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The summer diet of demersal fish at the South Shetland Islands

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Abstract: The stomach contents of demersal fish in late January 1982 were analysed. Samples were taken at 100, 300 and 500 m depth south of Elephant Island, Bransfield Strait and north of Livingston Island, and at 800 m to the east of Smith Island. Fifty four taxa of fish belonging to 11 families were collected. The diets of 2101 fish representing 38 taxa were examined. These were classified into three categories, fish feeders, krill feeders and benthos feeders. Fish prey species fed on krill and/or benthos. Krill was a major dietary component for 32 (84.2%) out of 38 taxa. *Gobionotothen gibberifrons* was distributed at all 10 stations (100–800 m in depth) and its diet comprised krill and benthos. The present findings verify the importance of krill in the Antarctic marine ecosystem and indicate that krill is consumed by benthic fish at greater depths than previously reported.

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Key words: Antarctic Peninsula, demersal fish, fish diet, krill

Introduction

The significance of Antarctic krill, *Euphausia superba* Dana, as a key species of the Antarctic marine ecosystem has long been recognized. Thus, krill was the major target of Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS), which was conducted for about 10 years from 1977 (El-Sayed 1994). Although the efforts devoted to BIOMASS field work were considerable, many aspects such as krill distribution still require further study (Marin *et al.* 1991, Gutt & Siegel 1994).

For krill predators, such as fish and squid, more detailed information is required to understand the food web (Hubold 1987), and the present knowledge of the diets of Antarctic fish, particularly the geographical, ontogenic and seasonal variation of diet, is still inadequate (Kellermann & North 1994).

To contribute to BIOMASS, the Japan Marine Fishery Resources Research Center carried out a bottom trawling survey to the north of the South Shetland Islands in the summer of 1981. From fish diet analysis of the survey it was shown that krill was one of the major food items in the diet of demersal fish and was also indicated that krill could be distributed throughout the water column even down near sea floor. To gain further information further bottom trawling survey was undertaken in the summer of 1982. This paper reports on the abundance and diet of demersal fish at the South Shetland Islands based on deeper samples than these previously reported.

Materials and methods

The four areas sampled between 21–30 January 1982 were south of Elephant Island, central part of Bransfield Strait, north of Livingston Island and east of Smith Island (Fig. 1 and Table I). At each of the first three areas, samples were taken at three stations in depths of about 100, 300 and 500 m. To the east of Smith Island, samples were only taken at 800 m depth. About 15 min towing of the bottom otter-trawl at a speed of 4 knots was repeated six times per station at intervals of 4 h. However, in the deepest stations off Elephant Island, in Bransfield Strait and in the station off Smith Island, the frequency of trawling was reduced due to sudden change of weather and time constraint. The data are given as the number of fish per km² to allow comparisons between the samples (Table II). The trawl net used was the 68.7 m in headline length, 23 m in width between wings and 8 m in headline height. The mesh-size of cod end was 60 mm.

Immediately after capture, fish were frozen using a contact freezer at -40°C to prevent further digestion of food in the stomach. The stomach contents of fish randomly sampled from catches at each station were fixed in 70% ethanol and

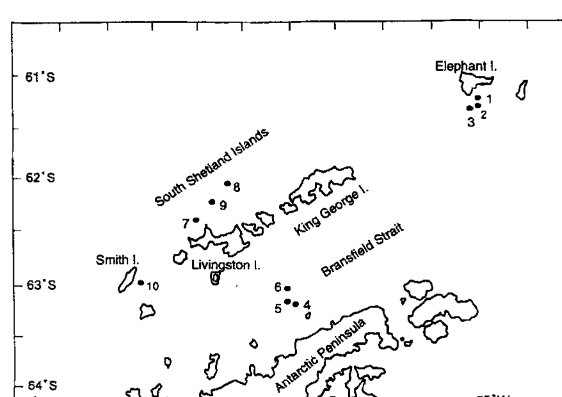

Fig. 1. Sampling stations

Table I. The bottom trawling stations in waters to the south of Elephant Island (Stns. 1–3), central part of Bransfield Strait (Stns. 4–6), north of Livingston Island (Stns. 7–9) and east of Smith Island (Stn. 10).

Station number	Location	Depth range (m)	Date (in 1982)
1	61°15'S, 55°03'W	98–118	Jan. 21, 22
2	61°20'S, 55°08'W	278–310	Jan. 22, 23
3	61°23'S, 55°11'W	460–528	Jan. 23
4	63°11'S, 58°55'W	96–105	Jan. 24, 25
5	63°09'S, 59°07'W	278–320	Jan. 25, 26
6	63°03'S, 59°08'W	486–525	Jan. 26
7	62°24'S, 61°00'W	100–109	Jan. 27, 28
8	62°02'S, 60°20'W	321–338	Jan. 28, 29
9	62°13'S, 60°43'W	490–505	Jan. 29, 30
10	62°59'S, 62°09'W	804–813	Jan. 30

examined. Fish and euphausiids were identified to species and other prey organisms were classified into general taxa when possible. Each food item was dried at 80°C for 12 h, cooled in a desiccator, and weighed (to 0.01 g). For comparison of food composition between taxa the diet from all fish of the same taxon examined were combined. However, the diet composition of *Gobionotothen gibberifrons* was investigated separately for each of the 10 trawling stations.

Results

The collection comprised 54 taxa of fish belonging to 11 families (Table II). As shown in Table II population density of fish was generally higher in the shallowest layer, except to the north of Livingston Island, Nototheniidae and Channichthyidae were prominent, followed by Myctophidae. The dominance of Nototheniidae was high off Elephant Island and low off Livingston Island. It was intermediate in Bransfield Strait. The proportion of Nototheniidae was high in the shallowest layer and that of Channichthyidae increased towards deeper layers except for the 300 m layer of Livingston Island, in which one species of Myctophidae, *Gymnoscopelus nicholsi*, occurred instead of Channichthyidae.

The species which exceeds 10% of the total at a station are considered as dominant species. *Gobionotothen gibberifrons* appeared in all sampling stations and was the dominant species except for the deepest station of Bransfield Strait. Dominant nototheniid species were *Trematomus newnesi* at the shallowest stations in Bransfield Strait and *Pleuragramma antarcticum* at the deepest station off Elephant Island. Dominant channichthyid species were *Chionodraco rastrospinosus*, *Champsocephalus gunnari*, *Chionodraco myersi* and *Chaenodraco wilsoni*. Among them, *C. rastrospinosus* was broadly distributed and *C. gunnari* was dominant in the shallow station off Livingston Island. *C. wilsoni* and *C. myersi* were dominant in the middle and deep stations in Bransfield Strait and in the deep station off Elephant Island, respectively. *G. nicholsi* was dominant in the middle and deep stations off Livingston Island. *Paraliparis* spp.was dominant in the deep station off Smith Island.

Analysis of 2101 stomachs of 38 taxa of fish showed the major components of diet to be fish, krill and various kinds of benthic invertebrates. Krill were observed in the stomachs of 32 taxa (84.2%). The fish examined were, for convenience, divided into two groups: 22 taxa in which more than 10 stomachs were analysed and 16 taxa of which less than 10 stomachs were observed. The majority of food (>50%) in 12 species of the former group was *E. superba* (Fig. 2). Three species, *Lepidonotothen nudifrons*, *Trematomus bernacchii* and *Paraliparis* sp. fed on invertebrates, most of which were benthic. *Trematomus hansoni* contained fish and benthic invertebrates in similar quantities and a small amount of *E. superba*. The fish ingested by *T. hansoni* clearly belonged to the nototheniid family but further identification was impossible. In *Notothenia rossii*, the amount of fish and *E. superba* were equal (about 40%), with some benthos. The majority (>50%) of stomach contents of five species were fish. The species composition of fish in the diets of *Parachaenichthys charcoti*, *Gymnodraco acuticeps*, *Chaenocephalus aceratus*, *Cryodraco antarcticus* and *Notothenia coriiceps* is shown in Table III. The main food items of these species were nototheniid fish, followed by channichthyids and myctophids. It was noted that *G. gibberifrons* was commonly found in the diet of these five species just mentioned.

In the second group composed of 16 taxa, the majority of stomach contents of three species were fish, those of nine taxa were *E. superba* and those of three species were benthic invertebrates (Fig. 3). The stomach contents of *Pseudochaenichthys georgianus* were composed of *E. superba* (55.3%) and fish (44.7%). In this group, the composition of fish species in the diets was simple in comparison with those of the first group. *G. gibberifrons* was abundant (85.4%) in the diet of *Dissostichus mawsoni*; *G. nicholsi* (87.7%) in the diet of *Chionobathyscus dewitti*, *Pleuragramma antarcticum* (100.0%) in the diet of *Bathyraja maccaini* and *Cryodraco antarcticus* (90.1%) in the diet of *P. georgianus*.

G. gibberifrons was the most common fish caught and the variation of its food composition in different habitats was investigated. *G. gibberifrons* appeared at all sampling stations and was the numerically dominant species at most of the stations (Table II). *E. superba* and benthic invertebrates formed the major part of its diet (Fig. 4). However, the proportion of *E. superba* and benthic invertebrates in the diet varied spatially. The proportion of *E. superba* was greatest off Livingston Island followed by off Smith Island, in Bransfield Strait and off Elephant Island and increased with depth. An apparent inverse correlation between *E. superba*

Table II. The number of fish per km² and the % of the total number of fish per each fish taxa at each depth horizon at each station sampled by bottom trawl. + represents <0.05% by number.

Sampling sites	South of Elephant Is			Bransfield Strait			North of Livingston Is			Smith Is
Stations	1	2	3	4	5	6	7	8	9	10
Taxa / Depth in m	100	300	500	100	300	500	100	300	500	800
Nototheniidae:										
Aethotaxis mitopteryx DeWitt									12	6
									0.8	0.4
Dissostichus mawsoni Norman	6								3	6
	+								0.2	0.4
Gobionotothen gibberifrons (Lönnberg)	14417	4139	615	12212	3997	191	746	2373	615	258
	91.2	87.5	27.2	77.2	47.8	3.9	72.5	43.0	41.0	17.8
Lepidonotothen kempi (Norman)		3						6		6
		0.1						0.1		0.4
Lepidonotothen larseni (Lönnberg)	3	89		63	81			21		
	+	1.9		0.4	1.0			0.4		
Lepidonotothen nudifrons (Lönnberg)	276			630	24	32	6			
	1.7			4.0	0.3	0.6	0.6			
Notothenia rossii Richardson	59	3					3		3	
	0.4	0.1					0.3		0.2	
Notothenia coriiceps Richardson	203			54	32		3	3		
	1.3			0.3	0.4		0.3	0.10		
Nototheniidae sp.				6			3			
				+			0.3			
Pleuragramma antarcticum Boulenger		37	255	6	4	48		63	129	6
		0.8	11.3	+	+	1.0		1.1	8.6	0.4
Trematomus bernacchii Boulenger	37			6	8					
	0.2			+	0.10					
Trematomus eulepidotus Regan		34			60	16	6	3		
		0.7			0.7	0.3	0.6	0.10		
Trematomus hansoni Boulenger	47	6	15		40			3		
	0.3	0.1	0.7		0.5			0.10		
Trematomus lepidorhinus (Pappenheim)					4					
					+					
Trematomus loennbergii Regan			15						3	30
			0.7						0.2	2.1
Trematomus newnesi Boulenger	9	3		2676	4		19			
	0.1	0.1		16.9	+		1.8			
Trematomus scotti (Boulenger)				9	4					6
				0.1	+					0.4
Trematomus tokarevi Andriashev					4			6		
					+			0.1		
Trematomus sp.							3			
							0.3			
Channichthyidae:										
Chaenocephalus aceratus (Lönnberg)	469	12				16	67	240	12	12
	3.0	0.3				0.3	6.5	4.3	0.8	0.8
Chaenodraco wilsoni Regan				3	1523	3732	3	120		
				+	18.2	75.3	0.3	2.2		
Champsocephalus gunnari Lönnberg	248			6			152	12		
	1.6			+			14.8	0.2		
Chionobathyscus dewitti Andriashev & Neelov			15					3	24	36
			0.7					0.1	1.6	2.5
Chionodraco myersi DeWitt and Tyler		58	855		60	48		24	117	24
		1.2	37.7		0.7	1.0		0.4	7.8	1.7
Chionodraco rastrospinosus DeWitt & Hureau		74	225	87	2414	508	3	114	195	582
		1.6	9.9	0.5	28.9	10.3	0.3	2.1	13.0	40.2
Cryodraco antarcticus Dollo		43	90	3	64	206		111	45	18
		0.9	4.0	+	0.8	4.2		2.0	3.0	1.2
Neopagetopsis ionah Nybelin			15			16		9	39	6
			0.7			0.3		0.2	2.6	0.4
Pagetopsis macropterus (Boulenger)				3	28		3			
				+	0.3		0.3			

Table II. (cont)The number of fish per km² and the % of the total number of fish per each fish taxa at each depth horizon at each station sampled by bottom trawl. + represents <0.05% by number.

Sampling sites	South of Elephant Is			Bransfield Strait			North of Livingston Is			Smith Is
Stations	1	2	3	4	5	6	7	8	9	10
Taxa / Depth in m	100	300	500	100	300	500	100	300	500	800
Pseudochaenichthys georgianus Norman							3 0.3	15 0.3		
Channichthyidae sp.										6 0.4
Bathydraconidae:										
Gymnodraco acuticeps Boulenger				21 0.1	12 0.1			3 0.0	6 0.4	
Parachaenichthys charcoti (Vaillant)	37 0.2			39 0.2			6 0.6			
Artedidraconidae:										
Artedidraco sp.				3 +						
Pogonophryne scotti Regan					4 +					
Pogonophryne spp. (2 species)			15 0.7			64 1.3				6 0.4
Artedidraconidae sp.									3 0.2	
Myctophyidae:										
Electrona sp.								3 0.1		
Gymnoscopelus nicholsi (Gilbert)		206 4.4	90 4.0			79 1.6		2358 42.7	183 12.2	54 3.7
Myctophyidae sp.								6 0.1		6 0.4
Bathylagidae:										
Bathylagus sp.										78 5.4
Trichiuridae:										
Paradiplospinus gracilis (Brauer)			15 0.7						6 0.4	24 1.7
Liparididae:										
Paraliparis somovi Andriashev & Neelov									3 0.2	
Paraliparis spp. (2 species)										162 11.2
Paralepididae:										
Notolepis coatsi Dollo										12 0.8
Paralepididae sp.		3 0.1								
Zoarcidae:										
Ophthalmolycus amberebsis (Tomo, Marschoff & Torno)									57 3.8	
Pachycara brachycephalum (Pappenheim)									6 0.4	
Seleniolycus laevifasciatus (Torno, Tomo & Marschoff)										60 4.1
Zoarcidae sp.									27 1.8	36 2.5
Rajidae:										
Bathyraja griseocauda (Norman)		3 0.1	45 2.0					27 0.5	12 0.8	
Bathyraja maccaini Springer		12 0.3								
Rajidae sp.		6 0.1					3 0.3			6 0.4
	15811	4731	2265	15827	8367	4956	1029	5523	1500	1446

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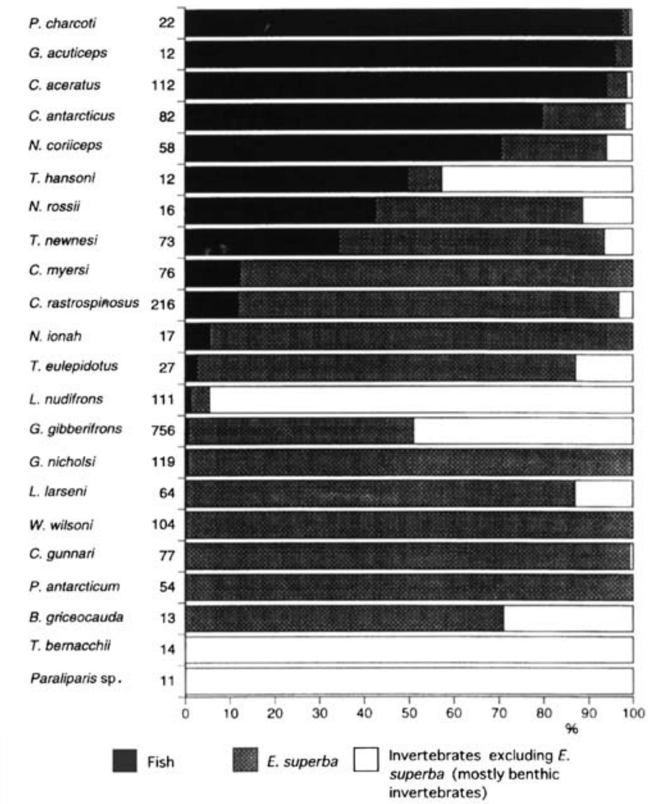

Fig. 2. Composition of fish diets, in % of dry weight. Number of stomachs examined follows the species name.

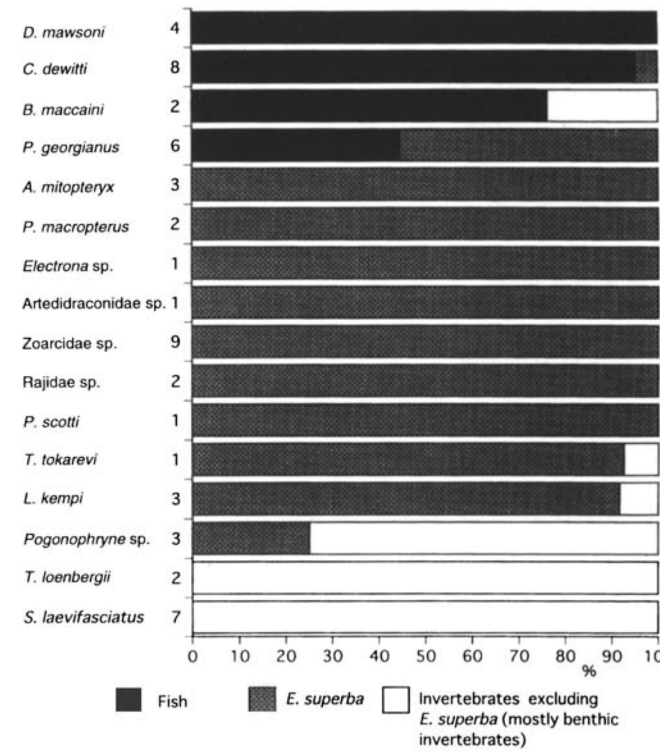

Fig. 3. Composition of fish diets, in % of dry weight. Number of stomachs examined follows the species name.

and benthic invertebrates was clearly observed.

Discussion

The present collection of 54 taxa of fish belonging to 11 families is greater in number of species than previous records from the vicinity of Antarctic Peninsula and Scotia Sea: 24 species (Targett 1981), 19 species (Daniels 1982) and 32 species (Takahashi 1983). The stations sampled in the present study were dominated by Nototheniidae and Channichthyidae. Targett (1981), sampling bottom fish at four stations shallower than 160 m and one station of 270–305 m depth found Nototheniidae was the dominant family at all stations. Takahashi (1983), sampling from the sea floor at eight stations between 189–429 m in depth in the waters north of South Shetland Islands found the dominant families were Nototheniidae and Channichthyidae. The greater diversity of species in the present study is ascribed to the larger vertical range of sampling than previously, giving new information on the diets of fish at the South Shetland Islands.

Two approaches, which are not clearly separable, have been followed in investigations of fish feeding habit in the Antarctic Peninsula and Scotia Sea areas. One aims to analyse the energy flow in the ecosystem (Permitin 1970, Richardson 1975, Tarverdiyeva & Pinskaya 1980, Targett 1981, Daniels 1982, Takahashi 1983, Nast *et al.* 1988) and the other attempts to clarify the diet selection in the life history of a species (Moreno & Osorio 1977, Burchett 1983, Barrera-Oro & Tomo 1987). Both these approaches have made clear that most of the fish fed demersally but could feed on krill when it was locally abundant.

In this study the fish stomach contents were classified into three groups based on the relative abundance of feed items; fish feeder, krill feeder and benthos feeder (Figs 2 & 3). As shown in Table III, fish species ingested by the predatory fish were also krill and/or benthos feeders. Accordingly it was concluded that the fish fauna of these regions were supported directly by krill and/or benthos and indirectly with the fish feeding on krill and/or benthos. It was noted that krill were present in the stomachs of 84.2% of the fish taxa examined.

G. gibberifrons appeared commonly and abundantly in the diets of the piscivorous fish (Table III). It also was distributed at all sampling stations (Table II). Consequently, it was considered that *G. gibberifrons* functioned as an energy transmitter, with some of other nototheniid and channichthyid fish, in the ecosystems. Overall *G. gibberifrons* (combining 10 sampling stations), fed on almost equal amounts of krill and benthos (Fig. 2). However the relative amounts of krill and benthos varied from station to station (Fig. 4). It was presumed that this variation resulted from the difference in local krill abundance. Permitin (1970) mentioned that *G. gibberifrons* and *L. nudifrons* were benthos feeders and

Table III. Dry weight proportion of each fish taxon to the total dry weight of fish taxa in the diet of each piscivorous fish.

Prey \ Predator	*P. charcoti*	*G. acuticeps*	*C. aceratus*	*C. antarcticus*	*N. coriiceps*
Gobionotothen gibberifrons	55.7%	34.3%	93.5%	57.7%	48.3%
Lepidonotothen larseni					2.7
Lepidonotothen nudifrons	20.2	10.0			4.6
Pleuragramma antarcticum		4.1		6.7	
Trematomus newnesi		46.8			19.8
Trematomus sp.	2.6				
Nototheniidae	21.6	4.7	6.5	2.6	10.4
Chaenodraco wilsoni				14.2	14.0
Chionodraco rastrospinosus				14.4	
Channichthyidae				1.5	
Gymnoscopelus nicholsi				2.9	
Myctophydae					0.1
No. of stomach containing fish	12	6	15	15	27
No. of empty stomach	4	4	52	43	6
No. of stomach examined	22	12	112	82	58

did not migrate to surface layers to feed on krill and this was confirmed by Richardson (1975) and Moreno & Osorio (1977). Subsequently, the vertical distribution range of krill has been considered to be wider than that reported before (Kock 1985, Williams & Duhamel 1994). Marin *et al.* (1991) observed krill in water layers between 1000 and 2000 m in relation to egg liberation in the Drake Passage. Gutt & Siegel (1994) recorded a krill swarm just above the sea floor at 400 m in the Weddell Sea in the summer. Targett (1981), Takahashi (1983), Kock (1985) and Naito & Iwami (1982) indicated the possible distribution of krill near the sea bottom from fish diet analysis. Kawaguchi *et al.* (1986) collected krill with a light trap on the sea floor of Lützow-Holm Bay in winter. Kock (1985) reported that sinking of krill to the bottom occurred in both winter and summer. Nast *et al.* (1988) mentioned a positive correlation between demersal fish abundance and krill biomass. The present results clearly indicate that a certain portion of the krill is distributed near the sea floor down to around 800 m depth and is one of the major food resources for dermersal fish. However, the present data cover only a short period of summer. Comparative researches on samples collected throughout the year are essential if we are to understand the seasonality component of the krill-fish interaction.

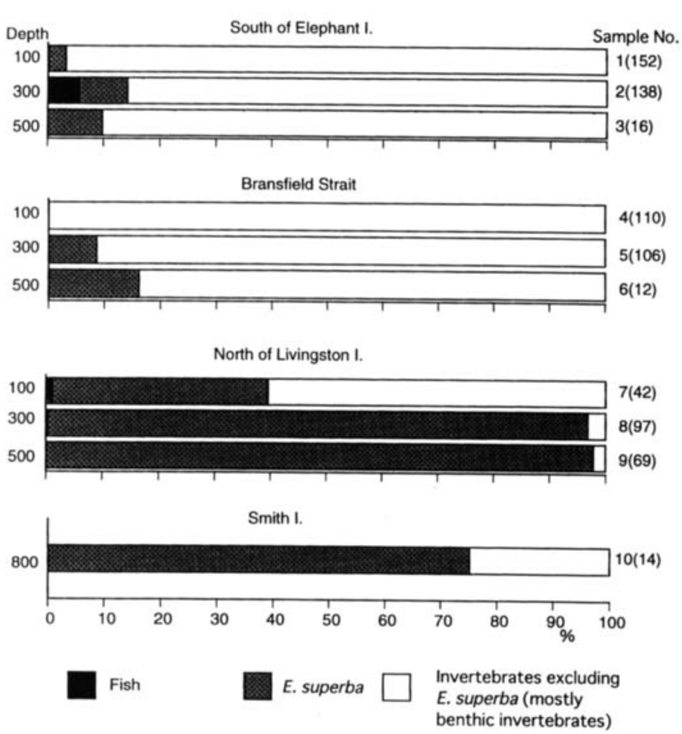

Fig. 4. Food composition of *G. gibberifrons* at each station. Number of stomachs examined is shown in parentheses after station number.

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References

BARRERA-ORO, E.R. & TOMO, A.P. 1987. Feeding and ecology of *Notothenia larseni*, Lonnberg. *In* EL-SAYED, S.Z. & TOMO, A.P., *eds.* Antarctic aquatic biology. *BIOMASS Scientific Series*, **7**, 99-106.

BURCHETT, M.S. 1983. Food and feeding behaviour of *Notothenia rossii nearshore* at South Georgia. *British Antarctic Survey Bulletin*, No. 61, 45-51.

DANIELS, R.A. 1982. Feeding ecology of some fishes of the Antarctic Peninsula. *Fishery Bulletin*, **80**, 575-588.

EL-SAYED, S.Z. *ed.* 1994. *Southern Ocean ecology: the BIOMASS perspective.* Cambridge: Cambridge University Press, 399 pp.

Gon, O. & Heemstra, P.C. 1990. *Fishes of the Southern Ocean.* Grahamstown, South Africa: J.L.B. Smith Institute of Ichthyology, 462 pp.

Gutt, J. & Siegel, V. 1994. Benthopelagic aggregations of krill (*Euphausia superba*) on the deeper shelf of the Weddell Sea (Antarctica). *Deep-Sea Research*, **41**, 169-178.

Hubold, G. 1987. Current problems in Antarctic krill and zooplankton research. *In* El-Sayed, S.E. & Tomo, A.P., *eds.* Antarctic aquatic biology. *BIOMASS Scientific Series*, **7**, 67-72.

Kawaguchi, K., Ishikawa, S. & Matsuda, O. 1986. A light trap to collect krill and other micronektonic animals under the Antarctic coastal fast ice. *Polar Biology*, **6**, 37-42.

Kellermann, A. & North, A.W. 1994. The contribution of the BIOMASS programme to Antarctic fish biology. *In* El-Sayed, S.Z., *ed. Southern Ocean ecology: the BIOMASS perspective*. Cambridge: Cambridge University Press, 191-209.

Kock, K.-H. 1985. Krill consumption by Antarctic nototheniid fish. *In* Siegfried, W.R., Condy, P.R. & Laws, R.M., *eds. Antarctic nutrient cycles and food webs*. Berlin: Springer-Verlag, 437-444.

Marin, V.H., Brinton, E. & Huntley, M. 1991. Depth relationship of *Euphausia superba* eggs, larvae and adults near the Antarctic Peninsula, 1986-87. *Deep-Sea Research*, **38**, 1241-1239.

Moreno, C.A. & Osorio, H.H. 1977. Bathymetric food habits in the Antarctic fish *Notothenia gibberifrons* Lonnberg (Pisces: Nototheniidae). *Hydrobiologia*, **55**, 139-144.

Naito, Y. & Iwami, T. 1982. Fish fauna in the northeastern parts of Lützow-Holm Bay with some notes on the stomach contents. *Memoirs of National Institute of Polar Research, Special Issue*, No. 23, 64-72.

Nast, F., Kock, K.H., Sahrhage, D., Stein, M. & Tiedtke, J.E. 1988. Hydrography, krill and fish and their possible relationships around Elephant Island. *In* Sahrhage, D., *ed. Antarctic Ocean and resources variability*. Berlin: Springer-Verlag, 183-198.

Permitin, Yu. E. 1970. The consumption of krill by Antarctic fishes. *In* Holdgate, M.W., *ed. Antarctic ecology.* London: Academic Press, 177-182.

Richardson, M.G. 1975. The dietary compositon of some Antarctic fish. *British Antarctic Survey Bulletin*, No. 41/42, 113-120.

Takahashi, M. 1983. Trophic ecology of demersal fish community north of the South Shetland Islands, with notes on the ecological role of the krill. *Memoirs of National Institute of Polar Research, Special Issue*, No. 27, 183-192.

Targett, T.E. 1981. Trophic ecology and structure of coastal Antarctic fish communities. *Marine Ecology Progress Series*, **4**, 243-263.

Tarverdiyeva, M.U. & Pinskaya, I.A. 1980. The feeding of fishes of the families Nototheniidae and Chaenichthyidae on the shelves of the Antarctic Peninsula and the South Shetlands. *Journal of Ichthyology*, **20**, 50-60.

Williams, R. & Duhamel, G. 1994. Studies on fish of the Indian Ocean sector of the Southern Ocean during the BIOMASS programme. *In* El-Sayed, S.Z., *ed. Southern Ocean ecology: the BIOMASS perspective.* Cambridge: Cambridge University Press, 211-229.