below the L_{50} value found by CARNEIRO and CASTRO (2005). This may be connected with on-board discarding of the smallest and non-commercialized strata, considering that PUZZI *et al.* (1985) registered lengths shorter than these in relation to experimental catches. Studies on bottom trawls have registered discarding of individuals of this species that were 50 mm in total length (GRAÇA LOPES *et al.*, 2002), thus indicating heavy fishery pressure on the resource.

Literature on the selectivity of *S. brasiliensis* in relation to the northern coast of Brazil shows a $L_{c50\%}$ estimated as 492 mm (GONÇALVES *et al.*, 2003), which was near to the value found in this study, and to the northeastern coast where FONTELE-FILHO e ALCANTARA-FILHO (1977) worked with experimental gillnets, obtaining a L_m of 473 mm for the 80 mm mesh size. Exploiting the senior individuals would be dangerous because this population stratum is in better condition for reproduction (ESPEGREN *et al.*, 1990; NORDWALL *et al.*, 2008). The largest fish that were observed (around 900 mm) were close to the L_∞ (1,250 mm) registered by COLLETTE and NAUEN (1983). Almost 65% of the catch was between 700 and 900 mm. Nevertheless, the lack of data in the literature demonstrates the need for a better approach to fisheries, and to the biological parameters of resources that are exploited by several fleets and different types of fishery gear along the whole Brazilian coast.

This study obtained an $L_{c50\%}$ for *C. chrysurus*. GRANT (1981), using a 70 mm mesh size in the bay of Kingston, Jamaica, estimated an $L_{c50\%}$ of 158 mm. In the present study, only individuals above the L_{50} of 153 mm, estimated by MASUMOTO and CERGOLE (2005), were observed. This may have been more related to possible on-board discarding or to the strata available in the fishing area, than to any situation in which most fish had a smaller perimeter that allowed their escape from the net (the mesh perimeter was 140 mm and the mesh size was 70 mm). According to these authors, this species is a constituent of the bycatch in southeastern Brazil, and there is no direct fishery towards it.

For all the sampled species, individuals below their L_{50} were caught by the gillnet fishery. Nonetheless, five of the six species were already sexually mature, thus indicating that the selectivity of this gear can be easily adjusted to avoid catching immature individuals. However, some species, like *M. americanus* and *M. atricauda*, present characteristic celomatic cavity expansion during their pre-spawning period, which increases the catch of females at the end of the reproductive period, mainly through using the 70 mm mesh size, thus creating a negative impact on the spawning stock of these populations.

For *M. furnieri* the $L_{c50\%}$ value was very close to the L_{50} . Nevertheless, the fact that 32% of the sample was below L_{50} suggests that this species is highly vulnerable to gillnets, which makes effective control over the fishery effort essential.

The lack of selectivity studies regarding biological parameters, particularly the reproductive cycle, is worrying when seen from the perspective of increasing fishery efforts on already overfished stocks. This is particularly so in cases such as that of the studied gillnet fishery, which presented an indiscriminate increase.

CONCLUSION

We suggest that temporal closed fishing areas and/or periods of gillnet usage suspension should be established, and revision of technological aspects, in particularly the gillnets of 70 mm mesh size, as a precautionary action to protect the earlier period of the reproductive cycle and thus diminishing the fishery pressure.

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