Antarctic Science 11 (3): 293–304 (1999) © British Antarctic Survey Printed in the United Kingdom

The fish fauna of the Ross Sea, Antarctica

JOSEPH T. EASTMAN[1]* and GERD HUBOLD[2]

[1]*Department of Biomedical Sciences, College of Osteopathic Medicine, Ohio University, Athens, OH 45701-2979, USA*
**eastman@ohiou.edu*
[2]*Bundesforschungsanstalt für Fischerei, Institut für Seefischerei, Palmaille 9, D-2000 Hamburg 50, Germany*

Abstract: The RV *Nathaniel B. Palmer* was used for bottom trawling at depths of 100–1200 m during two recent cruises in the south-western Ross Sea. Although only 10 of 20 trawls were completely successful, a diverse collection of 979 specimens was obtained representing 47 species (36 notothenioids and 11 non-notothenioids) and eight families. The collection included four new species, a new colour morph of a known species and eight rare species. The collection also established four new locality records, three second occurrences, three most southerly records and eleven new depth records for fish in the Ross Sea. Good taxonomic coverage for some groups was indicated by collection of all four species of *Artedidraco*, nine of ten bathydraconids and seven of eight channichthyids occurring in East Antarctica. The most abundant species were *Trematomus scotti* (29.7%), *Bathydraco marri* (10.4%), *Trematomus eulepidotus* (8.7%) and *Dolloidraco longedorsalis* (6.1%). Fish biomass was determined at two stations. The fish fauna of the Ross Sea south of the 1000-m isobath includes at least 80 species – 54 notothenioids and 26 non-notothenioids, approximately the same number as the Weddell Sea. Species diversity ($H' = 1.88$) was higher than both the Weddell Sea and boreal regions. This collection indicates that, even in relatively shallow water, knowledge of specific and intraspecific diversity in the Ross Sea fauna is incomplete.

Received 11 November 1998, accepted 2 March 1999

Key words: Antarctica, bottom trawl, fish fauna, Notothenioidei, Ross Sea

Introduction

The Ross Sea is a large embayment of the Antarctic continental shelf extending to nearly 78°S. As the historic point of entry for Antarctic exploration, the Ross Sea was also the initial source of specimens of the high latitude fish fauna. In spite of heavy ice cover, early collectors and ichthyologists were exceptionally thorough in obtaining and describing the inshore fauna near Cape Adare and McMurdo Sound (Boulenger 1902, 1907, Waite, 1911, Regan 1913, 1914). These two areas of the Ross Sea served as type localities for approximately 35% of the 51 high latitude East Antarctic species described during first two decades of this century. Nearly 50 years elapsed before collecting resumed and additional new species were discovered in the Ross Sea (DeWitt & Tyler 1960, DeWitt 1962a, 1962b, Andriashev 1980). Documentation of the offshore fauna, dependent on ship-based collecting, has been sporadic (Reseck 1961, Anonymous 1967, 1968, DeWitt 1970a, 1971, table 1, Iwami & Abe 1981). Although the USNS *Eltanin* made five cruises in the Ross Sea, only cruises 27 (1966–67), 32 (1967–68) and 51 (1972) involved any biological collecting (Capurro 1973) and a comprehensive summary of the Ross Sea fish fauna has never appeared. The *Eltanin* collections, however, contained many new species and provided material for decades of systematic and zoogeographic work on notothenioids (DeWitt 1964, 1970a, 1971, 1985, Eakin 1981), myctophids (McGinnis 1982), zoarcids (Anderson 1988), liparids (Stein & Tompkins 1989, Andriashev & Stein 1998) and muraenolepidids (Chiu & Markle 1990).

The Antarctic shelf is an insular evolutionary site, roughly equivalent to Lake Baikal or the Galápagos, with radiations of both notothenioid and liparid fish (Eastman 1993, Eastman & Clarke 1998, Andriashev & Stein 1998). Baseline information on species composition is an essential foundation for most biological research, especially studies aimed at revealing phyletic relationships and at understanding the structure of communities and ecosystems. The Ross Sea fauna is not as thoroughly documented as that of the Weddell Sea where Germany has maintained a regular collecting program for 15 years (Kock *et al.* 1984, Kock 1992, Schwarzbach 1988, Ekau 1988, 1990, Hubold 1991, 1992). Both the Weddell and Ross Seas fall within the East Antarctic Zoogeographic Province (Andriashev 1987). Since the Weddell Sea fauna includes 83 species (Hubold 1992), the suggestion that the Ross Sea fauna includes only 45 species (Anonymous 1967) is certainly an underestimate.

In this paper we summarize the results of bottom trawling during two recent cruises of the RV *Nathaniel B. Palmer* in the south-western Ross Sea. Although the catch was small, we were able to make a preliminary comparison with the fish fauna of the Weddell Sea.

Materials and methods

We conducted bottom trawling during cruises 96–6 (11 December 1996–8 January 1997) and 97–9 (20 December

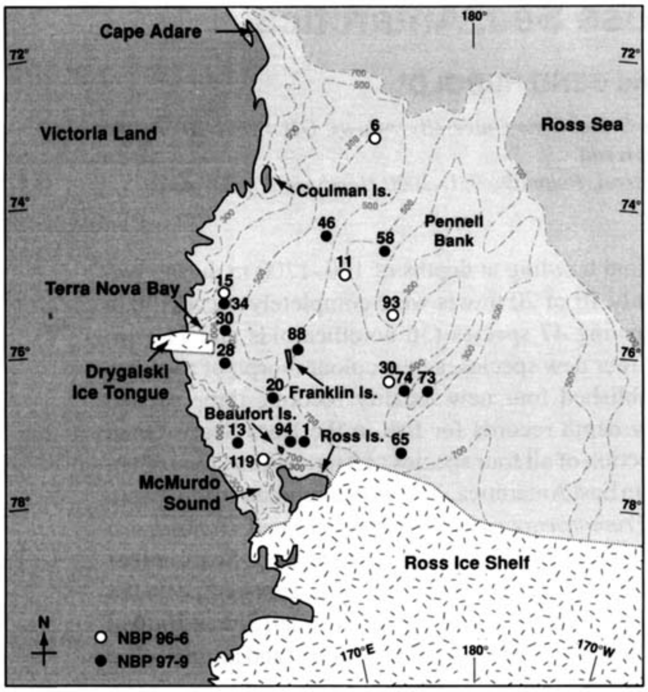

Fig. 1. Diagram of the western Ross Sea showing locations of benthic trawling stations during cruises 96–6 and 97–9 of the RV *Nathaniel B. Palmer*. Bathymetry is modified from the General Bathymetric Chart of the Ocean, Sheet 5.18 (5th edition). The greatest depths of the narrow Drygalski Basin are not shown and the shallow bathymetry around Franklin and Beaufort islands is not resolved at this scale.

1997–10 January 1998) of the RV *Nathaniel B. Palmer* in the southern and western Ross Sea (Fig. 1, Table I). The ship pulled a 9.1-m long Marinovich Gulf Coast style flat trawl, a type of light duty commercial otter trawl. The foot-rope was 11 m long, but the effective width or mouth opening covered by netting was only 7.6 m. The trawl body consisted of 70-mm mesh, composed of No. 42 thread (3.2 mm thick), with a liner of 13-mm mesh. We also used a far less effective Blake trawl with a frame measuring 1.5 m wide by 0.5 m high. The netting was identical to that of the Marinovich trawl. Towing speed was 2.0–3.0 knots for 30–60 min. Ice cover at trawling stations ranged from 0/10 to 9/10; bottom temperature was -1.5 to -1.9°C.

Specimens were identified, counted and preserved in formalin aboard ship. Some were maintained in aquaria and their activity and swimming behaviour was observed for several days. Species identification was based on taxonomic keys and scientific nomenclature in Gon & Heemstra (1990). Except where noted, this reference was also used as the most comprehensive summary of distribution records and for statements of the rarity or abundance of species. In establishing new distribution records for the Ross Sea, we deposited voucher specimens or multiple lots of specimens in various museums, with institutional abbreviations following Levinton *et al.* (1985). We considered as new records those species not

Table I. Data for 20 bottom trawling stations during cruises 96–6 and 97–9 of RV *Nathaniel B. Palmer* in the south-western Ross Sea.

Station number	Latitude (S)	Longitude (E)	Date	Depth range (m)	Trawl
NBP 96–6			1996–97		
6	72°59'	175°08'	18 Dec	360	Blake
11	74°59'	172°33'	20 Dec	560	Blake
15	75°02'	166°16'	21 Dec	939	Blake
30	76°30'	175°00'	23 Dec	469	Blake
93	75°30'	174°56'	3 Jan	300–310	Otter
119	77°19'	165°41'	8 Jan	900–910	Otter
NBP 97–9			1997–98		
1	76°56'	167°32'	20 Dec	230–268	Otter
13	77°04'	164°16'	23 Dec	258–261	Otter
20	76°30'	166°17'	24 Dec	642–663	Otter
28[a]	75°46'	164°47'	27 Dec	773–806	Otter
28[b]	75°46'	164°44'	27 Dec	746–763	Blake
30[c]	76°16'	165°16'	27 Dec	721–737	Otter
34[b]	75°04'	165°10'	28 Dec	1181–1191	Otter
46[b]	74°17'	171°56'	30 Dec	465–466	Otter
58	74°21'	176°28'	2 Jan	333–344	Otter
65[b]	77°15'	173°59'	3 Jan	512–530	Otter
73	76°34'	176°54'	5 Jan	379–399	Otter
74[b]	76°31'	175°24'	5 Jan	439–444	Otter
88	76°02'	168°26'	8 Jan	107–287	Otter
94	77°00'	167°17'	9 Jan	449–702	Otter

[a]Net destroyed (no fish caught)
[b]Significant net damage (reduced catch)
[c]Net twisted (reduced catch)

previously documented with a catalogued museum specimen and a citation in the mainstream literature. It is possible that there were reports in the grey literature that were unavailable to us. Several specialists generously identified or verified our identifications of species.

We designated species as numerically abundant if their number was at least 5% of the catch. We calculated diversity indices for the nine stations with a catch of at least 39 specimens. We also determined fish biomass at Stations 93 and 119 during cruise 96–6, the only two stations where otter trawling was conducted. A balance was not available during cruise 97–9. We obtained the weight for each specimen; 65 at Station 93 and 83 at Station 119. We took fresh weight for some specimens aboard ship and back calculated fresh weight for other specimens that had been preserved in formalin and stored in 70% ethanol for two months. These specimens lost 23% of their fresh weight during storage.

Results

Overview of the collection

Figure 1 and Table I provide locations of trawling stations. During the two cruises we made a total of 20 trawls, 15 with the Marinovich trawl and five with the Blake trawl. Since large erratic (ice rafted) boulders were a regular feature of the bottom in the Ross Sea, both types of net were frequently damaged and needed repeated mending. Two Marinovich and

https://doi.org/10.1017/S0954102099000383 Published online by Cambridge University Press

one Blake trawl were completely destroyed during cruise 97–9. As a result of damage, one of our 20 tows caught no fish and nine others yielded six or fewer specimens. Although only 50% of the trawls were successful, we nevertheless obtained a diverse collection of 979 fish representing 47 species (36 notothenioids and 11 non-notothenioids) and 8 families (Table II). Since the collection was small, we did not analyse community structure. The noteworthy systematic and zoogeographic findings are summarized in Table III. With four new species, the catch generally indicates that the Ross Sea fauna is incompletely known. The new artedidraconid species and colour morph have been described (Eakin & Eastman 1998, Eastman & Eakin 1999) but work on the new liparids has not yet been undertaken. The new locality record for *Dacodraco hunteri* has also been reported (Eastman 1999).

Notothenioids were dominant by number, consisting of 91.5% of the individuals captured (Table II). The most abundant species, comprising at least 5% of the catch, were *Trematomus scotti* (29.7%), *Bathydraco marri* (10.4%), *Trematomus eulepidotus* (8.7%) and *Dolloidraco longedorsalis* (6.1%), all circum-Antarctic in distribution. Other aspects of the collection are discussed below.

Diversity indices

There were peaks of species diversity (>13 species/station) at depths of 250–344 m, 466 m and 663 m (Table II). Over 66% of the total catch by number was taken at depths of less than 400 m. Table IV provides values for various diversity indices. Interestingly, the two stations with maximum catch by number (Stations 1 and 58), and with relatively high absolute species diversity, had the lowest evenness values. This shows that the high numbers were attributable to aggregations of a few species in those hauls. In case of Station 1, this was due to the presence of many, large pre-spawning individuals of *Trematomus eulepidotus*. At Station 58, there was a large aggregation of small (40–80 mm SL) *T. scotti*. Thus while absolute diversity at these two stations was relatively high, the aggregations probably resulted in the lower overall relative diversity indicated by the Shannon-Weaver index (H').

Biomass

We calculated fish biomass for two stations, at the relatively shallow Pennell Bank (Station 93, 310 m, 75°30'S) and at a deep locality (Station 119, 910 m, 77°19'S). Fish biomass was nearly 5-fold higher at the shallower station and was composed of 77% notothenioids and 23% non-notothenioids (Table V). Channichthyids and artedidraconids of the genus *Pogonophryne* were the dominant taxa by weight at 50.6% and 17.5% of the total biomass. Bathydraconids made up only 5.2% of biomass at this shallow station. At the deep station near McMurdo Sound, biomass was more heavily weighted toward notothenioids at 91%. Here bathydraconids, at 30.1%, were a more important component than in shallower water; channichthyids were 29.2%. Nototheniids were 16.8% of the biomass and artedidraconids of the genera *Dolloidraco* and *Histiodraco* accounted for 15.1%.

The most obvious instance in which biomass differed from overall abundance data (Table II) was the case of the numerous small trematomids that accounted for 50% of the abundance but only 4–17% of the biomass. It must be noted that the biomass calculation for Station 93 probably reflects a sampling bias since *Trematomus scotti* was absent and *T. eulepidotus* was represented by just one specimen. These two abundant shallow water species would normally be represented in the catch at shallow stations (Table II) and would contribute more heavily to the biomass than indicated in Table V. Conversely channichthyids, especially relatively few large individuals of the genera *Chionodraco* and *Cryodraco*, dominated the biomass at both stations (51% and 29%) while accounting for only 20% and 7% of the abundance. In the case of artedidraconids, the biomass and abundance values were concordant with each other.

Nototheniidae

One-half of all individuals collected were members of the family Nototheniidae and, with the exception of *Pleuragramma antarcticum*, all were species of *Trematomus*. *Trematomus scotti* was the most abundant species, comprising about 30% of the catch. It was present at 12 of 19 stations. *Trematomus eulepidotus* was also abundant at 8.7% of the catch. This species was well represented at Station 1 where the collection was dominated by large adults with ripe gonads (TL = 270–290 mm; SL = 230–250 mm; Wt = 250–400 g). Stomach contents indicated that they were feeding in the water column on juvenile (20–25 mm) *Euphausia crystallorophias* and *Pleuragramma antarcticum*. It was our subjective impression that *T. eulepidotus* was second in biomass to channichthyids at this station.

The epibenthic species *T. eulepidotus*, *T. lepidorhinus* and *T. loennbergii* exhibited graded and disjunct depth distributions (Table II). *Trematomus eulepidotus* was most common in shallow water (130–344 m), *T. loennbergii* occurred in deep water (663–1191 m) and *T. lepidorhinus* had an extended depth range from shallow to intermediate depths (130–663 m).

Artedidraconidae

With 13 species, the family Artedidraconidae was dominant in terms of species richness. We obtained all four species of *Artedidraco* known to occur in East Antarctica as well as a new species, *Artedidraco glareobarbatus* (Eastman & Eakin 1999). Species of this genus were frequently collected in the vicinity of sponge beds, especially in water less than 261 m deep (Stations 1, 13, and 88). They are usually small in size (40–80 mm SL), especially *A. loennbergi* and *A. skottsbergi*, and a minor component of the fish biomass. *Histiodraco*

https://doi.org/10.1017/S0954102099000383 Published online by Cambridge University Press

Table II. Fish species distribution and number of specimens by depth, cruises 96–6* and 97–9 of the RV *Nathaniel B. Palmer* in the south-western Ross Sea. Arrangement is phylogenetic for families and alphabetical for genera and species.

Taxa Station no.	88	1	13	93*	58	6*	73	74	46	30*	65	11*	94	20	30	28	119*	15*	34	Frequency of occurrence	
Depth (m)	130	250	261	310	344	360	399	444	466	469	530	560	600	663	737	763	910	939	1191	no.	%
Σ Rajidae																				7	0.7
Bathyraja eatonii				5																5	0.5
Bathraja maccaini					1															1	0.1
Bathyraja sp.					1															1	0.1
Muraenolepididae																					
Muraenolepis microps				2	13	1														16	1.6
Σ Liparidae																				8	0.8
Paraliparis antarcticus														2					1	3	0.3
Paraliparis new sp. 1																			1	1	0.1
Paraliparis new sp. 2									4											4	0.4
Σ Zoarcidae																				52	5.3
Lycodichthys dearborni									11				1							12	1.2
Ophthalmolycus amberensis				8	1				5			1		8			10	1		34	3.5
Ophthalmolycus bothriocephalus									2											2	0.2
Pachycara brachycephalum				3										1						4	0.4
Σ Non-Notothenioidei																				83	8.5
Σ Nototheniidae																				490	50.1
Pleuragramma antarcticum	8		2	2	1		1										2			16	1.6
Trematomus bernacchii	2		1																	3	0.3
Trematomus eulepidotus	9	68	3	1	4															85	8.7
Trematomus lepidorhinus	10	9	5	4	4				1					2						35	3.6
Trematomus loennbergii														8	4	1	1		18	32	3.3
Trematomus pennellii	25	2	1																	28	2.9
Trematomus scotti	2	44	21		178	4		1	18	1	1	3	2	16						291	29.7
Σ Artedidraconidae																				142	14.5
Artedidraco glareobarbatus	2																			2	0.2
Artedidraco loennbergi	1	1			14				4											20	2.0
Artedidraco orianae					1	1			3											5	0.5
Artedidraco shackletoni	6	3																		9	0.9
Artedidraco skottsbergi	2	8	19																	29	3.0
Dolloidraco longedorsalis											1			33	1		20		5	60	6.1
Histiodraco velifer		1												3			1			5	0.5
Pogonophryne cerebropogon				1																1	0.1
Pogonophryne marmorata									1											1	0.1
Pogonophryne mentella														1						1	0.1
Pogonophryne phyllopogon				1																1	0.1
Pogonophryne scotti				5										2						7	0.7
Pogonophryne sp. (small)														1						1	0.1
Σ Bathydraconidae																				185	18.9
Akarotaxis nudiceps														8	3	2	13	2	3	31	3.2
Bathydraco macrolepis														3			4		1	8	0.8
Bathydraco marri				1	49				26					3			13		10	102	10.4
Cygnodraco mawsoni		1		1																2	0.2
Gerlachea australis				1																1	0.1
Gymnodraco acuticeps														1						1	0.1
Prionodraco evansii				7	5												13			25	2.6
Racovitzia glacialis				10	3				1											14	1.4
Vomeridens infuscipinnis												1								1	0.1
Σ Channichthyidae																				79	8.1
Chionodraco hamatus	2	24	1	1										2			1			31	3.2
Chionodraco myersi		5		2	3				3		1			1	1					16	1.6
Cryodraco antarcticus		6		9	2															17	1.7
Dacodraco hunteri															1		4			5	0.5
Neopagetopsis ionah					1															1	0.1
Pagetopsis macropterus		1		1					1					3						6	0.6
Pagetopsis maculatus		1							1								1			3	0.3
Σ Notothenioidei																				896	91.5
Σ species per station	11	14	8	19	16	3	1	1	14	1	3	3	2	18	5	2	12	2	7		
Σ specimens per station	69	174	53	65	281	6	1	1	81	1	3	5	3	98	10	3	83	3	39	979	100.0

For authorities see Table VI

Table III. Specimens of systematic and zoogeographic significance collected during cruises 96–6 and 97–9 of the RV *Nathaniel B. Palmer* in the south-western Ross Sea.

Specimens	Museum catalogue no.[a]
New species	
Pogonophryne cerebropogon[b]	USNM 345594
Artedidraco glareobarbatus[c]	USNM 348711& 348712
Paraliparis new sp. 1 (pink and grey, orange on fins)	
Paraliparis new sp. 2 (light pink posteriorly)	
New intraspecific colour morphs	
Artedidraco shackletoni (spotted morph)[c]	USNM 348713
Rare species (number caught)	
Bathyraja eatonii (5)	TCWC 8909.01
Histiodraco velifer (5)	
Akarotaxis nudiceps (31)	
Bathydraco macrolepis (8)	
Cygnodraco mawsoni (2)	MCZ 152944
Gerlachea australis (1)	MCZ 152945
Vomeridens infuscipinnis (1)	MCZ 152946
Dacodraco hunteri (5)	MCZ 154360 & 154361
New locality records (first occurrences in Ross Sea)	
Bathyraja maccaini	TCWC 10629.01
Bathyraja sp.[d]	TCWC 10628.01
Ophthalmolycus bothriocephalus	RUSI 56529
Dacodraco hunteri	MCZ 154360 & 154361
Second occurrences in Ross Sea	
Bathyraja eatonii	TCWC 8909.01
Lycodichthys dearborni[e]	RUSI 57869
Cygnodraco mawsoni	MCZ 152944
New most southerly occurrences	
Bathyraja eatonii (75°30.1'S, Station 93)[f]	TCWC 8909.01
Muraenolepis microps (75°30.1'S, Station 93)[g]	RUSI 57870
Artedidraco orianae (72°59.8'S, Station 6)	
New maximum size record (in fresh condition)	
Neopagetopsis ionah (TL = 57.5 cm; wt = 1300 g)	MCZ 154376
New depth records	
Paraliparis antarcticus (1191 m, Station 34)[h]	
Ophthalmolycus amberensis (939 m, Station 15)	RUSI 54824
Trematomus loennbergii (1191 m, Station 34)	
Histiodraco velifer (910 m, Station 119)	
Dolloidraco longedorsalis (1191 m, Station 34)	
Akarotaxis nudiceps (1191 m, Station 34)	
Gymnodraco acuticeps (663 m, Station 20)[h]	
Prionodraco evansii (910 m, Station 119)	
Chionodraco hamatus (910 m, Station 119)	
Dacodraco hunteri (910 m, Station 119)[h]	
Pagetopsis maculatus (910 m, Station 119)	
New most shallow occurrences	
Trematomus lepidorhinus (130 m, Station 88)	
Artedidraco loennbergii (130 m, Station 88)	

[a]Museum abbreviations: MCZ, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts; RUSI, J.L.B. Smith Institute of Ichthyology, Grahamstown, South Africa; TCWC, Texas A&M University Texas Co-operative Wildlife Collection, College Station, Texas; USNM, Smithsonian Institution, National Museum of Natural History, Washington, DC
[b]Eakin & Eastman (1998)
[c]Eastman & Eakin (1999)
[d]This specimen keys out as *Bathyraja* sp. in the key of Stehmann & Bürkel (1990, p. 88). According to these authors it is a new species, or possibly a new genus, to date known only from specimens in the Atlantic and Indian Ocean sectors (J.D. McEachran, personal communication October 1998)
[e]Not including specimens documented from McMurdo Sound
[f]Skates have been observed but not captured in McMurdo Sound at nearly 78°S (J.T. Eastman, personal observation)
[g]The RUSI collection contains an unpublished record of a specimen collected farther south (M.E. Anderson, personal communication June 1998)
[h]Life history and morphological observations suggest that these specimens may have been captured in the water column rather than on the bottom

For authorities see Table V1

Table IV. Diversity indices for fish at stations yielding at least 39 specimens during cruises 96–6* and 97–9 of RV *Nathaniel B. Palmer* in the south-western Ross Sea. Stations arranged from shallow to deep; identical 7.6-m otter trawl used at all stations.

Station no. Depth (m)[a]	88 130†	1 250†	13 261	93* 310	58 344	46 466	20 663	119* 910	34 1191
Specimens per trawl	69	174	53	65	281	81	98	83	39
Species per trawl	11	14	8	19	16	14	18	12	7
Shannon-Weaver diversity [$H' = -\Sigma\ p \ln p$]	1.95	1.77	1.45	2.62	1.33	2.05	2.25	2.06	1.45
Margalef's species richness [SR = (no. spp.-1) ln (no. indiv.)$^{-1}$]	2.36	2.52	1.76	4.31	2.66	2.96	3.71	2.49	1.64
Pielou's evenness [$J' = H' \ln (\text{no. spp.})^{-1}$]	0.81	0.67	0.71	0.89	0.48	0.78	0.78	0.83	0.74

[a]Mean depths indicated by (†), other depths are maximums as given in Table I

https://doi.org/10.1017/S0954102099000383 Published online by Cambridge University Press

Table V. Biomass calculations for fish at stations 93 (310 m) and 119 (910 m), cruise 96–6 of RV *Nathaniel B. Palmer* in the south-western Ross Sea.

Family and species	Station 93 No.	Station 93 Weight (g)	Station 93 % by wt.	Station 119 No.	Station 119 Weight (g)	Station 119 % by wt.
Rajidae						
Bathyraja eatonii	5	819.5	10.7			
Muraenolepididae						
Muraenolepis microps	2	61.0	0.8			
Σ Zoarcidae	11	856.0	11.2			
Ophthalmolycus amberensis	5	381.5	5.0	10	168.6	8.8
Pachycara brachycephalum	6	474.5	6.2			
Σ Non-Notothenioidei	18	1736.5	22.7	10	168.6	8.8
Σ Nototheniidae	7	310.4	4.0	3	324.0	16.8
Pleuragramma antarcticum	2	91.0	1.2	2	124.0	6.4
Trematomus eulepidotus	1	91.0	1.2			
Trematomus lepidorhinus	4	128.4	1.6			
Trematomus loennbergii				1	200.0	10.4
Σ Artedidraconidae	7	1345.3	17.5	21	290.4	15.1
Dolloidraco longedorsalis				20	193.9	10.1
Histiodraco velifer				1	96.5	5.0
Pogonophryne cerebropogon	1	368.0	4.8			
Pogonophryne phyllopogon	1	9.3	0.1			
Pogonophryne scotti	5	968.0	12.6			
Σ Bathydraconidae	20	395.2	5.2	43	579.3	30.1
Akarotaxis nudiceps				13	98.0	5.1
Bathydraco macrolepis				4	240.6	12.5
Bathydraco marri	1	6.1	0.1	13	91.6	4.8
Cygnodraco mawsoni	1	84.7	1.1			
Gerlachea australis	1	7.2	0.1			
Prionodraco evansii	7	75.7	1.0	13	149.1	7.7
Racovitzia glacialis	10	221.5	2.9			
Σ Channichthyidae	13	3881.9	50.6	6	563.3	29.2
Chionodraco hamatus	1	63.0	0.8	1	222.0	11.5
Chionodraco myersi	2	675.0	8.8			
Cryodraco antarcticus	9	3131	40.8			
Dacodraco hunteri				4	301.1	15.6
Pagetopsis macropterus	1	12.9	0.2			
Pagetopsis maculatus				1	40.2	2.1
Σ Notothenioidei	47	5932.8	77.3	73	1757.0	91.2
Σ All species	65	7669.3	100.0	83	1925.6	100.0
Σ (kg km^{-2})		437.50			89.62	
Σ (g m^{-2})		0.44			0.09	
Σ (kg m^{-2})		0.0004			0.0001	

For authorities see Table V1.

velifer was eurybathic (250–910 m) and *Dolloidraco longedorsalis* was the most abundant artedidraconid comprising 6.1% of the entire collection. It was confined to water 530–1191 m deep. *Pogonophryne* were collected at depths of 310–663 m. *Pogonophryne scotti* was the most common species of the genus and most individuals were relatively large, some approaching 240 mm SL. The new species *P. cerebropogon* (Eakin & Eastman 1998) was collected at a depth of 310 m on the edge of the Pennell Bank. It is likely that both new artedidraconid species will be found to have circum-Antarctic distributions.

Bathydraconidae

We obtained good taxonomic coverage for the family Bathydraconidae, collecting nine of ten species occurring in East Antarctica. Representing 10.4% of the entire collection, *Bathydraco marri* was both the most abundant and the most eurybathic bathydraconid. Although bathydraconids are generally found in the deepest areas of the Antarctic shelf (Ekau 1988, 1990, Schwarzbach 1988), our collections were only slightly biased in this direction in terms of species diversity. In dividing the bathydraconids into those captured above and below 500 m, five species and 105 individuals occurred at less than 500 m and six species and 80 individuals were taken at greater than 500 m. This was probably an artefact of the small number of trawls and the preponderance of small *B. marri* at stations less than 500 m deep.

Channichthyidae

We also obtained wide taxonomic representation for the

https://doi.org/10.1017/S0954102099000383 Published online by Cambridge University Press

family Channichthyidae, collecting seven of eight species occurring in East Antarctica. The specimens of *Dacodraco hunteri* were a new record for the Ross Sea (Eastman 1999). *Chionodraco hamatus* was the most abundant and eurybathic channichthyid. Channichthyids dominated the fish biomass at Station 1 (Table II) with several large specimens of *Cryodraco antarcticus* weighing over 1 kg. The channichthyids were near a sponge bed at a depth of 250 m.

Discussion

In spite of a nearly century-long history of ichthyological collecting in the Ross Sea, our bottom trawling resulted in a number of noteworthy findings (Table III). Since ten successful bottom trawls collected four new species, it is unlikely that Antarctic fish diversity in the Ross Sea is completely documented. Early collecting was focused on inshore localities in the vicinity of camps and bases. Set lines or traps were deployed through holes or tide cracks in sea ice, and sampling was limited to a small area. Later fishing operations at Cape Adare, McMurdo Sound and Terra Nova Bay, also conducted through the sea ice, yielded a maximum of seven (Miller 1961), 11 (Eastman & DeVries 1982) and 26 species, respectively (Vacchi *et al.* 1999). Previous bottom trawling in the Ross Sea employed small Blake trawls (DeWitt & Tyler 1960, Reseck 1961) as well as large commercial bottom trawls (Iwami & Abe 1981) that captured a maximum of 24 species. Both Blake and midwater trawls were used during the *Eltanin* cruises (DeWitt 1970a, 1971), and 45 species were captured during cruise 27 (Anonymous 1967). A number of benthic species were simply missed by these bottom and midwater trawls. Our use of a mid-sized otter trawl to scour the bottom on shallow banks and sponge beds may account for the new and uncommon species as well as the relatively high species diversity at some of our stations.

Statements of the "rarity" and distribution of certain species will need to be modified in the light of recent findings (Table III). For example, the bathydraconid *Cygnodraco mawsoni* is considered rare (Gon 1990) and was recently reported for the first time in the Ross Sea (Vacchi *et al.* 1991). Our two specimens are only the second record for this species in the Ross Sea. *Cygnodraco* has never been taken in traps or with hook and line in McMurdo Sound. It is, however, the most commonly collected bathydraconid at Terra Nova Bay where it is captured with gill nets (Vacchi *et al.* 1999). This suggests that it is more pelagic than many other bathydradconids and that the type of fishing gear used is an important factor in detecting its presence. *Cygnodraco* are also common in the Weddell Sea (Ekau 1990) and hundreds have been collected on the shelf of the Cosmonaut Sea at 67°S, 40–45°E (Pakhomov 1998).

The collection of the zoarcid *Ophthalmolycus bothriocephalus* is a new record for the Ross Sea and supports Anderson's (1994, p. 82) prediction that many coastal zoarcids will ultimately be found to have circum-Antarctic distributions. The same can be said for our documentation of the rajids *Bathyraja* sp. and *Bathyraja maccaini* in the Ross Sea, species also suspected to have wide distributions (Stehmann & Bürkel 1990, p. 88, 91). Finally, possible Ross Sea endemics include *Lycodichthys dearborni* and *Paraliparis devriesi* which are locally abundant in McMurdo Sound. While *Paraliparis andriashevi*, *P. fuscolingua* and *Pogonophryne albipinna* are also known only from the Ross Sea, they are represented by few specimens and are probably rare species with wide distributions.

Inshore/offshore differences in the Ross Sea fauna

Although inshore/offshore depth differences are minimal in the south-western Ross Sea, the fish fauna collected offshore with benthic trawls differs in taxonomic composition from the inshore fauna obtained by fishing and trapping through the sea ice. Drawing heavily on data from *Eltanin* cruise 27, DeWitt (1971) recognised a near-shore (sublittoral) group and two offshore groups, a near-shore (sublittoral)/continental shelf group and a continental shelf/upper slope group. These groupings reflect ecological preferences for some species, but may also represent some sampling artefact in that it is difficult to sample representative inshore habitats through small holes in the ice. For example, the benthic nototheniids *Trematomus bernacchii* and *T. hansoni* are frequently captured near stations but rarely taken offshore even though some offshore areas are shallower. On the other hand, bottom trawling documented the availability offshore of a large number of artedidraconids, bathydraconids and channichthyids that, while probably also living inshore near sponge beds or in deep water in McMurdo Sound, are not obtained by methods other than bottom trawling. For example, at Terra Nova Bay artedidraconids comprised only four of 3330 specimens collected with trammel nets, gill nets, long lines and traps (Vacchi *et al.* 1999). A major inshore/offshore faunal difference is seen farther north at the latitude of Cape Adare (71–72°S) where the endemic shelf fauna is supplemented by a mesopelagic oceanic component (DeWitt 1970a, maps on p. 307).

Benthic habitats in the Ross Sea

Although we made relatively few trawls, we sampled representative depths and habitats in the south-western Ross Sea including sponge beds, shallow banks and deep basins.

The shoals around Beaufort and Franklin islands, small volcanic islands near Stations 1 and 88, supported extensive beds of siliceous sponges and reasonably diverse fish communities (Table II). Previous collections in this area (Dearborn 1965, Bullivant & Dearborn 1967, Dayton *et al.* 1970, 1974) revealed that a large assemblage of invertebrates inhabits the sponge beds. These beds are long-lived, cover over 50% of the bottom in some localities and represent a large amount of benthic biomass with considerable vertical relief (Dearborn 1965, Dayton *et al.* 1974). In providing a topographically and trophically complex habitat, these sponge communities may be the polar equivalent of fringing coral reefs in tropical areas. The cavities of sponges provide sites for fish to spawn and hide (Konecki & Targett 1989, Ekau & Gutt 1991, Gutt & Ekau 1996, Barthel 1997). Sponges also furnish elevated sites for perching allowing fishes to monitor potential prey in an expanded field of vision encompassing both the bottom and the water column (Dayton *et al.* 1974).

Although trawling destroys the precise ecological relationships, our collections suggest that sponge beds or the area around beds provide habitat for small artedidraconids of the genus *Artedidraco*. For example, at Station 88 near Franklin Island, a single trawl yielded four species of *Artedidraco* including a new species as well as an undescribed spotted colour morph of *Artedidraco shackletoni* (Eastman & Eakin 1999).

The shelf of the Ross Sea becomes deeper from the north to the south-west due to landward deepening from isostatic depression. East of the Victoria Land coast, the shelf consists of a series of elongate, N–NE trending banks or shoals about 300 m deep. These are separated by basins at least 500 m deep. The banks are covered with current-winnowed sediments containing abundant calcareous shell debris (Dunbar *et al.* 1985, p. 297). In our trawls bryozoans were characteristic of this sediment. This is consistent with descriptions of the Pennell Bank assemblage as including calcareous bryozoans, gorgonaceans, stylasterine corals, tunicates, echinoderms, polychaetes and pycnogonids (Bullivant & Dearborn 1967). Our trawls at Stations 93 and 58 on the Pennell Bank captured 19 and 16 fish species, respectively. A new species of *Pogonophryne* was collected at Station 93 (Eakin & Eastman 1998). Fourteen species were taken at Station 46, although this locality was not on the shallowest portion of Mawson Bank, a bank to the west of the Pennell Bank.

Although species diversity and biomass were reduced, trawling in deep troughs was also productive. In the south-western Ross Sea these depressions, eroded by outlet glaciers, are parallel to the coast (Dunbar *et al.* 1985). In spite of damage to the net, the trawl in the Drygalski Basin (Station 34), the deepest locality in the Ross Sea at nearly 1200 m, produced a distinctive new species of *Paraliparis* characterized by pink colour on the anterior body, dark grey posteriorly and orange-flecks on the fins. This species may be endemic to this isolated innershelf depression. Another new species of *Paraliparis* was captured at Station 46 (depth 466 m). Although we obtained some invertebrates at deep localities, the small number of trawls at these sites precludes any general comments on the habitat diversity.

Size of the Ross Sea fauna

The northern boundary of the Ross Sea is the shelf break at 500 m and the slope falls off rapidly to bathyal depths. For zoogeographic purposes, however, we will consider the northern limit to include the water column and bottom to the 1000-m isobath. This falls near the latitude of Cape Adare at 71–72°S and is the transition zone between the shelf fauna and oceanic fauna (DeWitt 1970a). Using this more northerly boundary, the total ichthyofauna of the Ross Sea, comprising the endemic shelf fauna as well as mesopelagic oceanic species, includes at least 12 families and 80 species – 54 (67.5%) notothenioids and 26 (32.5%) non-notothenioids (Table VI). This count is based on the 47 species captured during the two cruises reported here plus the distribution records in *Fishes of the Southern Ocean* (Gon & Heemstra 1990), with the emendations noted in Table VI. Based on 113 midwater and bottom trawls made during *Eltanin* cruise 27, the size of the Ross Sea fauna had previously been estimated at 45 species (Anonymous 1967). No species list or area of coverage was provided, but the cruise track included trawling on the continental slope (Anonymous 1967, DeWitt 1971, p. 2) and was thus similar to the boundaries of the Ross Sea stated above.

Faunal comparison: Ross and Weddell seas

The Weddell Sea fish fauna is thoroughly documented by a sample of over 200 000 specimens collected with a variety of benthic and midwater trawls (Hubold 1992). This fauna is similar in size and taxonomic composition to that of the Ross Sea (Table VI). The Weddell fauna includes 83 species in 14 families, 69 (83%) notothenioid species and 14 (17%) non-notothenioid species. The pelagic element of the Weddell fauna consists of 10 species and, while dominated by *Pleuragramma,* also includes channichthyids, bathydraconids, liparids and macrourids (Hubold & Ekau 1987). Mesopelagic myctophids, bathylagids and paralepidids are not present on the shelf of the southern Weddell Sea, although they are represented farther north in the warmer (>-0.5°C) oceanic waters over the continental slope off Vestkapp (73°S). The pelagic fauna of the Ross Sea, also dominated by *Pleuragramma*, includes a number of the same non-notothenioid families (DeWitt 1970a). The cold (<-1.5°C) ice shelf water probably excludes these mesopelagic oceanic species from the southernmost parts of both the Weddell and Ross Seas. Moreover, since they live at depths >500 m and exhibit diel vertical migration, mesopelagic species may also be restricted from shelf waters by the relatively shallow bathymetry in some areas. The only exception is the paralepidid *Notolepis coatsi* which has been recorded far south in both the Ross (DeWitt 1970a) and Weddell Seas (Hubold 1992). Our inclusion of myctophids and other mesopelagic components in the Ross Sea fauna (Table VI) accounts for the higher percentage of non-notothenioids listed for the Ross Sea. This is not a significant biological difference as mesopelagic fishes are also part of the Weddell fauna (Hubold & Ekau 1987).

In a comparison of the Ross and Weddell seas, different sampling procedures will contribute to a portion of the qualitative and quantitative differences in the two faunas. Hubold's (1992, p. 49) faunal list and numbers of specimens

Table VI. Fishes of the Ross Sea including the shelf fauna and mesopelagic oceanic species living over the continental shelf and slope to a depth of 1000 m (northern limit of area is Cape Adare, approximately 71–72°S).

Family and species[a]
Rajidae
Bathyraja eatonii (Günther)*
Bathyraja maccaini Springer*
Bathyraja sp.*
Raja georgiana Norman
Bathylagidae
Bathylagus antarcticus Günther
Paralepididae
Notolepis coatsi Dollo[b]
Myctophidae
Electrona antarctica (Günther)[c]
Gymnoscopelus
braueri (Lönnberg)
nicholsi (Gilbert)
Krefftichthys anderssoni (Lönnberg)
Lampanyctus achirus Andriashev
Protomyctophum bolini (Fraser-Brunner)
Muraenolepididae
Muraenolepis microps Lönnberg*
Macrouridae
Macrourus whitsoni (Regan)
Liparidae
Careproctus polarsterni Duhamel[d]
Edentoliparis terraenovae (Regan)[e]
Paraliparis
andriashevi Stein & Tompkins
antarcticus Regan*
devriesi Andriashev
fuscolingua Stein & Tompkins
new sp. 1*
new sp. 2*
Zoarcidae
Lycodichthys dearborni (De Witt)*
Ophthalmolycus
amberensis Tomo, Marschoff & Torno*
bothriocephalus (Pappenheim)*
Pachycara brachycephalum (Pappenheim)*
Nototheniidae
Aethotaxis mitopteryx De Witt
Dissostichus mawsoni Norman
Gvozdarus svetovidovi Balushkin
Notothenia coriiceps Richardson[f]
Pagothenia
borchgrevinki (Boulenger)
brachysoma (Pappenheim)
Paranotothenia dewitti Balushkin[g]
Pleuragramma antarcticum Boulenger*
Trematomus
bernacchii Boulenger*
eulepidotus Regan*
hansoni Boulenger
lepidorhinus (Pappenheim)*
loennbergii Regan*
newnesi Boulenger
nicolai (Boulenger)
pennellii Regan*
scotti (Boulenger)*
tokarevi Andriashev
Artedidraconidae
Artedidraco
glareobarbatus Eastman & Eakin*
loennbergi Roule*
orianae Regan*
shackletoni Waite*
skottsbergi Lönnberg*
Dolloidraco longedorsalis Roule*
Histiodraco velifer (Regan)*
Pogonophryne
albipinna Eakin
barsukovi Andriashev
cerebropogon Eakin & Eastman*
dolichobranchiata Andriashev
lanceobarbata Eakin
macropogon Eakin
marmorata Norman*
mentella Andriashev*
permitini Andriashev
phyllopogon Andriashev*
scotti Regan*
Bathydraconidae
Akarotaxis nudiceps (Waite)*
Bathydraco
macrolepis Boulenger*
marri Norman*
scotiae Dollo
Cygnodraco mawsoni Waite*
Gerlachea australis Dollo*
Gymnodraco acuticeps Boulenger*
Prionodraco evansii Regan*
Racovitzia glacialis Dollo*
Vomeridens infuscipinnis (De Witt)*
Channichthyidae
Chaenodraco wilsoni Regan
Chionodraco
hamatus (Lönnberg)*
myersi De Witt & Tyler*
Cryodraco antarcticus Dollo*
Dacodraco hunteri Waite*
Neopagetopsis ionah Nybelin*
Pagetopsis
macropterus (Boulenger)*
maculatus Barsukov & Permitin*

* indicates species captured during cruises 96–6 and 97–9 of the RV *Nathaniel B. Palmer*.
[a]Species distributions and nomenclature based on *Fishes of the Southern Ocean* (Gon & Heemstra 1990) except for additions indicated by footnotes. Arrangement is phylogenetic for families (Nelson 1994) and alphabetical for genera within families and for species within genera
[b]DeWitt (1970a, p. 307)
[c]A single specimen collected 241 km offshore from Terra Nova Bay Station at about 74°55'S, 172°30'E (Guglielmo *et al.* 1998). As this is well south of the shelf break, the specimen is likely a stray
[d]Andriashev & Stein (1998)
[e]Formerly *Paraliparis terraenovae* (Andriashev 1990)
[f]A single specimen has been collected at Terra Nova Bay; this is probably the southern extent of its range in the Ross Sea (Vacchi *et al.* 1999)
[g]Species described by Balushkin (1990), formerly included in *Notothenia magellanica*. Represented by one specimen (USNM 171000) from surface waters of the eastern Ross Sea at Kainan Bay, 78°14´S, 161°55´W (DeWitt 1970b, 304–308)

https://doi.org/10.1017/S0954102099000383 Published online by Cambridge University Press

summarizes catches of all gears, including juvenile specimens taken with pelagic gear. Pelagic *Pleuragramma antarcticum* comprise 91% of the catch in the Weddell Sea (Hubold 1992). Although our collecting in the Ross Sea did not involve midwater trawling, *Pleuragramma* are known to dominate the midwater fauna of the Ross Sea by a similar percentage (DeWitt 1970a, p. 310). Large bottom trawls used in the Weddell Sea always captured *Pleuragramma* (Hubold 1992), probably because the nets were sufficiently open to collect on the way down and up from the bottom. Since *Pleuragramma* may avoid the smaller bottom trawls used in the Ross Sea, the numbers of *Pleuragramma* (Table II) cannot be compared between the two areas.

A similar problem may hinder comparison of data for some channichthyid species. The fact that *Chionodraco hamatus* is the most abundant channichthyid in our sample from the Ross Sea (Table II) may be due to its benthic behaviour and the ease with which it is captured by small bottom trawls. In the Weddell Sea *Chionodraco myersi*, a partially pelagic species (Ekau 1990), is the most abundant channichthyid (Hubold 1992). The small size of the sample of *Chionodraco* from the Ross Sea does not allow quantitative comparison; it is likely that this is not a true difference in abundance but rather a sampling effect. Since pelagic and benthopelagic trawls were not used in the Ross Sea, channichthyids with pelagic or partly pelagic lifestyles are probably under-represented in our collection.

Given that faunal differences may be attributable to different gear, the Shannon-Weaver diversity index (H') of 1.88 is higher for the Ross Sea (mean of nine stations, Table IV) than for the Weddell Sea and is the highest reported to date for any Antarctic area. This is surprising considering that larger gear was used in the Weddell Sea. The H' of 1.79 for the Weddell Sea is derived from catches with trawls having an approximately a 3-fold larger mouth opening than the 7.6-m trawl used in the Ross Sea (Hubold 1992). Thus when compared to other Antarctic or boreal regions, the Ross Sea fish fauna is diverse at the alpha (or local) level. Comparable H' values for the North Sea and Greenland are 1.05 and 1.24, respectively (Hubold 1992, p. 52).

There are similarities in the abundance data for benthic fishes in the Ross and Weddell Seas. In both areas *Trematomus scotti* is the most abundant nototheniid, *Dolloidraco longedorsalis* is the most abundant artedidraconid, *Bathydraco marri* is the most abundant bathydraconid and *Chionodraco* is the most abundant channichthyid genus (Hubold 1992). If additional data from the Weddell Sea are considered (Ekau 1990, Ekau & Gutt 1991, Gutt & Ekau 1996), *T. eulepidotus* is also an abundant species in both areas. On the other hand, some species common in the Weddell Sea, *C. mawsoni* and *G. australis* (Hubold 1992), were each represented by only a few specimens in collections from the Ross Sea. As *C. mawsoni* is active and semipelagic, the relatively small bottom trawls used in the Ross Sea may not have collected it. Also surprising is that *T. lepidorhinus*, a dominant species of the outer shelf of the Weddell Sea, occurs in water as shallow as 130 m in the Ross Sea (Table II).

Finally, it is worthwhile noting that the bottom fish fauna of the southern Scotia Sea, part of the West Antarctic Zoogeographic Province, links the high Antarctic Ross and Weddell Seas, components of the East Antarctic Province, with the Subantarctic Region to the north (Permitin 1977). For example, all four Ross Sea dominants are found in the southern Scotia Sea. In the formation of the Antarctic fish fauna, the Scotia Sea served as the point of entry for subantarctic elements into the Antarctic Region.

Concluding remarks

After a nearly a century of exploration, the fish fauna of the Ross Sea is not completely documented. The small collection summarized in this paper indicates that, even in relatively shallow water, knowledge of specific and intraspecific diversity in the Ross Sea fauna is incomplete, and that the discovery of new species is a frequent occurrence. Research on fish assemblages lags far behind what is known for the Weddell Sea, although our study indicates some similarities. Additional collecting should be a priority as knowledge of species diversity is a fundamental requirement for research on the ecology and evolution of the Antarctic fish fauna.

Acknowledgements

We thank Herb Baker, Art DeVries, Al Hickey, Chris Jensen, Bob Kluckhohn, Mike Lannoo, Jocelyn Turnbull and Captain Joe Borkowski and the crew of the RV *Nathaniel B. Palmer* for their assistance in collecting the specimens. Eric Anderson and Tony North reviewed the manuscript and provided many helpful comments. We are also grateful to Danette Pratt for producing Fig. 1. M.E. Anderson (RUSI), Karsten Hartel (MCZ), Susan Jewett (USNM) and J.D. McEachran (TCWC) facilitated the deposition of specimens into museum collections. The following specialists generously identified or verified our identifications of species: M.E. Anderson (zoarcids), R.R. Eakin (artedidraconids) and J.D. McEachran (rajids). Jim Barry, Rob Dunbar, Jackie Grebmeier and Mike Van Woert provided useful information on the bottom and oceanographic conditions at the fishing stations. This research was conducted under protocol LV95–02 as approved by the Institutional Animal Care and Use Committee of Ohio University. In collecting specimens, we adhered to provisions of the Antarctic Conservation Act that does not regulate marine fishes. For transhipping and importing specimens, we had permits from the New Zealand Ministry of Agriculture and Fisheries (Nos. A.S. 7015 and A.S. 7016) and the United States Fish and Wildlife Service (a cleared form 3–177). Supported by National Science Foundation grant OPP 94–16870.

References

ANDERSON, M.E. 1988. Studies on the Zoarcidae (Teleostei: Perciformes) of the Southern Hemisphere. I. The Antarctic and Subantarctic regions. *Antarctic Research Series*, **47**, 59–113.

ANDERSON, M.E. 1994. Systematics and osteology of the Zoarcidae (Teleostei: Perciformes). *Ichthyological Bulletin, J.L.B. Smith Institute of Ichthyology*, No. 60, 1–120.

ANDRIASHEV, A.P. 1980. A new liparid fish in McMurdo Sound. *Antarctic Journal of the United States*, **15**(5), 150.

ANDRIASHEV, A.P. 1990. Remarks on the taxonomic status of the Antarctic species *Paraliparis edentatus* (Liparididae) and description of a new genus. *Journal of Ichthyology*, **30**, 60–66.

ANDRIASHEV, A.P. 1987. A general review of the Antarctic bottom fish fauna. *In* KULLANDER, S.O. & FERNHOLM, B., *eds*. *Fifth congress of European ichthyologists, proceedings, Stockholm, 1985*. Stockholm: Swedish Museum of Natural History, 357–372.

ANDRIASHEV, A.P. & STEIN, D.L. 1998. Review of the snailfish genus *Careproctus* (Liparidae, Scorpaeniformes) in Antarctic and adjacent waters. *Contributions in Science, Natural History Museum of Los Angeles County*, No. 470, 1–63.

ANONYMOUS. 1967. *Eltanin* Cruise 27. *Antarctic Journal of the United States*, **2**(4), 150–152.

ANONYMOUS. 1968. *Eltanin* Cruise 32. *Antarctic Journal of the United States*, **3**(3), 74–75.

BALUSHKIN, A.V. 1990. Review of blue notothenias of the genus *Paranotothenia* Balushkin (Nototheniidae) with description of a new species. *Journal of Ichthyology*, **30**, 132–147.

BARTHEL, D. 1997. Fish eggs and pentacrinoids in Weddell Sea hexactinellids: further examples for the structuring role of sponges in Antarctic benthic ecosystems. *Polar Biology*, **17**, 91–94.

BOULENGER, G.A. 1902. Pisces. *In Report on the collections of natural history made in the Antarctic regions during the voyage of the* "Southern Cross". London: British Museum (Natural History), 174–189.

BOULENGER, G.A. 1907. Fishes. *National Antarctic Expedition 1901–1904, Natural History, Zoology*, **2**, 1–5.

BULLIVANT, J.S. & DEARBORN, J.H. 1967. The fauna of the Ross Sea: Part 5, general accounts, station lists and benthic ecology. *New Zealand Oceanographic Institute, Memoirs*, No. 32, 1–77.

CAPURRO, L.R.A. 1973. USNS *Eltanin's* 55 cruises – scientific accomplishments. *Antarctic Journal of the United States*, **8**(3), 57–61.

CHIU, T.S. & MARKLE, D.F. 1990. Muraenolepididae. *In* GON, O. & HEEMSTRA, P.C., *eds*. *Fishes of the Southern Ocean*. Grahamstown: J.L.B. Smith Institute of Ichthyology, 179–182.

DAYTON, P.K., ROBILLIARD, G.A. & PAINE, R.T. 1970. Benthic faunal zonation as a result of anchor ice at McMurdo Sound, Antarctica. *In* HOLDGATE, M.W., *ed*. *Antarctic ecology*, vol. I. London: Academic Press, 244–258.

DAYTON, P.K., ROBILLIARD, G.A., PAINE, R.T. & DAYTON, L.B. 1974. Biological accommodation in the benthic community at McMurdo Sound, Antarctica. *Ecological Monographs*, **44**, 105–128.

DEARBORN, J.H. 1965. *Ecological and faunistic investigations of the marine benthos at McMurdo Sound, Antarctica*. Ph.D. thesis, Stanford University, 238 pp. [Unpublished.]

DEWITT, H.H. 1962a. A new genus and species of zoarcid fish from McMurdo Sound, Antarctica. *Copeia*, No. 4, 819–826.

DEWITT, H.H. 1962b. A new Antarctic nototheniid fish with notes on two recently described nototheniiforms. *Copeia*, No. 4, 826–833.

DEWITT, H.H. 1964. A revision of the Antarctic genus *Racovitzia* (Pisces, Bathydraconidae). *Copeia*, No. 3, 496–506.

DEWITT, H.H. 1970a. The character of the midwater fish fauna of the Ross Sea, Antarctica. *In* HOLDGATE, M.W., *ed*. *Antarctic ecology, vol. 1*. London: Academic Press, 305–314.

DEWITT, H.H. 1970b. A revision of the fishes of the genus *Notothenia* from the New Zealand region, including Macquarie Island. *Proceedings of the California Academy of Sciences* (4th series), **38**, 299–339.

DEWITT, H.H. 1971. Coastal and deep-water benthic fishes of the Antarctic. *In* BUSHNELL, V.C., *ed*. *Antarctic Map Folio Series, Folio 15*. New York: American Geographical Society, 1–10.

DEWITT, H.H. 1985. Reports on fishes of the University of Southern California Antarctic Research Program, 1962–1968. 1. A review of the genus *Bathydraco* Günther (family Bathydraconidae). *Cybium*, **9**, 295–314.

DEWITT, H.H. & TYLER, J.C. 1960. Fishes of the Stanford Antarctic Biological Research Program, 1958–1959. *Stanford Ichthyological Bulletin*, **7**, 162–199.

DUNBAR, R.B., ANDERSON, J.B., DOMACK, E.W. & JACOBS, S.S. 1985. Oceanographic influences on sedimentation along the Antarctic continental shelf. *Antarctic Research Series*, **43**, 291–312.

EAKIN, R.R. 1981. Two new species of *Pogonophryne* (Pisces, Harpagiferidae) from the Ross Sea, Antarctica. *Antarctic Research Series*, **31**, 149–154.

EAKIN, R.R. & EASTMAN, J.T. 1998. New species of *Pogonophryne* (Pisces, Artedidraconidae) from the Ross Sea, Antarctica. *Copeia*, No. 4, 1005–1009.

EASTMAN, J.T. 1993. *Antarctic fish biology: evolution in a unique environment*. San Diego: Academic Press, 322 pp.

EASTMAN, J.T. 1999. Aspects of the biology of the icefish *Dacodraco hunteri* (Notothenioidei, Channichthyidae) in the Ross Sea, Antarctica. *Polar Biology*, **21**, 194–196.

EASTMAN, J.T. & CLARKE, A. 1998. Radiations of Antarctic and non-Antarctic fish. *In* DI PRISCO, G., PISANO, E. & CLARKE, A., *eds*. *Fishes of Antarctica: a biological overview*. Milan: Springer-Verlag Italia, 3–26.

EASTMAN, J.T. & DEVRIES, A.L. 1982. Buoyancy studies of notothenioid fishes in McMurdo Sound, Antarctica. *Copeia*, No. 2, 385–393.

EASTMAN, J.T. & EAKIN, R.R. 1999. Fishes of the genus *Artedidraco* (Pisces, Artedidraconidae) from the Ross Sea, Antarctica, with the description of a new species and a colour morph. *Antarctic Science*, **11**, 13–22.

EKAU, W. 1988. Ökomorphologie nototheniider Fische aus dem Weddellmeer, Antarktis. *Berichte zur Polarforschung*, **51**, 1–140. [English summary.]

EKAU, W. 1990. Demersal fish fauna of the Weddell Sea, Antarctica. *Antarctic Science*, **2**, 129–137.

EKAU, W. & GUTT, J. 1991. Notothenioid fishes from the Weddell Sea and their habitat, observed by underwater photography and television. *Proceedings of the National Institute of Polar Research Symposium on Polar Biology*, No. 4, 36–49.

GON, O. 1990. Bathydraconidae. *In* GON, O. & HEEMSTRA, P.C., *eds*. *Fishes of the Southern Ocean*. Grahamstown: J.L.B. Smith Institute of Ichthyology, 364–380.

GON, O. & HEEMSTRA, P.C., *eds*. 1990. *Fishes of the Southern Ocean*. Grahamstown: J.L.B. Smith Institute of Ichthyology, 462 pp.

GUGLIELMO, L., GRANATA, A. & GRECO, S. 1998. Distribution and abundance of postlarval and juvenile *Pleuragramma antarcticum* (Pisces, Nototheniidae) off Terra Nova Bay (Ross Sea, Antarctica). *Polar Biology*, **19**, 37–51.

GUTT, J. & EKAU, W. 1996. Habitat partitioning of dominant high Antarctic demersal fish in the Weddell Sea and Lazarev Sea. *Journal of Experimental Marine Biology and Ecology*, **206**, 25–37.

HUBOLD, G. 1991. Ecology of notothenioid fish in the Weddell Sea. *In* DI PRISCO, G., MARESCA, B. & TOTA, B., *eds*. *Biology of Antarctic fish*. Berlin: Springer-Verlag, 3–22.

HUBOLD, G. 1992. Zur Ökologie der Fische im Weddellmeer. *Berichte zur Polarforschung*, **103**, 1–157. [English summary.]

HUBOLD, G. & EKAU, W. 1987. Midwater fish fauna of the Weddell Sea, Antarctica. *In* KULLANDER, S.O. & FERNHOLM, B., *eds. Fifth congress of European ichthyologists, proceedings, Stockholm, 1985*, Stockholm: Swedish Museum of Natural History, 391–396.

IWAMI, T. & ABE, T. 1981. The collection of fishes trawled in the Ross Sea. *Antarctic Record, National Institute of Polar Research*, No. 71, 130–141.

KOCK, K.-H. 1992. *Antarctic fish and fisheries*. Cambridge: Cambridge University Press, 359 pp.

KOCK, K.-H., SCHNEPPENHEIM, R. & SIEGEL, V. 1984. A contribution to the fish fauna of the Weddell Sea. *Archiv für Fischereiwissenschaft*, **34**, 103–120.

KONECKI, J.T. & TARGETT, T.E. 1989. Eggs and larvae of *Nototheniops larseni* from the spongocoel of a hexactinellid sponge near Hugo Island, Antarctic Peninsula. *Polar Biology*, **10**, 197–198.

LEVITON, A.E., GIBBS JR, R.H., HEAL, E. & DAWSON, C.E. 1985. Standards in herpetology and ichthyology: Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. *Copeia*, No. 3, 802–832.

MCGINNIS, R.F. 1982. Biogeography of lanternfishes (Myctophidae) south of 30°S. *Antarctic Research Series*, **35**, 1–110.

MILLER, R.G. 1961. Notothenioid fishes from Cape Hallett and Ross Sea, Antarctica. *New Zealand Journal of Science*, **4**, 664–668.

NELSON, J.S. 1994. *Fishes of the world* (3rd edition). New York: John Wiley & Sons, 600 pp.

PAKHOMOV, E.A. 1998. Diet of two Antarctic dragonfish (Pisces: Bathydraconidae) from the Indian sector of the Southern Ocean. *Antarctic Science*, **10**, 55–61.

PERMITIN, YU.YE. 1977. Species composition and zoogeographical analysis of the bottom fish fauna of the Scotia Sea. *Journal of Ichthyology*, **17**, 710–726.

REGAN, C.T. 1913. The Antarctic fishes of the Scottish National Antarctic Expedition. *Transactions of the Royal Society of Edinburgh*, **49**, 229–292.

REGAN, C.T. 1914. Fishes. *British Antarctic ("Terra Nova") Expedition 1910, Natural History Report, Zoology*, **1**, 1–54.

RESECK JR, J. 1961. A note on fishes from the Ross Sea, Antarctica. *New Zealand Journal of Science*, **4**, 107–115.

SCHWARZBACH, W. 1988. Die Fischfauna des östlichen und südlichen Weddellmeeres: geographische Verbreitung, Nahrung und trophische Stellung der Fischarten. *Berichte zur Polarforschung*, **54**, 1–94. [English summary.]

STEHMANN, M. & BURKEL, D.L. 1990. Rajidae. *In* GON, O. & HEEMSTRA, P.C., *eds. Fishes of the Southern Ocean*, Grahamstown: J.L.B. Smith Institute of Ichthyology, 86–97.

STEIN, D.L. & TOMPKINS, L.S. 1989. New species and new records of rare Antarctic *Paraliparis* fishes (Scorpaeniformes: Liparididae). *Ichthyological Bulletin, J.L.B. Smith Institute of Ichthyology*, No. 53, 1–8.

VACCHI, M., GRECO, S. & LA MESA, M. 1991. Ichthyological survey by fixed gears in Terra Nova Bay (Antarctica). Fish list and first results. *Memorie di Biologia Marina e di Oceanografia*, **19**, 197–202.

VACCHI, M., LA MESA, M. & GRECO, S. 1999. Some ecological features of the coastal fish community of Terra Nova Bay. *IN* FARANDA, F., GUGLIELMO, L. & IANOVA, A., *eds. Ross Sea Ecology: Italian Antarctic Expeditions (1987–1995)*, Milan: Springer-Verlag Italia.

WAITE, E.R. 1911. Antarctic fishes. *British Antarctic Expedition 1907–1909, Reports on the Scientific Investigations, Biology*, **2**, 11–16.