http://dx.doi.org/10.32360/acmar.v57i1.93234
ISSN 0374-5686 e-ISSN 2526-7639
SCIENTIFIC NOTE

Arquivos de Ciências do Mar

LENGTH-WEIGHT RELATIONSHIPS OF THREATENED SHARK SPECIES FROM THE BRAZILIAN AMAZON COAST

Relações comprimento-peso de espécies de tubarões ameaçados da costa amazônica brasileira

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ABSTRACT

Length-weight relationships are valuable in fisheries biology for estimating a fish's average weight at a given length, aiding in predicting population conditions based on total biomass. This study presents length-weight relationships for six threatened shark species captured off the Brazilian Amazon Coast. The specimens of *Carcharhinus porosus*, *Carcharhinus oxyrhynchus*, *Rhizoprionodon porosus*, *Sphyrna lewini*, *Sphyrna mokarran,* and *Sphyrna tudes* were caught by commercial fleets using gillnets with a mesh size of 95-100mm in three distinct periods: from 1997 to 1999, from 2010 to 2012, and from 2018 to 2019. The values of parameter *b* ranged between 2.98 and 3.28.

Keywords: Fishery biology, artisanal fishery, allometry, elasmobranchs.

Received: 1 April 2024
Accepted for publication: 10 July 2024

RESUMO

As relações comprimento-peso são valiosas na biologia pesqueira para estimar o peso médio de um peixe em um determinado comprimento, auxiliando na previsão das condições das populações com base na biomassa total. Este estudo apresenta as relações comprimento-peso para seis espécies de tubarões ameaçados capturados na Costa Amazônica Brasileira. Os espécimes de Carcharhinus porosus*,* Carcharhinus oxyrhynchus*,* Rhizoprionodon porosus*,* Sphyrna lewini*,* Sphyrna mokarran *e* Sphyrna tudes *foram capturados por frotas comerciais utilizando redes de emalhar com malhas de 95-100 mm em três períodos distintos: de 1997 a 1999, de 2010 a 2012 e de 2018 a 2019. Os valores do parâmetro b variaram entre 2,98 e 3,28.*

Palavras-chave*: Biologia pesqueira, pesca artesanal, alometria, elasmobrânquios.*

INTRODUCTION

Length-weight relationships (LWRs) are valuable tools for investigations on fisheries biology as it allows the estimation of the average weight of a fish at a given length, enabling the prediction of populations' condition based on total biomass and condition factor metrics (Froese, 2006; Giarrizzo *et al.,* 2015). Moreover, historical data provides an essential baseline for identifying variations in fishery stocks of non-monitored species (Lessa *et al.,* 1999).

This study reports length-weight relationships for six threatened shark species found off the Brazilian Amazon Coast. Individuals of Smalltail shark *Carcharhinus porosus* (Ranzani, 1839), Daggernose shark *Carcharhinus oxyrhynchus* (Valenciennes, 1839), Caribbean sharpnose shark *Rhizoprionodon porosus* (Poey, 1861), Scalloped hammerhead *Sphyrna lewini* (Griffith & Smith, 1834), Great hammerhead *Sphyrna mokarran* (Rüppell, 1837), and Smalleye hammerhead *Sphyrna tudes* (Valenciennes, 1822), are commonly caught as bycatch in artisanal fisheries since the 1990s in the studied region, leading to sharp population declines (Lessa *et al.,* 2016; Barreto *et al.,* 2016; Santana *et al.,* 2020). Despite the critical situation, few studies have examined the weight-length relationships of sharks along the Brazilian Amazon Coast. Most research in this region has focused on distribution and abundance (Aguiar-Santos *et al.,* 2024), dietary habits (Silva & Almeida, 2001), population and reproductive structure (Lessa *et al.,* 1999), and the impacts of metals on shark health and physiology (Wosnick *et al.,* 2021).

Fisheries pressure is still present and management measures in place are rarely incorporated by commercial fleets, reducing the effectiveness of conservation strategies within this global hotspot for elasmobranch conservation (Martins *et al.,* 2018). This study provides the first length-weight relationship data for *S. tudes* and *C. oxyrhynchus*, an endemic and highly threatened species (Lessa *et al.,* 2016).

MATERIAL AND METHODS

The specimens of *Carcharhinus porosus*, *Carcharhinus oxyrhynchus*, *Rhizoprionodon porosus*, *Sphyrna lewini*, *Sphyrna mokarran,* and *Sphyrna tudes* were caught in shallow waters along the Brazilian Amazon Coast in Maranhão State. Shark catches in this region are mainly incidental, although there are instances of targeted capture for local consumption. The primary target species for these fisheries are *Cynoscion acoupa* and *Scomberomorus brasiliensis*. The specimens were caught by artisanal fishers using gillnets with a mesh size ranging from 95 to 100mm in three distinct time periods: from October 1997 to March 1999,

from September 2010 to May 2012, and from August 2018 to December 2019. The captured sharks were stored in thermal coolers with ice and transported to the Federal University of Maranhão for further analysis. The species were identified according to Compagno (1984), and all captured sharks were sexed, measured fresh for total length (in centimeters - cm) and weighted for total weight (in grams - g) immediately after catches. Biometric measurements were conducted using a digital balance and ichthyometer, with precision of 0.1 g and 0.1 cm, respectively. Sample transport was conducted with the approval of the Brazilian Ministry of Environment (IBAMA/ ICMBio- SISBIO nº. 60306-1).

The length-weight relationships were estimated using the equation: $W = aTL^b$. This equation was transformed into its logarithmic expression: $logW = \log(a) + b * \log(TL)$, where W is the total weight (g), TL is the total length (cm), a is the intercept and b is the slope of the linear regression. The LWR parameters were estimated for combined sexes and separated sexes (Table I). Scatter plots of W and TL were utilized to identify and eliminate outliers prior to conducting the regression analysis (Figure 1) (Froese, 2006). Statistical analysis was carried out using R version 4.2.2.

RESULTS

This study examined 287 sharks belonging to two families, Carcharhinidae and Sphyrnidae. The sample included 11 *C. porosus*, 48 *C. oxyrhynchus*, 202 *R. porosus*, 11 *S. lewini*, 10 *S. mokarran*, and 5 *S. tudes.* All LWR were significant, with the coefficient of determination (R^2) ranging from 0.9501 to 0.9946 (Table 1).

Table 1 – Descriptive statistics and length-weight relationship of six shark species from Brazilian Amazon Coast. The specimens were caught during three periods: from 1997 to 1999, from 2010 to 2012, and from 2018 to 2019. Codes for Conservation Status: CR (Critically Endangered); EN (Endangered); VU (Vulnerable). Codes for Sex: C (Combined); M (Male); F (Female)

Species	Conservation status*	Sex	*n*	TL range (cm)	W range (g)	*a* (Cl 95% *a*)	*b* (Cl 95% *b*)	R^2
C. porosus	CR	C	11	33.2 – 115	185 – 8930	0.0043 (0.0011 – 0.0158)	3.06 (2.74 – 3.38)	0.9790
		C	48	67.2 – 139.8	1100 – 14000	0.0017 (0.0008 – 0.0035)	3.21 (3.06 – 3.37)	0.9742
C. oxyrhynchus	CR	M	19	71 – 119.5	1100 – 8600	0.0016 (0.0031 – 0.0087)	3.22 (2.85 – 3.59)	0.9501
		F	29	67.2 – 139.8	1300 – 14000	0.0016 (0.0095 – 0.0029)	3.24 (3.11 – 3.36)	0.9906
R. porosus	VU	C	202	38 – 90.5	184 – 3440	0.0031 (0.0021 – 0.0046)	3.06 (2.98 – 3.16)	0.9557
S. lewini	CR	C	11	48 – 210	500 – 65000	0.0014 (0.0005 – 0.003)	3.28 (3.06 – 3-50)	0.9912
S. mokarran	CR	C	10	80 – 105.5	2140 – 5100	0.0019 (0.0004 – 0.0081)	3.16 (2.85 – 3.47)	0.9840
S. tudes	CR	C.	5	41 – 124	300 – 7800	0.0047 (0.0010 – 0.0212)	2.98 (2.63 – 3.33)	0.9946

Note: n: sample size; TL: total length; W: weight; range: maximum and minimum size or weight; intercept (a) and allometric coffecient (b): parameters of the equation; Cl: confidence limit 95%; R^2: coefficient of determination. *Conservation status by IUCN Red List 2023.

There were no differences in LWR between sexes, so the values were estimated for combined sexes, except for *C. oxyrhynchus*, where the analysis of covariance showed significant differences between the length-weight relationships of males and females (F= 5.40; p = 0.025). The estimated values of a for combined sexes were: 0.0043 (Cl 95%: 0.0011 – 0.0158) for *C. porosus*, 0.0017 (Cl 95%: 0.0008 – 0.0035) for *C. oxyrhynchus*, 0.0031 (Cl 95%: 0.0021 – 0.0046) for *R. porosus*, 0.0014 (Cl 95%: 0.0005 – 0.003) for *S. lewini*, 0.0019 (Cl 95%: 0.0004 – 0.0081) for

S. mokarran and 0.0047 (Cl 95%: 0.0010 – 0.0212) for *S. tudes*.

The estimated values of allometric coefficient (*b*) for combined sexes were: 3.06 (Cl 95%: 2.74 – 3.38) for *C. porosus*, 3.21 (Cl 95%: 3.06 – 3.37) for *C. oxyrhynchus*, 3.06 (Cl 95%: 2.98 – 3.16) for *R. porosus*, 3.28 (Cl 95%: 3.06 – 3.50) for *S. lewini*, 3.16 (Cl 95%: 2.85 – 3.47) for *S. mokarran* and 2.98 (Cl 95%: 2.63 – 3.33) for *S. tudes*.

For male *C. oxyrhynchus*, the values of *a* was 0.0016 (Cl 95%: 0.0031 – 0.0087) and for female, it was 0.0016 (Cl 95%: 0.0095 – 0.0029). The values of *b* for males was 3.22 (Cl 95%: 2.85 – 3.58), and female, it was 3.24 (Cl 95%: 3.11 – 3.36).

The LWR parameters, sample size, minimum and maximum length and weight for each shark species are presented in Table I. Additionaly, the LWR for each shark species is illustrated in Figure 1.

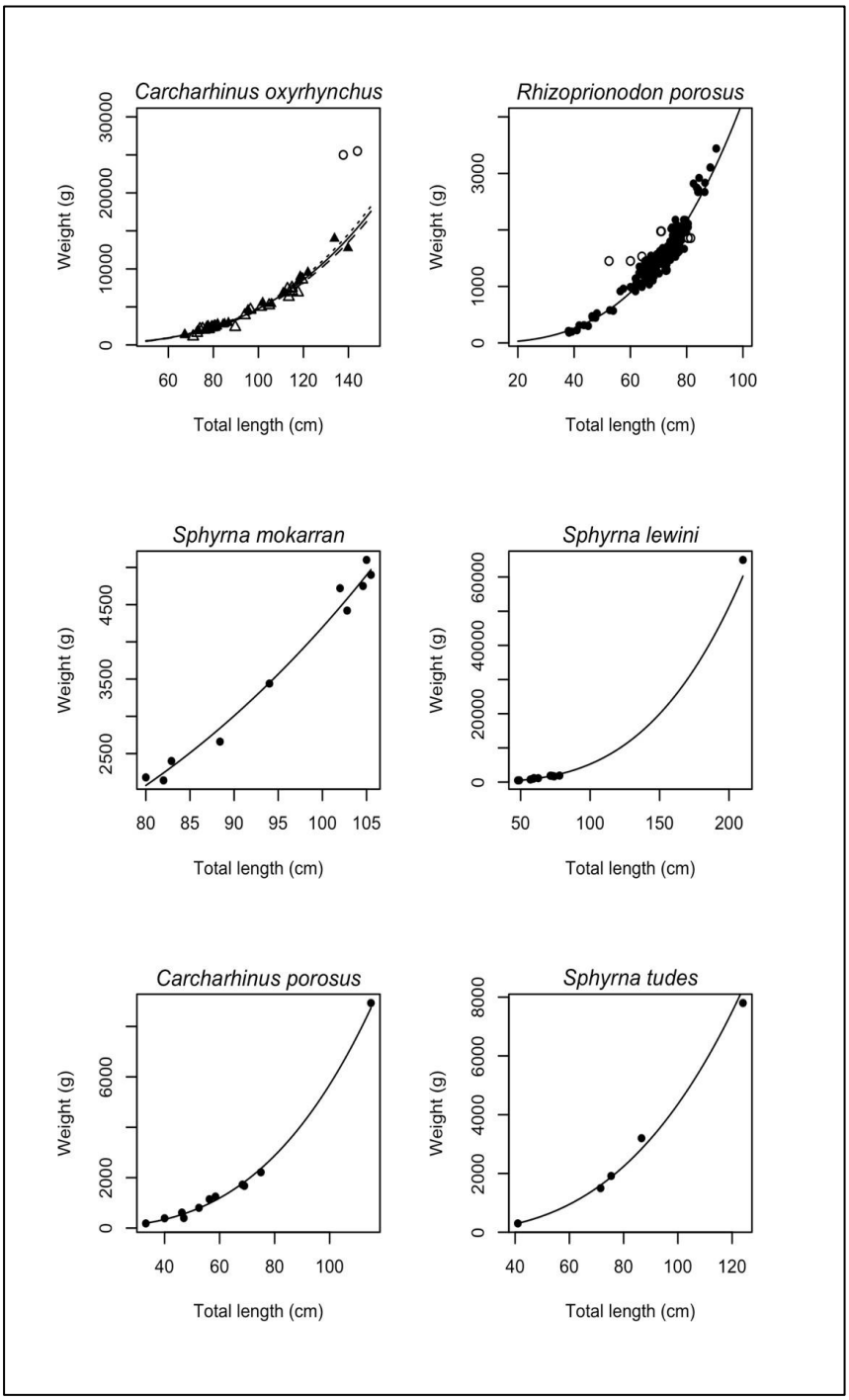

Figure 1 – Length-weight relationship of *Carcharhinus oxyrhynchus*, *Rhizoprionodon porosus*, *Sphyrna mokarran, Sphyrna lewini*, *Carcharhinus porosus*, and *Sphyrna tudes*. Black triangles represent female *C. oxyrhynchus*, while white triangles represent males. Black dots are combined sexes, and white circles are removed datapoints. The dotted line represents the model fit for *female C. oxyrhynchus*, the dashed line represents the model fit for male *C. oxyrhynchus*, and the solid line represents the model fit for combined sexes

DISCUSSION

The present analysis represents a multi-annual mean value of the LWR parameters or a mean estimation for the collecting period and do not represent a specific period or a seasonal variation in response to environmental or biological factors reflecting on the studied population. In this study, all examined species are threatened and categorized as Vulnerable or Critically Endangered according to IUCN Red List (Rigby *et al.,* 2019a, b; Pollom *et al.,* 2020b, c, a; Carlson *et al.,* 2021). Despite that, some species lack published LWR data. All estimated values of *a* and *b* fell within the expected range predicted by Froese (2006), indicating that the parameters are valid for each species within their respective length ranges.

Our results differ from some previously established estimates. For instance, Kohler *et al.* (1996) used a fork length, while Lessa *et al.* (1999) based their estimates on the weight of the eviscerated individual. It's important to note that various factors can influence these values, including sex, sexual maturity, environmental conditions, food availability, geographic region, climatic changes, and fishing pressure (Ma *et al.,* 2017).

Based on a molecular assessment, the taxonomic status of *Isogomphodon oxyrhynchus* has recently been reclassified to *Carcharhinus oxyrhynchus* (Rodrigues-Filho *et al.,* 2023). The daggernose shark *C. oxyrhynchus* is an endemic species with a restricted occurrence zone along the northern coast of South America, from Trinidad and Tobago to the Brazilian Amazon Coast (Lessa *et al.,* 1999; Wosnick *et al.,* 2019). It is a medium-sized shark with a maximum total length of 160 cm and reaches sexual maturity between 103 and 115 cm TL (Lessa *et al.,* 2000). Here, we report juvenile individuals measuring 67 cm in total length (TL) and weighing 1100 g, to mature individuals reaching almost 140 cm TL and weighing 14000 g. The average length observed is 92.4 cm TL, with an average weight of 4301 g. In the 1990s, the species was commonly caught in the region, but today it is on the verge of extinction due to fishing mortality and habitat degradation (Dulvy *et al.,* 2014; Lessa *et al.,* 2016).

The hammerhead sharks *S. lewini, S. mokarran,* and *S. tudes* are three out of the five species belonging to the Sphyrnidae family that occur in the region (Wosnick *et al.,* 2019). They are all listed as Critically Endangered by IUCN Red List (Rigby *et al.,* 2019a, b; Pollom *et al.,* 2020a). The great hammerhead, *S. mokarran,* it is the largest species of hammerhead shark, reaching a total length of up to 6 meters and sexual maturity at 210 to 300 cm (Compagno, 1984). The scalloped hammerhead, *S. lewini*, reach sexual maturity at 140 to 273 cm TL (Froese & Pauly, 2024), while *S. tudes* is one of the smallest hammerhead sharks that lives in the coastal region, and reaches sexual maturity at 80-98 cm TL (Castro, 1989). The size range of the specimens in this dataset indicates that *S. lewini* and *S. tudes* were juveniles and adults and *S. mokarran* mainly juveniles. This is likely because adult individuals tend to inhabit offshore waters while commercial fishing operations are concentrated in the coastal region (Lessa *et al.,* 1998; Piercy *et al.,* 2010). While Motta *et al.* (2014) focused on hundreds of neonates and juvenile *S. lewini* individuals from southeastern Brazil, our research extended to include adult specimens, albeit with a smaller sample size. For rare and threatened species, a low number of sample size is acceptable (Froese *et al.,* 2011). The estimated parameters in Motta's study fall within the confidence intervals estimated by us. The life history parameters of hammerhead sharks suggest that fishing mortality could potentially compromise the equilibrium of their populations (Jiao *et al.,* 2011; Giglio & Bornatowski, 2016; Ayres *et al.,* 2024).

The Caribbean sharpnose shark *R. porosus* and the smalltail shark *C. porosus* are small coastal Carcharhinidae species that have historically been caught as accessory species by artisanal fisheries on Brazilian Amazon Coast (Lessa, 1986; Lessa & Almeida, 1997; Silva & Almeida, 2001). Unlike the other four species listed here, these small coastal species reach maturity at approximately 65 cm (Machado *et al.,* 2000) and 75 cm TL (Lessa, 1986), respectively. Consequently, the specimens in this dataset include neonates, juveniles and adults. We recorded *R. porosus* individuals ranging from 38 - 90.5 cm TL and *C. porosus* individuals ranging from 33.2 - 115 cm TL. The Caribbean sharpnose shark *R. porosus* is classified as Vulnerable by IUCN Red List while *C. porosus* was recently classified as Critically Endangered after experiencing a drastic

population decline on the Brazilian Amazon Coast, with several local extinctions in the northeast and southeast regions of Brazil (Santana *et al.,* 2020).

The capture of *C. porosus*, *C. oxyrhynchus*, *S. lewini*, *S. mokarran,* and *S. tudes* is prohibited in Brazil due their threatened status on the Brazilian Red List (Brasil, 2018). However, these species are frequently captured and marketed in the study region (Feitosa *et al.,* 2018; Martins *et al.,* 2018). On the other hand, *R. porosus* is nationally listed as Data Deficient (Brasil, 2018), which means that its capture, landing, and marketing are permitted.

Obtaining biological and populational data on these threatened elasmobranchs is crucial for their management and conservation along the Brazilian Amazon Coast. The lack of information on these little-known species and the pernicious fishing pressure which they have been subjected reveal the present analysis as an important and necessary component in the management of these species.

ACKNOWLEDGEMENTS

We thankful to members of the Laboratório de Organismos Aquáticos for assistance in field work.

FUNDING

This research has been carried out by research grants of the Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Estado do Maranhão (Grant number AQUIPESCA-06605/16; BEPP-02588/23; APP-12166/22), the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES – financial code 001) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq – Postdoc Fellowship - 150413/2023-8).

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTION

J.A.S.: Conceptualization; Investigation; Formal Analysis; Writing – original draft; Writing – review & editing; **R.M.S.B.**: Writing – original draft; Writing – review & editing; **A.R.O.P.N.**: Writing – original draft; Writing – review & editing; **G.R.**: Writing – original draft; Writing – review & editing; **N.W.**: Writing – original draft; Writing – review & editing; **Z.S.A.**: Funding Acquisition **J.L.S.N**.: Supervision; Writing – review & editing; Funding Acquisition

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