



UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL  
INSTITUTO DE BIOCÊNCIAS - DEPARTAMENTO DE ZOOLOGIA  
COMISSÃO DE GRADUAÇÃO DO CURSO DE CIÊNCIAS BIOLÓGICAS

TRABALHO DE CONCLUSÃO DE CURSO

**Elasmobranchs from Patos lagoon estuary:  
occurrence of catches and population structure**



Periódico científico de referência: Neotropical Ichthyology

Érika Endo Kokubun

Orientadora: Prof. Dra. Clarice Bernhardt Fialho

PORTO ALEGRE

2017/2

## Elasmobranchs from Patos lagoon estuary: occurrence of catches and population structure

Érika Endo Kokubun<sup>1</sup>, Paulo Roberto dos Santos<sup>2</sup> and Clarice Bernhardt Fialho<sup>1</sup>.

<sup>1</sup>Laboratório de Ictiologia da Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, Agronomia, 91501-970 Porto Alegre, RS, Brazil. (EEK) [erikakokubun@gmail.com](mailto:erikakokubun@gmail.com), (CBF) [cbfialho@via-rs.net](mailto:cbfialho@via-rs.net)

<sup>2</sup> Universidade Federal Paulista, Praça Infante Dom Henrique s/nº, Parque Bitaru, 11330-100 São Vicente, SP, Brazil. [prs.dossantos@gmail.com](mailto:prs.dossantos@gmail.com) (corresponding author)

### Abstract

As high-trophic level predators, elasmobranchs significantly influence the ecosystem, according to how they use the habitat. To understand better how they use the habitat, this study describes the occurrence of elasmobranchs in Patos lagoon estuary and their populational structure. In total, 581 individuals from 19 species were captured. CPUE presented correlation with salinity ( $r_s = 0.96$ ;  $P < 0.00001$ ), but no correlation with depth ( $r_s = 0.24$ ,  $p = 0.218$ ) or water surface temperature ( $r_s = -0.32$ ,  $p = 0.101$ ). The highest values were during spring and summer, when salinity levels are known to get higher in the estuary, along with increases in the abundance in the South Platform due to parturition season. This combination of variables indicates a sporadic use of the estuary. The most representative species were *Sphyrna lewini* (6.71), *Pseudobatos horkelii* (2.39), *Sphyrna zygaena* (1.25) and *Carcharhinus brevipinna* (0.98). Their populational patterns were similar to those found in offshore waters, indicating that the Patos lagoon estuary is a good representative of the biodiversity from Southern Brazil. This study helps to understand elasmobranch occurrence in different habitats throughout their life cycle.

### Resumo

Por serem predadores de topo, elasmobrânquios significativamente influenciam o ecossistema dependendo de como usam o habitat. Para melhor compreender como o habitat é usado, este estudo descreve a ocorrência de elasmobrânquios no estuário da Lagoa dos Patos e sua estrutura populacional. No total, 581 indivíduos de 19 espécies foram amostrados. CPUE

apresentou correlação com salinidade ( $r_s = 0.96$ ;  $P < 0.00001$ ), mas não com profundidade ( $r_s = 0.24$ ,  $p = 0.218$ ) ou temperatura superficial da água ( $r_s = -0.32$ ,  $p = 0.101$ ). Os maiores valores ocorreram na primavera e verão, quando a salinidade aumenta no estuário, assim como a abundância na Plataforma Sul devido à época de parto. Essa combinação de variáveis indica um uso esporádico do estuário. As espécies mais representativas foram *Sphyrna lewini* (6.71), *Pseudobatos horkelii* (2.39), *Sphyrna zygaena* (1.25) e *Carcharhinus brevipinna* (0.98). Seus padrões populacionais são similares aos encontrados na plataforma continental, indicando que o estuário da Lagoa dos Patos é um bom representante da biodiversidade do sul do Brasil. Este estudo ajuda a compreender a ocorrência de elasmobrânquios em diferentes habitats ao longo dos seus ciclos de vida.

**Keywords:** Abiotic factors, Estuary, Salinity, Southern Brazil

**Palavras chave:** Estuário, Fatores abióticos, Salinidade, Sul do Brasil

## Elasmobranch occurrence in a Brazilian estuary

### Introduction

Elasmobranchs are considered high-trophic level predators, either close to the top of the trophic chain or even as the apex predators (Heithaus *et al.*, 2012), therefore influencing the ecosystem they live in (Stevens *et al.*, 2000; Myers *et al.*, 2007). This influence may be either direct, if they act upon a certain population (*e.g.*: control over population size of preys (Lucas, Stobo, 2000; Myers *et al.*, 2007), induction of behaviors that avoid predation (Heithaus, 2004; Heupel *et al.*, 2007), as prey items (Heithaus, 2004)), or indirect, if they affect other groups through acting upon an intermediate one (*e.g.*: trophic interactions (Gregory *et al.*, 1979; Thrush *et al.*, 1991; Myers *et al.*, 2007; Heithaus *et al.*, 2012)). Consequently, a reduction in their populational size may initiate a series of negative effects over the community and ecosystem: release of mesoconsumers from predation pressure (Scheffer *et al.*, 2005; Myers *et al.*, 2007), loss of trophic chain links, decrease of ecosystem stability and resilience (Holmlund, Hammer, 1999; Myers *et al.*, 2007; Heithaus *et al.*, 2010), etc. This influence, though, is also affected by their patterns of movement and distribution and by how they use the habitat (Speed *et al.*, 2010).

Sharks, skates and rays are found in a variety of habitats: deep, shallow, pelagic, neritic, and even in freshwater (Charvet-Almeida *et al.*, 2005; Heupel, Simpfendorfer, 2012). However, they do not occur in all of the habitats within their distribution range, rather presenting specificity for certain habitats and/or limited distribution (Walker, 1998; Stevens *et al.*, 2000). Moreover, they are commonly found segregated according to their sex, size and/or stage of development (Springer, 1967; Kinney, Simpfendorfer, 2008). Segregation may occur either due to competition for resources or due to predation pressure (Sims *et al.*, 2003), or even because of different physiological tolerances to environmental conditions (e.g.: salinity, depth, dissolved oxygen) (Schlaff *et al.*, 2014). And how they use the habitat will depend on a variety of factors, such as food availability, reproductive behavior, social interactions, predation pressure (Heithaus *et al.*, 2002). For instance, in the protected and shallow waters from coastal habitats, elasmobranchs can avoid and/or escape from potential predators (Simpfendorfer *et al.*, 2005; Wetherbee *et al.*, 2007), forage in search of prey (Simpfendorfer, Milward, 1993; Heithaus *et al.*, 2002), and even have reproductive benefits from the higher water temperatures (Robbins, 2007; Jirik, Lowe, 2012; Nosal *et al.*, 2014;). Therefore, coastal habitats like bays, estuaries and lagoons are commonly utilized as foraging, reproductive and/or nursery grounds (Simpfendorfer, Milward, 1993; Pratt, Carrier, 2001; Heithaus *et al.*, 2002; Heupel, Simpfendorfer, 2008). Accordingly, estuaries have been identified as areas of use for a big array of species, being even considered vital for their life cycles (Carlisle, Starr, 2009; Espinoza *et al.*, 2011; Farrugia *et al.*, 2011; Werry *et al.*, 2011; Jirik, Lowe 2012). Yet, many of their habitats have not been identified (Parsons *et al.*, 2005), neither many aspects of the relationship between their biological and ecological traits with the environment (Lessa *et al.*, 2005; Aguiar, Valentin, 2010; Kiszka, Heithaus, 2014). Given that their habitats are being threatened by pollution and climate change (Amaral, Jablonski, 2005; Simpfendorfer *et al.*, 2011a), their patterns of habitat use may change in the upcoming years (Chin *et al.*, 2010; Hazen *et al.*, 2013), affecting all the community they are inserted in.

In Rio Grande do Sul state, a potential habitat for elasmobranchs is the Patos lagoon estuary. Within the estuary area, there is the presence of many prey items considered common in the diet of sharks, skates and rays (Navia *et al.*, 2007; Bornatowski *et al.*, 2014; Viana *et al.*, 2017): decapods (D’Incao, Dumont, 2010), macro zoobenthos in general (Bemvenuti, Colling, 2010), as well as a high relative abundance of fish (Vieira *et al.*, 2010). Besides, the estuarine area of Patos lagoon has a mean depth of 5 m, with a predominance of sand banks with depths ranging from 1 to 5 m (Calliari, 1998); shallow waters offer protection for smaller elasmobranchs, since bigger animals that feed on them are not frequent in these areas

(Simpfendorfer, Milward, 1993). However, only a few studies have registered the presence of elasmobranchs in the Patos lagoon estuary. Chao *et al.* (1982) found specimens of *Sphyrna lewini* (Griffith & Smith, 1834) during three seasons; Garcez, Sánchez-Botero (2005) reported the presence of *Squatina guggenheim* Marini, 1936; Pereira (1994) sampled, in a two years study, five species of elasmobranchs (two sharks, one ray and two skates). Nowadays, though, these species, and other unknown ones, may have their habitat use patterns affected by modern impacts of anthropic origin (Tagliani *et al.*, 2003; Garcia *et al.*, 2004; Burns *et al.*, 2006; Spengler *et al.*, 2007), since environmental changes have been shown to change how the habitat is used by them (Chin *et al.*, 2010; Hazen *et al.*, 2013). Considering the importance of sharks, skates and rays for the ecosystem, and how their influence may change due to alterations in their habitat use patterns caused by environmental changes, it is important to conduct studies on how elasmobranchs use the habitat. Thus, the objective of this study is to describe habitat use by elasmobranchs in the Patos lagoon estuary: which species predominate in the region, which environmental variables influence their distribution and abundance the most and how the population is structured.

## Material & methods

**Study area.** The Patos lagoon estuary is located at Southern Brazil's coastal plain from Rio Grande do Sul (RS) state, parallel to the coast in the direction NE-SW, close to Rio Grande city, where it connects to the ocean (Asmus, 1998) (Fig. 1). It presents an area of around 10000 km<sup>2</sup>, mean depth of 5 m, and it is connected to the drainage basin at their superior portion and to the Mirim lagoon, through the São Gonçalo waterway (Calliari, 1998; Möller, Fernandes, 2010). The sum of the monthly discharges from the main rivers of the Patos Mirim system (Jacuí, Taquari and Camaquã) corresponds to more than 70% of the total water flow from the drainage basin (Vaz *et al.*, 2006). The salinity follows a seasonal pattern which depends on the discharges from Patos Mirim system and which wind is predominant (Möller, Fernandes, 2010). The estuary area is located between the point where it connects to the ocean and an imaginary line that connects the Ponta da Feitoria to the Ponta dos Lençóis. In the estuary, it is possible to verify the shallow coves environment (protected areas with depth < 2 m) and the open waters environment (central body with depth > 2 m) (Castello, 1985).

FIGURE 1

**Sampling and data analysis.** The sampled material was obtained between March, 2013 and April, 2016 in 227 boardings (summer: 76; autumn: 41; winter: 31; spring: 79) with the artisanal fishing fleet based in Rio Grande municipality. In each boarding, information about fishing gear (gill nets, trawling and artisanal line) and how many times it was used (fishing periods), latitude, longitude, salinity (ppm), water surface temperature (°C) and depth of captures (m) were obtained.

The sampled individuals were identified, to species level, and had their total length (cm), or disk length (cm) for rays and skates, and total weight (g) measured, as well as identification of sex and development stage (neonate, juvenile and adult), according to Simpfendorfer, Milward (1993). Neonates were considered as all specimens that still possessed evident birthmark; juveniles as all that measured a size inferior to the mean length of first maturation ( $L_{50}$ ); and adults, the specimens which the length was above  $L_{50}$ .

With the data obtained, the Frequency of Occurrence (%FO) (number of fishing periods in which the species occurred per number of total fishing periods with the presence of elasmobranchs) and Catch per unit of effort (CPUE) (number of elasmobranchs captured per fishing period) were defined. In order to evaluate possible seasonal variations in CPUE values, a one-way Analysis of Variance (ANOVA) and Tukey test ( $p < 0.05$ ) were used to evaluate possible seasonal variations in CPUE values. In order to satisfy these test assumptions, a Shapiro-Wilk test was made, along with a Barlett test to check for the normality and homocedasticity of data, after a ( $\log_{10}(x+1)$ ) transformation. The most representative species were defined through the Capture Importance Index ( $C_{ii}$ ):

$$C_{ii} = (FO \times CPUE) \times 100$$

The four most representative species had a chi-square test run to test for significative differences in proportion between males and females ratio and between developmental stages (neonates X juveniles; juveniles X adults; neonates X adults).

A Spearman's correlation ( $p < 0.05$ ) was made to evaluate the correlation between CPUE values and three environmental variables (depth, salinity and water surface temperature).

## Results

In all 227 boardings, 314 fishing periods occurred, with all three different fishing gears (gill nets, trawling and artisanal line) (Tab. 1). Due to the low share of trawling and artisanal line in the catches (3.78%), these fishing gears were excluded from the calculation of CPUE.

TABLE 1

Shapiro-Wilk test pointed normality of data ( $W_1 = 0.784$ ,  $p_1 = 0.042$ ;  $W_2 = 0.763$ ,  $p_2 = 0.027$ ;  $W_3 = 0.638$ ,  $p_3 = 0.001$ ;  $W_4 = 0.747$ ,  $p_4 = 0.001$ ) and the Bartlett test rejected the heterogeneity hypothesis (Bartlett = 1.417;  $df = 4$ ;  $p = 0.286$ ), thus it was possible to proceed with the analysis of variance. The one-way ANOVA ( $F = 1512$ ;  $df = 1.806$ ;  $p = 0.001$ ) and Tukey-test (Tab. 2) identified significant seasonal differences between CPUE values.

TABLE 2

CPUE was found to have a positive correlation with salinity ( $r_s = 0.96$ ;  $p < 0.001$ ), but no significant correlation with depth ( $r_s = 0.24$ ,  $p = 0.218$ ) and water surface temperature ( $r_s = -0.32$ ,  $p = 0.101$ ) (Fig. 2).

FIGURE 2

In total, 581 individuals were captured, totalizing 19 species from 12 families (Tab. 3). Sharks were represented by 11 species from six families; skates and rays were represented by eight species from six families. The biggest shark individual was an adult male *Carcharias taurus* Rafinesque, 1810 (220 cm), while the smallest one was a neonate male *Mustelus schmitti* Springer, 1939 (21.9 cm). The biggest ray was an adult female *Pseudobatos horkelii* (Müller & Henle, 1841) (71 cm), while the smallest were a neonate female *P. horkelii* and a neonate male *Sympterygia acuta* Garman, 1877 (both 15 cm) (Tab. 3). The highest values for %FO were for *S. lewini* (0.084), *P. horkelii* (0.057), *Sphyrna zygaena* (Linnaeus, 1758) (0.053), *Rhizoprionodon lalandii* (Müller & Henle, 1839) (0.053) and *S. acuta* (0.035) (Tab. 3). Highest CPUE values were for *S. lewini* (0.802), *P. horkelii* (0.419), *Carcharhinus brevipinna* (Müller & Henle, 1839) (0.374), *S. zygaena* (0.238) and *R. lalandii* (0.167) (Tab. 3). So, according to Cii, the most representative species were *S. lewini* (6.71), *P. horkelii* (2.39), *S. zygaena* (1.25) and *C. brevipinna* (0.98) (Tab. 3).

TABLE 3

Altogether, these four species represented 74.4% of the catches and the same pattern of seasonal variation of general CPUE, with high values during spring and summer. There were no catches during autumn and low values during winter for *S. zygaena* (Fig. 3).

FIGURE 3

Neonates and juveniles were predominant, with only five adult individuals of *P. horkelii* recorded. The proportion of stages of development revealed that the neonate stage is of greater importance in the catches for *C. brevipinna*, *S. lewini* and *S. zygaena* species, whereas the juvenile stage was more important for *P. horkelii* (Tab. 4).

TABLE 4

When analyzed together, there was a significant difference in the sex ratio (252 females and 164 males), considering the four most representative species (1:1.53,  $\chi^2 = 18.615$ ,  $p < 0.001$ ). However only *P. horkelii* maintained the proportion when separately analyzed. Significant differences in sexual proportion in developmental stages only occurred in the juvenile stage of *P. horkelii* (Tab. 5).

TABLE 5

## Discussion

The presence of elasmobranchs inside the estuary was highly correlated with salinity levels: CPUE was positively correlated with higher salinity levels. This is a variable already correlated with habitat use by a series of elasmobranch species (Hopkins, Cech, 2003; Heupel, Simpfendorfer, 2008), influencing both their abundance and distribution (Matern *et al.*, 2000; Simpfendorfer *et al.*, 2005; Collins *et al.*, 2008; Ubeda *et al.*, 2009; Poulakis *et al.*, 2011; Francis, 2013). Marine elasmobranchs keep themselves slightly hyperosmotic to the environment (Hammerschlag, 2006), so periods of low salinity lead individuals to go through physiological stress, possibly affecting their capacity to withstand longer or more severe changes in salinity (Guffey, Goss, 2014; Cramp *et al.*, 2015; Morash *et al.*, 2016).

Osmoregulation energetic costs were already considered as higher for small sharks, given that



they have a high surface to volume ratio (Pillans, Franklin, 2004; Heupel, Simpfendorfer, 2008), which may explain why the majority of the specimens sampled in this study were either neonates or juveniles. Thus, selection for habitats within a preferred salinity range potentially minimize osmoregulation energy costs (Froeschke *et al.*, 2010; Schlaff *et al.*, 2014) and/or is caused by physiological limitations (Heupel, Simpfendorfer, 2008). This behavior enables the saved energy to be allocated to other physiological processes (Heupel, Simpfendorfer, 2008; Froeschke *et al.*, 2010), many of which can be essential for the development of juveniles (*e.g.*: growth) (Morrisey, Gruber, 1993; Simpfendorfer, Milward, 1993). Additionally, movement in order to remain within a specific salinity range may also be affected by biotic factors, such as predator avoidance (Poulakis *et al.*, 2011; Simpfendorfer *et al.*, 2011b) or even prey distribution (Heithaus *et al.*, 2002); but biotic factors rarely occur isolated, making it difficult to identify which factors and/or interactions are relevant to habitat selection.

Notwithstanding, only higher salinity levels are not enough to explain increases in CPUE values, as their presence in the area depends on their abundance close to the estuary mouth. The salinity within the Patos lagoon estuary follows a seasonal pattern, as it increases towards the end of spring and beginning of summer due to low freshwater discharges (Möller, Fernandes, 2010). Also, it is during spring and summer that most of the native species give birth (Vooren, Klippel, 2005). Considering that most of the neonates and juveniles remain close to the shore (Vooren, Klippel, 2005), the probability of individuals getting in the estuary increases. However, during autumn, the salinization of waters is intensified due to the combination of even lower freshwater discharges and predominance of SW winds (Möller, Fernandes, 2010). Even so, CPUE values were low, since during autumn many species migrate towards the external part of the continental shelf (*e.g.* *P. horkelii*) and/or leave the shallow waters (Vooren, Klippel, 2005).

Given that the majority of coastal species of sharks and rays are ectothermic, alterations in water temperature also impact their physiological processes (Schlaff *et al.*, 2014); therefore temperature is considered an important variable related to abundance and distribution of elasmobranchs as well (Hopkins, Cech, 2003; Bernal *et al.*, 2012). Preference for higher temperatures has been associated with higher CPUE (Froeschke *et al.*, 2010), since it enhances growth and other metabolic processes rates (Heupel *et al.*, 2007) as well as granting reproductive benefits for females (*e.g.*: shorter gestation period, earlier sexual maturity) (Robbins, 2007; Jirik, Lowe, 2012; Nosal *et al.*, 2014). Nevertheless, extremely high temperatures were negatively correlated with CPUE, probably due to a physiological upper

limit (Froeschke *et al.*, 2010), or even, correlated but with no visible preference for a certain value, for some species (Ubeda *et al.*, 2009). Likewise, in the Patos lagoon estuary, CPUE correlation with temperature was not significant ( $r_s = -0.32$ ,  $p = 0.101$ ). As most species are resident from the South Platform, much likely the difference in mean water surface temperature from the estuary and from the Platform is not significant enough. Accordingly, data from the Instituto Nacional de Meteorologia (INMET) (INMET - [inmet.gov.br](http://inmet.gov.br)), shows, for the coast of Rio Grande do Sul, similar monthly temperature ranges as the values measured in Patos lagoon estuary during this study. Still, from 20 °C onwards there seems to be a correlation, as seen in Fig. 2. A more detailed analysis can be done in the future to verify this relationship; however, it is possible that this is a reflection of the higher temperatures registered during summer. Similarly, depth was not significantly correlated with CPUE. The sampling design in this study probably was not enough for significant influences over CPUE to be detected, given that the South Platform presents a gentle declivity, with shallow depths in the area closer to the shore (up to 20 m) (Vooren *et al.*, 2005). Moreover, the shallow waters from the South Platform propitiate a protected habitat for the elasmobranchs as well the estuary.

The combination of favorable conditions for the presence of elasmobranchs create an environmental window which allows sharks, skates and rays to enter the estuary. Thus, higher salinity is a condition for an environmental window for the elasmobranchs of the South Platform. However, in general, CPUE values within the estuary were low especially when compared to studies conducted in close areas (Vooren, Klippel, 2005). Then, probably the estuary is being used as a sporadic area rather than, for instance, a nursery. In order to be considered a nursery, an area should have bigger probabilities of shark encounters than close ones (Heupel *et al.*, 2007), which is not the case for the South Platform for the majority of species.

Therefore, our results point that the Patos lagoon estuary is being only sporadically used by local populations of elasmobranchs. When given favourable demographic and environmental conditions, individuals, specifically the younger ones, entered the estuary. Other biotic factors, though, may have affected their movements, *e.g.* prey movement and distribution, predator avoidance (Poulakis *et al.*, 2011; Simpfendorfer *et al.*, 2011b). Such variables were not approached in this study, but should be considered in future studies.

During the period of this study, 19 species of elasmobranchs were found in the Patos lagoon estuary: more than double the amount of species found in studies conducted in similar brazilian habitats. Basílio *et al.* (2008) and Basílio *et al.* (2009), at the Curu River estuary, in

Ceará state, found six species of elasmobranchs. SEMACE/LABOMAR (2005), in an ichthyofauna assessment for Ceará state estuaries, found other three different species, none of them in common with the ones found in Patos lagoon estuary. As for Southern Brazil, a study conducted in Itajaí - Santa Catarina found 85 species of elasmobranchs, captured in coastal and offshore waters (Mazzoleni, Schwingel, 1999): 11 of the shark species and six of the ray and skate species were also found in Patos lagoon estuary. The two exclusive species found in this study were *Dasyatis hypostigma* Santos & Carvalho, 2004 and *S. acuta* (in Itajaí 43 different shark species and 25 different rays and skates species were found). These two species have been described as shallow waters inhabitants (Vooren, Klippel, 2005), probably the reason why they were found in the Patos lagoon estuary but not in the Itajaí assessment. Given that the species sampled in the estuary were found offshore by Mazzoleni, Schwingel (1999), and are also different from the fauna found in estuaries from Northern Brazil, this may be indicative that this elasmobranch estuarine community is a reliable representation from the sharks, skates and rays biodiversity from Southern Brazil.

From all 581 specimens sampled, almost all (90.53%) were either neonates or juveniles. Coastal areas are known to be of high importance for younger sharks (Knip *et al.*, 2010), as they offer protection from predators, abundance of prey, etc (Simpfendorfer, Milward, 1993; Heithaus *et al.*, 2002; Simpfendorfer *et al.*, 2005; Wetherbee *et al.*, 2007). The adult individuals sampled were considered occasional visitors of the estuary area: *C. taurus* have been reported in shallow waters (Otway, Ellis, 2011), as well as *Gymnura altavela* (Linnaeus, 1758) (Rocha, Rossi-Wongtschowski, 1998; Schwarz *et al.*, 2006; Psomadakis *et al.*, 2009) and *M. schmitti* (Cortés *et al.*, 2011). The individuals of *Myliobatis goodei* Garman, 1885 and *Myliobatis ridens* Ruocco, Lucifora, Díaz de Astarloa, Mabragaña & Delpiani, 2012 are sporadically found inshore in the warmer months (spring - summer) to give birth (Araújo *et al.*, 2016): accordingly, all *M. goodei* and *M. ridens* sampled were adult females captured during September - October and December, respectively. As for *S. acuta* and *R. lalandii*, they are both resident species from the coastal waters of Rio Grande do Sul (Vooren, Klippel, 2005), so it is expected to occasionally find adult individuals inshore, either foraging or looking for safe spots to give birth. Since *Sympterygia bonapartii* Müller & Henle, 1841 and *S. guggenheim* were, in their majority, captured with artisanal line and trawling, respectively, the adults sampled were not included in our analyses.

According to the Capture of Importance Index (*Cii*), the four most representative species in the Patos lagoon estuary were, in order of importance: *S. lewini*, *P. horkelii*, *S. zygaena* and *C. brevipinna*. *Sphyrna lewini* has a global distribution, found in deep waters and, the young

ones in particular, close to the shore, in bays and estuaries (Compagno, 1984; Vooren, Klippel, 2005). In Brazil, they are captured in abundant numbers along the southeast - south coastal region (Gadig, 2001), and the South Platform from Rio Grande do Sul houses a resident population that completes all its life cycle in the continental shelf and surrounding waters (Vooren, Klippel, 2005). The predominance of neonate individuals found (95.05%) agrees with the literature, that mentions the South Platform as a nursery ground for the species (Vooren, Klippel, 2005). The other 4.94% were comprised by juvenile individuals, captured mostly during the summer months. The predominance of neonates and juveniles over adults was expected, as neonates are known for remaining in shallow waters close to the shore during their first months of life (Kotas, 2004; Vooren, Klippel, 2005). And the juveniles are occasionally present during summer and absent during winter, when they migrate to the external part of the platform as they develop (Vooren, Klippel, 2005), a pattern observed in our samplings.

*Sphyrna zygaena* has a similar ecology, living around the continental shelf and surrounding waters (Vooren, Klippel, 2005). It is considered a resident species at the South Platform, with a local population that shares habitat with *S. lewini* (Vooren, Klippel, 2005). Even though *S. zygaena* presented the same predominance of neonates (77.78%) and juveniles (22.22%) over adults as *S. lewini*, there was a disproportion between the species: 182 *S. lewini* captured but only 54 *S. zygaena* captured. Such disproportion has already been reported (Kotas, 2004; Mader *et al.*, 2007). Both species give birth during the summer months (Vooren, Klippel, 2005), therefore the significative presence of neonates and juveniles during the November - March period is a pattern that was already observed in other studies (Kotas, 2004). Also, both presented a balanced sex ratio (1:1.09 and 1:1, respectively). The specimens sampled from both species are neonates and juveniles using the area, either for protection, feeding, etc, and not adults looking for mating grounds or a safe spot for giving birth.

Following *S. lewini*, *P. horkelii* was the second most significant species for Patos lagoon estuary. This species occurs along a gradient of depths, presenting a characteristic seasonal pattern of migration (Vooren, Klippel, 2005), observed in our results. During winter, the bulk of their biomass is found in deeper waters, between 50 - 150 m (Vooren, Klippel, 2005); accordingly, no specimen was sampled during the winter months, since the samplings occurred only in the shallow waters of the estuary. As spring arrives, adult individuals from both sexes start to migrate towards coastal areas: the pregnant females arrive around November - December, reaching a biomass peak in depths shallower than 20 m during summer (Lessa, 1982; Vooren, Klippel, 2005). Accordingly, *P. horkelii* started to be sampled

in October. From the five adult individuals sampled, four were females captured during summer and the beginning of autumn. The females give birth around February - March and soon after they migrate out, towards the external parts of the continental shelf (Vooren, Klippel, 2005): the majority of individuals sampled during autumn were either neonates or juveniles. It is due to this seasonal pattern of migration, in which the females approach the coast to give birth while the males only arrive later (Vooren, Klippel, 2005), that a disproportion in the sexual ratio was found. From the 10 male individuals sampled, only one was an adult, so most likely the other nine were specimens born in the South Platform area: neonate *P. horkelii* stay in coastal waters within the South Platform during their first year of life (Vooren, Klippel, 2005). The species may go into the estuary area to forage, as this is a habitat for shrimps (D’Incao, Dumont, 2010), which may be preyed upon by *P. horkelii*. Also, the continental shelf and coastal waters are considered vital areas for the reproduction of *P. horkelii* (Lessa, 1982; Vooren, Klippel, 2005). Thus, their presence inside the Patos lagoon estuary, following the seasonal trends on distribution found in the literature, indicates this habitat as a vital part of the life cycle of the local population from Rio Grande do Sul state. *Carcharhinus brevipinna* ranked fourth in importance according to the *Cii* calculated. It is a species found on continental and insular shelves, offshore and inshore, in warm, temperate waters (Compagno, 1984). Most of *C. brevipinna* individuals caught were neonates (96.47%), and three juveniles (3.53%) but no adults. They were all caught during summer, which is a pattern also found in the continental shelf. Their presence inside the estuary may be a reflection of their birth season, which happens during spring and summer (Santos *et al.*, 2017). Similarly, to *S. lewini* and *S. zygaena*, the young *C. brevipinna* may be entering the estuary searching for food or protection from bigger sharks.

The Patos lagoon estuary appears to be an area of sporadic use for the elasmobranchs living in the South Platform. During spring and summer, not only the majority of species give birth, increasing the elasmobranch abundance in the South Platform, but also the salinity levels are higher within the estuarine area. This situation creates conditions both demographically and environmentally for the occurrence of sharks, skates and rays in the Patos lagoon estuary. The populational structure and patterns of habitat use of the four most representative species (*S. lewini*, *P. horkelii*, *S. zygaena* and *C. brevipinna*), as well as the list of species sampled, follow the trends found for offshore waters, indicating the Patos lagoon estuary as a reliable representation of the elasmobranch biodiversity of Rio Grande do Sul. This result helps to understand that each coastal area has different levels of importance in the life cycle of

elasmobranchs and also the patterns of habitat selection of coastal shark species from Southern Brazil.

## References

- Aguiar AA, Valentin JL. Biologia e ecologia alimentar de elasmobrânquios (Chondrichthyes: Elasmobranchii): uma revisão dos métodos e do estado da arte no Brasil. *Oecologia Australis*. 2010; 14(2):464-489.
- Amaral ACZ, Jablonski S. Conservação da biodiversidade marinha e costeira no Brasil. *Megadiversidade*. 2005; 1(1):43-51.
- Araújo PR, Odone MC, Velasco G. Reproductive biology of the stingrays, *Myliobatis goodei* and *Myliobatis ridens* (Chondrichthyes: Myliobatidae), in southern Brazil. *J Fish Biol*. 2016; 89(1):1043-1067.
- Asmus ML. A Planície costeira e a Lagoa dos Patos. In: Castello JPO, Seeliger C, editors. Os ecossistemas costeiro e marinho do extremo sul do Brasil. Rio Grande/RS: Ecoscientia; 1998. p. 9-12.
- Basílio TH, Faria VV, Furtado-Neto MAA. Fauna de elasmobrânquios do estuário do Rio Curu, Ceará, Brasil. *Arq Cienc Mar*. 2008; 41(2):65-72.
- Basílio TH, Godinho WO, Araújo ME, Furtado-Neto MA, Faria VV. Ictiofauna do estuário do Rio Curu, Ceará, Brasil. *Arq Cienc Mar*. 2009; 42(2):81-88.
- Bemvenuti CE, Colling LA. As comunidades de macroinvertebrados bentônicos. In: Seeliger U, Odebrecht C, editors. O estuário da Lagoa dos Patos: um século de transformações. Rio Grande/RS: FURG; 2010. p. 101-114.
- Bernal D, Carlson JK, Goldman KJ, Lowe CG. Energetics, metabolism, and endothermy in sharks and rays. In: Carrier JC, Musick JA, Heithaus MR, editors. *Biology of sharks and their relatives*. 2nd ed. Boca Raton/FL: CRC Press; 2012. p. 211–237.
- Bornatowski H, Wosnick N, Carmo WPD, Corrêa MFM, Abilhoa V. Feeding comparisons of four batoids (Elasmobranchii) in coastal waters of southern Brazil. *J Mar Biol Assoc UK*. 2014; 94(7):1491-1499.
- Burns MDM, Garcia AM, Vieira JP, Bemvenuti MA, Marques DMLM, Condini V. Evidence of habitat fragmentation affecting fish movement between the Patos and Mirim coastal lagoons in southern Brazil. *Neotrop Ichthyol*. 2006; 4(1):69-72.

- Calliari LJ. O Ambiente e a Biota do Estuário da Lagoa dos Patos. In: Seeliger C, Odebrecht C, Castello JPO, editors. Os ecossistemas costeiro e marinho do extremo sul do Brasil. Rio Grande/RS: Ecoscientia; 1998. p. 13-18.
- Carlisle AB, Starr RM. Habitat use, residency, and seasonal distribution of female leopard sharks *Triakis semifasciata* in Elkhorn Slough, California. Mar Ecol Prog ser. 2009; 380: 213-228.
- Castello JP. The Ecology of Consumers from dos Patos Lagoon Estuary, Brazil. In: Yáñez-arancibia, A, editor. Fish Community Ecology in Estuaries and Coastal Lagoons: Toward an Ecosystem Integration. Ciudad de Mexico: DR(R) UNAM Press; 1985. p. 383-406.
- Chao LN, Pereira LE, Vieira JP, Bemvenuti MA, Cunha LPR. Relação preliminar dos peixes estuarinos e marinhos da Lagoa dos Patos e região costeira adjacente, Rio Grande do Sul, Brasil. *Atlântica*. 1982; 5(1):67-75.
- Charvet-Almeida P, Araújo MLG, Almeida MP. Reproductive Aspects of Freshwater Stingrays (Chondrichthyes: Potamotrygonidae) in the Brazilian Amazon Basin. J Northw Atl Fish Sci. 2005; 35:165-171.
- Chin A, Kyne PM, Walker TI, McAuley RB. An integrated risk assessment for climate change: analysing the vulnerability of sharks and rays on Australia's Great Barrier Reef. Glob Chang Biol. 2010; 16(7):1936–1953
- Compagno JVL. FAO species catalogue Vol. 4, part 2 sharks of the world: An annotated and illustrated catalogue of shark species known to date. Rome: Food and Agriculture Organization of the United Nations; 1984.
- Cramp RL, Hansen MJ, Franklin CE. Osmoregulation by juvenile brown-banded bamboo sharks, *Chiloscyllium punctatum*, in hypo- and hyper-saline waters. Comp Biochem Physiol A Mol Integr Physiol. 2015; 185:107-114.
- Collins AB, Heupel MR, Simpfendorfer CA. Spatial distribution and long-term movement patterns of cownose rays *Rhinoptera bonasus* within an estuarine river. Estuaries Coasts. 2008; 31(6):1174-1183.
- Cortés F, Jaureguizar AJ, Menni RC, Guerrero. Ontogenetic habitat preferences of the narrownose smooth-hound shark, *Mustelus schmitti*, in two Southwestern Atlantic coastal areas. Hydrobiologia. 2011; 661(1):445-456.
- D'Íncao F, Dumont LFC. A comunidade de crustáceos decápodes. In: Seeliger U, Odebrecht C, editors. O estuário da Lagoa dos Patos: um século de transformações. Rio Grande/RS: FURG; 2010. p. 117-122.

Espinoza M, Farrugia TJ, Lowe CG. Habitat use, movements and site fidelity of the gray smooth-hound shark (*Mustelus californicus* Gill 1863) in a newly restored southern California estuary. *J Exp Mar Biol Ecol.* 2011; 401(1):63-74.

Farrugia TJ, Espinoza M, Lowe CG. Abundance, habitat use and movement patterns of the shovelnose guitarfish (*Rhinobatos productus*) in a restored southern California estuary. *Mar Freshwater Res.* 2011; 62(6):648-657.

Francis MP. Temporal and spatial patterns of habitat use by juveniles of a small coastal shark (*Mustelus lenticulatus*) in an estuarine nursery. *PloS one* [serial on the Internet]. 2013; 8(2):e57021. Available from: <https://doi.org/10.1371/journal.pone.0057021>

Froeschke J, Stunz GW, Wildhaber ML. Environmental influences on the occurrence of coastal sharks in estuarine waters. *Mar Ecol Prog Ser*, 2010; 407:279-292.

Gadig OBF. Tubarões da costa brasileira (Doctoral dissertation, Instituto de Biociências de Rio Claro of Universidade Estadual Paulista). 2001.

Garcez DS, Sánchez-Botero JI. Comunidades de pescadores artesanais no estado do Rio Grande do Sul, Brasil. *Atlântica*. 2005; 27(1):17-29.

Garcia AM, Loebmann D, Vieira JP, Bemvenuti MA. First records of introduced carps (Teleostei, Cyprinidae) in the natural habitats of Mirim and Patos Lagoon estuary, Rio Grande do Sul, Brazil. *Rev Bras Zool* [serial on the Internet]. 2004; 21(1):157-159. Available from: [dx.doi.org/10.1590/S0101-81752004000100027](http://dx.doi.org/10.1590/S0101-81752004000100027)

Gregory MR, Ballance PF, Gibson GW, Ayling AM. On how some rays (Elasmobranchia) excavate feeding depressions by jetting water. *J Sediment Petrol.* 1979(4); 49:1125–1130.

Guffey SC, Goss GG. Time course of the acute response of the North Pacific spiny dogfish shark (*Squalus suckleyi*) to low salinity. *Comp Biochem Physiol A Mol Integr Physiol.* 2014; 171:9-15.

Hammerschlag N. Osmoregulation in elasmobranchs: a review for fish biologists, behaviourists and ecologists. *Mar Freshwater Behav Physiol.* 2006; 39(3):209-228.

Hazen EL, Jorgensen S, Rykaczewski RR, Bograd SJ, Foley DG, Jonsen ID, Shaffer SA, Dunne JP, Costa DP, Crowder LB. Predicted habitat shifts of Pacific top predators in a changing climate. *Nat Clim Chang.* 2013; 3:234–238

Heithaus MR. Predator-prey interactions. In: Carrier JC, Musick JA, Heithaus MR, editors. *The biology of sharks and their relatives.* Boca Raton/FL: CRC Press; 2004. p. 487–521.

Heithaus M, Dill L, Marshall G, Buhleier B. Habitat use and foraging behavior of tiger sharks (*Galeocerdo cuvier*) in a seagrass ecosystem. *Mar Biol.* 2002; 140(2):237-248.



- Heithaus MR, Frid A, Vaudo JJ, Worm B, Wirsing AJ. Unraveling the ecological importance of elasmobranchs. In: Carrier JC, Musick JA, Heithaus MR, editors. *Sharks and Their Relatives II: Biodiversity, Adaptive Physiology, and Conservation*. Boca Raton/FL: CRC Press; 2010. p. 607-634.
- Heithaus MR, Wirsing AJ, Dill LM. The ecological importance of intact top-predator populations: a synthesis of 15 years of research in a seagrass ecosystem. *Mar Freshwater Res.* 2012; 63(11):1039-1050.
- Heupel MR, Carlson JK, Simpfendorfer CA. Shark nursery areas: concepts, definition, characterization and assumptions. *Mar Ecol Prog Ser.* 2007; 337:287–297.
- Heupel MR, Simpfendorfer CA. Assessing habitat use and movement. In: Carrier JC, Musick JA, Heithaus MR, editors. *Sharks and Their Relatives*. Boca Raton/FL: CRC Press; 2004. p. 579-601.
- Heupel MR, Simpfendorfer CA. Movement and distribution of young bull sharks *Carcharhinus leucas* in a variable estuarine environment. *Aquat Biol.* 2008; 1:277-289.
- Holmlund CM, Hammer M. Ecosystem services generated by fish populations. **Ecological economics**. 1999; 29(2):253-268.
- Hopkins TE, Cech JJ. The influence of environmental variables on the distribution and abundance of three elasmobranchs in Tomales Bay, California. *Environ Biol Fishes.* 2003; 66(3):279-291.
- Jirik KE, Lowe CG. An elasmobranch maternity ward: female round stingrays *Urolophus halleri* use warm, restored estuarine habitat during gestation. *J Fish Biol.* 2012; 80(5):1227-1245.
- Kinney MJ, Simpfendorfer CA. Reassessing the value of nursery areas to shark conservation and management. *Conserv Lett.* 2008; 2(2):53-60.
- Kiszka JJ, Heithaus MR. The state of knowledge on sharks for conservation and management. In: Techera EJ, Klein N, editors. *Sharks: Conservation, Governance and Management*. Abingdon: Routledge; 2014. p. 69.
- Knip DM, Heupel MR, Simpfendorfer CA. Sharks in nearshore environments: models, importance, and consequences. *Mar Ecol Prog Ser.* 2010; 402:1-11.
- Kotas JE. Dinâmica de populações e pesca do tubarão-martelo *Sphyrna lewini* (Griffith & Smith, 1834), capturado no mar territorial e zona econômica exclusiva do sudeste-sul do Brasil (Doctoral dissertation, PhD Thesis. São Paulo University–USP). 2004.

Lessa R, Lahaye J. Biologie et dynamique des populations de *Rhinobatos horkelii* du plateau continental du Rio Grande do Sul (Brésil). (Doctoral thesis, Université Bretagne Occidentale). 1982.

Lessa R, Vooren CM, Araújo MLG, Kotas JE, Charvet-Almeida P, Rincón G, Santana FM, Gadig OB, Sampaio C. Plano nacional de ação para a conservação e o manejo dos estoques de peixes elasmobrânquios no Brasil. Recife/PE: SBEEEL; 2005.

Lucas Z, Stobo WT. Shark-inflicted mortality on a population of harbour seals (*Phoca vitulina*) at Sable Island, Nova Scotia. *J Zool*. 2000; 252(3):405-414.

Mader A, Sander MM, Casa GEJ, Altenhofen RJ, Anjos CS. Evidências de sobrepesca do Tubarão Martelo (*Sphyrna* spp.) no Rio Grande do Sul, Brasil. *Biodiversidade pampeana*. 2007; 5(2):3-5.

Matern SA, Cech JJ, Hopkins TE. Diel Movements of Bat Rays, *Myliobatis californica*, in Tomales Bay, California: Evidence for Behavioral Thermoregulation? *Environ Biol Fishes*. 2000; 58(2):173-182.

Mazzoleni RC, Schwingel PR. Elasmobranch species landed in Itajaí harbor, Southern Brazil. *Notas Técnicas FACIMAR*. 1999; 3:111-118.

Möller O, Fernandes E. Hidrologia e hidrodinâmica. In: Seeliger U, Odebrecht C, editors. O estuário da Lagoa dos Patos: um século de transformações. Rio Grande/RS: FURG; 2010. p. 17-27.

Morash AJ, Mackellar SRC, Tunnah L, Barnett DA, Stehfest KM, Semmens JM, Currie S. Pass the salt: physiological consequences of ecologically relevant hyposmotic exposure in juvenile gummy sharks (*Mustelus antarcticus*) and school sharks (*Galeorhinus galeus*). *Conserv Physiol* [serial on the Internet]. 2016; 4(1):cow036. Available from: <https://doi.org/10.1093/conphys/cow036>

Morrisey JF, Gruber SH. Habitat selection by juvenile lemon sharks, *Negaprion brevirostris*. *Environ Biol Fishes*. 1993; 38(4):311-319.

Myers RA, Baum JK, Shepherd TD, Powers SP, Peterson CH. Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science*. 2007; 315(5820):1846–1850.

Navia AF, Mejía-Falla PA, Giraldo A. Feeding ecology of elasmobranch fishes in coastal waters of the Colombian Eastern Tropical Pacific. *BMC Ecol* [serial on the Internet]. 2007; 7(1): 8. Available from: <https://doi.org/10.1186/1472-6785-7-8>

Nosal A, Caillat A, Kisfaludy E, Royer M, Wegner N. Aggregation behavior and seasonal philopatry in male and female leopard sharks *Triakis semifasciata* along the open coast of southern California, USA. *Mar Ecol Prog Ser*. 2014; 499:157–175

Otway NM, Ellis MT. Pop-up archival satellite tagging of *Carcharias taurus*: movements and depth/temperature-related use of south-eastern Australian waters. *Mar Freshwater Res.* 2011; 62(6):607-620.

Parsons GR, Hoffmayer ER. Seasonal changes in the distribution and relative abundance of the Atlantic sharpnose shark *Rhizoprionodon terraenovae* in the north central Gulf of Mexico. *Copeia.* 2005; 4:914-920.

Pereira LE. Variação diurna e sazonal dos peixes demersais na Barra do Estuário da Lagoa dos Patos, RS. *Atlântica.* 16:5-23.

Pillans RD, Franklin CE. Plasma osmolyte concentrations and rectal gland mass of bull sharks *Carcharhinus leucas*, captured along a salinity gradient. *Comp Biochem Physiol A.* 2004; 138(3):363–371.

Poulakis GR, Stevens PW, Timmers AA, Wiley TR, Simpfendorfer CA. Abiotic affinities and spatiotemporal distribution of the endangered smalltooth sawfish, *Pristis pectinata*, in a south-western Florida nursery. *Mar Freshwater Res.* 2011; 62(10):1165-1177.

Pratt HL, Carrier JC. A review of elasmobranch reproductive behavior with a case study on the nurse shark, *Ginglymostoma cirratum*. *Environ Biol Fishes.* 2001; 60: 157–188.

Psomadakis PB, Dalù M, Scacco U, Vacchi M. A rare batoid fish *Gymnura altavela* (Chondrichthyes, Gymnuridae) captured in the Tyrrhenian Sea. *Mar Biodivers Rec [serial on the Internet].* 2008; 1:e6. Available from: <https://doi.org/10.1017/S1755267206000662>

Robbins RL. Environmental variables affecting the sexual segregation of great white sharks *Carcharodon carcharias* at the Neptune Islands South Australia. *J Fish Biol.* 2007; 70(5):1350–1364.

Rocha GRA, Rossi-Wongtschowski CLDB. Demersal fish community on the inner shelf of Ubatuba, southeastern Brazil. *Braz J Oceanogr.* 1998; 46(2):93-109.

Santos PRS, Santoro P, Chelotti LD. Length-weight relationship of the spinner shark (*Carcharhinus brevipinna*) on the continental shelf of southern Brazil. *Arq Cienc Mar.* 2017; 50(2):1-4.

Scheffer M, Carpenter S, Young B. Cascading effects of overfishing marine systems. *Trends Ecol Evol.* 2005; 20(11):579–581.

Schlaff AM, Heupel MR, Simpfendorfer CA. Influence of environmental factors on shark and ray movement, behaviour and habitat use: a review. *Rev Fish Biol Fish.* 2014; 24(4):1089-1103.

Schwarz R JR, Franco ACNP, Spach HL, Sarpedonti V, Pichler HA, Queiroz GMLN. Composição e estrutura da ictiofauna demersal na Baía dos Pinheiros, Paraná. *Braz J Aquat Sci Technol.* 2006; 10(1):27-39.

SEMACE/LABOMAR. Ictiofauna dos estuários do estado do Ceará: Zoneamento Ecológico e Econômico (ZEE) da Zona Costeira do Estado do Ceará. Fortaleza/CE: Governo do Estado do Ceará, Universidade Federal do Ceará; 2005.

Sims DW, Southall EJ, Richardson AJ, Reid PC, Metcalfe JD. Seasonal movements and behaviour of basking sharks from archival tagging: no evidence of winter hibernation. *Mar Ecol Prog Ser.* 2003; 248:187–196

Simpfendorfer CA, Freitas GG, Wiley TR, Heupel MR. Distribution and habitat partitioning of immature bull sharks (*Carcharhinus leucas*) in a southwest Florida estuary. *Estuaries.* 2005; 28(1):78-85.

Simpfendorfer CA, Milward NE. Utilization of a tropical bay as a nursery area by sharks of the families Carcharhinidae and Sphyrnidae. *Environ Biol Fishes.* 1993; 37(4):337–345.

Simpfendorfer CA, Heupel MR, White WT, Dulvy NK. The importance of research and public opinion to conservation management of sharks and rays: a synthesis. *Mar Freshwater Res.* 2011a; 62(6):518-527.

Simpfendorfer CA, Yeiser BG, Wiley TR, Poulakis GR, Stevens PW, Heupel MR. Environmental influences on the spatial ecology of juvenile smalltooth sawfish (*Pristis pectinata*): results from acoustic monitoring. *PLoS One.* 2011b; 6(2):1–12

Speed CW, Field IC, Meekan MG, Bradshaw CJ. Complexities of coastal shark movements and their implications for management. *Mar Ecol Prog Ser.* 2010; 408:275-293.

Spengler A, Wallner-Ksarnach M, Baumgarten MGZ. Rio Grande municipal dump site impact in the estuary of the Patos Lagoon (RS, Brazil). *Acta Limnol Bras [serial on the Internet].* 2007; 19(2):197-210. Available from: <http://repositorio.furg.br/handle/1/5850>

Springer S. Social organization of shark populations. In: Gilbert PW, Mathewson RF, Rall DP, editors. *Sharks, Skates and Rays.* Baltimore/MD: The John Hopkins University Press; 1967. p. 149–174.

Stevens JD, Bonfil R, Dulvy NK, Walker PA. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES J Mar Sci.* 2000; 57(3):476-494.

Tagliani PRA, Landazuri H, Reis EG, Tagliani CR, Asmus ML, Sánchez-Arcilla A. Integrated coastal zone management in the Patos Lagoon estuary: perspectives in context of developing country. *Ocean Coast Manag.* 2003; 46(9):807-822.

Thrush SF, Pridmore RD, Hewitt JE, Cummings VJ. Impact of ray feeding disturbances on sandflat macrobenthos: do communities dominated by polychaetes or shellfish respond differently? *Mar Ecol Prog Ser.* 1991; 69(3):245–252.

Ubeda AJ, Simpfendorfer CA, Heupel MR. Movements of bonnetheads, *Sphyrna tiburo*, as a response to salinity change in a Florida estuary. *Environ Biol Fishes.* 2009; 84(3):293-303.

Vaz AC, Junior OOM, de Almeida TL. Análise quantitativa da descarga dos rios afluentes da Lagoa dos Patos. *Atlântica (Rio Grande)*. 2006; 28(1):13-23.

Viana AF, Valentin JL, Vianna M. Feeding ecology of elasmobranch species in southeastern Brazil. *Neotrop Ichthyol.* 2017; 15(2):e160176 . Available from: <http://dx.doi.org/10.1590/1982-0224-20160176>

Vieira JP, Garcia AM, Moraes L. A assembléia de peixes. In: Seeliger U, Odebrecht C, editors. *O estuário da Lagoa dos Patos: um século de transformações.* Rio Grande/RS: FURG; 2010. p. 79-88.

Vooren CM, Klippel S. Ações para a conservação de tubarões e raias no sul do Brasil. Porto Alegre/RS: Igaré; 2005.

Vooren CM, Klippel S, Lamónaca AF, Galina AB. A Plataforma Sul e os métodos de trabalho. In: Vooren CM, Klippel S, editors. *Ações para a conservação de tubarões e raias no sul do Brasil.* Porto Alegre/RS: Igaré; 2005.

Walker TI. Can shark resources be harvested sustainably? A question revisited with a review of shark fisheries. *Mar Freshwater Res.* 1998; 49(7):553-572.

Werry JM, Lee SY, Otway NM, Hu Y, Sumpton W. A multi-faceted approach for quantifying the estuarine–nearshore transition in the life cycle of the bull shark, *Carcharhinus leucas*. *Mar Freshwater Re.* 2011; 62(12):1421-1431.

Wetherbee BM, Gruber SM, Rosa RS. Movement patterns of juvenile lemon sharks *Negaprion brevirostris* within Atol das Rocas, Brazil: a nursery characterized by tidal extremes. *Mar Ecol Prog Ser.* 2007; 343:283-293.

### Captions

**Fig. 1.** Map showing the location of Patos lagoon estuary in Rio Grande do Sul state (RS) - Brazil. In evidence, detailed map of Patos lagoon estuary (PLE). Dotted line (---): imaginary line between Ponta dos Lençóis and Ponta da Feitoria, indicating the end of the estuarine area; arrow (◄): point of connection with the ocean.

**Fig. 2.** Correlation between environmental variables and CPUE (individuals/fishing period) from gill nets. **a)** CPUE correlation with salinity (ppm); **b)** CPUE correlation with depth (m); **c)** CPUE correlation with water surface temperature (WST) (°C).

**Fig. 3.** Seasonal CPUE values (only gill nets) for *Sphyrna lewini*, *Pseudobatos horkelii*, *Sphyrna zygaena* and *Carcharhinus brevipinna*.

### Tables

**Tab. 1.** Number of boardings and number of elasmobranch captures per fishing gear. NB: number of landings; NFP: number of fishing periods; NBE: number of landings with elasmobranchs; NFPE: number of fishing periods with elasmobranchs; N: number of elasmobranchs captured.

	<b>NB</b>	<b>NFP</b>	<b>NBE</b>	<b>NFPE</b>	<b>N</b>
<b>Gill net</b>	212	234	77	85	559
<b>Trawl</b>	10	30	3	4	16
<b>Artisanal line</b>	5	50	1	6	6
<b>Total</b>	227	314	81	95	581

**Tab. 2.** Tukey test results ( $p < 0.05$ ) showing the significance between the variation of seasonality data and CPUE values from gill nets.

	<b>Summer</b>	<b>Autumn</b>	<b>Winter</b>	<b>Spring</b>
<b>Summer</b>	-	0.001	0.001	0.738
<b>Autumn</b>	15.780	-	0.999	0.001
<b>Winter</b>	15.880	0.102	-	0.001
<b>Spring</b>	1.472	14.310	14.410	-

**Tab. 3.** Systematic classification of the species sampled in Patos lagoon estuary and data on captures and length. N: total of individuals sampled; %FO: Frequency of Occurrence; CPUE: Catch per Unit of Effort; *Cii*: Capture Importance Index; LA: amplitude of length (cm); DLA: amplitude of disk length (cm); ML/SD: mean length and standard deviation (cm).

Family	Species	N	%FO	CPUE	Cii	LA	DLA	ML / SD
<b>Hexanchidae</b>	<i>Notorynchus cepedianus</i> (Péron, 1807)	3	0.009	0.013	0.0116	87 – 97.5	-	92.2 ± 4.29
<b>Squatinae</b>	<i>Squatina guggenheim</i> Marini, 1936 **	35	0.013	0.154	0.2038	24 – 67	-	41.21 ± 10.22
<b>Odontaspidae</b>	<i>Carharias taurus</i> Rafinesque, 1810	3	0.013	0.013	0.0175	124 – 220	-	158.5 ± 43.59
<b>Triakidae</b>	<i>Mustelus fasciatus</i> (Garman, 1913)	2	0.009	0.009	0.0078	37.5 – 39	-	38.25 ± 0.75
	<i>Mustelus schmitti</i> Springer, 1939	16	0.013	0.070	0.0931	21.9 – 48.2	-	32.64 ± 10.81
<b>Carcharhinidae</b>	<i>Carcharhinus brevipinna</i> (Müller & Henle, 1839)	85	0.026	0.374	0.9897	31.2 – 91.4	-	38.21 ± 9.53
	<i>Carcharhinus obscurus</i> (Lesueur, 1818)	6	0.004	0.026	0.0116	42.1 – 43.5	-	43.02 ± 0.54
	<i>Carcharhinus plumbeus</i> (Nardo, 1827)	2	0.004	0.009	0.0039	78.1 – 78.8	-	78.45 ± 0.35
	<i>Rhizoprionodon lalandii</i> (Müller & Henle, 1839)	38	0.053	0.167	0.8849	22.3 – 89.2	-	59.34 ± 18.11
<b>Sphyrnidae</b>	<i>Sphyrna lewini</i> (Griffith & Smith, 1834)	182	0.084	0.802	6.7108	38.8 – 97	-	52.44 ± 7.03
	<i>Sphyrna zygaena</i> (Linnaeus, 1758)	54	0.053	0.238	1.2575	43 – 102	-	58.82 ± 12.84
<b>Rhinobatidae</b>	<i>Pseudobatos horkelii</i> (Müller & Henle, 1841)	95	0.057	0.419	2.3967	-	15 – 71	34.27 ± 8.55
<b>Narcinidae</b>	<i>Narcine brasiliensis</i> (Olfers, 1831)	1	0.004	0.004	0.0019	-	22.1*	-
<b>Arhynchobatidae</b>	<i>Sympterygia acuta</i> Garman, 1877 **	36	0.035	0.159	0.5589	-	15 – 30	20.84 ± 4.1
	<i>Sympterygia bonapartii</i> Müller & Henle, 1841	10	0.018	0.044	0.0776	-	31 – 43	38.7 ± 3.32
<b>Gymnuridae</b>	<i>Gymnura altavela</i> (Linnaeus, 1758)	2	0.009	0.009	0.0078	-	88 -98	93 ± 7.07
<b>Dasyatidae</b>	<i>Dasyatis hypostigma</i> Santos & Carvalho, 2004	4	0.013	0.018	0.0233	-	24.3 – 34.9	29.07 ± 4.56
<b>Myliobatidae</b>	<i>Myliobatis goodei</i> Garman, 1885	5	0.009	0.022	0.0194	-	48 – 57.7	51.94 ± 3.52
	<i>Myliobatis ridens</i> Ruocco, Lucifora, Díaz de Astarloa, Mabrugaña & Delpiani, 2012	2	0.004	0.009	0.0039	-	27.6 – 30.1	28.85 ± 1.25



**Tab. 4.** Chi-square results (  $\chi^2$  ) (p = 0.05) testing for differences between the ratios between stages of development for *Carcharhinus brevipinna*, *Pseudobatos horkelii*, *Sphyrna lewini* and *Sphyrna zygaena*. NJR: neonates X juveniles ratio; JAR: juveniles X adults ratio; NAR: neonates X adults ratio.

	NJR	$\chi^2$	p	JAR	$\chi^2$	p	NAR	$\chi^2$	p
<i>C. brevipinna</i>	1:27.33	73.424	< 0.001	-	-	-	-	-	-
<i>P. horkelii</i>	1:0.16	45.511	< 0.001	1:15.40	63.220	< 0.001	1:2.6	3.556	0.593
<i>S. lewini</i>	1:19.22	147.780	< 0.001	-	-	-	-	-	-
<i>S. zygaena</i>	1:3.5	16.667	< 0.001	-	-	-	-	-	-

**Tab. 5.** Biological data on the four most representative species in Patos lagoon estuary (*Carcharhinus brevipinna*, *Pseudobatos horkelii*, *Sphyrna lewini* and *Sphyrna zygaena*). T: total of specimens sampled; M: number of males; F: number of females; SR: sex ratio (M:F);  $\chi^2$  : chi-square values for differences between males and females (p = 0.05); N: number of neonates; J: number of juveniles; A: number of adults.

	T	N	J	A		T	N	J	A
<i>C. brevipinna</i>	85	85	3	0	<i>S. lewini</i>	182	173	9	0
M	37	35	2	-	M	87	81	6	-
F	48	47	1	-	F	95	92	3	-
SR	1:1.29	1:1.34	1:0.50	-	SR	1:1.09	1:1.13	1:0.5	-
$\chi^2$	1.423	1.756	0.333	-	$\chi^2$	0.351	0.699	1.000	-
p	0.232	0.185	0.563	-	p	0.553	0.403	0.317	-

<i>P. horkelii</i>	95	13	77	5	S.	54	42	12	0
<b>M</b>	13	3	9	1	<i>zygaena</i>	27	19	8	-
<b>F</b>	82	10	68	4	<b>M</b>	27	23	4	-
<b>SR</b>	1:6.31	1:3.33	1:7.55	1:4	<b>F</b>	1:1	1:1.21	1:0.5	-
$\chi^2$	50.116	3.769	45.208	1.800	<b>SR</b>	0	0.380	1.333	-
<b>P</b>	< 0.001	0.522	< 0.001	0.179	$\chi^2$	1	0.537	0.248	-
					<b>P</b>				