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ECOSYSTEMS

Fishing profile and commercial landings of shark and batoids in a global elasmobranchs conservation hotspot

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Abstract: This paper describes the fishing profile and the temporal variation in the commercial landings of elasmobranchs in a global hotspot for their conservation and investigates the variables that influenced the landings. Census data on commercial catches were obtained between April 2008 and October 2010 from nine landing sites in Bragança (Pará, northern Brazil). Five vessel types, four fishing gears, and eight fishing techniques engaged with elasmobranch capture were identified. A total of 2,357 landings were recorded, with a total production of 354 t. The highest yields were recorded in 2009, with sharks being harvested mostly by small and medium-sized vessels, and batoids, by small vessels and canoes. Drifting nets and longlines played a prominent role in elasmobranch fisheries. The results show that the landings were influenced by days at sea, which is common in tropical fisheries. The elasmobranch data series is discontinuous as statistics are absent for most fishing sites albeit imperative for proper management, as well as relevant for decision-makers focusing on their conservation.

Key words: Amazon, artisanal fisheries, fisheries management, fisheries statistics, northern Brazil.

INTRODUCTION

The Amazon estuary is characterized by four seasons: rainy, from March to May attaining its maximum annual discharge; drying between June and August; dry, with little rainfall, between September and November; rising waters from December to February (Nittrouer et al. 1995).

The effects of the hydrological cycle on fishing activity are evident and characterize complex processes involving fleet operations and catch composition (Bentes et al. 2012). Marine species are caught more intensely during dry season, leading to an increased salinity in the coastal areas where the majority of small-scale fisheries operates (Cattani et al. 2022, Gamarra et al. 2023).

Northern Brazil (comprising the States of Amapá, Pará and Maranhão) has been identified as an important global hotspot for elasmobranch (Dulvy et al. 2014) and exhibits the highest rates of incidental capture of elasmobranchs in the country (Oliver et al. 2015). More specifically, sharks and batoids constitute of gillnet bycatch targeting the spanish mackerel *Scomberomorus brasiliensis*, the smooth weakfish *Cynoscion leiarchus*, the acoupa weakfish, *Cynoscion acoupa* (Lessa et al. 1999), the laulao catfish *Brachyplatystoma vaillantii* (Lessa et al. 1999), and the gillbacker sea-catfish *Sciades parkeri* (Pinheiro & Fredóu 2004), main target species in the area.

Nowadays, sharks and batoids are among the vertebrates with the highest risk of extinction, due to finning fishing, habitat degradation, pollution and climate changes (Dulvy et al. 2014, Pacoureau et al. 2021). Currently, 36% of the threatened all species are sharks and batoids, and most of the countries in which elasmobranch overfishing is detected do not have efficient legal measures to properly manage their stocks (Barreto et al. 2017).

In Brazil, elasmobranch fishing is an extremely profitable activity, as the country is the first importer and eleventh producer of shark meat worldwide. However, low-income coastal communities depend on this low-cost protein for their livelihood (Barreto et al. 2017).

Although the fishing statistics in the region are scarce and discontinuous, they indicate an increasing fishing effort in the last decades and so elasmobranch stocks are in substantial decline (Martins et al. 2018). In addition to the need of monitoring commercial landings, it is also necessary to determine the profile of the operating fishing fleets in order to generate subsidies for decision making taking into account not only the landings and fishing gears, but its dynamics, reaching and fishing power.

In this context, this paper describes the fishing profile and the temporal variation in the commercial landings of elasmobranchs in a global hotspot for their conservation.

MATERIALS AND METHODS

Study area

The Ajuruteua Peninsula extends from Maiaú to the mouth of the Caeté River, covering an area of 1,570 km² of coastal plateaus, and fluvial, estuarine, and coastal plains (Souza Filho & El Robrine 1996). The regional climate is humid equatorial type Am according to the Köppen classification, with temperatures ranging from 25.1°C to 30.9°C (Martorano et al. 1993), with an average annual precipitation of approximately 2,500 mm (Lara & Dittmar 1999). The vegetation is predominantly composed of mangrove forest (95%) with three tree species - *Rhizophora mangle* L., *Avicennia germinans* (L.), and *Laguncularia racemosa* (L.), supporting rich fishing resources used as an important protein source by the local populations (Krause & Glaser 2003).

Data collection

Data were obtained through the database of the Fisheries Statistics Project (UFPA, Executive Secretary of Fisheries and Aquaculture - SEPAQ, and Ministry of Fisheries and Aquaculture - MPA), from April 2008 to October 2010. We monitored the landings of the commercial fishing in the Ajuruteua Peninsula (Braga et al. 2006, IBAMA 2006, 2007) in nine fishing sites: Bragança, Bacuriteua, Caratateua, Furo Grande, Castelo, Tamatateua, Taperaçú Village, Pescadores Village and Treme (Figure 1).

For the data analysis, semi-structured questionnaires were daily applied. Trained collectors were enlisted, most of whom resided near the landing sites. This enabled the collection of data on the types of vessels used in the fishing, fishing gear, days at sea and yield.

The profiles of the commercial fleets were classified according to SEAP/IBAMA/PROZEE (2006) and Isaac et al. (2006) (Table I and Table II). Fishing gears were also categorized based on their characteristics (Table II).

Statistical analyses

A raw data careful inspection identified several missing cells, resulting in interrupted series as is common in tropical marine fisheries. Data were grouped by month to decrease the noise of individual landings, revealing patterns and balancing observation per cell.

Figure 1. Geographic location of the Ajuruteua Peninsula on the Brazilian North Coast. The ports where the data was collected are indicated on the map.

To explore the variability of the data, box plots were constructed with the averages and confidence intervals of the landings by vessel and fishing gear. Further exploratory data analyses have been executed aiming to identify which variables were correlated, thus allowing a reduction in the ones used in a final multiple regression model.

The statistical analyses were carried out using the software R 4.2.2 (R Core Team 2023), using the *readxl* (Wickham & Bryan 2023), *tidyverse* (Wickham et al. 2019), and *MASS* (Ripley et al. 2023) packages. The graphics were generated with the *ggplot 2* package (Wickham et al. 2023).

RESULTS

Vessels engaged in elasmobranch commercial catches

Five types of vessels were identified in the commercial sharks and batoids catches (Table II). The dugouts (DU; also known as montaria or logboats) are rowing boats, made of a single or multiple pieces of wood. Canoes (CAN) are propelled by oars or both oars and sails, without a deck or with a semi-open deck, usually with a hut. Motorized canoes (CAM) are less than 8 meters long powered by an engine or both engine and sail, with or without a deck, with or without a hut.

Small vessels (SM) range from 8 to 11.9 meters in length, with an engine or engine with sail, and a wooden hull with a closed or

Table I. **Vessels engaged with commercial elasmobranch fishing in an Amazon Brazilian North fishing site (Bragança-PA), between April 2008 and October 2010.**

Type of vessel	N° of vessels	Length	Propulsion	Description
Dugout (DU)	47	-	Paddle	Made from a single tree-trunk, sometimes with added planks
Canoe (CAN)	439	-	Paddle and/or sail	No deck or semi-exposed deck, typically without a cabin
Motorized canoe (CAM)	435	< 8 m	Outboard engine with/without sail	May have deck and cabin
Small vessel (SM)	833	8–11.9 m	Engine with/without sail	Wooden hull, with closed or semi-exposed deck
Medium-sized vessel (MD)	363	> 12m	Internal engine with/without sail	Closed deck and cabin, with wooden hull

Table II. **Number of vessels, fishing gear category and type engaged with the commercial landings of elasmobranchs in an Amazon Brazilian North fishing site (Bragança-PA), between April 2008 and October 2010.**

	N° of vessels per category					Fishing gear	Fishing techniques
	DU	CAN	CAM	SM	MD		
	27	199	87	254	116	Trap	Pot
							Weir
	5	118	117	197	135	Line	Dropline
							Longline
							Handline
	15	119	165	353	112	Drift net	Cast net
	-	3	66	29	-	Gill net	Block net
Total	47	439	435	833	363		

DU – Dugout; CAN – Canoe; CAM – Motorized canoe; SM – Small-vessel; MD – Medium-sized vessel.

semi-open deck. Medium-sized vessels (MD) are larger than 12 meters, with an engine or engine with sail with cabin, and a closed deck, with a wooden or metal hull.

A total of 2,117 vessels operated in this area over the studied period assessed. SM and MD accounted for approximately 56% of all captured elasmobranch individuals. Sharks were more commonly captured by SM in 2009 (n = 250) and 2010 (n = 78), while MD accounted for the largest number of captures in 2008 (n = 157). For the other vessel types (44% of captured elasmobranch individuals), CAM presented the largest number of shark captures for all year (28, 79, and 32 individuals for 2008, 2009, and 2010, respectively). Similarly, batoids were more commonly captured by SM for all years (258, 224, 355 individuals, respectively), while MD accounted for the lowest number of captures for all years. In fact, SM alone accounted for 40% of all captured elasmobranch individuals, followed by CAM (22.3%), CAN (19.3%), MD (16.3%), and DU (1.9%).

Fishing gears used by vessels engaged in the elasmobranch fishing

Four types of fishing gears have been identified, with eight associated fishing techniques (Table

II), with drifting net playing a prominent role, followed by hand lines. Pot traps are cylindrical or conical made of bamboo or iron mad with a funnel allowing fish entrance. Smaller vessels (dugouts, rowing and motorized canoes, and small vessels) usually use bamboo traps, while medium-sized vessels use metal traps. Weirs are fixed structures made of timber, designed to intercept, and capture fish through tidal movements. These structures have low selectivity, and they are typically harvested during low tide once a day (by dugouts and rowing canoes) or twice a day (by motorized vessels)

Hand lines usually have a single hook, whereas longlines have a set of several hooks arranged equidistantly on secondary lines. The diameter of the polyamide lines is 2.0 mm for the main and 1.8 mm to the branch line. SM uses longlines with approximately 2,000 hooks, while canoes may use up to 1,600 hooks, and dugouts, approximately 200.

Gill nets are built with rectangular polyamide mesh of varying sizes (20 to 60 mm between opposite knots). Small vessels use nets of approximately 1,900 m in length, motorized canoes use nets with a mean length of 1,700 m, canoes with a mean length of 900 m, and dugouts use nets of 200 m in length. Cast nets are circular with small lead weights distributed around its entire circumference. Block nets of approximately 270 m in length, consist of gill nets placed by small and other vessels across the entrance of tidal channels or small inlets. They may also be fixed at specific locations along the beach line, with an average length of 130 m.

Landing trends

A total of 2,359 elasmobranch individuals were landed (Table III), from which 1,360 were batoids and 999 were sharks. The highest number of catches occurred in 2009 (n = 1,243), followed by 2008 (n=789), and n = 327 in 2010. Regarding

Table III. Number of individuals (N) and yield (in tons) of commercial landing at the ports monitored in an Amazon Brazilian North port (Bragança-PA) between April 2008 and October 2010.

		Sharks		Batoids	
Year	Season	Number of landings (N)	Yield (ton)	Number of landings (N)	Yield (ton)
2008	Drying	55	8.473	0.108	3.713
	Dry	168	34.577	0.247	9.713
	Rising waters	47	3.918	0.036	1.680
	Rainy	25	1.770	0.103	3.559
2009	Drying	63	42.976	0.132	6.293
	Dry	235	52.100	0.257	9.511
	Rising waters	60	19.292	0.072	2.597
	Rainy	182	56.796	0.242	10.154
2010	Drying	-	-	-	-
	Dry	-	-	-	-
	Rising waters	-	-	-	-
	Rainy	164	82.657	0.161	4.180
Total		999	302.559	1.358	51.400

catch per season, in 2008 and 2009, both shark and batoid catches were highest in the dry season. In 2008, shark landings were lower in the rainy season. Batoid landings were lower in the rising water season. In 2009, both shark and batoid landings were lower in the raising water season. In 2010, both shark and batoid capture occurred only in the rainy season, except for 2 batoids caught in the dry season.

As for production, total landings (in kg) were 3.3 times higher for sharks. As they are heavier their number is 1.4 times lower than batoids (Table III). A total of 302.5 kg was reported for sharks in all years of monitoring, being 48.7 kg from 2008 (16.1%), 171.2 kg from 2009 (56.6%), and 82.6 kg from 2010 (27.3%). For batoids, the total production was 47.3 kg, being 18.7 kg in 2008 (36.2%), 28.5 kg from 2009 (55.4%), and 4.2 kg from 2010 (8.2%).

Considering the seasons, in 2008, for both shark and batoids, production was higher in the dry season. In 2009, production was higher in the rainy season for both. Interestingly, in 2010, shark production was restricted to the dry season and exceeded the catches of all other seasons in the other years.

Fishing statistics

Shark landings amounts were higher in 2009 for both number of individuals and yield (ton) (Figure 2a). While the number of individuals was higher for small vessels, the landings was higher for medium-sized vessels. In the two subsequent years, we observed a strong decrease in catches.

As for batoid landings, the peak of individuals landed occurred in 2008, whereas the largest yield were in 2009 (Figure 2b). More specifically, small vessels were responsible for the greater number of batoids, while canoes were responsible for the largest amount landed. Although both the number of individuals landed and the number of catches were different along the years and vessel types, canoes, motorized canoes and small vessels were engaged with the most representative batoid landings during the monitoring period.

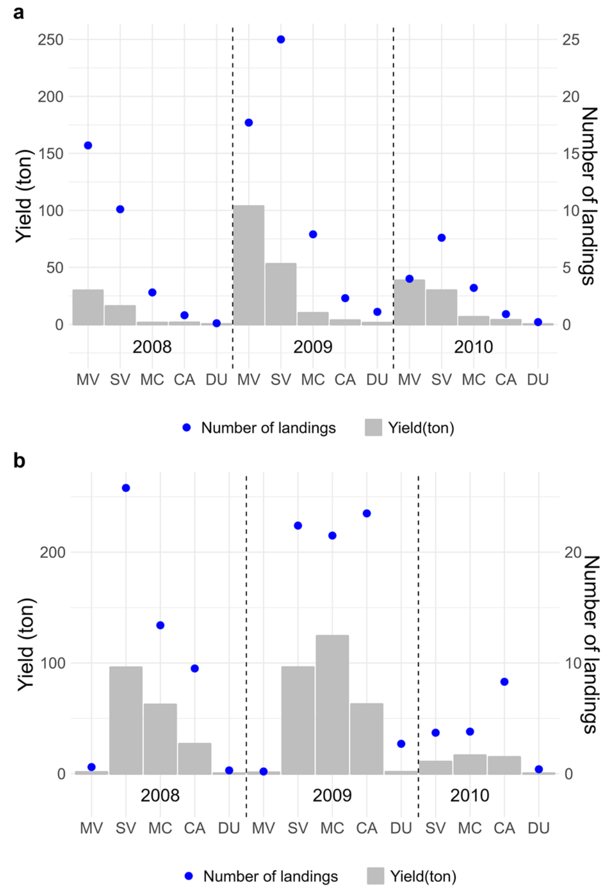

Figure 2. Elasmobranch landing yield (tons) and number of individuals landed (N) considering vessel type and years at Ajuruteua Peninsula between April 2008 and October 2010. a = sharks; b = batoids. MV = Medium-sized vessel; SV= Small vessel; MC= Motorized canoe; CA= Canoe; DU= Dugout.

In terms of yield for each category of vessel, the highest average total catch of sharks was recorded by medium-size vessels using drift nets (Figure 3a). For batoids, the highest total mean was recorded for medium-sized vessels operating with lines, while small vessels operating with gill nets (Figure 3b).

Regarding seasons, the highest average shark production was recorded for medium-sized vessels and drift nets, both in the drying

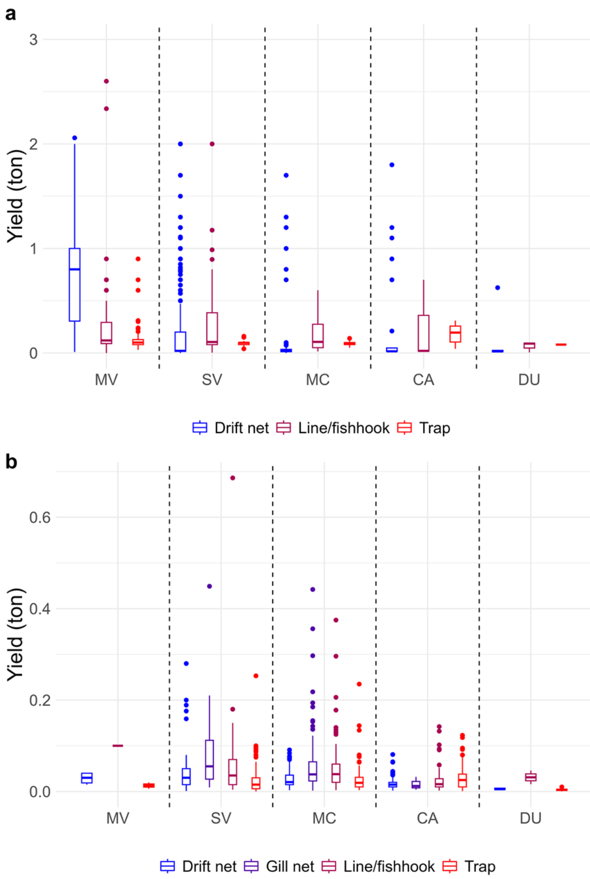

Figure 3. Shark landing yield (tons) (a) by vessel and fishing gear category. Batoid landing yield (tons) (b) by vessel and fishing gear category recorded at Ajuruteua Peninsula between April 2008 and October 2010. MV = Medium-sized vessel; SV= Small vessel; MC= Motorized canoe; CA= Canoe; DU= Dugout.

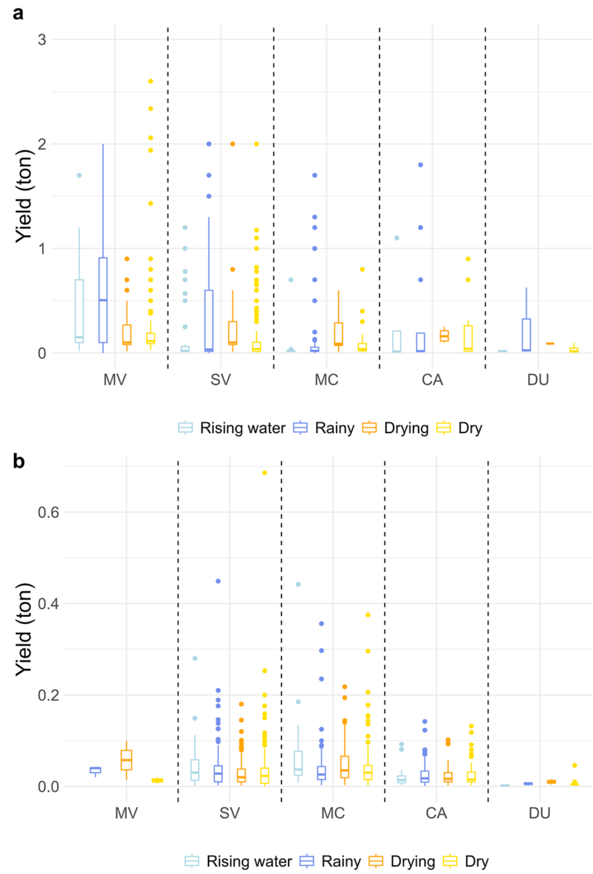

Figure 4. Seasonal variation in elasmobranch landing yield (tons) by vessel type at Ajuruteua Peninsula between April 2008 and October 2010. a = sharks; b = batoids. MV= Medium-sized vessel; SV= Small vessel; MC= Motorized canoe; CA= Canoe; DU= Dugout.

season (Figures 4a and 5a). For batoids, the highest mean production was recorded for medium-sized vessels in the drying period (Figure 4b). Gill nets had the highest average production of batoids during the rising period (Figure 4d).

From the original six independent variables, only one (days at sea) was found to be significant and it is included in the final model:

$$\ln(\text{yield}) = 0.9221 + 1.3550*\ln(\text{daysatsea})$$

$$N = 34;\ R^2_{\text{adjusted}} = 0.69;\ F = 78.05^{**}$$

The model was fully validated after a careful residual analysis, which are normal, (SW statistic =0.980; p =0.760), with no outliers and constant variance (Figure 6).

DISCUSSION

Presently, few scientific data addressing which vessel types and fishing gears are engaged with northern Brazil elasmobranch commercial fisheries are available. Along with incomplete fisheries data, low taxonomic resolution in the landing reports is an additional challenge to adequate management in the region. More

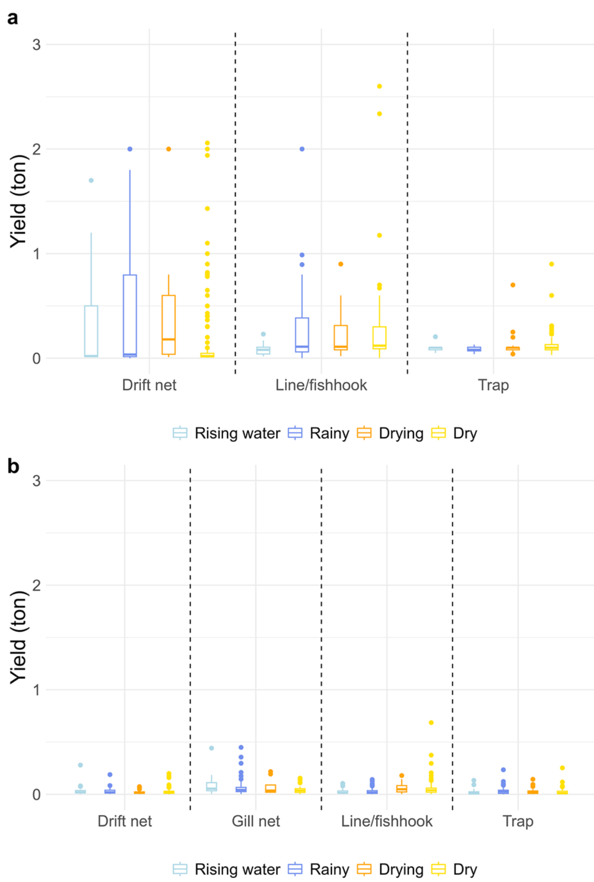

Figure 5. Seasonal variation in elasmobranch landing yield (tons) by fishing gear category at Ajuruteua Peninsula between April 2008 and October 2010. a = sharks; b = batoids.

specifically, sharks and batoids are placed in general categories (e.g., "cação", and "arraias"), without further details, or at least which genus are being caught and traded (Freire et al. 2021, Lutz et al. 2023). A total of 69 species distributed into 20 families were identified due to onboard observations, zoological collections, and literature review. The families Carcharhinidae (16 species), Sphyrnidae (5 species), Potamotrygonidae (8 species), Dasyatidae (6 species), and Myliobatidae (5 species) were the most representative (Marceniuk et al. 2019). Furthermore, elasmobranchs are processed and sold without heads or fins, hindering species recognition. In an analysis of molecular data, Martins et al. (2021) identified 11 sharks and 9 rays, while Feitosa et al. (2018) identified 17 shark species found in fish markets and landing ports in the region. Therefore, the generic classification by vulgar names and the uncharacterized elasmobranchs commercialization biases landing diversity (Lutz et al. 2023). As many elasmobranchs are now on the verge of extinction (Dulvy et al. 2014, Davidson et al. 2016), the collection of more detailed data should be prioritized. Moreover, several elasmobranchs are typically landed as unidentified bycatch (Oliver et al. 2015, Davidson & Dulvy 2017, Freire et al. 2021).

In this paper, five vessel types engaged in the fishing were identified, including dugouts, canoas, motorized canoas, small boats, and medium-sized boats. This profile indicates that shark and batoid fisheries might be classified as small-scale and semi-industrial. Such pattern corroborates the fishing profile of adjacent regions, such as the one in the state of Maranhão, where elasmobranch fishing is predominantly small/medium scale (Almeida et al. 2006). However, the capture of elasmobranch by industrial fishing also occurs in the region (Marceniuk et al. 2019), evidencing stocks exploited by all categories of commercial fisheries. Elasmobranch commercial landings in northern Brazil has a very important food security role for the poorest communities (WildAid 2007).

Under this scenario, fisheries management becomes particularly mandatory as a high-priority social demand. However, considering the risk of extinction that many elasmobranchs are facing, it is also necessary to establish strong and realistic fishing regulations.

As for the fleet profile, for both sharks and batoids, small vessels were the most representative, while dugouts were the least ones. Such capture patterns may be a result

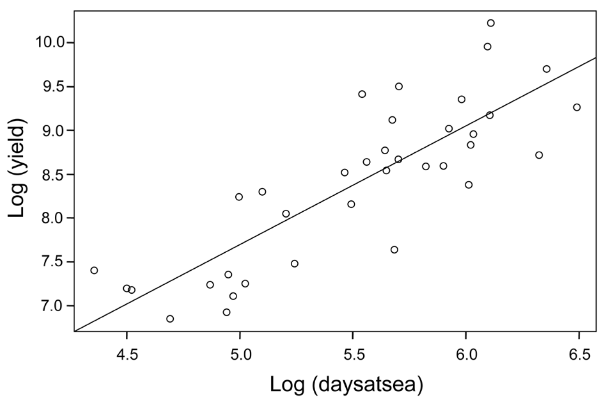

Figure 6. **Scatterplot between ln(yield) and ln(daysatsea) of elasmobranchs landed at Ajuruteua Peninsula between April 2008 and October 2010.**

of vessels' fishing power. Specifically, dugouts, rowing and motorized canoes carry out their activities closer to the landing sites, with consequently shorter fishing trips. In contrast, small and medium-sized vessels operate off coast, in this case in longer fishing trips (Isaac et al. 2008). The same is observed in elasmobranch fisheries performed in southern Brazil, with a greater volume of captures by vessels operating off coast (Giareta et al. 2021). Despite individual comparative lower catches, smaller vessels still exert strong pressure upon regional stocks, with rowing and motorized canoes accounting for 41.6%. However, landings from these vessels tend to be neglected in fisheries statistics. Thus, future monitoring activities should pay more attention to both vessel types.

Sharks and batoids are most often caught using drift nets and lines, as noted in other fisheries in the Amazon continental shelf (Espírito-Santo & Isaac 2012, Marceniuk et al. 2019). Data on the number of individuals caught by each fishing technique and which gear and technique had the stronger impact on sharks and batoids separately were not available, preventing us from discussing the effect of each fishing technique. In the future, monitoring should consider these interactions. Although drift nets were related to higher landings, most catches were incidental, indicating that an important share of elasmobranch production is due to bycatch, as observed at global level (Oliver et al. 2015). Moreover, longline fisheries are responsible for 23% of sharks weight.

The landings decreased from 2009 to 2010, possibly due to the reduced fleet operating in the region. However, as depletion of stocks of many elasmobranchs are observed worldwide (Dulvy et al. 2008), and in Brazilian waters in particular (Barreto et al. 2016), this cannot be ruled out.

Medium-sized vessels operating with drift nets exhibited the highest total landings. As for batoids, landings were related to medium-sized vessels operating with lines, pointing to a multimodal fishing pressure. In fact, batoids landings were higher when compared to sharks. This may reflect fleet profile, fishing spots (i.e., more vessels operating in coastal areas), and a result of the fishing gear and techniques employed. It is also possible that more batoids are caught to compensate for their smaller size. Furthermore, a growing interest in batoid meat in northern Brazil is noted (Silva Rodrigues Filho et al. 2020), as well as increasingly reduced shark populations and stringent legislation for their capture and trade (Rodrigues Filho et al. 2009), which might also explain the observed fishing landing patterns.

It is noted that the periods of higher sharks and batoids landings occurred during drying and rising water period, as different types of vessel and fishing gear employed. In these transitional periods, the availability of nutrients increases, leading to a greater productivity of all resources (Smith & DeMaster 1996). So, the highest shark trip numbers were recorded in these periods for medium-sized vessels, although the larger variation for smaller vessels (canoes and dugouts), indicates that production in estuaries or coastal areas is more sensitive to rainfall levels. The complex fish abundance variation in the Amazon mouth are related to other variables than just rainfall, including other meteorological (El Niño and La Ninã) and oceanic factors (e.g. salinity) leading to Catch Per Unit Effort (CPUE) fluctuations (Pinaya et al. 2016). For sharks, the mean production with drift nets in the drying period was numerically higher than other periods. The increasing in catches may be related to the decreasing in river discharge, leading to coastal waters salinity increasing enhancing the incursion of marine species (Grant et al. 2019) justifying why fishing days at sea were positively correlated with landings (Figure 5).

Reliable fisheries statistics are urgent in the northern region, as it is listed as a global hotspot for elasmobranch conservation (Dulvy et al. 2014), and home for rare/endemic species, such as the Daggernose shark (*Isogomphodon oxyrhynchus*) and the Colares stingray (*Fontitrygon colarensis*), both listed as critically endangered (Pollom et al. 2020a, b), albeit presently is impossible to estimate its current catch rates. However, considering the global trends, it is likely that most species are under even more pressure.

Some important study limitations must be considered here. First, historical data from the present report are older than a decade, which may not reflect the current reality of elasmobranch fisheries. The absence of reliable data on commercial fisheries in Brazil is detrimental to the development and adoption of adequate public policies. Sadly, this has been a challenge for over a decade, as the official fisheries statistics programs were discontinued in 2011 and are still not expected to return.

In this case, data poor analysis might provide the understanding of sharks and batoids stocks. The landings reduction is evident throughout all the Amazon continental shelf and the fishing systems traditionally which change the target species to adapt to a new reality (Castello et al. 2014).

In this context, it is very important to urgently adopt environmental education initiatives, to establish small scale fisheries co-participative management strategies also including the commercial sector in conservation planning. Thus, data sources like the one presented here are valuable tools in a comparative context, as they can be faced as baseline for future studies related to elasmobranch fisheries.

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