

Notes on the feeding habits of the skate *Rioraja agassizi* (Chondrichthyes, Rajidae) off southeastern Brazil

by

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ABSTRACT. - Feeding habits of the skate *Rioraja agassizi* were analyzed in southeastern Brazil from samples obtained along São Paulo coast. A total of 258 specimens were examined, ranging between 96 and 532 mm total length. About 57.85% were females and 42.15% were males, resulting in a 1:1.37 sex-ratio to females. From 223 stomachs collected (94 males and 129 females) empty stomachs represented only 1.4%. Nine prey categories were identified: Polychaeta, Copepoda, Cumacea, Isopoda, Gammaridea, Dendrobranchiata, Brachyura, Teleostei, and one non-animal category (non-identifiable items). Crustaceans were the most important item, indicating that the species has a carcinophagic preference. The presence of fish was just verified in juveniles and some adult individuals, with predominance in summer. Sex, maturity stage and seasonality did not influence the feeding habits of the species.

RÉSUMÉ. - Notes sur les habitudes alimentaires de *Rioraja agassizi* (Chondrichthyes, Rajidae) dans le sud du Brésil.

Les habitudes alimentaires de *Rioraja agassizi* ont été analysées dans le sud-ouest du Brésil, tout au long de la côte de l'État de São Paulo. Au total, 258 exemplaires ont été examinés, leurs tailles variant entre 96 et 532 mm de longueur totale. Les femelles ont représenté 57,85% de l'échantillon, conduisant à un sex-ratio secondaire de 1 : 1,37 en leur faveur. Sur 223 estomacs recueillis (94 mâles et 129 femelles) ceux qui étaient vides représentaient seulement 1,4%. Neuf catégories de proies ont été identifiées: Polychaeta, Copepoda, Cumacea, Isopoda, Gammaridea, Dendrobranchiata, Brachyura, Teleostei, et des restes inorganiques (items non identifiées). Les crustacés sont la proie la plus importante, indiquant une préférence carcinophage pour cette espèce. La présence de poissons a été vérifiée seulement dans les estomacs de juvéniles avec une prédominance durant les mois d'été. Aucune influence des variables "sexe", "maturité" et "saison" sur les habitudes alimentaires n'a été détectée.

Key words. - Rajidae - Elasmobranch - *Rioraja agassizi*- SW Atlantic - Trophic ecology.

Skates are an important link of the trophic food webs in benthic and demersal communities (McEachran and Dunn, 1998). Thousands of tons of skates are captured every year by the shrimp fishery and discarded as bycatch. The genus *Rioraja* is represented by a single species, *Rioraja agassizi* (Müller and Henle, 1841), which has a distribution limited to the southwestern Atlantic, from Rio de Janeiro to Argentina, in waters between 5 and 100 m deep (Figueiredo, 1977; Vooren, 1997; Gomes, 2002).

Although *R. agassizi* is a well-known species in local fisheries, there is scarce biological information in the literature. Only recent studies have been performed concerning size composition, condition factor and morphometrics (Oddone *et al.*, 2007a), and reproduction (Oddone *et al.*, 2007b). Feeding studies are reported to local samples from Ubatuba region, São Paulo State northern coast (Soares *et al.*, 1992, 1999; Muto, 1993; Muto *et al.*, 2001). Although *R. agassizi* is abundant along the coast of São Paulo, its feeding habits are still partially known, a fact that might be very relevant

in future studies of fisheries management, since the species has a restricted distribution and its proportion in the captures is increasing in local fisheries. The present study aims to analyse the feeding habits of *R. agassizi* along the coast of São Paulo as well as seasonal and ontogenetic variations, for both sexes.

MATERIAL AND METHODS

The specimens were collected among bycatch of a local shrimp fishery, in 10 sampling stations, within depths varying between 10 and 50 meters, between Baía de Santos and São Sebastião Island, São Paulo coast, southeastern Brazil. Samples were obtained only for winter, spring and summer 2002, due to a regular period of shrimp moratorium during the austral autumn (MMA n.74, 13 Feb. 2001). All individuals were identified during landing, measured (disc width, DW and total length, TL), weighed, and stored frozen. In the

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laboratory, stomachs were removed, fixed in formalin 4%, and stored in ethanol 70%.

Stomach fullness (SF) of each stomach was classified according to Pillay (1952), as follows: I) empty stomach; II) 1 to 25% full; III) 26 to 50% full; IV) 51 to 75% full; and V) 76 to 100% full. Prey items were identified to the lowest possible taxonomic level, and the volumes in the stomach contents were taken. Occurrence frequency (%F), points percent (%P), and numerical percent (%N) of prey were recorded. The method of the percentage of points (%P) was used to give a determined quantity of points based in the volume of each food item. The points were multiplied by the SF, and the result is the characterization of the food item in the diet (Mantelatto and Christofoletti, 2001) following the equation: $\% P_i = (\sum a_{ij}/A) \times 100$, where: $\% P_i$ = points percentage of the food item "i"; a_{ij} = number of points of the food item "i" in the stomach of predator "j"; A = total number of points for all food items of all stomachs.

The frequency of occurrence of each item was determined as follows: $\%FO = e_i \times 100 / E$, where: e_i = number of stomachs with occurrence of food item i ; E = total stomachs analyzed. The Index of Relative Importance (IRI) (Pinkas et al., 1971, modified) was obtained from $\%FO$ and $\%P$: $IRI = \%FO \times \%P / \sum (\%FO \times \%P)$.

Sexual maturity was determined in agreement with Ponz-Louro (1995). The Kruskal-Wallis test (Zar, 1999), followed by the Tukey test, was used to compare feeding differences based on IRI between skates according to sex, season and maturity stage. Log-linear analysis was used to analyse frequency of occurrence and Stomach fullness.

RESULTS

A total of 223 specimens were examined, corresponding to 29.6% of the 754 specimens captured. Length classes ranged between 96 and 532 mm of TL. Length varied between 96 mm and 438 mm for males (94), and between 114 mm and 532 mm for females (129). Weight ranged between 2.4 g and 344.1 g for males, and between 3.4 g and 723.7 g for females. Newborns represented 4.9% (11), juveniles 11.2% (25), adults 64.6% (144), and 43 animals (19.3%) could not have their maturity stage identified.

Raja agassizi was frequent during spring and summer, and decreased during winter. The sex ratio was 1 male to 1.37 females. No significant differences were observed in the sex-ratio ($p > 0.05$). Younger individuals (smaller than 350 mm) were common during spring and winter, and adults (larger than 450 mm TL) were more abundant during spring and summer.

The seasonal distribution showed a high occurrence of specimens in spring and summer, with an even higher number in spring (Fig. 1). For the total sample analysed,

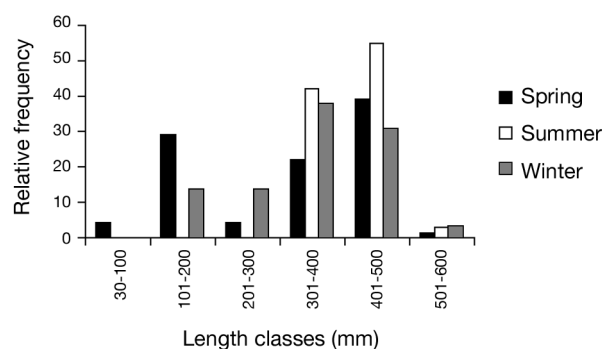


Figure 1. - Total length classes of *Rioraja agassizi* collected on São Paulo coast, SW Brazil, distributed according to seasons.

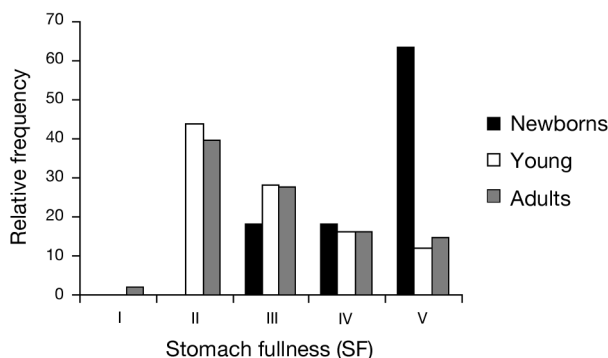


Figure 2. - Stomach fullness of *Rioraja agassizi* collected off São Paulo coast, SW Brazil, distributed according to gonadal maturity.

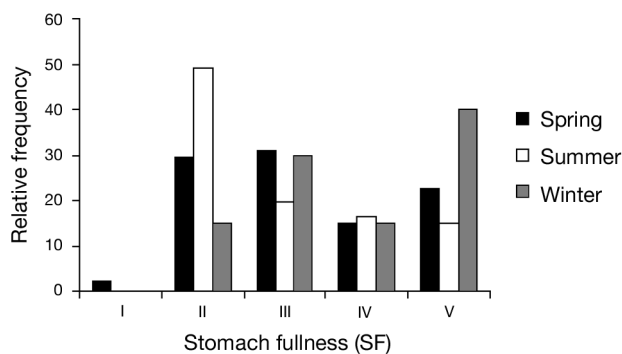


Figure 3. - Stomach fullness of *Rioraja agassizi* collected off São Paulo's coast, SW Brazil, distributed according to seasons.

1.35% of the stomachs were empty. Stomach fullness was III for 65% of the total sample, 96.9% for males and 64.3% for females. Log-linear analysis showed no significant differences in SF among food items in newborns, juveniles and adults ($p > 0.05$) (Fig. 2). All newborns showed SF equal or higher than III, as much as 56% of juveniles, and 58.3% of adults. Along seasonal periods, SF was over III; 69.3% during spring, 50.8% during summer, and 85% during winter (Fig. 3).

We identified 9 prey categories: Polychaeta, Copepoda, Teleostei, Cumacea, Isopoda, Dendrobranchiata, Gammari-

dea, Brachyura, and one non-animal category (Non-identifiable items). The main prey item was Crustacea for the variables analyzed (males and females, newborns, juveniles and adults, and spring, summer and winter). The Percentage of Points analysis (%P) of Crustacea sharply declined due to increase of Teleostei, eaten just by adults. For Polychaeta, a slightly increase in %P for juveniles and adults occurred, as for spring and summer. The Percentage of Points analysis was statistically constant for males and females, with high values for adults in the summer.

All data from IRI, %FO and %V are presented in tables I, II and III. Frequency of occurrence showed that Crustacea was present in 96% of stomachs examined, followed by Sediment (93.7%), Teleostei (18.4%), Non-identifiable Items (8.1%), and Polychaeta (2.7%) for all specimens together. According to the IRI importance, Crustacea and Sediment were the most important items except for newborns.

Table I. - Frequency of Occurrence (%FO), Points (%P), and Index of Relative Importance (IRI) for males and females of *Rioraja agassizi* collected on São Paulo coast, SW Brazil (n = 223).

| Food items | %FO | | %P | | IRI | |
|--------------|-------|---------|-------|---------|--------|---------|
| | Males | Females | Males | Females | Males | Females |
| Polychaeta | 0 | 4.65 | 0 | 1.12 | 0 | 0.0013 |
| Crustacea | 96.8 | 95.35 | 78.46 | 73.07 | 0.5125 | 0.4477 |
| Teleostei | 10.64 | 24.03 | 10.81 | 15.12 | 0.0001 | 0.1127 |
| Unidentified | 8.51 | 7.75 | 1.7 | 1.77 | 0 | 0 |
| Sediment | 94.68 | 93.02 | 9.03 | 8.92 | 0.4865 | 0.4382 |

Table II. - Frequency of Occurrence (%FO), Points (%P), and Index of Relative Importance (IRI) for newborns (new), juveniles (juv.) and adults of *Rioraja agassizi* collected on São Paulo coast, SW Brazil (n = 223).

| Food items | %FO | | | %P | | | IRI | | |
|--------------|-----|------|-------|-------|-------|-------|-----|--------|--------|
| | New | Juv. | Adult | New | Juv. | Adult | New | Juv. | Adult |
| Polychaeta | 0 | 4 | 2.78 | 0 | 0.56 | 0.98 | 0 | 0.0019 | 0.0004 |
| Crustacea | 100 | 100 | 93.75 | 88.76 | 88.43 | 66.14 | 0.5 | 0.4620 | 0.4488 |
| Teleostei | 0 | 8 | 25.69 | 0 | 1.49 | 22.01 | 0 | 0.0935 | 0.1101 |
| Unidentified | 0 | 4 | 6.94 | 2.15 | 0.56 | 1.92 | 0 | 0 | 0 |
| Sediment | 100 | 8 | 92.36 | 9.09 | 8.96 | 9.05 | 0.5 | 0.4426 | 0.4407 |

Table III. - Frequency of Occurrence (%FO), Points (%P), and Index of Relative Importance (IRI) according seasons for *Rioraja agassizi* collected on São Paulo coast, SW Brazil (n = 223).

| Food items | %FO | | | %P | | | IRI | | |
|--------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | Spring | Summer | Winter | Spring | Summer | Winter | Spring | Summer | Winter |
| Polychaeta | 3.52 | 1.64 | 0 | 0.74 | 0.68 | 0 | 0.0017 | 0.0001 | 0 |
| Crustacea | 97.18 | 93.44 | 100 | 85.47 | 42.99 | 87.89 | 0.5145 | 0.4223 | 0.4529 |
| Teleostei | 7.04 | 45.9 | 15 | 3.17 | 44.71 | 2.95 | 0.0027 | 0.1598 | 0.0942 |
| Unidentified | 8.45 | 9.83 | 0 | 1.5 | 3.15 | 0 | 0 | 0 | 0 |
| Sediment | 94.36 | 90.16 | 100 | 9.12 | 8.48 | 9.17 | 0.4810 | 0.4178 | 0.4529 |

DISCUSSION

Although we observed that almost all specimens belong to the length classes 301-400 and 401-500 mm, our sample was composed by all size classes (newborns, juveniles and adults).

Sex ratio (1.37 females for each male) suggests sexual segregation, but we cannot specify a reason for this distribution. Oddone *et al.* (2007a) found a sex ratio quite different from our data. Their samples involved 3.7 females for each male and this discordant data may be caused by some difference in fishing gear or different sample depths, since their study was in deeper water (20-70 m). Information concerning sexual segregation in Rajidae is scarce, while more commonly found in other oceanic elasmobranch species (Lessa *et al.*, 1999).

High proportions of maximum Stomach Fullness were observed. Silva *et al.* (2001), pointed out that in the feeding habit of *Dasyatis guttata* in the coast of Ceará, northeast Brazil, a small proportion (22.7%) of the stomachs were more than half full of food. Meanwhile, in the present study, 65% of individuals presented SF equal or higher than III (26%-100%). Abdel-Aziz *et al.* (1993) observed that females have less intense feeding activity than males. It was attributed to a necessity of space in the abdominal cavity in females for gonads and embryos. Few females and none male of *R. agassizi* presented empty stomach, where it can be concluded that the specimens were not captured in pre-reproductive period (October-January according to Oddone *et al.*, 2007b). On the other hand, according to Carvalho-Neta and Alme-

ida (2001), the high number of stomachs containing food in *Dasyatis guttata* is due to constant feeding activity or coincident capture of the individuals in a probable feeding period. Maybe *R. agassizi* follows a regular and full time feeding habit, also observed by Muto *et al.* (2001) and Soares *et al.* (1999) in the Ubatuba region, northern São Paulo.

In the same way, a high activity may reflect a high amount of food in the local environment. Nevertheless, if the food is not energetically adequate, a large number of prey items may be consumed to attain optimal metabolic rates, as also observed by Muto *et al.* (2001). According to Pillay (1952), the low percentage of empty stomachs depends primarily on the morphology and feeding behaviour of the species, and also on the quantity and availability of food.

The high number of specimens with food in their stomachs found in this study was also comparable with other studies conducted in Brazilian coastal waters (Soares *et al.*, 1999; Muto *et al.*, 2001), and could be explained by the current inclusion of small preys even in the diet of larger animals since these have a higher probability of capture.

The same prey items were also observed in stomachs of specimens from Argentina (Barbini and Lucifora, 2010), where found the smallest preys (cumaceans, isopods and amphipods) were found in the stomachs of the smaller specimens, while adults preyed more on shrimps, crabs and teleosts, larger and faster preys. This pattern was also observed, in part, by Muto *et al.* (2001), where it could be noted that ontogenetic shifts are extremely common in skates. These differences in prey consuming by skates is more a function of body size (mouth length especially) and prey availability than a consequence of the species life story.

The presence of lancelets in *Rioraja agassizi* studied in Uruguay and Argentina (Barbini and Lucifora, 2010), revealed a new prey item never detected before according to the literature for this species. Maybe the presence of this item in these localities could be more intense and explain its importance to the diet of local populations of *R. agassizi*.

The presence of sediment in almost all analysed stomachs (more than 90%) may be associated to the bottom dwelling habits of this species (Castello, 1971; Figueiredo, 1977), where sediment is forced through the mouth with prey ingestion. Rajids show mechanisms for suction feeding that are used to prey on crustaceans and other invertebrates associated to sandy bottoms (Moyle and Cech Jr., 1988). Despite the high %FO found for this item, the low %V allows us to question the iliofagous tendencies of the species.

It can be concluded that *R. agassizi* is a benthic feeder, having preference for crustaceans along the coast of São Paulo. Fish were found only during summer in juveniles and adults, which could imply that larger individuals are more suitable to prey upon larger and faster prey. Sexual differences have no influence in the feeding habit of the species.

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