SOME BIOLOGICAL ASPECTS OF THE NEARSHORE FISH POPULATIONS AT SOUTH GEORGIA

M. S. BURCHETT, P. J. SAYERS, A. W. NORTH *and* M. G. WHITE

British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, England

ABSTRACT. An investigation into some biological aspects of 13 nearshore fish species was undertaken. All specimens were caught in Cumberland East Bay, South Georgia, in waters between 1 and 240 m deep. Four species of fish were investigated in detail; they were *Notothenia neglecta, Parachaenichthys georgianus, Chaenocephalus aceratus* and *Trematomus vicarius*. Less detailed data are presented on nine other nearshore fish species. Different species of fish inhabited slightly different areas and depth ranges. Length–frequency data showed distinct size differences between adult males and females of the species. Male *N. neglecta, P. georgianus* and *C. aceratus* were of significantly smaller size compared to the females (on average by 54, 19 and 101 mm respectively). Analysis of stomach contents showed that nearshore demersal fish preyed primarily on benthic invertebrates and small fish (mainly Nototheniidae). However, there are differences in the diet between the species. *Notothenia neglecta* and *N. rossii* juveniles have a high proportion of amphipods, isopods and algae in their diet, while *P. georgianus* and *C. aceratus* feed mostly on decapod shrimps and fish. The spawning season for most of the fish species sampled nearshore was over a limited time period from mid-February to mid-May. However, the time lapse between spawning and occurrence of larvae in the ichthyofauna during the year varied widely according to the fish species.

Previous ecological research on the biology of nearshore fish populations at South Georgia has been that of Olsen (1954, 1955), Crisp and Carrick (1975), Kock (1979), Freytag (1980), and Burchett (1982). Offshore research at South Georgia has primarily been carried out by Permitin and Tarverdiyeva (1972), Shcherbich (1975) and Linkowski and Rembiszewski (1978). Useful comparative studies at Signy Island (South Orkney Islands) have been carried out by Everson (1970*a*, *b*) and Richardson (1975). A year-round ecological study of the nearshore fish populations was undertaken at Grytviken, South Georgia (54° 17′ S, 36° 30′ W) to investigate the biology, growth, reproduction and feeding behaviour of the various fish species. Data for 13 species commonly caught nearshore are presented in this paper with a more detailed study on four of the species: *Notothenia neglecta, Parachaenichthys georgianus, Chaenocephalus aceratus* and *Trematomus vicarius*. These data have been collected during a more detailed programme investigating the autecology of nearshore juvenile *Notothenia rossii* (Burchett, 1982).

HABITAT

Habitats within the fjords frequented by fish were divided into four basic types with their major associations of flora and fauna, substrate class and depths.

Type A. Areas of shallow flocculent black mud with a depth range of 1–20 m. Here the kelp beds were less dense than elsewhere, due to the lack of hard substrate and there were only sporadic occurrences of *Macrocystis pyrifera*. Bottom debris supported colonies of sabellids, hydrozoans, tunicates, anemones and filamentous algae. The surface of the mud was covered by a thin layer of diatoms and errant epifauna included gastropods, molluscs, ophiuroids and opisthobranchs.

Type B. Areas of sand and mud with boulders and stones, and having a depth range of 1–30 m. These areas supported the most dense beds of macroalgae which

included the species *Macrocystis pyrifera* and *Himantothallus grandifolius*. A good encrusting fauna was associated with the holdfasts of the algae and the surfaces of the rocks. Encrusting fauna included sponges, tunicates, sabellids, hydrozoans and anemones. Wandering epifauna consisted of various species of the isopod *Serolis*, *Cassidonopsis emarginata*, amphipods (both lysianassids and eusirids), gastropods and the decapod prawn *Chorismus antarcticus*.

Type C. Grey mud areas with occasional boulders and having a depth range of 30–90 m. In the upper parts of the depth range, a sparse covering of filamentous algae and diatoms gradually gave way to bare mud as depths increased. Major epifaunal groups included nudibranchs, gastropods, ophiuroids and the decapod shrimp *Notocrangon antarcticus*.

Type D. The fjord bottom at about 240 m consisted of grey mud. Associated faunal groups included ophiuroids, large scavenging amphipods and gastropods.

Materials and Methods

Fish were caught nearshore in Cumberland East Bay and King Edward Cove, South Georgia (Fig. 1), between January 1979 and December 1980. To obtain the different species of fish and size ranges, a variety of sampling techniques were employed. These included: Agassiz trawl (1 m); baited traps (1 m); trammel nets (27 and 54 m); collection by SCUBA diving using a hand net; hand-operated dip net with a light source; plankton trawl (1 m); and rod and line. Individual species of fish tended to be caught by specific methods of sampling. Most of the larvae and postlarvae which were present in the surface waters were caught at night using plankton trawls, diver-operated hand nets and hand-operated dip nets. Trammel nets provided an effective method of sampling fish more than 26 cm long. Burchett (1982) demonstrated that many of the fish species displayed nocturnal behaviour, therefore trammel nets were laid in the evening on the seabed and collected early the following morning. Fish species most often sampled by trammel nets were *Notothenia rossii, Notothenia neglecta, Parachaenichthys georgianus, Chaenocephalus*

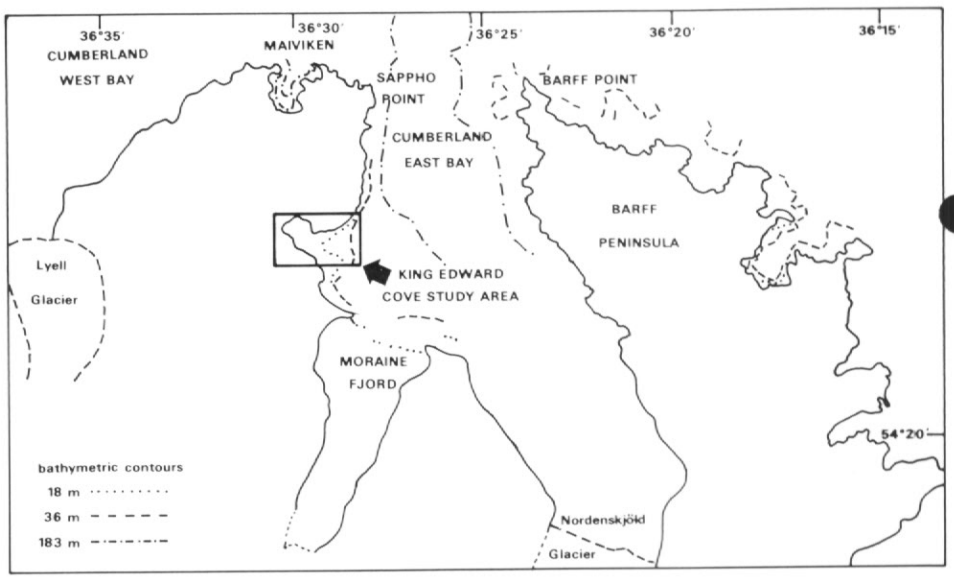

Fig. 1. Cumberland East Bay, South Georgia.

aceratus, Champsocephalus gunnari, Trematomus vicarius, Trematomus hansoni and *Muraenolepis microps*. Species caught in traps included *Notothenia gibberifrons, Notothenia rossii* and *Notothenia neglecta*. Agassiz trawling was an effective method of sampling the smaller size classes and some of the smaller demersal fish species such as *Notothenia angustifrons, Notothenia nudifrons, Harpagifer georgianus (bispinis)* and *Artedidraco mirus*.

Specimens were killed immediately on return to the labortory. Gut examinations and analysis were conducted soon after death to ensure that stomach contents were readily identifiable. Body measurements are the same as those described by Holden and Raitt (1974). Fish length was measured to the nearest millimetre and the body weight taken to the nearest gram. Gonads of each specimen were removed, sexed and weighed.

Water temperatures at 30 m depth within Cumberland East Bay varied seasonally with a mean temperature of +3.30°C in February (1980), to −1.3°C in September (1980). The annual mean monthly temperature throughout 1979 and 1980 was +1.4°C.

Results

Fish species sampled

The fish species most frequently sampled in the nearshore waters of Cumberland East Bay are presented in Table I. Thirteen fish species were commonly caught, but four larger fish species dominated trammel net hauls in terms of numbers and biomass. The fish included *Notothenia rossii, Notothenia neglecta, Parachaenichthys georgianus* and *Chaenocephalus aceratus*.

Length and weight

The length–frequency of four fish species present in the nearshore fish fauna is given in Fig. 2. The mathematical relationship between length and weight can be described by the equation $W_f = bL^k$, where b and k are constants, L is the total length of the fish in millimetres and W_f is the total fresh weight of the fish in grams. The length–weight relationship, mean lengths and mean weights of four nearshore fish species are presented in Table II.

In the published literature there is no standard procedure for expressing length when describing the biometry of fish. Some authors use total length while others use standard length. Therefore a knowledge of the relationship between the two measurements is of practical value for comparative purposes. The transformations of L_s to L_t are given in Table III.

Reproductive biology

Reproductive aspects of five species of fish commonly sampled nearshore in Cumberland East Bay by trammel nets are given in Table IV. Where sufficient data was available, the frequency occurrence of each stage in the gonad maturation cycle for each sex was calculated. The maturation cycles for *N. neglecta* and *P. georgianus* are presented in Figs. 3 and 4 and different stages of the maturation cycle have been described Everson (1970*b*). Spawning and hatching ranges and presence of larval stages for nine of the fish species is shown in Fig. 5.

Feeding

Detailed analysis of stomach components of four fish species including the frequency occurrence of different prey items is given in Table V and Fig. 6 and major prey groups associated with different fish species is given in Table VI.

Table I. Fish species commonly caught in Cumberland East Bay, South Georgia, and their biometry, depth range, habitat and prey.

Species	*Total length (mm)*	*Total weight (g)*	*Depth range (m)*	*Habitat**	*Major prey items found in stomachs*
Notothenia rossii (juv.)	25–460	< 1–1437	1–90	B, C	Benthos and fish (mostly Nototheniidae)
Notothenia neglecta	45–620	< 1–3200	1–90	B, C	Benthos and fish (mostly Nototheniidae)
Notothenia angustifrons	8–172	0.002–44.7	1–30	B	Small benthos and crustacea
Notothenia nudifrons	15–220	< 1–52	1–30	B	Benthos and crustacea
Notothenia gibberifrons	25–455	< 1–455	5–240	C	Mollusca, crustacea and annelida
Trematomus vicarius	208–351	92–580	90–240	D	Crustacea and fish eggs
Trematomus hansoni	6.5–346	0.05–539	90–240	D	Amphipoda and fish eggs
Chaenocephalus aceratus	10–715	< 1–3530	1–240	B, C	Decapod crustacea, fish and mysidacea
Champsocephalus gunnari	10–494	< 1–910	10–240	C, D	*Parathemisto* spp., mysidacea and krill
Parachaenichthys georgianus	10–591	0.008–1250	1–90	A, B, C	Decapod crustacea and fish (mostly Nototheniidae)
Harpagifer georgianus	6.2–85	0.001–3.5	1–15	B	Small crustacea (mostly amphipoda)
Muraenolepis microps	4–370	0.5–465	10–100	B, C	Decapod crustacea, fish, bivalvia, isopoda, amphipoda
Artedidraco mirus	8–88	< 1–9.0	1–30	B, C	Crustacea, mollusca and annelida

* See text for key.

Table II. The mean length, mean weight and length–weight relationship of four species of fish caught nearshore at South Georgia by trammel net in 1979 and 1980.

Species	*Sex*	*Length–weight relationship* ($W_f = bL^k$)	*n*	*r*	*Total length* $\bar{x} \pm s$ *(mm)*	*Fresh weight* $\bar{x} \pm s$ *(g)*	*n*
Chaenocephalus aceratus	Male	$6.39 \times 10^{-6} \times L^{2.9967}$	43	0.88	541 ± 32.1	990 ± 203	42
Chaenocephalus aceratus	Female	$2.85 \times 10^{-6} \times L^{3.1331}$	66	0.85	642 ± 33.1	1810 ± 338	64
Parachaenichthys georgianus	Male	$1.31 \times 10^{-3} \times L^{2.0961}$	131	0.71	510 ± 44.7	639 ± 171	124
Parachaenichthys georgianus	Female	$1.44 \times 10^{-4} \times L^{2.4635}$	84	0.76	529 ± 43.5	745 ± 200	128
Notothenia neglecta	Male	$1.64 \times 10^{-4} \times L^{2.5962}$	143	0.92	389 ± 47.5	894 ± 279	121
Notothenia neglecta	Female	$1.98 \times 10^{-5} \times L^{2.9565}$	165	0.94	443 ± 59.7	1403 ± 577	146
Trematomus vicarius	Female	$4.34 \times 10^{-6} \times L^{3.1720}$	67	0.96	293 ± 26.2	301 ± 94	67

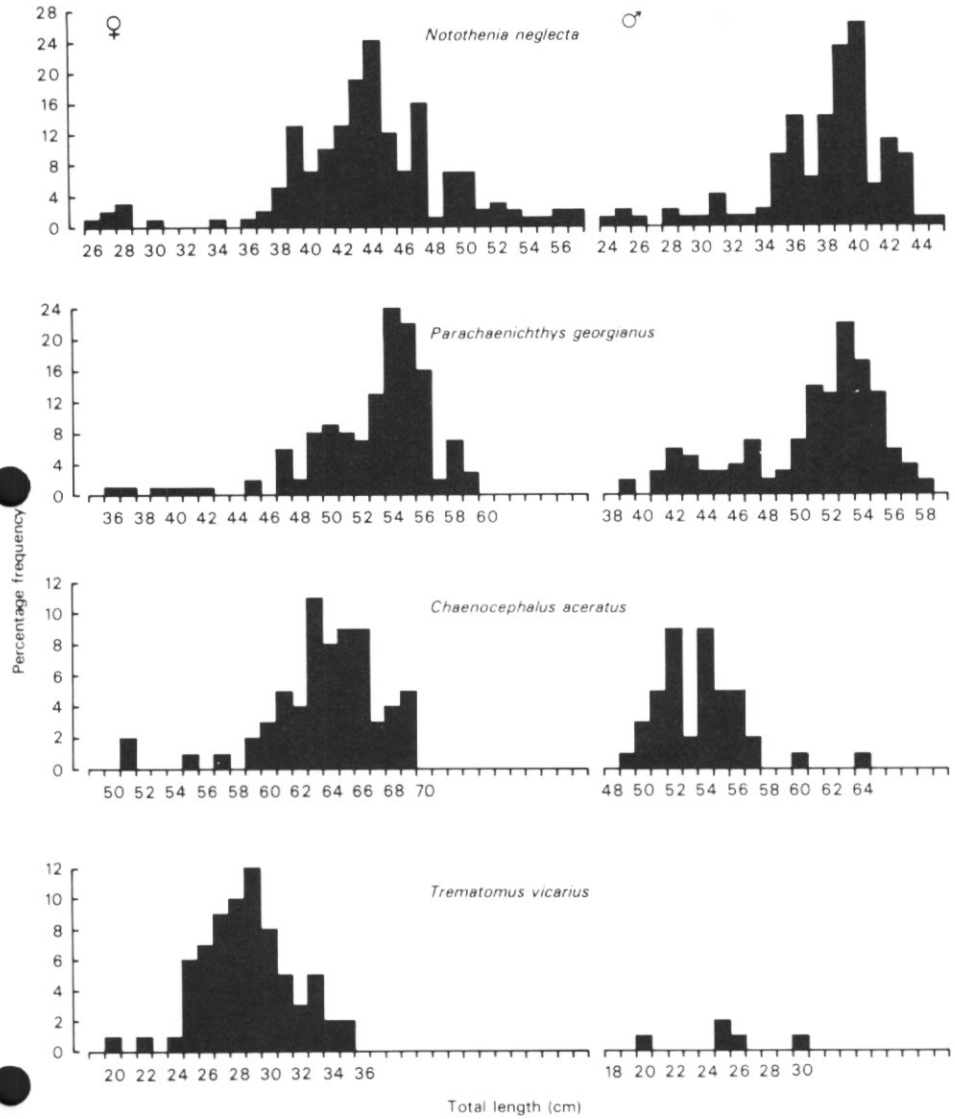

Fig. 2. The length–frequency of four fish species caught nearshore at South Georgia by trammel net in 1979 and 1980.

Table III. Size transformations for the conversion of different length measurements for four species of fish found nearshore in Cumberland East Bay, South Georgia.

Species	*Standard length to total length*	*s*	*n*
Notothenia neglecta	$L_t = L_s \times 1.148$	0.348	270
Parachaenichthys georgianus	$L_t = L_s \times 1.129$	0.020	228
Chaenocephalus aceratus	$L_t = L_s \times 1.117$	0.013	96
Trematomus vicarius	$L_t = L_s \times 1.152$	0.013	72

Table IV. Reproductive aspects of five species of fish commonly caught by trammel net in Cumberland East Bay, South Georgia, in 1979 and 1980.

Species	*Sex ratio Male : female*	*n*	*Spawning period*	*Spawning depth (m)*	*Fecundity range*	*Diameter of egg (mm)*	*n*	*References*
Notothenia neglecta	1:1.2	309	April/May	1–90	36397–48383	4.1 ± 0.460	9	This study
Parachaenichthys georgianus	1:1.0	272	April	1–90	19658–23910	4.0 ± 0.134	25	This study
Chaenocephalus aceratus	1:1.6	111	May	240	5898–18039*	3.9*		*Kock, 1979; Permitin and Tarverdyeva, 1972
Champsocephalus gunnari	†1:1.2	255	May	240	1564–31045*	2.9 ± 0.14	25	*Kock, 1979; †Olsen, 1955
Trematomus vicarius‡	(1:14.4)	77	May	240	11598–15924	3.8 ± 0.10	35	This study

‡Shoaling females.

Table V. The number (n) and frequency (%) of prey items found in stomachs of four species of Antarctic fish from nearshore waters of South Georgia.

	Notothenia neglecta		*Parachaenichthys georgianus*		*Chaenocephalus aceratus*		*Trematomus vicarius*	
Stomach components	*n*	%	*n*	%	*n*	%	*n*	%
Algae	32	13.4	3	1.2	1	1.0	0	0
Ctenophora	4	1.7	0	0	0	0	0	0
Nemertinia	1	0.4	1	0.4	0	0	1	1.3
Priapulida	2	0.8	0	0	0	0	0	0
Annelida (total)	13	5.4	3	1.2	0	0	2	2.6
Polychaeta (errant) *Tomopteris* sp.	5	2.1	0	0	0	0	0	0
Polychaeta (sedentary)	8	3.3	2	0.8	0	0	1	1.3
Mollusca (total)	33	13.8	10	4.1	0	0	0	0
Gastropoda (total)	24	10.0	10	4.1	0	0	0	0
Archaeogastropoda *Nacella concinna*	19	7.9	3	1.2	0	0	0	0
Opisthobranchia *Philine gibba*	1	0.4	3	1.2	0	0	0	0
Bivalvia (total)	9	3.8	0	0	0	0	0	0
Crustacea (total)	100	41.8	94	33.8	5	5.2	11	14.1
Amphipoda (total)	62	25.9	18	7.4	1	1.0	7	9.0
Isopoda (total)	33	13.8	2	0.8	0	0	1	1.3
Cassidonopsis emarginata	5	2.1	2	0.8	0	0	0	0
Serolis spp.	7	2.9	2	0.8	0	0	0	0
Glyptonotus antarcticus	9	3.8	0	0	0	0	0	0
Decapoda (total)	5	2.1	59	24.4	9	9.4	2	2.6
Natantia (total)	5	2.1	59	24.4	9	9.4	2	2.6
Chorismus antarcticus	3	1.3	49	20.2	0	0	1	1.3
Notocrangon antarcticus	2	0.8	10	4.1	6	6.2	1	1.3
Euphausiacea	0	0	1	0.4	9	9.4	0	0
Mysidacea	0	0	2	0.8	46	48.0	1	1.3
Fish (total)	20	8.4	88	36.4	14	14.6	1	1.3
Fish larvae and fingerlings	6	2.5	29	12.0	0	0	1	1.3
Fish juveniles and adults	14	5.9	59	24.4	14	14.6	0	0
Fish eggs	1	0.4	1	0.4	0	0	35	44.9
Unidentifiable	4	1.7	3	1.2	0	0	1	1.3
Numbers of empty stomachs	27	11.3	94	38.8	81	84.4	25	32.0
Total number of stomachs examined	239	—	78	—	96	—	242	—

Table VI. Variety in the diet of four species of Antarctic fish from nearshore at South Georgia expressed as prey components in each stomach examined.

	Notothenia neglecta		*Parachaenichthys georgianus*		*Chaenocephalus aceratus*		*Trematomus vicarius*	
Number of prey types	*n*	%	*n*	%	*n*	%	*n*	%
1	145	67.7	94	64.8	15	100	52	100
2	36	17.3	42	29.0	0	0	0	0
3	19	9.1	7	4.8	0	0	0	0
4 +	8	3.9	2	1.4	0	0	0	0

Discussion

Nearshore in the fjords of Cumberland Bay, 13 species of fish were regularly sampled using a variety of fishing techniques. From diving observations and sample hauls, there were distinct diurnal variations in catches and most of the fish displayed a high level of nocturnal activity (Burchett, 1982). Information from Table I clearly

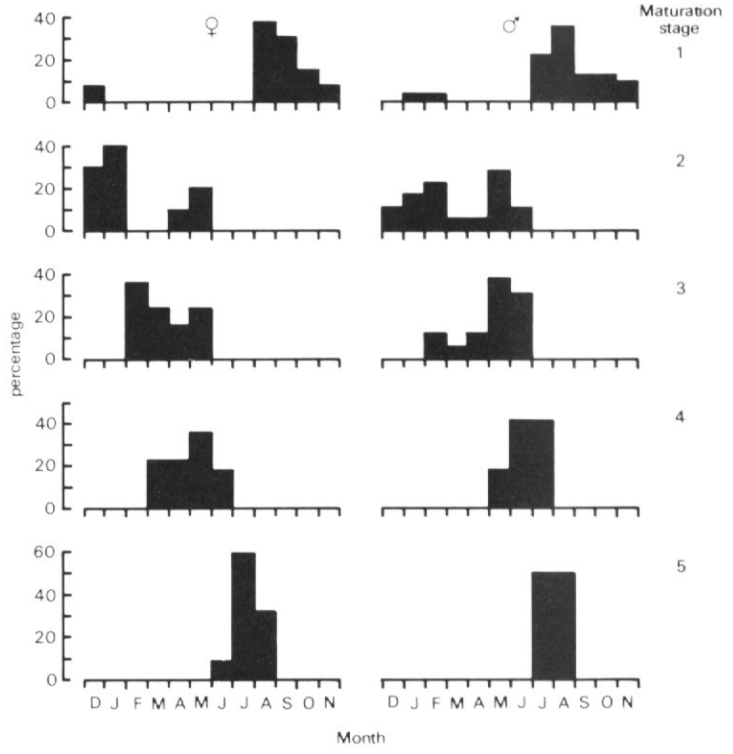

Fig. 3. Percentage occurrence of each stage of the maturation cycle in the gonads of *Notothenia neglecta* at South Georgia in 1979 and 1980.

shows that different species of fish inhabit slightly different areas and depth ranges. It is known that *N. neglecta*, *P. georgianus* and juvenile *N. rossii* all prefer shallow water habitats in waters of less than 90 m deep (Burchett, 1982). *Notothenia angustifrons*, *N. nudifrons*, *H. georgianus* and *A. mirus* inhabit shallow waters and were often found in the 2–7 m depth range. *Harpagifer georgianus* was commonly observed on the gravel swash zone between 0.5 and 2 m depth. *Notothenia rossii* juveniles and *N. neglecta* prefer areas of dense macroalgae, but *P. georgianus* has been caught and observed swimming slowly over open mud, foraging for food. Other fish species such as *C. gunnari*, *T. hansoni*, *T. vicarius* and *N. gibberifrons* were mostly caught in the deeper waters of the fjord between 90 m and the fjord bottom at about 240 m. *Chaenocephalus aceratus* is distributed extensively over a wide area of the continental shelf of South Georgia and nearshore can be caught over a wide depth range from 1 to 240 m. *Trematomus vicarius*, *C. gunnari* and *C. aceratus* move inshore from the shelf areas to spawn as indicated by the large numbers of shoaling fish caught in the nets at depths of 240 m during late summer.

From length–frequency data of four fish species caught in shallow waters, it is clear that there are distinct size differences between males and females of the species (Fig. 2). Males of *N. neglecta*, *P. georgianus* and *C. aceratus* were of significantly smaller size ($d = 17.2$, 4.5 and 15.6 respectively), compared to the females. A comparison of mean lengths of male and female *N. neglecta*, *P. georgianus* and *C. aceratus* (Table II) shows the males were smaller by 54, 19 and 101 mm respectively. the difference in the growth parameters (K, t_0 and L_∞) are known, but the evidence from the length–weight relationships suggests that the South Georgia and Signy

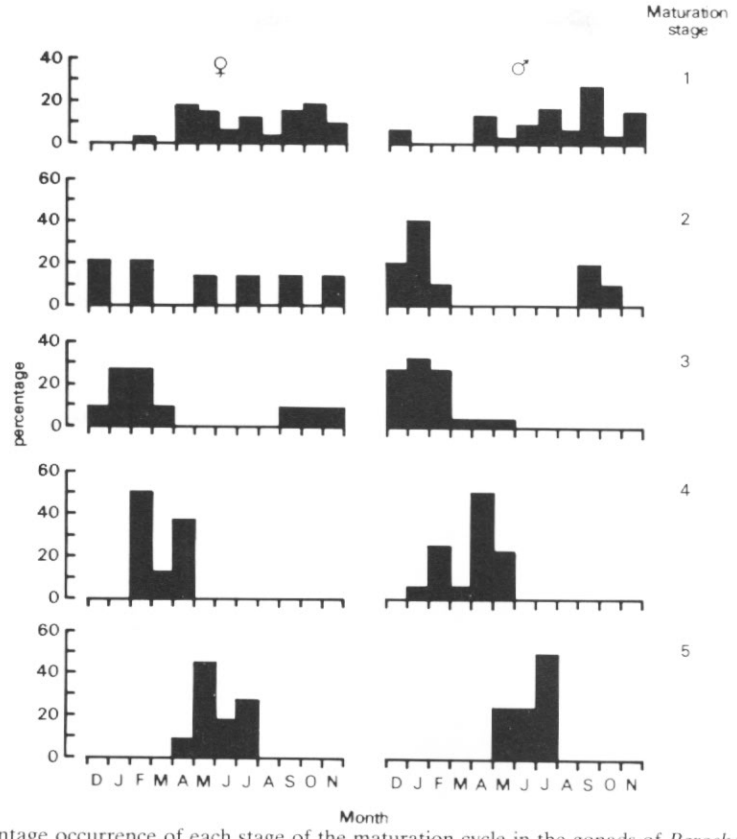

Fig. 4. Percentage occurrence of each stage of the maturation cycle in the gonads of *Parachaenichthys georgianus* at South Georgia in 1979 and 1980.

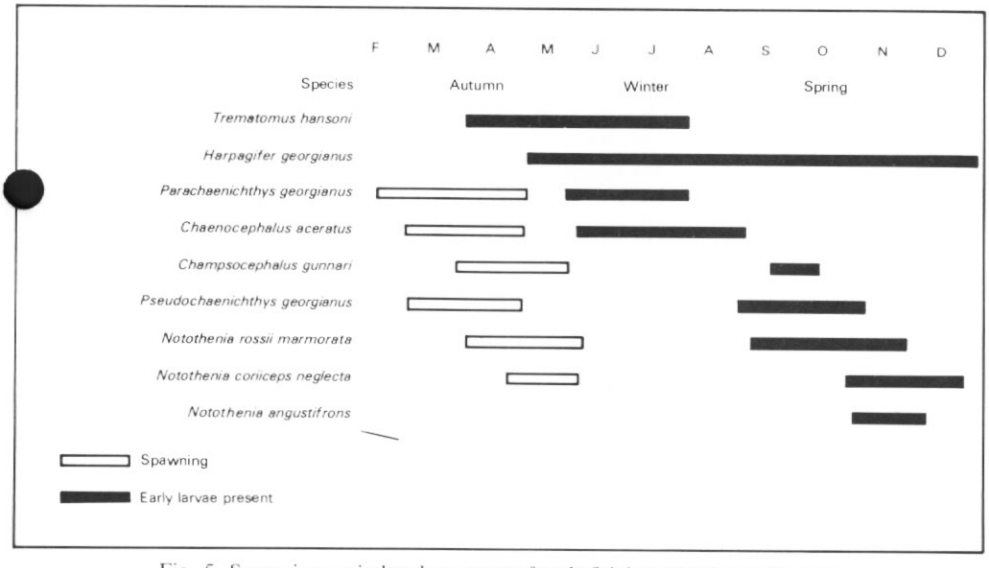

Fig. 5. Spawning period and presence of early fish larvae at South Georgia.

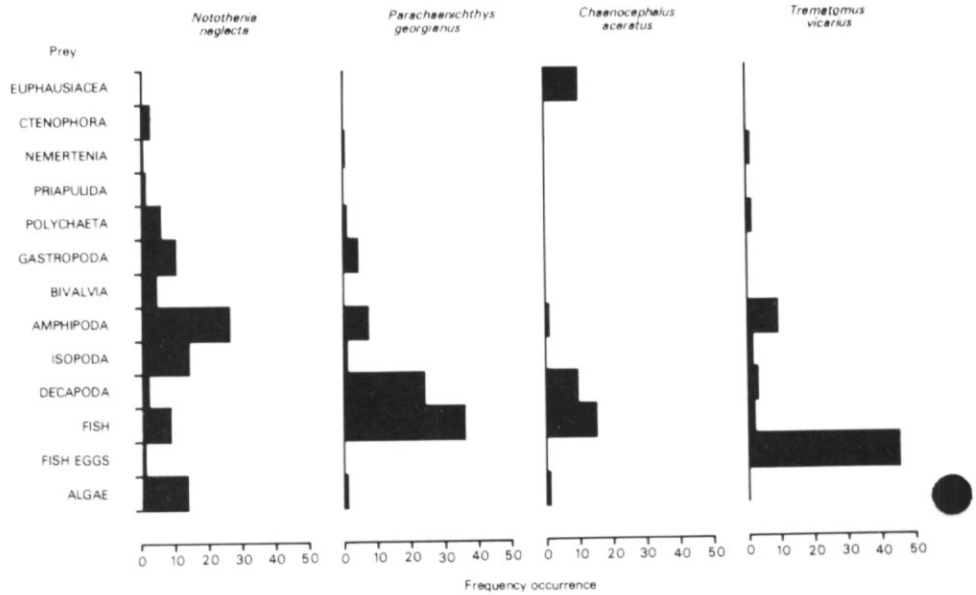

Fig. 6. Percentage occurrence of major prey items found in the stomachs of four species of fish caught nearshore at South Georgia.

Island stocks of *N. neglecta* are separate. At South Georgia, *N. rossii* is the dominant fish nearshore but at Signy (South Orkney Islands), *N. neglecta* is the dominant nearshore fish.

Analysis of stomach contents (Table I) showed that nearshore demersal fish prey primarily upon benthic invertebrates and smaller fish (mostly Nototheniidae). A more detailed analysis of the stomach contents of four major species (Table V and Fig. 6) demonstrated that there are slight differences in the diets. Major prey groups include polychaetes, gastropods, bivalves, amphipods, isopods, decapod crustaceans, algae and fish. Size of prey consumed depends on the size of fish, but the larger the fish and/or the gape of the mouth the greater the choice of prey. Amphipods are of suitable dimensions for many size classes of fish to predate and are consumed in large quantities by many of the nearshore fish species. Amphipoda inhabit both shallow and deep waters in the fjords and are associated mainly with weed or mud.

N. neglecta and *N. rossii* juveniles have a high proportion of amphipods, isopods and algae in the diet, while *P. georgianus* and *C. aceratus* feed mostly on decapod shrimps and fish. *Trematomus vicarius* which inhabits the deeper waters of the fjord, feeds primarily on fish eggs and deep water amphipods. The large consumption of fish eggs suggests that *T. vicarius* was feeding opportunistically on eggs of fish species migrating into the fjords to spawn in late summer. The diet of some fish species varied during the life-cycle, notably *C. aceratus, C. gunnari* and *N. rossii*. Data from Permitin and Tarverdiyeva (1972) showed that offshore, *C. aceratus* fed mainly upon mysids and fish while *C. gunnari* consumed krill (*Euphausia superba*) and mysids. *Notothenia rossii*, although a benthic feeder nearshore, feeds mostly on krill offshore as well as on scyphozoans, ctenophores, tunicates and hyperiid amphipods. From detailed gut analysis it is thought that some prey items are under-represented because of rapid digestion in the stomach (Table V). These groups are Cnidaria, ctenophores and mysids.

It is known that the majority of demersal fish inhabiting shallow coastal waters at depths of less than 90 m display a high level of nocturnal activity (Burchett, 1982). Nearshore, 87% of fish were caught at night compared to 13% caught during the day (Burchett, 1982). This nocturnal behaviour is probably linked to benthic feeding activity as much of the benthos is also more active at night. Linkowski and Rembiszewski (1978) demonstrated that offshore feeding intensity of adult *N. rossii* is highest during the day. Therefore behaviour as well as habitat vary during the life-cycle of certain Antarctic fish species such as *N. rossii*.

A characteristic of Antarctic fish is the production of large yolky eggs. The advantage of producing large yolky eggs is that the larger the individual, the more advanced it will be on hatching, the smaller its relative food requirements and the faster it will be capable of swimming in search of food (Marshall, 1953). The advantage may, however, be offset to a certain extent by the amount of organic matter required for oogenesis (Everson, 1970*b*). The development of mature ova takes two years in *N. neglecta* at South Orkney Islands. This biennial process in the development of mature ova has also been found to take place in *C. gunnari* and *C. aceratus* at South Georgia (Kock, 1979) and it probably occurs in many Antarctic fish species.

The spawning season for most of the fish species sampled nearshore was over a limited time period from mid-February to mid-May (Fig. 5). However, the time lapse between spawning and occurrence of larvae in the ichthyoplankton during the year, varied widely according to the fish species. The reason for this is not certain but a temporal separation will reduce interspecific competition for planktonic food required by early larval stages of fish.

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