NOTES ON THE BATHYPELAGIC FAUNA OF THE SEAS AROUND SOUTH AFRICA

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INTRODUCTION

The bathypelagic fauna of the sea may be regarded as comprising those pelagic animals which dwell during daylight hours in the darkness of the mid-depths of the ocean, below the depth to which visible light penetrates. At night most of these bathypelagic animals migrate vertically upwards and some actually reach the surface. The present study was limited to animals obtained with a mid-water trawl, with netting of half-inch stretched mesh size, fishing down to a depth of approximately 500 metres. The area covered included southern African coastal waters and the South West Indian Ocean, as shown in Figure 1.

Until recently collecting in the bathypelagic zone was hampered by lack of suitable equipment. Available devices were based either on some sort of frame net, such as beam trawls and scaled up plankton nets, or adaptations of otter trawls, where the shearing effect of doors takes the place of the frame, as in the case of the Petersen young fish trawl and Parr's (1934) triangular trawl. Both types suffered from a number of disadvantages, the major ones being that to maintain depth they had to be towed slowly. They required a great length of cable to reach even moderate depths and, because of the slow speed of towing, they had to be large to capture the faster swimming animals and were therefore extremely unwieldy.

The Isaac-Kidd mid-water trawl (Devereaux & Winsett 1953) developed at the Scripps Institution of Oceanography, has to a large extent overcome many of the faults of earlier types. The diving action of the wide V-shaped steel depressor vane enables fast towing and the trawl maintains its fishing depth within wide margins of speed. If the ship's speed is increased, the additional drag on the cable tends to lift the net, but the depressing action of the vane also increases. The vane used in the present programme was slightly modified to increase its strength.

In 1960 the South African Museum began a survey of the biology of tuna in South African waters, including a study of their stomach contents. To make a reference collection of the possible forage organisms of the tuna a ten ft. Isaacs-Kidd mid-water trawl was obtained. This trawl proved so efficient for the collection of bathypelagic animals that its use was continued after the end of the tuna survey and it is hoped to continue this programme further to cover more intensively the seas around South Africa. Little work in this field had been done in these seas apart from the early trawling surveys by the S.S. *Pieter Faure* (1897–1907) and S.S. *Pickle* (1920–1929) and a few stations worked by the Danish Dana expedition (1928–1930).

The stations at which successful trawls have so far been made are shown on the chart

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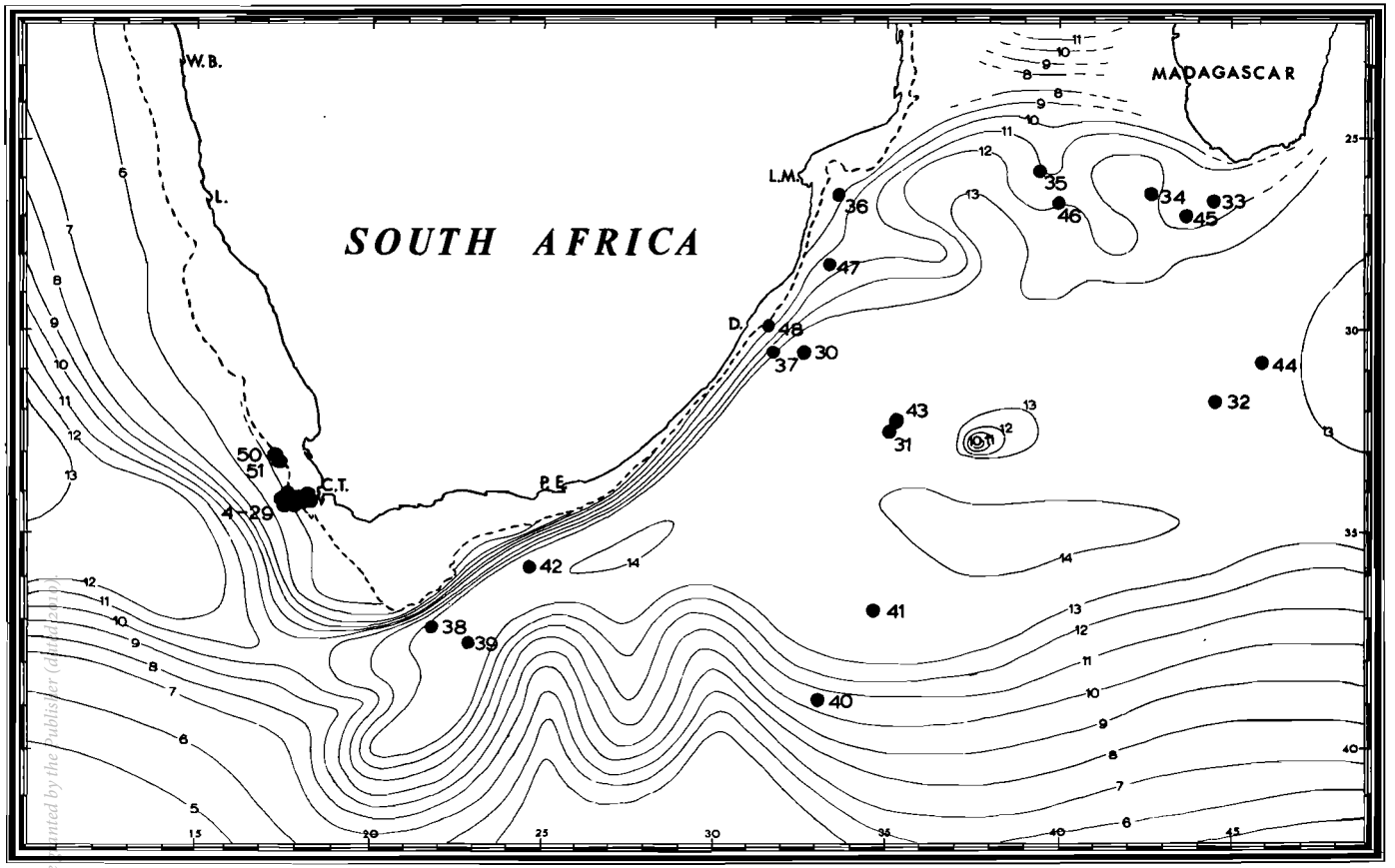

FIGURE 1. Chart showing positions of mid-water trawl stations and isotherms (°C) at the 500 metre depth level. The isotherms were plotted on the basis of published data from several sources enumerated in the text. To allow for seasonal and other variations recorded by different vessels at different times the isotherms have been smoothed in several places. The continental margin at the 500 metre level has been indicated by a broken line.

(Figure 1) and station list (Table 1), and were in the following six general areas: (1) Two trawls off Saldanha Bay (IK 50, 51) at estimated fishing depths (E.F.D.) of 120 and 280 metres. (2) Twenty-four trawls (IK 4–7 and 10–29) west of the Cape Peninsula at varying depths between 10 and 500 metres. (3) Three trawls south-east of Cape Agulhas (IK 38, 39 and 42) at E.F.D. 500 metres. (4) Five trawls east of Natal (IK 30, 36, 37, 47, 48) at E.F.D. 200 and 500 metres. (5) Nine trawls in the south-west Indian Ocean (IK 31–35, 43–46) E.F.D. 500 metres. (6) Two trawls (IK 40, 41) just north of the subtropical convergence, E.F.D. 500 metres. The estimated fishing depth has been assumed to be equal to half the length of cable out. King and Iversen (1961) give a table for estimating fishing depth at different wire angles, but the slightly modified trawl used in this programme appeared to go deeper. The depth factor of half cable out was confirmed on several occasions when the net touched the bottom. In the first three trawls the gear hit the bottom and no catch was made and the bottom was also touched at Station IK 16.

Except for certain of the trawls made off the Cape Peninsula and one off Durban, all were made at night. As the trawls made in daylight caught extremely few bathypelagic invertebrates and fish, and as time available for trawling was limited, especially in the Indian Ocean, it was felt that a large collection in this poorly known area was of the first importance.

Many of the species found are new records for the Indian Ocean, although usually known from the Atlantic and Pacific Oceans whereas off the Cape Peninsula and west coast, where there has long been much active scientific collecting and a large deep-sea trawling industry, few new South African records have been obtained.

It must be emphasised that this is a general report, and that more detailed taxonomic reports on the various animal groups will be published later. In the following account the first author is responsible for the work on invertebrates and hydrography, and the second author is responsible for the work on fishes. A preliminary report on this work was read at the Oceanography Symposium in Durban in 1963 (Penrith & Grindley 1963).

TABLE 1. STATION LIST

IK Station Number	Date	Time	Estimated Fishing Depth (Metres)	Water Depth (Metres)	Position (Approx.)
4	1/10/60	1415–1515	200	600	N.W. of Cape Town
5	23/ 4/61	1500–1515	10	2,000	West of Slangkop*
6	23/ 4/61	1800–2030	200	1,600	West of Cape Town
7	25/ 5/61	1900–2045	250	300	West of Slangkop
10	7/ 9/61	1310–1510	20	140	West of Slangkop
11	7/ 9/61	1820–2220	40	130	West of Slangkop
12	7–8/ 9/61	2230–0630	40	140	West of Slangkop
13	8/ 9/61	1345–1545	500	2,000	West of Slangkop
14	8/ 9/61	1830–2230	500	2,000	West of Slangkop

IK Station Number	Date	Time	Estimated Fishing Depth (Metres)	Water Depth (Metres)	Position (Approx.)	
15	8–9/ 9/61	2300–0300	15	400	West of Slangkop	
16	9/ 9/61	0345–0745	350	350	West of Slangkop	
17	9/ 9/61	1115–1315	400	1,600	West of Slangkop	
18	9/ 9/61	1800–2200	400	1,600	West of Slangkop	
19	11–12/11/61	2200–0700	100	200	West of Slangkop	
20	12/11/61	0800–1300	100	200	West of Slangkop	
21	12/11/61	1330–1800	10	200	West of Slangkop	
22	12–13/11/61	1830–0600	15	200	N.W. of Slangkop	
23	14–15/11/61	2000–0600	250	500	West of Slangkop	
24	15/11/61	0600–1200	100	300	West of Slangkop	
25	15/11/61	1200–1900	400	600	West of Slangkop	
26	15–16/11/61	1900–0600	400	700	West of Slangkop	
27	16/11/61	0600–1200	100	600	West of Slangkop	
28	16/11/61	1200–1900	15	300	West of Slangkop	
29	16/11/61	1900–2200	15	150	West of Slangkop	
30	10/ 8/62	1430–1700	500	3,120	30° 30′	32° 33′
31	12/ 8/62	0300–0500	500	1,320	32° 30′	35° 08′
32	15/ 8/62	0145–0440	500	1,880	31° 44′	44° 35′
33	17/ 8/62	2200–0420	500	2,900	26° 38′	44° 28′
34	18/ 8/62	1825–2125	500	4,540	26° 30′	42° 40′
35	19/ 8/62	1825–0745	500	4,320	25° 55′	39° 30′
36	21/ 8/62	1800–0725	500	710	26° 30′	33° 40′
37	23/ 8/62	1815–0330	200	930	30° 30′	31° 45′
38	7/11/62	2100–2340	500	3,300	37° 10′	21° 50′
39	10/11/62	2036–2345	500	5,750	37° 40′	22° 59′
40	13–14/11/62	2230–0050	500	5,000	38° 50′	33° 08′
41	14/11/62	2030–2300	500	3,920	36° 47′	34° 40′
42	17–18/11/62	2030–0015	500	4,810	35° 42′	24° 40′
43	14/ 2/63	2100–0330	500	1,390	32° 20′	35° 15′
44	19–20/ 2/63	2045–0005	500	1,980	30° 47′	45° 50′
45	21–22/ 2/63	2037–0045	500	4,310	27° 00′	43° 30′
46	22/ 2/63	2035–2337	500	4,760	26° 40′	40° 00′
47	24/ 2/63	2030–2335	500	1,820	28° 12′	33° 24′
48	25–26/ 2/63	2130–0040	500	810	29° 52′	31° 36′
50	17–18/ 4/63	1835–0710	280	450	33° 10′	17° 20′
51	18–19/ 4/63	1850–0700	120	400	33° 10′	17° 20′

*Slangkop is on the west coast of the Cape Peninsula (Pos. 34° 09′ S., 18° 19′ E.).

TABLE 2. DISTRIBUTION OF INVERTEBRATE SPECIES

	Off West Coast	West of Cape Peninsula	S.E. of Agulhas	Off Natal Coast	S.W. Indian Ocean	Stations 40 and 41
COELENTERATA						
Siphonophora		+	+	+	+	
*Periphylla periphylla (Péron and Leseur)		+	+		+	+
Unidentified medusae	+	+	+	+	+	+
CTENOPHORA						
Beroe sp.	+	+				+
Pleurobrachia sp.		+				
CHAETOGNATHA						
Sagitta bipunctata Quoy and Gaimard						+
*Sagitta gazellae Ritter-Zahony		+				
Sagitta hexaptera d'Orbigny				+		
Sagitta lyra? Krohn			+			
Sagitta sp. indet.					+	
ANNELIDA						
Polychaete larvae		+			+	
CRUSTACEA						
Hoplocarida						
Larval stages	+	+	+		+	
Amphipoda						
Cystisoma spp.		+	+		+	+
Hyperia galba Mont.		+				
Oxycephalus sp.		+				
Phronima sedentaria (Forskal)	+	+	+	+	+	
Phrosina semilunata Risso	+	+	+	+	+	+
Platyscelus c.f. armatus	+	+	+	+	+	
Scina c.f. crassicornis		+			+	
Scinids (other)			+	+		
Streetsia sp.		+				
Mysidacea						
Gnathophausia ingens (Dohrn)		+			+	
Euphausiacea						
*Euphausia longirostris Hansen		+				
Euphausia lucens Hansen	+	+				

	Off West Coast	West of Cape Peninsula	S.E. of Agulhas	Off Natal Coast	S.W. Indian Ocean	Stations 40 and 41
Euphausia recurva Hansen		+				
Euphausia similis var. armata Hansen	+	+				
Euphausia spinifera Sars			+	+		+
Nematobrachion flexipes (Ortman)	+					
Nematoscelis megalops Sars	+	+	+	+	+	+
Nematoscelis tenella Sars		+				
Stylocheiron abbreviatum Sars		+		+	+	
Stylocheiron maximum Hansen	+	+	+	+	+	+
Thysanoëssa gregaria Sars					+	
Thysanopoda acutifrons Holt and Tatt.	+		+	+	+	+
*Thysanopoda cristata Sars				+		
Thysanopoda monocantha Ortman	+	+	+	+	+	
Thysanopoda obtusifrons Sars		+			+	+
*Thysanopoda orientalis Hansen	+			+	+	+
*Thysanopoda pectinata Ortman			+		+	+
*Thysanopoda tricuspidata Milne-Edwards				+		
Juvenile Euphausiids	+	+		+		
Decapoda						
Acanthephyra haeckelii (von Martens)						+
Acanthephyra quadrispinosa Kemp	+	+	+	+	+	+
Aristeomorpha foliacea (Risso)				+		
Chlorotocus crassicornis (Costa)	+					
Funchalia woodwardi Johnson		+	+	+	+	
Gennadas gilchristi Calman			+	+		+
Gennadas spp.	+	+		+	+	+
*Notostomus longirostris Bate		+				
Notostomus juv.				+		
Oplophorus grimaldi Coutière					+	
*Oplophorus typus Bate					+	
Oplophorus juv.		+				
*Pasiphaea acutifrons Bate		+			+	+
Plesionika longirostris Borradaile			+		+	
Plesiopenaeus nitidus Barnard					+	
Sergestes arcticus Kröyer	+	+				+

	Off West Coast	West of Cape Peninsula	S.E. of Agulhas	Off Natal Coast	S.W. Indian Ocean	Stations 40 and 41
Sergestes armatus Kröyer	+	+	+	+	+	
Sergestes gloriosus Stebbing	+	+	+	+	+	+
Sergestes phorcus Faxon		+		+	+	+
Sergestes splendens Sund	+	+		+	+	
Sergestes spp.	+	+	+	+	+	+
Solenocera africanum Stebbing		+				
Systellaspis debilis (Milne Edwards)	+	+	+	+	+	+
Decapod larvae						
Eryoneicus larva					+	
Megalopa larva		+			+	
Phyllosoma larva	+	+	+	+	+	
Puerulus larva		+				
Other decapod larvae		+		+	+	+
MOLLUSCA						
Pteropoda						
Cavolinia tridentata Forskal		+	+			
Heteropoda						
Carinaria lamarcki Péron and Leseur		+				
Pterotrachea coronata Forskal		+		+		
Pterotrachea hippocampus Philippi		+				
Pterotrachea scutata Gegenbaur	+			+	+	
Cephalopoda						
Spirula spirula Linnaeus				+	+	
Other cephalopods	+	+	+	+	+	+
PROTOCHORDATA						
Larvacea						
Oikopleura sp.		+				+
Thaliacea						
Doliolum spp.	+	+	+	+	+	+
Pyrosoma sp.	+	+		+	+	
Salpa spp.		+	+	+	+	+

* New records for South Africa

TABLE 3. DISTRIBUTION OF FISH SPECIES

	Off West Coast	West of Cape Peninsula	S.E. of Agulhas	Off Natal Coast	S.W. Indian Ocean	Stations 40 and 41
Alepocephalidae						
Xenodermichthys socialis Valliant				+		
Bathylagidae						
Bathymacrops macrolepis Gilchrist		+				
†*Bathylagus microcephalus Norman			+	+		+
Gonostomidae						
†*Margrethia obtusirostra Jespersen and Taning			+		+	+
Gonostoma elongatum Gunther		+	+	+	+	+
Vinciguerria sanzoi Jespersen and Taning ..				+		+
†Photichthys argenteus Hutton			+	+		
Diplophos taenia Gunther					+	
Maurolicus muelleri (Gmelin)	+	+				+
*Valenciennellus tripunctulatus Esmark ..	+	+				
Sternoptychidae						
*Argyropelecus aculeatus Cuvier and Valenc. ..	+		+	+	+	+
†*Argyropelecus amabilis Ogilby			+		+	
Argyropelecus hemigymnus Cocco	+	+	+	+	+	+
Polyipnus spinosus Gunther				+		
Chauliodontidae						
Chauliodus sloani Schneider				+	+	+
Stomiatidae (sensu lato)	+	+	+	+	+	
Idiacanthidae						
Idiacanthus niger Regan						+
Idiacanthus fasciola Peters				+		
Evermanellidae						
†*Evermanella balbo Risso			+	+	+	
Myctophidae						
*Electroma subasper (Gunther)	+					
*Electroma tenisoni (Norman)		+				
*Hygophum hygomi Lutken		+	+	+	+	+
*Hygophum hanseni (Taning)		+				
Hygophum reinhardti (Lutken)			+		+	
*Benthosema fibulata (Gilbert and Crane) ..				+		

	Off West Coast	West of Cape Peninsula	S.E. of Agulhas	Off Natal Coast	S.W. Indian Ocean	Stations 40 and 41
Myctophum evermanni Gilbert				+		
Myctophum humboldti (Risso)		+				
Diaphus gemellari (Cocco)					+	
*Diaphus brachycephalus Taning		+				
†*Diaphus dofleini Zugermayer				+		
Diaphus effulgens Goode and Bean				+	+	
*Diaphus diadematus Taning					+	
†*Diaphus fulgens Brauer		+	+	+		
†*Diaphus lutkeni Brauer			+		+	
†*Diaphus theta Eigenmann and Eigenmann	+		+	+		+
Lampanyctodes hectoris (Gunther)	+	+				
Lampanyctus niger Gunther					+	
†*Lampanyctus leucosaurus Eigenmann and Eigenmann					+	
†*Lampanyctus superlateratus Parr					+	
†Lampanyctus alatus Goode and Bean	+	+	+	+	+	+
*Lampanyctus pyrosobolus Alcock						+
Ceratoscopelus townsendi (Eigenmann and Eigenmann)				+		+
Neoscopelidae						
†*Notoscopelus elongatus (Costa)			+	+	+	
Scoleopsis multipunctatus Brauer		+	+	+	+	
Cetomimidae						
Rondeletia bicolor Goode and Bean						+
Nemichthyidae						
Nemichthys scolopacea Richardson		+		+	+	
Avocettina infans (Gunther)			+	+	+	+
Serrivomer beani Gill				+	+	
Gadidae						
Physiculus capensis Gilchrist	+					
Malacocephalus laevis (Lowe)	+					
Bregmaceros macclellandi Thompson					+	
*Melanonus gracilis Gunther					+	+
Merluccius capensis Castlenau	+	+				

	Off West Coast	West of Cape Peninsula	S.E. of Agulhas	Off Natal Coast	S.W. Indian Ocean	Stations 40 and 41
Trachipteridae						
Regalecus glesne (Ascanius)		+		+		
Trachipterus arcticus (Brunnich)		+				
Melamphaidae						
*Melamphaes microps Gunther			·		+	
*Sio nordenskjoeldi (Lonnberg)			+	+	+	
Zeidae						
Zeus faber Linn		+				
Oreosoma atlanticum Cuvier		+				
Scombropidae						
†Howella sherborni (Norman)				+		
Caragidae						
Trachurus trachurus Linn		+				
Bramidae						
Brama brama					+	
†*Collybus drachme Snyder				+		
†*Taractes asper Lowe				+	+	
Champsodontidae						
Champsodon capensis Regan		+				
Chiasmodontidae						
Chiasmodon niger Thompson		+				
Brotulidae						
†*Brotulotaenia crassa Parr					+	
Callionymidae						
Paracallionymus costatus (Boulenger)	+					
Gempylidae						
Thrysites atun (Euphrasen)		+				
Trichiuridae						
Benthodesmus tenuis Gunther				+	+	
Lepidopus caudatus (Euphrasen)	+	+				
Scomberidae						
Scomber japonicus Houttyn		+				
Scorpaenidae						
Helicolenus maculatus (Cuvier)		+				

* New South African records † New Indian Ocean Records

SYSTEMATIC NOTES ON SPECIES

Lists of the species of invertebrates (Table 2) and fishes (Table 3) taken during this survey have been given above, but it must be emphasised that these are not complete lists. Detailed taxonomic reports on the major groups will be published separately.

Among the Coelenterata was the characteristic bathypelagic medusa *Periphylla periphylla* (Péron and Leseur) which has been described under a number of different names throughout the world. Kramp (1961) has, however, indicated that there is only a single species with an extensive synonymy. This is apparently the first record of this species from the South African region.

Sagitta gazellae is a species new to the South African list but the other *Sagitta* species are previously known from South Africa (Heydorn 1959).

The Amphipoda obtained were mostly not typical bathypelagic forms and may have been caught near the surface, but two species of the rare and interesting bathypelagic genus *Cystisoma* are represented.

Some of the specimens of *Phronima sedentaria* were in their transparent gelatinous "houses". Others, however, were found inside *Pyrosoma* colonies and there were a number of houses that were clearly the remains of *Pyrosoma* colonies that had the zooids missing to varying degrees, until they formed a normal smooth, gelatinous house. *Phronima* is normally reported to live in the tests of salps and doliolids.

The giant mysid *Gnathophausia ingens* (Dohrn) is a remarkable example of evolutionary convergence, resembling closely the bathypelagic prawns. It is large and red and has a long serrated rostrum like a bathypelagic prawn and it is many times the size of a normal mysid. This genus has seven abdominal segments instead of six. Typical mysids have seven abdominal segments as embryos, of which the last two fuse, while in *Gnathophausia* they remain separate (Manton 1928). The specific identification of the *Gnathophausia* specimens proved problematical as they showed a wide range of size and proportions, particularly in the length of the rostrum and carapace spines. The forms they appeared to resemble were regarded by Fage (1943) as synonymous and grouped under the name *ingens*.

Various characters such as the lengths of the rostrum and carapace spines, and the numbers of teeth on the rostrum and antennal scale were compared graphically with total lengths. These morphometric data when plotted indicated that all our material could be regarded as a single species, *G. ingens*, and that the striking differences in appearance were merely due to allometric growth.

Amongst the Euphausiacea four species of Thysanopoda, (*T. cristata*, *T. orientalis*, *T. pectinata* and *T. tricuspidata*) as well as *Euphausia longirostris* appear to be new records for South Africa, although *T. cristata* is the only species not included in Boden's (1951) review which includes records from neighbouring regions.

The Decapoda have not yet all been identified and there appear to be some new records for South Africa in several genera. Earlier records of bathypelagic prawns obtained by trawling around South Africa are included in Barnard's (1950) monograph, while Lebour (1954) has discussed material from the Benguela current off South West Africa.

Further work is required particularly on the species of the genus *Sergestes*. The *Notostomus* obtained has been referred to *N. longirostris* Bate although the rostrum is relatively shorter than in the small original specimen. The specimens of *Plesionika* obtained have been referred to *P. longirostris* but the rostral teeth are rather more widely spaced than is normal for the species. The erioneicus larva appears to be the form described as "*Kempi*" which is the larva of *Polycheles typhlops*.

Most of the phyllosoma and puerulus larvae obtained off the west coast appeared to be *Jasus lalandii* as described by Gilchrist (1916), whereas the phyllosomata obtained elsewhere represented other genera and species.

The small squid *Spirula spirula* (Linnaeus) is generally regarded as rare throughout the world although its characteristic spiral shell is found on beaches everywhere. It was, however, found in large numbers in the southern Mozambique channel by the *Dana* expedition (Bruun 1943). This expedition also obtained a single juvenile specimen from south of Cape Point and there is a specimen in the South African Museum believed to be from Table Bay. During this survey we obtained live specimens of *Spirula* from three stations off Natal and in the South West Indian Ocean.

Pelagic molluscs other than Cephalopoda included the pteropod *Cavolinia tridentata* and four species of Heteropoda. One specimen of *Pterotrachea coronata* was exceptionally large, measuring approximately 300 mm. in total length, which is larger than any known to Tesch (1949).

The list of the fishes identified (Table 3) does not include Stomiatid fishes (*sensu lato*), larval fishes, and some of the myctophid fishes, which still require study.

Schultz (1961) in his review of the hatchet fishes states that *Argyropelecus hemigymnus* is confined to the Mediterranean and Atlantic while in the Indo-Pacific it is replaced by the related *A. intermedius*, and he places *A. hemigymnus* recorded off South Africa by Gilchrist (1913), Barnard (1925) and Smith (1949) in the synonomy of *A. intermedius*. Unfortunately no Cape or Indian Ocean specimens of this fish were available to Schultz at the time. All specimens found in this survey having a barbed dorsal blade, clearly fitted *A. hemigymnus* rather than *A. intermedius*. Both seem to be very closely related and rather variable species. It was also surprising that although large numbers of *Argyropelecus* species were taken, only one specimen of the related genus *Polyipnus* was caught.

A single specimen of *Brotulotaenia* was found and has been assigned to *B. crassa*; the two known species *B. nigra* Parr (1933) and *B. crassa* Parr (1934) are very similar, but the present species seems to be closer to *crassa*. This catch is not only the first record of the genus outside the Caribbean but is also believed to be only the fourth example of the genus ever found.

Bathylagus microcephalus was formerly only recorded from the South Atlantic. These further records indicate that it is present in the southern Indian Ocean also.

Smith (1949) placed *Lampanyctus alatus* in the synonymy of *L. pusillus* although they can be separated easily by the presence of a luminous organ at the adipose fin in *alatus*. All the specimens recorded here were clearly *alatus* rather than *pusillus*. All examples in the collections of the South African Museum on which Barnard's (1925) records of *alatus* were based were re-examined and found to be correctly identified as *alatus*.

Included in the table are a few species taken off the Cape Peninsula which do not form part of the bathypelagic fauna, but are rather the juveniles of common Cape fishes. It is presumed that they were caught while the net was being hauled. They are mostly the juveniles of the bottom-dwelling species *Lepidopus caudatus*, *Merluccius capensis* and *Helicolenus maculatus*, but other juveniles included *Trachurus trachurus* and *Scomber japonicus*.

One of the most unexpected results of the survey has been the complete absence of *Cyclothone* species. Of all bathypelagic fish genera this is considered to be the most abundant in number of individuals (Marshall 1954), yet apart from one doubtful and badly damaged specimen, no fish of this genus were found. Most *Cyclothone* are small, but the posterior end of the trawl was lined with half inch stretched mesh netting which captured many other very small species of fishes.

HYDROGRAPHY OF THE ENVIRONMENT

Most specimens obtained in this survey were caught at night at a depth of about 500 metres, and it is well known that most bathypelagic animals migrate down to a deeper level diurnally. To understand their distribution it is thus necessary to know something of the hydrographic conditions in the seas around South Africa at a depth of 500 metres and perhaps a few hundred metres below this. Conditions at these depths differ greatly from surface conditions and data on their hydrography is limited and scattered in the literature. It has, however, been possible to obtain a picture of the hydrographic environment of this bathypelagic fauna by extracting data from the following published reports: Clowes and Deacon (1935), Dietrich (1935) Clowes (1950), Zoutendyk (1960), le Pichon (1960), Trotti and Welsh (1961), Fukase (1962), Kort (1962), Menaché (1963), Orren (1963), Zoutendyk (1963), Taft (1963), Darbyshire (1963), Darbyshire (1964), Shipley and Zoutendyk (1964), Station lists in the Discovery Reports, and Annual Reports of the Division of Sea Fisheries.

In the south-western part of the Indian Ocean there are three main water masses that concern us (Figure 2). In vertical sections Agulhas water, which, following the delimitations of Darbyshire (1964), may be regarded as water above the 17° C isotherm, extends down to approximately 300 metres below the main stream of the Agulhas current. Further offshore, however, the Agulhas water does not extend down so far, and near the coast it may be considerably less than 100 metres thick. The southern limit of the Agulhas water varies but the 17° C isotherm reaches the surface between about 35° and 40° south, where Fukase (1962) has described the "Agulhas Convergence".

Below the Agulhas water is the South Indian Central Water which may be regarded as extending down from the 17° C isotherm to the 5° C isotherm. Salinities in this water mass lie between approximately $35{\cdot}5^{\circ}/_{\circ\circ}$ and $34{\cdot}5^{\circ}/_{\circ\circ}$, and there is an approximately linear temperature-salinity gradient within this range. It extends down to about 1,300 metres in the open ocean but only to about 800 metres at the continental margin (Darbyshire 1964). The origin of this water mass is problematical, probably involving sinking at the subtropical convergence, northward drift, and mixing with adjoining water along its path (Orren 1963). In the south of

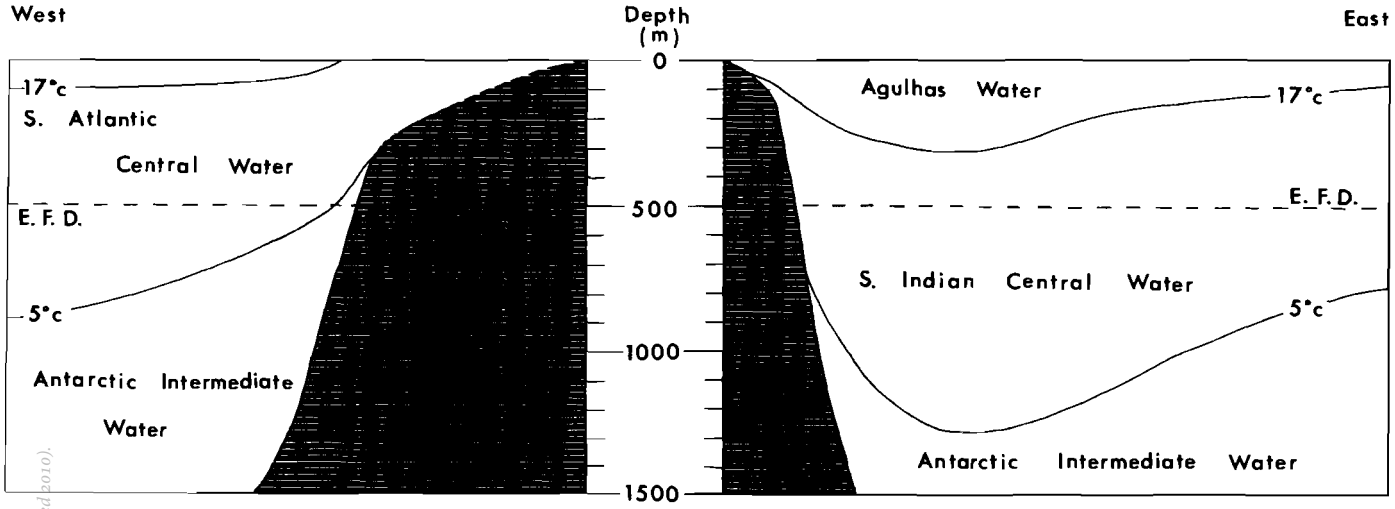

FIGURE 2. Diagrammatic hydrographic section to show the general pattern of the water masses present down to a depth of 1,500 metres off the west and east coasts of South Africa, in the South Atlantic and South-west Indian Oceans. The broken line E.F.D. represents the Estimated Fishing Depth of the 500 metre deep trawls. The offshore water above 17°C in the West (not labelled) is part of the South Atlantic Gyral.

the region covered it lies closer to the surface and may extend down to a depth of less than 700 metres. Under the Agulhas Current, Le Pichon (1960), Kort (1962) and Taft (1963) have suggested that the South Indian Central Water has a strong westward component and tends to follow the Agulhas water. In the north of the region covered the South Indian Central Water lies closer to the surface and the work of Menaché (1963) has shown that it extends steeply upwards to within about 150 metres of surface at the divergence at 24° S in the southern end of the Mozambique channel.

Under the South Indian Central Water lies the Antarctic Intermediate Water which may be regarded as being below 5° C and which is characterised by a marked salinity minimum. This water originates by sinking just north of the Antarctic Convergence, and drifts northwards under the South Indian Central Water, except under the Agulhas Current where it may also drift towards the south-west.

In the south-eastern Atlantic, west of the Cape, the same pattern of three water masses is present. The warm waters of the South Atlantic Gyral, which may also be delimited by the 17° C isotherm, are only found offshore and in the area concerned only extend down about 100 metres.

The Central Water, here known as the South Atlantic Central Water, occupies the layer between about 100 and about 700 metres. Clowes (1950) showed that there was a well marked linear T-S relationship between 6° C, 34·4‰ and 16° C, 35·5‰ and that the same T-S characteristics were found in water along the west coast right up to the surface indicating upwelling of South Atlantic Central Water.

The Antarctic Intermediate Water delimited by the 5° C isotherm and characterised by the salinity minimum is usually below 700 metres but marked fluctuations occur. It may be below 1,000 metres, or as suggested by the data of Trotti and Welsh (1961), may come up to less than 300 metres over the shelf in August, 1959).

It is thus apparent that all the mid-water catches which were made at a depth of about 500 metres were in Central Water (South Indian and South Atlantic). Shallower hauls made near the coast would also have been in the same water mass owing to the tendency of the Central Water to approach the surface at the coast. Even during the hours of daylight when these bathypelagic animals may migrate downwards a few hundred metres they would in most areas remain within the Central Water.

Conditions within the Central Water mass vary considerably at any particular level in different parts of the area concerned. Using all the data available it was possible to get a picture of the temperature distribution at the 500 metre level over the region covered by this survey (Figure 1). The isotherms were plotted on the basis of published data from a number of sources enumerated above. To allow for seasonal and other variations recorded by different vessels at different times the isotherms were smoothed in a few places. Periodic variations appear to occur particularly in the area south of the Cape Province (Darbyshire 1963), in the eddies in the northern and southern parts of the South West Indian Ocean (Darbyshire 1964), and in the extent of the upwelled water west of the Cape Peninsula (Trotti and Welsh, 1961), and further north (Hart and Currie 1960, Stander 1964). Over most of the South West Indian Ocean temperatures at the 500 metre level range between 12° and 14° C. Where the Antarctic Inter-

mediate Water is not far below, temperatures at the 500 metre level are lower. In the south they may be as low as 8° C at 38° S. Near the east coast of South Africa the isotherms curve up sharply so that near the continental margin temperatures fall in places to 10°C and well below, particularly off the southern coast. The low temperature shown in Figure 1 at a point in the middle of the South West Indian Ocean (33° 02′ S., 37° 35′ E.) is based on a single series of observations at Station NIOE-102 (Shipley and Zoutendyk, 1964). This anomaly has not been found in any other data and it may not be a normal feature. Off the south-west Cape coast in the region of upwelling temperatures are even lower. The data of Trotti and Welsh (1961) for this area show considerable seasonal fluctuations in the temperature at the 500 metre level between 8° C and 5° C and occasional incursions of Antarctic Intermediate Water onto the shelf probably occur.

Regional differences in the bathypelagic fauna may be associated in some way with the variations of temperature at the 500 metre level described above. They might also be related to the depth of the Antarctic Intermediate Water, because many bathypelagic animals are capable of making extensive vertical migrations, and where this lower water mass is closest, animals from it may be represented in catches.

NOTES ON DISTRIBUTION OF FISHES AND INVERTEBRATES

Several interesting features in the distribution of the invertebrates and fishes represented in these collections appear worthy of discussion although it would be premature to draw final conclusions.

Vertical distribution

Hauls made during daylight were remarkably poor. No prawns at all were obtained, only two euphausiids (and those at 500 metres) and few fish. Even at night most prawns and euphausiids appeared only in the deep hauls at 500 metres. *Solenocera africanum* was however obtained at night at only 100 metres and *Funchalia woodwardi* came up to only 20 metres at night. Amphipods, salps and medusae appeared in both day and night hauls but many of these should perhaps be regarded as epipelagic, as should many of the juvenile fishes.

Regional distribution

It has been shown above that the Central Water Mass extends throughout the region concerned so that many species may be expected to occur throughout the region. In fact few species have so far been found in all areas, but this may be due to differences in depth of the Central Water Mass in different parts of the region. Many species were not obtained in the warmer central area of the South West Indian Ocean (Figure 1), where they may occur deeper down than 500 metres. Several species obtained only in the upwelled water off the Cape Peninsula and West Coast may also be more widely distributed at greater depths.

Amongst the prawns most species were found in both the Atlantic and Indian Oceans. Five species (*Plesiopenaeus nitidus, Aristeomorpha foliacea, Gennadas gilchristi, Acanthephyra haeckelii* and *Plesionika longirostris*) were found only in the Indian Ocean samples while *Solenocera africanum* was only obtained from the Atlantic. *Acanthephyra haeckelii* only appeared in the extreme south (Station 40). The closely related form *A. acanthitelsonis* was recorded by Lebour (1954) in the Benguela Current off South West Africa. *Sergestes arcticus* also appeared in the extreme south and otherwise only in the cold upwelled water west of the Cape. *Gnathophausia ingens* appeared only in the colder regions, and it is interesting to note that Fage (1941) found that this species in the north Atlantic was limited to regions below a temperature of 10° C at 600 metres. (There are large areas above 13° C at this depth in the N. Atlantic also.)

Many fish also showed very wide ranges, and the scattered incidence of many rarer species suggests that they are probably also widely if sparsely distributed. A distinct distribution pattern was however evident in the presence of vast numbers of *Maurolicus muelleri* and large numbers of *Lampanyctodes hectoris* in the cold water off the west coast and their almost complete absence in the Indian Ocean. Only one example of *M. muelleri* was found in the extreme south (IK 40). Inshore off the east coast it appeared that the place of *M. muelleri* was taken by *Scoleopsis multipunctatus* which was not found off the west coast and only once off the Cape Peninsula.

Two specimens of *Sagitta gazellae* were obtained in the cold upwelled water west of the Cape Peninsula. David (1955) in his study of the distribution of *Sagitta gazellae* found that it was limited to waters south of the region of the subtropical convergence. David (1955), however, did find specimens in some hauls just north of the subtropical convergence where subantarctic water was present below the surface. He remarked that they might penetrate further north in deeper waters but regarded this as unlikely as a large number of hauls in areas further north had not revealed a single specimen. The present specimens thus represent a very interesting extension of the range of this characteristically antarctic and subantarctic species. The other *Sagitta* species appearing in Table 2 represent too few specimens to draw any conclusions as to their regional distribution.

Spirula spirula which is generally regarded as a tropical species was only found in the northern part of the region.

Amongst the amphipods *Phrosina semilunata* was found throughout the area and *Phronima sedentaria* and a species of *Platyscelus* appeared everywhere except in the extreme south.

One of the most striking distributional features was the great abundance of *Euphausia similis* var. *armata* off the west coast and its complete absence elsewhere. Numerically there were far more of this species than of all the other euphasiids together. It occurred associated with very large numbers of the fish *Maurolicus muelleri*. It would appear that this strikingly distinct population was related to the cold water upwelling and possibly to the presence of Antarctic Intermediate Water in this area. It is interesting that Nepgen (1957) in his study of the euphausiids of this same region west of the Cape found that *Euphausia similis* var. *armata* "did not occur in large numbers or often". It seems probable that this anomaly is due to his work being based mainly on shallower plankton hauls, taken mainly in daylight.

Euphausia spinifera appeared at almost all of the southern stations in this survey and otherwise only inshore off Durban. This species is known to occur in waters north of the subtropical convergence while it is replaced by a closely related species *E. longirostris* south of the convergence (Boden 1951). The occurrence of *E. spinifera* off Durban is not surprising as the temperatures at the 500 metre level are much lower close to the coast than in the regions offshore. *E. spinifera* occurred at most of the southerly stations while the prawns *Sergestes arcticus* and *Acanthephyra haeckelii* only appeared at the most southerly station (IK 40) and west of the Cape in the case of *S. arcticus*. In both these areas the Antarctic intermediate water is not far below 500 metres and they may have migrated up from this water. These prawns are larger and perhaps migrate further than *Euphausia spinifera*, which would probably be confined to the Central Water Mass. However more work is required before the apparent differences in distribution pattern can be explained.

It is interesting that *Euphausia longirostris* was obtained in the cold upwelled water west of the Cape Peninsula. Boden (1951) regarded it as characteristically subantarctic and reported that it was rarely encountered north of the subtropical convergence, and he did not find it in the Benguela Current off South West Africa either (Boden, 1955).

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SUMMARY

The results of a mid-water trawling survey for bathypelagic fauna in the seas around South Africa and in the South West Indian Ocean is described. The programme was carried out by the South African Museum using a 10 ft Isaacs-Kidd mid-water trawl down to a depth of 500 m from several vessels. A station list gives details of the trawling stations and the species

of invertebrates and fishes obtained are listed for six areas resulting from a grouping of these stations. Many species new to the South African fauna list and new to the Indian Ocean fauna list are recorded. Brief systematic notes have been included where necessary. The hydrography of the environment of the bathypelagic fauna at a depth of 500 m is discussed on the basis of data extracted from published reports and the temperature distribution at this level is described. Outstanding features of the distribution of species are discussed in relation to the hydrographic background. Distribution patterns appear to be related largely to the depth of the central water mass and some interesting records appear where this water upwells to near the surface. Two species, *Sagitta gazellae* and *Euphausia longirostris*, previously regarded as characteristically sub-antarctic are recorded in the cold upwelled water west of the Cape.

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ADDENDUM

Since this paper was written a number of other publications have appeared which have some bearing on this work. A paper on towing characteristics of plankton-sampling gear by Aron, W., Ahlstrom, E. H., Bary B.McK., Bé, A. W. H., and Clarke, W. D. (*Limnol.Oceanogr.*10: 333–340, 1965) shows that the fishing depth of an Isaacs-Kidd midwater trawl is reduced considerably with increased towing speed. In the present work low towing speeds of the order of two knots were used. Alvarino, A., in his review on chaetognaths (*Oceanogr. Mar. Biol. Ann. Rev.* 3: 115–194, 1965) records *Sagitta gazellae* north of the subtropical convergence in deep waters, reaching 21° S. in the Pacific and 36° S. in the Indian Ocean. De Decker, A. and Mombeck, F. J. in their preliminary report on the planktonic Copepoda (*Invest. Rep. Div. Sea Fish. S.Afr.* 51: 10–67, 1965) show clearly there are groups of species of Copepoda associated with the water masses at different levels in the south west Indian Ocean, and that species previously considered Atlantic or Sub-Antarctic occur frequently, as bathypelagic species in this region. The work of Visser, G. A. and van Niekerk, M. M. on ocean currents and water masses at 1,000, 1,500 and 3,000 metres in the south west Indian Ocean (*Invest. Rep. Div. Sea. Fish. S. Afr.* 52: 1–46, 1965) gives data for these deeper levels which may be compared with the conditions at 500 metres described in the present work.