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Feeding selectivity in *Notothenia neglecta*, Nybelin, from Potter Cove, South Shetland Islands, Antarctica.

E.R. BARRERA-ORO and R.J. CASAUX

Instituto Antártico Argentino, División Biología, Cerrito 1248, 1010 Buenos Aires, República Argentina.

Abstract: A study of feeding selectivity in *Notothenia neglecta* Nybelin 1951, was carried out between October 1988 and January 1989 at Potter Cove, King George Island, where this is the dominant fish species. The abundance and biomass of benthic organisms from 0–40m were compared with their occurrence in the diet of 142 fish. The Ivlev index indicated that the food items positively selected by the fish were sedentary polychaetes, the isopod *Glyptonotus antarcticus*, the gammarid amphipod *Paradexamine* sp., the bivalve *Dacrydyum* sp., the gastropods *Margarella antarctica* and *Eatoniella* sp., and algae. The biomass of the benthic community in the sampling area was low, presumably due to the effects of anchor ice. Despite being pelagic, krill (*Euphausia superba*) was by far the main food of *N. neglecta* which is considered a benthic feeder.

Key words: Antarctic fish, marine ecology.

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Introduction

The Antarctic fish *Notothenia neglecta* Nybelin 1951, is widely distributed, inhabiting the shelf area of the Scotia Arc; and of the Antarctic continent, the Antarctic Peninsula water, South Georgia, Bouvetoya and Peter I° Islands (Everson 1977a, Fischer & Hureau 1985). It is a coastal demersal species in water 0–450 m deep (Kock 1989, Tiedtke & Kock 1989). In Potter Cove, King George Island, South Shetland Islands, it is the dominant fish. Most individuals caught were 20–40 cm total length and weighed 200–1600 g (Casaux *et al.* unpublished), although specimens up to 60 cm and 3 750 g were found. Although not commercially exploited, *N. neglecta* is considered potentially important for coastal fishing (Everson 1977a, Fischer & Hureau 1985).

Few studies have been conducted on food selectivity by Antarctic fish in relation to food availability (Moreno & Zamorano 1980, Duarte & Moreno 1981, Asencio & Moreno 1984, Kellermann 1987). Several papers have given information on the composition of *N. neglecta* diet in different areas, including the west zone of the Antarctic Peninsula (Showers *et al.*1977, Daniels & Lipps 1978, Daniels 1982), the South Shetland Islands (Moreno & Bahamonde 1975, Moreno y Zamorano 1980, Tarverdiyeva & Pinskaya 1980, Linkowski *et al.* 1983), the South Orkney Islands (Richardson 1975, Everson 1977b, Permitin & Tarverdiyeva 1978), South Georgia (Burchett *et al.* 1983), and Terre Adélie (Arnaud & Hureau 1966, Hureau 1970). However, only Moreno & Zamorano (1980) examined the food selectivity of *N. neglecta* and established a correlation between the proportion of organisms in the diet and that available in the local environment. The aim of this paper is to examine feeding selectivity of *N. neglecta* on benthic organisms. The importance of algae, indicated by some authors as actively eaten by fish (Burchett 1982, Daniels 1982, Casaux *et al.*), is considered. We will also attempt to evaluate the value of pelagic prey such as krill, in the diet of a benthic feeding fish.

Materials and methods

Samples were obtained in Potter Cove, King George Island (62° 14' S, 58° 40' W), between October 1988 and January 1989 (Fig.1). The biotic components and abiotic features of this area have been described by Casaux *et al.* in a future paper.

Using SCUBA we sampled the benthos along three parallel transects spaced at 50 m, running perpendicular to the shore from 0–40 m water depth. We sampled a mean of 26 stations per transect, with stations spaced at about every 5 m measured along the bottom. Thus, sampling density becomes proportional to bottom surface at each depth interval. Data from all transects were grouped at intervals of 5 m water depth and are expressed as mean values. At each station all macrobenthos included within a square area of 0.1 m^2 was removed by hand; mobile organisms were collected by means of a hand operated dip-net. In the laboratory, the material was identified, counted and wet weighed, and the biomass (gm^{-2}) along the transect calculated.

Simultaneously, in the same area, *N. neglecta* were caught with trammel nets (length 25 m; width 1.5 m; mesh 2.5 cm) set on the bottom between 5–40 m water depth. The net was laid at different hours of the day (darkness and daylight) for periods of 10–24 hours. Total length (TL) in cm, weight in g and the sex of fish were recorded. The age was determined from otolith and scale analysis, (Barrera-Oro 1989).

Stomach contents were evaluated immediately after capture

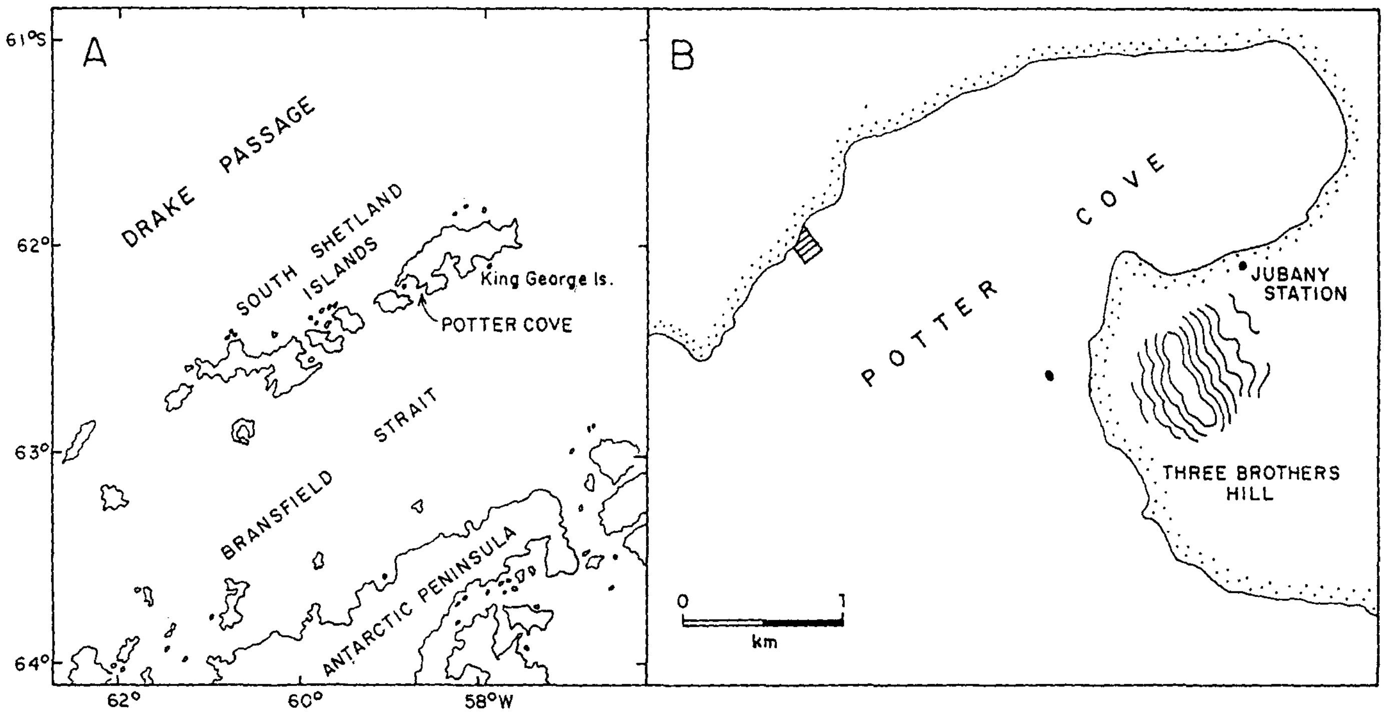

Fig. 1. The location of Potter Cove at the South Shetland Islands (A) and the sampling area (square) in the cove (B).

according to the mixed method of Hureau (1970), following the recommendation of the BIOMASS Program (Anon. 1981). Diet data are expressed in terms of the dietary coefficient (Q), which is the product of the percentage by number and the percentage by weight of each prey type. All algae species were grouped as a single item. For selectivity estimations the Ivlev (1961) index was used:

$$I = \frac{Ei - Bi}{Ei + Bi}$$

where Ei is the percentage by number of taxon i in the stomach contents, and Bi is the percentage by number of taxon i in the benthos. Positive values indicate that the fish select the relevant prey.

Results

The size, weight and age range of the *N. neglecta* (N = 152) caught were 15.5–49.5 cm, 60–1598 g, and 3–12 years respectively. The sex ratio between males and females was 1:1.09.

Benthos

Observations of the bottom revealed basaltic cobbles with *Ascoseira* sp. (Ascoseirales) and *Iridaea* sp. (Gigartinales), generally down to 2 m deep; followed by a gravel zone of 2–15 m depth dominated by *Adenocystis utricularis* (Dictyosiphonales), *Plocamium coccineum* (Gigartinales), *Iridaea* sp and *Desmarestic* sp. (Desmarestiales) and at 15–30 m depth by *Plocamium coccineum* and *Desmarestia* sp. The slope was steeper below 30 m, with the bottom covered by fine grained sediments with corals and asciids.

Table I shows the biomass of the macrobenthos. Mean values of biomass and density were 465.21 gm^{-2} and 481.97 individuals m^{-2}, respectively.

The limpet *Nacella concinna* dominated the benthos in the upper 10 m (88% total animal biomass). *N. concinna* biomass diminished with depth while the bivalve *Laternula elliptica* became more abundant down to 30 m depth, where corals, asciids and echinoids occurred. Gammarids, other gastropods, polychaetes, asteroids, chitons and serolids were found all along the transects with no clear depth-related trend. In general the sampled area was homogeneous with limited species zonation (Table I).

Stomach contents

Of the 142 stomachs examined, nine were empty. Main prey (Q>200) were the euphausiid *Euphausia superba* (f%=16) and the gammarid *Paradexamine* sp; algae were a secondary food item (200>Q.20) (Table II). The sum of the Q values of these items represented 96% of the diet. The most frequent preys were algae (f%=80), gammarids (f%=48) and gastropods (f%=44).

To facilitate presentation of the relationship between predator size and food type, *N. neglecta* specimens were grouped arbitrarily into three length categories: small (<28cm); medium (28–38 cm); large (>38 cm). Krill was a main food item in all categories (Table III). Algae constituted the main

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Table I. Mean biomass (gm^{-2}) of benthos in the sampling area, stratified by depth.

	Depth Range (m)							
Item	40-35	35-30	30-25	25-20	20-15	15-10	10-05	5-00
Algae	88.04	43.75	167.20	28.15	62.22	127.63	134.85	98.86
Polychaetes	6.66		0.04		0.70	0.53	2.86	0.29
Errant	2.01		0.04		0.70	0.53	2.82	0.29
Sedentary	4.65						0.05	
Gammarids	1.19	1.90	9.66	4.23	14.49	23.16	9.27	2.93
Paradexamine sp.	0.05	0.03	3.17	0.59	0.08	7.53	3.38	0.06
Eurymera monticulosa	1.02		1.24	1.10	0.62	9.31	0.94	1.38
Pontogeneiella sp.					1.68			
Pontogenela antarctica			3.06		8.24	0.96	0.35	0.47
Jassa sp.		0.97					0.53	
Bovallia gigantea						1.62	3.30	0.24
Unidentified sp.	0.27	0.68	1.43	1.04	2.04	3.39	0.67	0.08
Family Ischyoceridae							0.02	
Bivalves	153.22		215.12	428.82	461.63	306.30		
Dacrydyum sp.	0.07		0.71		2.17			
Laternula elliptica	153.15		214.41	428.82	495.45	306.30		
Gastropods	8.35	72.65	17.28	20.45	9.41	92.74	191.35	276.78
Margarella antarctica	4.65	7.30	3.13	1.75		2.40	1.02	0.42
Eatoniella sp.	0.01		0.21		0.67			0.01
Chlamydota signyana	3.69	65.35			5.05	6.54	0.55	0.60
Antimargarita dulcis			1.32		3.62	3.30		
Nacella concinna			12.62	18.70	0.07	80.50	189.77	275.76
Chiton								
Hemiarthrum setunosum	0.33		0.18	0.16	0.08		0.08	0.02
Isopods	0.33	18.10	1.30	0.29	1.13	0.24	0.06	0.10
Serolis sp.	0.33	18.10	1.30	0.29	1.00	0.02	0.05	0.09
Unidentified sp.					0.02	0.21	0.01	0.02
Glyptonotus antarcticus					0.11			
Corals	13.49	9.13						
Ophiuroids								
Ophionotus victoriae	64.28	0.46	7.99	63.17			0.05	
Echinoids								
Sterechinus neumayeri	36.85	95.11					10.55	
Asteroids	78.35	7.93	6.03	1.17	11.33	5.95	14.37	3.26
Asciids	47.54							
Total	498.62	249.02	424.50	546.75	561.32	556.62	363.44	382.50

Mean Biomass: 465.21 gm^{-2}
Mean Density: 481.97 ind.m^{-2}

food in small fish only, being consumed less with increasing fish size. The gammarid amphipod *Paradexamine* sp. was the main prey of medium-sized fish and of secondary importance in the remaining sizes. A wider trophic spectrum occurred in specimens of intermediate length. However, this could be due to fewer fish in the small and large sample categories.

Selectivity

Table IV shows diet selectivity indices for the benthic species taken by *N. neglecta*. All these organisms were present and in the same size ranges in the benthos samples. Fish and pelagic groups such as krill, salps and hyperiid amphipods were not considered because mid-water environmental samples were not taken.

The Ivlev index indicated seven food items as being selected by the fish: sedentary polychaetes, the isopod *Glyptonotus antarcticus*, the gammarid amphipod *Paradexamine* sp., the bivalve *Dacrydyum* sp., the gastropods *Margarella antarctica* and *Eatoniella* sp. and algae. There was little variation in the feeding selectivity of *N. neglecta* with size except for *Dacrydyum* sp., which were selected only by larger fish.

Discussion

The increase of biomass and diversity with depth in the benthos of coastal Antarctic localities is well known (Moreno & Zamorano 1980, Zamorano 1983). In Potter Cover, however, the biomass and density of much of the benthos was consistently low and varied little with depth. This might

Table II. Diet of *Notothenia neglecta* showing the frequency of occurrence (F%), total weight (W) in g, number (N) and dietary coefficient "Q" of each food item.

Food Item	F%	W	N	W%	N%	"Q"
Algae	80.3	296.55	106	28.3	4.7	131.6
Polychaetes	15.9	14.16	29	1.3	1.3	1.7
Errant	13.6	12.67	24	1.2	1.1	1.3
Sedentary	2.3	1.48	5	0.1	0.2	0.0
Gammarids	47.7	89.81	1082	8.6	47.5	406.7
Paradexamine sp.	42.4	75.44	1017	7.2	44.6	321.1
Eurymera monticulosa	3.0	10.90	20	1.0	0.9	0.9
Pontogeneiella sp.	1.5	0.37	2	0.0	0.1	0.0
Pontegenia antarctica	27.3	3.09	43	0.3	1.9	0.6
Hyperiids	5.3	0.82	27	0.1	1.2	0.1
Euphausiids						
Euphausia superba	15.9	328.40	745	31.3	32.7	1023.9
Isopods	4.6	11.06	19	1.0	0.9	0.9
Serolis sp.	2.3	2.49	15	0.2	0.7	0.2
Glyptonotus antarcticus	2.3	8.57	4	0.8	0.2	0.1
Gastropods	44.6	48.42	189	4.6	8.3	38.4
Margarella antarctica	28.8	4.37	120	0.4	5.3	2.2
Eatoniella sp.	9.9	0.32	44	0.0	1.9	0.1
Nacella concinna	9.9	43.73	25	4.2	1.1	4.6
Bivalves	2.3	59.23	50	5.7	2.2	12.4
Dacrydyum sp.	1.5	1.43	45	0.2	2.0	0.3
Laternula elliptica	0.8	57.80	5	5.5	0.2	1.2
Chiton						
Hemiarthrum setunosum	0.8	0.02	1	0.0	0.0	0.0
Squids	0.8	7.36	1	0.7	0.0	0.0
Ophiuroids						
Ophionotus victoriae	0.8	0.64	1	0.1	0.0	0.0
Salps						
Salpa thomsoni	3.8	8.95	10	0.9	0.4	0.4
Fish	12.9	183.56	18	17.5	0.8	13.8
Sediments	24.2					
Total		1048.98	2278			1629.8

Main food: Q>200 Secondary food:200>Q>20 Accidental food:Q<20

be due to anchor ice, that strongly affects the sampling area and the larger adjacent zone, Maxwell Bay, as well as other Antarctic benthic communities (see also Dayton *et al.* 1969, Bellisio *et al.* 1972, Castellanos 1973, Zamorano 1983, Castilla & Rozbaczylo 1985, Kirkwood & Burton 1988).

During SCUBA diving *N. neglecta* was often observed laying amongst the algae or in shelters (see also Moreno & Zamorano 1980, Daniels 1982, Daniels & Lipps 1982, Burchett *et al.* 1983). This behaviour corresponds with its muscle mass constitution, characteristic of sedentary fish (Johnston 1989). The limited mobility of *N. neglecta*, at least in late spring-summer, and the fact that all the prey species found in the stomachs were also present in the benthos samples allow us to assume that the fish specimens studied had eaten in the sampled area.

In our study *N. neglecta* preyed upon euphausiids (*E. superba*) and gammarid amphipods, which agrees with the finding of Casaux *et al.* (unpublished) who found that in Potter Cove *N. neglecta* fed mainly on gammarids in autumn, winter and early spring, whilst krill was the most important prey in late spring and summer.

Algae appeared to be only a secondary food when assessed by the dietary coefficient Q. However, other studies indicate that this item is underestimated by Hureau's (1970) method (Linkowski *et al.* 1983) and our data shows that algae was the most frequently occurring component of the diet (f%=80) and supports the hypothesis that the ingestion of algae is not accidentally associated with the consumption of gammarids (f%=48), but the algae is eaten actively by the fish (Daniels 1982).

The predation of *N. neglecta* upon *L. elliptica* (siphon) indicated here (Table II) as well as in other studies (Linkowski *et al.* 1983) was not reported by Zamorano *et al.* (1986) in South Bay, Palmer Archipelago.

The importance of krill (*E. superba*) in the diet of Antarctic fish is well known (Permitin 1970, Targett 1981, Kock 1985, Williams 1985, Nast *et al.* 1988). Although krill is mostly consumed by pelagic fish, when abundant it is often ingested by demersal fish. This may be explained in two ways:

Table III. Food composition for three size (total length) categories of *Notothenia neglecta.*

	Size Range					
	15.5-27.9 cm (N=40)		28.0-37.9 cm (N=84)		38.0-49.5 cm (N=18)	
Food Item	F%	"Q"	F%	"Q"	F%	"Q"
Algae	74.3	317.9	81.3	117.5	83.3	114.3
Polychaetes	28.6	51.3	12.5	0.8	5.6	0.2
Errant	28.6	51.3	7.5	0.4	5.6	0.2
Sedentary			5.0	0.1		
Gammarids	28.6	31.2	51.3	680.3	33.3	22.0
Paradexamine sp.			47.5	621.6	16.7	0.2
Eurymera monticulosa	5.7	2.9	1.3	0.1	5.6	10.1
Pontogeneiella sp.			2.5	0.0		
Pontogeneia antarctica	22.9	10.4	12.5	0.4	11.1	0.2
Hyperiids	11.4	10.4	3.8	0.0		
Euphausiids						
Euphausia superba	8.6	1145.5	16.3	494.2	27.8	4041.1
Isopods			6.3	1.8		
Serolis sp.			3.8	0.3		
Glyptonotus antarcticus			3.8	0.3		
Gastropods	45.7	167.8	43.0	30.8	33.3	4.2
Margarella antarctica	37.1	109.5	27.5	0.6	16.7	0.1
Eatoniella sp.	8.6	1.7	12.5	0.0	5.6	0.0
Nacella concinna	2.9	0.2	8.8	6.0	22.2	1.6
Bivalves			2.5	6.3	5.6	4.9
Dacrydyum sp.			1.2	0.0	5.6	4.9
Laternula elliptica			1.3	2.4		
Chiton						
Hemiarthrum setunosum			1.3	0.0		
Squids			1.3	0.0		
Ophiuroids						
Ophionotus victoriae			1.3	0.0		
Salps						
Salpa thompsoni			6.3	0.8		
Fish	2.9	4.7	16.3	16.0	16.7	12.2

1) in shelf waters krill descends to the bottom occasionally, being eaten by opportunistic feeders (Everson 1977a, 1981, Targett 1981, Kock 1985),
2) demersal fish migrate to the mid-water zone to feed on pelagic forms (Everson 1977a, Freytag 1980, Daniels 1982, Duhamel & Hureau 1985, Kock 1985).

Krill constituted the main food of the benthic *N. neglecta*, confirming the seasonal variation in fish diet to be reported by Casaux *et al.* (unpublished), and agree with the results of Permitin & Tarverdiyeva (1978) and Tarverdiyeva & Pinskaya (1980). In summer, Linkowski *et al.* (1983) also found pelagic prey (salps) as main food (Q=268.5) of *N. neglecta* collected around the South Shetland Islands. Information on winter-spring feeding by this fish (Arnaud & Hureau 1966, Hureau 1970, Everson 1970, Daniels 1982) indicates extensive predation on benthos. This suggests that in some localities, benthic fish like *N. neglecta* take advantage of the summer abundance of certain pelagic organisms (mainly krill), preying on them intensively. This could be related to the high energy content of krill compared to benthos. Feeding selectivity of krill by *N. neglecta* could not be evaluated since mid water samples were not taken.

Ivlev's index (1961) discriminates between abundance and preference, and can give an insight as to why particular organisms are eaten. Paloheimo (1979) discussed the density-dependent biases of the index and recommended that only those species present both in the benthos and in stomach contents were included. It may be argued that prey sizes should also be taken into account in a similar manner. We did not investigate this particular problem since the size range of organisms was the same in the benthos and in the stomach contents.

The food items positively selected by *N. neglecta* included sessile organisms (algae), those with little mobility (*G. antarcticus, M. antarctica and Eatoniella* sp.), mobile species (*Paradexamine* sp.) and some infauna (sedentary polychaete and *Dacrydyum* sp.). From the eight species of gammarid amphipod present, four were ingested by the fish, with *Paradexamine* sp. being the only one selected. *Bovallia gigantea* was consumed by *N. neglecta* in South Bay, (Moreno & Zamorano 1980) but not in Potter Cove. It is possible that the consumption of this amphipod was related to its local biomass and density. Despite being abundant in the sampling area the limpet *N. concinna* was negatively

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Table IV. Mean percent of the number of organisms in the stomachs of *Notothenia neglecta* and in the benthos at 0–40m depth, together with the Ivlev index inidcating prey selectivity during the late spring-summer at Potter Cove, King George Island.

Food Item	Stomach %	Benthos %	Ivlev
Algae	7.2	5.7	+ 0.12
Polychaetes	1.9	2.2	- 0.05
Errant	1.6	2.1	- 0.12
Sedentary	0.3	0.1	+ 0.62
Gammarids	73.3	43.0	+ 0.26
Paradexamine sp.	68.9	25.5	+ 0.46
Eurymera monticulosa	1.4	8.3	- 0.72
Pontogeneiella sp.	0.1	0.3	- 0.39
Pontogeneia antarctica	2.9	8.9	- 0.51
Isopods	1.3	6.6	- 0.67
Serolis sp.	1.0	6.5	- 0.73
Glyptonotus antarcticus	0.3	0.1	+ 0.54
Gastropods	12.8	37.6	- 0.49
Margarella antarctica	8.1	4.5	+ 0.29
Eatoniella sp.	3.0	1.8	+ 0.24
Nacella concinna	1.7	31.3	- 0.90
Bivalves	3.4	2.9	+ 0.08
Dacrydyum sp.	3.1	1.4	+ 0.38
Laternula elliptica	0.3	1.5	- 0.63
Chiton			
Hemiarthrum setunosum	0.1	1.4	- 0.91
Ophiuroids			
Ophionotus victoriae	0.1	0.8	- 0.84

selected while other less abundant gastropods were positively selected (see also Moreno & Zamorano 1980). A possible explanation is that *N. concinna* adheres very strongly to rocks and is therefore difficult to remove, while *Eatoniella* sp. and *M. antarctica* are attached only to algae. Echinoids, asteroids, asciids and some gammarids (Jassa sp., *Bovallia gigantea* and family *Ischyoceridae*) were other benthic organisms present in the transect samples, but absent in the stomach contents.

It is difficult to determine why a particular prey type is selected. We suggest that several of the important factors are: prey size, mobility, type of fixing to substratum, activity, digestibility and camouflage. These factors should be studied using specifically designed sampling and experimental work.

The present study has shown that *N. neglecta* is omnivorous with a wide trophic spectrum of food composed of both benthic and pelagic organisms. It is basically an ambush feeder that feeds occasionally in the water column (Showers *et al.* 1977, Moreno & Zamorano 1980, Daniels 1982), and, because it feeds selectively, *N. neglecta* has a role in the regulation of biomass and diversity in the Antarctic coastal benthic community.

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