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SHORT COMMUNICATION

Sexual dimorphism of sharks from the amazonian equatorial coast

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Abstract

Sexual dimorphism is a widespread feature in several groups of vertebrates. Chondrichthyans differ sexually due to the presence of the clasper, a structure for internal fertilization, and other sexual differences in secondary characteristics. Nevertheless, studies assessing these variations are fairly rare. The main goal of this study is to identify differences in sexual dimorphism in three species of sharks from the Carcharhinidae family (*Rhizoprionodon porosus, Carcharhinus porosus* and *Isogomphodon oxyrhynchus*) using morphometric tools. A total of 213 specimens were captured in the Amazonian Equatorial Coast and analyzed using 65 morphometric characters. Discriminant analysis and The Student's t-test were used to demonstrate the morphological differences among sexes. Sexual dimorphism was reported at different levels for the three species. This study suggests that the most likely explanation for the presence of these variations is related to their reproductive characteristics and mating behavior.

Keywords: sexual dimorphism; sharks; ecological features; Carcharhinidae

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Introduction

Sexual dimorphism is common among vertebrates (Kajiura et al. 2005). With regard to fishes, in mature specimens the internal differences between genders are usually clear, but externally they are not easily differentiated (Moyle & Cech 2004). Conversely, all cartilaginous fishes exhibit external sexual dimorphism brought about by the modification of males' pelvic fins. This results in a specialized structure for internal fertilization, called clasper. Beyond this evident characteristic, many other species also exhibit sexual dimorphism through other morphological features (Orlov et al. 2010, Orlov & Cotton 2011).

Males and females of the same species may respond differently to selective pressures (Filiz & Taşkavak 2006). In the case of elasmobranchs, the differences between males and females include variations in their external reproductive anatomy, body size (Compagno 1984, Carlson & Parsons 1997), dental formula (Kajiura et al. 1996), number and distribution of Ampullae of Lorenzini (Crooks & Waring 2013a), and dermal thickness (Kajiura et al. 2000, Crooks & Waring 2013b).These morphological differences can impact ecological aspects such as foraging, competition, and habitat use (Ellis & Shackley 1995, Piorski & Nunes 2001). Also, males and females of the same elasmobranch species show different behaviors during mating (Gointein et al. 1998). Nonetheless, these variations in intra-specific secondary sexual characteristics have been poorly studied worldwide (Kajiura 2000, Filiz & Taşkavak 2006). The Amazonian Equatorial Coast, one of the elasmobranchs conservation hotspots of the world (Dulvy et al. 2014), is no exception.

It is known that *Rhizoprionodon porosus* and *Carcharhinus porosus* are the most abundant elasmobranch catches in Maranhão state (Almeida et al. 2011) and that *Isogomphodon oxyrhynchus* is an endemic species of the coastal waters off northern South America. These species are listed as critically endangered by the Brazilian government (ICMBIO 2012) but are still captured in some of these areas (Lessa et al. 2006, Rodrigues-Filho et al. 2012). Despite their importance for the local ecosystem and the high fishing economic value in the state, information on the biology and ecology of the shark species of this region is not widely available.

Since updated data about these species is scarce and consistent knowledge is required for developing management strategies for local species, this study aims to evaluate the presence of sexual dimorphism within three Carcharhinidae sharks captured off the coast of Maranhão state, Amazonian Equatorial Coast, Brazil.

Materials and methods

Area of study: The coastline of Maranhão is the second most extensive in Brazil, with a length of 640 km. The west side of the coastline belongs to the Amazonian Equatorial Coast and is characterized by the presence of recesses with excessively drained river valleys formed by the influence of fluvial estuarine bays (Muehe 2006). As a result, the region has high turbid waters, exuberant mangroves, and rich biotic communities (Souza-Filho 2005) (**Figure 1**).

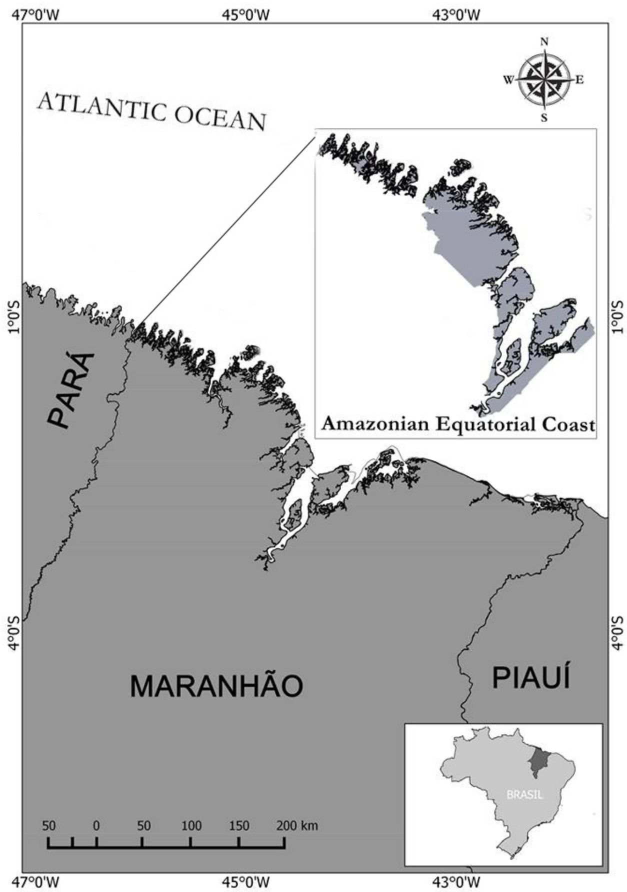

Fig. 1. Map of the coast of Maranhão State, Brazil.

Sampling. morphometric measurements and data analysis: The specimens were caught between October 1997 and March 1999 in shallow waters along the Amazonian Equatorial Coast of Maranhão using gillnets with a mesh size of 95-100mm. The sharks were stored in thermal coolers with ice and taken to the Ichthyology Laboratory of the *Universidade Federal do Maranhão* (Federal University of Maranhão) for morphometric analysis. The taxonomic identification was carried out using specialized literature (Compagno 1984).

Using a caliper and metric tape and applying the Piorski et al. (2010) protocol adapted from Compagno (1984), 65 morphometric characteristics were measured in various sized specimens of three shark species: *Carcharhinus porosus* (50 females with size range: 41.1 – 89.6 cm and 20 males with size range: 42.3 – 91.1 cm), *Rhizoprionodon porosus* (11 females with size range: 47. 6 – 83.5 cm and 58 males with size range: 52.3 – 85.7 cm), and *Isogomphodon oxyrhynchus* (44 females with size range: 40.6 – 144.0 cm and 30 males with size range: 70.4– 115.0 cm) (**Table 1**) .

In order to annul the effect of specimen size, the morphometric measurements were transformed using the Isometric Burnaby method, which projects a series of measured distances within an orthogonal space. The data set was divided into three categories: head, body, and fins. The discriminant analysis (DA) was used to distinguish the differences between sexes in a dependent non-metric variable that characterized the several known classes. Therefore, the objective is to understand the differences between the sexes and predict the probability of an individual belonging

Table 1. Morphometric measures taken from shark species of the Carcharhinidae family caught in the State of Maranhão, Brazil. Ac = Acronyms.

Head measures	Ac	Fin measures	Ac	Body measures	Ac
Upper labial fold	ULF	D1 base	D1B	Total length	TL
Lower labial fold	LLF	Posterior margin D1	PMD1	Fork length	FL
Mouth width	MW	Anterior margin D1	AMD1	Snout to nostrils	S_N
Mouth length	ML	Internal margin D1	IMD1	Snout to orbit	S_O
Inter-orbital	IO	D1 height	D1H	Snout to mouth	S_M
Orbit diameter	OD	Free margin D1	FMD1	Snout to 1st gill slits	S1G
Inter-nostril internal distance	INI	D2 base	D2B	Snout to 2nd gill slits	S2G
Inter-nostril	IN	Posterior margin D2	PMD2	Snout to 3rd gill slits	S3G
		Anterior margin D2	AMD2	Snout to 4th gill slits	S4G
		Internal margin D2	IMD2	Snout to 5th gill slits	S5G
		D2 height	D2H	Snout to pectoral fin origin	SP1FO
		Anal base	AB	Snout to pectoral fin, end of base	SP1FE
		Posterior margin Anal	PMA	Snout to pelvic fin origin	SP2FO
		Anterior margin Anal	AMA	Snout to 1st dorsal fin origin	SD1FO
		Internal margin Anal	IMA	Snout to 2nd dorsal fin origin	SD2FO
		Anal height	AH	Snout to anal fin origin	SAFO
		Pectoral base	PB	Snout to upper caudal fin	SUCF
		Posterior margin P1	PMP1	Snout to lower caudal fin	SLCF
		Anterior margin P1	AMP1	Inter-dorsal fins	ID
		Internal margin P1	IMP1	Pectoral to pelvic fin	PP2
		Pelvic base	P2B	Pelvic to anal fin	P2A
		Posterior margin P2	PMP2	2nd dorsal to anal fin	D2A
		Anterior margin P2	AMP2	Anal to caudal fin	AC
		Internal margin P2	IMP2	1st gill slits length	1GL
		Dorsal caudal fin lobe	DCFL	3rd gill slits length	3GL
		Ventral caudal fin lobe	VCFL	5th gill slits length	5GL
		Notch of the caudal fin's length	NCFL	Width of the trunk in the pectoral fin origins	WTP1O
		Notch of the caudal fin's depth	NCFD	Height of the trunk in the pectoral fin origins	HTP1O
				1st to 5th gill slits	1-5G

to a particular sex by using the independent metric variables. This analysis was performed using the Paleontological Statistics Software (PAST) Package for education and data analysis, version 3 (Hammer et al. 2001). After normality of the data and homogeneity of the variances were verified, all variables were also tested dichotomously between sexes in order to detect possible sexual dimorphisms, with the Student's t-test considering a significance of 0.05. This analysis was performed using the program R (R Core Team 2013).

Results and discussion

A total of 213 specimens were caught in shallow waters of Maranhão state, Amazonian Equatorial Coast. The discriminant analysis for *Isogomphodon oxyrhynchus* showed no significant difference among the head measurements between sexes, while the measurements of body and fins resulted in discriminant effects (DA(HEAD) = 0.711, p = 0.7332, DA(BODY) = 7.57, p < .0001, DA(FINS)= 16.124, p < .0001). This species showed

Table 2. Results of t-student test for *Rhizoprionodon porosus* and *Carcharhinus porosus*. F – Female, M – Male, SD - standard deviation, T – t-test result and p – p-value (considered significant if p<0.05).

R. porosus	Variable	F	SD	M	SD	T	p	Variable	F	SD	M	SD	T	p
	ULF	1.276	±0.183	1.610	±0.277	-3.75	0.0005	3GL	1.467	±0.103	2.002	±0.278	-4.62	<.0001
	LLF	0.817	±0.098	1.121	±0.176	-4.12	0.002	5GL	1.067	±0.051	1.545	±0.308	-3.76	<.0001
	MW	3.100	±0.253	4.200	±0.679	-3.90	0.0003	D1B	5.250	±0.207	6.493	±0.697	-4.30	<.0001
	ML	4.017	±0.495	5.441	±0.741	-4.54	<.0001	PMD1	5.450	±0.301	6.524	±1.028	-2.52	<.0001
	IO	4.800	±0.456	6.619	±0.746	-5.79	<.0001	AMD1	6.483	±0.479	8.000	±0.755	-4.76	<.0001
	IN	2.850	±0.242	3.750	±0.375	-5.67	<.0001	D1H	5.417	±0.360	6.112	±0.498	-3.28	0.0020
	S_N	2.817	±0.348	3.671	±0.390	-5.07	<.0001	D2B	1.633	±0.280	2.088	±0.230	-4.40	<.0001
	S_O	4.817	±0.213	5.912	±0.526	-5.00	<.0001	PMD2	2.783	±0.040	3.626	±0.400	-5.10	<.0001
	S_B	4.550	±0.197	5.536	±0.488	-4.85	<.0001	AMD2	1.900	±0.400	2.205	±0.223	-2.81	0.0072
	S1G	10.450	±0.595	13.486	±1.480	-4.93	<.0001	IMD2	2.433	±0.413	3.188	±0.339	-4.97	<.0001
	S2G	10.983	±0.577	14.188	±1.544	-4.99	<.0001	D2H	1.317	±0.183	1.710	±0.309	-3.02	0.0041
	S3G	11.567	±0.575	14.945	±1.644	-4.95	<.0001	AB	2.717	±0.098	3.229	±0.407	-3.04	<.0001
	S4G	12.117	±0.624	15.648	±1.687	-5.04	<.0001	PMA	3.167	±0.121	3.843	±0.419	-3.90	<.0001
	S5G	12.583	±0.624	15.017	±1.878	-4.41	<.0001	AMA	2.400	±0.328	2.929	±0.269	-4.37	<.0001
	SP1FE	14.283	±0.682	18.000	±1.969	-4.55	<.0001	AH	1.783	±0.229	2.045	±0.288	-2.13	0.0386
	SP2FO	25.850	±1.893	32.712	±3.224	-5.06	<.0001	PB	3.233	±0.287	3.881	±0.422	-3.62	<.0001
	SD1FO	17.133	±0.880	22.252	±2.366	-5.21	<.0001	PMP1	5.183	±0.895	6.636	±0.626	-5.04	<.0001
	SD2FO	35.633	±1.894	45.890	±6.723	-3.68	<.0001	AMP1	7.283	±0.457	9.248	±0.950	-4.94	<.0001
	SAFO	34.050	±1.923	44.798	±4.512	-5.72	<.0001	IMP1	2.567	±0.051	3.036	±0.304	-3.73	0.0005
	SUCF	41.817	±2.487	55.086	±6.369	-5.01	<.0001	P2B	2.650	±0.207	3.293	±0.343	-4.44	<.0001
	SLCF	41.067	±2.631	54.350	±6.174	-5.16	<.0001	PMP2	2.450	±0.137	2.898	±0.322	-3.34	0.0017
	ID	13.733	±0.833	18.462	±2.048	-5.55	<.0001	AMP2	2.633	±0.206	3.393	±0.389	-4.66	<.0001
	PP2	12.533	±1.506	15.831	±1.560	-4.86	<.0001	IMP2	3.133	±0.216	2.279	±0.325	6.22	<.0001
	P2A	6.450	±1.459	8.983	±1.156	-4.87	<.0001	DCFL	15.500	±0.784	18.01	±2.350	-2.57	0.0134
	D2A	4.767	±0.680	6.210	±0.687	-4.81	<.0001	VCFL	6.583	±0.778	8.157	±0.580	-5.96	<.0001
	AC	4.967	±0.582	6.355	±0.713	-4.54	<.0001	NCFD	1.750	±0.083	1.917	±0.139	-2.84	0.0067
	1GL	1.083	±0.040	1.479	±0.190	-5.02	<.0001							

only three significant variations (Paired t test, tP2A = -3.47, p = 0.0009; tPMP2 = 2.29, p = 0.0253; tIMP2 = 9.07, p < 0.0001) in the t-test analysis conducted for each of the 65 morphometric measurements.

Distinctions between sexes for the *Rhizoprionodon porosus* were identified by all the discriminant analysis. Significant head, body, and fin measurements were obtained (DA(HEAD) = 3.641, p = 0.0013, DA(BODY) = 3.509, p = 0.0036, DA(FINS) = 68.176, p < .0001). The t-test result identified 53 significantly distinct morphometric measurements among males and females (**Table 2**). Concerning *Carcharhinus porosus*, only the head measurements were statistically significant in the discriminant analysis, while the measures of body and fins were not (DA(HEAD) = 3.578, p = 0.0091, DA(BODY) = 1.319, p = 0.3726, DA(FINS) = 1.975, p = 0.5174). The t-test showed 54 morphometric measurements significantly different between males and females (Table 2).

C. porosus	Variable	F	SD	M	SD	T	p	Variable	F	SD	M	SD	T	p
	SLS	0.300	±0.081	0.200	±0.077	3.29	0.0027	5GL	1.695	±0.297	1.391	±0.144	3.16	0.0037
	MW	4.063	±0.501	3.118	±0.543	4.83	<.0001	D1B	6.900	±0.952	5.346	±0.621	4.83	<.0001
	ML	5.442	±0.683	4.182	±0.485	5.37	<.0001	PMD1	7.558	±1.186	5.546	±0.747	5.06	<.0001
	IO	6.353	±0.931	4.946	±0.965	3.93	0.0005	AMD1	7.979	±1.208	6.182	±0.702	4.49	0.0001
	IN	3.468	±0.400	2.682	±0.651	4.12	0.0003	FMD1	3.537	±0.450	2.455	±0.317	7.01	<.0001
	S_N	3.821	±0.369	3.082	±0.312	5.58	<.0001	D1H	6.253	±1.053	4.573	±0.703	4.70	<.0001
	S_O	6.100	±0.597	4.882	±0.666	5.16	<.0001	D2B	2.258	±0.403	1.846	±0.206	3.15	0.0039
	S_B	5.151	±0.539	4.718	±0.599	3.72	0.0009	PMD2	3.074	±0.506	2.373	±0.431	3.85	0.0006
	S1G	17.911	±2.213	14.645	±1.427	4.38	0.0002	IMD2	2.737	±0.321	2.027	±0.195	6.61	<.0001
	S2G	13.611	±1.600	11.100	±1.097	4.58	<.0001	D2H	1.753	±0.412	1.273	±0.190	3.62	0.0012
	S3G	14.363	±1.710	11.700	±1.192	4.55	<.0001	AB	2.879	±0.404	2.218	±0.240	4.91	<.0001
	S4G	15.047	±1.750	12.282	±1.226	4.61	<.0001	PMA	2.790	±0.546	2.146	±0.344	3.51	0.0015
	S5G	15.721	±1.808	12.900	±1.253	4.56	<.0001	AMA	3.442	±0.567	2.773	±0.337	3.55	0.0014
	SP1FO	14.389	±1.938	12.100	±1.141	3.56	0.0013	IMA	2.642	±0.365	1.973	±0.214	5.52	<.0001
	SP1FE	17.911	±2.213	14.645	±1.427	4.38	0.0002	AH	2.247	±0.453	1.573	±0.214	4.61	<.0001
	SP2FO	30.674	±4.610	24.209	±2.364	4.3	0.0002	PB	4.190	±0.628	3.303	±0.234	5.27	<.0001
	SD1FO	19.711	±2.360	16.455	±1.496	4.11	0.0003	PMP1	8.105	±1.425	5.755	±0.759	5.05	<.0001
	SD2FO	40.400	±6.231	32.300	±3.323	3.98	0.0004	AMP1	9.221	±2.290	7.400	±0.883	2.52	0.0179
	SAFO	39.000	±6.001	31.218	±3.212	3.96	0.0005	IMP1	3.447	±0.545	2.709	±0.298	4.13	0.0003
	SUCF	46.763	±6.045	38.073	±3.921	4.26	0.0002	P2B	3.205	±0.458	2.436	±0.459	4.42	0.0001
	SLCF	45.558	±5.952	37.145	±3.872	4.19	0.0003	PMP2	3.253	±0.489	3.436	±0.528	3.85	0.0006
	ID	14.458	±1.993	11.573	±1.358	4.25	0.0002	AMP2	3.663	±0.409	2.736	±0.429	5.87	<.0001
	PP2	13.053	±1.961	10.673	±1.149	3.66	0.0010	IMP2	3.984	±0.600	1.709	±0.661	9.64	<.0001
	D2A	4.726	±0.688	4.109	±0.568	2.51	0.018	DCFL	15.800	±1.958	12.99	±1.497	4.10	0.0003
	AC	4.942	±0.708	4.191	±0.678	2.84	0.083	VCFL	7.726	±1.192	6.218	±0.625	3.88	0.0006
	1GL	1.503	±0.339	1.227	±0.161	2.54	0.0168	ANCFL	4.500	±0.785	3.491	±0.493	3.83	0.0007
	3GL	2.068	±0.351	1.627	±0.190	3.83	0.0007	NCFD	2.258	±0.285	1.864	±0.283	3.65	0.0011

The presence and absence of variations found in the three species could be related to different factors. According to Navarro et al. (2013) foraging specialization occurs between sexes within marine predators, including sharks. This could result in the development of distinctive features for each sex, which can arise in response to an increase in the competition for food resources (Wearmouth & Sims 2008). However, we discard this factor for two reasons: (1) *I. oxyrhynchus* showed no differences in head measurements, the area most related to this process. This suggests that if differences in dietary habits existed, they were not sufficient to derive any morphological variations among sexes of this species; (2) The several studies that have evaluated feeding habits in Maranhão's coast have not found any sexually dimorphic diets for these three species (Lessa & Almeida 1997, Lessa et al. 1999, Silva & Almeida 2001, Almeida et al. 2011).

Another factor related to sexual dimorphism is body size. Sexual dimorphism expressed in body size is common among viviparous and ovoviviparous shark species (Sims 2003). According to Lessa et al. (2000), Machado et al. (2000), and Santos et al. (2000) females of the three species studied, as the vast majority of shark species, tend to be larger than males. This is the case for *I. oxyrhynchus* and *R. porosus*, whose differences in body size can be related to the reproductive pattern of shark females. Females have larger energy expenditure than males due to the selection pressure for large offspring (Sims 2003). Additionally, males and females may present different growth rates as juveniles, which directly influences body size (Lessa et al. 2000). This hypothesis was also discarded given that the results were presented with the size effects standardized, preventing the size of the individuals from influencing the results.

In the present study, fin measurements for *R. porosus* and *I. oxyrhynchus* showed significant variations. Likewise, head measurements for *R. porosus* and *C. porosus* also demonstrated significant values. Due to the lack of documented ecological data for these species it is hard to assess the more likely cause for these results. It is hypothesized that the distinction of head and fins may be related to reproductive behavior. According to Crooks & Waring (2013a) sharks usually display a complex pattern of reproductive behavior in which the male has to bite one of the female's fins to enable copulation. The differences found may suggest adaptations of the male's head to bite and of the female's fins to receive these bites.

The t-test results for males and females of *R. porosus* and *C. porosus* showed the same morphological patterns. According to Lessa (1997), these species are very similar morphologically, which makes it difficult to distinguish Them taxonomically, thus explaining these similar results. The t-test result for *I. oxyrhynchus* was significant only for the pelvic area and may be related to the parturition and copulation processes. All three species analyzed were viviparous, and therefore had the same pelvic measurements with statistically significant values. as expected due to the known sexual dimorphism in primary characters of sharks.

Conclusion

A possible cause for the variations in the external morphology among males and females of *I. oxyrhynchus*, *R. porosus* and *C. porosus* is their reproductive patterns. It is clear that in order to further elucidate and test this hypothesis, further research on reproductive and behavioral features for each species must be carried out. This study revealed important details about the sexual dimorphism of *Isogomphodon oxyrhynchus*, *Rhizoprionodon porosus* and *Carcharhinus porosus* through morphometric analysis, and will help facilitate the development of future studies in the area.

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Conflicts of interest

The authors certify that there are no conflicts of interest related to Individual Authors' Commitments, Project Support, Commitments of Editors, Journal Staff, or Reviewers. The authors also certify that they have NO affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

References

Almeida ZS, Frédou FL, Nunes JLS, Lessa RP, Pinheiro ALR (2011) Biodiversidade de elasmobrânquios. In: Nunes JLS & Piorski NM (eds) Peixes marinhos e estuarinos do Maranhão. Editora Café e Lápis, Brasil, pp 37-94

Carlson J K, Parsons GR (1997) Age and growth of the bonnethead sharks, *Sphyrna tiburo*, from northwest Florida, with comments on clinal variation. *Environmental Biology of Fishes* 50:331–341

Compagno LJV (1984) FAO species catalogue: Sharks of the world, an annotated and illustrated catalogue of shark species known to date. *FAO Fisheries Synopsis* 125(4) Part 2:251–655

Crooks N, Waring CP (2013a) A study into the sexual dimorphisms of the Ampullae of Lorenzini in the lesser-spotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758). *Environmental Biology of Fishes* 96:585–590 doi: 10.1007/s10641-012-0048-8

Crooks N, Waring CP (2013b) Sexual dimorphisms in the dermal structure of the lesser-spotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758). *Acta Zoologica* 94:331–334 doi: 10.1111/j.1463-6395.2012.00560.x

Dulvy NK, Fowler SL, Musick JA, Cavanagh RD, Kyne PM et al. (2014) Extinction risk and conservation of the world's sharks and rays. *eLife3*:e00590 doi: 10.7554/eLife.00590.001

Ellis JR, Shackley SE (1995) Onthogenetic changes and sexual dimorphism and the head, mouth and teeth of the lesser spotted dogfish. *Journal of Fish Biology* 47(1):155-164

Filiz H, Taşkavak E (2006) Sexual dimorphism in the head, mouth, and body morphology of the smallspotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758) (Chondrichthyes: Scyliorhinidae) from Turkey. *Acta Adriatica* 47(1):37–47

Gointein R, Torres FS, Signorini CE (1998) Morphological aspects related to feeding of two marine skates *Narcine brasiliensis* Olfers and *Rhinobatos horkelli* Muller & Henle. *Acta Scientiarum* 20(2):165-169

Hammer O, Harper DAT, Ryan PD (2001) PAST: Paleontological Statistics Software Package for Education and Data Analysis http://palaeoelectronica.org/2001_1/past/issue1_01.htm. Retrieved November 12 2014

ICMBIO 2012. Avaliação Científica do Risco de Extinção da Fauna Brasileira – Resultados Alcançados em 2012

Kajiura SM, Tricas TC (1996) Seasonal dynamics of dental sexual dimorphism in the Atlantic stingray, *Dasyatis sabina*. *Journal of Experimental Biology* 199:2297–2306

Kajiura SM, Sebastian AP, Tricas TC (2000) Dermal bite wounds as indicators of reproductive seasonality and behaviour in the Atlantic stingray, *Dasyatis sabina*. *Environmental Biology of Fishes* 58:23–31

Kajiura SM, Tyminski JP, Forni JB, Summers AP (2005) The Sexually Dimorphic Cephalofoil of Bonnethead Sharks, *Sphyrna tiburo*. *Biological Bulletin* 209:1–5

Lessa RP (1997) Sinopse dos estudos sobre elasmobrânquios da costa do Maranhão. *Boletim do Laboratório de Hidrobiologia* 10:19-36

Lessa RP, Almeida ZS (1997) Analysis of stomach contents of the small tail shark, *Carcharhinus porosus*, from northern Brazil. *Cybium* 21(2):123-133

Lessa RP, Santana FM (1998) Age determination and growth of the small tail shark, *Carcharhinus porosus*, from northern Brazil. *Marine and Freshwater Research* 49:705–11

Lessa RP, Batista V, Almeida ZS (1999) Occurrence and biology of the daggernose shark *Isogomphodon oxyrhynchus* (Chondrichthyes: Carcharhinidae) off the Maranhão coast (Brazil). *Bulletin of Marine Science* 64(1):115-128

Lessa RP, Santana FM, Batista V, Almeida ZS (2000) Age and growth of the daggernose shark, *Isogomphodon oxyrhynchus*, from northern Brazil. *Marine and Freshwater Research* 51:339–47

Lessa RP, Charvet-Almeida P, Santana FM, Almeida ZS (2006) *Isogomphodon oxyrhynchus*. The IUCN Red List of Threatened Species Version 2014.2. www.iucnredlist.org. Retrieved August 31 2014

Machado MRB, Almeida ZS, Castro ACL (2000) Estudo da biologia reprodutiva de *Rhizoprionodon porosus* Poey 1861 (Pisces – Elasmobranchii - Carcarhinidae) na plataforma continental do estado do Maranhão, Brasil. *Boletim do Laboratório de Hidrobiologia* 13: 51-65

Moyle PB, Cech J J (2004). Fishes: an introduction to ichthyology. Upper Saddle River, NJ: Pearson Prentice Hall, 726 p.

Muehe D (2006) Erosão e Progradação do Litoral Brasileiro. *Ministério do Meio Ambiente*, D.F., Brasil.

Navarro J, Coll M, Preminger M, Palomera I (2013) Feeding ecology and trophic position of a Mediterranean endemic ray: consistency between sexes, maturity stages and seasons. *Environmental Biology of Fishes* 96:1315–1328 doi: 10.1007/s10641-013-0109-7

Orlov AM, Cotton CF, Shevernitsky DA (2010) Sexual Dimorphism of External Morphological Characters in Some Deepwater Skates (Rajidae, Rajiformes, Chondrichthyes) of the North Atlantic. *Moscow University Biological Sciences Bulletin* 65(1):40–44 doi: 10.3103/S0096392510010086

Orlov AM, Cotton CF (2011) Sexually dimorphic morphological characters in five north Atlantic deepwater skates (Chondrichthyes: Rajiformes). *Journal of Marine Biology* 2011:1-18 doi: 10.1155/2011/842821

Piorski NM, Nunes JLS (2001) Dimorfismo sexual e tendência alométrica de *Urotrygon microphthalmum* Deslman, 1941 (Elasmobranchii: Urolophidae). *Boletim do Laboratório de Hidrobiologia* 13:67-81

R Core Team (2013) R: A language and environment for statistical computing. R Foundation for Statistical Computing

Rodrigues-Filho LF, Pinhal D, Sodré D, Vallinoto M (2012) Shark DNA Forensics: Applications and Impacts on Genetic Diversity. *Analysis of Genetic Variation in Animals* 269-286

Santos CRC, Almeida ZS, Castro ACL, Machado MRB (2000) Biologia reprodutiva de *Carcharhinus porosus* Razani 1839 (Condrichthyes, Elasmobranchii) em águas rasas maranhenses. *Boletim do Laboratório de Hidrobiologia* 12:49-63

Silva CML, Almeida ZS (2001) Alimentação de *Rhizoprionodon porosus* (Elasmobranchii: Carcharhinidae) da costa do Maranhão, Brasil. *Boletim do Instituto de Pesca* 27(2):201-207

Sims DW (2003) Tractable models for testing theories about natural strategies: foraging behaviour and habitat selection of free-ranging sharks. *Journal of Fish Biology* 63(A):53-73

Souza Filho PWM (2005) Costa de manguezais de macromaré da Amazônia: Cenários morfológicos, mapeamento e quantificação de áreas usando dados de sensores remotos. *Revista Brasileira de Geofísica* 23(4):427-435

Wearmouth VJ, Sims DW (2008) Sexual segregation in marine fish, reptiles, birds and mammals behaviour patterns, mechanisms and conservation implications. *Advances in Marine Biology* 54:107–70 doi: 10.1016/S0065-2881(08)00002-3

Dimorfismo sexual de tiburones de la costa ecuatorial amazónica

Resumen. El dimorfismo sexual es una característica presente en diversos grupos de vertebrados. Machos y hembras de Chondrichthyes se identifican fácilmente por la presencia de una estructura para la fertilización interna, el clasper, y otras pequeñas diferencias en las características secundarias. Sin embargo, los estudios que evalúan estas variaciones en la morfología entre los sexos son poco frecuentes. El objetivo de este trabajo es identificar el dimorfismo sexual en tres especies de tiburones de la familia Carcharhinidae (*Rhizoprionodon porosus, Carcharhinus porosus* y *Isogomphodon oxyrhynchus*) con el uso de herramientas morfométricas. Se capturaron un total de 213 ejemplares en la costa Ecuatorial Amazónica y fueran analizados utilizando 65 caracteres morfométricos. Fueran aplicadas análisis discriminantes y prueba t-student para mostrar las diferencias morfológicas entre los sexos. Se observó dimorfismo sexual en diferentes niveles para las tres especies. Sugerimos que la explicación más probable para la presencia de estas variaciones está relacionada con las características reproductivas y el comportamiento de cópula.

Palabras clave: dimorfismo sexual, tiburones, aspectos ecológicos; Carcharhinidae

Dimorfismo sexual de tubarões da costa equatorial amazônica

Resumo. O dimorfismo sexual é uma característica presente em vários grupos de vertebrados. Machos e fêmeas de Chondrichthyes são facilmente identificados pela presença de uma estrutura para a fertilização interna, o clasper, além de outras diferenças em características secundárias. No entanto, estudos que avaliam estas variações na morfologia externa entre os sexos são raros. O principal objetivo deste estudo é identificar dimorfismo sexual em três espécies de tubarão da família Carcharhinidae (*Rhizoprionodon porosus, Carcharhinus porosus* e *Isogomphodon oxyrhynchus*) através do uso de ferramentas morfométricas. Um total de 213 espécimes foi capturado na costa Equatorial Amazônica e analisado através de 65 caracteres morfométricos. Análises discriminantes e teste t-student foram aplicados para evidenciar as diferenças morfológicas entre os sexos. Nós observamos dimorfismo sexual, em diferentes níveis, para as três espécies estudadas e sugerimos que a causa mais provável para a presença de tais variações está relacionada a características reprodutivas e comportamentos copulatórios.

Palavras-chave: dimorfismo sexual, tubarões, aspectos ecológicos, Carcharhinidae