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Amparo García-Mellado [a]; Francisco José Oliva-Paterna [a]; Edmir Daniel Carvalho [b]; Mar Torralva [a]
[a] Department of Animal Biology (Zoology), University of Murcia, Murcia, Spain [b] Department of Morphology, Institute of Biosciencies, Botucatu, UNESP, Brazil

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Catch and selectivity parameters of the anastomid fish *Schizodon nasutus* using gillnets in the Jurumirim reservoir (São Paulo, Brazil)

AMPARO GARCÍA-MELLADO
FRANCISCO JOSÉ OLIVA-PATERNA
Department of Animal Biology (Zoology), University of Murcia, 30100, Murcia (Spain)
E-mail: *amparoga@um.es, fjoliva@um.es*

EDMIR DANIEL CARVALHO
Institute of Biosciencies, Department of Morphology, Botucatu, UNESP (Brazil)

MAR TORRALVA
Department of Animal Biology (Zoology), University of Murcia, 30100, Murcia (Spain)

ABSTRACT

Catch and selectivity parameters using gillnets were calculated for *Schizodon nasutus* in the Jurumirim reservoir on the Paranapanema River in southern Brazil. The simple gillnets used were made of monofilament nylon of 30 to 140 mm mesh size and of different heights. The relative abundance of the *S. nasutus* caught was analysed monthly and a positive relationship was found between catches per unit effort in number and biomass. The relative catches were more abundant for the nets of 40 and 50 mm mesh size. Catches were characterized by clear temporal variations and a predominance of medium size fish throughout the study period. The selectivity curve of gillnets for *S. nasutus* in this ecosystem was obtained. The catch obtained was compared with the available catch for each mesh size, and the available catch for a certain length of fish was calculated starting from the theoretical selectivity curve. The 50 mm mesh size gillnet showed the best fit between real and available captures and was considered the most suitable, because a smaller mesh size resulted in a catch of predominantly immature specimens. It is expected that these results will contribute to improving management strategies for conservation of resources. Parameters such as the minimum catch length advisable or the mesh size permitted for a given species are indispensable for such decision-making.

KEY WORDS: Freshwater fish - Fishery management - Reservoir - Catches per unit effort - Selectivity - Gillnet.

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INTRODUCTION

Ximbore or Campineiro, *Schizodon nasutus* (Kner, 1859), is a medium sized fish indigenous to the Paranapanema River, which flows into the Jurumirim reservoir (Adrian *et al.*, 1994). It is widely distributed throughout the south-east of Brazil, occurring in natural and artificial aquatic systems. With other species of the *Leporinus* genus, *S. nasutus* is one of the most abundant fish species in the Sao Paulo Region (Nelson, 1994). It is a herbivore with aquatic macrophyta as its main food resource, and is the dominant species of the Jurumirim reservoir (Carvalho *et al.*, 1996, *Abstract* in III Congr. Ecol. Bras., Brasilia, p. 283), where the species presents a life-history which is characterized by its short-life span and high growth-rate, early maturity, and a spawning period beteween September and January (Carvalho *et al.*, 1997, *Abstract* in XII Encontro Brasil Ictiol., Sao Paulo, p. 173). Although this species has little commercial value, it is indispensable for sustaining the human riverside population and is the basic catch of an important fishery on the reservoir (Carvalho *et al.*, 1998a). The damming of rivers for hydro-electric power plants has led to the impoverishment of the native icthyofauna, which has been totally or partially eliminated, and replaced by groups of lower commercial value (Woynarovich, 1991). Carvalho *et al.* (1998b) demonstrated the need to preserve many ecological zones, and the necessity of correct fishery management in the Jurumirim reservoir.

The methods for estimating selectivity, which indirectly use fish length or girth frequency data from fishing catches, can also be used to predict the minimum mesh size in the gillnets which should be used to increase the size of fish captured. Such nets are widely used in small-scale fisheries because they require little investment in terms of manpower and equipment and are effective in catching widely scattered fish (Reis & Pawson, 1992). When the mesh size is appropriate to the size of fish, the gillnet is a more effective catch method than the trammel net (Losanes *et al.*, 1992).

Specific studies of gillnet selectivity for *S. nasutus* have been performed only by Campos *et al.* (1980b), who used information referring to commercial catches using multifilament nylon gillnets of 140, 160 and 180 mm mesh size.

The aims of the present study are to analyse gillnet selectivity and the seasonal catchability of *S. nasutus* and to provide a tool which would help improve the fishing of this species in the Jurumirim reservoir. Such information could be used in management of this fishery resource. Parameters, such as the minimum catch length to be allowed or the mesh size that should be used for a given species, are indispensable for drafting regulations.

MATERIALS AND METHODS

Study area

The study area ("Recanto dos Cambarás") consisted of the transition zone between the River Paranapanema and the Jurumirim reservoir, in the state of São Paulo, southern Brazil (23°30'10" S, 48°42'35" W) (Fig. 1). The region is characterized by two distinct climatic seasons: a dry period (April-September) and a rainy one (October-March). The water-level fluctuates by around 2 m, with water temperature, both in the river and lagoons, ranging from 17 to 29 °C. The dissolved oxygen levels are between 4.0 and 10.5 mg l^{-1}, the ionic conductivity is between 78.4 and 90.5 mS cm^{-1}, and the pH varies from 5.8 to 7.6 (Henry, 1993; Henry *et al.*, 1995). Limnologically, the main body of the Jurumirim reservoir is an oligotrophic (in terms of phytoplankton primary production), lentic and dynamic ecosystem (Henry, 1990, unpubl. thesis; 1993).

During the present study monthly information was compiled on the variation of abiotic factors (Table I). Abiotic parameters were taken near the surface (0.5 m depth) in 10 points throughout the studied area. The monthly variations in rainfall and water-levels (above sea level) of the reservoir were provided by the meteorological station located at Jurimirm Weather Station (CESP) during the study period (Fig. 2). The data confirm the two different climatic seasons mentioned above: a dry period running from April to September (with the exception of June 1997) and a rainy one from October to March. There was a negative correlation between rainfall and water-level of the reservoir (Pearson's correlation coefficient, $r = -0.531$, $P < 0.05$; Fig. 2), a factor which is a consequence of the operational system of the Jurumirim hydroelectric power station. During the dry months, the power station stores water and during the rainy months it produces electricity, a procedure which has an artificial control effect on the hydrological cycle of this ecosystem.

Catch

A total of 649 specimens was obtained during monthly experimental samplings between July 1996 and December 1997. Fish were caught with simple monofilament nylon gillnets of different mesh sizes and heights. Nets were placed transversely running from the reservoir edge and with mesh sizes ranging from small to large. Sampling started between 2 p.m. and 3 p.m. and finished the following morning between 8 a. m. and 9 a.m., resulting in a soaking time of 18 hours.

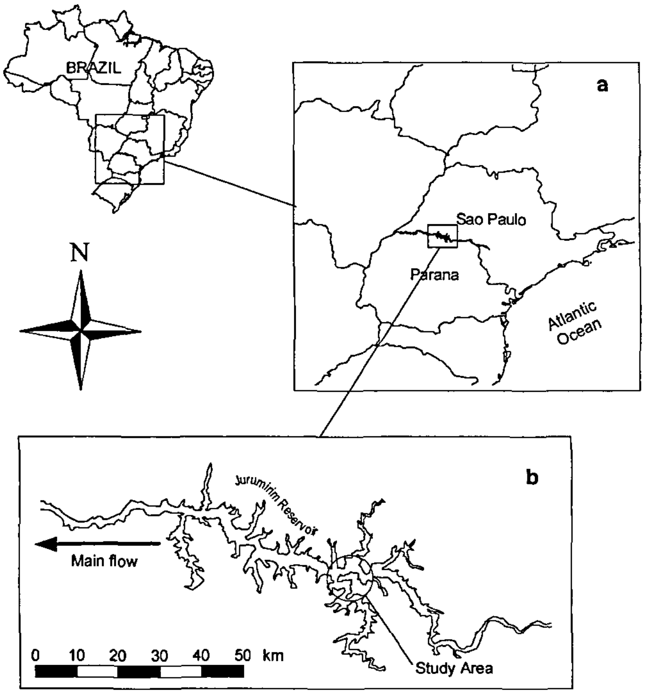

Fig. 1 - Location of the sampling zone: **a**, River Paranapanema in the hydrographic basin region in the State of São Paulo; **b**, sampling zone ("Recanto dos Cambarás") located in the river-reservoir connection area.

In areas near the reservoir edge and in aquatic vegetation zones (3 m maximum depth), four net sets at the surface were used, each consisting of six 20-m-long sheets (30, 40, 50, 60, 70, and 90 mm

TABLE I - *Monthly variations of abiotic factors in the sampling site ("Recanto dos Cambarás") recorded during the study period (mean values are presented).*

	Rainfall (mm)	Water level (m)	Temperature (°C)	Dissolved oxygen (mg l^{-1})	pH	Conductivity (µS cm^{-1})	Suspension solids (mg l^{-1})
July 1996	9.8	567.0					
August 1996	23.4	566.5	19.4	6.9	6.3	55.0	8.8
September 1996	161.3	566.2	20.9	8.3	6.3	44.4	1.7
October 1996	140.5	565.6	21.6	6.4	5.9	66.0	2.6
November 1996	69.1	565.1	24.3	8.2	6.8	37.9	4.5
December 1996	344.8	564.6	24.8	6.1	7.0	42.7	4.1
January 1997	415.6	565.7	24.5	5.5	6.8	28.4	4.6
February 1997	169.5	567.7	27.8	6.2	6.3	40.7	5.3
March 1997	55.9	567.3	27.1	8.9	7.8	48.6	1.6
April 1997	57.7	567.3	23.4	8.2	5.3	45.0	1.2
May 1997	69.1	567.3	19.7	7.6	6.5	43.7	2.2
June 1997	181.3	567.3	18.7	8.1	7.1	37.0	2.7
July 1997	19.1	567.1	18.5	8.3	7.9	39.6	1.1
August 1997	65.6	566.7	18.4	7.5	7.5	46.0	1.7
September 1997	82.1	566.3	24.3	8.2	7.1	5.3	0.9
October 1997	85.4	566.3	26.5	6.7	6.4	39.8	3.0
November 1997	360.1	565.7	26.8	7.9	7.4	36.3	4.9
December 1997	137.9	566.4	25.9	6.3	6.4	37.4	6.9
Mean	136.0	566.4	23.1	7.4	6.7	43.2	3.4
Standard Deviation	121.7	0.8	3.3	1.0	0.7	8.3	2.2

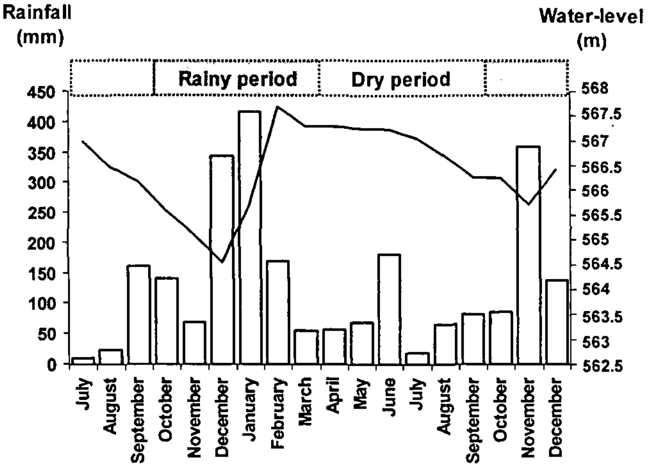

Fig. 2 - Monthly variations in rainfall (in columns) and water-level (lines) of the Jurumirim Reservoir recorded during the study period.

mesh size) and varying from 1.50 to 2.30 m in height, with an estimated total area of 912 m^2. In deep zones (5 m maximun depth), two net sets at 1 m depth, each consisting of five 20-m-long sheets (70, 90, 100, 120, and 140 mm mesh size) and varying from 1.75 to 2.30 m in height, with an estimated total area of 405 m^2, were used.

Captured fish were labelled with their fishing set number and mesh size, preserved on dry ice (carbon dioxide) and transported to the laboratory, where their length (total and standard length, ± 1 mm) and weight [fresh and somatic weight (= eviscerated weight), ± 0.1 g] were recorded. Sex (female, male, and immature) was determined by visual observation of the gonads.

The relative abundance of the *S. nasutus* catch was analysed monthly. Catch per unit effort (CPUE) was calculated as follows: (1) fish number × 10^3 / gill net area (m^2) / 24 h (CPUEn); and (2) fish biomass (kg) / 24 h (CPUEb) (Santos *et al.*, 1994; Bini *et al.*, 1997).

Selectivity

The selectivity curve of gillnets was obtained using the method described by Holt (1963) and recommended by Gulland (1969). The same method was used for several species by Campos *et al.* (1980a and 1980b) and Gomes *et al.* (1997). This selectivity curve is expressed by the formula:

$$C^*_L = e^{-E\,(L - h \cdot M)^2}$$

where C^*_L is the relative frequency of catch (or retention), E and h are constant, L is the standard length of fish, M is the mesh size of the net (mm).

To determine the optimum mesh size for *S. nasutus*, Baranov's method as described in Nakatani *et al.* (1991) was used. This method proposes the formula:

$$M = K\,L$$

where: M = optimum mesh size, K = specific coefficient (empirical procurement), L = average length of fish which will be captured.

To calculate K we use the mathematical expression:

$$K = 2M_a\,M_b \,/\, L_0\,(M_a + M_b)$$

where: M_a = mesh size, M_b = following mesh size, L_0 = fish length whose M_a catch probability is the same as that of M_b.

Finally, the catch obtained was compared with the available catch for each mesh size, following Holt's method. In this way, we calculated the available catch for a certain length, starting from the theoretical selectivity curve.

RESULTS

Catch

Both in males and females the catch results clearly showed a positive relationship between the gillnet CPUE estimates for number and biomass (Pearson's correlation coefficient, r = 0.983 for males and r = 0.971 for females, $P < 0.05$; regression analysis, $R^2 = 0.965$ for males and $R^2 = 0.943$ for females, $P < 0.05$). There were no significant differences in the equations obtained for each sex (ANCOVA, $P > 0.05$), so overall data were pooled and one single regression was obtained (Fig. 3) (Pearson's correlation coefficient, r = 0.955, $P < 0.05$; regression analysis, $R^2 = 0.912$, $P < 0.05$). The proportionality of catch in number and biomass suggests that most samples of *S. nasutus* in this reservoir were of medium size. However, females had a higher mean standard length (19.5 ± 0.3 cm, 95% confidence limits) than males (17.9 ± 0.3 cm, 95% confidence limits) (ANOVA, $P < 0.05$). Moreover, there was a temporal significant correlation between male and female sizes (Pearson's correlation coefficient, r = 0.569, $P < 0.05$) but no significant difference between seasons in female and male size (ANOVA, $P > 0.05$).

The temporal pattern of gillnet CPUE estimates for *S. nasutus* showed a high degree of monthly variation in number and biomass (Fig. 4), the greatest catches being obtained in November and December 1996, and June and July 1997.

When the relationship between relative abundance (CPUE number and biomass) and abiotic factors was investigated (Table I, Fig. 2), no significant correlation was found (Pearson's correlation analysis, $P > 0.05$). Nevertheless, it can be seen that the large catches of June and July 1997 coincided with an increase in rainfall, and captures and rainfall showed a slight temporal correspondence during the rainy season (Figs 2 and 4).

When the relative abundance data for individual sexes were analysed, no relationship between sex-stock densities and the abiotic parameters were found (Pearson's correlation analysis, $P > 0.05$). However, temporal variation in abundance differed between females and

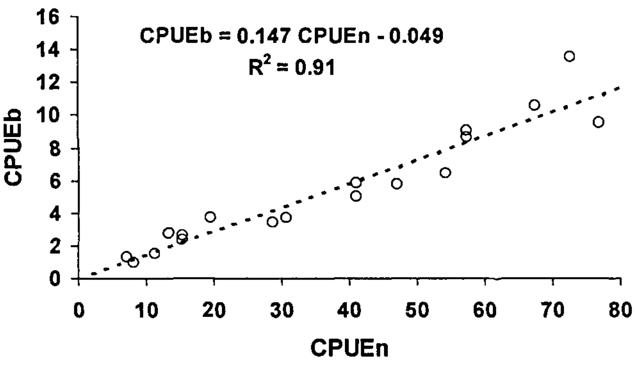

Fig. 3 - Relationship between the gillnet capture estimates for number (CPUEn) and biomass (CPUEb) of *Schizodon nasutus*.

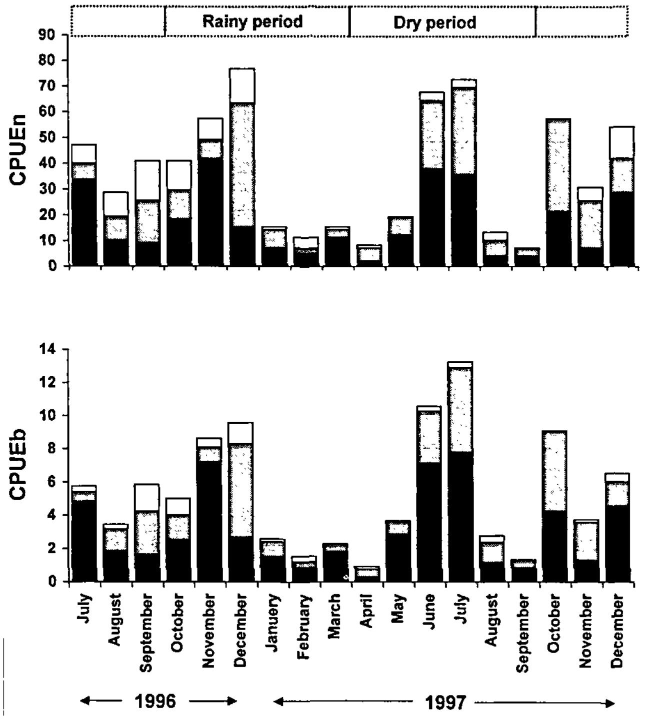

Fig. 4 - Temporal pattern of gillnet capture estimates in number (CPUEn) and biomass (CPUEb) of *Schizodon nasutus* throughout the study period (grey, males; black, females; white, indeterminate).

TABLE II - *Total and relative catches by different mesh size used for the selectivity analysis.*

Standard length (cm) class intervals	Mesh sizes (mm)				
	30	40	50	60	70
(9-10.5)	11				
(10.5-12)	18	3	1		
(12-13.5)	10	11			
(13.5-15)	5	40	1		
(15-16.5)	2	42	13	1	
(16.5-18)	6	44	35	7	1
(18-19.5)	3	32	49	31	2
(19.5-21)		13	40	27	6
(21-22.5)	1	6	22	16	11
(22.5-24)		1	6	4	13
(24-25.5)			1	1	7
(25.5-27)					2
Total	56	192	168	87	42
Catch (%)	10.27	35.23	30.83	15.96	7.71

males (Fig. 4) (Pearson's correlation analysis, $P > 0.05$), with the highest catches of females being obtained in July and November 1996 and in June, July, and December 1997, while the greatest catches of males were in December 1996 and June, July, and October 1997. In accordance with these results, the overall sex ratios differed from 1:1 over six months (Fig. 4).

Selectivity

The catches of *S. nasutus* in gillnets of larger mesh size (i.e., 90, 120, and 140 mm) were low and a heterogeneous size and did not differ from those using the medium size (i.e., 60 and 70 mm). For the analysis, therefore, only fish caught by gillnets of small and medium mesh size, from 30 to 70 mm, were used. Moreover, the relative catches were more abundant for the 40 and 50 mesh size nets (Table II). Given that real captures did not differ from theoretical captures for these mesh sizes (χ^2 test for the five most commonly caught length-classes, $P = 0.53$, 40 mm; $P = 0.12$, 50 mm), the efficacy was highest the 40 and 50 mm mesh sizes (Fig. 6).

The general selectivity curve for *S. nasutus* caught by gillnets is given by the mathematical expression:

$$C^*_L = e^{-0.0584\,(L - 3.931 \cdot M)^2}$$

The probability of capture by the different mesh sizes is represented in Fig. 5a, where it can be seen that the selectivity curves are unimodal for the five mesh sizes. The overlap of over 80% between the different selectivity curves means that one of our net sets was not selective for *S. nasutus*. The optimum standard length catch and the standard length intervals, which mean that the minimum probability of capture is 50%, increased proportionally with mesh size (Fig. 5b). The relative frequency of retention was greatest for fish of a standard length of between 14.25 and 21.75 cm, which represented more than 80% of total catches (Fig. 5c). The optimum mesh size formula for *S. nasutus* in the Jurumirim reservoir was $M = 0.249$ L.

Finally, the predominantly medium size of available captures (from 14 to 21 cm standard length) is clear (Fig. 6). When the real and available captures were analysed for all different mesh sizes, the 50 mm mesh size presented the best fit (χ^2 test for the five length-classes caught most, $P = 0.045$).

DISCUSSION

The catch of a fish of a given length in a gillnet can be described as the product of the abundance of that length class, the retention probability, the effort unit, and the efficiency of the net (Hamley, 1975; Madsen *et al.*, 1999). As Bini *et al.* (1997) found with other species in the Segredo reservoir, also the present study pointed to a strong correlation between the CPUE in biomass and number. Moreover, the must abundant length-classes in the catch were between 14.25 and 21.75 cm (constituting about 80% of the total catch). All *Schizodon* species reach a slightly larger size (standard length maximum of 40 cm) (Goulding, 1980; Nelson, 1994; Vazzoler, 1997), so in the ecosystem studied, the sam-

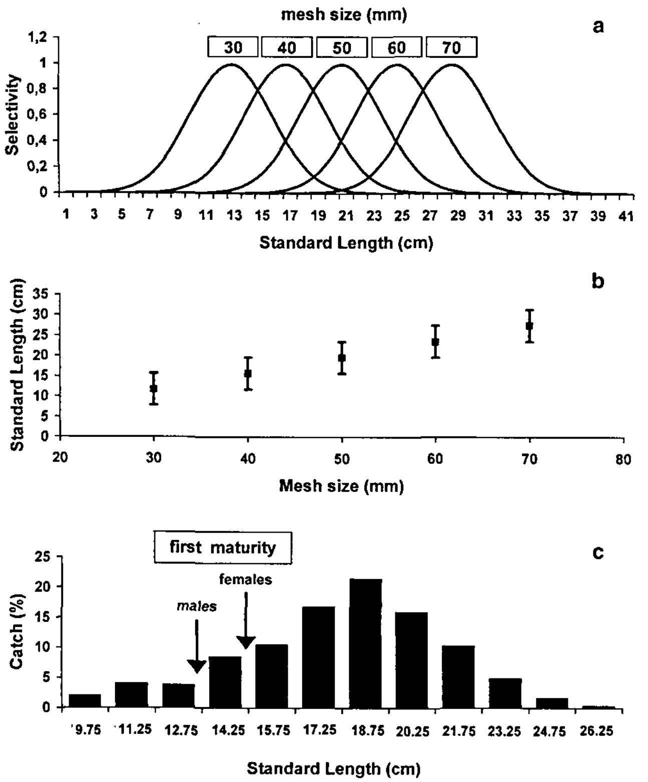

Fig. 5 - **a**, selection curves for the five mesh sizes obtained using the method described by Holt; **b**, optimun standard length catch and the standard length intervals, which mean that the minimum probability of capture is 50%, for the five mesh sizes; **c**, relative catches for standard length intervals of fish.

ples caught were predominantly of medium size throughout the study period.

Monitoring the CPUE does not provide a good estimate of absolute fish densities but, instead, information on proportional changes in the exploited populations, i.e., selective estimates (Peltonen *et al.*, 1999). Temporal variations in CPUE for *S. nasutus* were clear, both for number and biomass. No significant correlation was found between relative abundance (CPUE) and abiotic factors for the sexes, either separately or jointly. However, many of the higher catches occurred at the same time that rainfall increased, i.e., in June and December, and both variables presented a certain temporal correspondence during the rainy season. *S. nasutus* is a planktophagous fish (Carvalho *et al.*, 1996) and increases in the density of herbivore species related to rainfall, water-level, and inundated bank vegetation as described in the Parana Basin (Agostinho *et al.*, 1997). Moreover, according to Carvalho *et al.* (1998a), this species makes short migrations to reproduce and feed, and is well--adapted to the lentic and semi-lotic conditions of the ecosystem and its small tributaries. However, the most reasonable hypothesis to explain the seasonal variations observed is fish movement between the reservoir and the rivers which flow into it, given that we detected a negative significant correlation between rainfall and the water-level of the reservoir. Such movements could explain the exclusive capture of medium size fish in the reservoir, probably because food availability is higher in the river systems that flow into the reservoir (Carvalho *et al.*, 1997), larger fish remaining in them since they do not have to move to the reservoir. In addition, movements between the sampling area and the more central part of the reservoir might have an important effect. However, more data on the movement of *S. nasutus* are needed before any firm conclusion can be made.

Baranov's principle of geometrical similarity (Baranov, in Hamley, 1975) established the dependence of selectivity on the relationship between geometry of the fish and mesh structure. Thus, both the modal length and spread of the curve are proportional to mesh size. Using a general lineal model, it is possible to estimate the selectivity of each mesh size, based on the total catch in each length group (Kirkwood & Walker, 1986; Huse *et al.*, 1999). Because the species presents a high frequency of catch and a wide variation in length-class, *S. nasutus* was deemed suitable for this study of gillnet selectivity. Although body shape may also explain some irregularity in the selectivity curves (McCombie & Berst, 1969), this does not seem to be the case for *S. nasutus*,

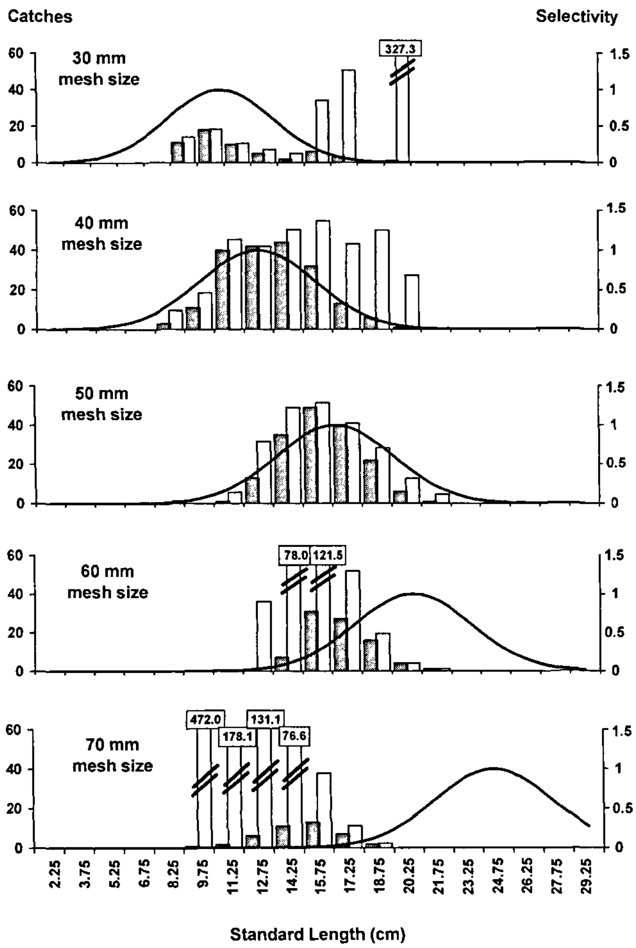

Fig. 6 - Real (grey columns) and available (white columns) captures and selectivity curves of *Schizodon nasutus* for the five mesh sizes.

for which the general selectivity curve is clearly unimodal (see Results).

Since most fishing operations are selective, the catch is not representative of the population as a whole (Lagler, 1978). When selectivity curves show an overlap of more than 70% in the probability of capture, it can be affirmed that the gillnet set is not sufficiently selective, although each individual net may be (Nakatani *et al.*, 1991; Gomes *et al.*, 1997). According to this, our samples are unselective (overlap higher than 80%, Fig. 5a), which, added to the greater capture effectivity for the 17.25-20.25 cm fish size range (Fig. 5c), points to the predominance of medium size *S. nasutus* in the Jurumirim reservoir. Moreover, the 50 mm mesh size gillnet presents the best fit between real and available captures.

The standard length for *S. nasutus* fish reaching maturity in the Jurumirim reservoir was fixed at 13 cm (male) and 15 cm (female) (Carvalho, unpubl. data). For this reason, in order to improve the reproductive potential of the population, the smallest mesh size used should never catch samples that have not participated in the reproductive cycle. Thus, nets of 50 mm mesh size are the most adequate for *S. nasutus* fishing and those of 40 mm or less are not to be recommended because most fish caught are immature specimens.

In the Jurumirim reservoir, the captures of *S. nasutus* were characterized by a predominance of medium sizes throughout the study period. The clear temporal variations observed probably stemmed from stock movements between the reservoir and the rivers which flow into it. The 50 mm mesh size gillnet is best for *S. nasutus* fishing.

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