THE DIETARY COMPOSITION OF SOME ANTARCTIC FISH

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ABSTRACT. Analyses were carried out on the stomach contents of 225 fish of seven Antarctic species. All specimens were caught in shallow water of less than 20 m. depth at Signy Island, South Orkney Islands. *Notothenia gibberifrons*, *Notothenia coriiceps neglecta*, *Trematomus newnesi* and *Harpagifer bispinis* are compared for food types. Brief comments on *Notothenia larseni*, *Notothenia nudifrons* and *Notothenia rossii* are included. Amphipods were the most prominent component of the fish diets and have been identified to the species level.

AMPHIPODA are one of the most conspicuous crustacean elements of the Antarctic shallow-water benthos. Their biomass is high, not only within soft sand and mud substrates (Hardy, 1972) but also in the heavily weeded areas that occur on mixed substrates from the immediate sub-littoral down to depths of 30 m. (Richardson, 1972). The amphipod families, Calliopiidae and Eusiridae, were the principal groups represented in the macro-algae beds; this differed from the near-shore infaunal habitats colonized predominantly by Lysianassidae. Benthic weed beds, dominated by *Phyllogigas* and *Desmarestia*, provided shelter for some species of fish.

The present study was carried out from April 1971 to March 1973 as part of a research programme to study the ecology of Antarctic weed-dwelling amphipods. Previous Antarctic literature (Holloway, 1969; Andriashev, 1970; Hureau, 1970) described in varying detail the role of fish as major predators of the Amphipoda. Initial investigations of fish stomach contents, at Signy Island, emphasized this trophic relationship. Further analyses were made to determine which fish species were exerting the greatest feeding pressure against weed-dwelling amphipods. The results of this investigation are presented as a qualitative list of the diets of inshore fish. Since amphipods often exhibit strict habitat preferences, their occurrence and the species composition in stomach contents emphasizes both the presence of different feeding niches between various fish species and the localities of active fish feeding.

MATERIAL AND METHODS

All specimens were obtained on the east coast of Signy Island, largely from Borge Bay. The methods of capture were:

i. Agassiz trawl (1 m.).
ii. A large diver-operated cylindrical collecting net (Richardson, 1971).
iii. Collecting by hand whilst diving.
iv. A plankton trawl net (0·33 m. diameter).
v. Hook and line.

Individual species of fish tended to be captured by specific techniques. *Trematomus newnesi* was taken by trawl nets but could not be easily obtained by divers, whilst the slower benthic dwelling *Notothenia gibberifrons* and *Harpagifer bispinis* were easily captured under water using small hand nets.

Specimens taken in trawl nets were isolated from the main catch as soon as possible to prevent any further predation on the other trawl inhabitants. Specimens were killed immediately on return to the laboratory and fixed in 10 per cent neutralized formal saline after first exposing the body cavity. Gut examinations and analyses were conducted soon after death, ensuring that the crustacean component of the stomach contents was readily identifiable. Table I summarizes the times and places of capture of all fish examined.

Copepods present in the stomachs could be divided into two discrete size classes: (a) small, $<2 \cdot 0$ mm. or (b) larger than 2·5 mm. The smaller species are commonly found amongst *Desmarestia anceps* fronds, and the larger being only recovered from pelagic trawling. One hundred specimens of the most commonly recorded small species in *T. newnesi* stomachs were measured using an ocular graticule and these had a size range of 0·60–1·59 mm. ($\bar{x} = 1 \cdot 21$ mm., S.D. $\pm 0 \cdot 62$).

TABLE I. THE TOTAL NUMBER OF FISH EXAMINED FOR STOMACH CONTENTS

Date	*Fish species* (*n*)	*Bottom type and plant association*	*Capture method*	*Depth* (m.)
4 May 1971	*H. bispinis* (14) *T. newnesi* (12)	Gravel, Rhodophyceae	i	7
8 Apr. 1972	*T. newnesi* (1) *N. gibberifrons*	Gravel/boulder, *D. anceps*	ii	20
27 Apr. 1972	*T. newnesi* (4) *N. larseni* (1) *N. nudifrons*	Gravel with few boulders, *P. grandifolias and* mixed Rhodophyceae	i	7
16 Aug. 1972	*N. c. neglecta* (14)	Boulder/rock, *D. anceps*	v	15
10 Nov. 1972	*H. bispinis* (1)	Gravel/boulder, *D. anceps*	iii	3
20 Nov. 1972	*H. bispinis* (2) *N. gibberifrons* (1)	Gravel/boulder	iii	20
23 Nov. 1972	*T. newnesi* (1)	Gravel/boulder	ii	20
14 Dec. 1972	*T. newnesi* (66) *N. larseni* (2) *N. rossii* (1) *N. gibberifrons* (11)	Gravel, Rhodophyceae	i	12–20
22 Dec. 1972	*H. bispinis* (9) *T. newnesi* (9) *N. gibberifrons* (2)	Gravel, Rhodophyceae	i	14–20
2 Jan. 1973	*H. bispinis* (10) *T. newnesi* (18) *N. gibberifrons* (6)	Gravel/boulder, *D. anceps* and mixed Rhodophyceae	i	12–20
16 Jan. 1973	*H. bispinis* (6) *T. newnesi* (1) *T. larseni* (1) *N. gibberifrons* (4)	Pebbles/silt	i	14–20
18 Jan. 1973	*N. c. neglecta* (7)	Boulder /rock, *D. anceps* and mixed Rhodophyceae	v	1–3
20 Jan. 1973	*N. c. neglecta* (13)	Boulder, *D. anceps* and mixed Rhodophyceae	v	2–3
8 Mar. 1973	*T. newnesi* (4)	Pelagic	iv	5

RESULTS

The stomach contents of 225 fish of seven species have been examined to assess diet composition (Fig. 1). The amphipod fraction of these prey types has been identified to species level where possible and analyses of their occurrence in stomachs of the four fish species most commonly captured are shown in Table II.

Species examined

Harpagifer bispinis (42 specimens). Most individuals of this species were obtained from a gravel bottom with associated Rhodophyceae. Standard length ranged from 3·0 to 7·9 cm. ($\bar{x}$ = 4·8 cm., S.D. ±1·1). The number of major food types encountered in the diet is the lowest of the four species analysed with Amphipoda occurring in 95 per cent of specimens.

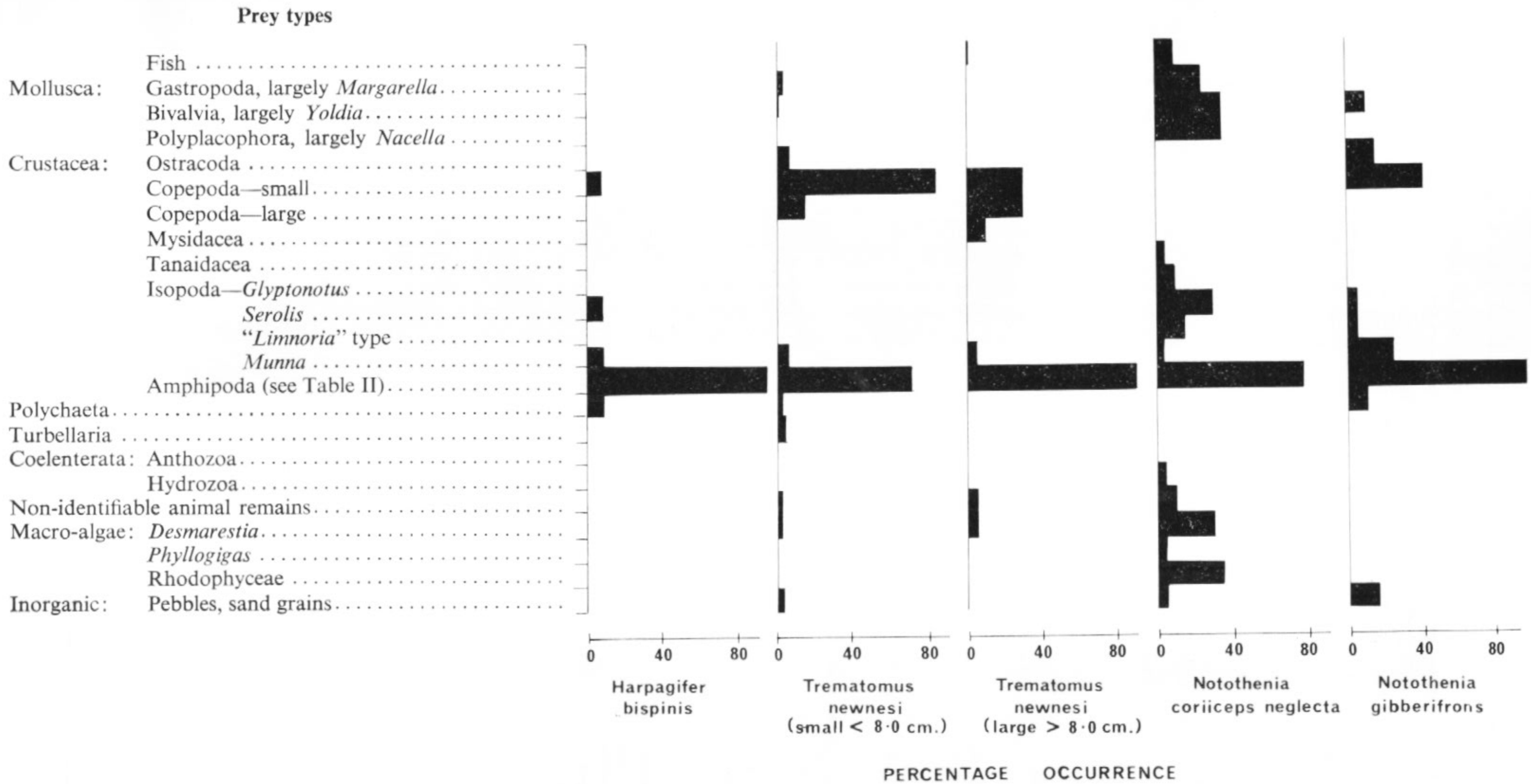

Fig. 1. The percentage occurrence of food types in four species of Antarctic fish.

TABLE II. THE PERCENTAGE OCCURRENCE OF AMPHIPOD SPECIES IN THE STOMACH CONTENTS OF FOUR ANTARCTIC FISH SPECIES

(Figures in square brackets represent a percentage frequency > 19.)

Amphipoda	*Harpagifer bispinis*	*Trematomus newnesi* Small (<8·0 cm.)	*Trematomus newnesi* Large (>8·0 cm.)	*Notothenia coriiceps neglecta*	*Notothenia gibberifrons*
Lysianassidae					
Cheirimedon femoratus (Pfeffer)	4	5	–	[60]	–
Lepidepecreum cingulatum Barnard	–	–	–	[20]	–
Tryphosella kergueleni (Miers)	–	–	–	[50]	–
Phoxocephalidae					
Parharpinia rotundifrons Barnard	8	2	–	[20]	–
Amphilochidae					
Gitanopsis squamosa (Thomson)	–	2	5	–	–
Thaumatelsonidae					
Thaumatelson walkeri Chilton	–	1	–	–	–
Stenothoidae					
Probolisca ovata (Stebbing)	4	6	5	–	[35]
Acanthonotozomatidae					
Pariphimedia integricaudata Chevreux	–	4	–	5	–
Oedicerotidae					
Methalimedon nordenskjoldi Schellenberg	–	–	–	–	–
Oediceroides lahilli Chevreux	–	–	–	–	5
Calliopiidae					
Oradarea bidentata Barnard	–	[25]	[45]	5	15
Oradarea ocellata Thurston	–	3	–	–	10
Oradarea unidentata Thurston	16	1	–	–	–
Metaleptamphopus pectinatus Chevreux	–	2	–	–	–
Eusiridae					
Atyloella magellanica (Stebbing)	4	2	–	–	5
Djerboa furcipes Chevreux	–	3	[20]	–	–
Schraderia gracilis Pfeffer	1	–	5	–	5
Schraderia spp.	–	–	5	–	5
Pontogeneia antarctica Chevreux	8	6	15	[20]	5
Prostebbingia gracilis (Chevreux)	8	[21]	[40]	–	[45]
Eurymera monticulosa Pfeffer	–	–	–	5	–
Pontogeniella brevicornis (Chevreux)	[73]	17	5	[55]	[40]
Bovallia gigantea (Chevreux)	12	3	15	[35]	–
Paramoera spp.?	4	17	15	–	10
Gammaridae					
Paraceradocus miersi (Pfeffer)	–	–	–	5	5
Dexaminidae					
Paradexamine fissicauda Chevreux	4	8	15	10	–
Gammaridean spp. not identified	[38]	[26]	15	–	[25]
Hyperidean spp. not identified	–	2	–	–	–
Number of species in diet	13	20	13	12	13

The only other groups recorded were small copepods, isopods of the genera *Serolis* and *Munna*, and unidentified polychaetes. Twelve amphipod species were recorded from stomach contents of which *Pontogeniella brevicornis* was the predominant species predated. Thurston (1972) mentioned this amphipod as being associated with sandy substrates where algae and boulders are also present. The copepod element of the diet in this species by comparison appears small as only one fish contained a small number of this group.

Trematomus newnesi (116 specimens). Individuals of this fish were obtained in various months of the year and Table I outlines the dates of capture. All fish were caught in trawl nets; the four smallest specimens (1·6–1·7 cm.) were taken with a plankton net on 8 March 1973, whilst the largest individual (15·2 cm.) was caught on 14 December 1972 in a benthic trawl collection. The length-frequency distribution for *T. newnesi* was poly-modal. The majority (66) was collected during December 1972 and had a tri-modal length-frequency distribution with size categories estimated using normal probability paper (I) range, 5·0–6·4 cm., $\bar{x}$ = 5·63 cm., S.D. ±0·29; (II) range, 8·6–9·8 cm., $\bar{x}$ = 9·26 cm., S.D. ±0·38; and (III) 15·2 cm. These three size groups within the sample may be year classes.

To differentiate the diet of differing sized *T. newnesi*, Table I and Fig. 1 were drawn up after dividing the fish into two size categories: (a) smaller than 8·0 cm. standard length, (b) 8·0 cm. and greater.

A visual estimate of the percentage fullness was made on 65 fishes' stomachs. Fish showed variable amounts of prey in the stomach with 17 per cent of the small and 25 per cent of the large fish having a more than 90 per cent full stomach, whilst 21 per cent of the small and 25 per cent of the large fish had a 10 per cent or less full stomach.

One medium-sized fish (8·6 cm.) contained the following:

Amphipoda	*Djerboa furcipes* 1
	Oradarea bidentata 2
	Prostebbingia gracilis 23
	Pontogeneia antarctica 1
Copepoda	2 large, 3 small
Macro-algae	*D. anceps* (2 fragments).

A similarly full small specimen (3·4 cm.) had a selection of the following prey types:

Amphipoda	*Probolisca ovata* 2
	Pariphimedia integricauda 1
	Paramoera spp. ? 3
Polychaeta	One specimen (2·6 mm. length)
Ostracoda	One specimen (2·2 mm. length)
Copepoda	20 small.

There are demonstrable differences between the diets of small and large fish; of the major food types shown in Fig. 1, small specimens were found to contain 12 categories, and large only eight (six categories were common to both fish size groups). Similarly, the diversity of Amphipoda species as prey diminishes with increasing size, individuals of large fish feeding on 13 species as opposed to 21 in small, with 11 species being common to both. The primary food of both size classes is Amphipoda of the Calliopiidae and Eusiridae families, most of whose inshore members at Signy Island inhabit the macro-algae beds of *D. anceps*, *Phyllogigas grandifolias* and mixed Rhodophyceae (Price and Redfearn, 1968). A greater percentage of large fish feed on *O. bidentata*, *D. furcipes* and, whilst the percentage occurrence of the large amphipod *Bovallia gigantea* appeared roughly the same in both length categories, the individual length size of this species in small fish stomachs was always less than 1·2 cm. The proportion of small fish stomachs containing the smaller copepods (84 per cent) was far higher than for any other group. The larger pelagic copepods are not taken so readily and were found in only 13 per cent of the stomachs. However, the percentage occurrence of both small and large copepods in the large *T. newnesi* stomachs was 30 per cent. Mysidacea were only found in larger *T. newnesi*, whilst small fish occasionally contained small turbellarians. The majority of food types taken are motile organisms, whilst benthic detritus and sessile organisms have little importance in the diet.

Notothenia coriiceps neglecta (34 specimens). All individuals were caught by hook and line over a boulder bottom where *D. anceps* was present. Though the standard lengths of most individuals were not recorded, they lay within the 30–45 cm. range. The percentage fullness of nearly all guts was very high, being over 70 per cent. The diversity of food types consumed (Fig. 1) was higher than any other species with appreciable numbers of fish with algae in their stomachs (Rhodophyceae 35 per cent, *Desmarestia* 30 per cent). Whether they browse plant material deliberately or inadvertently consume portions of plant whilst feeding on animals amongst the algae beds is not clear. Anthozoa and hydroids were certainly actively fed on. *N. c. neglecta* is large enough to devour some of the bigger individuals of the isopods *Glyptonotus antarcticus* and *Serolis polita* and these feature in stomach contents. In contrast to the other species, no Copepoda were found in the gut contents. Again differing from other fish, the percentage occurrence of molluscs was high with the limpet *Nacella concinna* found in 35 per cent, the bivalve *Yoldia eightsii* occurring in 35 per cent and gastropods, mainly *Margarella antarctica*, in 25 per cent of the stomachs. Some remains of unidentified fish were apparent in a small number of stomachs. Amphipods were again the predominant food type with 12 species being found. *N. c. neglecta* was obviously capable of handling larger food types than other species and this becomes apparent in its choice of amphipods; none of the species preyed on was in the small category. *B. gigantea* features commonly, as does *P. antarctica* and *Parharpinia rotundifrons*. The great bulk of the food is made up by the lysianassid burrowing species of amphipod *Cheirimedon femoratus*, *Tryphosella kergueleni* and *Lepidepecreum cingulatum* with *P. brevicornis* also being readily taken.

Notothenia gibberifrons (27 specimens). All fish of this species proved to be small, the largest specimen measuring 7·3 cm. ($\bar{x}$ = 5·1 cm., S.D. ±0·88). The ventral position of the mouth of *N. gibberifrons* suggests that it is a bottom-feeding species and the presence of infaunal representatives of bivalves, ostracods, polychaetes and also pebbles and sand grains reinforces this hypothesis. The fish also takes small numbers of benthic isopods, mainly of the genus *Munna*. However, copepods do not represent a major component of the diet.

The most commonly occurring amphipod constituent of the stomach contents was the species *P. brevicornis*, *P. gracilis* and *P. ovata*.

Notothenia larseni (four specimens). The mean length was 5·6 cm. (range 5·0–6·4 cm.). Amphipod species represented in the stomach contents were: *P. ovata*, *Gitanopsis squamosa*, *O. bidentata*, *P. gracilis*, *P. brevicornis* and *Paramoera* spp. (?). Small copepods were also present in three individuals.

Notothenia nudifrons (one specimen). This single small specimen contained *P. antarctica*, *P. gracilis* and over 100 small copepods.

Notothenia rossii (one specimen). The gut contents consisted solely of unidentified amphipod fragments.

Discussion

Large numbers of Antarctic fish do not possess swim bladders and Andriashev (1965) noted that 81 per cent of coastal continental-water fish belong to the family Nototheniidae. The indications are that fish-feeding in Antarctic coastal waters is primarily of a benthic nature though workers studying the diets of fish around South Georgia have stressed the dependence of many species on pelagic feeding areas. A comprehensive survey of the food of ten fish species occurring at South Georgia has been conducted by the Russians, Permitin and Tarverdieva (1972). Many workers have stressed the importance of amphipod Crustacea in the diet of polar fish species (Holloway, 1969; Andriashev, 1970; Bellan-Santini, 1972; Rakusa-Suszczewski, 1972). The diet of the genus *Trematomus* has been investigated by a number of authors; Andriashev (1968, 1970) mentioned that the cryopelagic fish, *Trematomus borchgrevinki* and *T. newnesi*, feed on krill and other crustaceans, whilst the cryophilic adaptation of these species enables young fish to avoid predation by hiding amongst the hollows and cavities within sea ice. The amphipod *Paramoera walkeri* has been observed (Rakusa-Suszczewski, 1972) being preyed on by these two fish species at Alasheyev Bight during the Antarctic winter. At McMurdo Sound, Wohlschlag (1964) observed that *Trematomus bernachii*, *Trematomus hansoni* and *Trematomus centronotus* along with the amphipod *Orchomenella* spp., were attracted to traps in deeper water. The former two were studied by Bellan-Santini (1972), who recorded five amphipod species from *T. hansoni* and nine from *T. bernachii*. *Oradarea walkeri* and *C. femoratus* were the commonest prey in *T. hansoni* and *O. walkeri* and *Orchomene nodimanus* in *T. bernachii*. By comparison, *T. newnesi*, at the South Orkney Islands, preyed on a total of 22 amphipod species. From the preliminary study done by Rakusa-Suszczewski and Piasek (1973) with *T. newnesi* and *T. bernachii* on the protein levels in their pyloric processes and the types of food taken (though identification was limited to very broad food types), it appeared that this genus avoided inter-specific competition by utilizing different diets. *T. newnesi* has higher pyloric protein levels and feeds on such food sources as copepods, amphipods (*P. walkeri*), hyperid amphipods and Euphausiidae during winter, whilst *Euphausia superba* occupies the total diet of summer-feeding *T. newnesi*. *T. bernachii* by comparison is a benthic feeder taking a winter diet of polychaetes, amphipods, gastropods, isopods and ostracods, including fish eggs, algae and on occasions euphausiids during the summer. Observations at Signy Island parallel those of Andriashev (1968, 1970) by indicating the importance of the epontic diatom—amphipod—fish food chain. Aqualung divers have noted that during the open-water season *Trematomus* shoal within 1·5 m. of benthic algae beds, seeking shelter rapidly when disturbed. In winter, the amphipod *P. antarctica* is found in great numbers in association with the sub-surface of the fast ice. *L. cingulatum* and *C. femoratus* are present sporadically and to a far lesser extent. *Trematomus* was observed at numerous times during winter higher up in the water body, congregating either just below the sea-ice surface or alongside the shore ice foot. On occasions fish appeared to be actively feeding at the ice surface and, though samples of cryopelagic fish have not been investigated, it is almost certain that the prey is *P. antarctica*.

The large number of copepods, some mysids and certain types of amphipod indicates that *T. newnesi* is semi-pelagic in its feeding during the whole year with the tendency to feed within the water body increasing with greater body size. Pelagic feeding by this species at Signy Island was not the principal method during the summer in contrast to the observations of Rakusa-Suszczewski and Piasek (1973) at Alasheyev Bight.

Little work appears to have been done on the diet of *Harpagifer bispinis* though this fish is a common component of the inshore benthos. A paper by Meier (1971) demonstrated a 100 per cent frequency of amphipods, and nothing else, in gut contents of the genus *Harpagifer* but no further division of food was attempted. Certainly, the present paper shows the diversity of food types in the diet of *Harpagifer* was small with the infaunal amphipod *P. brevicornis* constituting the major food source.

N. gibberifrons and *N. c. neglecta* are also exclusively benthic feeders though their size disparity and mode of feeding differentiates their possible preys. Bellan-Santini (1972), in looking at *N. c. neglecta*, noted 21 species of amphipod taken as food with *O. walkeri*, *Schraderia gracilis* and *C. femoratus* being most commonly eaten. Most of the fish specimens investigated by Bellan-Santini were captured by drag net, grab or trap and the latter may well influence the percentage occurrence of prey in subsequent gut analyses. *N. c. neglecta* is readily attracted to meat-baited traps (personal communication from E. L. Twelves) along with great numbers of various lysianassid amphipods. Bone (1972) mentioned *B. gigantea* being predated by *N. c. neglecta*, though the percentages of fish containing this large amphipod were far lower (12 per cent) than in samples collected by Everson, and subsequently analysed by Bone (1972) (57 per cent). Lack of *Laternula elliptica*, the large bivalve, in the guts is unusual, since its biomass is high (Hardy, 1972), and Everson (personal communication) has noted *N. c. neglecta* feeding on the fleshy siphons. The absence of *L. elliptica* remains in the fish investigated is attributed to the probable lack of this bivalve in the fish-sampling area. Indications from Signy Island are that the main foodstuff of *N. c. neglecta* is lysianassid amphipods. The feeding pattern of *N. c. neglecta* is most probably synchronized with the activity rhythm of burrowing amphipods. During the day *N. c. neglecta* seeks shelter within *Desmarestia* beds and feeding and increased activity occur during the evening and darkness when Bregazzi (1973) observed the peak of infaunal amphipod activity.

The main implication of the results for this small sample of *N. gibberifrons* is that the fish is a benthic feeder obtaining its prey within or in the near vicinity of algal beds. No movement away from the weed beds to feed is implied from the gut contents of *N. gibberifrons*. It must be noted that all *N. gibberifrons* dealt with in this paper were small individuals of a fish species that in deeper water achieves a far greater size, comparable to *N. c. neglecta*.

Although the sample sizes of the fish species investigated were small, obvious differences in diet and feeding-niche separation were apparent. *T. newnesi* carried out vertical movements within the water body in the search for food, whilst the indications are that *N. c. neglecta* seeks shelter and food in different benthic habitats. *H. bispinis* and *N. gibberifrons* (of the size range encountered) do not move appreciable distances away from the weed beds. Fish, feeding farther from the shore or in deeper water, may feed both on plankton and benthos but the Antarctic fish species examined in shallow coastal water at Signy Island rely heavily on benthic amphipods, their main food source, with pelagic feeding being greatly reduced.

ACKNOWLEDGEMENTS

Certain fish specimens were obtained by J. Hoogesteger, to whom I am very grateful. My thanks are also due to Dr. I. Everson and M. G. White for their constructive criticisms of the manuscript.

MS. received 21 November 1974

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