Cephalopods in the diet of marine mammals stranded or incidentally caught along Southeast and Southern Brazil (21° to 34°S).

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Abstract

Cephalopod remains in 286 stomach contents of 13 species of odontocetes and four pinnipeds were identified and measured. The stomachs were collected from stranded or incidentally caught marine mammals from Rio de Janeiro to Paraná states (21° to 26°S) and Rio Grande do Sul (29° to 34°S), between 1985 and 1998. A total of 3233 upper beaks, 3521 lower beaks and remains of 55 whole animals were found and 25 species of 16 families of cephalopods were identified. Loliginid squids were the most frequent cephalopod found in the diet of the dolphins Lagenodelphis hosei, Pontoporia blainvillei, Sotalia fluviatilis, Stenella frontalis, Steno bredanensis and Tursiops truncatus and the fur seals Arctocephalus australis, A. gazzella and A. tropicalis. Loligo sanpaulensis was mainly found in these specimens collected in Rio Grande do Sul, whilst Loligo plei and Loliguncula brevis, besides L. sanpaulensis, were frequent in those from Rio de Janeiro to Paraná. Oegopsids squids of the families Chiroteuthidae, Cranchiidae, Enoploteuthidae, Histiooteuthidae, Lycoteuthidae, Octopoteuthidae, Onychoteuthidae and especially Ommastrephidae were found in the stomach contents of Foreresa attenuata, Globicephala melas, Kogia breviceps, Kogia simus, Orcinus orca, Pseudorca crassidens and in the seals Arctocephalus tropicalis and Mirounga leonina. Ommastrephid and loliginid squids, besides the sepioïd Sarsirossa tenera, were equally important in the diet of Delphinus delphis. Benthic octopuses were found only in Tursiops truncatus and Pontoporia blainvillei. Pelagic octopuses, particularly Argonauta nodosa, were relatively frequent in the stomach contents of Pontoporia blainvillei. The diversity of cephalopods as prey was smaller for the inshore marine mammals. Loliginids and ommastrephids were the most frequent cephalopods in the diet of inshore and offshore marine mammals respectively.

Key words: Trophic relations, marine mammals, Southwestern Atlantic Ocean, Brazil, foodwebs, cephalopods

Introduction

The species composition and distribution of the coastal cephalopod fauna along southern and southeastern Brazil is relatively well known from commercial landings and bottom trawl survey data (Palacio, 1977; Haimovici and Perez, 1991a; Haimovici et al., 1994). Far less is known on the cephalopods from the upper slope and open ocean species where only longline fishing for large pelagic fishes occurs and no surveys targeting cephalopods have been performed. Many marine mammals are cephalopod predators and can be excellent collectors of cephalopods, although generally only beaks can be recovered (Clarke, 1980; Clarke, 1986a; Clarke, 1996). Therefore, the analysis of marine mammals stomach contents can provide substantial information on cephalopod distribution and biology, since many species, particularly the oceanic ones, are rarely caught by nets and other sampling methods. On the other hand, the knowledge of the
distribution, life-style and habitat of cephalopod species found in the diet of marine mammal predators can aid the understanding of their distribution and feeding habits.

At least 23 species of odontocetes and seven of pinnipeds were recorded for southern (26°S - 34°S) and southeastern Brazil (21°S-26°S) (Pinedo et al., 1992). The diet of several species was formerly studied and some of them were found feed to some degree on cephalopods: Pontoporia blainvillei (Pinedo, 1982); Kogia simus (Pinedo, 1987); Physeter macrocephalus (Clarke et al., 1980) and more recently Kogia breviceps (Secchi et al., 1994); Globicephala melas (Santos and Pinedo, 1994); Orcinus orca (Dalla Rosa, 1995); Feresa attenuata (Zerbini and Santos, 1997) and Pontoporia blainvillei (Ott, 1994; Basso, 1997).

There are several problems in the interpretation of the diet and the geographic distribution of the prey from the stomach contents of stranded animals. Beaks of cephalopods are known to remain retained undigested for longer periods than fish bones and otoliths. Clarke (1986a) suggest that cephalopods and fishes should be analysed in separate, to avoid misinterpretation in relation to the importance of both items in the diet. Other point to be considered is that stranded animals generally are unhealthy and may not be representative of the normal diet, but this cannot be considered a rule, as, in a comparative study in South Africa, no significant difference in the percentage of cephalopod in the diet between stranded and non-stranded Delphinus delphis, Lagorhynchus obscurus and Cephalorhynchus heavisidii was observed (Sekiguchi et al., 1992). Despite the known limitations, the use of beaks from stranded animals is well established (Clarke, 1986a, b) and some times is the only available source of information.

The material for this study were the cephalopods remains in the stomach contents of diverse marine mammals incidentally caught or stranded from Rio de Janeiro to Paraná (Zone A: 21°S to 26°S) and along Rio Grande do Sul (Zone B: 29° to 34°S) (Fig.1) and sent to us by colleagues for identification (Appendix I). The scope was to assess the relative importance of the different cephalopods in their diet and to contribute to the understanding of the distribution and trophic relations of cephalopods in the region.

**Materials and methods**

The cephalopods in 286 stomach contents of 13 species of odontocetes and four of pinnipeds collected between 1985 and 1998 were examined (Table 1). Cephalopod remains, consisting mainly of beaks, were identified (RAS) with help of a reference collection at the Depto. Oceanografia of the Fundação Universidade do Rio Grande.

The sizes of preyed cephalopods were estimated from measurements on the beaks: upper (URL) and lower (LRL) rostral length in squids and sepiolids and

![Figure 1. Study area. Zone A: Rio de Janeiro to Paraná (21°S to 26°S) and Zone B: Rio Grande do Sul (29° to 34°S)](image-url)
upper (UHL) and lower (LHL) hood length in octopuses. Measures followed Clarke (1986b) to 0.1 mm. Most prey mantle length and masses were calculated from regressions relating squid rostral length and octopus hood length with dorsal mantle length (ML, mm) and with total mass (TM, g) obtained from the specimens in the reference collections. When local data were not available, size was estimated from regressions presented in Clarke (1986b).

Table 1. Stomach contents of marine mammals collected from Zone A: Rio de Janeiro to Paraná (21° to 26°S) and Zone B: Rio Grande do Sul (29° to 34°S) and number of families of cephalopods identified.

<table>
<thead>
<tr>
<th>Marine mammal species</th>
<th>Common name</th>
<th>Families</th>
<th>Species</th>
<th>Zone A</th>
<th>Zone B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odontocetes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delphinus delphis</td>
<td>common dolphin</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feresa attenuata</td>
<td>pigmy killer whale</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Globicephala melas</td>
<td>pilot long-finned whale</td>
<td>7</td>
<td>7</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Lagenodelphis hosei</td>
<td>Fraser's dolphin</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Orcinus orca</td>
<td>killer whale</td>
<td>9</td>
<td>11</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Pseudorca crassidens</td>
<td>false killer whale</td>
<td>1</td>
<td>2</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Sotalia fluvatilis</td>
<td>estuarine dolphin</td>
<td>1</td>
<td>4</td>
<td></td>
<td>58</td>
</tr>
<tr>
<td>Stenella frontalis</td>
<td>atlantic spotted dolphin</td>
<td>1</td>
<td>1</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Steno bredanensis</td>
<td>rough-toothed dolphin</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Tursiops truncatus</td>
<td>bottlenose dolphin</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pontoporia blainvillei</td>
<td>franciscana dolphin</td>
<td>4</td>
<td>7</td>
<td>57</td>
<td>111</td>
</tr>
<tr>
<td>Kogia breviceps</td>
<td>pigmy sperm whale</td>
<td>8</td>
<td>9</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Kogia simus</td>
<td>dwarf sperm whale</td>
<td>11</td>
<td>14</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pinnipeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arctocephalus australis</td>
<td>south american fur seal</td>
<td>2</td>
<td>2</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Arctocephalus gazella</td>
<td>antarctic fur seal</td>
<td>2</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Arctocephalus tropicalis</td>
<td>subantarctic fur seal</td>
<td>5</td>
<td>7</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Mirounga leonina</td>
<td>southern elephant seal</td>
<td>3</td>
<td>3</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Results

A total of 3233 upper beaks, 3521 lower beaks and remains of 55 whole animals were examined in the stomach contents of 286 marine mammals, 13 odontocete and four pinniped species (Fig. 2). Twenty-five species of 16 families of cephalopods were identified (Table 2).

*Delphinus delphis*

In the two stomachs contents of stranded specimens from from Zone A, only a few beaks of *Loligo plei* and unidentified loliginids were found. In three incidentally caught specimens from Zone B, *Loligo sanpaniensis*, the sepiolid *Semirrosia tenera* and the ommastrephid *Hlex argentinus* were frequent. *Hyaloteuthis pelagica* and unidentified Cranchiidae also occurred (Table 3).

Most prey were small, mean estimated mass ranged from 77 g for a few *Loligo plei* in Zone A, to 2 g for *Semirrosia tenera* in Zone B. Feeding appears to have occurred in the outer shelf and upper slope, but small *Loligo sanpaniensis* could have been eaten in the inner shelf. Sepiolidae, Loliginidae and Ommastrephidae were also found in its diet in Northwestern Spain (González et al., 1994) and South Africa (Sekiguchi et al., 1992).
Figure 2. Cephalopods in the diet of marine mammals from Rio de Janeiro to Paraná (21° to 26°S) and Rio Grande do Sul (29° to 34°S) states. Circles indicate the presence of cephalopod in the diet, in black main cephalopod prey.

**Lagenodelphis hosei**

Four stomach contents of Fraser’s dolphin stranded in Zone B contained mostly middle sized *Loligo sanpaulensis* (6 to 242 g). The beak of a single specimen of a 6 mm ML *Argonauta nodosa* does not seem to be part of the diet (Table 3). In South Africa oceanic cephalopods were the main prey found in the diet of Fraser’s dolphin (Sekiguchi et al., 1992). According to Klinowska (1991) *Lagenodelphis hosei* is a oceanic species and the presence of only neritic cephalopods in the diet probably indicate that feeding occurred on the shelf before stranding and may not represent its normal diet.
Table 2. Families and species of cephalopods observed in the diet of 13 odontocete and four pinniped species from Rio de Janeiro to Paraná (21° to 26 °S) and Rio Grande do Sul (29° to 34°S).

<table>
<thead>
<tr>
<th>Families</th>
<th>Genera and species</th>
<th>Odontocete species</th>
<th>Pinniped species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepiolidae</td>
<td>Semirossia tenera</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heteroteuthis atlantis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loliginidae</td>
<td>Loligo plei</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loligo sanpaulensis</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Loliguncula brevis</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unidentified</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Alluroteuthidae</td>
<td>Alluroteuthis antarcticus</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Chiroteuthidae</td>
<td>Chiroteuthis veranyi</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Cranchiidae</td>
<td>(several species)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Enoplooteuthidae</td>
<td>Abralia redfieldi</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abralia sp</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ancistrocheirus leueuri</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>other species</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Gonatidae</td>
<td>Gonatus antarcticus</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Histiotoeuthidae</td>
<td>Histiotoeuthis spp</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Lycoteuthidae</td>
<td>Lycoteuthis diadema</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Octopoteuthidae</td>
<td>Octopoteuthis sp</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Onychoteuthidae</td>
<td>Moroteuthis ingens</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moroteuthis robsoni</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ommastrephidae</td>
<td>illex argentinus</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hyaloteuthis polagica</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ommastrephes bartramii</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Ornithoteuthis antillarum</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unidentified</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Octopodidae</td>
<td>Eledone gaucha</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Octopus tehuelchus</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Octopus vulgaris</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Argonautidae</td>
<td>Argonauta nodosa</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bolitaenidae</td>
<td>Japetelia diaphana</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ocythoidae</td>
<td>Ocythoe tuberculata</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Stenella frontalis, Steno bredanensis and Tursiops truncatus**

In Zone A, all three species preyed mostly on small and middle sized *Loligo plei* (40 to 138 g) (Table 3). *Tursiops truncatus* also fed on a wide range of sizes of *Octopus vulgaris* (155 to 1210 g). A single stomach of bottlenose dolphin examined from Zone B had two specimens of *Loligo plei* (65 and 72 g) (Table 4). Loliginidae and Octopodidae were also common in the diet of the bottlenose dolphin in other regions (Mercer, 1973; Sekiguchi et al., 1992; González et al., 1994).

**Feresa attenuata**

A single pigmy killer whale stranded in Zone A was found to have eaten two *Loligo plei* (42 to 61 g), two *Illex argentinus* (130 to 360 g) and one *Ornithoteuthis antillarum* (32 g) (Table 4).

**Globicephala melas**

Stomachs of the long-finned pilot whale stranded in Zone B were found to contain remains of continental slope and oceanic cephalopods (Table 4). Seventy percent of the identified specimens where neutrally buoyant *Histiotoeuthis* spp (53 to 287 g), *Chiroteuthis*
veranyi, Cranchiidae, Octopoteuthis sp. (124 to 241 g) and Ancistrocheirn lesueurii and the rest were Ommastrephidae, mainly middle sized to large Illex argentinus (67 to 693 g) and Lycoteuthis diadema (50 to 284 g).

Table 3. Numbers, mantle length and total masses of cephalopods preyed by Delphinus delphis, Lagenodelphis hosei, Stenella frontalis, Steno bredanensis and Tursiops truncatus sampled from Zone A: 21° to 26°S, and Zone B: 29° to 34°S (n= number of stomachs examined, S= number of stomachs with the cephalopod species and N= total number of individuals of each cephalopod species found).

<table>
<thead>
<tr>
<th>Cephalopod species</th>
<th>S</th>
<th>N</th>
<th>Mantle length (mm)</th>
<th>Total mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>mean</td>
<td>range</td>
</tr>
<tr>
<td>Delphinus delphis (Zone A)</td>
<td>2</td>
<td>2</td>
<td>180</td>
<td>177-183</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loligo plei</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loliginidae unidentified</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oegopsida</td>
<td>1</td>
</tr>
<tr>
<td>Delphinus delphis (Zone B)</td>
<td>3</td>
<td>69</td>
<td>17</td>
<td>10-22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Semirossa tenera</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loligo sanpaulensis</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cranchiidae unidentified</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hyaloteuthis pelagica</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Illex argentinus</td>
<td>3</td>
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<td></td>
<td></td>
<td>Loligo sanpaulensis</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Argonauta nodosa</td>
<td>1</td>
</tr>
<tr>
<td>Stenella frontalis (Zone A)</td>
<td>6</td>
<td>121</td>
<td>69</td>
<td>21-220</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loligo plei</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ommastrephidae</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ommastrephidae</td>
<td>1</td>
</tr>
<tr>
<td>Steno bredanensis (Zone B)</td>
<td>1</td>
<td>2</td>
<td>171</td>
<td>168-175</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loligo plei</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ommastrephidae</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ommastrephidae</td>
<td>2</td>
</tr>
<tr>
<td>Tursiops truncatus (Zone B)</td>
<td>1</td>
<td>2</td>
<td>171</td>
<td>168-175</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Loligo plei</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ommastrephidae</td>
<td>1</td>
</tr>
</tbody>
</table>

The long-finned pilot whale is considered to feed heavily on squid. In the Northern Atlantic, G. melas was found to feed on oceanic squids of the families Ommastrephidae, Cranchiidae, Chiroteuthidae, Histioteuthidae (Sergeant, 1962; Desportes and Mouritsen, 1993). In other regions as south Argentina (Clarke and Goodall, 1994), Tasmania (Gales et al., 1992) and South Africa (Sekiguchi et al., 1992) neritic cephalopods were also found to be important in the diet of the long-finned pilot whale.

Orcinus orca and Pseudorca crassidens

The cephalopods found in the stomachs of three killer whales Orcinus orca stranded in Zone B included the same families found in the diet of Globicephala melas, but also coastal loliginids (10 to 158 g), the pelagic octopus Ocythoe tuberculata and the antarctic squid Gonatus antarcticus (143 to 203 g). This last probably eaten in cold subantarctic waters beyond the study area (Table 4). Neutral buoyant species amounted 53% of the identified specimens and other squids 46%. The squids were small to middle sized and the possibility that, at least the loliginids, could have been eaten by some killer whale’s prey cannot be discarded.

In the stomach contents of the three Pseudorca crassidens stranded in Zone B, the identified squids were middle sized Ommastrephes bartramii of 206 to 1038 g (Table 4). Ommastrephidae were also found in the stomach contents of false killer whales from South Africa (Sekiguchi et al., 1992).
Table 4. Numbers, mantle length and total masses of cephalopods preyed by Feressa attenuata, Globicephala melas, Orcinus orca and Pseudorca crassidens sampled from Zone A: 21° to 26°S, and Zone B: 29° to 34°S (n= number of stomachs examined, S= number of stomachs with the cephalopod species and N= total number of individuals of each cephalopod species found).

<table>
<thead>
<tr>
<th>Cephalopod species</th>
<th>Mantle length (mm)</th>
<th>Total mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>N</td>
</tr>
<tr>
<td>Feressa attenuata (Zone A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loligo plei</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Illex argentinus</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ornithoteuthis antillarum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ommastrephidae unidentified</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Globicephala melas (Zone B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chiroteuthis veranyi</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Cranchiidae unidentified</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Ancistrocheirus lesueuri</td>
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<td>3</td>
</tr>
<tr>
<td>Histioleuthis spp</td>
<td>3</td>
<td>98</td>
</tr>
<tr>
<td>Lycoteuthis dladema</td>
<td>2</td>
<td>45</td>
</tr>
<tr>
<td>Octopoteuthis sp</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Illex argentinus</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Ommastrephidae unidentified</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Oegopsida unidentified</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Orcinus orca (Zone B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loligo plei</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Loligo sanpaulensis</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Cranchiidae unidentified</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Gonatus antarcticus</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Histioleuthis spp</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Lycoteuthis dladema</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Octopoteuthis sp</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Moroteuthis robsoni</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Ommastrephes bartrami</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ornithoteuthis antillarum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Oegopsida unidentified</td>
<td>1</td>
<td>44</td>
</tr>
<tr>
<td>Ocythoe tuberculata</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Pseudorca crassidens (Zone B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ommastrephes bartrami</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Oegopsida unidentified</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cephalopoda unidentified</td>
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</tr>
</tbody>
</table>

Pontoporia blainvillei and Sotalia fluvatili

Most of Pontoporia blainvillei examined were incidentally caught and were found to eat only neritic cephalopods. In the Zone A it preyed on all three loliginids of that region, Loligo sanpaulensis (1 to 154 g), that was the most frequent, Loligo plei (8 to 183 g) and Lolliguncula brevis (1 to 77 g). In the Zone B, from the estimated 2775 preyed cephalopods, 2686 were Loligo sanpaulensis measuring from 22 to 220 mm and 1 to 197 g followed by the pelagic Argonenta nodosa, Loligo plei and a few benthic sepiolids and octopuses (Table 5).

Loligo sanpaulensis is an important prey for the franciscana dolphin in all its distribution range, with high frequency of occurrence in its diet as formerly observed by Pinedo (1982), Ott (1994) and Bassoi (1997) for Rio Grande do Sul, Brownell (1975, 1989) from Uruguay and Perez et al. (1996) from Argentina.

Most Sotalia fluvatili were also incidentally caught and occurred only in the Zone A. The cephalopods eaten by the estuarine dolphin were Loligo sanpaulensis (0.3 to 150
g). Lolliguncula brevis (1 to 17 g) and Loligo plei (3 to 183 g) (Table 5) of similar sizes than those eaten by Pontoporia blainvillei in the same zone (Fig. 3).

Table 5. Numbers, mantle length and total masses of cephalopods preyed by Pontoporia blainvillei and Sotalia fluviatilis sampled from Zone A: 21° to 26°S, and Zone B: 29° to 34°S (n= number of stomachs examined, S= number of stomachs with the cephalopod species and N= total number of individuals of each cephalopod species found).

<table>
<thead>
<tr>
<th>Cephalopod species</th>
<th>S</th>
<th>N</th>
<th>mean</th>
<th>range</th>
<th>mean</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pontoporia blainvillei</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(Zone A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loligo plei</td>
<td>26</td>
<td>155</td>
<td>166</td>
<td>66</td>
<td>266</td>
<td>69</td>
</tr>
<tr>
<td>Loligo sanpaulensis</td>
<td>41</td>
<td>593</td>
<td>51</td>
<td>20</td>
<td>219</td>
<td>8</td>
</tr>
<tr>
<td>Lolliguncula brevis</td>
<td>21</td>
<td>134</td>
<td>49</td>
<td>24</td>
<td>84</td>
<td>11</td>
</tr>
<tr>
<td>Pontoporia blainvillei</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Zone B)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loligo plei</td>
<td>17</td>
<td>27</td>
<td>154</td>
<td>68</td>
<td>211</td>
<td>58</td>
</tr>
<tr>
<td>Loligo sanpaulensis</td>
<td>21</td>
<td>134</td>
<td>49</td>
<td>24</td>
<td>84</td>
<td>11</td>
</tr>
<tr>
<td>Loligidae unidentified</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sotalia fluviatilis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Zone A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loligo plei</td>
<td>28</td>
<td>137</td>
<td>152</td>
<td>41</td>
<td>266</td>
<td>61</td>
</tr>
<tr>
<td>Loligo sanpaulensis</td>
<td>24</td>
<td>260</td>
<td>85</td>
<td>14</td>
<td>195</td>
<td>6</td>
</tr>
<tr>
<td>Loligidae unidentified</td>
<td>11</td>
<td>14</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>n=56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loligidae unidentified</td>
<td>11</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The sizes of L. sanpaulensis from both Pontoporia and Sotalia in the Zone A were smaller than those eaten by Pontoporia in the Zone B, while Loligo plei from both zones were small to middle sized, with mean ML around 150 mm (Fig. 3).

Figure 3. Mantle length distribution of Loligo sanpaulensis, Loligo plei and Lolliguncula brevis from the diet of Pontoporia blainvillei and Sotalia fluviatilis from Zone A: 21° to 26°S, and Zone B: 29° to 34°S. n= number of squids.
**Kogia breviceps and K. simus**

*K. breviceps* stranded in both zones and *K. simus* in Zone A were found to feed on continental slope and oceanic cephalopods (Table 6). Neutrally buoyant squids as *Histiotethus* spp, *Chiroteuthis veranyi*, *Octopoteuthis* sp and Cranchiidae amounted to 65% of the specimens. Muscular families as Ommastrephidae, Lycoteuthidae and Onychoteuthidae represented 31%. No remarkable differences in the families of cephalopods preyed between species and zones were observed and the cephalopods preyed were small to middle sized (1 to 413 g).

Cephalopods are found to be a major part of the diet of *Kogia* species (Caldwell and Caldwell, 1989). As also observed in our study, oceanic families as Chiroteuthidae, Histiotethidae, Ommastrephidae, Onychoteuthidae, Lycoteuthidae and Octopoteuthidae were found in the diet of *Kogia breviceps* and *K. simus* from South Africa (Ross, 1979; Sekiguchi et al., 1992).

**Table 6. Numbers, mantle length and total masses of cephalopods preyed by *Kogia simus* and *Kogia breviceps* sampled from Zone A: 21° to 26°S, and Zone B: 29° to 34°S (n = number of stomachs examined. S = number of stomachs with the cephalopod species and N = total number of individuals of each cephalopod species found).**

<table>
<thead>
<tr>
<th>Cephalopod species</th>
<th>S</th>
<th>N</th>
<th>Mean mantle length (mm)</th>
<th>Mean total mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Kogia simus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Zone A) n=2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Semirossia tenera</em></td>
<td>1</td>
<td>2</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td><em>Heteroteuthis atlantis</em></td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chiroteuthis veranyi</em></td>
<td>1</td>
<td>1</td>
<td>119</td>
<td>43</td>
</tr>
<tr>
<td><em>Cranchiidae unidentifed</em></td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Abralia redfieldi</em></td>
<td>1</td>
<td>23</td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td><em>Enoplateuthidae unidentifed</em></td>
<td>1</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Histiotethus spp</em></td>
<td>2</td>
<td>94</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td><em>Lycoteuthis diadema</em></td>
<td>1</td>
<td>7</td>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td><em>Octopoteuthis sp</em></td>
<td>1</td>
<td>1</td>
<td>147</td>
<td>109</td>
</tr>
<tr>
<td><em>Moroteuthis ingens</em></td>
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<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Moroteuthis robsoni</em></td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Illex argentinus</em></td>
<td>1</td>
<td>1</td>
<td>224</td>
<td>11</td>
</tr>
<tr>
<td><em>Ommithotethus antilliaram</em></td>
<td>1</td>
<td>1</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td><em>Oegopsida unidentifed</em></td>
<td>2</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Japetella diaphana</em></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Octopoda unidentifed</em></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Kogia breviceps</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Zone A) n=1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chiroteuthis veranyi</em></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Octopoteuthis sp</em></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oegopsida unidentifed</em></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Heteroteuthis atlantis</em></td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Kogia breviceps</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Zone B) n=2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chiroteuthis veranyi</em></td>
<td>1</td>
<td>1</td>
<td>104</td>
<td>29</td>
</tr>
<tr>
<td><em>Abralia sp</em></td>
<td>1</td>
<td>5</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td><em>Histiotethus spp</em></td>
<td>2</td>
<td>16</td>
<td>71</td>
<td>3</td>
</tr>
<tr>
<td><em>Lycoteuthis diadema</em></td>
<td>2</td>
<td>17</td>
<td>89</td>
<td>2</td>
</tr>
<tr>
<td><em>Octopoteuthis sp</em></td>
<td>1</td>
<td>4</td>
<td>162</td>
<td>2</td>
</tr>
<tr>
<td><em>Moroteuthis robsoni</em></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Illex argentinus</em></td>
<td>2</td>
<td>25</td>
<td>217</td>
<td>2</td>
</tr>
<tr>
<td><em>Ommithotethus antilliaram</em></td>
<td>1</td>
<td>2</td>
<td>81</td>
<td>7</td>
</tr>
</tbody>
</table>


Pinnipeds

All stomach contents of the three species of fur seals and the elephant seal were from Zone B (Table 7). Arctocephalus australis was found to eat Loligo sanpaulensis (5 to 157 g) and very small Argonauta nodosa (0.2 to 1 g). The only Arctocephalus gazzella sampled, besides Loligo sanpaulensis (46 g), ate Alluroteuthis antarcticus. Arctocephalus tropicalis fed on Loligo sanpaulensis (9 to 65 g), small to large Ommastrephes bartrami (21 to 1135 g), large Illex argentinus (483 to 836 g), large Argonauta nodosa of 71 to 439 g and Ocythoe tuberculata.

Young fur seals Arctocephalus australis, from breeding grounds off Uruguay, and vagrant adult males of A. gazzella and A. tropicalis from the Antarctic Convergence reach southern Brazil in winter (Pinedo et al., 1992). Alluroteuthis antarcticus found in our samples, were probably eaten before the arrival to southern Brazil. All three species, fed to some degree on Loligo sanpaulensis, particularly large ones, only common in the inner shelf. It is probable that these neritic squids were eaten shortly before stranding. In the diet of Arctocephalus tropicalis from Antarctica, slope and oceanic cephalopods were also found (Bester and Laycock, 1985).

The stomach contents of a single Mirounga leonina had two large Illex argentinus (331, 351 g), one Lycoteuthis diadema (25 g) and one Histiotheuthis sp (32 g) (Table 7). Cephalopods are frequent prey of the southern elephant seal (Klages, 1996). In Antarctic waters various squids and benthic octopods are frequent in its diet (Rodhouse et al., 1992). The examined stomach content was of a vagrant sea elephant, well out of the usual distribution range of the species (Pinedo et al., 1992) and probably is not representative of the diet of the species.

Table 7. Numbers, mantle length and total masses of cephalopods preyed by Arctocephalus australis, Arctocephalus gazzella, Arctocephalus tropicalis and Mirounga leonina sampled from Zone A: 21° to 26°S, and Zone B: 29° to 34°S (n= number of stomachs examined, S= number of stomachs with the cephalopod species and N= total number of individuals of each cephalopod species found).

<table>
<thead>
<tr>
<th>Cephalopod species</th>
<th>(Zone B) n=15</th>
<th>(Zone B) n=1</th>
<th>(Zone B) n=5</th>
<th>(Zone B) n=1</th>
<th>(Zone B) n=1</th>
<th>(Zone B) n=5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctocephalus australis Loligo sanpaulensis</td>
<td>15 37</td>
<td>98 45 185</td>
<td>39 5 157</td>
<td>1 3 15</td>
<td>10 18</td>
<td>1 0.2 1</td>
</tr>
<tr>
<td>Arctocephalus gazzella Alluroteuthis antarcticus</td>
<td>1 1 111 111 111</td>
<td>46 46 46</td>
<td>3 14 93 58 135</td>
<td>31 9 65</td>
<td>1 5</td>
<td>1 1</td>
</tr>
<tr>
<td>Arctocephalus tropicalis Moroteuthis robsoni Illex argentinus</td>
<td>1 6 332 297 359</td>
<td>677 483 836</td>
<td>2 23 221 93 343</td>
<td>425 21 1135</td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Ommastrephes bartrami Ommastrephidae unidentified</td>
<td>3 10</td>
<td>1 2</td>
<td>2 2</td>
<td>103 78 131</td>
<td>255 71 439</td>
<td>2 103 78 131</td>
</tr>
<tr>
<td>Oegopsida unidentified Argonauta nodosa</td>
<td>2 2</td>
<td>53 53 53</td>
<td>63 63 63</td>
<td>1 1</td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Ocythoe tuberculata Histiotheuthis sp</td>
<td>1 1</td>
<td>53 53 53</td>
<td>63 63 63</td>
<td>1 1</td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Mirounga leonina Lycoteuthis diadema Illex argentinus</td>
<td>1 2 263 260 265</td>
<td>341 331 351</td>
<td>1 2 263 260 265</td>
<td>341 331 351</td>
<td>1 2 263 260 265</td>
<td>341 331 351</td>
</tr>
</tbody>
</table>
Discussion

Because coastal marine mammals were better represented in our samples, Loliginidae was the most frequently preyed family and *Loligo sanpaulensis* was the most frequent prey found in both regions. *Loliguncula brevis* is a tropical estuarine and coastal species and its presence to the south of Santa Marta Grande Cape (29°S) was not confirmed in several surveys (Haimovici and Andriguetto, 1986; Haimovici and Perez, 1991a) and Museum collection revisions (Haimovici et al., 1989; Perez and Haimovici, 1991). It was only preyed upon by *Pontoporia blainvillei* and *Sotalia fluvialis* in coastal or estuarine waters in Zone A. Its absence in the stomach contents of franciscana dolphins from Rio Grande do Sul supports the assumption that the distribution limit of this species to the south is around 29°S.

*Loligo sanpaulensis* occurs in the shelf in the Subtropical Convergence Zone from 20° to 42°S (Roper et al., 1984; Haimovici and Perez, 1991a) and is the most common coastal squid in southern Brazil (Haimovici and Andriguetto, 1986) where larger specimens occur only in the inner shelf and the small specimens can be found in the cold season up to the shelf break (Andriguetto and Haimovici, 1991; Haimovici and Perez, 1991b). Most of the coastal marine mammals, and some of the offshore species prior to stranding, fed on this squid. Its maximum sizes in the stomach contents from Zone A were smaller than those from Zone B (Fig. 3). This is consistent with observations from bottom trawl surveys in both zones (Juanico, 1979; Haimovici and Andriguetto, 1986; Andriguetto and Haimovici, 1991; Costa and Fernandez, 1993).

*Loligo plei* is a warm water species that is more abundant to the north of Santa Catarina (Costa and Haimovici, 1990; Perez et al., 1997). Along Rio Grande do Sul it is only occasionally caught in the inner shelf but is frequent in the warm season in the outer shelf and upper slope (Haimovici and Andriguetto, 1986, Haimovici and Perez, 1991b). For this reason its presence in the stomach contents of offshore species as *Feresa attenuata* and *Orcinus orca* can be considered to be part of their normal diet in the region.

Benthic shelf octopuses and sepiolids were preyed in small numbers. This probably reflects the relative scarcity of benthic cephalopods in coastal waters of the region (Haimovici and Perez, 1991a). Few pelagic octopuses were also recorded and were unimportant in the diet of both coastal and oceanic marine mammals, found only in the diet of *Pontoporia blainvillei*, *Orcinus orca* and *Arctocephalus tropicalis*.

Ommastrephids were the most frequent offshore cephalopod prey: small and middle sized *Illex argentinus* and *Ommastrephis antillarum* in both zones and middle sized *Ommastrephes bartramii* in the Zone B. The presence of *Illex argentinus*, as expected, was more frequent in the stomach contents collected in the Zone B, in the cold season, when reproductive concentrations of this squid are found along the slope of southern Brazil (Santos and Haimovici, 1997). The families Histioteuthidae, Ommastrephidae, Cranchiidae, Onychoteuthidae, Lycoteuthidae and Chiroteuthidae were mostly preyed by offshore marine mammals as *Kogia breviceps*, *K. simill*, *Globicephala melas*, *Orcinus orca* and *Pseudorca crassidens*. No differences associated with latitudes that recalled our attention in the cephalopod family composition were observed between offshore marine mammals.
Cephalopod sizes varied from small to middle sized, the smaller was an Argonauta nodosa (0.02 g) eaten by Pontoporia blainvillei and the largest was an Octopus vulgaris (1210 g) eaten by a Tursiops truncatus. The mean weight of the different families of preyed cephalopods were plotted against the total length of their odontocete predators (Fig. 4). Odontocetes of less than 3 m long ingested cephalopods varying from 2 to 134 g, while odontocetes between 3 and 6 m long, fed on cephalopods of 309 g of mean TM. Differences were more evident for ommastrephids, that had mean masses of 56 to 62 g for odontocetes smaller than 3 m and 190 to 309 g in the larger specimens. Small sized squid are commonly observed in the diet of odontocetes, varying according to the types of cephalopods and regions in which they were eaten (Clarke, 1996).

Coastal marine mammals were frequently incidentally killed by fisherman in their gill nets (Pinedo, 1994), for this reason their stomach contents reflect better their “normal diet” than those of stranded offshore species. Despite our ignorance of the type of death and the low number of stomach contents per species and zone, some patterns were observed. The diversity of cephalopods as prey was small for shelf marine mammals and increased in upper slope and oceanic species (Fig. 2). As reported by Clarke (1996) for other regions, in southern Brazil loliginids were the most important cephalopods in the diet of inshore marine mammals and ommastrephids in diet of the offshore marine mammals. Globally, marine mammals do not seem to be important predators of cephalopods along southern Brazil compared with the far more abundant large pelagic tunas and related species fished in the region (Santos, 1992; Santos and Haimovici, in preparation).

References


Appendix I. Source of stomach contents of marine mammal predators examined for predation on cephalopod species. (n= number of stomachs examined).  

<table>
<thead>
<tr>
<th>Marine mammal</th>
<th>n</th>
<th>Years</th>
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