Diet of the white-dotted skate, *Bathyraja albomaculata*, in waters of Argentina

By N. L. Ruocco¹,², L. O. Lucifora³, J. M. Díaz de Astarloa¹,²,⁴ and C. Bremec¹,²

¹Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET); ²Instituto Nacional de Investigación y Desarrollo Pesquero, Mar del Plata, Argentina; ³Department of Biology, Dalhousie University, Halifax, NS, Canada; ⁴Departamento de Ciencias Marinas, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata (UNMdP), Mar del Plata, Argentina

Summary

The present paper analyzes the diet, feeding strategy and niche width of *Bathyraja albomaculata* over the Patagonian continental shelf and upper slope. The diet comprised a variety of 14 small invertebrates, although the most important prey were polychaete worms. The opheliid polychaete *Travisia* sp. and the gammarid amphipod *Cirolana* sp. were the main prey present in stomach contents of *B. albomaculata*. No differences were found between the diets of males and females, however ontogenetic changes were detected. Skates < 40 cm of disk width (DW) preyed on amphipods, and sizes > 40 cm DW largely consumed polychaetes. As size increased, polychaetes became more important and the importance of amphipods decreased. *B. albomaculata* showed a narrow food niche and a marked specialization towards polychaetes.

Introduction

The white-dotted skate, *Bathyraja albomaculata* (Norman, 1937), is widely distributed over the Argentine continental shelf and upper slope between 37° and 55°S, and from 72 to 945 m depth (Cousseau et al., 2000; Menni and Stehmann, 2000; Brickle et al., 2003). This species has been also referred to as *Rhinoraja albomaculata* based on the putative presence of a basal joint in the rostral cartilage typical of the genus *Rhinoraja* (Compagno, 1999). However, we failed to find such a joint; pending any formal generic re-assignment of the species, we prefer to refer to it as belonging in the genus *Bathyraja*. Its highest abundances have been reported in northern and southern Patagonian waters (Ruocco et al., 2006), and it is regarded as one of the most abundant skates in the Islas Malvinas rajid fishery (Agnew et al., 1999). This species has traditionally been caught as bycatch in trawling fisheries targeting Argentine hake, *Merluccius hubbsi* (Coscarella et al., 1997), southern blue whiting, *Micromesistius australis*, hoki, *Macrourus magellanicus* and Argentine squid, *Illex argentinus*. A 59-m Engel-type bottom trawl net, with a stretched mesh size of 200 mm in the wings and 103 mm in the codend, a vertical height of 4 m, and a horizontal opening of 15 m was used in all research cruises. Haul duration was 30 min at a trawling speed of 3.6 knots.

Materials and methods

Samples used in this paper were obtained from three research cruises conducted in the southwest Atlantic between 41°S and 54°S, over a depth range of 43–440 m, by the RVs ‘Capitán Oca Balda’ and ‘Doctor Eduardo Holmberg’ of the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP, Argentina) between 2000 and 2003. The sampling scheme was randomly stratified and designed for assessment of hake, *Merluccius hubbsi*, southern blue whiting, *Micromesistius australis*, hoki, *Macrourus magellanicus* and Argentine squid, *Illex argentinus*. A 59-m Engel-type bottom trawl net, with a stretched mesh size of 200 mm in the wings and 103 mm in the codend, a vertical height of 4 m, and a horizontal opening of 15 m was used in all research cruises. Haul duration was 30 min at a trawling speed of 3.6 knots.

For each specimen, disk width (DW), total length (TL) and sex were recorded. Maturity stage was assessed according to macroscopic observation of the uteri, oviducal glands, ovarian follicles and eggs in females, and the degree of calcification of the claspers and shape of efferent ducts in males (Ruocco et al., 2006).

The stomachs were removed, frozen and subsequently analyzed in the laboratory. Prey were identified to the lowest possible taxonomic level, using keys, field guides and specific catalogues (Bastida and Torti, 1973; Moreira, 1973; Boschi et al., 1992). Prey were categorized into four groups, Polychaeta, Amphipoda, Isopoda and Others (i.e. cirripeds,
unidentified crustaceans, crabs and cumaceans), for statistical analyses.

The number and the wet weight of each prey were recorded using a digital scale accurate to 0.01 g. For both sexes cumulative curves were used to determine whether enough samples had been collected to describe the diet precisely and for subsequent comparisons (Ferry and Cailliet, 1996). The order of stomachs sampled was randomized 100 times and the mean number of new prey categories (± 1 SD) was plotted as a function of sample size. Cumulative curves were separately built for males and females using the four prey groups. The asymptote of the curve indicated the minimum sample size required to describe the diet (Ferry and Cailliet, 1996).

The importance of each prey was determined by calculating the index of relative importance:

$$IRI = \%F \times (\%N + \%W)$$

where %F is the percent frequency of occurrence (i.e. the number of stomachs in which a given prey was found as percentage of the number of stomachs with food) of each prey taxa; %N is the number of a given prey as percentage of the total number of prey; and %W is the number of a given prey as percentage of the total weight of prey. The index of relative prey importance was expressed as a percentage (%IRI), where:

$$%IRI = 100 \times IRI / \sum \frac{1}{IRI}$$

n is the total number of food categories considered at a given taxonomic level (Cortés, 1997).

A two-way non-parametric multivariate analysis of variance (NPMANOVA) was used to describe variation in stomach contents owing to sex and size (Anderson, 2001). The number of the main prey groups and the Bray–Curtis distance were used to test sexual and ontogenetic effects on the diet of B. albomaculata. The specimens were grouped in four size classes: < 33; 33–40; 40.1–47 and > 47 cm DW. These classes were based on the approximate size at maturity of B. albomaculata. According to Ruocco et al. (2006) length at first maturity of B. albomaculata in the study area was 62.8 and 65.3 cm TL for males and females, respectively, which corresponds to 43.9 and 45.6 cm DW, respectively. Thus, specimens > 47 cm DW are mostly mature, and specimens below 40 cm DW are mostly juveniles. A posteriori, we performed a Kruskal–Wallis test for each prey group comparing all sizes; if significant differences were detected, we conducted pair-wise comparisons between length classes with a Wilcoxon paired rank test to locate the significant differences. In all a-posteriori tests, a correction control for the false discovery rate was used to avoid inflation of type-I error (Benjamini and Hochberg, 1995).

The prey importance (dominant or rare), feeding strategy (specialist or generalist) and niche width contribution were based on the approximate size at maturity of B. albomaculata (i.e. the prey-specific abundance of the prey i) and S, the stomach content (total number of the prey i) and $S_T$ the total stomach content in only those predators with prey i in their stomach.

$$P_i = \frac{\sum S_i}{\sum S_T} \times 100$$

This analysis consists on a two dimensional representation where each point represents the specific abundance of the prey and the frequency of occurrence.

Results

Of a total of 89 stomachs examined, only 11 were empty. Digeneans were observed in 44.9% (40 individuals) of the samples. Females (17 immature and 18 mature) ranged from 30.8 to 53.0 cm DW, and males (17 immature and 26 mature) ranged from 25.9 to 55.1 cm DW. In both sexes, the four most important prey found were polychaetes, present in 95.5% of the stomachs, amphipods in 56.7%, isopods in 41.79% and cirripeds, unidentified crustaceans, crabs and cumaceans in 19.4%.

Fourteen prey taxa were identified (Table 1). Cumulative prey curves reached an asymptote, indicating that the sample sizes (n = 35 and n = 43 for females and males, respectively) were sufficient to describe the diet of B. albomaculata. The estimate of the minimum sample size needed were 13 in females and 20 in males (Fig. 1).

Among the four different prey categories found, polychaetes had the highest importance (IRI% = 56.8); the opheliid polychaete Travisia sp. was the main prey ingested; in second place were amphipods (IRI% = 26.7) and in third place isopods (IRI% = 15.2), with Cirolana as the most important isopod genus consumed. The Others category had a much lower importance in the diet (%IRI < 1) (Table 1).

Polychaetes were the main prey in both sexes, followed by amphipods. There were no significant differences between the diets of males and females (NPMANOVA, F = 214.75, d.f. = 1, P = 0.129). Size had a significant effect: large and small skates showed differences in the number of the major prey groups consumed (NPMANOVA, F = 605.52, d.f. = 3, P = 0.0002); however there was no significant multivariate interaction between sex and size (NPMANOVA, F = 166.481, d.f. = 3, P = 0.086).

Significant differences among size groups were detected only for amphipods (Kruskal–Wallis, $\chi^2 = 30.68$, d.f. = 3, $P = 0.0001$).

Table 1

<table>
<thead>
<tr>
<th>Prey items</th>
<th>%N</th>
<th>%W</th>
<th>%F</th>
<th>n</th>
<th>%IRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polychaeta</td>
<td>(38.55) (45.52) (83.14)</td>
<td>56.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyceridae</td>
<td>0.96</td>
<td>2.69</td>
<td>1.49</td>
<td>9</td>
<td>0.058</td>
</tr>
<tr>
<td>Lumbrineridae</td>
<td>3.84</td>
<td>3.31</td>
<td>8.95</td>
<td>36</td>
<td>0.68</td>
</tr>
<tr>
<td>Nephthyidae</td>
<td>1.6</td>
<td>1.46</td>
<td>17.9</td>
<td>15</td>
<td>0.58</td>
</tr>
<tr>
<td>Onuphidae</td>
<td>1.7</td>
<td>2.44</td>
<td>7.46</td>
<td>16</td>
<td>0.33</td>
</tr>
<tr>
<td>Opheliidae</td>
<td>Travisia sp</td>
<td>12.59</td>
<td>15.8</td>
<td>38.8</td>
<td>118</td>
</tr>
<tr>
<td>Terebellidae</td>
<td>2.02</td>
<td>1.88</td>
<td>16.41</td>
<td>19</td>
<td>0.68</td>
</tr>
<tr>
<td>Unidentified Polychaetes</td>
<td>22.09</td>
<td>17.7</td>
<td>86.56</td>
<td>36.75</td>
<td></td>
</tr>
<tr>
<td>Decapoda</td>
<td>Amphipoda</td>
<td>(44.09) (15.53) (55.05)</td>
<td>(26.68)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gammaridea</td>
<td>37.67</td>
<td>13.99</td>
<td>56.7</td>
<td>353</td>
<td>31.21</td>
</tr>
<tr>
<td>Isopoda</td>
<td>(14.08) (33.4) (39.32)</td>
<td>(15.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cirolana sp</td>
<td>11.21</td>
<td>33.19</td>
<td>35.8</td>
<td>105</td>
<td>16.95</td>
</tr>
<tr>
<td>Serolis schythei</td>
<td>0.2</td>
<td>0.058</td>
<td>2.98</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>Macrothricoidea stebbingi</td>
<td>1.71</td>
<td>0.81</td>
<td>5.97</td>
<td>16</td>
<td>0.162</td>
</tr>
<tr>
<td>Antarcturidae</td>
<td>0.53</td>
<td>0.66</td>
<td>4.47</td>
<td>5</td>
<td>0.06</td>
</tr>
<tr>
<td>Others</td>
<td>(3.26) (5.47) (17.97)</td>
<td>(1.27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diocapoda</td>
<td>Pelatarion spinosulus</td>
<td>0.11</td>
<td>1.3</td>
<td>1.49</td>
<td>1</td>
</tr>
<tr>
<td>Cumaceans</td>
<td>0.21</td>
<td>0.073</td>
<td>2.98</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>Lepadidae</td>
<td>2.35</td>
<td>2.78</td>
<td>4.47</td>
<td>22</td>
<td>0.24</td>
</tr>
<tr>
<td>Unidentified Crustaceans</td>
<td>1.17</td>
<td>1.72</td>
<td>16.4</td>
<td>11</td>
<td>0.51</td>
</tr>
</tbody>
</table>
P = 0.0001), while all other prey did not differ significantly. In specimens with DW < 40 cm, amphipods were the group with the highest %IRI values, and in individuals > 40 cm DW, polychaetes had the highest %IRI.

Results of the pair-wise comparisons in amphipod consumption were not significant within the smallest (Pairwise Wilcoxon test, <33 vs 33–40 cm DW, P = 0.929), and the largest (40.1–47 vs > 47 cm DW, P = 0.766) size classes, although there were differences between the smallest and the largest size classes (<33 vs 40.1–47 cm DW, P = 0.008; <33 vs > 47 cm DW, P = 0.002; 33–40 vs > 47 cm DW, P = 0.004) (Fig. 2).

Plotting prey-specific abundance against frequency of occurrence showed that polychaetes were the dominant prey, followed by amphipods and isopods, the latter with a value of F% and P, lower than 50%. Cirripeds, decapods, unidentified crustaceans and cumaceans were included within the category of rare species (Fig. 3).

**Discussion**

The results of the present paper show that *B. albomaculata* feed on benthic prey, mainly polychaetes, and have a narrow food niche and a marked specialization on polychaetes, followed by amphipods and isopods in decreasing order of importance.

A specialist predator has a narrow dietary niche, in contrast to the large variety of prey found in the stomach contents of a generalist predator (Pianka, 1988). The analysis of the prey-specific abundance against frequency of occurrence shows that *B. albomaculata* is a specialized feeder, polychaetes being the dominant prey. Similarly, in *B. albomaculata* collected around Islas Malvinas (Brickle et al., 2003) and on the southwest Atlantic continental shelf (Sánchez and Mabragaña, 2002; Mabragaña et al., 2005), polychaetes were the dominant prey. The specialist nature of the feeding habits in *B. albomaculata* are reflected in the lower diversity of the prey consumed in comparison to other congeners, like *B. griseocauda* and *B. brachyurops* (Brickle et al., 2003).

Our results on ontogenetic shifts in the *B. albomaculata* diet agree with those of Brickle et al. (2003) who observed that, around Islas Malvinas, juveniles fed upon benthic amphipods and as they increased in size, polychaetes and isopods became important. In the present paper the opheliid polychaete *Travisia* sp. was the main prey found in the diet of *B. albomaculata*. The family Opheliidae reached the highest frequency of occurrence in benthic samples of the southwest Atlantic continental shelf (Bremer et al., 2000), which suggests that these polychaetes may be highly available to skate predators searching for polychaetes.

No differences in diet between sexes were found in *B. albomaculata*; however, a dental sexual dimorphism was observed; juvenile males present a tooth morphology similar to that of adult females (grinding blunt teeth), but mature males have pointed conical cusps. Dental sexual dimorphism was originally proposed as a result of feeding segregation among sexes (DuBuit, 1978). Feduccia and Slaughter (1974) suggested that sexually dimorphic skate dentition implies differential foraging by males and females, reducing intraspecific competition for food. However it is well known that elasmobranchs exhibit a complex reproductive behavior in which the teeth are used by...
the male for firmly gripping the female during copulation (Price, 1967; Meachran, 1977; Kajura et al., 2000). Meachran (1977) suggested that if tooth dimorphism is related to ecological niche segregation, it should appear prior to sexual maturation. Here we show that male and female B. albomaculata have a similar diet, suggesting that differences in tooth morphology could be more related to reproductive behaviour than to feeding.

Our results suggest that B. albomaculata has a specialized polychaetes diet over its entire Atlantic geographic range. Given that the polychaetes consumed are most abundant on soft bottoms (Bremec et al., 2000) that are also best trawlable, its specialized diet can make B. albomaculata especially vulnerable to trawl fisheries over most of its geographic range.

Acknowledgements

N. L. Ruocco was supported by a scholarship from CONICET (Argentina). L. O. Lucifora was supported by a fellowship from the Lenfest Ocean Program. We thank two anonymous reviewers for comments that greatly improved the manuscript. This study was supported by funds from CONICET (PIP 5009), and Universidad Nacional de Mar del Plata (EXA 342/06).

References


Author’s address: Luis O. Lucifora, Department of Biology, Dalhousie University, 1355 Oxford Street, Halifax, NS B3H JJ1, Canada.

E-mail: luis.lucifora@dal.ca