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# Food habits of nototheniid fishes (*Nototheniidae*) in Admiralty Bay (King George Island, South Shetland Islands)*)

ABSTRACT: Analysis of food contents of 784 stomachs was made in 5 species of fishes of the family *Nototheniidae: Notothenia coriiceps neglecta. Notothenia rossi marmorata, Notothenia nudifrons, Trematomus newnesi* and *Pleuragramma antarcticum*. In the food of the first two of the mentioned species benthic forms predominated and among them *Amphipoda* were a decidedly preferred component. The composition of the food of *N. nudifrons* indicates that they feed at the bottom of the sea, the most preferred component of their diet, however, were pelagic *Salpae*. *T. newnesi* and *P. antarcticum* are characterized by a typically pelagic kind of food. The comparison of food composition and the values of the stomach fullness indices in *N. coriiceps neglecta, N. rossi marmorata* and *T. newnesi* in the summer and winter seasons shows a markedly higher feeding intensity in the summer.

Key words: Antarctic, food, *Nototheniidae*

## 1. Introduction

In the Admiralty Bay (King George Island) the occurrence of over 40 species of fishes was recorded. The families *Nototheniidae* and *Channichthyidae* were represented by the greatest variety of species. The representatives of *Nototheniidae* predominated also in respect of their numerousness (Rembiszewski, unpublished materials).

Food composition of the species under examination was the subject of

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a series of publications in the past years. The dietary habits of *Notothenia coriiceps neglecta* Nybelin were investigated by Arnaud and Hureau (1966) in the regions of Terre Adélie; Hureau (1970) in the vicinity of Kerguelen Islands; Richardson (1975), Permitin and Tarverdieva (1978) in the regions of the South Orkney Islands; Showers, Daniels and Laine (1977) at Arthur Harbour (Anvers Island).

The food habits of *Notothenia rossi marmorata* Fischer were most thoroughly investigated in the regions of South Georgia (Olsen 1954; Permitin 1970; Latogurskij 1972; Tarverdieva 1972; Linkowski and Rembiszewski 1978). Permitin and Tarverdieva examined the food of *Notothenia nudifrons* Lönnberg in the regions of South Georgia (1972) and the South Orkney Islands (1978). Studies on the food habits of *Trematomus newnesi* Boulenger cover the regions of Alašejev Bight (Rakusa-Suszczewski and Piasek 1973) and the South Orkney Islands (Richardson 1975) and of *Pleuragramma antarcticum* Boulenger — the regions of Bransfield Strait (Rembiszewski, Krzeptowski and Linkowski 1978 and the South Orkney Islands (Permitin and Tarverdieva 1978).

This study constitutes one of the stages of a larger thematic cycle devoted to identification of fish species and determination of trophic dependence of fishes and cephalopods of the shelf and epi- and mesopelagic Antarctic waters with particular regard to Admiralty Bay. The results obtained from qualitative analysis of food composition make possible the determination of food preferences of the investigated fish species.

## 2. Material and methods

The analysed material was collected at Admiralty Bay (King George Island) in winter 1977 and the summer 1979/1980. The range of total length of investigated species, number of the analysed stomachs, date, fishing gear and approximate depth of catches, are given in Table I.

Gill nets were set out in the evening and caught fishes were collected next morning. Catches with pelagic trawl were carried out exclusively by night and the depth of catches was determined by triangulation on the basis of the length and the angle of the hauling wire. Beam trawl (beam length 1 m) was used in daytime. Fishes caught by means of traps — set without bait — were also used for food analyses. The fishing methods employed in winter season were described by Żukowski (1980).

Immediately after the capture fish specimens were measured (total body length) and their stomachs were preserved in 4% formalin. The analysis of stomach contents was made as follows: the content of a slit stomach was washed out with water into a fine mesh (0.25 mm) screen. The food components of the stomach contents were determined to general taxonomic groups and in some cases to species. The identified material was dried on

filter paper for about two minutes and weighed on torsion balance (wet weight) with an accurracy of 0.01 g (0.001 g in the case of the food of *P. antarcticum*). The methods of food analyses and the presentation of the results are after the Hureau (1970) method, recommended by SCAR (Anon. 1979). The results are presented in tabular form using the following indices:

$V$ — coefficient of emptiness $\left(V = \frac{N_e}{N_s} \cdot 100\%\right)$

$I$ — index of stomach fullness $\left(I = \frac{W_{sc}}{W_f} \cdot 100\%\right)$

$f$ — frequency of occurrence of each prey $\left(f = \frac{N_i}{N_s}\right)$

$C_{ii}$ — percent of diet by number of each prey $\left(C_{ii} = \frac{N_{ii}}{N_p} \cdot 100\%\right)$

$C_p$ — percent of diet by weight of each prey $\left(C_p = \frac{W_i}{W_{sc}} \cdot 100\%\right)$

$Q$ — dietary coefficient $(Q = C_{ii} \cdot C_p)$

where:

$N_e$ — number of empty stomachs in given species,
$N_s$ — total number of stomachs of that species examined,
$W_{sc}$ — wet weight of stomach contents of an individual,
$W_f$ — wet weight of that individual,
$N_i$ — number of individuals of a species containing prey $i$,
$N_{ii}$ — number of prey individuals taken from that species,
$W_i$ — total weight of prey taken from a species,
$W_{sc}$ — total weight of stomach contents in that species.

The dietary coefficient estimates the importance of the various groups found in the food of a fish:

$Q \geqslant 200$ — preferential preys,
$20 < Q < 200$ — secondary preys,
$1 < Q < 20$ — accidental preys.

In the calculations of the dietary coefficient ($Q$) stones and parasites found in the stomachs were not taken into account. This index does not show the importance of algae in the food of fishes. Due to the difficulties in an objective determination of the quantity of this component in the food the quantity of *Algae* = 1 was accepted for each stomach where they were present.

## 3. Results

The contents of 684 stomachs from 5 species of fishes of the family *Nototheniidae* were thoroughly examined. The characteristic of food composition in various species is as follows:

Table I

Samples of *Notothenia coriiceps neglecta*, *Notothenia rossi marmorata*, *Notothenia nudifrons*, *Trematomus newnesi* and *Pleurogramma antarcticum* used for the stomach contents analysis

| Species | season | Range of total length of examined fishes (cm) | Number of examined stomachs | Date | Approximated depth of catch (m) | Fishing gear |
|---|---|---|---|---|---|---|
| *Notothenia coriiceps neglecta* | winter | 27.5—30.5 | 2 | 17 Jul. 77 | 10—15 | hooks |
| | | 30.5 | 1 | 15 Jul. 77 | 10—15 | ,, |
| | | 29.0—34.0 | 3 | 16 Jul. 77 | 10—15 | ,, |
| | | 26.0—39.0 | 24 | 18 Jul. 77 | 10—15 | ,, |
| | | 24.5—37.0 | 6 | 13 Aug. 77 | 10—15 | ,, |
| | | 23.0—36.5 | 16 | 18 Aug. 77 | 10—15 | ,, |
| | | 23.0—32.5 | 8 | 29 Aug. 77 | 10—15 | ,, |
| | | 27.0 | 1 | 08 Sep. 77 | 10—15 | ,, |
| | | 22.5—35.0 | 15 | 09 Sep. 77 | 10—15 | ,, |
| | | 24.5—36.5 | 8 | 15 Sep. 77 | 10—15 | ,, |
| | | 19.0—45.0 | 16 | 23 Sep. 77 | 10—15 | ,, |
| | summer | 38.0—42.0 | 6 | 17 Dec. 79 | 30 | gill nets |
| | | 37.0—45.0 | 5 | 21 Dec. 79 | 50 | ,, |
| | | 32.5—44.5 | 15 | 22 Dec. 79 | 60 | ,, |
| | | 38.5—39.5 | 2 | 30 Dec. 79 | 100 | ,, |
| | | 31.0—38.5 | 8 | 04 Jan. 80 | 50 | ,, |
| | | 27.5 | 1 | 07 Jan. 80 | 5 | ,, |
| | | 22.0—38.5 | 19 | 08 Jan. 80 | 40 | ,, |
| | | 28.0—44.5 | 9 | 12 Jan. 80 | 40 | ,, |
| | | 30.5—44.5 | 35 | 20 Jan. 80 | 40—60 | ,, |
| | | 36.5—49.0 | 10 | 22 Jan. 80 | 40—60 | ,, |
| *Notothenia rossi marmorata* | winter | 19.0—28.5 | 4 | 13 Jul. 77 | 10—15 | hooks |
| | | 22.5—29.5 | 7 | 15 Jul. 77 | 10—15 | ,, |
| | | 21.0—33.5 | 22 | 16 Jul. 77 | 10—15 | ,, |
| | | 21.5—30.5 | 23 | 18 Jul. 77 | 10—15 | ,, |
| | | 19.0—31.0 | 20 | 13 Aug. 77 | 10—15 | ,, |
| | | 25.5—36.0 | 12 | 18 Aug. 77 | 10—15 | ,, |
| | | 18.5—34.0 | 29 | 29 Aug. 77 | 10—15 | ,, |
| | | 18.0—31.5 | 8 | 08 Sep. 77 | 10—15 | ,, |
| | | 19.0—32.5 | 15 | 09 Sep. 77 | 10—15 | ,, |
| | | 14.5—30.5 | 22 | 15 Sep. 77 | 10—15 | ,, |
| | | 21.0—34.5 | 16 | 23 Sep. 77 | 10—15 | ,, |
| | summer | 32.0—41.0 | 3 | 17 Dec. 79 | 30 | gill nets |
| | | 28.0—36.0 | 4 | 21 Dec. 79 | 50 | ,, |
| | | 23.0—34.5 | 15 | 22 Dec. 79 | 60 | ,, |
| | | 31.5—35.0 | 2 | 28 Dec. 79 | 60 | ,, |
| | | 28.5—37.5 | 4 | 04 Jan. 80 | 50 | ,, |
| | | 24.5—35.5 | 38 | 08 Jan. 80 | 40 | ,, |
| | | 26.5—31.5 | 14 | 12 Jan. 80 | 40 | ,, |
| | | 24.0—36.0 | 2 | 20 Jan. 80 | 40—60 | ,, |
| | | 31.0—33.0 | 3 | 22 Jan. 80 | 40—60 | ,, |

| 1 | | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| *Notothenia nudifrons* | summer | 9.5—20.0 | 10 | 07 Jan. 80 | 60—90 | traps |
| | | 7.0—15.0 | 2 | 12 Jan. 80 | 60—90 | ,, |
| | | 7.5—13.0 | 5 | 19 Jan. 80 | 90 | beam trawl |
| | | 4.5—13.0 | 5 | 23 Jan. 80 | 70—100 | ,, ,, |
| | | 6.5—13.0 | 22 | 14 Feb. 80 | 120 | ,, ,, |
| | | 8.0—16.0 | 7 | 20 Feb. 80 | 60 | ,, ,, |
| *Trematomus newnesi* | winter | 19.0 | 1 | 03 Aug. 77 | 10—15 | hooks |
| | | 16.5—20.0 | 8 | 13 Aug. 77 | 10—15 | ,, |
| | | 14.5—22.5 | 3 | 18 Aug. 77 | 10—15 | ,, |
| | summer | 14.0—18.0 | 20 | 23 Jan. 80 | 70—100 | beam trawl |
| | | 9.5—13.0 | 2 | 14 Feb. 80 | 70 | ,, ,, |
| | | 12.5 | 1 | 18 Feb. 80 | 150 | ,, ,, |
| | | 12.5—14.5 | 3 | 21 Feb. 80 | 150 | ,, ,, |
| | | 8.0—15.0 | 3 | 29 Feb. 80 | 30 | ,, ,, |
| | | 16.5 | 1 | 01 Mar. 80 | 130 | ,, ,, |
| *Pleuragramma antarcticum* | summer | 8.9—11.9*) | 6 | 11 Jan. 80 | 0—100 | pelagic trawl |
| | | 11.2 | 1 | 19 Jan. 80 | 0—50 | ,, |
| | | 12.3—12.7 | 2 | 20 Jan. 80 | 0—50 | ,, |
| | | 10.8—14.3 | 14 | 07 Feb. 80 | 0—150 | ,, |
| | | 10.8—14.2 | 10 | 18 Feb. 80 | 0—150 | ,, |
| | | 10.4—11.9 | 2 | 21 Feb. 80 | 0—150 | ,, |
| | | 10.7—12.6 | 26 | 24 Feb. 80 | 0—150 | ,, |
| | | 10.4—14.3 | 46 | 29 Feb. 80 | 0—150 | ,, |

*) *P. antarcticum* total length denotes Standard Length

*Notothenia coriiceps neglecta* (210 specimens collected in the winter and summer seasons).

In the region under investigations the presence of 9 age-groups (from 4 to 12 years) of *N. coriiceps neglecta* was found (Linkowski and Żukowski 1980). All the examined stomachs of this species contained food. The composition of the food of *N. coriiceps* (Tables II and III) indicates that this is a benthophagous species.

In the winter season *Amphipoda* ($Q = 3465.2$) were the preferential component of the food. Very often the examined stomachs were filled almost exclusively with these tiny crustaceans. Representatives of the families *Lysianassidae* and *Eusiridae* — *Cheirimedon femoratus, Bovallia gigantea* and *Pontogeneiella* sp. — were consumed first of all; less frequently: *Hippomedon kergueleni, Eurymera monticulosa, Orchomene plebs, Waldeckia obesa* and others. An approximate evaluation of the quantitative distribution of various species of *Amphipoda* in the food of *N. coriiceps neglecta* shows predominance of *Cheirimedon femoratus, Pontogeneiella* sp., *Hippomedon kergueleni* and *Bovallia gigantea*. *Amphipoda* made up 82.9% of the total number of the devoured animals and algae and 41.6% of their total weight.

Table II

Diet composition of *Notothenia coriiceps neglecta* (winter)

| Food item | $N_{ni}$ | $N_i$ | $f$ | $C_i$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Algae* | 83 | 83 | 0.83 | 1.0 | 18.49 | 5.5 | 5.5 |
| *Polychaeta* | 97 | 45 | 0.45 | 1.1 | 15.85 | 4.7 | 5.2 |
| *Euphausiacea* | 39 | 14 | 0.14 | 0.5 | 3.22 | 0.9 | 0.5 |
| *Amphipoda* | 6798 | 97 | 0.97 | 82.9 | 141.71 | 41.8 | 3465.2 |
| *Isopoda* | | | | | | | |
| *Glyptonotus* sp. | 15 | 11 | 0.11 | | 22.63 | | |
| *Serolidae* | 44 | 15 | 0.15 | 0.8 | 7.80 | 9.0 | 7.2 |
| Other | 7 | 5 | 0.05 | | 0.06 | | |
| *Gastropoda* | 218 | 47 | 0.47 | 2.7 | 12.72 | 3.8 | 10.3 |
| *Bivalvia* | | | | | | | |
| *Laternula elliptica* | 1 | 1 | 0.01 | 2.3 | 1.40 | 0.5 | 1.2 |
| Other | 190 | 29 | 0.29 | | 0.42 | | |
| *Cephalopoda* | 4 | 4 | 0.04 | 0.1 | 16.91 | 5.0 | 0.5 |
| *Salpae* | 542 | 65 | 0.65 | 6.6 | 18.92 | 5.6 | 37.0 |
| *Pisces* | 54 | 47 | 0.47 | 0.6 | 76.02 | 22.4 | 13.4 |
| Various | | | | | | | |
| *Nemertini* | 6 | 6 | 0.06 | | 1.00 | | |
| *Hirudinea* | 2 | 2 | 0.02 | | 0.02 | | |
| *Copepoda* | 2 | 2 | 0.02 | 1.4 | 0.02 | 0.8 | 1.2 |
| *Bryozoa* | 6 | 6 | 0.06 | | 0.17 | | |
| *Ascidiacea* | 1 | 1 | 0.01 | | 0.01 | | |
| Eggs | 95 | 18 | 0.18 | | 1.49 | | |

$N_i$ — number of individuals of the species containing prey i
$N_{ni}$ — number of individuals of prey i taken the species
$f$ — frequency of occurrence of each prey
$W_i$ — total weight of prey taken from the species
$C$ — percent of diet by number of each prey
$C_p$ — percent of diet by weight of each prey
$Q$ — dietary coefficient

In winter only salps ($Q = 37$) belonged to the group of secondary preys. They made up 6.6% of total number of components and 5.6% of the total food weight.

On the basis of the values of the dietary coefficient all other components of the diet must be regarded as accidental food of this species. However, it is worthy of notice that some of them appeared in the food quite often (e.g. *Algae* — $f = 0.83$, *Gastropoda* and *Pisces* — f = 0.47, polychaetes — $f = 0.45$) or made up a considerable percentage of the total food weight (e.g. *Pisces* — 22.4%, *Isopoda* — 9%). The occurrence of stomachs filled almost exclusively by one or several fishes or by one or several isopods — *Glyptonotus antarcticus* was observed frequently.

In the summer season the highly preferred food components of *N. coriiceps neglecta* were *Amphipoda* ($Q = 1714.3$) and *Salpae* ($Q = 268.5$). Among

Table III

Diet composition of *Notothenia coriiceps neglecta* (summer)

| Food item | $N_{ui}$*) | $N_i$ | $f$ | $C_{ii}$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Algae* | 86 | 86 | 0.78 | 0.5 | 282.40 | 19.4 | 9.7 |
| *Polychaeta* | 48 | 19 | 0.17 | 0.3 | 25.44 | 1.8 | 0.5 |
| *Euphausiacea* | | | | | | | |
| *Euphausia superba* | 110 | 15 | 0.14 | 0.6 | 25.19 | 1.8 | 1.1 |
| Unidentified | 6 | 6 | 0.05 | | 0.96 | | |
| *Amphipoda* | 14140 | 99 | 0.90 | 79.0 | 315.41 | 21.7 | 1714.3 |
| *Isopoda* | | | | | | | |
| *Glyptonotus* sp. | 6 | 4 | 0.04 | 1.3 | 63.53 | 8.5 | 11.1 |
| *Serolidae* | 220 | 32 | 0.29 | | 60.12 | | – |
| *Gastropoda* | 125 | 32 | 0.28 | 0.7 | 17.21 | 1.2 | 0.8 |
| *Bivalvia* | | | | | | | |
| *Laternula elliptica* | 7 | 5 | 0.05 | 9.8 | 63.22 | 6.0 | 58.8 |
| Other | 1752 | 31 | 0.28 | | 25.01 | | |
| *Salpae* | 1334 | 106 | 0.96 | 7.5 | 519.58 | 35.8 | 267.5 |
| *Pisces* | 17 | 15 | 0.14 | 0.1 | 51.57 | 3.5 | 0.4 |
| *Various* | | | | | | | |
| *Scyphozoa* | 1 | 1 | 0.01 | | 0.19 | | |
| *Nemertini* | 6 | 4 | 0.04 | | 2.62 | | |
| *Hirudinea* | 1 | 1 | 0.01 | | 0.02 | | |
| *Ostracoda* | 2 | 1 | 0.01 | | 0.01 | | |
| *Tanaidacea* | 3 | 1 | 0.01 | 0.2 | 0.02 | 0.3 | 0.1 |
| *Pycnogonida* | 1 | 1 | 0.01 | | 0.24 | | |
| *Bryozoa* | 5 | 5 | 0.05 | | 0.25 | | |
| *Cephalopoda* | 1 | 1 | 0.01 | | 0.57 | | |
| *Ascidiacea* | 8 | 4 | 0.04 | | 0.51 | | |
| Eggs | 11 | 5 | 0.05 | | 0.32 | | |

*) explanations see Table II

amphipods making up 79% of the total numbers and 21.7% of the total weight of the eaten animals and algae — *Pontogeneiella* sp. and *Hippomedon kergueleni* occurred most frequently and in greatest numbers. *Cheirimedon femoratus, Bovallia gigantea, Eurymera monticulosa* and *Waldeckia obesa* were observed much less frequently and in much smaller numbers. The most frequently observed component of food of the fishes caught in summer were salps ($f = 0.96$). Despite of relatively low percent frequency of occurrence of this prey ($C_{ii} = 7.5$) they made up as 35.8% of the total weight of the examined food.

The value of the $Q$ coefficient suggests that bivalves can be considered secondary preys for this species ($Q = 58.8$). A detailed analysis of very numerous small *Bivalvia* (2—3 mm diameter of the shell), however, showed that in the greater part these were remains of dead animals (empty shells) occurring in the stomachs of fishes most often together with gravel and

fine stones. Fragments (mostly siphons) of *Laternula elliptica,* though not very numerous, constituted an important part in the total food weight.

In the accidental prey ($Q < 20$) the presence of a wide range of animals was observed, among them the most frequently occurring and most numerous were *Isopoda* of the family *Serolidae,* tiny gastropods, polychaetes and krill. As regards the $C_p$ values *Isopoda* (*Glyptonotus antarcticus* and *Serolidae* made up 8.5% and *Pisces* 3.5% of the weight of all the components. Very often ($f = 0.78$) remnants of algae were found in the stomachs, making up 19.4% of the total weight of food.

The above observations show that there are little differences between the composition of *N. coriiceps neglecta* food in summer and winter. In spite of the changes in the structure of predominance of *Amphipoda* species they are always in the group of highest preference. In the summer an increased number of pelagic animals (*Salpae* and *Euphausiacea*) is observed in food composition. Also, the variety of accidental food is greater (representatives of *Tanaidacea, Ostracoda* and *Pycnogonida* were found in the stomachs only in summer) and there is a markedly increased participation of the fragments of algae in the total weight of food contents. A decrease in the ratio of the weight of *Amphipoda* and *Pisces* to the total weight of food was observed.

The comparison of the indices of stomach fullness *I,* (Table IV) shows a much higher feeding intensity of *N. coriiceps neglecta* in the summer season.

Table IV

Mean values of the index of stomach fullness for the examined fish species in the winter and summer seasons

| Species | Index of stomach fullness (%) | |
|---|---|---|
| | winter | summer |
| *N. coriiceps neglecta* | 0.88 | 1.55 |
| *N. rossii marmorata* | 0.71 | 1.50 |
| *N. nudifrons* | no data | 1.71 |
| *T. newnesi* | 1.22 | 2.37 |
| *P. antarcticum* | no data | 0.63 |

*Notothenia rossi marmorata* (263 specimens collected in the winter and summer seasons).

The examined fishes belong to the group of the so-called "fiord fish", i.e. young individuals living in the littoral zone. In the Admiralty Bay the presence of fishes aged from 3 to 7 years was observed (Linkowski and Żukowski 1980). Food was found in all examined stomachs. Just as in the preceding species benthic forms predominate in *N. rossi marmorata* food (Tables V and VI).

Table V

Diet composition of *Notothenia rossi marmorata* (winter)

| Food item | $N_{ji}$*) | $N_i$ | $f$ | $C_{ji}$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Algae* | 96 | 96 | 0.54 | 1.5 | 4.85 | 1.5 | 2.3 |
| *Polychaeta* | 461 | 87 | 0.49 | 7.0 | 42.26 | 13.5 | 94.5 |
| *Euphausiacea* | | | | | | | |
| *Euphausia superba* | 2 | 2 | 0.01 | 0.6 | 0.67 | 0.6 | 0.4 |
| Unidentified | 39 | 22 | 0.12 | | 1.09 | | |
| *Amphipoda* | 4111 | 167 | 0.94 | 62.1 | 73.33 | 23.4 | 1453.1 |
| *Bivalvia* | 470 | 26 | 0.15 | 7.1 | 2.21 | 0.7 | 5.0 |
| *Salpae* | 951 | 116 | 0.65 | 14.4 | 30.11 | 9.6 | 138.2 |
| *Pisces* | 109 | 86 | 0.48 | 1.7 | 143.65 | 45.8 | 77.9 |
| Eggs | 320 | 57 | 0.32 | 4.8 | 3.92 | 1.2 | 5.8 |
| Various | | | | | | | |
| *Nemertini* | 6 | 4 | 0.03 | 0.8 | 1.24 | 3.7 | 3.0 |
| *Hirudinea* | 1 | 1 | | | 0.01 | | |
| *Isopoda* | 27 | 20 | 0.11 | | 4.21 | | |
| *Bryozoa* | 3 | 3 | 0.02 | | 0.22 | | |
| *Gastropoda* | 15 | 15 | 0.08 | | 2.58 | | |
| *Chaetognatha* | 1 | 1 | | | 0.08 | | |
| *Ascidiacea* | 4 | 4 | 0.02 | | 3.32 | | |

*) explanations see Table II

Table VI

Diet composition of *Notothenia rossi marmorata* (summer)

| Food item | $N_{ji}$*) | $N_i$ | $f$ | $C_{ji}$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Algae* | 49 | 49 | 0.58 | 1.2 | 23.33 | 3.5 | 4.2 |
| *Polychaeta* | 4 | 4 | 0.05 | 0.1 | 9.04 | 1.3 | 0.1 |
| *Euphausiacea* | | | | | | | |
| *Euphausia superba* | 36 | 5 | 0.06 | 1.0 | 8.86 | 1.3 | 1.3 |
| Unidentified | 3 | 3 | 0.04 | | 0.19 | | |
| *Amphipoda* | 2943 | 71 | 0.84 | 75.6 | 84.84 | 12.7 | |
| *Bivalvia* | 3 | 1 | 0.01 | 0.1 | 23.90 | 3.5 | 0.4 |
| *Salpae* | 817 | 81 | 0.95 | 21.0 | 290.38 | 43.3 | 909.3 |
| *Pisces* | 24 | 19 | 0.22 | 0.6 | 228.55 | 29.3 | 17.6 |
| Various | | | | | | | |
| *Nemertini* | 1 | 1 | 0.01 | 0.4 | 0.04 | 0.2 | 0.1 |
| *Isopoda* | 4 | 4 | 0.05 | | 0.43 | | |
| *Bryozoa* | 1 | 1 | 0.01 | | 0.02 | | |
| *Gastropoda* | 9 | 5 | 0.06 | | 0.97 | | |

*) explanations see Table II

In the winter season *Amphipoda* ($Q = 1453$) were the decidedly preferred food component. They made up 62.1% of the total numbers of all the components of the diet. Among them the most often occurring were: *Cheiremedon femoratus, Bovallia gigantea, Pontogeneiella* sp. and *Hippomedon kergueleni*. As regards numerousness tiny *Cheirimedon femoratus* were predominant. *N. rossi marmorata* food was considerably diversified by willingly eaten salps, fishes and polychaetes (secondary preys). Animals belonging to these groups were found in more or less the half of the examined stomachs. A very high percentage of *Pisces* in the total weight of the analysed food is noteworthy (predominance — 45.8%). Among the animals eaten accidentally ($Q < 20$) there were: *Isopoda* of the genus *Serolis*, tiny snails and bivalves and pelagic forms (*Euphausiacea* and *Chaetognatha*). Tiny fragments of algae ($f = 0.54$) and eggs of unidentified animals were found frequently.

In the summer season high preference for *Amphipoda* and *Salpae* was observed; *Amphipoda* made up 75.6% of the total number of food components, whereas *Salpae* as much as 43.3% of their total weight. Among amphipods most frequently found and most numerous were: *Hippomedon kergueleni* and *Pontogenciella* sp. The presence of *Cheirimedon femoratus, Eurymera monticulosa, Bovallia gigantea* and *Waldeckia obesa* was observed as well. *Pisces* were also eaten rather willingly; they made up a fairly high percentage (29.3%) of the total weight of the food. All the identifiable remnants of fishes contained in the food of *N. rossi marmorata* belonged without doubt to *Notothenia gibberifrons*. The remaining, occasional components had very little participation in food composition. Among them most important (mainly as regards their share in the total weight of the food) were algae, *Euphausia superba* and polychaetes.

The comparison of the indices of stomach fullness for *N. rossi marmorata* in the winter and summer seasons indicates higher feeding intensity in summer. Also the composition of the diet in the compared seasons is markedly different. A considerably increased preference for salps in the summer and for fishes and polychaetes in the winter is noteworthy. In spite of the decreased number of *Amphipoda* in food composition in summer they remain just as in winter the dominant component of the diet. Only the structure of species composition of the eaten amphipods is changed, that is most probably connected with different feeding grounds in various seasons.

*Notothenia nudifrons* (62 specimens collected exclusively in the summer season).

This species occurred at a markedly greater depth than the two species described above. All the examined stomachs of *N. nudifrons* contained food. A high percentage of benthic forms in food contents (Table VII) indicates that they feed at the bottom of the sea. The most preferred component of the diet, however, were pelagic salps, making up 41.9% of the total number of components and 70.7% of the food weight. The observations carried out in

Table VII

Diet composition of *Notothenia nudifrons* (summer)

| Food item | $N_{.i}$*) | $N_i$ | $f$ | $C_{.i}$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Polychaeta* | 49 | 27 | 0.44 | 5.8 | 2.11 | 10.3 | 59.7 |
| *Amphipoda* | 268 | 44 | 0.71 | 31.9 | 1.40 | 6.8 | 216.9 |
| *Isopoda* | 62 | 22 | 0.35 | 7.4 | 0.54 | 2.6 | 19.2 |
| *Gastropoda* | 29 | 12 | 0.19 | 3.4 | 0.66 | 3.2 | 10.9 |
| *Salpae* | 352 | 45 | 0.73 | 41.9 | 14.50 | 70.7 | 2962.3 |
| Various | | | | | | | |
| *Algae* | 20 | 20 | 0.32 | | 0.26 | | |
| *Euphausiacea* | 10 | 5 | 0.08 | | 0.28 | | |
| *Ostracoda* | 4 | 4 | 0.06 | | 0.01 | | |
| *Tanaidacea* | 17 | 10 | 0.16 | | 0.03 | | |
| *Cumacea* | 5 | 3 | 0.05 | | 0.02 | | |
| *Copepoda* | 5 | 3 | 0.05 | | 0.01 | | |
| *Pycnogonida* | 5 | 4 | 0.06 | 9.6 | 0.48 | 6.3 | 61.4 |
| *Bryozoa* | 2 | 2 | 0.03 | | 0.01 | | |
| *Cephalopoda* | 1 | 1 | 0.02 | | 0.01 | | |
| *Ophiuroidea* | 1 | 1 | 0.02 | | 0.01 | | |
| *Crinoidea* | 2 | 2 | 0.03 | | 0.01 | | |
| *Ascidiacea* | 6 | 2 | 0.03 | | 0.15 | | |
| *Pisces* | 3 | 3 | 0.05 | | 0.01 | | |

*) explanations see Table II

the Admiralty Bay in the summer 1980 showed the occurrence of these animals throughout all the water layers from the surface downwards to the bottom at the depth of over 100 metres (Presler, unpublished materials). The preferred food of *N. nudifrons* were *Amphipoda* ($Q = 216.9$). Among them representatives of *Pontogeneiella* sp. and *Orchomene plebs* were identified. Among the animals eaten rather willingly were also polychaetes, isopods and gastropods. The diet of *N. nudifrons* was extremely diversified (crustaceans, echinoderms, cephalopods, fishes, and others), but none of the animal groups mentioned in Table VII as "Others" did not exceed the limits of accidental preys ($1 < Q < 20$).

*Trematomus newnesi* (42 specimens collected in the summer and winter seasons).

All the examined stomachs contained food. All the investigated specimens were caught at the bottom of the sea, in the daytime. The obtained material (Tables VIII and IX), though scanty, indicates that this species feeds mainly in pelagic waters.

In the winter season *Euphausiacea* (mainly *E. superba*) constituted the essential part of the food. Copepods eaten in great numbers despite of the high percentage (46%) of the total abundance of food components made up only 2.9% of the food weight. *Amphipoda*, among them typically pelagic *Hyperiidae*, constituted secondary preys.

Table VIII

Diet composition of *Trematomus newnesi* (winter)

| Food item | $N_{ii}$*) | $N_i$ | $f$ | $C_{ii}$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Copepoda* | 142 | 7 | 0.58 | 46.7 | 0.28 | 2.9 | 135.4 |
| *Euphausiacea* | | | | | | | |
| *Euphausia superba* | 22 | 5 | 0.42 | 7.2 | 5.85 | 62.3 | 448.5 |
| *Euphausia crystallorophias* | 2 | 1 | 0.08 | 0.7 | 0.07 | 0.7 | 0.5 |
| Unidentified | 70 | 10 | 0.83 | 23.0 | 1.96 | 20.9 | 480.7 |
| *Amphipoda* | | | | | | | |
| *Hyperiidae* | 27 | 7 | 0.58 | 12.8 | 0.44 | 5.2 | 66.5 |
| Other | 12 | 5 | 0.42 | | 0.05 | | — |
| *Chaetognatha* | 8 | 4 | 0.33 | 2.7 | 0.41 | 4.4 | 11.9 |
| *Salpae* | 17 | 4 | 0.33 | 5.6 | 0.10 | 1.1 | 6.1 |
| Various | | | | | | | |
| *Algae* | 1 | 1 | 0.08 | 1.3 | 0.01 | 2.5 | 3.2 |
| *Polychaeta* | 1 | 1 | 0.08 | | 0.21 | | |
| Eggs | 2 | 2 | 0.16 | | 0.02 | | |

*) explanations see Table II

Table IX

Diet composition of *Trematomus newnesi* (summer)

| Food item | $N_{ii}$*) | $N_i$ | $f$ | $C_{ii}$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Copepoda* | 67 | 6 | 0.20 | 21.0 | 0.05 | 0.1 | 2.1 |
| *Euphausiacea* | | | | | | | |
| *Euphausia superba* | 96 | 18 | 0.60 | 30.1 | 36.51 | 94.5 | 2844.5 |
| *Euphausiacea* larvae | 69 | 3 | 0.10 | 21.6 | 0.27 | 0.7 | 15.2 |
| *Amphipoda* | | | | | | | |
| *Hyperiidae* | 7 | 4 | 0.13 | 23.8 | 0.10 | 1.7 | 40.5 |
| Other | 69 | 11 | 0.37 | | 0.56 | | |
| *Salpae* | 11 | 7 | 0.23 | 3.5 | 1.15 | 3.0 | 10.5 |

*) explanations see Table II

Food preference in the summer was similar to that in winter. *T. newnesi* fed most willingly on *Euphausia superba*, which made up as much as 94.5% of the total food weight. The percentage of copepods has decreased markedly in food composition. The comparison of the stomach fullness indices (Table IV) shows higher feeding intensity of *T. newnesi* during the Antarctic summer season.

*Pleuragramma antarcticum* (107 specimens collected in the summer season).

The coefficient of emptiness, $V = 29.9\%$; the index of stomach fullness, $I = 0.65$.

In the food of *P. antarcticum* only pelagic forms were found (Table X). The basic component of the food consisted of *Euphausia superba* and other *Euphausiacea* (over 50% of the total number and over 80% of the total weight of animals eaten). *Amphipoda* (mainly *Hyperiidae*) and *Salpae* constituted secondary preys of this species. The remaining animals found in *P. antarcticum* food, i.e. *Polychaeta, Copepoda, Ostracoda* and *Pisces,* must be regarded as accidental components of the diet, though some of them were fairly numerous (e. g. *Copepoda* — $C_n = 27.3\%$).

Table X

Diet composition of *Pleuragramma antarcticum* (summer)

| Food item | $N_{ii}$*) | $N_i$ | $f$ | $C_{ii}$ | $W_i$(g) | $C_p$ | $Q$ |
|---|---|---|---|---|---|---|---|
| *Copepoda* | 40 | 23 | 0.21 | 27.3 | 0.060 | 0.5 | 13.7 |
| *Euphausiacea* | | | | | | | |
| *Euphausia superba* | 21 | 18 | 0.17 | 14.3 | 8.346 | 70.5 | 1008.2 |
| *Thysanoessa macrura* | 1 | 1 | 0.01 | 0.7 | 0.086 | 0.7 | 0.5 |
| *Euphausiacea larvae* | 25 | 20 | 0.19 | 17.0 | 0.022 | 0.2 | 3.4 |
| *Euphausiacea* Unidentified | 29 | 28 | 0.26 | 19.8 | 1.400 | 11.8 | 233.6 |
| *Amphipoda* | 16 | 15 | 0.14 | 10.9 | 0.649 | 5.5 | 59.9 |
| *Salpae* | 8 | 7 | 0.07 | 5.0 | 1.185 | 10.0 | 50.0 |
| *Pisces* | 4 | 4 | 0.04 | 3.0 | 0.084 | 0.7 | 2.1 |
| Various | | | | | | | |
| *Polychaeta* | 1 | 1 | 0.01 | 2.0 | 0.010 | 0.1 | 0.2 |
| *Ostracoda* | 2 | 2 | 0.02 | | 0.002 | | |

*) explanations see Table II

## 4. Discussion

Earlier studies of feeding habits of the examined five fish species generally describe in detail qualitative food composition and frequency of various components (Permitin and Tarverdieva 1972; Rakusa-Suszczewski and Piasek 1973; Richardson 1975; Linkowski and Rembiszewski 1978; Rembiszewski, Krzeptowski and Linkowski 1978). The quantity (Arnaud and Hureau 1966) and weight of food components (Tarverdieva 1972) were less often taken under consideration. Only in the study by Hureau (1970) the quantity and weight of food components were described simultaneously, enabling the calculation of the dietary coefficients. This method of food analysis was later recommended by SCAR (Anon. 1979).

The results from the analyses of food of five fish species of the family *Nototheniidae* show that the basic diet of three of them (*N. coriiceps neglecta*, *N. rossi marmorata* and *N. nudifrons*) consists of benthic organisms, whereas *T. newnesi* and *P. antarcticum* feed on pelagic organisms. It is worth mentioning that the three species of *Notothenia* showed a tendency to necrophagy — they were caught, as well in the summer as in the winter season, into traps with meat bait and then they were observed eating up the bait (Presler, unpublished materials). The necrophagous feeding habits of the fishes of the family *Nototheniidae* were also mentioned Arnaud and Hureau (1966).

A comparison of the published results of the studies dealing with *N. coriiceps neglecta* feeding habits indicate that the diet of this species may differ considerably even in the same region of investigations. The results from the studies by Permitin and Tarverdieva (1978) and Richardson (1975) in the regions of the South Orkney Islands may serve as a good example of the fact that dietary composition of this species may be dependent on localization of the collection of the samples. Richardson (1975) examining specimens caught in the littoral zone (downwards to the depth of 20 m) observed a typically benthic character of their diet (*Amphipoda, Gastropoda, Bivalvia* and a complete lack of pelagic forms in the food). Permitin and Tarverdieva (1978), using samples collected in deeper waters (downwards to the depth of 170 m and more), noted predominance of pelagic organisms (*E. superba, Pisces, Hyperiidae*) in the *N. coriiceps neglecta* food. The results obtained by Showers, Daniels and Laine (1977) indicate differences in food composition of *N. coriiceps neglecta* in the winter and summer seasons. The diet habits of this species are similar in the Admiralty Bay and in the region of Arthur Harbour (Showers, Daniels and Laine 1977). Also seasonal changes in food composition are much alike. The only noteworthy difference consists in the lack of *Salpae* in the food of *N. coriiceps neglecta* in the region of Arthur Harbour. The adduced results suggest that *N. coriiceps neglecta*, generally a benthophagous species, shows a high adaptability of the dietary habits to local feeding conditions.

The investigations of the food habits of *N. rossi marmorata* carried out in the regions of South Georgia were devoted mainly to adult species forming the so-called "spawning stock" (Permitin 1970; Latogurskij 1972; Tarverdieva 1972; Linkowski and Rembiszewski 1978). The present study concerned young individuals of this species i.e. the so-called "fiord fish". It is difficult to decide to what extent the differences in the food of *N. rossi marmorata* in the regions of South Georgia and Admiralty Bay are conditioned by the specific region of investigations and to what extent by age of the examined fishes or the depth of catches. The comparison of food composition in these two groups of *N. rossi marmorata* shows analogic dependence to that observed in *N. coriiceps neglecta*. Fish

specimens caught in deeper waters (spawning stock in the region of South Georgia) are characterized by a much higher percentage of typically pelagic organisms (among others *E. superba* and *Parathemisto gaudichaudii*) in their food (Permitin 1970; Tarverdieva 1972; Linkowski and Rembiszewski 1978). On the other hand, young specimens caught in the littoral zone of Admiralty Bay feed on benthic fauna (mainly *Amphipoda*) and *Salpae*.

Likewise, dietary composition of *Trematomus newnesi* in the Admiralty Bay differs significantly from the results published by Richardson (1975), but it is similar to the diet of this species in the region of Alašejev Bight (Rakusa-Suszczewski and Piasek 1973). In the region of Signy Island (South Orkneys) *T. newnesi* feeds mostly on *Amphipoda* (*Calliopiidae*, *Eusiridae*) and *Copepoda* (Richardson 1975). In the vicinity of the Molodežnaja Station alimentary tracts of this species contained *Copepoda*, *Amphipoda* (*Paramoera walkeri*, *Hyperiidae*) and *Euphausiacea* in the winter and almost exclusively *E. superba* in the summer (Rakusa-Suszczewski and Piasek 1973).

The results obtained from the analysis of *Pleurogramma antarcticum* food corraborate earlier observations, as regards the pelagic character of the food habits of this species (Permitin and Tarverdieva 1978; Rembiszewski, Krzeptowski and Linkowski 1978).

The authors give their thanks to Ewa Presler M.Sc., for identification of the *Amphipoda* found in the food of the examined fishes.

## 5. Резюме

Проводился анализ пищи 5 видов рыб из семейства *Nototheniidae: Notothenia coriiceps neglecta, N. rossi marmorata, N. nudifrons, Trematomus newnesi, Pleuragramma antarcticum.* Составление проанализированного материала дается в таблице I. Способ анализа и представления результатов принят согласно Иро (Hureau 1970), по рекомендациям СКАР (Аноним 1979).

По представленному составу пищи (таблицы II и III) *N. coriiceps neglecta* можно определить как хищный бентосоядный вид. На протяжении обоих исследовательских сезонов наиболее предпочитаемым компонентом пищи этого вида были ракообразные из отряда *Amphipoda*. Летом в составе пищи *N. coriiceps neglecta* было установлено повышенное количество пелагических животных (*Salpae* и *Euphausiacea*), а также водорослей. Величины индекса наполнения желудков (таблица IV) в оба исследовательских сезона указывают на исключительный рост интенсивности питания этого вида летом.

Также в пище *N. rossi marmorata* преобладают бентосные формы (таблицы V и VI). В оба сезона пищевой базой обсуждаемого вида были *Amphipoda*. Летом присутствие этих ракообразных в пище мраморной нототении снижалось, и одновременно повышалось значение сальп. Было установлено, что потребление рыб и полихет особями мраморной нототении значительно выше зимой чем летом. Остатки рыб, пригодные для идентификации, в пище этого вида принадлежали *N. gibberifrons*. Летом интенсивность питания мраморной нототении вдвое повышается по сравнению с зимой (таблица IV).

Третий из названных видов — *N. nudifrons* — обитал значительно глубже, чем предыдущие (таблица I). Высокая доля бентосных форм в рационе *N. nudifrons* (таблица VII)

указывает на придонный тип питания этого вида. Преобладающим компонентом пищевого рациона этого вида были однако пелагические сальпы.

Два остальных вида: *T. newnesi* и *P. antarcticum* отличались пелагическим типом питания. Если в составе пищи *T. newnesi* (таблицы VIII и IX) было установлено лишь небольшое количество бентосных форм, то рацион *P. antarcticum* состоял исключительно из пелагических форм (таблица IX).

## 6. Streszczenie

Przeprowadzono analizę pokarmu 5 gatunków ryb z rodziny *Nototheniidae: Notothenia coriiceps neglecta, N. rossi marmorata, N. nudifrons, Trematomus newnesi, Pleuragramma antarcticum.* Zestawienie analizowanego materiału przedstawiono w tabeli I. Sposób analizy pokarmu i przedstawienia wyników przyjęto za pracą Hureau (1970), zalecaną przez SCAR (Anon. 1979).

Przedstawiony skład pokarmu *N. coriiceps neglecta* (tabele II i III) świadczy, że jest to drapieżny gatunek bentosożerny. W obu sezonach badań najbardziej preferowanym składnikiem pokarmu tego gatunku były skorupiaki z rzędu *Amphipoda.* W okresie lata zaznaczył się w składzie pokarmu *N. coriiceps neglecta* zwiększony udział zwierząt pelagicznych (*Salpae* i *Euphausiacea*) oraz glonów. Wartości współczynnika napełnienia (tabela IV) w obu sezonach badań wskazują na znaczny wzrost intensywności żerowania *N. coriiceps neglecta* latem.

Również w pokarmie *N. rossi marmorata* dominują formy betonowe (tabele V i VI). W obu sezonach podstawę pokarmu tego gatunku stanowiły *Amphipoda.* Latem udział tych skorupiaków w pokarmie *N. rossi marmorata* malał, wzrastało natomiast znaczenie *Salpae.* Zauważono również wyższą preferencję *N. rossi marmorata* w stosunku do ryb i *Polychaeta* w sezonie zimowym niż letnim. Szczątki ryb możliwe do identyfikacji w pokarmie tego gatunku należały do *N. gibberifrons.* W sezonie letnim intensywność żerowania *N. rossi marmorata* wzrosła wyraźnie w stosunku do okresu zimowego (tabela IV).

Trzeci z wymienionych gatunków — *N. nudifrons* występował wyraźnie głębiej od poprzednich (tabela I). Znaczny udział form bentosowych w pokarmie *N. nudifrons* (tabela VII) wskazywał na przydenny typ żerowania tego gatunku. Najbardziej preferowanym składnikiem diety były jednak pelagiczne *Salpae.*

Dwa pozostałe gatunki: *T. newnesi* i *P. antarcticum* charakteryzował pelagiczny typ pokarmu. O ile w pokarmie *T. newnesi* (tabele VIII i IX) stwierdzono występowanie nielicznych form bentosowych, to pokarm *P. antarcticum* zawierał wyłącznie formy pelagiczne (tabela X).

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