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The diets of four *Bathyraja* skates (Elasmobranchii, Arhynchobatidae) from the Southwest Atlantic

by

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Résumé. – Étude du régime alimentaire de quatre espèces du genre *Bathyraja* (Elasmobranchii, Arhynchobatidae) dans l'océan Atlantique sud-ouest.

Le régime alimentaire de quatre raies appartenant au genre *Bathyraja* (*B. cousseauae*, *B. griseocauda, B. multispinis* et *B. scaphiops*) a été étudié dans l'Atlantique sud-ouest. Les proies les plus importantes de *B. cousseauae* ont été les poissons téléostéens, suivis des isopodes et amphipodes. Comparativement, les isopodes ont été consommés préférentiellement par *B. griseocauda*, suivis des poissons téléostéens. *Bathyraja multispinis* est une espèce benthique se nourrissant quasi exclusivement de crabes et secondairement d'isopodes. Enfin, les poissons téléostéens, puis les amphipodes ont été les proies les plus importantes de *B. scaphiops*. Les résultats de l'étude sur le régime alimentaire de ces quatre espèces peu fréquentes ont permis de compléter les connaissances sur l'écologie trophique du genre *Bathyraja* pour cette région géographique.

Key words. – Arhynchobatidae - *Bathyraja cousseauae - Bathyraja griseocauda - Bathyraja multispinis - Bathyraja scaphiops* – Southwest Atlantic - Argentinean continental shelf - Diet composition.

Among all genera of the family Arhynchobatidae, *Bathyraja* shows the widest distribution and the major species diversity (Ebert and Compagno, 2007). In the Argentinean Continental Shelf waters (ACS, Southwest Atlantic between 35° and 55°S), the genus *Bathyraja* is represented by eight species (Menni and Stehmann, 2000; Figueroa, 2011). In this region, life history of some of these species is relatively well known, but for others the information on their basic biology is scarce. For example, feeding habits of Patagonian skate *Bathyraja macloviana*, broadnose skate *B. brachyurops*, white-dotted skate *B. albomaculata* and Magellan skate *B. magellanica* were thoroughly studied along species distribution in the Southwest Atlantic (Brickle *et al.*, 2003; Mabragaña *et al.*, 2005; Scenna *et al.*, 2006; Belleggia *et al.*, 2008; Ruocco *et al.*, 2009; Barbini *et al.*, 2010, 2013). Conversely, the diet composition of the gray-tail skate *B. griseocauda* (Norman, 1937) has only been studied around Malvinas/Falkland Islands (Brickle *et al.*, 2003), and the diet of the joined-fins skate *B. cousseauae* (Díaz de Astarloa and Mabragaña, 2004), the multispine skate *B. multispinis* (Norman, 1937) and the cuphead skate *B. scaphiops* (Norman, 1937) have not been previously documented.

Bathyraja multispinis, *B. griseocauda* and *B. cousseauae* inhabit the Southwest Atlantic and the Southeast Pacific off Chile (Pequeño and Lamilla, 1993; Cousseau *et al.*, 2007; Reyes and Torres-Florez, 2008), whereas *B. scaphiops* occurs in the Southwest Atlantic (Pequeño and Lamilla, 1993; Cousseau *et al.*, 2007). These four species are the less abundant of the genus on the ACS (Buratti, 2004; Cousseau *et al.*, 2007). They are caught as by-catch in deepwater bottom trawl fisheries in Argentina, whereas *B. multispinis*, *B. griseocauda* and *B. scaphiops* are targeted by multispecies skate fishery around Malvinas/Falkland Islands (Agnew *et al.*, 2000; Buratti, 2004). From a viewpoint of marine conservation, fishery researchers need basic diet composition data for each species to develop ecosystem models involving energy (Cochrane, 2002; Thrush and Dayton, 2010). Furthermore, skates as top and meso-predators may play an important role in the benthic communities, because of their abundance and biodiversity (Ebert and Bizzarro, 2007). In this scenario, the goal of this work was to describe the diet of four *Bathyraja* species in the ACS.

MATERIAL AND METHODS

The study area covered the ACS and continental slope, between 37° and 55° S, and from 77 to 403 m depth (Fig. 1). Skates were caught from fourteen scientific trawl surveys conducted by the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP, Argentina) between 2003 and 2007. Fishing trawls were conducted during daylight hours (07:00-19:00), at 3-4 knots for 30 min in each sampling site, using an Engel type bottom trawl (200 mm mesh in the wings, 103 mm in the cod ends, 4 m vertical opening and 15 m horizontal aperture). Skates were sexed, and total length (TL) and disc width (DW) were measured to the nearest mm. Stomachs were excised, labeled and preserved in plastic bags and fixed in 4% formaldehyde.

Once at the laboratory, prey items found in the stomachs were identified to the lowest possible taxonomic level, using taxonomic keys (Bastida and Torti, 1973; Hobson and Banse, 1981), field guides (Boschi *et al.*, 1992; Cousseau and Perrota, 2004), and consulting the opinion of specialists. Prey items were counted and weighed to the nearest 0.01 g. The importance of each prey in the

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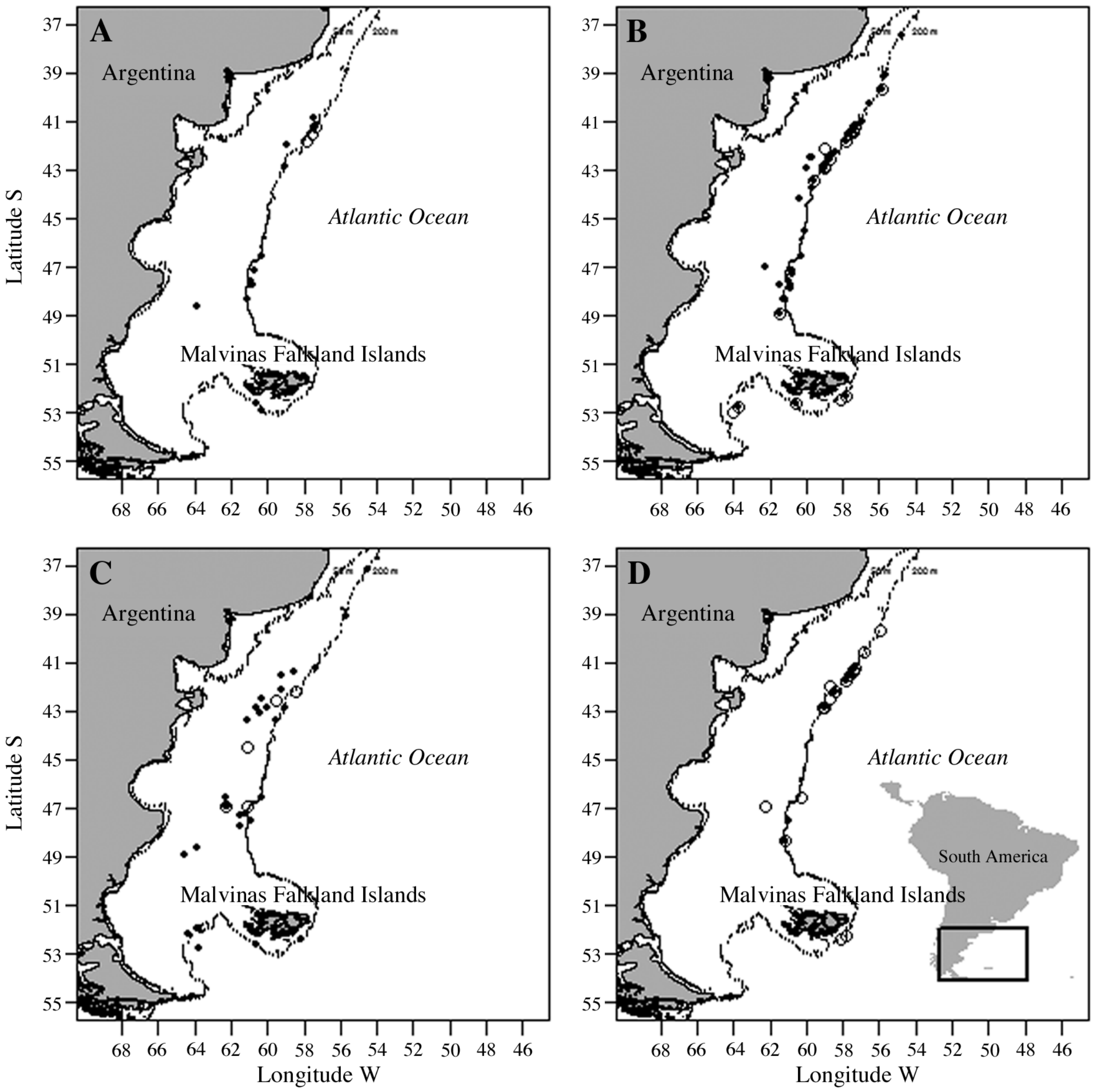

Fig. 1. - Maps of the study area indicating sampling sites where specimens were caught in the Southwest Atlantic. **A**: *Bathyraja cousseauae*; **B**: *B. griseocauda*; **C**: *B. multispinis*; **D**: *B. scaphiops*. The empty (empty circles) and full (black circles) stomachs are shown; the latter used for study their diet.

diet composition was evaluated using the percentage frequency of occurrence (%F, the total number of stomachs in which a given prey was found expressed as percentage of the total number of stomachs with food), the percentage by number (%N, the total number of a given prey as percentage of the total number of prey found), percentage by weight (%W, the weight of a given prey as percentage of the total weight of prey found), and Index of Relative Importance: IRI = %F × (%N + %W) (Pinkas *et al.*, 1971), expressed in percentage (%IRI; Cortés, 1997). These indexes were calculated for the lowest taxon identified and also for the six major prey categories: teleosts, polychaetes, molluscs, amphipods, isopods and decapods. The sample sizes were not enough to adequately separate the analyses by size classes, but this study provides an important first step towards addressing the diet of these four rare species, for which very limited biological data are available. Additional samples would be necessary in order to properly explore such more in depth analyses.

RESULTS

Of a total of 32 specimens of *Bathyraja cousseauae* examined, 68.75% contained food (10 males and 12 females). They ranged between 332 and 1134 mm TL (191 and 794 mm DW). The main prey category was teleosts, followed by isopods and amphipods. The nototheniid *Patagonotothen* was the only genus of teleosts that could be identified in the stomach contents. Isopods were represented by four genera and amphipods by two families. The % IRI of polychaetes, molluscs and decapods were lower than 5 (Tab. I).

The stomach contents of 120 specimens of *B. griseocauda*, which ranged from 332 to 1250 mm TL (235 to 922 mm DW) were analyzed. Eighty percent of stomachs contained food (44 males and 52 females). Isopods were the most important prey category, with *Acanthoserolis schythei* dominating the diet. Teleosts were the second most important prey category, and the first by weight, being *Macruronus magellanicus* the principal prey species in this catego-

Table I. - Diet composition of *Bathyraja cousseauae*, *B. griseocauda*, *B. multispinis* and *B. scaphiops* expressed as percentage of frequency of occurrence (%F), percentage of number (%N), percentage of weight (%W), and percentage of Index of Relative Importance (%IRI).

Prey	*B. cousseauae* (n=22)				*B. griseocauda* (n=96)				*B. multispinis* (n=37)				*B. scaphiops* (n=11)			
	%F	%N	%W	%IRI	%F	%N	%W	%IRI	%F	%N	%W	%IRI	%F	%N	%W	%IRI
Teleosts	**40.91**	**16.84**	**58.39**	**47.96**	**43.00**	**12.71**	**61.98**	**33.33**	**–**	**–**	**–**	**–**	**63.64**	**24.14**	**99.65**	**79.63**
Congridae *Bassanago albescens*	–	–	–	–	2.08	0.15	6.72	0.36	–	–	–	–	–	–	–	–
Merlucciidae *Macruronus magellanicus*	–	–	–	–	7.29	0.51	35.80	6.70	–	–	–	–	–	–	–	–
Ophidiidae *Genypterus blacodes*	–	–	–	–	1.04	0.07	0.95	0.03	–	–	–	–	–	–	–	–
Nototheniidae *Patagonotothen* spp.	4.55	11.05	3.36	1.72	10.42	8.38	3.83	3.22	–	–	–	–	27.27	10.34	83.78	53.01
Unidentified teleosts	36.36	5.79	55.04	58.04	26.04	3.60	14.68	12.04	–	–	–	–	36.36	13.79	15.87	22.27
Polychaetes	**22.73**	**4.74**	**0.61**	**1.89**	**9.00**	**1.47**	**0.56**	**0.19**	**2.70**	**0.16**	**0.01**	**<0.01**	**–**	**–**	**–**	**–**
Terebellidae	–	–	–	–	–	–	–	–	2.70	0.16	0.01	<0.01	–	–	–	–
Unidentified polychaetes	22.73	4.74	0.61	3.19	9.38	1.47	0.56	0.48	–	–	–	–	–	–	–	–
Molluscs	**13.64**	**1.58**	**20.98**	**4.79**	**15.00**	**1.40**	**13.13**	**2.26**	**2.70**	**0.16**	**2.16**	**0.05**	**–**	**–**	**–**	**–**
Omastrephidae *Illex argentinus*	13.64	1.58	20.98	8.07	8.33	0.81	3.60	0.88	2.70	0.16	2.16	0.14	–	–	–	–
Volutidae *Odontocymbiola magellanica*	–	–	–	–	7.29	0.81	9.53	1.91	–	–	–	–	–	–	–	–
Amphipods	**22.73**	**43.16**	**1.03**	**15.65**	**14.00**	**2.57**	**0.05**	**0.38**	**–**	**–**	**–**	**–**	**27.27**	**72.41**	**0.32**	**20.05**
Ampeliscidae	18.18	28.95	0.68	14.14	11.46	2.35	0.04	0.69	–	–	–	–	9.09	13.79	0.04	2.60
Lysianassidae *Erikus* sp.	4.55	14.21	0.35	1.74	–	–	–	–	–	–	–	–	18.18	55.17	0.26	20.81
Liljeborgidae	–	–	–	–	1.04	0.07	0.00	<0.01	–	–	–	–	–	–	–	–
Hyperiidea *Themisto gaudichaudii*	–	–	–	–	2.08	0.15	0.01	0.01	–	–	–	–	9.09	3.45	0.02	0.65
Isopods	**40.91**	**28.95**	**10.04**	**24.86**	**59.00**	**81.12**	**22.83**	**63.65**	**43.24**	**61.97**	**10.30**	**24.78**	**9.09**	**3.45**	**0.03**	**0.32**
Cirolanidae *Cirolana* spp.	13.64	1.58	0.81	0.86	8.33	0.59	0.22	0.17	–	–	–	–	–	–	–	–
Arcturidae *Arcturus* spp.	9.09	1.58	0.59	0.52	13.54	2.65	0.45	1.06	8.11	14.56	1.74	0.35	–	–	–	–
Serolidae *Acanthoserolis schythei*	4.55	17.89	5.09	2.74	29.17	38.80	9.61	35.71	32.43	43.20	7.76	6.17	–	–	–	–
Serolidae *Acutiserolis neaera*	4.55	2.63	1.36	0.48	13.54	12.05	5.34	5.96	–	–	–	–	–	–	–	–
Unidentified Serolidae	22.73	5.26	2.20	4.45	35.42	27.04	7.21	30.68	13.51	4.21	0.79	0.26	9.09	0.03	3.45	0.01
Decapods	**22.73**	**4.74**	**8.94**	**4.84**	**8.00**	**0.73**	**1.45**	**0.18**	**75.68**	**37.70**	**87.54**	**75.16**	**–**	**–**	**–**	**–**
Caridea *Thymops birsteini*	–	–	–	–	–	–	–	–	2.70	0.16	0.54	0.04	–	–	–	–
Galatheidae *Munida spinosa*	–	–	–	–	–	–	–	–	2.70	0.16	0.58	0.04	–	–	–	–
Paguridae *Pagurus* spp.	4.55	1.05	0.34	0.17	1.04	0.15	1.17	0.03	–	–	–	–	–	–	–	–
Paguridae *Pagurus comptus*	–	–	–	–	3.13	0.29	0.01	0.02	5.41	2.10	0.22	0.03	–	–	–	–
Majidae *Peltarion spinosulum*	13.64	2.63	5.53	2.92	–	–	–	–	54.05	29.61	55.92	74.07	–	–	–	–
Majidae *Libidoclaea granaria*	–	–	–	–	1.04	0.07	0.03	<0.01	27.03	5.02	27.81	18.42	–	–	–	–
Unidentified decapods	9.09	1.05	3.07	0.98	3.13	0.22	0.24	0.04	8.11	0.65	2.48	0.49	–	–	–	–

ry. Polychaetes, molluscs, amphipods and decapods were uncommon prey in the diet, contributing less than 3% IRI (Tab. I).

Of the 42 specimens of *B. multispinis* examined, 88.09% contained food in their stomachs (24 males and 13 females). Specimens analyzed ranged from 380 to 1006 mm TL (249 to 700 mm DW). Decapods were the main prey ingested, with *Peltarion spinosulum* and *Libidoclaea granaria* the top two most consumed species. Isopods were the second prey category according to importance in the diet, but the first by number. Polychaetes and molluscs were less common in the diet (% IRI < 0.05) (Tab. I).

Stomachs contents of 34 individuals of *B. scaphiops* that ranged from 380 to 825 mm TL (265 to 578 mm DW), were analyzed, of which 32.35% contained food (3 males and 8 females). Teleosts were the most important prey category, followed by amphipods.

Isopods accounted less than 1% IRI (Tab. I).

DISCUSSION

The results of the present paper show that the diets of *Bathyraja cousseauae* and *B. scaphiops* consisted mostly of teleosts followed by isopods and amphipods, whereas *B. griseocauda* fed on isopods and teleosts. The dominance of fish and crustaceans in other *Bathyraja* species has also been documented in Southeast Atlantic (Ebert *et al.*, 1991), North Pacific (Orlov, 1998; Brown *et al.*, 2012) and North Atlantic (Bjelland *et al.*, 2000; González *et al.*, 2006). Our results also showed that *B. multispinis* was a specialist benthic predator that fed almost exclusively upon crustaceans (mainly crabs, followed by isopods). The only reported case of specialized diet among *Bathyraja* genus, excluding specialist species from the ACS mentioned below, was *B. kincaidii* in central California, which fed upon shrimp-like crustaceans (euphausiids) (Rinewalt *et al.*, 2007). However, this was associated with upwelling conditions and when productivity was great (Rinewalt *et al.*, 2007; Brown *et al.*, 2012). The remarkable flattened crushing dentition of *B. multispinis* (Bizikov *et al.*, 2004), could be related to a clear morphological adaptation to this unique carcinophagous diet.

The diets of the four sympatric species of *Bathyraja* examined in this study indicated some degree of food partitioning. When other *Bathyraja* species from this region are considered, the partitioning of prey resource is conspicuous. For instance, with both the knowledge provided by our work and published information, *Bathyraja* species on the ACS could be grouped into three trophic patterns: (1) a carcinophagous group represented by only one species, *B. multispinis*; (2) a ichthyophagous-carcinophagous group, that includes *B. cousseauae*, *B. griseocauda*, *B. brachyurops*, *B. magellanica* and *B. scaphiops*, which feed on teleosts and crustaceans, and some cases showed diet shifts with body size (Brickle *et al.*, 2003; Belleggia *et al.*, 2008; Barbini *et al.*, 2010); (3) specialized group that feed on polychaetes is represented by *B. macloviana* (Mabragaña *et al.*, 2005; Scenna *et al.*, 2006; Barbini *et al.*, 2013) and *B. albomaculata* (Ruocco *et al.*, 2009). Trophic partitioning observed among *Bathyraja* species, shows an important mechanism of competition, dietary segregation and evolutionary diversification within this genus, allowing the coexistence of eight sympatric species in the ACS. These results also address how food resources within a given area are partitioned minimizing competition for food among different species.

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