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STOMACH CONTENTS OF FALSE KILLER WHALES *(PSEUDORCA CRASSIDENS)* STRANDED ON THE COASTS OF THE STRAIT OF MAGELLAN, TIERRA DEL FUEGO

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ABSTRACT

We examined the stomachs of 25 false killer whales collected from a mass stranding of 181 animals along both coasts of the Strait of Magellan, Chile, in March 1989. The 21 stomachs (nine males and 12 females), with food remains contained 11 prey species (nine cephalopods and two fishes) with a total of 442 individuals. Except for one case, food remains were meager, indicating that the animals had not eaten for some time or through stress had vomited on the beach. Eleven of the 21 animals had mud (often with squid beaks) in the esophagus and first stomach. The prey were identified employing squid beaks, fish otoliths and bones, and their wet weights were estimated using regressions between hard parts and known weights of species. The most important prey were the oceanic and neritic-oceanic squids, *Martialia hyadesi* and *Illex argentinus*, followed by the neritic fish, *Macruronus magellanicus*. Of less importance were the oceanic squid, *Todaroes fillipovae,* the

oceanic and epipelagic octopus, *Ocythoe sp.*, and the oceanic squid, *Moroteuthis ingens*. The rest of the prey were poorly represented and included four oceanic squids and one neritic fish. The prey species of these animals were subantarctic, with two antarctic species, abundant over the Patagonian shelf and adjacent oceanic waters around Tierra del Fuego.

Key words: false killer whale, *Pseudorca crassidens*, stomach contents, feeding habits, diet, southwestern South Atlantic Ocean, Strait of Magellan, Tierra del Fuego.

The false killer whale is found worldwide in tropical, subtropical, and warm temperate oceans and occasionally moves into cooler waters. It is a gregarious species, with pods which may include more than 100 individuals of both sexes and all age classes, and frequently strands in large numbers (Lannguth 1977, Odell *et al.* 1980, Stacey *et al.* 1994).

In the northern hemisphere, the false killer whale feeds mainly on squid and large fish. It also attacks dolphins escaping from purse seines for tuna in the eastern tropical Pacific and takes fish caught on longlines (Perryman and Foster 1980, Leatherwood *et al.* 1991, Stacey *et al.* 1994). There are few data on the food habits of this species in the southern hemisphere. Ross (1984) reported on the stomach contents of one individual caught southeast of South Africa in the southwestern Indian Ocean. The stomachs of 13 animals from southern Africa were studied by Sekiguchi *et al.* (1992). There is one report of the prey of this species from the southwestern South Atlantic Ocean based on four animals individually stranded along the coast of Brazil (Pinedo and Rosas 1989). Here we describe the stomach contents of 25 false killer whales from a mass stranding of at least 181 individuals in March 1989 on the shores of the northeastern Strait of Magellan, Chile (Oporto *et at.* 1994).

Materials and Methods

Sample collection—The stranding began on the evening of 7 March 1989 with some 50 animals stranding at Punta Delgada, First Narrows (52°27′S, 69°31′W), 35 of which refloated spontaneously or were helped to refloat. On 9 March, some 90 individuals stranded at Banco Orange, Bahía Lomas (52°35′S, 69°14′W). They were seen from a helicopter still alive but later died. Strandings and refloatings continued to the westward until 16 March. Flights on 22 March showed 181 animals[1] dead on both coasts of the Strait from Bahía Lomas to Bahía Shoal (52°55′S, 70°54′W) (Oporto *et al.* 1994). These animals had evidently entered the strait from the South Atlantic and gradually moved to the west and south within the strait.

In two expeditions to Chile, from 12 to 15 March and 29 March to 5 April, the Goodall team examined 91 false killer whales on the south (Tierra del Fuego) side of the Strait of Magellan from Bahía Azul at the First Narrows

[1] N. Maslov (1990). Qué produce varamiento de falsas orcas? *Impactos* 1(6):20–21), a popular article which is almost a replica of Oporto *et al.* (1994), claims there were 151 individuals.

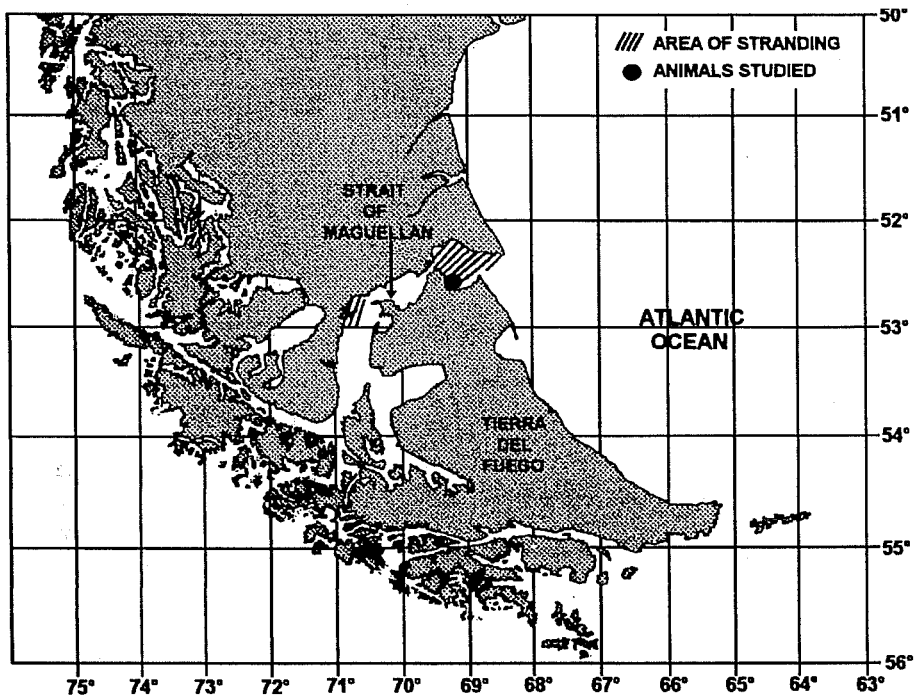

Figure 1. Area of stranding and location of animals studied.

to Cabo Orange and Bahía Lomas (Fig. 1). We measured and necropsied 39 (including two fetuses) of these *in situ*. We removed the stomachs of 25 animals (some of the others had been opened previously) after ligation of the esophagus and intestine. These were opened and examined on the beach, with major food items removed, then washed with sea water and the contents passed through a 1.0-mm diameter mesh sieve. The contents were stored in 70% ethanol.

Prey identification—Squid beaks were identified following Clarke (1980, 1986) and with reference material in the collections of CADIC and CENPAT. Fish prey items were identified using local fish reference collections of otoliths and bones. Some ommastrephid lower beaks ($n = 57$) were broken or deteriorated, preventing their definite identification to species level, but it was evident that they belonged to either *Illex argentinus* or *Martialia hyadesi*. These beaks were therefore assigned to these species in the same proportion as the beaks positively identified to the two species in each stomach.

Length and weight of prey—The dorsal mantle length in cm (*DML*) and wet weight in grams (*W*) of the squids were estimated employing regressions between the lower rostral length in mm (*LRL*) and *DML*, and between *LRL* and *W*. The *DML* of *I. argentinus* was estimated using the equation given by Koen Alonso *et al.* (1998) and the equation $W = 0.801LRL^{3.542}$ (functional regression $n = 64$, $r^2 = 0.908$). The *DML* and *W* of *M. hyadesi* were estimated using the equations given by Rodhouse and Yeatman (1990), while *DML* and

W of the rest of the squid species were estimated using the equations given by Clarke (1986) and Rodhouse *et al.* (1990). The *W* of the octupus, *Ocythoe* sp., could not be estimated because there was no allometric regression available. The total length (*TL*) and *W* of the Patagonian grenadier, *Macruronus magellanicus*, were estimated from otolith length using the equations of Aguayo (1971) and IFOP (1979). That of the kingclip, *Genypterus blacodes*, could not be calculated because only skull bones without otoliths were present. In the cases where beaks or otoliths were broken and could not be measured, weight was assigned as the mean *W* for the species in the total sample.

Relationship between predator and prey size was evaluated using the Spearman rank correlation coefficient (*rs*) (Sokal and Rohlf, 1995), considering the total length (*TL*) of false killer whales and the mean length of prey from each stomach. The mean length of prey was calculated on the basis of the measurement of items in each stomach. Broken beaks or otoliths were excluded from this calculation because the assignment of a mean length to these items could distort the relationship between predator and prey size.

Relative importance of prey—The relative importance of prey species was evaluated by means of the percentage by number (*%N*), percentage by estimated wet weight (*%W*), and the frequency of occurrence (*%FO*) (Hyslop 1980).

Trophic diversity—Sekiguchi *et al.* (1992) estimated trophic diversity using the Shannon index (*H*) on the basis of the estimated ingested biomass. For comparative purposes, trophic diversity was calculated here in a similar way. The 95% confidence interval for trophic diversity was estimated using the percentile method on a bootstrap sample of 1,000 replicates obtained from the 21 stomachs which had content.

Biomass ingestion—The estimated ingested biomass (*IB*) content of each stomach was calculated. The *IB* was compared to the expected daily biomass ingestion (*EB*). The *EB* was calculated using the rates of biomass ingestion of juvenile and adult odontocetes given by Innes *et al.* (1987), taking into account the body weight of the dolphins. Sexual maturity was determined by examination of gonads, uterus, and mammary glands; physical maturity was determined by fusion of vertebral epiphyses. Sexual maturity in this species in the northern hemisphere is reached in both sexes at a total length of 366–427 cm (Purves and Pilleri 1978, Odell *et al.* 1980). Body weight was estimated using the length-weight relationship given by Odell *et al.* (1980).

Results and Discussion

Twenty-one of the 25 stomachs contained food remains. Only trace items (well-digested, disarticulated skeletal remains, squid beaks, or spines) were found (Gannon *et al.* 1997). Most stomachs had only squid beaks and a few fish bones, but two contained many fish bones, suggesting that fish were the last prey consumed prior to stranding.

The esophagi and stomachs of 11 of the 21 animals were full of sandy mud mixed with squid beaks, indicating that the animals may have vomited and swallowed sea water in the shallows. The western shore of Bahía Lomas is a

wide, shallow mud flat. When seen from a helicopter on 9 March, these animals were still alive. They were dead when we arrived on 13 March. The meager food remains could indicate that the animals had not fed recently before the stranding, that digestion took place on the beach, or that much of the food had been vomited (Geraci and St. Aubin 1979). Most of the food remains found were in the second stomach; the first stomach was usually empty. Several additional animals of the Bahía Lomas group examined earlier by the Oporto team had empty stomachs.[2]

The sample was made up of nine males and twelve females. These ranged in two size groups, three very young animals of up to 259 cm in total length (cranial bones still unfused), and 18 large animals of 404–484 cm (females) and 491–547 cm (males) (Table 1). Two of the females had aborted on the beach, three more probably had aborted, two had fetuses and one was lactating. Two females of 422 and 447 cm were physically mature, with all vertebral epiphyses fused to the centra. In the whole sample of 91 animals there were only large animals and small animals; larger juveniles and subadults were absent in the stranding.

The stomach of one 535-cm male (RNP 1433) contained a 15 × 15 × 9-cm ball of 1-cm diameter net entangled with food items. One of the young animals (RNP 1429) had only coagula in the stomach that could not be positively identified and was presumed to be coagulated blood. In another animal, together with milk and beaks, four fragments of the alga, *Macrocystis pyrifera*, were found (Table 1).

Relative importance of prey—Eleven prey species, including nine cephalopods and two fishes, with a total of 442 individuals were found in the stomach contents. The most important prey were the squids *M. hyadesi* and *I. argentinus*, 95% by number and 74% by weight of the total. The next prey species in importance, taking into account the *%N*, *%W* and *%FO*, were the Patagonian grenadier, the squid, *Todarodes fillipovae*, the octopus, *Ocythoe* sp., (although its *W* could not be estimated) and the squid, *Moroteuthis ingens* (Table 2).

The least common prey species were muscular, ammoniacal, and oily squids and one fish species, the kingklip. The squids included non-antarctic (*Teuthowenia megalops* and *Octopoteuthis* sp.) and antarctic species (*Gonatus antarcticus* and *Mastigoteuthis* sp.) (Rodhouse *et al.* 1987, 1990). These prey were represented by only a few beaks, the antarctic species being the least represented (Table 2).

In one animal from waters off South Africa, Ross (1984) found the lower beaks of 11 cephalopods of the genera *Todarodes*, *Lycoteuthis cf. diadema* (called *Oregoniateuthis* in the original paper and now reclassified[3], *Phamatopsis*, *?Galiteuthis*, an ommastrephid, and an unidentified fragment. The first genus was

[2] Personal communication from Dr. Jorge A. Oporto. Corporación Terra Australis, Casilla 828, Valdivia, Chile.

[3] Personal communication from Dr. Graham Ross. Australian Biological Resources Study, Environment Australia, GPO Box 636, Canberra ACT 2601, Australia.

prevalent in our samples, being the fourth prey in order of importance and comprising 19% by *W* in the pooled sample (Table 2).

Sekiguchi *et al.* (1992) found eight cephalopods and no fish in 13 stomachs they examined, but only *Thysanoteuthis rhombus*, *Todaroes angolensis*, *Lycoteuthis ?diadema*, and *Loligo v. reynaudii* were important by *%W*. The former two represented about 95% of the estimated biomass (Sekiguchi *et al.* 1992). *Thysanoteuthis rhombus* is an oceanic and epipelagic species while *Todaores angolensis* is a deep-water squid; this suggests that these false killer whales fed mostly on the continental slope (Roper *et al.* 1984, Sekiguchi *et al.* 1992). In comparative terms, the Sekiguchi sample was similar to our sample, where mostly neritic and oceanic squids were eaten and a few species comprised most of the estimated ingested biomass. Nevertheless, the trophic diversity of the Tierra del Fuego sample was higher than for the southern Africa sample, even considering that two species in our sample were not represented by estimates of biomass and were excluded from the calculation of *H*. The trophic diversity of our sample was 1.4156 with a 95% confidence interval of 1.218–1.4701 while the *H* of southern Africa false killer whales was 0.935 (Sekiguchi *et al.* 1992). This difference in the trophic diversity could be related to sampling biases (both samples were small) or to differences in the availability and relative abundance of prey (diversity of the potential prey community) in these two geographical regions.

Only fish were found in the stomachs of the four Brazilian animals. They were mostly sciaenid fish such as *Micropogonias furnieri* and *Pogonias cromis*, indicating feeding in southern Brazilian coastal waters (Pinedo and Rosas 1989). No stomach contents of this species have been examined from New Zealand[4] or Australian waters.[3]

No relationship was found between predator size and prey size ($rs = 0.15$, $n = 18$, $P = 0.54$). Considering that squid usually form schools of restricted size range, this result could indicate that false killer whales hunted cooperatively on the same schools.

The prey species (in order of importance)—The sevenstar squid, *Martialia hyadesi*, is an oceanic species (Roper *et al.* 1984), although it occasionally may occur over the Patagonian shelf, where it is considered abundant and potentially exploitable in the deeper waters off South Georgia and Tierra del Fuego (Nigmatullin 1989, Rodhouse 1990, Rodhouse and Yeatman 1990) and its capture has been reported by the Argentine fishery, together with *Illex argentinus* (Crespo *et al.* 1997). Those found in this sample ranged from 17 to 40 cm *DML*.

The Argentine shortfin squid, *Illex argentinus*, is a neritic-oceanic species; most of its life cycle develops on the Patagonian shelf, where it is abundant and intensively exploited by the Argentine fishery (Otero *et al.* 1982, Angelescu and Prenski 1987, Nigmatullin 1989, Brunetti 1990, Crespo *et al.* 1997). The size of the individuals consumed ranged from 8 to 33 cm *DML*.

[4] Personal communication from Dr. Alan N. Baker. Science & Research Unit, Department of Conservation, PO Box 10-420, Wellington, New Zealand.

Table 1. List of specimens of false killer whales studied, with details of stomach contents. RNP N°: collection numbers of RNP Goodall.

RNP N°	Sex	Total length (cm)	Estimated body weight[a] (kg)	Presence of mud	Stomach contents	Weight of remains (g)	Estimated ingested biomass[b] (g)	Expected daily biomass ingestion (g)	% of expected biomass ingestion
Juveniles									
1429	M	221	112	no	coagulated blood?	95.45	—	—	—
1410	M	225	117	no	milk, squid and algae	0.73	337	7,237	4.65
1413	F	259	164	no	empty	—	—	—	—
Adults									
1415	F	404	486	no	squid	0.48	496	18,554	2.67
1426	F	418	528	yes	squid, octopus and fish	15.06	13,992	19,599	71.39
1423	F	421	537	no	squid	0.05	471	19,826	2.37
1400	F	422	540	yes	squid	0.06	1,412	19,902	7.09
1434	F	429	562	full	empty	—	—	—	—
1436	F	437	588	no	squid and fish	1.77	3,121	21,052	14.82
1427	F	438	591	yes	squid, octopus and fish	2,996.80	35,166	21,129	166.43
1424	F	439	594	no	squid	4.63	5,897	21,207	27.81
1425	F	440	598	some	empty	—	—	—	—
1437	F	440	598	yes	squid and octopus	46.98	37,343	21,285	175.45
1419	F	446	618	much	squid, octopus and fish	1.17	5,924	21,753	27.23
1430	F	447	621	yes	squid, octopus and fish	0.55	8,746	21,832	40.06
1401	F	448	625	no	squid and fish	1.05	12,974	21,911	59.21
1431	F	484	754	no	squid	16.40	8,377	24,811	33.77
1435	M	491	781	no	squid and fish	0.88	2,173	25,391	8.56
1438	M	496	800	no	squid	3.85	1,888	25,808	7.32
1417	M	515	877	much	squid and fish	7.40	8,299	27,416	30.27

Table 1. Continued.

RNP N°	Sex	Total length (cm)	Estimated body weight[a] (kg)	Presence of mud	Stomach contents	Weight of remains (g)	Estimated ingested biomass[b] (g)	Expected daily biomass ingestion (g)	% of expected biomass ingestion
1421	M	525	919	no	squid, octopus and fish	3.22	5,891	28,278	20.83
1439	M	525	919	no	squid and fish	0.30	2,189	28,278	7.74
1432	M	526	924	yes	squid and fish	8.80	13,642	28,364	48.10
1433	M	535	963	no	squid, fish and net	418.00	16,085	29,149	55.18
1416	M	547	1,016	no	squid	8.17	8,827	30,208	29.22

[a] Odell *et al.* (1980).
[b] Innes *et al.* (1987).

Table 2. Prey species identified in pooled stomachs of 21 false killer whales studied, with estimates of mean length and weight of prey and index employed to evaluate relative importance. Length indicates dorsal mantle length for squids and total length for fishes. *n*: number of measured items considered to estimated mean length and weight; SD: standard deviation; *N*: total number of prey items; *%N* percent by number; W: regression estimated wet weight; %W: percent by W; %FO: frequency of occurrence, NE: not evaluated.

	Length (cm)		Weight (g)							
	Mean	SD	Mean	SD	*n*	*N*	*%N*	W (g)	%W	%FO
Squids										
Ommastrephidae										
Martialia hyadesi	28.77	3.98	470.54	189.53	153	177	44.70	83,285.96	57.44	80.95
Illex argentinus	24.56	2.91	122.28	39.25	160	198	50.00	24,210.88	16.70	76.19
Todarodes fillipovae	49.54	5.43	2701.69	794.50	8	10	2.53	27,016.92	18.63	23.81
Onychoteuthidae										
Moroteuthis ingens	50.32	15.07	1699.68	1066.41	6	6	1.52	10,198.08	7.03	14.29
Cranchiidae										
Teuthowenia megalops	16.95	11.40	68.71	84.35	2	3	0.76	206.14	0.14	9.52
Octopoteuthidae										
Octopoteuthis sp	7.40	0.51	34.28	5.42	2	2	0.51	68.55	0.05	9.52
Mastigoteuthidae										
Mastigoteuthis sp	11.94	—	73.27	—	1	1	0.25	73.27	0.05	4.76
Gonatidae										
Gonatus antarticus	14.59	—	73.06	—	1	1	0.25	73.06	0.05	4.76
Octopods										
Octhoidae										
Ocythoe sp	NE	NE	NE	NE		11	2.78	NE	NE	28.57
Fishes										
Macrouridae										
Macruronus magellanicus	86.20	4.64	1718.49	272.29	2	28	7.07	48,117.76	33.19	57.14
Ophidiidae										
Genypterus blacodes	NE	NE	NE	NE		5	1.26	NE	NE	4.76
					335	442		193,250.63		

The Patagonian grenadier, *Macruronus magellanicus*, is a neritic species which inhabits the Patagonian shelf and slope and is most often found at a depth of 100–200 m (Otero *et al.* 1982). It is one of the most abundant fish on the Patagonian shelf and slope around Tierra del Fuego. During the austral summer, large concentrations of Patagonian grenadier can be found close to the east coast of Tierra del Fuego and the mouth of the Strait of Magellan (Bellisio *et al.* 1979, Otero *et al.* 1982, Malaret 1986). This species is exploited on the Patagonian shelf, together with the southern blue whiting, *Micromesistius australis*, for the production of fish paste or "surimi" (Crespo *et al.* 1997). The otoliths of only two individuals of this species could be measured; the estimated *TL*s were 83 and 89 cm.

The antarctic flying squid, *Todaroes fillipovae*, is an oceanic muscular squid which reaches larger sizes than the other two ommastrephid species in the sample. The range of sizes eaten by the false killer whales was 40–57 cm *DML* This squid has a circumpolar distribution and has been taken as by-catch in the Falklands (Malvinas) fishery, but is most common in the Antarctic Convergence zone. It can be found from the surface to a depth of 500 m, but is most abundant to about 200 m (Roper *et al.* 1984).

The genus *Ocythoe* is considered to include the single species *Ocythoe tuberculata*. This octupus is epipelagic and found mainly in subtropical waters, although its biology is poorly known (Clarke 1986, Smale *et al.* 1993). Females are much larger than males; the mantle lengths of mature males measure 2–3 cm while those of females reach over 30 cm (Clarke 1986). In this sample, *LHL* ranged from 11.5 to 12.3 mm, indicating that the false killer whales fed upon females of this species.

The greater hooked squid, *Moroteuthis ingens*, is a muscular, oceanic, and epipelagic species which is abundant in subantarctic waters north of the Antarctic Convergence and probably occurs at <200 m depth (Roper *et al.* 1984). Squids of this genus are considered abundant and potentially exploitable in oceanic waters off South Georgia and Tierra del Fuego (Nigmatullin 1989, Rodhouse 1990). This species is occasionaly taken as a by-catch on the Patagonian shelf by the Argentine fishery. The specimens examined ranged from 38 to 72 cm in *DML*.

The kingclip, *Genypterus blacodes*, is a demersal-benthic species which lives over the shelf (Angelescu and Prenski 1987) and is usually caught by the Argentine trawling fishery (Crespo *et al.* 1997). It reaches sizes >1 m in length. Five individuals of this species were present in the sample, but their sizes could not be estimated because only skull bones were found.

Of the less important squids, the oceanic non-antarctic species, *Teuthowenia megalops* and *Octopoteuthis* sp., were represented by two individuals each. Their mean *DML* were 17 and 7 cm, respectively. The antarctic species, *Mastigoteuthis* sp. and *Gonatus antarcticus*, were represented by one individual each; their estimated *DML*s were 12 and 15 cm, respectively (Table 2).

Biomass ingestion—Squid beaks may accumulate in predator stomachs and probably represent several days of feeding (Clarke 1980). In this study the estimated ingested biomass (*IB*) of the stomach contents was in most cases

much smaller than the expected daily biomass ingestion (*EB*) according to the equations of Iness *et al.* (1987). False killer whales kept in aquaria ate an average of 15–20 kg of fish per day (Odell *et al.* 1980). Six of the animals studied had an *IB* near or over this range.

The *IB* of one Brazilian false killer whale was estimated at 59.4 kg (Pinedo and Rosas 1989); the *EB* would have been 20.97 kg. In this case, the *IB* was 283% of the *EB*.

The lower *IB* of most of the false killer whales analyzed in this study could be related to a period of low food consumption before stranding or possibly vomiting during stranding. The presence of worn beaks in the stomachs suggests there had been some retention of beaks. If there is an inverse relationship between proportion of broken beaks in the stomach and *IB*, a normal feeding process and loss during stranding could be suggested; if not, it could reflect poor feeding conditions. This relationship was evaluated using the *rs*, and a significant negative correlation was found ($rs = -0.52$, $n = 21$, $P = 0.01$). The results support the vomiting hypothesis. On the other hand, two of the animals had *IB*'s which were 166% and 175% of the EB (Table 1). Taking into account these results and the information on the Brazilian animal, we suggest that the highest *IB* represents about 2–3 d of feeding.

Concluding remarks—Northern Hemisphere false killer whales feed on squid and large fish, and sometimes interact with fisheries (Perryman and Foster 1980, Leatherwood *et al.* 1991, Stacey *et al.* 1994). In the Southern Hemisphere South African animals fed only on squid. In our sample most of the prey were squids, of 7–50 cm in mean *DML* and fish with a mean *TL* of 86 cm. One stomach contained a ball of net. The prey species identified in this sample were subantarctic and antarctic species abundant over the Patagonian shelf or in adjacent deep waters. The oceanic prey species were pelagic, while the neritic prey were demersal fish species. In the Brazilian animals, the prey were mainly Sciaenidae, demersal fish which are the most frequent and abundant in that area during that month (Pinedo and Rosas 1989). This suggests that false killer whales in the western South Atlantic are opportunistic feeders on mainly pelagic, schooling, and locally abundant squid and fish down to a depth of about 200 m.

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