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OCEAN AND COASTAL RESEARCH

Length at first sexual maturity of economically important fishes in the Brazilian Northeast Coast

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Research involving fish stocks' reproductive aspects has social, economic, and biological importance; (Pinheiro, 2010; Véras and Almeida, 2016). Studies dealing with mean fish length at first sexual maturity are essential to assess and manage the exploited fish population and determine the minimum permissible size for capture, since some marine species have been overfished (King and McFarlane, 2003; Chellappa et al., 2010). According to Pinheiro (2010), the mean length at first sexual maturity represents the mean fish size when 50% of the individuals are ready to enter a new cohort, actively participating in the reproductive process.

This work's objective was to estimate the mean length at first sexual maturity of economically important fishes in the Brazilian Northeast coast, thus improving the biological understanding of these species in the light of more efficient stock management.

Samples from the following species were captured from 2013 to 2019, through artisanal fishery brought to the municipality of Raposa, in the state of Maranhão, Brazil (Figure 1): *Genyatremus luteus* (478 individuals - 182M; 296F), *Micropogonias furnieri* (190 individuals - 107M; 83F), *Oligoplites palometa* (172 individuals - 97M; 75F), *Nebris microps* (95 individuals - 36M; 59F), *Peprilus crenulatus* (84 individuals - 43M; 41F), *Trichiurus lepturus* (146 individuals - 43M; 103F), *Selene setapinnis* (102 individuals - 62M; 40F), *Bagre bagre* (123 individuals - 55M; 68F), *Lutjanus synagris* (359 individuals - 149M; 210F) and *Mugil curema* (75 individuals - 29M; 46F).

The following data were collected: total (Lt), and furcal (Lf) lengths (mm), total (Wt), and eviscerated (We) weights (g). Lengths were measured using a ruler, and weights were determined with a balance with a precision of 0.01 g. The fishes were longitudinally cut in the ventral part to remove the gonads, which were fixed in a 5% formalin solution for subsequent preservation in 70% ethanol.

The determination of young and adult specimens was done by verifying the gonad sexual maturity level according to the stages suggested by Brown-Peterson et al. (2011) and Lowerre-Barbieri et al. (2011).

The mean fish length at first sexual maturity (L50) was estimated from the accumulated curve of the frequencies of occurrence of adult specimens per length class fitted to a logistic function. The fish maturation stages were grouped in young (stage A) and adult (stages B, C, and D). The immature stage (A) was similar in both sexes characterized by the small size and light color of the gonads. The development stage (B) had a larger size than the previous one and by the macroscopic visualization of blood vessels and small oocytes. The spawning stage (C) presented larger-sized gonads with prominent blood vessels. When gonads were in the regressing stage (D), they had darker coloration and flaccidity.

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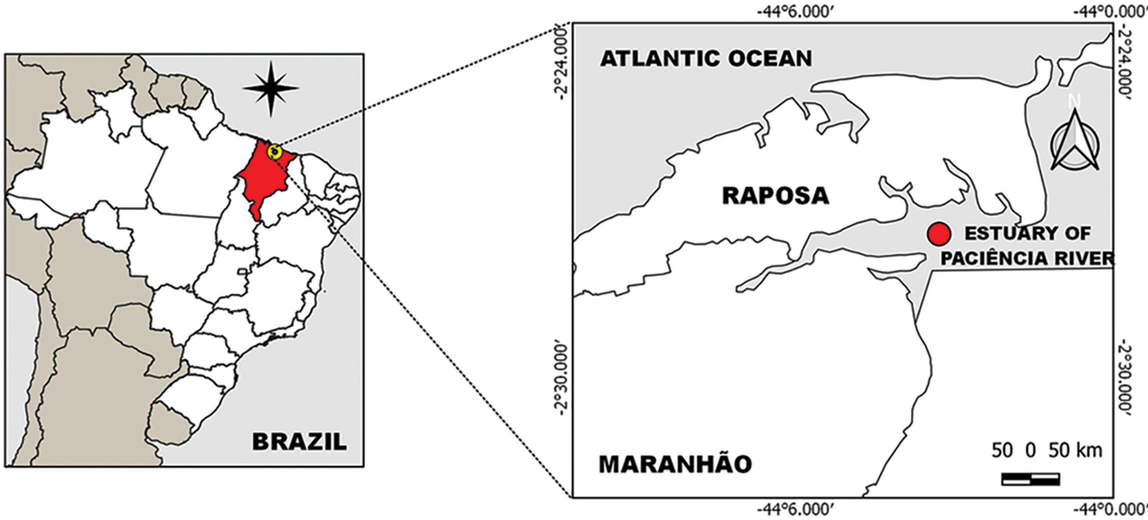

Figure 1. Location of the municipality of Raposa, in the state of Maranhão, Brazil.

The percentage of mature fish per length class was calculated and considered as dependent variable (Y), and the total length as an independent variable (X). Subsequently, the values were fitted to a logistic curve, according to the formula:

$$P = 1/(1 + \exp[-r (L - Lm)])$$

Where P is the proportion of mature specimens, r is the curve slope, L is the length, and Lm is the mean length at sexual maturity. The total length (Lt) of the specimens evaluated was used as a morphometric measure for the calculations. Protocol 037/2018 of the Ethics Committee on animal use of the State University of Maranhão was respected.

When considering fishes from both sexes that are economically important in the North Coast of Maranhão, Brazil (Table 1), the L50 indicated that 4.9% of the *T. lepturus* specimens were immature when captured. The other species evaluated presented proportions of immature specimens of 26.3% (*Nebris microps*), 34.5% (*P. crenulatus*), 31.7% (*B. bagre*), 11.6% (*M. furnieri*), 17.6% (*S. setapinnis*), 18.9% (*O. palometa*), 28% (*M. curema*), 21.7% (*G. luteus*) and 12.2% (*L. synagris*).

The species *O. palometa* (Berry and Smith-Vaniz, 1978; Duque-Nivia et al., 1995), *L. synagris* (Freitas, 2009; Lessa et al., 2004; Trindade-Santos and Freire, 2015) and *B. bagre* (Véras and Almeida, 2016) had a higher L50 than that calculated in previous studies. The species *M. furnieri* (Carneiro et al., 2005; Haimovici and Ignacio, 2005; Santos et al., 2015), *T. lepturus* (Magro, 2005; CMFRI, 2016; Costa et al., 2018) and *M. curema* (Araújo and Silva, 2013; Trindade-Santos and Freire, 2015) had similar or lower L50 compared to other studies. *S. setappinis* showed significant variation when comparing its L50 with other studies in Brazil (Bastos et al., 2005; Costa et al., 2018). *N. microps*, *G. luteus*, and *P. crenulatus* have no L50 information from previous studies.

The estimated L50 showed that most of the species presented maturing females, with sizes relatively larger than males (Table 2). However, *P. crenulatus* and *S. setapinnis* showed an opposite trend, probably because of the lack of selectivity of the fishing gears used in the captures. Based on the maturity size, management measures for these stocks should be considered by establishing a permissible capturing size. The number of specimens captured below the L50 was relatively low for all species evaluated, compared to mature fishes.

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Table 1. Variation of total length and length at first sexual maturity (L_{50}), considering both sexes of economically important fishes in the North Coast of the state of Maranhão, Brazil.

Order	Family	Species	Total length (cm)			Immature (%)	L_{50} considering both sexes (cm)
			MinLt	MaxLt	M ± SD		
Perciformes	Sciaenidae	*Nebris microps* Cuvier, 1830	23.0	36.3	30.29±3.23	26.3	23.33
	Sciaenidae	*Micropogonias furnieri* Desmarest, 1823	30.6	46.5	37.84±3.41	11.6	30.73
	Carangidae	*Oligoplites palometa* Cuvier, 1832	29.4	54.7	38.59±4.78	18.9	30.76
	Trichiuridae	*Trichiurus lepturus* Linnaeus, 1758	55.5	111.0	78.36±7.06	4.9	60.37
	Haemulidae	*Genyatremus luteus* Bloch, 1790	12.0	33.0	23.18±3.67	21.7	14.40
	Stromateidae	*Peprilus crenulatus* Cuvier, 1829	10.9	22.0	14.91±2.12	34.5	10.87
	Carangidae	*Selene setapinnis* Mitchill, 1815	13.4	42.0	27.46±5.50	17.6	24.00
	Lutjandae	*Lutjanus synagris* Linnaeus, 1758	24.9	53.0	35.24±4.68	12.2	26.13
Siluriformes	Ariidae	*Bagre bagre* Linnaeus, 1766	21.0	51.0	31.87±6.16	31.7	24.16
Mugiliformes	Mugilidae	*Mugil curema* Valenciennes, 1836	12.0	30.0	20.31±3.45	28.0	16.49

MinLt = Minimum total length; MaxLt = Maximum total length; M ± SD = Mean ± Standard deviation.

Table 2. Minimum and maximum length, at first sexual maturity (L_{50}) for male and female of commercially important fish in the North Coast of the state of Maranhão, Brazil.

Species	Male				Female			
	MinLt	MaxLt	Maturity equation	Immature (%)	MinLt	MaxLt	Maturity equation	Immature (%)
Nebris microps	23.0	35.4	y=1/(1+exp(-(0.13)*(x-(26.04))))	44.4	24.5	36.3	y=1/(1+exp(-(1.64)*(x-(25.41))))	15.5
Micropogonias furnieri	30.6	46.5	y=1/(1+exp(-(0.26)*(x-(32.97))))	7.7	32.4	42.4	y=1/(1+exp(-(0.51)*(x-(32.36))))	16.1
Oligoplites palometa	29.4	52.2	y=1/(1+exp(-(0.52)*(x-(29.91))))	11.8	33.2	54.7	y=1/(1+exp(-(0.18)*(x-(32.32))))	26.4
Trichiurus lepturus	61.0	94.0	y=1/(1+exp(-(0.02)*(x-(60.25))))	9.3	55.5	111	y=1/(1+exp(-(1.24)*(x-(67.51))))	9.7
Genyatremus luteus	13.0	33.0	y=1/(1+exp(-(2.20)*(x-(14.43))))	6.5	12.0	33.0	y=1/(1+exp(-(0.18)*(x-(16.90))))	30.7
Peprilus crenulatus	10.9	22.0	y=1/(1+exp(-(0.17)*(x-(16.24))))	51.1	11.0	20.5	y=1/(1+exp(-(3.07)*(x-(11.48))))	21.9
Selene setapinnis	13.4	42.0	y=1/(1+exp(-(2.97)*(x-(24.00))))	16.1	13.7	33.5	y=1/(1+exp(-(1.42)*(x-(22.03))))	20
Lutjanus synagris	24.9	44.0	y=1/(1+exp(-(1.08)*(x-(26.00))))	9.5	25.0	53.0	y=1/(1+exp(-(0.70)*(x-(26.27))))	16.1
Bagre bagre	22.5	51.0	y=1/(1+exp(-(0.02)*(x-(23.57))))	44.2	21.0	51.0	y=1/(1+exp(-(0.31)*(x-(24.61))))	22.1
Mugil curema	15.0	30.0	y=1/(1+exp(-(0.49)*(x-(16.07))))	27.5	12.0	29.5	y=1/(1+exp(-(0.91)*(x-(17.03))))	28.2

MinLt = Minimum total length (cm); MaxLt = Maximum total length (cm).

AUTHOR CONTRIBUTIONS

Y. B. S. N.: Formal analysis; Writing - original draft.
M. B. A.: Data curation; Formal analysis.
J. F.: Data curation; Formal analysis.
J. F. F. F.: Data curation; Formal analysis.
L. R. S.: Data curation; Formal analysis.
M. B. F. Writing - review & editing; Validation; Visualization.

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