Analysis of food habits of skate *Rioraja agassizii* (Elasmobranchii, Rajidae) from southern Brazil

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Abstract

Catches and exports of skate *Rioraja agassizii* place this species as "vulnerable to extinction" on the IUCN Red List; therefore, biological and ecological knowledge becomes an important instrument for its conservation control. This study described and quantified the diet composition of *R. agassizii* by means of stomach analysis contents in the periods 2005-2006 and 2012-2013. We analyzed and quantified stomach contents in terms of abundance (%N), weight (%M), frequency of occurrence (% FO), and index of relative importance (IRI). The results showed differences in the food rates between the periods. However, the groups of food items were the same: Teleostei fish, decapods, and mollusks. In 2005-2006, the diet consisted mainly of shrimp, however, in 2012-2013 it consisted of fish, followed by decapods, especially shrimps. The differences in diets may be attributed to shrimp abundance, which do not characterize a change in the eating habits in 2012-2013, because, in addition to fish, shrimps were also important food sources. The presence of a certain prey is more related to its availability rather than the feeding preference of skate. The amount of ingested items is associated to biological and environmental factors, so that further studies relating diet with capture area, seasonality, depth, and other factors should be conducted.

Keywords: diet, feeding ecology, feeding preference, prey, stomach content.

Análise quantitativa dos hábitos alimentares da raia *Rioraja agassizii* (Elasmobranchii, Rajidae) do Sudeste e Sul do Brasil

Resumo

A raia-santa, *Rioraja agassizii* é uma espécie endêmica da qual pouco se conhece sobre sua biologia e ecologia, o que a leva a ser classificada como "vulnerável a extinção". O objetivo foi identificar e quantificar a composição da dieta alimentar da *R. agassizii* através da análise do conteúdo estomacal de exemplares capturados nos períodos de 2005-2006 e 2012-2013. Foram analisados os conteúdos alimentares e quantificados em abundância (N%), peso (M%), frequência de ocorrência (FO%) e índice de importância relativa (IRI) de cada item. Os resultados mostraram que em 2012-13 a dieta foi composta por peixes, seguido de decápodes, especialmente camarões, entretanto em 2005-06 foi composta basicamente por camarões. A diferença nas dietas não quer dizer que os hábitos alimentares mudaram, pois em 2012-13 além dos peixes, os camarões também foram classificados como maior importância alimentar. Considerando que a quantidade e variedade dos itens ingeridos está relacionada, principalmente, a fatores ambientais são necessários mais estudos que relacionem áreas de captura, sazonalidade e profundidade.

Palavras-chave: dieta, ecologia alimentar, preferencia alimentar, presa, conteúdo estomacal.

1. Introduction

Elasmobranchs present slow growth rate, late maturation, and low fecundity (Frisk, 2010). These factors, along with bycatch, can lead these organisms to a population decline, and the family Rajidae is one of the most vulnerable to exploitation (Dulvy and Reynolds, 2002).

The scenario of overfishing, lack of biological information, and catches led to overexploitation of various demersal elasmobranchs in Southeast Atlantic or South Occidental Atlantic (Vooren and Klippel, 2005). Gaichas et al. (2005) claim for a proper management to protect the Rajidae family against locally depletion, especially when little is known about habits and structure of the population.

According to Ellis et al. (2010), research shows that some species of Rajidae feature very unequal distributions, which may make them locally prone to depletion.

In Brazil, this family is represented by 11 genera and 26 species including the skate *Rioraja agassizii* (Müller and Henle, 1841), which occurs from the Espírito Santo State in Brazil to Argentina, more frequently on the coast of Rio de Janeiro and São Paulo States (Figueiredo, 1977). There is no conservation measure for the genera *Atlantoraja* and *Rioraja* (Hozbor et al., 2004; Massa et al., 2006; San Martín et al., 2007). The population of the genus *Atlantoraja* shows a trend to decline, however, for the genus *Rioraja*, this trend is still unknown (Kyne et al., 2007; IUCN, 2012). According to the IUCN, *Atlantoraja castelnaui* (Miranda-Ribeiro, 1907) is classified as "endangered at risk", while *A. cyclophora* (Regan, 1903), *A. platana* (Günther, 1880) and *Rioraja agassizii* are listed as "vulnerable" (IUCN, 2012).

Although endemic, the Rajidae family features a diversified diet, consuming different prey types such as fish, mollusks, and crustaceans (Ebert and Bizzarro, 2007). Because they inhabit higher trophic levels, they can compete directly with deep-sea fish (Link and Garrison, 2002). According to Wetherbee and Córtes (2004), to understand the energy flow between trophic levels, it is necessary to understand not only what elasmobranchs eat, but also characterize their digestion, energy processing, and nutrients in the prey consumed.

Food biology of sharks and skates have been studied to understand the natural history of a particular species, its ecological role in the ecosystem, the predation impact on preys with economic value such as the pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) and *F. paulensis* (Pérez-Farfante, 1967), and risks of extinction due to overexploitation (Wetherbee and Córtes, 2004; Aguiar and Valentin, 2010).

Many studies have investigated the diet and feeding habits of fish based on the analysis of stomach contents, but there is a lack of consistency in the results (Cortés, 1997). According to Vianna et al. (2000), studies on feeding habits are important to explain changes in aspects of fish growth, migration and reproduction.

Because of the constant catches of *R. agassizii*, especially bycatch, trawl fisheries, with high rejection on board, export increase, and mainly lack of information, the species was classified as "vulnerable". The knowledge of biological and ecological factors of this species is important for its effective management and conservation. This study described and quantified the diet composition of *R. agassizii* using stomach contents of specimens captured during 2005-2006 and 2012-2013 in southern Brazil.

2. Material and Methods

We analyzed stomach contents in 351 specimens of *R. agassizii* from March 2005 to April 2006 captured by fishing pair trawling, at depths ranging from 10 to 146 m. Between June 2012 to September 2013, we captured 49 specimens by means of pink shrimp double trows, at depths of 25 to 70 m. There was no specimen sampling during the closed shrimp season between March 1st and May 31st, 2013 (Brasil, 2008) for the sampling period of 2012-2013. In both periods, the study site includes the coastal region from the states of Rio de Janeiro to Santa Catarina, southern Brazil (see Figure 1).

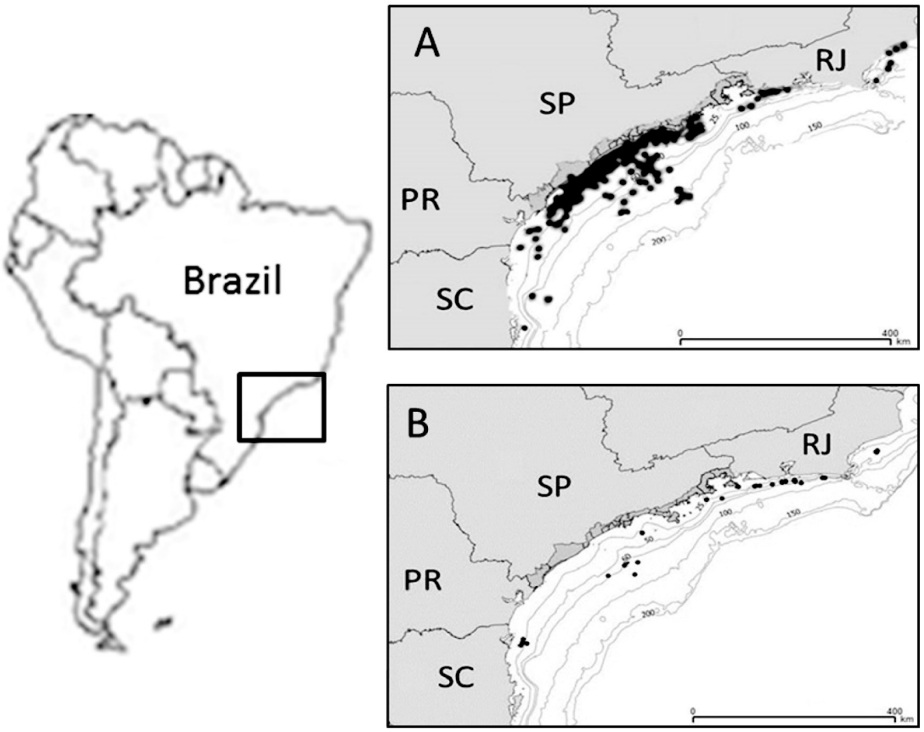

Figure 1. Capture area of skate *Rioraja agassizii*, captured in southern Brazil, in two periods, by pair trawl over the period of 2005-2006 (A) and by pink shrimp double trawls over the period of 2012-2013 (B).

The specimens collected were identified, sexed, weighed (TW, kg) and the total length (TL, cm) was measured. After removal, their stomachs were weighed on a 1-g precision balance and classified at five levels in terms of repletion degree (RD): empty stomach = RD 0; almost empty (up to 25%) = RD I; half full (25-50%) = RD II; almost full (51-75%) = RD III; and full stomach (>75%) = RD IV (Soares et al., 1999; Dolgov, 2005).

The stomach contents were preserved in alcohol 70% for crustaceans, and in formalin 10% for fish. Afterwards, the contents were identified in taxonomic groups and weighed. The digestion degree of each prey was registered in three levels, as follows: undigested, with no signs of digestion = 1; partially digested, but identifiable = 2; and digested without identification with presence of otoliths, crystalline, and other appendages = 3 (Soares and Apelbaum, 1994).

Each item of stomach contents was identified for the lowest possible taxon, according to identification guides (Figueiredo, 1977; Figueiredo and Menezes, 1978, 1980; Menezes and Figueiredo, 1985) and crustaceans (Melo, 1996, 1999; Pérez-Farfante and Kensley, 1997; Carpenter, 2002; Costa et al., 2003). For food analysis, abundance was represented by number of individuals (N%) of each item. For biomass calculation, we used the weight (W%) and calculated the frequency of occurrence (FO%) of the food items in the stomach contents. We also estimated the index of relative importance (IRI), which establishes the importance of food items, using the formula of Schwingel and Castello (1994). For items of greater food importance, the IRI value was higher than 1,000. For items of intermediate importance, the IRI ranged between 50-1,000, and those with lesser importance, the IRI values were smaller than 50.

3. Results

3.1. Samples from 2005-2006

Of the 351 specimens sampled between 2005-2006, 93.1% were adults and only 6.9% juveniles. The sample contained 88 males with TL between 29.3-56.2 cm and 259 females with TL ranging from 26.5-58.2 cm. Four specimens, one female and three males, did not provide TL measures, because their tails were damaged. Figure 2a shows the TL distribution of the groups of sex of 347 specimens.

Only 5.2% of stomachs examined were empty and 94.8% contained some food. Most stomachs (35.9%) showed RD I, followed by 20.8%, RD II; 27%, RD III; and 11.1%, RD IV. Three major groups were identified, and shrimps (Penaeidae family) were the most important food source with IRI = 7,213.6, followed by unidentified fish with IRI = 649.7 (as shown in Table 1). Among the shrimps, we identified *Xiphopenaeus kroyeri* (Heller, 1862), *Farfantepenaeus paulensis*, *Rimapenaeus constrictus* (Stimpson, 1874), and *Litopenaeus schmitthi* (Burkenroad, 1936).

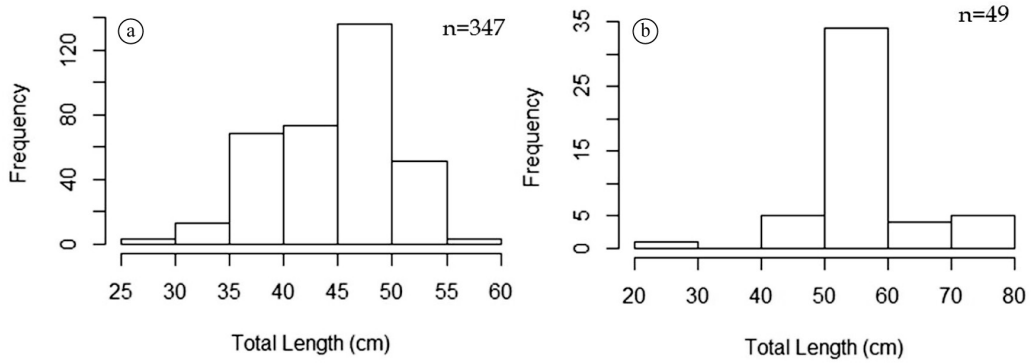

Figure 2. Histogram of total length (TL - cm) of skate *Rioraja agassizii*, collected during 2005-2006 (a) and 2012-20013 (b).

Table 1. Diet composition of skate *Rioraja agassizii* in the 2005-2006 period.

PREYS	%N	%M	%FO	IRI	%IRI
TELEOSTEI	**3.2**	**43.5**	**14.7**	**686.5**	**7.2**
Bothidae (*Bothus sp.*)	0.0	1.7	0.3	0.4	-
Unidentified teleosts	3.2	41.8	14.5	649.7	-
CRUSTACEA	**92.9**	**44.0**	**65.0**	**8,901.1**	**92.8**
Penaeidae	90.9	37.0	56.4	7,213.6	-
Brachyura	0.1	0.3	0.5	0.2	-
Portunidae	0.9	2.5	4.7	15.8	-
Squillidae	0.0	0.1	0.3	0.0	-
Unidentified crustaceans	1.0	4.1	3.2	16.3	-
MOLLUSCA_CEPHALOPODA	**0.1**	**0.5**	**0.5**	**0.3**	**<0.01**
Unidentified cephalopods	0.1	0.5	0.5	0.3	-

N% - numerical percentage; M% - mass percentage; FO% - frequency of occurrence percentage; IRI - index of relative importance; IRI% - percentage of IRI. Bold indicates the largest taxonomic group.

3.2. Samples from 2012-2013

A number of 49 stomachs of 49 specimens of *R. agassizii*. Of the total sampled, two specimens were males with TL of 48.5 and 71.5 cm. The TL of females ranged from 26.3-76.5 cm and all individuals were adults. Figure 2b shows the TL histogram for grouped sex of the specimens sampled.

The results showed that 20.4% of the stomachs had RD 0; 36.7%, RD I; 20.4%, RD II; 8.2%, RD III; and 14.3%, RD IV. We identified three major food groups: fish, crustaceans, and mollusks, among which the teleostei group had the highest representativeness for food source according to the IRI, followed by decapods (as shown in Table 2). Most fish (N = 27.1%) were classified as "unidentified fish" because of the advanced digestion state (grade 3) observing only with presence of otoliths, crystalline, and appendices. The ost representative groups among the Teleostei fish were the Paralichthyidae family with N = 8.2%. In the group of decapods, the food item of greater importance was the shrimp with IRI = 746.8, followed by the *Achelous spinicarpus* (Stimpson, 1871) with IRI = 364.9.

4. Discussion

The food items were grouped into Teleostei (fish), Penaeidae (shrimp), Brachyura (crabs), Crustacea (Squillidae, Nephropidae) to facilitate the comparison of periods. We also observed a difference in the diet composition of *R. agassizii* in the 2005-2006 period, predominated by decapods, mainly shrimps of the family Penaeidae. Comparatively, in 2012-2013, the Teleostei fish showed the largest IRI and FO levels (see Figure 3). We also observed a difference between the

Table 2. Diet composition of skate *Rioraja agassizii*, in 2012 and 2013.

PREYS	N%	M%	FO%	IRI	IRI%
TELEOSTEI	**50.0**	**78.3**	**64.1**	**8,224.7**	**62.0**
Paralichthyidae	8.2	14.8	15.4	354.9	-
Ophidiidae (*Raneya brasiliensis*)	0.8	1.6	2.6	6.1	-
Anguiliforme	2.2	6.4	7.7	66.6	-
Mullidae (*Mullus sp*)	1.5	10.7	2.6	31.3	-
Triglidae (*Prionotus sp*)	0.8	13.0	2.6	35.5	-
Batrachoididae (*Porichthys porosissimus*)	0.8	10.8	2.6	29.7	-
Unidentified teleosts	35.8	19.2	46.2	2,540.3	-
CRUSTACEA	**48.5**	**21.7**	**71.8**	**5,039.6**	**38.0**
Brachyura	1.5	2.5	5.1	20.7	-
Portunidae (*Achelous spinicarpus*)	12.7	3.1	23.1	364.9	-
Nephropidae (*Metanephrops rubellus*)	3.0	5.1	10.3	83.3	-
Penaeidae	22.4	1.9	30.8	746.8	-
Squillidae	3.0	6.2	10.3	94.2	-
Unidentified crustaceans	6.0	4.5	15.4	160.7	-
MOLLUSCA_GASTROPODA	**1.5**	**0.01**	**5.1**	**7.7**	**0.1**
Unidentified gastropods	1.5	0.01	5.1	7.7	-

N% - numerical percentage; M% - mass percentage; FO% - frequency of occurrence percentage; IRI - index of relative importance; IRI% - percentage of IRI. Bold letters indicates the largest taxonomic group.

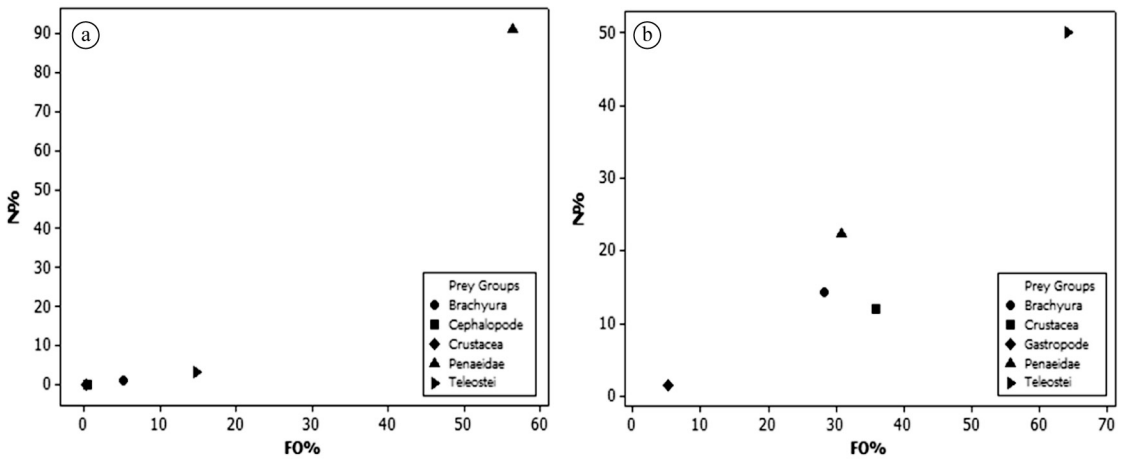

Figure 3. Graphical representation of the diet of skate *Rioraja agassizii*; (a) sampling of the 2005-2006 period; (b) sampling of 2012-2013 period. N% = numerical percentage, FO% = frequency of occurrence percentage.

structure of the two populations, where in 2012-2013, the sample showed a smaller number of specimens, but with greater TL from 71.5 to 80 cm and predominance between 50-60 cm. On the other hand, the sample of 2005-2006 showed the highest number of specimens, however, with predominance between 45-50 cm with maximum TL of 60 cm. In both samples, all specimens were adults, which is confirmed in the literature (Oddone et al., 2007).

According to Muto et al. (2001), *R. agassizii* feeds on benthic items, mainly crustaceans such as shrimp and crabs, corroborated by the results obtained in the sample collected between 2005-2006. Food chronology of this skate was also studied by Soares et al. (1999), which concluded that its diets was also based on crustaceans and small teleostei fish. Soares et al. (1999) and Muto et al. (2001) performed his works on the coast of Ubatuba (Sao Paulo-SP State, Brazil) from scientific cruises, in a different sampling scenario from that conducted by commercial fishing boats.

The differences, comparing the two periods studied in this work with results obtained by other authors, were probably caused by different fishing gears (pair trawling and double trawls) that were used at different depths, sample size, time interval, in addition to the biotic and oceanographic factors.

The small number of specimens captured in the 2012-2013 sample may have been caused by ecological factors, environmental changes, modification of the fishing area, and fishing pressure from other vessels, since other studies show that this species is considered abundant in trawling.

Mazzoleni and Schwingel (1999) observed that the species *R. agassizii*, *A. cyclophora*, *A. castelnaui*, and *A. platana*, from catches of the fishing fleet landed in Itajaí (Santa Catarina State, Brazil), are classified as abundant in pair trawling. Muto et al. (2001) also consider *R. agassizii* and *Psammobatis extenta* (Garman, 1913) important in terms of abundance and biomass on the coast of Ubatuba (SP State, Brazil).

The fact that fish was the group with the highest IRI in 2012-2013 does not characterize a change in diet of *R. agassizii*, because decapods, mainly shrimps, were also identified in the stomach contents. For Schwingel and Assunção (2009), the Rajidae feature varied diet, while Muto et al. (2001) state that the diet of *R. agassizii* was based on shrimps (Caridae and Penaeidae) and small teleostei fish. According to Marion et al. (2011), the presence of crustaceans in the stomach contents of batoid elasmobranchs is relatively common, as found in *Zapteryx brevirostris* and other studies.

Barbini and Lucifora (2011) also studied feeding habits of *R. agassizii*, however, in the region between Uruguay and Argentina, and observed values similar to the IRI for teleostei fish and decapods, 34.4% and 33.9%, respectively. The authors also observed that their results are different from results obtained by Soares et al. (1999) and Muto et al. (2001) on the coast of Ubatuba (SP State, Brazil). The results obtained by Barbini and Lucifora (2011) were similar to those found in the 2012-2013 sampling, with fish showing IRI values slightly higher than those for the group of decapods.

The presence (or absence) of a prey in the stomach of predator may be attributed to the availability (or not) in the environment or to the facility or difficulty of capture (Zavala-Camin, 1996). Seasonal and geographical differences found in food diets are more related to prey community and availability, which can change, for example, due to intense fishing activity (Muto et al., 2001; Wetherbee and Córtes, 2004; Ebert and Bizzarro, 2007; Aguiar and Valentin, 2010). The quantity and quality of foods ingested are associated with the life cycle, prey and predator sizes and the digestion degree (Bowen, 1983).

Changes in diet observed in the 2012-2013 sample and by authors Barbini and Lucifora (2011) may indicate a change in the eating habits of *R. agassizii* due to environmental and anthropogenic factors, therefore, further studies connecting the diet with the area of capture, seasonality, depth, and other factors are required.

Mazzoleni and Schwingel (1999) state that the increase of fisheries for elasmobranchs in Brazil can be a result of increased international demand for meat of Rajidae. This fact can be confirmed, because data from the Information Analysis System for Foreign Trade (ALICEWEB2, 2013) of the Foreign Trade Secretariat show that from January 1997 to September 2013, Brazilian exports to South Korea reached roughly 2,500 t of skates of the Rajidae family classified in two categories: fresh or chilled and frozen (ALICEWEB2, 2013).

The population structure of samples was also different, where the specimens collected in 2012-2013 showed greater TL, while specimens from the 2005-2006 sample had a higher FO and smaller TL.

The diet of the skate *R. agassizii* in both periods analyzed was composed of the same food groups, however in the 2012-2013 period, the main diet group was teleostei fish captured at lower depths (25-70 m). In the 2005-2006 period, the most important group was the decapods, mainly shrimps captured at higher and lower depths (10-146 m). These differences were probably caused by different fishing gears used at different depths and sampling period, besides the biological, ecological, and oceanographic factors.

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