Length-weight relation, condition factor and gonadosomatic index of the whitemouth croaker, *Micropogonias furnieri* (Desmarest, 1823) (Actinopterygii: Sciaenidae), caught in Lençóis Bay, state of Maranhão, eastern Amazon, Brazil

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Abstract

The whitemouth croaker, *Micropogonias furnieri*, which is exploited off the state of Maranhão, Brazil, reinforces the need for maintenance programs of natural stocks of this species to assist in the management of this exploited resource. The aim of the present study was to describe aspects regarding its reproductive characteristics (gonadosomatic index and condition factor) and also the length distribution and weight-length relationships. The fish were caught in Lençóis Bay in the state of Maranhão (eastern Amazon) between June 2010 and July 2011. A total of 570 individuals were caught (318 males and 252 females). Differences in length were found between the sexes, with females larger than males. The sex ratio indicated a tendency for females to be more abundant in the rainy season (first semester), whereas males predominated in the dry season (second semester). The weight-length relationship indicated negative allometric growth for both sexes. The analysis of the variation in the condition factor suggests that lower values coincided with higher gonadosomatic index values and that this factor is a good reproductive indicator for *M. furnieri* in the region.

Descriptors: Population structure, Sex ratio, Weight-length relationship, Gonadosomatic index, Condition factor.

Resumo

A corvina, *Micropogonias furnieri*, é explotada no Maranhão, Brasil, ressaltando a necessidade de programas de manutenção de estoques naturais desta espécie para auxiliar na gestão deste recurso explorado. O objetivo do presente estudo foi o de adquirir informações sobre as características reprodutivas (índice gonadossomático e fator de condição) e também sobre a distribuição de comprimento e relação peso-comprimento da espécie. Os peixes foram capturados na Baía dos Lençóis, no estado do Maranhão (Amazônia Oriental) entre junho de 2010 e julho de 2011. Um total de 570 indivíduos foram capturados (318 machos e 252 fêmeas). Os valores de comprimento apresentaram diferença entre os sexos, com fêmeas sendo maiores que os machos. A proporção entre os sexos indicaram uma tendência para as fêmeas serem mais abundantes na estação chuvosa (primeiro semestre), enquanto os machos predominaram na estação seca (segundo semestre). A relação peso-comprimento indicou crescimento alométrico negativo para ambos os sexos. A análise da variação do fator de condição sugere valores mais baixos coincidindo com os resultados mais elevados para a relação gonadossomática, apresentando-se como um bom indicador reprodutivo de *M. furnieri* na região.

Descritores: Estrutura populacional, Razão sexual, Relação peso-comprimento, Relação gonadossomática, Fator de condição.

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INTRODUCTION

The marine and estuarine fishing resources in northeastern Brazil are considered to be of vital importance to the integrated development of the region, especially as a raw material for fishing industries as well as a means of sustenance and source of protein for the populations that live near the areas of occurrence of these resources (CASTRO, 1997).

The family Sciaenidae stands out among highly exploited fishing resources. This family includes species of considerable importance throughout the world and is represented in Brazil by 21 genera and 54 marine species (MENEZES *et al*., 2003). One member of this family found on the coast of the state of Maranhão (northeastern Brazil) is the whitemouth croaker, *Micropogonias furnieri,* (DESMAREST, 1823), which is a coastal species with demersal habits and a broad geographical distribution running from the Yucatan Peninsula (Gulf of Mexico 20º N) to the San Matias Gulf (Argentina, 41º S), associated with the mouths of rivers (ISAAC, 1988). This species is of considerable commercial importance in Brazil, Uruguay and Argentina (VASCONCELLOS; HAIMOVICI, 2006).

In the state of Maranhão, the whitemouth croaker is caught by the artisanal fleet using drum nets on muddy bottoms under the influence of rivers. Catches are also performed in the open sea at depths greater than 40 m using gillnets or in estuarine regions using fyke nets (IBAMA, 2007). The intensive exploitation of *Micropogonias furnieri* underscores the need for maintenance programs of natural stocks of this species to assist in the management of this exploited resource. The management of stocks submitted to fishing pressure requires current knowledge on the resource as well as the best scientific evidence available to ensure the sustainability of exploited species and the management of fishing activities. It is therefore essential to conduct studies to acquire knowledge on the fishing resources in the state of Maranhão to assist in the establishment of exploitation limits and management measures.

The length-weight relationships of fishes, for example, are important in fish biology because they allow the estimation of the average weight of the fish of a given length group by establishing a mathematical relation between them (MIR *et al*., 2012). The relationship can be used to characterize the differentiation of taxonomic units and the relationship changes with the various developmental events in life such as metamorphosis, growth and onset of maturity (THOMAS *et al*., 2003).

The condition factor (K) is another parameter widely used in fishery biology. Its calculation depends on the relationship between the weight of a fish and its length, with the intention of describing the "condition" of that individual fish (FROESE, 2006). Different values in K of a fish indicate the state of its sexual maturity, the degree of food source availability and the age and sex of some species (ANIBEZE, 2000).

The aim of the present study was to acquire information on *Micropogonias furnieri* through the study of variables related to its population and reproductive characteristics, such as length distribution, weight-length relationship, gonadosomatic index and condition factor, to offer knowledge that can assist in the management and sustainable exploitation of this resource.

MATERIAL AND METHODS

The study area encompassed coastal and estuarine areas of Lençóis Bay (01º18'S to 01º19'S; 44º51'W - 44º53'W) (Figure 1). Lençóis Island is located in the Maiau archipelago on the coast of Cururupu, state of Maranhão, eastern Amazon, which is an eco-tourism center of the Guarás Forest.

The study was conducted in 2010 (June, September, October, December) and in 2011 (January, February, March, May, July). Floating drift gillnets with a mesh of 95 to 100 mm between adjacent knots, 4 to 5 meters high and 2,500 meters long were used for the catches. After capture, the individuals were placed in plastic bags labeled with the date and catch site, conserved on ice and taken to the laboratory. Voucher material was deposited at the Ichthyology Collection of the Department of Oceanography and Limnology of the Federal University of Maranhão, Brazil.

In the lab, the total weight (g) of each individual was determined using a scale with a precision of 1 centimeter and both total and standard length (cm) were determined using an ichthyometer with decimal precision. Evisceration was performed with surgical scissors by cutting in the ventral region, followed by the removal of the gonads. The gonads were weighed (g), and sex and maturation identified after gonad inspection based on macroscopic characteristics (e.g., size, coloration, transparency, surface vascularization, flaccidity). Gonad development was divided into four stages (immature - A, maturing - B, mature - C and spent - D) for both sexes, as recommended by VAZZOLER (1996).

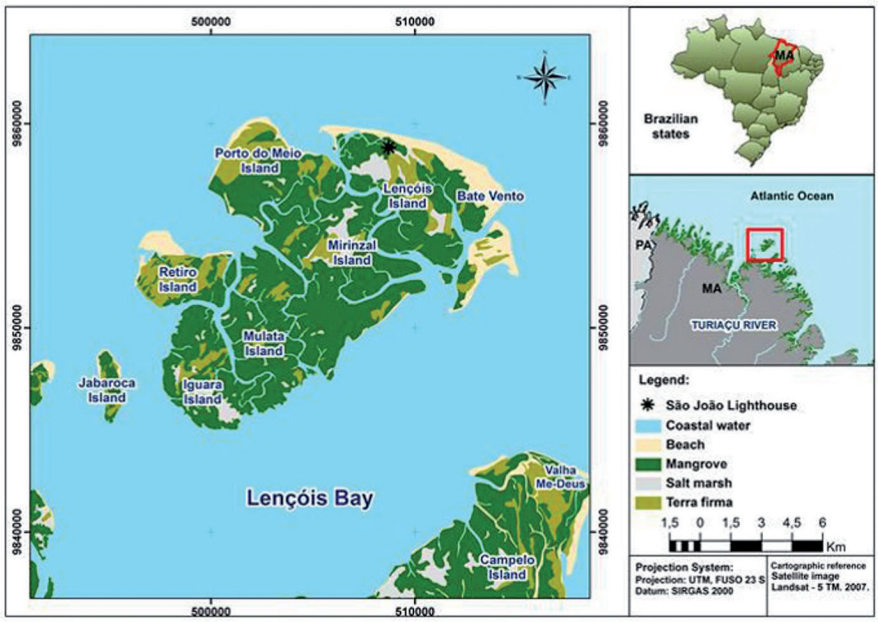

Figure 1. Catch region of *M. furnieri*.

The population was characterized based on the total number of individuals caught per sampling month, with the calculation of mean and standard deviation values in length (cm) and weight (g). The population was also analyzed based on the frequency of females and males in total length (cm) classes.

Size frequency distribution was analyzed using a Kolmogorov-Smirnov test (VANZOLINI, 1993) in order to identify a normality pattern. The comparative size of the sexes was calculated using a Student´s t-test.

Sex ratio was calculated per month and considering the entire sample. The chi-squared (χ^2) test was used to determine statistically significant differences between the sexes, the level of significance being set to 5% (p<0.05). This test was based on the following equation:

$$x^2 = \sum \frac{(O-E)^2}{E}$$

in which O is observed frequency and E is expected frequency.

The relationship between total weight and total length was determined using the method established by LE CREN (1951). The empirical values of the variables were plotted on a dispersion graph, which demonstrated a tendency towards fitting to a potential curve represented by the following equation:

$$Wt = aLt^b$$

in which Lt is the total length of the individuals at time *t*, Wt is the total weight of the individuals at time *t,* a is the condition factor related to the degree of fattening and b is the constant related to the type of growth of the individuals.

Logarithmic transformation of the data was then performed, resulting in the following equation: lnWt = lna + blnLt.

Analysis of covariance (ANCOVA) was used to determine possible differences between the regression parameters for males and females.

The gonadosomatic index (GSI) and condition factor (K) were determined for the quantitative analysis of the reproductive activity of the species based on the following equations, as described by VAZZOLER (1996):

$$RGS = \frac{Wg}{Wt} \times 100 \text{ and } K = \frac{Wt}{Lt^b}$$

in which Wg is the gonad weight of individual *i*, Wt is the total weight of individual *i* , Lt is the total length of individual *i* and b is the growth coefficient.

After the calculation of the results for each individual, graphic analyses of the mean monthly GSI and K values were performed for the sexes separately. Student's *t*-test was used to determine possible differences in mean GSI and K between the sexes. All the statistical analyses were

performed using the PAlaeontological STatistics (PAST) computational package, version 2.17 (HAMMER *et al*., 2001).

RESULTS

In the period sampled, 570 specimens of *Micropogonias furnieri* were analyzed (318 males and 252 females). Total length range for females was 26.9 to 48.9 cm (mean: 37.8±4.07 cm). The largest female was caught in May 2011 and the smallest was caught in June 2010. The months of January and February 2011 respectively had the largest and smallest mean total length values. Female biomass ranged from 224.97 g to 1094.42 g (mean: 557.49±153.8 g). The total biomass for females was 140,487.43 g, with December 2010 and February 2011 demonstrating the largest and smallest mean biomass, respectively. The total length distribution for males ranged from 26.3 to 50.0 cm (mean: 36.1±3.7 cm). The smallest individual was caught in September 2010 and the largest in December 2010. Male biomass ranged from 204.35 to 1267.84 g (mean: 519.67±138.83 g). Total biomass for males was 165,255.93 g.

Regarding the frequency distribution of total length for *M. furnieri* males and females, the modal value was found in the size class 34.1 to 36.7 cm (Figure 2). Males were more numerous in the smaller length classes and females dominated the largest length classes. The statistical analyses revealed significant differences in length between sexes (p=0.008), with females reaching larger sizes.

The sex ratio was significantly different (p<0.05) in September and October 2010 as well as February, March and July 2011 (Table 1). Males dominated in September and October 2010 and July 2011 and females dominated in February and March 2011. The overall sex male to female ratio was 1.3:1.

The results of the weight-length relationship indicated negative allometric growth for both males and females. ANCOVA indicated homogeneous variance (F>0.5) for the regressions between sexes. The parallelism test between the angular coefficients and intercepts also indicated similarity (p>0.05), demonstrating the overlap of regression lines in the weight-length relationship of *M. furnieri* males and females.

The weight-length relationship and correlation coefficient (r) for both sexes was submitted to logarithmic transformation as depicted in Figure 3. The value of 'b' was 2.3767 and the correlation coefficient (r) was

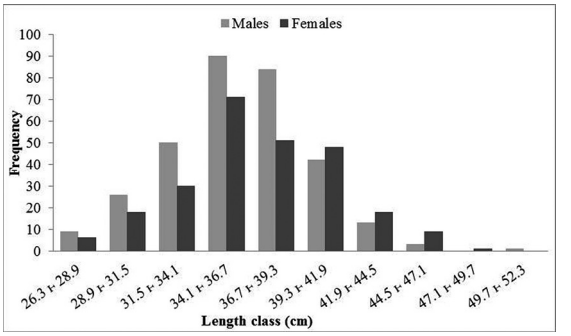

Figure 2. Frequency distribution per total length class (cm) for *M. furnieri* males and females.

0.9226 for the combined sexes. The equations for the weight-length relationship in this study was as follows: LnWt=-2.2869+2.3767LnLt.

The highest GSI values for females were found in December 2010 and March 2011 (Figure 4a), whereas males demonstrated a peak in February 2011 (Figure 4b). GSI values were significantly higher for females (p<0.01). The high values for females in December 2010 were associated with the period in which higher incidences of mature gonads were found (Stage C). The gonad maturation stages revealed the constant presence of mature individuals throughout all the sampling months, indicating continuous spawning for the species in Lençóis Bay (state of Maranhão, Brazil). However, the reproductive peaks indicate periods of greater breeding activity.

Throughout the sampling period, the condition factor ranged from 0.058 to 0.198 for males and 0.078 to 0.185 for females. The findings indicate, on average, a tendency towards an increase in the condition factor between March and October and a decrease between October and February (Figure 5), suggesting October to be the transition period for the biological activity of the species. The evaluation of the condition factor indicates low values coinciding with higher GSI values, demonstrating that the condition factor is an adequate reproductive indicator for *M. furnieri* in Lençóis Bay in the state of Maranhão (northeastern Brazil). Student's *t*-test revealed a significant difference in the condition factor between the sexes (p<0.5), with higher values being found for females.

DISCUSSION

Larger individuals of *M. furnieri* for both sexes were found in October and January, while smaller ones appeared in February and September. This pattern may be associated with the dynamics of the mangrove environment during

Table 1. Monthly sex proportion between *Micropogonias furnieri* males and females (χ^2 test).

Month	Females	%	Males	%	Total	Expected frequency	χ^2
June 2010	24	48.0	26	52.0	50	25.0	0.08
September 2010	14	18.4	62	81.6	76	38.0	30.32 *
October2010	12	28.6	30	71.4	42	21.0	7.71*
November 2010	22	44.0	28	56.0	50	25.0	0.72
December 2010	47	47.5	52	52.5	99	49.5	0.25
January 2011	27	54.0	23	46.0	50	25.0	0.32
February 2011	36	78.3	10	21.7	46	23.0	14.70*
March 2011	31	66.0	16	34.0	47	23.5	4.79*
May 2011	22	37.3	37	62.7	59	29.5	3.81
July 2011	17	33.3	34	66.7	51	25.5	5.67*
Total	252	44.2	318	55.8	570	285	7.64*

*5% significance level; $\chi^2_{0.05}$=3.841

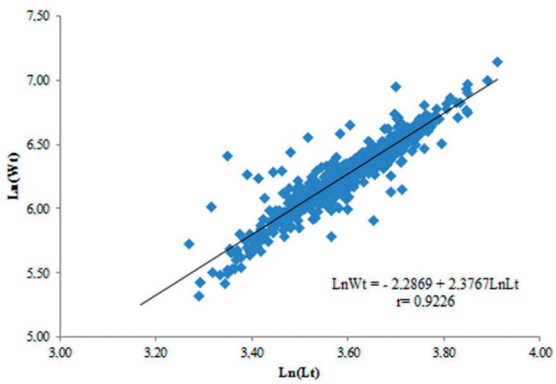

Figure 3. Length-weight relation for *M. furnieri* for both sexes.

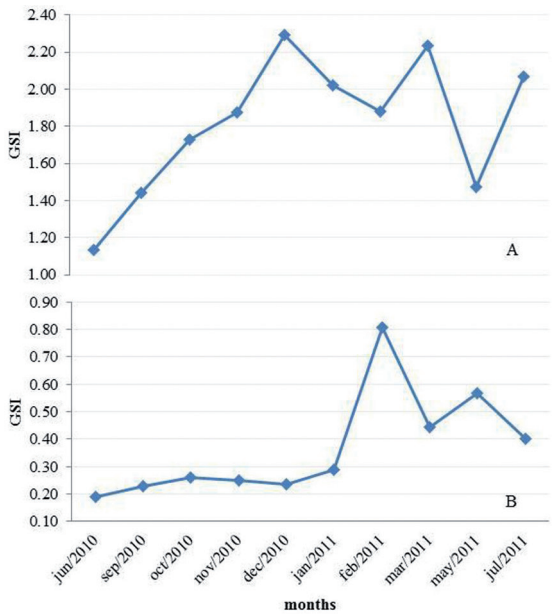

Figure 4. Gonadosomatic index (GSI) for *M. furnieri* females (A) and males (B) caught in Lençóis Bay, state of Maranhão, Brazil.

the rainy season, when the rivers normally overflow, thereby favoring juveniles due to the increase in areas of shelter and foraging. In studies conducted in Santos Bay (southeastern Brazil), GIANNINI and PAIVA FILHO (1990) caught larger *M. furnieri* individuals during the summer, which is the rainy season in the northern region of Brazil. VICENTINI and ARAÚJO (2003) found no indication of seasonality by size group in Sepetiba Bay, State of Rio de Janeiro.

In this study, the sex ratio of *M. furineri* off Maranhão was 1.3:1, which differs from that described by VICENTINI and ARAÚJO (2003), who found a ratio of 1:1 for the same species in Sepetiba Bay (state of Rio de Janeiro, southeastern Brazil). SANTOS *et al.* (2015) also recorded a majority proportion of males (1.56M:1F). In the Colombian Caribbean, MOZO *et al.* (2006) found a female to male ratio of 2.4:1, which demonstrates a predominance of females associated with the concentration of samplings in the rainy season. Besides the overall sample, the monthly sex ratio demonstrated significant differences between the sexes for September and October 2010 as well as February, March and July 2011. The findings show a tendency for females to be more abundant in the rainy season (January to June) and males to predominate in the dry season (July to December). Similar patterns were found by MANICKCHAND-HEILEMAN and KENNY (1990), MOZO *et al*. (2006) and SANTOS *et al*. (2015), pointing out that females of *M. furnieri* are most vulnerable to fishing in periods of high atmospheric precipitation, both

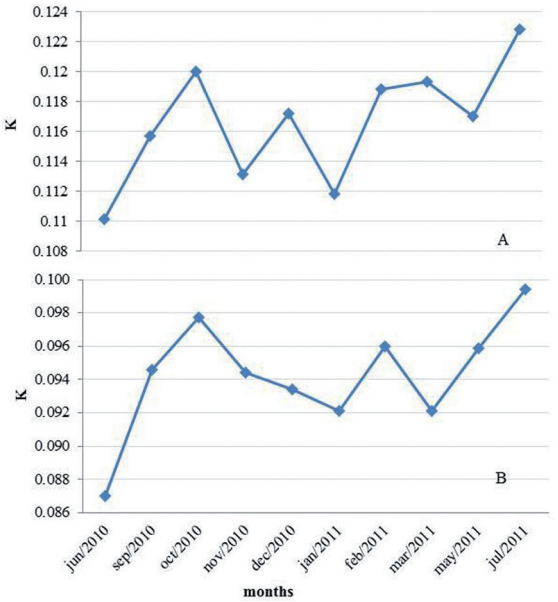

Figure 5. Condition factor for *M. furnieri* females (A) and males (B) caught in Lençóis Bay, state of Maranhão, Brazil.

on the North coast of the South-American continent, as in the Southeast of Brazil.

The results of the weight-length relationship demonstrate negative allometric growth (MOREY *et al*., 2003) for both *M. furnieri* males and females (b=2.38), with ANCOVA revealing no significant differences between the regression parameters. Studying populations of *M. furnieri* on Patos Lagoon (state of Rio Grande do Sul, southern Brazil), CASTELLO (1986) found positive allometric growth (b=3.15), as did ANDRADE-TUBINO *et al.* (2009) for the same species (b=3.18) in Guanabara Bay (Rio de Janeiro, southeastern Brazil). ARAÚJO and VICENTINI (2001); COSTA and ARAÚJO (2003) found figures close to 3 for the species in Sepetiba Bay (state of Rio de Janeiro), characterizing isometric growth. According to LE CREN (1951), b values range from 2.0 to 4.0, with a value of 3.0 considered ideal for a fish to maintain the same shape during ontogenetic growth. Figures less than 3.0 indicate that individuals become either more elongated or rounder throughout the growth process.

Total weight and length are influenced by a set of factors mainly related to the environment. Such factors affect the values of estimated regression parameters (NASCIMENTO *et al.,* 2012). Thus, the environmental conditions, such as hydrodynamic patterns, physicochemical aspects, nutrient availability and fishing pressure in each area, can contribute to different b values for *M. furnieri* caught in different regions of the country or even within the same state. Thus, temporal scales should also be considered when analyzing the weight-length relationship due to the environmental, social and economic changes in each region, which can exert a substantial influence on fish communities, thereby altering the growth pattern or other biological variables.

The GSI results reveal a tendency for the studied population to use the period at the end of the second semester and beginning of the first semester to intensify their reproductive activity. This period seems to be shorter for males than for females. Off the city of Ubatuba on the coast of the state of São Paulo (southeastern Brazil), ISAAC-NAHUM and VAZZOLER (1987) identified modal GSI values for *M. furnieri* in April, August, September and November. In the southern and southeastern regions of Brazil, reproductive peaks of species of the family Sciaenidae seem to be more closely associated with periods of higher temperatures (BERNARDES; DIAS, 2000; FÁVARO *et al.,* 2003). However, this factor does not likely exert an influence on the reproductive behavior of *M. furnieri* in the north and northeastern regions of the country, as the temperature is virtually the same throughout the year in the state of Maranhão, allowing continuous spawning, with peaks due to specific factors, such as periods of greater food availability and the expansion of areas of shelter. MULATO et al. (2014) emphasized salinity's influences on the breeding activities of *M. furnieri* in the Southeast of Brazil. However, in this research, although the higher outcomes to GSI appeared in periods of higher salinity (the drought season), the studied population showed a synchronism with its spawning apparently occurring in the months of heavy precipitation. This is the time when the shelter and feedings conditions became most propitious for spawn survival. Nevertheless, the females became most vulnerable to fishery exploitation during these migrations. Such a scenario makes it crucial to the implementation of future research regarding the average length definition of the first maturity of *M. furnieri* in the northern region of Brazil.

The condition factor constitutes an important quantitative element for the evaluation of the relationship between the body shape and relative weight of a species (ISAAC-NAHUM; VAZZOLER, 1983). *M. furnieri* exhibited greater weight for a particular size at the end of the second semester through to the beginning of the first semester, indicating the possibility of greater reproductive

investment and/or differences in environmental conditions in this period. The condition factor tended to reduce with the increase in the GSI. MANICKCHAND-HEILEMAN and KENNY (1990), on the island of Trinidad, found for the same species, higher values of K in the months of March, May and April and lower values in August, a result similar to that of this present study. The condition factor exhibited an inverse relationship to the gonadosomatic index and is therefore a good reproductive indicator for *M. furnieri* in the eastern Amazon region.

The findings for *M. furnieri* suggest environmental dynamics (seasonality) rather than intrinsic factors related to the physiological functioning of each organism as the main reason for the regulation of biological activities, especially for species that spend part of their lifecycle in mangrove areas.

Thus, the outcomes of the current study allow a clearer understanding of the effect of size on catches of *M. furnieri* in estuarine environments using drift gillnets. Furthermore, all the information available in the present research might contribute to an integrated assessment of the fishery of this important resource resulting in the development of fisheries management models for species under the different units of effort and gear types.

The analysis of the findings of the various studies in the literature and the present investigation suggest the strong influence of the typical environmental dynamics of each latitude, whether natural or of human origin, as the main factor acting on the population dynamics of the whitemouth croaker, *Micropogonias furnieri*.

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