Echinoderms of the Rockall Trough and adjacent areas

I. Crinoidea, Asteroidea and Ophiuroidea

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Synopsis

Four species of crinoid, forty species of sea star and thirty-six species of brittle star are identified from recent benthic sampling in the deep-sea area to the west of the British Isles, mainly in the Rockall Trough. Of these, one crinoid, nine asteroids and eighteen ophiuroids have not previously been recorded from the seas around the British Isles. The zoogeographical distribution and bathymetric range of each species is summarised as far as was previously known giving the range extension provided by the present records. Notes are also provided on observations on the biology, including the mode of reproduction, of the more abundant species. The records demonstrate a broader bathymetric distribution of juvenile and post larval stages than of the adult populations of some of the more abundant species. A greater diversity of species also is evident from the small number of samples from the western, probably current-swept, side of the Rockall Trough compared with the much larger number of samples collected at similar depths in the east.

Introduction

The cruises of H.M.S. *Lightning* and H.M.S. *Porcupine* in the years 1868–70 in the Rockall Trough and other deep sea areas lying west of the British Isles and of the Iberian peninsula asserted beyond doubt the presence of life at great depths.

Echinoderm data figure prominently in the literature (Lyman, 1882; Sladen, 1889; Thomson, 1872, 1873, 1874) resulting from these cruises that covered deep-sea areas not subsequently sampled by the *Challenger* expedition of 1872–76. Many useful echinoderm records also were made on the cruises of H.M.S. *Knight-Errant* in 1880 and H.M.S. *Triton* in 1882 in the course of exploration of the submarine sill bounding the northern end of the Rockall Trough that was subsequently named the Wyville Thomson Ridge (e.g. Hoyle, 1884; Sladen, 1882). To the authors' knowledge most subsequent records of deep-sea echinoderm fauna from this area have emanated from opportunistic extension into deeper water of essentially coastal sampling programmes. Notable among these are the cruises of the Irish Fisheries Department cruiser *Helga* in the early years of this century. Exploration of some of the outer banks and shelf areas around the northern perimeter of the Rockall Trough has also resulted in many useful records of fauna including echinoderms (Danielssen & Koren, 1884; Süssbach & Breckner, 1911; Pawsey & Davis, 1924). Other records have come from stations worked in the Rockall area in the course of wider ranging cruises, such as those of the *Thor,* and the *Michael Sars* in her Atlantic expedition of 1910, and more recently

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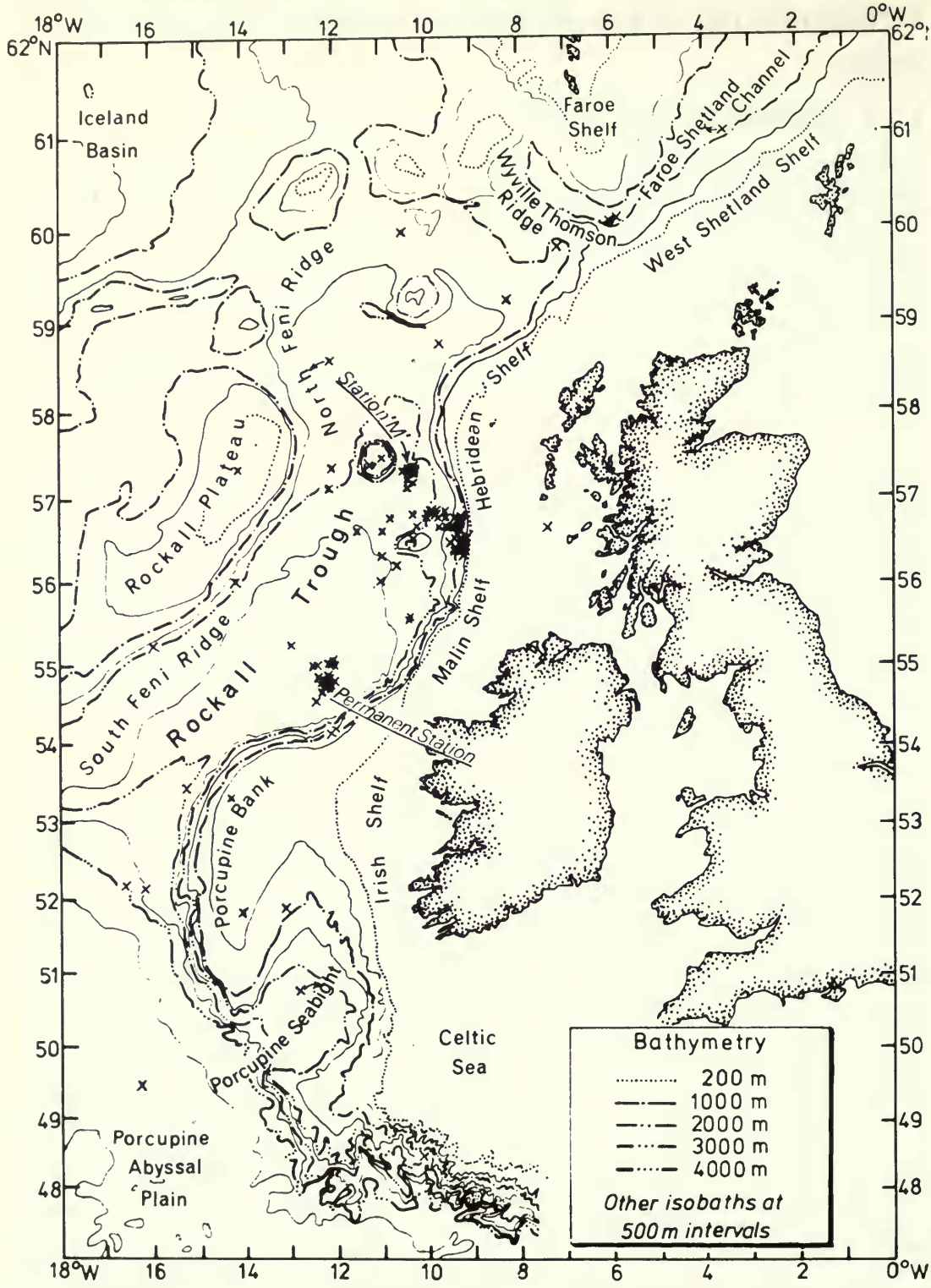

Fig. 1 Bathymetric chart showing Permanent Station and Station 'M' and all other sample stations (crosses).

by the French oceanographic ship *Jean Charcot* in 1969 (Cherbonnier & Sibuet, 1973) and in 1976 (INCAL expedition). Although not extending into the Rockall Trough the sampling in neighbouring northern areas by the major expeditions to the N. Atlantic such as the cruises of the *Voeringen* Norwegian North Atlantic Expedition, 1876–1878, and the Danish *Ingolf* expedition, 1895–6, should also be mentioned in this context.

The Scottish Marine Biological Association (SMBA) in 1973 initiated exploratory biological sampling in the deep waters off the continental shelf as an extension of programmes previously restricted to coastal environments. Subsequent sampling has been undertaken on many cruises mainly on R.R.S. *Challenger,* in the Rockall Trough and the adjacent continental slope off the west of Scotland (Fig. 1). This work has been focussed both as quantitative and seasonal sampling programmes in studies of the structure, reproduction and growth of midwater, demersal and benthic populations of fish and invertebrate species at fixed stations located in the middle and southern part of the Rockall Trough (Gordon, 1979; Gage *et al.,* 1980; Gage & Tyler, 1982; Kawaguchi & Mauchline *a, b* in press). In addition there has been some sampling by the SMBA in the N Feni Ridge and Wyville Thomson Ridge areas, in the Porcupine Seabight and its vicinity, and on the S. Feni Ridge (Fig. 1).

The present account concentrates on echinoderm distributions, because populations of echinoderm species are conspicuous elements of the benthic megafauna, animals easily recognisable in sea-bed photographs). Echinoderms hence may frequently occur in the fish catches obtained by coarse-meshed demersal trawls, such as the large commercial pattern Granton trawl and smaller single-warp otter trawls. Echinoderms also dominate catches made with a 3-metre wide Agassiz trawl. This trawl has been deployed in poor weather that has precluded use of other gear employed in the SMBA programme, such as the epibenthic sled (Hessler & Sanders, 1967) and USNEL 0·25 m^2 Box Corer (Hessler & Jumars, 1974) both of which have the advantage of retaining benthic larval and juvenile stages, many of them identifiable. Results indicate that juvenile stages may extend over a wider area and greater bathymetric range than that of adult specimens caught in trawls. Therefore in describing the distributional range of species it is necessary to distinguish records where larvae or juveniles only have been found from those where adults have been collected, and where presumably a breeding population exists.

In the present account, the geographical distribution and bathymetric data relating to both past and present records are interpreted in relation to the properties and dynamics of water masses, which are relatively well known in the Rockall area (Ellett & Martin, 1973; Roberts, 1975).

Station List

Details of bottom sampling stations worked are listed below. Except for benthic stations 118–125 that were worked from R.R.S. *Shackleton,* all stations listed were worked from R.R.S. *Challenger.* Benthic stations and fishing stations, worked by Dr J. D. M. Gordon of SMBA, are listed separately in chronological order with a prefix to the station number that identifies gear used: ES, epibenthic sled; ABD, anchor-box dredge; SBC, $\frac{1}{4}$ m^2 spade box corer; AT, 3 m Agassiz trawl; GT, Granton trawl; SWT, single warp otter trawl, OTSB, semi-balloon otter trawl 14. For most fish trawls (GT, SWT and OTSB) depths at mid-point of haul is unknown and total depth range of haul is given.

St. No.	Date	Position (at mid-point of track on bottom if applicable)	Depth (m)
Benthic stations			
ES 2	4 June 1973	55°04′N, 12°33′W	2857
ABD 3	5 June 1973	56°46′N, 10°02′W	1997

St. No.	Date	Position (at mid-point of track on bottom if applicable)	Depth (m)
ES 4	5 June 1973	56°52′N, 10°01′W	1993
ES 5	5 June 1973	56°43′N, 09°05′W	763
ES 6	2 July 1973	55°03′N, 12°29′W	*c.* 2900
ES 8	3 July 1973	54°45′N, 12°10′W	*c.* 2900
ES 10	4 July 1973	56°37′N, 10°04′W	*c.* 2540
ES 12	20 Sept. 1973	56°49′N, 10°15′W	2076
ES 14	22 Sept. 1973	56°45′N, 09°46′W	1770
ES 15	22 Sept. 1973	56°44′N, 09°28′W	1632
ES 18	22 Sept. 1973	56°44′N, 09°20′W	1392
ES 20	23 Sept. 1973	56°46′N, 09°17′W	1271
ES 22	23 Sept. 1973	56°41′N, 09°11′W	1028
ES 23	23 Sept. 1973	56°37′N, 09°10′W	704
ABD 24	23 Sept. 1973	56°36′N, 09°13′W	810
ABD 25	23 Sept. 1973	56°36′N, 09°10′W	588
ES 27	3 Nov. 1973	54°40′N, 12°16′W	*c.* 2880
ES 28	3 Nov. 1973	54°33′N, 12°21′W	*c.* 2880
ES 31	20 Mar. 1975	55°03′N, 12°01′W	2875
ES 32	22 Mar. 1975	55°16′N, 12°58′W	2871
ES 33	23 Mar. 1975	56°35′N, 07°16′W	148
ES 34	10 May 1975	56°36′N, 11°30′W	2515
SBC 46	6 Sept. 1975	55°04′N, 12°06′W	2875
SBC 47	6 Sept. 1975	55°03′N, 12°03′W	2875
SBC 48	7 Sept. 1975	55°04′N, 12°04′W	2875
SBC 49	7 Sept. 1975	55°03′N, 12°05′W	2875
SBC 50	7 Sept. 1975	55°04′N, 12°02′W	2875
SBC 51	7 Sept. 1975	55°03′N, 12°03′W	2875
ES 52	15 Nov. 1975	*c.* 54°40′N, 12°16′W	2886
ES 53	15 Nov. 1975	*c.* 54°40′N, 12°16′W	2886
ES 54	17 Nov. 1975	*c.* 54°40′N, 12°16′W	2878
ES 55	17 Nov. 1975	*c.* 54°40′N, 12°16′W	2878
ES 56	1 Mar 1976	*c.* 54°40′N, 12°16′W	2886
ES 57	21 June 1976	*c.* 54°41′N, 12°23′W	*c.* 2900
SBC 58	21 June 1976	54°41′N, 12°17′W	*c.* 2900
ES 59	21 June 1976	54°40′N, 12°20′W	*c.* 2900
SBC 60	23 June 1976	56°35′N, 11°03′W	*c.* 2500
SBC 61	23 June 1976	57°08′N, 12°09′W	*c.* 2000
SBC 62	23 June 1976	57°28′N, 11°00′W	*c.* 610
SBC 63	25 June 1976	56°37′N, 09°49′W	*c.* 1800
SBC 64	26 June 1976	56°38′N, 09°29′W	*c.* 1400
SBC 65	26 June 1976	56°39′N, 09°40′W	*c.* 1600
SBC 66	26 June 1976	56°39′N, 09°23′W	*c.* 1200
SBC67	26 June 1976	56°39′N, 09°13′W	*c.* 1000
SBC 68	1 July 1976	58°42′N, 09°43′W	*c.* 1800
AT 68A	2 July 1976	59°13′N, 08°01′W	1330
ES 69	2 July 1976	59°39′N, 07°12′W	1050
ES 87	4 July 1976	61°13′N, 03°59′W	1050
ES 90	7 July 1976	60°05′N, 05°55′W	1040
AT 90A	7 July 1976	60°05′N, 05°57′W	1040
ES 99	9 July 1976	60°00′N, 10°35′W	1160
ES 105	10 July 1976	58°27′N, 12°35′W	1600
AT 107A	11 July 1976	57°07′N, 12°06′W	*c.* 2000
ES 111	22 Oct. 1976	54°40′N, 12°16′W	2886
ES 112	25 Oct. 1976	55°12′N, 15°50′W	1900

St. No.	Date	Position (at mid-point of track on bottom if applicable)	Depth (m)
ES 113	27 Oct. 1976	57°18′N, 14°07′W	168
AT 114	28 Oct. 1976	56°48′N, 10°54′W	2400
ES 115	28 Oct. 1976	56°29′N, 10°22′W	1000
ES 118	28 Jan. 1977	54°39′N, 12°14′W	2910
AT 119	28 Jan. 1977	54°40′N, 12°14′W	2908
ES 120	28 Jan. 1977	54°39′N, 12°16′W	2911
AT 121	29 Jan. 1977	54°37′N, 12°09′W	2910
ABD 125	30 Jan. 1977	52°56′N, 12°58′W	394
ES 129	7 April 1977	54°39′N, 12°17′W	*c.* 2900
AT 131	7 April 1977	55°03′N, 12°20′W	*c.* 2900
AT 132	8 April 1977	53°14′N, 14°16′W	225
AT 133	8 April 1977	52°30′N, 14°03′W	315
AT134	9 April 1977	54°05′N, 12°06′W	800
ES 135	7 Aug. 1977	54°39′N, 12°16′W	2900
ES 137	22 Feb. 1978	54°34′N, 12°19′W	2900
AT 138	23 Feb. 1978	55°31′N, 10°24′W	2450
AT 139	24 Feb. 1978	55°35′N, 10°25′W	2450
ES 140	13 April 1978	54°40′N, 12°16′W	2912
AT 141	14 April 1978	54°44′N, 12°14′W	2909
ES 143	14 April 1978	54°41′N, 12°14′W	2892
AT 144	19 April 1978	57°13′N, 10°20′W	2240
ES 147	2 June 1978	54°36′N, 12°19′W	2921
SBC 150	3 June 1978	54°37′N, 12°13′W	2916
AT 151	6 June 1978	57°21′N, 10°22′W	2175
ES 152	13 Jan. 1979	54°42′N, 12°02′W	2900
AT 153	15 Jan. 1979	57°20′N, 10°27′W	2200
AT 154	21 May 1979	57°08′N, 10°22′W	2264
SBC 155	4 Aug. 1979	48°27′N, 10°20′W	1330
AT 157	6 Aug. 1979	49°31′N, 13°11′W	1752
AT 161	8 Aug. 1979	50°52′N, 12°22′W	2055
AT 162	9 Aug. 1979	51°50′N, 13°00′W	992
SBC 163	10 Aug. 1979	54°41′N, 12°24′W	2910
ES 164	11 Aug. 1979	54°37′N, 12°22′W	2925
SBC 166	12 Aug. 1979	57°07′N, 10°20′W	2274
AT 167	13 Aug. 1979	57°05′N, 10°25′W	2300
AT 169	28 Feb. 1980	54°40′N, 12°17′W	2910
AT 171	3 Mar 1980	57°16′N, 10°17′W	2225
ES 172	27 May 1980	54°39′N, 12°17′W	2910
AT 175	28 May 1980	57°19′N, 10°16′W	2210
ES 176	28 May 1980	57°15′N, 10°26′W	2245
AT 177	29 May 1980	57°18′N, 10°16′W	2220
ES 178	29 May 1980	56°33′N, 09°17′W	997
ES 180	15 Sept. 1980	54°42′N, 12°11′W	2886
AT 181	16 Sept. 1980	57°19′N, 10°28′W	2220
ES 182	16 Sept. 1980	57°19′N, 10°28′W	2170
ES 184	17 Sept. 1980	57°14′N, 10°24′W	2260
ES 185	10 April 1981	54°44′N, 12°15′W	2907
AT 186	12 April 1981	57°22′N, 10°19′W	2170
ES 190	16 Aug. 1981	54°41′N, 12°18′W	2898
AT 191	17 Aug. 1981	56°00′N, 13°58′W	2190
AT 192	18 Aug. 1981	57°21′N, 12°02′W	1862
AT 194	18 Aug. 1981	57°27′N, 11°10′W	630
AT 195	18 Aug. 1981	57°23′N, 10°27′W	2190

St. No.	Date	Position (at mid-point of track on bottom if applicable)	Depth (m)	
ES 197	19 Aug. 1981	57°21′N, 10°29′W	2220	
AT 198	15 Oct. 1981	57°15′N, 10°20′W	2215	
ES 200	6 Feb. 1982	57°20′N, 10°32′W	2220	
Fishing stations			mean	range
GT 1	19 Mar. 1975	56°37′N, 09°09′W	713	650–805
GT 2	19 Mar. 1975	56°37′N, 09°15′W	1027	972–1084
GT 7	3 Sept. 1975	56°28′N, 09°11′W	689	640–780
GT 8	3 Sept. 1975	56°25′N, 09°20′W	1054	1024–1072
GT 11	7 April 1976	56°32′N, 09°17′W	1014	934–1054
GT 13	8 April 1976	56°33′N, 09°07′W	523	508–543
GT 14	9 April 1976	56°33′N, 09°12′W	761	713–788
GT 15	24 June 1976	56°28′N, 09°11′W	720	672–740
GT 16	25 June 1976	56°25′N, 09°20′W	958	916–992
GT 17	25 June 1976	56°28′N, 09°27′W	1237	1190–1296
SWT 10	5 Aug. 1977	56°51′N, 09°58′W	2018	2000–2030
SWT 11	6 Aug. 1977	56°03′N, 11°05′W	2530	2500–2560
SWT 12	9 Aug. 1977	53°25′N, 15°24′W	2996	2980–3000
SWT 13	9 Aug. 1977	52°04′N, 16°09′W	3463	3425–3500
SWT 15	11 Aug. 1977	49°30′N, 16°12′W	4810	constant
AT 1	19 Oct. 1977	56°24′N, 09°12′W	750	—
AT 3	20 Oct. 1977	56°23′N, 09°18′W	1000	—
SWT 16	21 Oct. 1977	56°12′N, 10°57′W	2441	2400–2490
SWT 17	22 Oct. 1977	56°49′N, 09°55′W	1977	1940–2020
SWT 18	22 Oct. 1977	56°46′N, 09°42′W	1809	1785–1845
SWT 27	4 May 1978	54°26′N, 12°52′W	2965	constant
SWT 32	31 Oct. 1978	56°48′N, 09°56′W	2006	1995–2020
OTSB 51001	30 April 1981	54°45′N, 12°24′W (starting position)	2890	2885–2895

List of Species

Class Crinoidea
- Order Millericrinida
  - Family Bathycrinidae
    - *Rhizocrinus lofotensis* M. Sars
- Order Comatulida
  - Family Pentametrocrinidae
    - *Thaumatocrinus jungerseni* A. H. Clark
  - Family Antedonidae
    - *Heliometra glacialis* (Owen)
    - *Hathrometra sarsi* (Düben & Koren)

Class Asteroidea
- Order Paxillosida
  - Family Luidiidae
    - *Luidia sarsi* (Düben & Koren)
    - *Luidia ciliaris* (Philippi)
  - Family Astropectinidae
    - *Astropecten irregularis* (Pennant)
    - *Bathybiaster vexillifer* (Wyville Thomson)
    - *Plutonaster bifrons* (Wyville Thomson)
    - *Dytaster insignis* (Perrier)
    - *Psilaster andromeda* (Müller & Troschel)
    - *Psilaster patagiatus* Sladen
  - Family Porcellanasteridae
    - *Porcellanaster ceruleus* Wyville Thomson
    - *Hyphalaster inermis* Sladen
- Order Notomyotida
  - Family Benthopectinidae
    - *Benthopecten simplex* (Perrier)
    - *Pectinaster filholi* Perrier
    - *Pontaster tenuispinus* (Düben & Koren)
- Order Valvatida
  - Family Odontasteridae

Hoplaster spinosus Perrier
Odontaster sp.
Family Radiasteridae
?*Radiaster tizardi* (Sladen)
Family Goniasteridae
Pseudarchaster parelii (Düben & Koren)
Pseudarchaster gracilis (Sladen)
Paragonaster subtilis (Perrier)
Plinthaster dentatus (Perrier)
Evoplosoma scorpio Downey
Family Poraniidae
Porania pulvillus O. F. Müller
Order Spinulosida
Family Pterasteridae
Pteraster militaris (O. F. Müller)
Pteraster pulvillus M. Sars
Pteraster reductus Koehler
Pteraster sp. aff. *P. acicula* (Downey)
Hymenaster membranaceus Wyville Thomson
Hymenaster pellucidus Wyville Thomson
Hymenaster gennaeus H. L. Clark
Hymenaster rex Perrier
Family Solasteridae
Crossaster squamatus (Döderlein)
Family Echinasteridae
Henricia sanguinolenta (O. F. Müller)
Henricia abyssicola (Norman)
Order Forcipulatida
Family Brisingidae
Brisinga endecacnemos Asbjörnsen
Brisingella coronata G. O. Sars
Freyella spinosa Perrier
Freyella sexradiata (Perrier)
Family Asteriidae
Hydrasterias sexradiata (Perrier)
Stichastrella rosea (O. F. Müller)
Family Zoroasteridae
Zoroaster fulgens Wyville Thomson

Class Ophiuroidea
Suborder Euryalida
Family Asteronychidae
Asteronyx loveni Müller & Troschel
Astrodia tenuispina Verrill
Family Asteroschematidae
Asteroschema inornatum Koehler
Family Gorgonocephalidae
Gorgonocephalus caputmedusae (Linnaeus)
Order Ophiurida
Family Ophiacanthidae
Ophiotrema alberti Koehler
Ophiomyces grandis Lyman
Ophiacantha abyssicola G. O. Sars
Ophiacantha bidentata (Retzius)
Ophiacantha crassidens Verrill
Ophiacantha cuspidata Lyman
Ophiacantha simulans Koehler
Ophiacantha aculeata Verrill
Ophiolimna bairdi (Lyman)
Family Ophiactidae
Ophiactis abyssicola (M. Sars)
Ophiactis balli (Thompson)
Family Amphiuridae
Amphiura otteri Ljungman
Amphiura fragilis Verrill
Amphiura griegi Mortensen
Amphipholis squamata (Delle Chiaje)
Subfamily Amphilepidinae
Amphilepis ingolfiana (Mortensen)
Family Ophiochitonidae
Ophiochiton ternispinus Lyman
Family Ophiuridae
Subfamily Ophiurinae
Ophiopleura inermis (Lyman)
Ophiopleura borealis Danielssen & Koren
Homalophiura tesselata (Verrill)
Amphiophiura convexa (Lyman)
Amphiophiura saurura (Verrill)
Stegophiura macrarthra H. L. Clark
Ophiocten gracilis G. O. Sars
Ophiocten hastatum Lyman
Ophiura affinis Lütken
Ophiura carnea Lütken
Ophiura irrorata (Lyman)
Ophiura imprudens (Koehler)
Ophiura ljungmani (Lyman)
Ophiura ophiura (Linnaeus)
Subfamily Ophiolepidinae
Ophiomusium lymani Wyville Thomson

Systematic Account

The following account aims to summarise known distributional records for the individual species together with observations related to the biology of the more abundant ones, including the colour of fresh material if this information is not given by Mortensen (1927).

Throughout, taxonomic references are kept to a minimum by citing, where available, one or more works containing a good description from which the original description and synonymy may be traced. After these citations the sampling stations from which each species has been collected are listed together with the total number of specimens, adults and juven-

iles, in parentheses. Records from benthic stations are followed by those for fishing stations, which include two Agassiz trawl hauls. Where juveniles only were collected, this is indicated but the term juvenile is used only as a guide and is based arbitrarily on size. The number of specimens has no quantitative significance in comparisons between samples because for most epibenthic sledge hauls a partial sorting only of the catch has been achieved. Total depth range of the present records is given in square brackets after this listing. Details of hauls, including depth range and positional coordinates are listed on pp. 265–268.

Systematic structure of the class Crinoidea follows A. M. Clark (1970*b*); that of the Asteroidea, Downey (1973), Clark (1981) and Blake (1981); while for the Ophiuroidea, including family and subfamily names, we follow Fell (1960). References to the size of animals refer to disk diameter of brittle stars and arm radius, R (measured from arm tip to the centre of the disk) and the interradius, r, of sea stars.

Although all co-authors of the present study have been involved in the preparation and revision of the text, taxonomic responsibility for the identifications of the crinoids and most of the asteroids is taken by A.M.C. and for the ophiuroids by G.L.J.P.

Examples of all species referred to in the present account have been or will be deposited with the British Museum (Natural History).

Class **CRINOIDEA**

Order **MILLERICRINIDA**

Family **BATHYCRINIDAE**

Rhizocrinus lofotensis M. Sars, 1868

See: A. M. Clark, 1970*b*: 19–22, fig. 4, map 2.

Samples. ES 18 (3), ES 20 (8). [1271–1392 m]

Distribution. Recorded from the W coast of Norway, the Rockall Trough area, Iceland, Greenland and the eastern side of North America. Depth range off Norway includes the minimum, 140–700 m, while those from both sides of Greenland include the maximum of 3135 m (*Ingolf* st. 37) but other records east of Iceland rarely much exceed 1200 m. [Carpenter's record from NE Brazil mentioned by A. M. Clark (1970*b*) was referred to *Democrinus* by A.M.C. (1977)].

Previous records from the Rockall Trough area include *Lightning* and *Knight Errant* material from 61°02′N, 12°04′W, 1990 m and *c.*60°N, 07°W, *c.*960 m (Carpenter, 1884) and *Thor* st. 99, 61°15′N, 09°35′W, 872 m, recorded by A. H. Clark (1923) who earlier (1913) recorded one specimen from *Helga* st. CXX, 53°58′N, 12°24′W, 687 m. The latter record probably validates Kemp's (1905) provisional record from '64 miles NW by N of Cleggan Head' (*c.*54½°N, 11½°W), 364 m.

The present sample from the Hebridean slope (56°46′N), consists only of calyces and separate stalk fragments.

Remarks. We retain the familiar and historic generic name *Rhizocrinus* M. Sars, 1868, although according to Roux (1976) it should probably be treated as a junior synonym of *Conocrinus* d'Orbigny, 1850, because of the fused calyx plates in both nominal genera. However, in 1978 Roux listed *Rhizocrinus* with *R. lofotensis* among the Bathycrinidae. *Conocrinus* was known only from lower Caenozoic fossil species until Roux ascribed to it two recent species from the Bay of Biscay which he named *C. cherbonnieri* and *C. cabiochi.* The former is based on a single incomplete specimen from the French research ship *Thalassa* st. Z397, 47°33·8′N, 07°12·6′W, 511 m; superficially very similar to *R. lofotensis* but said to differ in the joint structure of the columnals.

Order **COMATULIDA**

Family **PENTAMETROCRINIDAE**

Thaumatocrinus jungerseni A. H. Clark, 1923

See: A. H. Clark, 1923 : 13–17, figs 2–4; A. M. CLark, 1980 : 204–205.

Samples. SWT 12 (8), SWT 13 (2). [2980–3000 m; 3425–3500 m]

Distribution. Previously known from the Denmark Strait, NW and SW of Iceland and far to the west of Ireland (*c.*53°N, 20°W) in 823–2734 m.

The present new records from the Porcupine Seabight from between 2980 m and 3500 m depth extend the geographical range eastwards and the lower limit of the bathymetric range. However, an unpublished record exists of four specimens from R.R.S. *Discovery* station 9640/1, (50°05′ N, 13°51′ W, 3749–3757 m depth, soft mud) that were identified by A.M.C.

Family **ANTEDONIDAE**

Heliometra glacialis (Owen, 1833)

See: A. M. Clark, 1970*b* : 24–27, fig. 5, map 3.

Sample. ES 112 (1). [1900 m]

Distribution. Previously known primarily from the Arctic where it is circumpolar, extending south in the NW Atlantic to George's Bank off Cape Cod, but in the east only to the Faroe Channel and northernmost Norway; 14–1358 m; usually on gravel with sand and mud or loose stones.

The present record from the South Feni Ridge extends both the known range southwards to latitude 55°N in the NE Atlantic and the lower limit of the bathymetric range.

Remarks. An arcturid amphipod, identified as such by Dr R. J. Lincoln of the British Museum (Natural History), was found associated with this specimen.

?***Hathrometra sarsi*** (Düben & Koren, 1846)

See: A. M. Clark, 1970*b*: 42–45, figs 15, 16 for *Poliometra prolixa*, 39–42, fig. 14 for *Hathrometra sarsi,* 36–39, fig. 12 for *Leptometra celtica.*

Sample. ES 20 (1). [1271 m]

Remarks. The single badly broken specimen has lost all the cirri completely and the arms from the first or second syzygy (brachials 3 or 9). An arm fragment from the same sample has pinnules with very long pinnulars. This fact and the blunt conical form of the centrodorsal suggest identity with *Poliometra prolixa* (Sladen) or *Hathrometra sarsi* (Düben & Koren), possibly *Leptometra celtica* (Barrett & McAndrew) but the depth and latitude are both too high to make this last identity likely. A. H. Clark (1913) recorded *P. prolixa* from *Silver Belle* st. 9, 60°18′N, 04°43′W, 905 m and referred to '*Hathrometra* sp.' single specimens from *Helga* sts SR 353 and 506 at *c.*50½°N, 11°W, down to 990 and 1230 m. In 1967 (*in* Clark & Clark) he cited both of these as *H. sarsi* without question, prompting A.M.C. (1970*b*) to repeat this southern record, though clearly it needs confirmatory material. Otherwise, the southernmost record of *H. sarsi* to the west of the British Isles is from *Triton* st. 2, 59°37′30″ N, 06°19′ W, 969 m very close to *Porcupine* st. 54, 633 m where *P. prolixa* was taken (Clark & Clark, 1967). Of the two species, *H. sarsi* is much more likely to extend further south since it extends in Scandinavia to Danish waters whereas *P. prolixa* is limited to northernmost Norway. Morphologically, the two are distinguished by the more regular arrangement of the cirri in *Poliometra,* tending to form vertical lines on the centrodorsal, especially in larger specimens; on this count, the present specimen inclines towards *Hathrometra.*

Class **ASTEROIDEA**

Order **PAXILLOSIDA**

Family **LUIDIIDAE**

Luidia sarsi Düben & Koren, 1845

See: Süssbach & Breckner, 1911 : 210–214; A. M. Clark, 1982 : 175–80, figs 1c, 2c, g, 3m–o, v, 6.

Samples. ES 33 (4), ES 113 (juvenile, 1). [148 m, 168 m]

Distribution. From the Faroe Bank Channel eastwards to Trondheim, Norway and southwards to the Mediterranean, Cap Blanc and the Azores; 9–1300 m; usually on muddy rather than clean sand, or on clay. *Luidia sarsi* was taken by the *Helga* at many stations worked off the west coast of Ireland.

The present records from the Hebridean Sea and the Rockall Bank are well within the known bathymetric range and its present occurrence further north and west is to be expected (Mortensen, 1927).

Luidia ciliaris (Philippi, 1837)

See: Süssbach & Breckner, 1911 : 209–210; Mortensen, 1927 : 70, fig. 39a.

Sample. GT 1 (1). [650–805 m]

Distribution. From the Faroe Channel east to southern Norway and south to the Mediterranean, Canary Is. and Azores; previously recorded from 1 to 400 m (Mortensen, 1927).

The present record surprisingly extends the deeper limit to at least 650 and possibly 805 m depth; substratum usually fine gravel, often with little or no mud.

Family **ASTROPECTINIDAE**

Astropecten irregularis (Pennant, 1777)

See: Süssbach & Breckner, 1911 : 203–207; Mortensen, 1927 : 57–58, fig. 32.

Samples. AT 133 (7 var. *pentacanthus*). GT 1 (1), GT 7 (3 var. *pentacanthus*). [315 m to 650–805 m]

Distribution. Coastal distribution from Norway south to Morocco; 10–1000 m. It is said to prefer a sandy bottom (Mortensen, 1927).

The presence of this well-known species on the upper Hebridean slope down to between 650 and 805 m depth is not unexpected. The specimens from GT 7 and AT 133 lack the large spine on the superomarginals and therefore agree with the variety *pentacanthus* (Delle Chiaje).

Bathybiaster vexillifer (Wyville Thomson, 1873)

See: Grieg, 1921 [1932]: 16–18; Mortensen, 1927 : 61–63, figs 34, 35 (as *B. robustus* and *B. vexillifer*).

Samples. ES 10 (1), ES 34 (3), AT 90A (1), AT 107A (2), AT 114 (6), AT 138 (juvenile, 1), AT 139 (6), AT 144 (23), AT 151 (15), AT 153 (22), AT 154 (34), AT 161 (6), AT 162 (8), AT 167 (9), AT 171 (28), AT 175 (10), ES 176 (4), AT 177 (11), ES 178 (2), AT 181 (25), ES 182 (1), ES 184 (7), AT 186 (10), AT 191 (juvenile, 1), AT 192 (6), AT 195 (17), ES 197 (20), AT 198 (9), ES 200 (3). SWT 10 (1), SWT 11 (1), SWT 16 (28), SWT 17 (3). [992 m–2540 (?2560) m]

Distribution. This purely circumpolar Arctic/N boreal species is known to extend south to North Carolina in the west and the Bay of Biscay in the east Atlantic; 630–3100 m (shallower depths only within the Arctic); on soft muddy sediments.

Our shallowest record at 992 m on the Porcupine Bank does not accord with a distribution limited by a temperature of 1–4°C suggested by Cherbonnier & Sibuet (1973) since

temperatures in the Rockall Trough between 900 and 1000 m, although showing little seasonal variation, may exceed 8°C (Ellett & Martin, 1973).

REPRODUCTION. Histological examination of the gonads of individuals collected in a time series from St. 'M' show no evidence of reproductive synchrony within or between samples taken at different times of the year; the sexes are separate and the large size of ripe oocytes (*c.* 1000 μm diameter) suggests direct, external lecithotrophic development (Tyler, Pain & Gage, 1982*a*). There is no evidence of brooding of young.

Plutonaster bifrons (Wyville Thomson, 1873)

See: Grieg, 1921 [1932]: 13–14; Mortensen, 1927 : 63–64.

SAMPLES. ES 4 (4), ES 6 (juvenile 1), ES 18 (1), ES 20 (3), AT 68A (1), ES 69 (1), ES 105 (1), AT

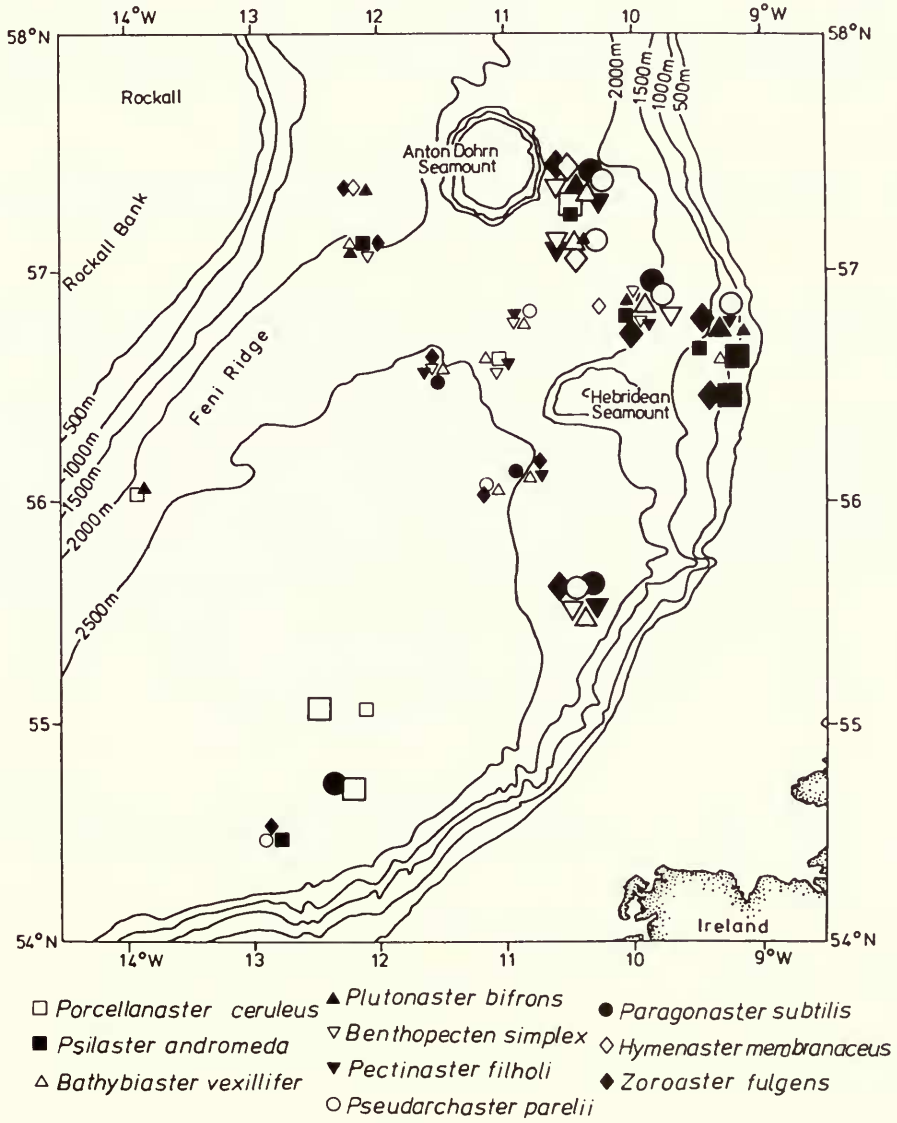

Fig. 2 Chart of central part of Rockall Trough showing station locations for records of the ten most abundant sea star species. Larger symbols denote records from more than one sample taken on or near the position.

107A (6), AT 144 (10), AT 151 (7), AT 153 (20), AT 154 (5), AT 161 (10), AT 167 (15), AT 171 (17), AT 175 (5), ES 176 (2), AT 177 (12), AT 181 (15), ES 182 (1), ES 184 (2), AT 186 (24), AT 191 (4), AT 192 (69), AT 195 (17), ES 197 (2), AT 198 (3), ES 200 (1). GT 17 (4), SWT 10 (40), SWT 11 (12), SWT 17 (3), SWT 18 (38), SWT 27 (4), SWT 32 (12), AT 3 (5). [1000–2965 m]

DISTRIBUTION. Previously known from the Faroe Channel to South Africa; 800–2500 m; on soft muddy sediments.

Our records for this species extend the lower limit of the known range to 2965 m. The bathymetric range of these records covers a temperature range of around 3·5–7°C in the Rockall Trough (Ellett & Martin, 1973). Farran (1913) indicates from trawlings in the Porcupine Seabight that *P. bifrons* does not usually occur off the Irish coast at depths less than 500 fathoms (914 m).

REPRODUCTION. The sexes are separate, and preliminary examination of the serially arranged gonads lying on the underside of the dorsal arm surface of females shows numerous small oocytes with a maximum size of about 120 µm diameter. There is also evidence of reproductive seasonality, with spawning in spring (Tyler, Pain & Gage, 1982*b*; Tyler & Pain, 1982*a*). Sibuet & Cherbonnier (1972) describe, with SEM figures, the post-metamorphosal stages.

REMARKS. Specimens of *P. bifrons* from St. 'M' contain a small flatworm in the body cavity; this appears not to affect gonadal development nor to harm the host in any way.

Dytaster insignis (Perrier, 1884)

See: Perrier, 1884 : 253, pl. 9, fig. 5; Downey, 1973 : 35–36, pl. 9, figs C, D.

SAMPLES. ES 53 (1), ES 55 (2), ES 56 (1), ES 120 (2), AT 121 (15), ES 129 (1), AT 131 (2), AT 153 (1), AT 181 (1), ES 182 (1). SWT 13 (3), SWT 27 (1). [2170 m to 3425–3500 m]

DISTRIBUTION. Downey (1973) has synonymised several previously described nominal N Atlantic species of this exclusively deep-water genus, including *D. biserialis* Sladen, the oldest name being *D. insignis*. This has a wide distribution throughout the N Atlantic deep sea and possibly extends over the entire Atlantic; on soft deep-sea ooze. *Dytaster biserialis* was recorded from the NE Atlantic from depths of 3645 m and 4360 m (Mortensen, 1927).

The present records confirm that this species has an essentially abyssal distribution.

REPRODUCTION. Histological study of the gonads of *D. insignis,* which are serially arranged along the underside of the dorsal surface of the arm, suggests a high fecundity, probably in excess of 10^6 eggs/individual. Maximum egg size is 120 µm, suggesting indirect, possibly pelagic, development (Tyler, Pain & Gage, 1982*b*; Tyler & Pain, 1982*a*). The latter authors also indicate that this species shows some form of gametogenic synchrony in the population sampled.

REMARKS. Species of the genus *Dytaster* are thought to be omnivorous scavengers; fragments of algae, foraminiferous worm tubes and molluscs having been found in the stomach (Downey, 1973) while Bruun & Wolff (1961) give a photograph with a specimen ingesting a large fish bone.

Psilaster andromeda (Müller & Troschel, 1842)

See: Süssbach & Breckner, 1911 : 208–209; Grieg, 1921 [1932]: 18–19 (?St. 70); Mortensen, 1927 : 59–60, fig. 33; D'yakonov, 1950 : 31.

SAMPLES. ES 23 (3), AT 68A (1), AT 107A (5), AT 186 (3), AT 192 (29; ? [juveniles] 5). GT 2 (1), GT 7 (1), GT 11 (5), GT 14 (2), GT 15 (1), GT 16 (4), SWT 18 (7), SWT 27 (4), AT 1 (3). [640–780 m to 2965 m]

DISTRIBUTION. Previously known from the southern Barents Sea south to Senegal and from the Azores; 20–1853 m. If *P. florae* Verrill, 1878 proves to be a synonym, then also from the western N Atlantic. On ooze and other soft muddy sediments.

The present records extend the lower limit of the known range of *P. andromeda* to 2965 m depth. Our shallowest record, between 640 and 780 m, roughly accords with that of specimens collected by the *Helga* off the west coast of Ireland (Farran, 1913). In more northerly latitudes it may extend into considerably shallower depths.

REPRODUCTION. The sexes are separate. Mortensen (1927) suggested that the large yolky eggs of this species indicate a direct development without a larval stage. Tyler, Pain & Gage (1982*b*) and Tyler & Pain (1982*a*) have noted a maximum egg size of 950 μm in histological preparations of the gonad of females. Hence, direct development with a benthic stage seems likely.

REMARKS. Our specimens were as described by Mortensen (1927), being slimy-skinned and pale pink or dirty white in colour, although D'yakonov (1950) describes Russian specimens as a bright red in life.

Psilaster andromeda is known as the host of an unidentified species of the parasitic barnacle genus *Dendrogaster* which causes severe regression of the gonads (P.A.T. personal observation).

Psilaster patagiatus Sladen, 1889

See: Grieg, 1921 [1932]: 19 (as *Psilasteropsis patagiatus*); Mortensen, 1927: 65–66, fig. 37 (as *Persephonaster patagiatus*); Downey, 1973: 32, pl. 8, figs A, B.

SAMPLES. ES 15 (2), ES 18 (3), AT 192 (1). SWT 18 (1). [1392–1862 m]

DISTRIBUTION. From the Rockall Trough, Porcupine Seabight (Farran, 1913) to the Azores and Cape Verde Islands (Koehler, 1909); and in the Gulf of Mexico and Caribbean Sea off Venezuela where the depths recorded are only 730 m and 915 m; on soft muddy sediments. Mortensen (1927) gives the lower bathymetric limit as 2165 m.

There is, however, a complication about the limits of this species. Although Downey (1973) has referred West Indian specimens to *P. patagiatus,* H. L. Clark (1941) used another name *spinulosus*, which he referred to *Persephonaster* together with *patagiatus*, for Cuban specimens from *c.*1000 m. He also thought the Azores specimens belonged to a third species. A.M.C. (MS) has provisionally named as *P. patagiatus* a *Discovery* specimen from the Canaries. Downey (1973) queried the Cape Verde area as type locality for *P. patagiatus* but this identification, if correct, would support it.

Family **PORCELLANASTERIDAE**

Porcellanaster ceruleus Wyville Thomson, 1877

See: Lieberkind, 1935: 5–19, pl. 2 figs 1–8, pl. 3 fig. 12, pl. 5 figs 16–17; Madsen, 1961: 1123–142, figs 22–24.

SAMPLES. ES 2 (18), ES 4 (5), ES 6 (835), ES 8 (22), ES 10 (101), ES 27 (41), ES 34 (4), SBC 49 (1), ES 52 (7), ES 55 (28), ES 56 (50), SBC 58 (1), ES 59 (20), ES 111 (26), ES 118 (11), AT 121 (6), ES 129 (39), ES 135 (29), ES 137 (53), ES 140 (150), AT 141 (2), ES 143 (12), ES 147 (46), ES 152 (61), ES 164 (91), ES 169 (68), ES 172 (71), ES 176 (2), ES 180 (110), ES 184 (3), ES 185 (195), ES 190 (63), AT 191 (3), ES 197 (2). SWT 13 (1). [1993 m to 3425–3500 m]

DISTRIBUTION. A cosmopolitan deep-sea species, except in Antarctic waters; known from 1160–6040 m depth; on soft deep-sea ooze.

Individuals of this small species (max. R *c.* 36 mm, Madsen, 1961) were most numerous in epibenthic sled hauls from the Permanent Station, decreasing in number in sled hauls from shallower stations.

REMARKS. The specific name of *ceruleus,* unnecessarily amended to *'caeruleus'* by Sladen (1889), was derived from the sky blue colouring of the sediment filling the stomach of the type specimen from *Challenger* st. 45, off Delaware, NW Atlantic. The stomachs of this

deposit-feeding species in the recent samples were likewise filled with mud, but of the khaki brown colour of the *Globigerina* ooze characteristic of the deep-sea sediment in the Rockall Trough.

Hyphalaster inermis Sladen, 1883

See: Madsen, 1961: 58–72, figs 6, 7, pls 1–3, 13, figs 3, 4.

SAMPLES. ES 147 (? [juvenile] 1). SWT 13 (1). [2921 m to 3425–3500 m]

DISTRIBUTION. Previously known from the West European Basin north to *c.* 47°N, 08°W, south to the Guinea Basin, also from the Labrador Basin and mid N Atlantic (*c.* 54°N, 27–28°W) and from the Indo-Pacific; 2280–5430 m; on mud, *Globigerina* ooze or calcareous clay.

The present records extend the known range slightly in the NE Atlantic.

REPRODUCTION. Egg size reaches 0·5–0·6 mm with presumably direct development (Madsen, 1961).

REMARKS. The specimen from SWT 13 has R 39 mm, r 19 mm. The specific identity of the single juvenile from ES 147 remains uncertain.

Order **NOTOMYOTIDA**

Family **BENTHOPECTINIDAE**

Benthopecten simplex (Perrier, 1881)

See: Mortensen, 1927 : 74–75, fig. 41 (as *B. armatus* (Sladen)); A. M. Clark, 1981 : 130–134.

SAMPLES. ES 4 (13), ES 10 (juvenile 1), ES 34 (2), AT 107A (3), AT 114 (5), AT 138 (5), AT 139 (10), AT 144 (117), AT 151 (25), AT 153 (71), AT 154 (49), AT 161 (47), AT 167 (33), AT 171 (110), AT 175 (62), ES 176 (56), AT 177 (171), AT 181 (98), ES 182 (7), ES 184 (16), AT 186 (139), AT 191 (juveniles, 45), AT 192 (93), AT 195 (113), ES 197 (27), AT 198 (20; ? [juveniles], 10), ES 200 (11). SWT 13 (2), SWT 16 (1), SWT 17 (1), SWT 18 (19), SWT 32 (10). [1785–1845 m to 3325–3500 m]

DISTRIBUTION. East of Cape Cod south to the Gulf of Mexico, Colombia and Guyana Basins, and south of Iceland (*c.* 62°N, 19°30′W) and the Rockall Trough south to the Gulf of Guinea; 1175 m to 2735–3670 m, this lower limit being derived from *Pillsbury* st. 681, off Surinam.

Our deepest record is from a trawling taken at the deep water confluence of the Rockall Trough with the Porcupine Abyssal Plain. The most northerly record was from the Feni Ridge at *c.* latitude 57°20′N in *c.* 1860 m depth close to *Michael Sars* st. 101 where Grieg (1921) also reported collecting 12 specimens of *Benthopecten.* Both the present and previous records strongly suggest a distribution centred on depths of *c.* 2000 m at temperatures below about 4°C in the N Atlantic, on soft muddy sediments.

Benthopecten simplex is fairly abundant in Agassiz hauls from st. 'M' and these samples usually include substantial, though varying, numbers of juveniles with a range of sizes (Pain, Tyler & Gage, 1982*b*).

Maximum size (R) recorded is *c.* 130 mm (Tyler, Pain & Gage, 1982*b*) whereas that of the few *Sarsia* specimens from the Bay of Biscay (E. C. Southward, personal communication) is only 30–35 mm. Sladen's *Challenger* expedition specimens, of *armatus,* are also smaller than equatorial Atlantic ones where R max. = *c.* 150 mm (A. M. Clark, 1981).

REPRODUCTION. The sexes are separate and no seasonal periodicity is evident from the histological comparison of the gonads of specimens taken at different times of the year; maximum oocyte size is 950 μm, suggesting non-pelagic, possibly lecithotrophic, direct larval development (Tyler, Pain & Gage, 1982*b* as *B. armatus*; Pain, Tyler & Gage, 1982*b*).

REMARKS. Farran (1913) and Mortensen (1927) used the name *B. armatus* (Sladen, 1889) while Grieg (1921) used *B. spinosus* Verrill (1884). A. M. Clark (1981) believes all NE Atlantic and some NW Atlantic specimens of *Benthopecten* to be conspecific with the tropical Atlantic *B. simplex* (Perrier, 1881) of which *armatus* is a synonym but *B. spinosus,* only known from the NW Atlantic, is a distinct species.

Pectinaster filholi Perrier, 1885

See: Sladen, 1889: 43–47, pl, 8, figs 3, 4, pl. 12, figs 3, 4 (as *Pontaster forcipatus*); A. M. Clark, 1981 : 119–121.

SAMPLES. ES 10 (6), ES 34 (7), AT 114 (13), AT 138 (3), AT 139 (14), AT 141 (juvenile 1), AT 144 (14), AT 153 (5), AT 154 (11), AT 157 (1), AT 161 (7), AT 167 (3), AT 171 (3), AT 175 (3), ES 176 (1; ? [juvenile] 13), AT 177 (4), AT 181 (5), ES 182 (1), ES 184 (4; ? [juveniles] 14), ES 185 (juveniles, 2), AT 186 (1), AT 198 (8). SWT 16 (38), SWT 17 (7). [1752–2909 m]

DISTRIBUTION. Previously recorded (A. M. Clark, 1981) from all four quadrants of the Atlantic, north to *c.* 60°N, 20°W (S from Ireland); 1260 m–4850 m, the maximum being the isolated record for the holotype of *Pontaster pristinus* Sladen, off the River Plate, the deepest other record being 3430 m. Cherbonnier & Sibuet (1973) cite a minimum depth of 1152 m but details of this record have not been traced; on mud or *Globigerina* ooze.

This species was present in Agassiz trawls from St. 'M'. Elsewhere, adult specimens were taken from a number of locations in the Rockall Trough and Porcupine Seabight area between 1752 m and 2540 m. Juveniles were also taken between 2200 m and 2900 m.

Cherbonnier & Sibuet (1973) recorded *P. filholi* sensu stricto from NW Africa, the Azores and the southern Bay of Biscay, their record on map 4 of the results of the Noratlante Expedition being misplaced to west of Brittany, if the station list data are correct. A. M. Clark (1981) returned *Pontaster forcipatus* Sladen, 1889, as well as *P. pristinus*, to the synonymy of *Pectinaster filholi,* bringing in records from eastern North America and South Africa, as well as two *Discovery* records from the central North Atlantic to the far west of Ireland and south from Iceland. Although no *Helga* specimens were recorded by Farran (1913), a small one was found in the British Museum collections from the sample of *Benthopecten armatus* [*simplex*] from st. SR 944, SW of Ireland.

REPRODUCTION. The sexes are separate; preliminary studies on the gametogenic cycle (Pain, Tyler & Gage, 1982*b*) indicate a maximum oocyte size of 850 μm, suggesting a non-pelagic, possibly lecithotrophic or direct development. Brooding has not been recorded. Individuals become mature at *c.* r 3 mm. Size frequencies in the sample time series from St. 'M' indicate a low, probably year-round recruitment by young of around r 1 mm. Adult size structure is variable in the samples which suggests a possibly patchy demographic composition on the bottom (Pain, Tyler & Gage, 1982*b*).

Pontaster tenuispinus (Düben & Koren, 1846)

See: Sladen, 1889 : 28–29, 29–30, pl. 6, fig. 7, pl. 7, figs 3, 4 (var. *platynota*), 35–38, pl. 6, figs 3, 4, pl. 7, figs 1, 2 (as *P. limbatus*); Süssbach & Breckner, 1911 : 201–202; Mortensen, 1927 : 72–73, fig. 40.

SAMPLES. ES 23 (4), ABD 25 (1), ES 87 (5 var. *platynota*), AT 90A (? [juveniles var. *platynota*] 3), AT 107A (1). GT 1 (4), GT 7 (4), GT 13 (1), GT 14 (2), GT 15 (4), AT 1 (74), AT 3 (2). [508–543 m to 2000 m]

DISTRIBUTION. Circum-arctic extending south in the Atlantic to the latitude of Cape Cod in the west and the eastern slope of the Bay of Biscay (*c.* 44°N) in the east, 16–*c.* 2000 m, (2330 m according to Perrier, 1894), rarely <200 m, except in arctic waters. The records of Farran (1913) are from *c.* 400–800 m in the Porcupine Seabight. The Porcupine record (Sladen, 1889) from 100–150 fathoms, 183–274 m, off Valentia, SW Ireland is surprisingly shallow. The round numbers, in fathoms, quoted suggest that this record might be regarded

with suspicion. Found on soft mud, muddy sand or clay, sometimes fine sand or sand with shell.

Specimens of *P. tenuispinus* forma *tenuispinus* were collected from hauls on the Hebridean Slope from 523 m to 1000 m depth and one only from the North Feni Ridge area in 2000 m, whereas others with basally broadened rays conforming to Sladen's variety *platynota* were identified in the 'cold' area north of the Wyville Thomson Ridge, the Faroe-Shetland Channel in 1040 m and 1050 m depth. The five specimens from ES 87 (61°13′N, 03°59′W) ranged from R 35 mm to R 5·8 mm. In the smallest specimen however, the bivalved adambulacral pedicellariae are not developed.

REPRODUCTION. The sexes are separate; maximum oocyte diameter is 800 μm, suggesting a non-pelagic possibly lecithotrophic or direct development (Pain, Tyler & Gage, 1982*b*).

Order **VALVATIDA**

Family **ODONTASTERIDAE**

Hoplaster spinosus Perrier, 1882

See: Perrier, 1894 : 324; Sladen, 1889 : 275 (as *Pentagonaster lepidus*).

SAMPLES. AT 121 (3), AT 167 (1). [2910 m, 2300 m]

DISTRIBUTION. Previously known from the vicinity of the Azores and in the Porcupine Seabight, recorded in an appendix by Mortensen 1927 : 439; 1800–2995 (?3307) m; soft mud or ooze.

The present records extend the known range north to 57°. The largest specimen, from the 2910 m haul, measured R 14 mm, whereas in the very few specimens previously described R did not exceed R 7·5 mm (Mortensen, 1927 : 77).

REMARKS. The monotypic genus *Hoplaster* does not have the reflected hyaline-tipped oral spines otherwise characteristic of the family Odontasteridae but does show the distinctive odd interradial marginal plates.

Odontaster sp.

See: von Marenzeller, 1893 : 6, figs 4A–C (*Gnathaster mediterraneus*); Mortensen, 1927 : 77–78, figs 42, 43 (? *O. mediterraneus*); Verrill, 1899 : 206–207, pl. 29, fig. 3 (*O. hispidus*).

SAMPLE. AT 162 (1). [992 m]

REMARKS. The single (dried) specimen, from the N slope of the Porcupine Seabight, has R/r 29/11·5 mm = 2·5/1 and a relatively narrow frame of marginal plates. The Atlantic specimens recorded as *O. mediterraneus* by Koehler (1909) from the Bay of Biscay (*Princesse Alice* st. 1450, *c.* 45°N, 3°W, 1804 m, R 15 mm) and Mortensen (1927) from the Porcupine Seabight (*Helga,* 51°26′N, 11°45′W, 927 m, 'small'), as well as a record from the Seabight (unpublished, IOS st. 50601, 51°20′N, 11°42′W, 927 m, R/r 20/13 = 1·5/1), all have more nearly pentagonal form and disproportionally broad marginals, though this is probably at least partly attributable to the relatively small size. *Odontaster hispidus* Verrill, 1880 has only been recorded from the NW Atlantic in 73–1160 m. The body shape is very variable in *Odontaster* and the mean R/r ratio for both species is *c.* 2·5/1 in larger specimens, R > 20 mm. The main differences in mediterranean specimens appear to lie in broadened paxillar columns on the distal abactinal plates, frequent rather than occasional glassy 'crystal bodies' embedded in the distal superomarginals, both visible when the plates are denuded, short capitate superomarginal spinelets and three or four rather than two, occasionally three, furrow spines. The present specimen has the distal abactinals no broader than the proximal ones, no crystal bodies and tapering slender superomarginal spinelets. However, it does have four furrow spines on a few plates, otherwise three; also the actinal armament is less crowded

than is usual in *hispidus,* though the dry condition may contribute to this. In the IOS specimen the abactinal areas are not at all prolonged on to the rays and the more distal plates still have round columns, there are no crystal bodies on the marginals and the furrow spines usually number three but the superomarginal armament is very short and slightly capitate. Clearly further material and comparison is needed for the specific identity of these specimens to be established.

Family **RADIASTERIDAE**

? Radiaster tizardi (Sladen, 1882)

See: Mortensen, 1927 : 97, fig. 55.

Sample. ES 10 (juvenile, 1). [2540 m]

Distribution. Although according to Mortensen (1927) this species is previously known only from the Faroe-Shetland Channel (*Triton* and *Knight Errant*) and the Porcupine Seabight (*Helga*) in 930 (? 730) m–1320 (? 1630) m, Sladen (1882) gives the single *Knight Errant* record as from 59°33′N, 07°14′W in 1015 m depth on the 'warm' side of the Wyville Thomson Ridge in the northern Rockall Trough; mud or ooze.

Remarks. The single specimen measures R = 3·5 mm, r = 2·0 mm. The abactinal armament appears clustered and the margins thick. The present record must be uncertain in view of the small size of the specimen, specimens of *tizardi* are not yet known with R < *c.* 60 mm, and the considerable depth (2540 m) from which it was collected.

Family **GONIASTERIDAE**

Pseudarchaster parelii (Düben & Koren, 1846)

See: Süssbach & Breckner, 1911 : 202–203 (as *Tethyaster parelii*); Mortensen, 1927 : 87–88, fig. 49; Halpern, 1972 : 366–370.

Samples. ES 55 (? [juveniles] 9), ES 56 (? [juveniles] 2), ES 87 (? [juvenile] 1), AT 114 (1), AT 132 (1), AT 138 (1), AT 139 (2), AT 144 (1), AT 151 (1), AT 154 (1), AT 167 (1), AT 175 (1), ES 176 (1), AT 177 (2), AT 181 (1), ES 184 (1), AT 191 (10), AT 192 (1), AT 195 (2), AT 198 (juvenile, 1), ES 200 (1). GT 1 (2), GT 7 (2), GT 13 (1), GT 14 (2), SWT 10 (2), SWT 11 (1), SWT 16 (4), SWT 17 (1), SWT 18 (8), SWT 27 (1). [225–2965 m]

Distribution. Previously known from Greenland south to the West Indies in the western Atlantic, and from northern Norway to the Bay of Biscay and the Azores in the east; 15–3000 m, southern records being from deep water; preferring waters with a temperature slightly above zero (D'yakonov, 1950) or from 4–8°C (Cherbonnier & Sibuet, 1973) and 1·5–6°C (Halpern, 1972); on bottoms of soft mud to sand, sometimes with pebbles (D'yakanov. 1950).

Our present records from the Rockall Trough range from 225 m on the Porcupine Bank to 2965 m in the vicinity of the Permanent Station, where juveniles only were collected, and hence apparently show an ability to tolerate temperatures from 2 to 5°C up to *c.* 9·5–10°C from hydrographic data in Ellett & Martin (1973).

Reproduction. Preliminary examination of the gonads of some of these specimens indicates that the sexes are separate, while the presence of large oocytes (*c.* 1000 μm) suggests direct or demersal development (Tyler, Pain & Gage, 1982*b*; Tyler & Pain, 1982*b*).

Remarks. The colour of fresh specimens was a rose pink; Mortensen (1927) and D'yakonov (1950) describe freshly collected specimens as bright red to red-brown on the dorsal side.

Pseudarchaster gracilis (Sladen, 1889)

See: Halpen, 1972 : 360–366, figs 1, 2; Downey, 1973 : 59–60, pl. 23, figs C, D.

SAMPLE. SWT 18 (1). [1785–1845 m]

DISTRIBUTION. Previously known from just south of Cape Cod and from the Gulf of Mexico to Surinam, in the W Atlantic; from the Azores and from Mauritania to the Gulf of Guinea in the east; 320–2736 m. (Only in the West Indies area from <1000 m).

This record on the Hebridean slope extends the known distribution of *P. gracilis* to British waters. Although it is known to occur on both sides of the North Atlantic, the most northerly of previous records in the east were from the Azores.

Paragonaster subtilis (Perrier, 1881)

See: Halpern, 1972 : 374–378, figs 5 (pt), 6 (pt); Downey, 1973 : 57, pl. 22, figs A, B.

SAMPLES. ES 6 (juvenile, 1), ES 27 (1), ES 28 (2), ES 34 (1), ES 53 (2), ES 56 (1), ES 111 (1), AT 121 (17), ES 129 (2), AT 131 (2), AT 138 (1), AT 139 (1), ES 140 (2; ? [juvenile] 1), AT 141 (6), ES 147 (1), ES 164 (1), AT 171 (juveniles, 2), AT 177 (juvenile, 1), ES 180 (3), AT 186 (5). SWT 16 (17), SWT 17 (5), SWT 18 (4), OTSB 51001 (1). [1785–1845 m to 2925 m]

DISTRIBUTION. Previously known from south of Cape Cod and the Gulf of Mexico, in the W Atlantic, the Azores and mid-equatorial Atlantic, and from the Bay of Biscay, C. Verde Is. area and Gulf of Guinea in the east; 2455–4700 m; soft ooze. This N Atlantic species has an abyssal distribution not previously known to extend further north than Biscay in the NE Atlantic.

The present records, although mostly from the vicinity of the Permanent Station (*c.* 2900 m depth) confirm the essentially abyssal distribution of *P. subtilis,* although the shallowest record of 1785–1845 m from 56°46′N on the Hebridean slope is less than the minimum depth of 2455 m quoted by Halpern (1972). The temperature range quoted by Halpern is 1·5–4°C.

REPRODUCTION. The sexes are separate with a maximum egg size of about 1000 μm in females, suggesting direct development (Tyler, Pain & Gage, 1982*b*; Tyler & Pain, 1982*b*).

Plinthaster dentatus (Perrier, 1884)

See: Halpern, 1970 : 244–252, figs 17, 18, 19; Downey, 1973 : 52–53, pl. 19, figs A, B.

SAMPLES. ES 59 (juvenile, 1), AT 68A (2), ES 169 (juvenile, 1), ES 185 (juvenile, 1) SWT 18 (1). [1331–2190 m]

DISTRIBUTION. Previously known from both sides of the north and central Atlantic, from North Carolina to northern Brazil in the west and from the west of Ireland to Liberia in the east and from the Azores; 229–2117 m; on muddy sediments.

Although previously collected in the Porcupine Seabight (Farran, 1913; Grieg, 1921), the present records extend the known northward distribution of this N Atlantic species to latitude 59° and extend the lower limit of its depth range from 1804 m (Halpern, 1970) in the eastern Atlantic to 2910 m.

Evoplosoma scorpio Downey, 1981

See: Downey, 1981 : 561–563, fig. 1.

SAMPLE. ES 112 (3). [1900 m]

DISTRIBUTION. Previously only known from the holotype taken by the *Sarsia* off the Western Approaches to the English Channel (*c.* 48°N, 10°W); *c.* 1600 m (Downey, 1981).

The new record provides a northward extension of range to the Feni Ridge in Rockall Trough. Two other species of *Evoplosoma* are known, one from the Pacific near Hawaii, the other south of Sri Lanka in the Indian Ocean.

REMARKS. The present specimens are large and robust, R 90–130 mm, R/r 3·3–3·6/1.

Evoplosoma is closely related to *Hippasteria* but differs from *H. phrygiana* in the long

narrow arms (R/r *c.* 3·5/1), continuous irregular granulation interspersed with conical spines and pedicellariae with the two valves elongate, projecting and spatuliform rather than extremely short but very broad and almost flush with the body surface, as in *Hippasteria.*

Family **PORANIIDAE**

Porania pulvillus (O. F. Müller, 1766)

See: Döderlein, 1900 : 217–218, pl. 8, figs 10, 10a; Süssbach & Breckner, 1911 : 218–219; Mortensen, 1927 : 90–92, fig. 51.

Samples. ES 33 (1), ES 113 (1, juveniles, 2). [148 m, 168 m]

Distribution. Previously known from Scandinavia, the Lousy Bank and west of Ireland south to the Bay of Biscay; 10–1000 m but rarely deeper than 300 m, on the usually mixed, sandy sediments of commercial trawling grounds.

The present records span the Rockall Trough and fall within the known bathymetric range although *P. pulvillus* apparently has not been previously recorded from Rockall Bank (ES 113).

Remarks. The two small specimens (R *c.* 6·5 mm) from ES 113 resemble the holotype of *Marginaster fimbriatus* Sladen, 1889 from *Porcupine* st. 31, *c.* 56°N, 11°30′W, 2487 m, in the prominent inferomarginal fringe but have relatively sparse abactinal and actinal armament, only a single actinal spinelet in each interradius. *Marginaster fimbriatus* was referred to the synonymy of the Mediterranean *M. capreensis* (Gasco) by Ludwig, 1897 followed by Mortensen (1927) (see fig. 54) but A.M.C. believes it more likely to be the juvenile form of another poraniid from this vicinity. The large specimen from the same station, R 55 mm, is unusual in having the inferomarginal spines mostly aborted, there being only one or sometimes two on five to seven proximal plates of each interradial arc.

Order **SPINULOSIDA**

Family **PTERASTERIDAE**

Pteraster militaris (O. F. Müller, 1776)

See: Süssbach & Breckner, 1911 : 226; Mortensen, 1927 : 104–105, fig. 60.

Samples. ES 87 (juveniles, 2). GT 2 (2), GT 11 (1). [934–1054 m to 1050 m]

Distribution. This is an arctic-boreal species with a circumpolar distribution in the Arctic and a NW and NE Atlantic distribution along the American coast to Cape Cod, off the north west of Scotland and in the Faroe Channel, and off the entire west coast of Norway (D'yakonov, 1950); 10–1100 m.

The present records are all from around 1000 m and extend the known distribution slightly (and predictably) to the Rockall Trough.

Pteraster pulvillus M. Sars, 1861

See: Süssbach & Breckner, 1911 : 227; Mortensen, 1927 : 103; D'yakonov, 1950 : 81.

Samples. ES 113 (juvenile, 1), ES 115 (? [juvenile] 1). [168 m, 1000 m]

Distribution. This circumpolar N boreal species is known to range southward along the Atlantic coast of N America to 42°N (Massachusetts Bay and Bay of Fundy) and on the Norwegian coast down to 60°N in the vicinity of Bergen (D'yakonov, 1950). The record from Rockall Bank together with that recently recorded on the West Irish shelf in 122 m depth (O'Connor, 1981), confirm Mortensen's (1927) prediction that this species would be found in areas round the British Isles; 36–3700 m (2021 fms [= 3696 m] according to Sladen, 1889).

REMARKS. The specimen from ES 115 is in poor condition and has the stomach everted, damaging the oral furrow armament so that the characteristic continuous webbing of the oral furrow spines across the apex of each jaw has been ruptured, if it was present. The good specimen from ES 113 has R/r 8/6 mm.

Pteraster reductus Koehler, 1907

See: Koehler, 1909 : 96–97, pl. 3, figs 8, 9, pl. 20, figs 10; Grieg, 1921 : 28–29, pls 5, 6, 7; Mortensen, 1927 : 103.

SAMPLE. ES 112 (juvenile, 1). [1900 m]

DISTRIBUTION. This species is known only from the Azores and a single specimen from the South Feni Ridge in 2215 m (Cherbonnier & Sibuet, 1973); 1920–2900 m.

It is interesting that the present specimen was also collected from the Feni Ridge at a depth nearly within the previously recorded bathymetric range.

Pteraster sp. aff. *P. acicula* (Downey, 1973)

See: Downey, 1973 : 79, pl. 34, figs C, D.

SAMPLE. GT 16 (1). [958 m]

DISTRIBUTION. *P. acicula* has only been recorded from a few small poorly-preserved specimens (R up to 8 mm) from the northern Gulf of Mexico in 1060–1316 m, so the identification of the Rockall Trough specimen remains to be confirmed.

REMARKS. The complete absence of webbing from the oral furrow spines, characteristic of the subgenus *Apterodon,* and the very large number of paxillar spinelets (*c.* 25 on one midradial paxilla) distinguish this specimen from all the NE Atlantic Pterasters hitherto recorded.

HYMENASTER Wyville Thomson

At present there is some confusion over the taxonomy of *Hymenaster* in the N Atlantic. We here retain the specific names *membranaceus, pellucidus, gennaeus* and *rex* according to the original identifications of the specimens made from Sibuet's tabular key to the Atlantic species (1976), pending a forthcoming comprehensive review of the family by M. E. Downey, in Clark & Downey (in prep.). A.M.C. dissociates herself from the identification of N Atlantic specimens as *H. gennaeus,* believing that Sibuet (1976) had a mistaken concept of *H. giganteus* as a membranous rather than a fleshy species as Farran (1913) describes the type and *Helga* specimens.

Hymenaster membranaceus Wyville Thomson

See: Sladen, 1889 : 521–2, pl. 92, figs 6, 7, pl. 93, figs 10–12; Mortensen, 1927 : 106; Sibuet, 1976 : 315–318, fig. 6 A, B.

SAMPLES. ES 12 (2), AT 141 (juvenile, 1), AT 144 (287), AT 151 (30), AT 153 (203), AT 154 (111), AT 161 (3), AT 167 (137), AT 171 (556), AT 175 (180), ES 176 (60), AT 177 (319), AT 181 (354), ES 182 (16), ES 184 (79), AT 186 (423), AT 191 (? [juveniles] 47), AT 195 (410), ES 197 (37), AT 198 (133), ES 200 (15; ? [juveniles] 4). SWT 32 (1). [1995–2020 m to 2909 m]

DISTRIBUTION. Known from the E, N and S Atlantic from a depth range of 1000–3000 m; on soft ooze. Results of recent intensive sampling in the Bay of Biscay indicate a somewhat restricted bathymetric range (2119–2878 m, Sibuet, 1976).

H. membranaceus was collected in large numbers from St. 'M' (*c.* 2200 m depth), apart from a single juvenile specimen from the Permanent Station (2909 m), a sample of three from the Porcupine Seabight (*c.* 2055 m) and two records (2; 1 specimen) from the Barra Fan in the northern Rockall Trough (2076 m; 1995–2020 m).

REPRODUCTION. The eggs of this species grow to 1100 μm diameter, suggesting direct development (Pain, Tyler & Gage, 1982*a*). These authors also indicate that there is no synchrony in gametogenic development in the population, and that breeding probably occurs year-round at a low level. Size frequency data from St. 'M' suggest a low possibly continuous recruitment to the population which consists mainly of mature adults. The sexes are separate and, although fertilization may take place in the supradorsal chamber, there is no evidence of brooding in the St. 'M' population.

REMARKS. *H. membranaceus* is thought to live partially buried in bottom sediment, with only the valves of the central opening protruding above the sediment in order to allow ventilation of the supradorsal cavity (Mortensen, 1927). However, we note here that in photographs of the bottom in the Porcupine Seabight in Rice *et al.* (1982), specimens of '*Hymenaster* sp.', that are probably the same as the present species, are shown lying on the sediment surface. Possibly these animals were in the process of changing station where they would normally be buried out of sight.

Hymenaster pellucidus Wyville Thomson, 1873

See: Danielssen & Koren, 1884 : 72–80, pl. 13, figs 1–17, pl. 15, figs 7–8; Grieg, 1921 [1932]: 29; Mortensen, 1927: 107– 108, figs 62, 63 1, 2.

SAMPLE. ES 87 (1). [1050 m]

DISTRIBUTION. Previously known from the Siberian and Norwegian Seas, extending to the Faroe Channel in *c.* 15–2800 m.

This very delicate, perfect specimen, R 22 r 15 mm, R/r 1·5/1, is from the Faroe-Shetland Channel.

Hymenaster gennaeus H. L. Clark, 1923

See: H. L. Clark, 1923 : 302–303, pl. 10; Sibuet, 1976 : 311–314, figs 4, 5B.

SAMPLES. AT 144 (1), AT 154 (1), AT 171 (1), AT 181 (1), AT 195 (? 1). SWT 11 (1). [2190 m to 2500–2560 m]

DISTRIBUTION. Known previously only from the holotype (Clark, 1923) taken by *Pieter Faure* in the SE Atlantic near Cape Point in 1400 m and one specimen from *c.* 47°35′N, 8°39′W in 2245 m (Sibuet, 1976) but see note on p. 282.

Our records are from St. 'M' *c.* 2200 m, except for one specimen from 2500–2560 m at *c.* 56°N, 11°W that was taken in a fish trawl.

REMARKS. The queried specimen from AT 195 is probably not conspecific with the rest, having a subpentagonal rather than pentagonal body form, R/r nearer 2/1 than 1·5/1, consistently single paxillar spines rather than usually three, but three rather than usually one, sometimes two adambulacral spines. It agrees better in these characters with *H. regalis* Verrill, 1895, known from Carolina to Cuba, but that species is supposed to lack the smooth interbrachial arcs found in this specimen.

REPRODUCTION. Preliminary observations of Pain, Tyler & Gage (1982*a*) indicate an egg size and mode of development similar to that of *H. membranaceus*.

Hymenaster rex Perrier, 1894

See: Perrier, 1894 : 186–189, pl. 13, fig 2; Grieg, 1921 [1932]: 29–30.

SAMPLE. AT 121 (1). [2910 m]

DISTRIBUTION. Previously known from the Bay of Biscay (*c.* 46°N, 07°W) south to off NW Africa, 1140–2285 m, so the present record provides extensions northwards and downwards.

REMARKS. This specimen has R/r 11/8·5 mm, the form being almost pentagonal. There are 3 adambulacral and oral furrow spines and 2 suboral spines on each plate.

Family **SOLASTERIDAE**

Crossaster squamatus (Döderlein, 1900)

See: Döderlein, 1900: 208–209, pl. 6, figs 5–5c (*as Solaster papposus* var. *squamata*); Greig, 1921 [1932]: 26–27 (as *Solaster squamatus*); Mortensen, 1927: 114 (as *S. squamatus*).

Sample. ES 87 (9). [1050 m]

Distribution. Known from west of Greenland to the Barents Sea, including most of the cold area of the Norwegian Sea south to the Faroe Channel (*c.* 61°N, 4°30′W, *M. Sars*); 100–1600 m. Previous records from the Faroe Channel area are all *c.* 1000 m.

Family **ECHINASTERIDAE**

HENRICIA Gray

The treatment of the genus *Henricia* provisionally follows Mortensen (1927) pending further study by A.M.C. in Clark & Downey (in prep.).

Henricia sanguinolenta (O. F. Müller, 1776)

See: Süssbach & Breckner, 1911: 224–226 (as *Cribrella sanguinolenta*); Mortensen, 1927: 118–120, fig. 70.

Sample. ES 23 (1). [704 m]

Distribution. Owing to confusion about the specific limits, it is impossible to give a precise range. *Henricia sanguinolenta* sensu stricto appears to range from the north east of the U.S.A. to Iceland, the Faroes, northern British Isles, Scandinavia and the White Sea in depths possibly from *c.* 10–1000 m.

The present record (R/r 57/13 mm) of this coastal species is from the Hebridean Slope.

Henricia abyssicola (Norman, 1869)

See: Mortensen, 1927: 120–121, fig. 71.

Samples. ES 99 (2), ES 112 (juvenile, 1), ES 113 (juvenile, 1). [168–1900 m]

Distribution. Previously recorded off SW Ireland (*Helga*) and from the 'warm' area of the Faroe Channel (*Triton*) in *c.* 930–1400 m.

The present records lie at widely varying localities and depths; two are from within the Rockall Trough, while one is from Rockall Bank (ES 113). They are considerably shallower than previous records of this species, which is apparently not recorded from localities other than off the British Isles.

Order **FORCIPULATIDA**

Family **BRISINGIDAE**

Brisinga endecacnemos Asbjörnsen, 1856

See: Farran, 1913: 27–28; Mortensen, 1927: 125–127, fig. 73.

Samples. AT 107A (1), AT 151 (1), AT 181 (1), AT 186 (8), AT 192 (14), ES 200 (2). SWT 17 (12), SWT 18 (1), SWT 32 (13). [1785–1845 m to 2220 m]

Distribution. Previously recorded from the Faroe Channel and southern Norway, south to the Cape Verde area and from the Porcupine Seabight, the last by Farran (1913); 286–2200 m.

Feeding. Bottom photographs and submersible observations have led to speculation on the

mode of life of members of this very singular deep-sea family. A bottom photograph in Rowe & Staresinic (1979) from the Tongue-of-the-Ocean (Bahama Is.) at 2000 m shows an asteroid (with arms raised up in a filter feeding posture) which probably belongs to this family. Pawson (1978) gives photographs of brisingids in a similar posture and comments that they are presumably capturing particulate matter from the water and transporting it to the mouth by ciliary currents.

REPRODUCTION. The oocytes grow up to 1250 μm in diameter (P.A.T., personal observations); this suggests a direct mode of reproductive development.

REMARKS. This species is thought to prefer a rocky bottom (Mortensen, 1927). Some of the present records of this very large species are of disks only. This is unfortunate, as the serial gonads in the arms of *Brisinga endecacnemos* provide the most obvious distinguishing feature from *Brisingella coronata.*

Brisingella coronata (G. O. Sars, 1871)

See: Ludwig, 1897 : 418; Mortensen, 1927 : 127.

SAMPLES. AT 138 (1), AT 162 (5), AT 167 (4), ES 176 (1), AT 177 (1). [992–2450 m]

DISTRIBUTION. Recorded from the Rockall Trough by Grieg (1921) and off northern Norway south to the Cape Verde Is. area and the Azores; 100–2600 m.

The present records at 992 m in the Porcupine Seabight, where it has previously been collected by Farran (1913), and at St. 'M' hence are not unexpected.

REPRODUCTION. The eggs grow up to 1200 μm diameter (P.A.T., personal observations); this suggests direct development.

Freyella spinosa Perrier, 1894

See: Perrier, 1894 : 85–89, pl. 8; Mortensen, 1927 : 129.

SAMPLE. SWT 15 (6). [4810 m]

DISTRIBUTION. Previously known from the Bay of Biscay south to the Azores and Angola; 1884–4060 m.

The present record extends the range northwards into the Porcupine Abyssal Plain and downwards to 4810 m depth.

REMARKS. Pawson (1978) mentions that he has observed from the submersible *Alvin* a species of *Freyella* feeding with '... arms upraised, and it tends to raise itself as far as it can into the water column by climbing to the tops of nearby rocks.'

The stronger articulation at the base of each arm ensures that most specimens of *Freyella* are preserved with at least the proximal parts of some arms still attached to the disk, unlike *Brisinga* and *Brisingella. F. spinosa* has 8–13 arms.

Freyella sexradiata (Perrier, 1885)

See: Perrier, 1894 : 89–90, pl. 3, fig. 2; Grieg, 1921 [1932]; 30–31, fig. 10; Mortensen, 1927 : 129.

SAMPLE. SWT 15 (1). [4810 m]

DISTRIBUTION. Previously recorded from the Bay of Biscay south to the latitude of Gibraltar (*c.* 35°N) and west to the Azores; 4020–5110 m.

The single specimen collected in the Porcupine Abyssal Plain along with *F. spinosa* likewise extends the known range northwards from the Bay of Biscay.

Family **ASTERIIDAE**

Hydrasterias sexradiata (Perrier, 1882)

See: Perrier, 1894 : 100–102, pl. 9, fig. 2 (as *Pedicellaster sexradiatus*).

SAMPLES. AT 138 (arms), AT 139 (arms), AT 154 (7), AT 167 (1), ES 176 (juvenile, 1). [2245–2450 m]

DISTRIBUTION. Previously known from the Bay of Biscay south to the Cape Verde Is. area and the Azores; 600–4260 m.

This record extends the known distribution of this species northward in the NE Atlantic to the Rockall Trough.

ONTOGENY. The juvenile specimen is at the armless 'Stellosphaera mirabilis' stage of Perrier (1894). The identification has been confirmed by Miss M. E. Downey of the Smithsonian Institution, Washington, U.S.A., partly on the basis of the structure of the crossed pedicellariae, which are much more compact than those of *Freyella sexradiata,* the only other six-rayed forcipulate known from this vicinity.

Stichastrella rosea (O. F. Müller, 1776)

See: Süssbach & Breckner, 1911 : 228–229 (as *Stichaster roseus*); Mortensen, 1927 : 136, fig. 77.

SAMPLES. ES 15 (1 var. *ambigua*), ES 33 (2), ES 113 (4; juvenile, 1). GT 1 (2 var. *ambigua*), GT 7 (1 var. *ambigua*), GT 14 (3). [168–1632 m]

DISTRIBUTION. Previously known from the Lofoten Is., Norway and the north and west of the British Isles south to the Bay of Biscay; 4–1150 (? 1330) m.

The present records are from the Hebridean Slope, adjacent shelf and the Rockall Bank and show a considerable depth range. Mortensen (1927) cites records of this species known only from the NE Atlantic from 4 m to 430 m depth, while in 586 (?–393) m–1146 (? 1331) m in the Porcupine Seabight Farran (1913) records a variety *ambigua* with shorter and stouter arms which differs also in the even more regular arrangement of the dorsal skeletal plates than is present in *S. rosea* sensu stricto, itself a relatively regular asteriid. On this account together with the bathymetric difference, A.M.C. considers that a specific rank for *ambigua* may prove to be more appropriate. The problem will be considered in Clark & Downey (in prep.).

REMARKS. The juvenile specimen from St. ES 113 has R only 3·9 mm, R/r 1·6/1. The relatively large semicircular terminal plates are 1·3 mm broad and each bears a conspicuous horizontal fan of fourteen flat petaloid spines similar to the two spines on each of three ambital inferomarginals in each series, the first inferomarginal being spineless and the fifth and distalmost with a single smaller spine.

Family **ZOROASTERIDAE**

Zoroaster fulgens Wyville Thomson, 1873

See: Farran, 1913 : 19–22, pl. 1, fig. 3 (as *Z. fulgens* var. *Ackleyi*); Mortensen, 1927 : 132–133, fig. 75.

SAMPLES. ES 10 (3), ES 18 (3), ES 20 (1), ES 34 (26), AT 107A (2), AT 114 (17), AT 138 (9), AT 139 (18), AT 171 (7), AT 175 (3), AT 177 (9), AT 181 (3), ES 182 (1), AT 186 (7), AT 191 (juveniles, 11), AT 192 (7), AT 195 (1). GT 17 (2), SWT 10 (1), SWT 11 (2), SWT 12 (1), SWT 13 (1), SWT 15 (1), SWT 16 (366), SWT 17 (128), SWT 18 (21), SWT 27 (2), AT 3 (2). [*c.* 1000–4810 m]

DISTRIBUTION. From its original discovery by the *Porcupine* in the N Rockall Trough in 1869 (W. Thomson, 1873), this species has been found from hauls on soft ooze all over the deep N Atlantic.

The deepest of the present records (SWT 15) from the Porcupine Abyssal Plain extends the previously known bathymetric range of 367–3660 m (Downey, 1973) to 4810 m. However, if *Z. longicauda* Perrier, 1885, from NW of Africa and the Azores, is conspecific with *Z. fulgens,* as Downey (1970) notes is probable, then the previously known depth range must be extended to 4255 m. Specimens were numerous in the vicinity of St. 'M' at depths around 2200 m. The shallowest station was on the adjacent Hebridean Slope.

A photograph showing *Z. fulgens* in situ on the bottom was taken during a RRS *Challenger* haul at *c.* 49°22′N, 12°49′W in 1398–1404 m depth (Rice *et al.*, 1982; fig. 2(e)).

REPRODUCTION. *Z. fulgens* has a maximum egg size of 950 μm (P.A.T., personal observation).

REMARKS. Specimens examined from St. 'M' occasionally contained one or more specimens of an unidentified species of the parasitic ascothoracid barnacle, *Dendrogaster* (P.A.T., personal observations).

Class **OPHIUROIDEA**

Suborder **EURYALIDA**

Family **ASTERONYCHIDAE**

Asteronyx loveni Müller & Troschel, 1842

See: Süssbach & Breckner, 1911 : 262; Mortensen, 1927 : 158–160, fig. 90; D'yakonov, 1954 : 21–22, fig. 4.

SAMPLES. SWT 18 (1), SWT 32 (1). [1785–1845 m to 1995–2020 m]

DISTRIBUTION. This is a widespread species found in all the major oceans except the Arctic; previously recorded bathymetric range, *c.* 100–2963 m. Mortensen (1927) lists several records around the coast of Scotland and Grieg (1921) took a specimen from the Porcupine Seabight at 1797 m.

The present specimens are from the Hebridean Slope and thus extend the known distribution into the Rockall Trough.

REMARKS. The long prehensile arms and climbing habit on gorgonians and pennatulids is typical of euryalids. One specimen collected was entwined in characteristic posture around the pennatulid *Distichoptilum gracile* Verrill. Grassle, Sanders, Hessler, Rowe & McLellan (1975) observed *Asteronyx loveni* from the submersible *Alvin* at *c.* 1800 m depth off New England, the ophiuroid being present coiled in the branches of every gorgonian seen. Hartman (1963) photographed *A. loveni* on the ocean floor using its long arms to feed from the water column above. Mortensen (1927), in notes on the biology of this species, states that adults are plankton eaters; two or three arms are wound around the pennatulid, while the others wave freely in the water catching the small pelagic animals, mainly copepods, on which it feeds. Mortensen also thought that this species may feed on the polyps of the pennatulid to which it clings.

Astrodia tenuispina Verrill, 1884

See: Verrill, 1884 : 219; Koehler, 1907 : 304, pl. 21, figs 48–50.

SAMPLE. SWT 13 (147). [3425–3500 m]

DISTRIBUTION. Previously recorded from the N Atlantic deep-sea region; 2365–3300 m.

This unusually large sample was recovered from the deep water connecting the southern Rockall Trough with the Porcupine Abyssal Plain, so being the first record for this species in the deep sea around the British Isles and from a greater depth than previously recorded.

REMARKS. Most specimens when examined were entwined around the pennatulid *Scleroptilum grandiflorum* Kölliker.

The stomach was devoid of recognisable contents except in one of ten individuals examined. In this specimen, remains of the uropods of a mysid crustacean were found. It seems likely that this species feeds on plankton in a manner similar to that which Mortensen (1927) supposed for *Asteronyx loveni.*

REPRODUCTION. Measurements of disk diameter show a unimodal frequency ranging from 5·25–11·25 mm, peaking in the 7·50–7·75 size interval. Of the ten individuals dissected, all appeared to have female interradial gonads, each gonad containing mainly large yolky-looking eggs. Fecundity, expressed as the number of visible gonads, may vary widely between individuals. In one specimen, the gonads extended dorsally over the large stomach.

Family **ASTEROSCHEMATIDAE**

Asteroschema inornatum Koehler, 1906

See: Koehler, 1909 : 206, pl. 3, figs 46, 47.

SAMPLE. ES 112 (1). [1900 m]

DISTRIBUTION. Known only from the NE Atlantic deep sea; 1480 m (Mortensen, 1933 : 114).

The present record from the Feni Ridge extends the bathymetric and northern geographic range of this species.

REMARKS. The single specimen was entwined in characteristic fashion on a gorgonian provisionally identified as *Paramuricea biscaya* Grasshoff, 1977.

Family **GORGONOCEPHALIDAE**

Gorgonocephalus caputmedusae (Linnaeus, 1758)

See: Mortensen, 1927 : 162–163, figs 91, 92.

SAMPLES. GT (1), AT 3 (1). [972–1084 m]

DISTRIBUTION. West of the British Isles this species has been recorded off Cornwall, off SW Ireland and Lousy Bank; 1116–1214 m. Elsewhere it is known from scattered localities all over the N Atlantic; full bathymetric range *c.* 150–1200 m.

The present samples were recorded from the Hebridean Slope west of Barra.

REMARKS. The recovery of a single specimen entangled around a sounding line cast to 800 fathoms (1463 m) in Baffin Bay during Sir John Ross' attempt to find the North West Passage represents probably the first ever record of a deep-sea animal (Menzies, George & Rowe, 1973). *Gorgonocephalus caputmedusae* uses its branched arms to ensnare plankton. Mortensen (1927) records that it is often found aggregated on rocks in current-swept areas.

Suborder **OPHIURIDA**

Family **OPHIACANTHIDAE**

Ophiotrema alberti Koehler, 1896

See: Koehler, 1909 : 196–198, pl. 28, figs 1, 2.

SAMPLE. AT 192 (2). [1862 m]

DISTRIBUTION. Previously recorded only from deep water off the Azores and in the S Atlantic (Mortensen, 1927); 3785–4060 m.

The present record from the Feni Ridge is considerably shallower than any previous record for this species.

REMARKS. The dorsal side of the disk was missing from both specimens and large orange-yellow gonads were visible.

Ophiomyces grandis Lyman, 1879

See: Lyman, 1879 : 46, pl. 14 figs 383–385; 1882 : 241–242, pl. 19 figs 13–15.

SAMPLE. SBC 62 (3). [610 m]

DISTRIBUTION. Previously recorded from off Tristan da Cunha (1800 m) and in the Bay of Biscay; 230–800 m.

These specimens were collected from the Hebridean Slope west of Barra. This is the first record of *O. grandis* off Britain and is a northern extension of its known previous range.

REMARKS. The scarcity of occurrence may reflect a lack of sampling in the present programme at depths between 230–800 m where it may be expected (Cherbonnier & Sibuet, 1973).

Ophiacantha abyssicola G. O. Sars, 1871

See: Mortensen, 1927 : 194, fig. 105; 1933 : 23–24, fig. 9.

SAMPLES. ES 23 (4), ES 115 (4; ? [juveniles] 6). [704–1000 m]

DISTRIBUTION. This species is distributed throughout the N Atlantic. Although a wide bathymetric range, *c.* 35–3500 m, is quoted (Mortensen, 1933; see also D'yakonov, 1954 and Cherbonnier & Sibuet, 1973), it appears to be essentially an upper bathyal species extending into the shallow coastal areas of the Norwegian Sea. It has also been recorded on the Irish shelf off Eagle Island at a depth of 301 m (Farran, 1913). Samples providing unpublished records of *O. abyssicola* collected by the *Porcupine* from Rockall and SW Ireland are to be found in the British Museum (Natural History).

Ophiacantha abyssicola was recovered only from the Hebridean Slope off Barra and on the Hebridean Terrace Seamount but, like *Ophiomyces grandis,* the apparent rarity of this species in the samples may result from lack of sampling at favourable depths.

Ophiacantha bidentata (Retzius, 1805)

See: Mortensen, 1927 : 196, fig. 105; 1933 : 20–22, figs 6–8.

SAMPLES. ES 10 (39), ES 12 (? 1), ES 34 (11), ES 55 (juvenile, 1), ES 56 (juveniles, 2), ES 69 (? [juveniles] 2), AT 107A (7), ES 112 (7), AT 121 (14), AT 139 (8), AT 141 (12), AT 144 (211), ES 147 (3), AT 151 (72), ES 152 (juvenile, 1), AT 153 (96), AT 154 (69), SBC 155 (juvenile, 1), AT 157 (2), ES 164 (?[juvenile] 1), AT 167 (264), AT 171 (168), ES 172 (juvenile, 1), AT 175 (85), ES 176 (10; ? [juveniles] 17), AT 177 (259), AT 181 (128), ES 184 (55), AT 186 (217), AT 191 (49), AT 192 (168), AT 195 (186), ES 197 (104), AT 198 (34), ES 200 (45). SWT 10 (1), SWT 11 (2), SWT 16 (1), SWT 18 (1), SWT 32 (14). [1330–2925 m]

DISTRIBUTION. A widespread Arctic species the range of which extends into the N Atlantic. A large bathymetric range of 10–4500 m is quoted (Mortensen, 1933), but in the 'warm water' areas of the N Atlantic the bathymetric distribution is more restricted and it rarely occurs above 500 m.

Ophiacantha bidentata occurs abundantly in the Rockall Trough. Agassiz trawls from the Feni Ridge and from the repeat station St. 'M' at depths of 1900–2200 m have collected large numbers of this species. It was also recorded from the Porcupine Seabight at 1765 m depth by Farran (1913) under the name *O. hibernica.*

REMARKS. *Ophiacantha bidentata* was collected with its arms typically entwined in the branches of the gorgonian *Acanella arbuscula* (Johnson), which occurs in abundance on the west and east sides of the Anton Dohrn Seamount. It was also found occasionally attached to the calcareous bases of both living and dead specimens of *Flabellum alabastrum* Moseley. Grassle, Saunders, Hessler, Rowe & McLellan (1975), observed an *Ophiacantha* sp. (either *O. bidentata, O. aculeata* or *O. simulans*) from the submersible *Alvin*, on rocks and small cobbles but not on the mud bottom, at *c.* 1800 m off New England. *Acanella* seems to occur on relatively current-swept bottoms on the continental margin where it may show a consistent orientation to the current direction (Laubier & Sibuet, 1979). At St. 'M', near-bottom currents may reach almost 50 cm/sec (Edelsten, 1980). Hence it seems likely that *Ophiacantha bidentata*, in common with other ophiacanthids, feeds on suspended material

using arms held out into the current in a similar way to that described by Warner & Woodley (1975) for *Ophiothrix fragilis* (family Ophiotrichidae).

The colour of the arms of fresh specimens was not drab brownish as Mortensen (1927) describes, but a fresh salmon pink, while the disk was a similar colour and greyish green where the underlying large green-coloured stomach showed through.

Reproduction. Studies on the breeding of this species show that the St. 'M' specimens are protandrous hermaphrodites with probably direct or abbreviated development, whereas re-examination of the shallow Arctic population, originally studied by Thorson (1936), confirms his finding that these individuals have separate sexes (Tyler & Gage, 1982*a*). A much needed revision of the genus *Ophiacantha* may well separate the N Atlantic deep-sea populations as a distinct species from the shallow Arctic populations.

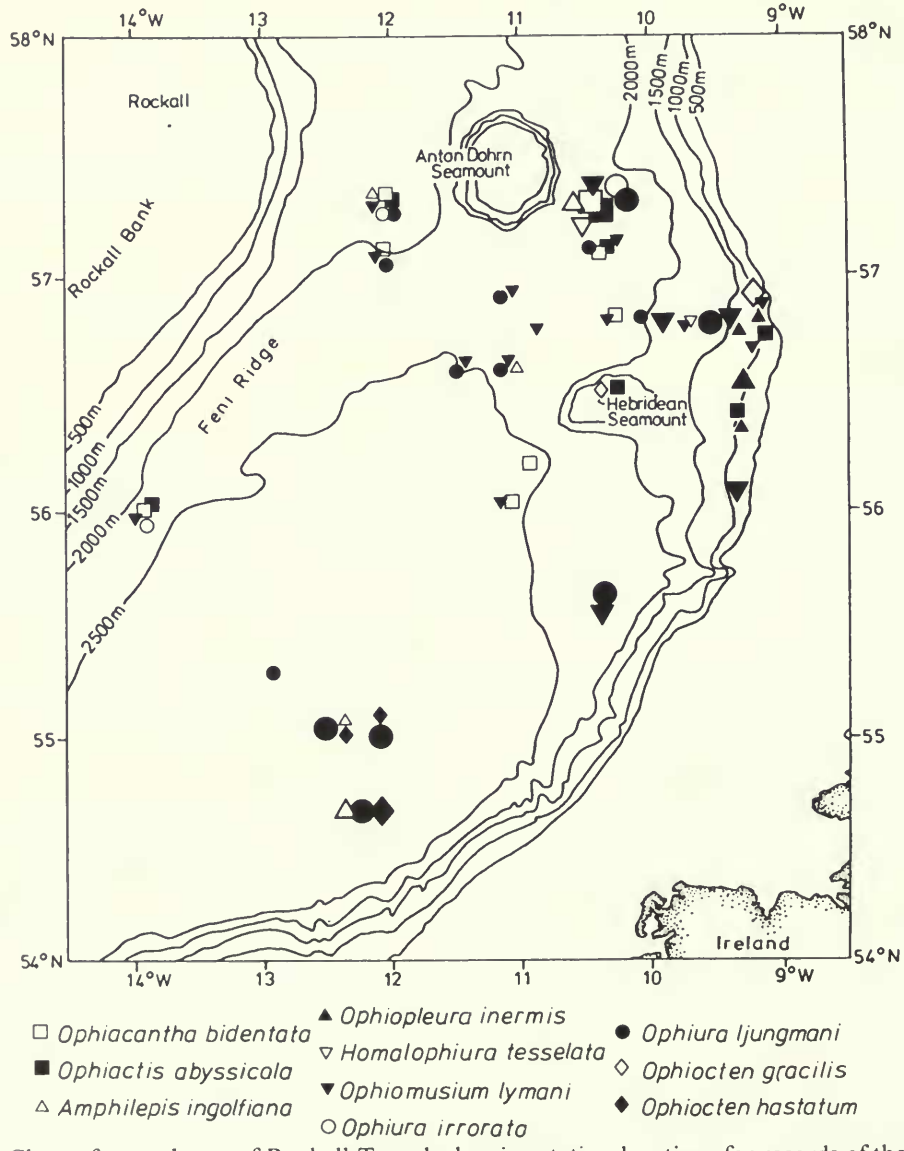

Fig. 3 Chart of central part of Rockall Trough showing station locations for records of the ten most abundant brittle star species. Larger symbols denote records from more than one sample taken on or near the station position.

Ophiacantha crassidens Verrill, 1885

See: Mortensen, 1927 : 192–193, fig. 106.

Sample. AT 192 (6). [1862 m]

Distribution. Previously known only from the N Atlantic deep-sea region (Mortensen, 1933); *c.* 970–3120 m. This species was taken by the *Helga* in the upper Porcupine Seabight from 986 m to 1861 m depth (Farran, 1913) but was not previously known from the Feni Ridge where these specimens were collected in a single haul.

Remarks. The colour of fresh specimens is a pale yellowish pink with slightly greyish darker areas on the disk. The underlying stomach is orange coloured.

Ophiacantha cuspidata Lyman, 1878

See: Mortensen, 1933 : 31–33, figs 17, 18.

Sample. ES 112 (2). [1900 m]

Distribution. Previously known from scattered localities in the eastern and central North Atlantic from Iceland and off the Azores; 785–2460 m.

Two specimens were collected from the southern Feni Ridge making this the first record of *O. cuspidata* in the deep water off the British Isles.

Ophiacantha simulans Koehler, 1896

See: Mortensen, 1933 : 26–29, figs 11, 13.

Sample. ES 112 (26). [1900 m]

Distribution. Previously known in the eastern and central North Atlantic from off the Azores, the Bay of Biscay and S and SW of Iceland from 1480 m to 3018 m (Mortensen, 1933); in the western north Atlantic from off North Carolina.

The present record of twenty-six individuals from a single sled haul on the southern Feni Ridge represents an extension of the known range of this species to the British seas.

Remarks. It is interesting to note that an apparently discrete zonation of this species centred on 1900 m depth is described by Menzies, George & Rowe (1973) off the Carolinas (NW Atlantic). These authors also provide, from the basis of bottom photographs, a 'habitat sketch' of this animal lying on the sediment surface in a characteristic posture with the greater length of the arms raised vertically in the water, presumably feeding.

Ophiacantha aculeata Verrill, 1885

See: Mortensen, 1933 : 28–29, figs 14c, 15.

Sample. SWT 13 (1). [3425–3500 m]

Distribution. Previously recorded from the NW Atlantic with a bathymetric distribution of 2425–2510 m.

This solitary record from the Rockall Trough is the first from the E Atlantic and extends the bathymetric range.

Ophiolimna bairdi (Lyman, 1883)

See: Lyman, 1883: 256, pl. 5 (as *Ophiacantha*); Lütken & Mortensen, 1899; 177, pl. 18 (as *Ophiacantha*); D'yakanov, 1954 : 24, fig. 6.

Sample. ES 118 (1). [2910 m]

Distribution. *Ophiolimna bairdi* has a circumpolar arctic, N Atlantic and Pacific range; previously known bathymetric range 620–2600 m. The vertical limits of this species appear to be restricted in the warm water area of the N Atlantic to bathyal or abyssal depths and

this species, like *O. bidentata,* seems to demonstrate Ekman's (1953) 'submergence' phenomenon.

This is the first record of this species in the Rockall Trough although Mortensen (1933) stated that this species can 'be expected to occur all over the deeper parts of the North Atlantic'.

Family **OPHIACTIDAE**

Ophiactis abyssicola (M. Sars, 1861)

See: Mortensen, 1933 : 47–50, figs 28–30.

SAMPLES. ES 18 (1), ES 34 (1), ES 112 (700), ES 113 (juvenile 1), ES 115 (7), AT 144 (2), AT 151 (1), AT 157 (43), AT 167 (3), AT 171 (2), AT 177 (9), ES 184 (2), AT 191 (16), AT 192 (26), AT 195 (9), ES 197 (1). GT 1 (3), GT 8 (1), SWT 12 (10), SWT 32 (2). [168 m to 2980–3000 m]

DISTRIBUTION. This species has a wide distribution throughout the Atlantic including the Norwegian Sea; 125–4000 m. *Ophiactis abyssicola* was previously taken in the Rockall Trough by the *Michael Sars* at 1856 m depth (Grieg, 1921).

Although occurring in small numbers in hauls from St. 'M', this species appears most abundant on the Feni Ridge from where in a single haul at 1900 m depth (ES 112) *O. abyssicola* dominated the ophiuroid catch. It also occurred in small numbers on the Hebridean slope as shallow as 650 m depth, and on the Hebridean Seamount at around 1000 m. Both locations are thought to be somewhat current-swept, as is also the area of the Feni Ridge sampled by ES 112 and the bottom at St. 'M'.

REMARKS. This species previously has been collected amongst branching corals and alcyonarians, and especially on the Bird's Nest Sponge, *Pheronema,* off western Ireland (Farran, 1913). The present records are mainly from St. 'M' where it was found entwined, along with *Ophiacantha bidentata,* amongst the bushy growths of the gorgonian *Acanella arbuscula.* It was occasionally also found in the base of both living and dead specimens of the solitary coral *Flabellum alabastrum.*

Freshly collected specimens are a fresh salmon-pink or orange colour, with grey colouring on the dorsal disk where the underlying stomach shows through the body wall.

Ophiactis balli (Thompson, 1840)

See: Süssbach & Breckner, 1911 : 252; Mortensen, 1927 : 200–202, fig. 112.

SAMPLE. ES 113 (1). [168 m]

DISTRIBUTION. Appears to be limited to the NE Atlantic where it has been recorded from both the Rockall and Lousy Banks, from off the south and west coasts of the British Isles and in the North Sea (Mortensen, 1927); mainly 60–400 m (extending to 1765 m). Farran (1913) lists records on the Porcupine Bank indicating that it is 'common . . . in water from about 30 fathoms downwards, wherever it can find crevices in stones or coral in which to insert itself'.

The present record on the Rockall Bank is not unexpected for this essentially upper bathyal-shelf species.

Family **AMPHIURIDAE**

Amphiura otteri Ljungman, 1871

See: Mortensen, 1933 : 59–61, fig. 35 (as *A. palmeri* Lyman).

SAMPLES. SBC 67 (1), ES 143 (1). [1000–2892 m]

DISTRIBUTION. This species is widespread, being found on both sides of the Atlantic; previously known bathymetric range, 210–1425 m.

These records from the Hebridean Slope and the Permanent Station appear to be the first published for this species from the deep sea around the British Isles, and the lower known depth range is extended.

REMARKS. The identification of this species was mistakenly given by Mortensen (1933) and Koehler (1907) as *A. palmeri* Lyman. Furthermore, we can find no difference between specimens described by Koehler (1896) as *A. grandis* and *A. otteri* Ljungman, 1871; *A. otteri* takes precedence.

Amphiura fragilis Verrill, 1885

See: Mortensen, 1927 : 214, fig. 121 (as *A. denticulata* Koehler).

SAMPLES. ABD 24 (2). [810 m]

DISTRIBUTION. *A. fragilis* has been recorded from both sides of the N Atlantic. In the west from off Martha's Vineyard north to the Davis Strait and W. Greenland. From the east it has been recorded from the Faroe Channel; 430–2640 m.

This sample is from the Hebridean Slope and is the first record of this species from the 'warm' water off the west of the British Isles.

Amphiura griegi Mortensen, 1920

See: Mortensen, 1927 : 210, fig. 119.

SAMPLE. ABD 24(1). [810 m]

DISTRIBUTION. Previously known from Norwegian fjords at 60 m to 300 m depth (Mortensen, 1920) and from the Bay of Biscay at 328–562 m (Cherbonnier, 1969; 1970). *Amphiura griegi* appears to be sporadically distributed from Norway south to the Bay of Biscay.

The present record of this little known species from the Hebridean Slope represents an interesting addition to its known geographic and bathymetric range.

Amphipholis squamata (Delle Chiaje, 1828)

See: Süssbach & Breckner, 1911: 253 (as *Amphiura elegans*); Mortensen, 1927: 221–222, fig. 125; A. M. Clark, 1970a: 30.

SAMPLES. ES 5 (5), ES 23 (juveniles, 2), SBC 66 (juveniles, 5), ES 99 (juveniles, 28), ES 115 (juvenile, 1), SBC 155 (juvenile, 1). [704–1330 m]

DISTRIBUTION. This species is known to have a cosmopolitan distribution throughout temperate and tropical coastal waters, which extends into the intertidal in the British Isles (Mortensen, 1927; Marine Biological Association, 1957); previously known from 0–809 m (Mortensen, 1933; Hartman & Barnard, 1958).

The present records on the Hebridean Slope, N Feni Ridge and Whittard Canyon considerably extend the lower limit of the previously known bathymetric range.

REMARKS. The microphagous suspension feeding mechanism of this species has been described by Pentreath (1970) from New Zealand material.

REPRODUCTION. *A. squamata* is known to brood its young (Mortensen, 1927; Fell, 1946) and hence it is difficult to explain the occurrence of individuals in deep water as sterile outliers resulting from fall-out of pelagic larvae emanating from shallower depths. We therefore infer a possibly continuous distribution from the intertidal zone (Loch Creran, personal observations of J.D.G.) to bathyal depths off the west of Scotland and probably elsewhere.

Subfamily **AMPHILEPIDINAE**

Amphilepis ingolfiana (Mortensen, 1933)

See: Mortensen, 1933 : 54–56, figs 31–33.

SAMPLES. ES 4 (134), ES 6 (10), ES 8 (1), ES 10 (29, ? 10), ES 12 (juvenile, 5), ES 27 (? [juveniles] 2), ES 32 (1), ES 34 (17), ES 55 (? 1), ES 56 (2), ES 111 (1), ES 118 (1), AT 121 (2), ES 135 (1), ES 140 (4), ES 143 (2), AT 151 (1), AT 153 (2), SBC 163 (1), ES 164 (2), ES 169 (juveniles, 3), ES 172 (juveniles, 5), ES 176 (18; ? [juveniles] 5), AT 177 (4), ES 180 (1), ES 184 (13), ES 185 (12), AT 186 (1), ES 190 (5), AT 192 (1), ES 197 (7, ? 1), ES 220 (1). [1862–2925 m]

DISTRIBUTION. Although Mortensen (1933) pointed out that the published records and descriptions of *A. norvegica* from the Atlantic (Lyman, 1882; Verrill, 1884; Koehler, 1924) refer to *A. ingolfiana,* it is likely that N Atlantic deep-sea records of *A. norvegica* made subsequent to publication of Mortensen's description of *A. ingolfiana* also should be referred to this species, notably those of Cherbonnier & Sibuet (1973) from the Bay of Biscay down to 4760 m depth.

Amphilepis norvegica then remains as an essentially shallow Arctic species with records from the northern Norwegian Sea down to the southern North Sea (Süssbach & Breckner, 1911) and the Faroe-Shetland Channel.

Amphilepis ingolfiana is probably widely distributed throughout the N Atlantic (see also Schoener, 1967) but because of the confusion existing between the two species, it is difficult to give an accurate geographic or bathymetric range. Mortensen (1933) quoted the depth range of *A. ingolfiana* as 957 to 2580 m.

REMARKS. Some specimens collected in our samples had a ferruginous staining that is often found on tubes or hard parts of burrowing fauna that generate a ventilatory current to their burrow. It is interesting to note that such currents have been observed in burrows of other amphiurid species (Woodley, 1975; Ockelmann & Muus, 1978).

Mortensen (1927) mentions that *Amphilepis norvegica* lives '. . . probably burrowed in the mud in the same way as the Amphiuras.' However, it seems unlikely that *A. ingolfiana* is a deep burrower in deep-sea sediments or else it would not be collected in Agassiz trawls or epibenthic sled hauls which disturb only the superficial sediment (Gage, 1975; Gage *et al.,* 1980). Barham, Ayer & Boyce (1967) observed and photographed a small ophiuroid, which they referred to as *Amphilepis* sp., from the bathyscaphe *Trieste* in the San Diego Trough at 1234 m depth: they describe it as normally buried '. . . with only its thin, sediment-colored rays splayed out on the surface.'

By analogy with Woodley's (1975) observations on five species of coastal amphiurids, it seems highly possible that *Amphilepis* is a shallow-burrowing deposit feeder, using the arms and tube feet as undulatory pumps that create a ventilating current, thus carrying mucus-trapped food particles from the tips to the mouth.

Schoener (1967) describes the morphology of the post-larvae and subsequent juvenile stages of this species, which would appear to have a widespread distribution in the N Atlantic deep sea (Mortensen, 1933).

Family **OPHIOCHITONIDAE**

Ophiochiton ternispinus Lyman, 1883

See: Lyman, 1883 : 255, pl. 5, figs 67–69; Mortensen, 1933 : 67–69, fig. 40, pl. 3, figs 25–26.

SAMPLES. AT 157 (2), AT 177 (1), AT 191 (1), AT 192 (1). SWT 18 (1). [1752–2200 m]

DISTRIBUTION. Previously recorded from the Faroes, W Ireland and N America; 425–1850 (? [2220) m. Mortensen (1933) considers that this large species probably is widely distributed in the N Atlantic deep sea. However, it seems likely that nowhere is it abundant, previous records being of single specimens in trawl hauls. The original description of Lyman (1883) was based on a specimen dredged by the *Porcupine* in the Porcupine Seabight. Grieg (1921) records a single specimen collected by the *Michael Sars* from a position in the Rockall Trough close to St. 'M'.

The present records extend the known deeper bathymetric range, although records for *O. grandis* Verrill, 1884, which Mortensen (1933) synonymises with *O. ternispinus,* and for *O.*

solutus Koehler 1907, which Mortensen (1927) considers may well represent the present species, extend the previous known range to 2220 m depth.

REMARKS. The colour of fresh material was a drab olive on the disk with fawn coloured arms.

Family **OPHIURIDAE**

Subfamily **OPHIURINAE**

Ophiopleura inermis (Lyman, 1878)

See: Mortensen, 1927 : 251–252, fig. 137 (as *O. aurantiaca* (Verrill)).

SAMPLES. ES 20 (1), ES 99 (1). GT 1 (3), GT 2 (1), GT 8 (5), GT 11 (1), GT 16 (6). [650–805 m to 1271 m]

DISTRIBUTION. On comparing the syntypes of *Ophiura inermis* (Lyman) with specimens of *Ophiopleura aurantiaca* held in the collections of the British Museum (Natural History), we can find no difference between them. We therefore agree with Mortensen (1933) that the two names are synonymous, the species being distributed in both the N and S Atlantic with a bathymetric range of 280–1875 m. In the NE Atlantic, this species has been collected from depths of 567 m and greater off Iceland and around 1000 m depth in the N Rockall Trough (Hoyle, 1884) to *c.* 1200 m in the Porcupine Seabight and 1490–1740 m in the Bay of Biscay and the Azores (Mortensen, 1927).

The present records may reflect an intermediate level of progressive submergence in the range of this species from high to lower latitudes in the N Atlantic.

Ophiopleura borealis Danielssen & Koren, 1877

See: Mortensen, 1927 : 249–250, fig. 136; 1933 : 94–96.

SAMPLE. ES 87 (4). [1050 m]

DISTRIBUTION. Known previously from Arctic seas and off Britain from the cold area of the Faroe Channel; 10–1885 m.

The occurrence of this impressively large species amongst the present records is confined to a single haul from the cold water to the north of the Wyville Thomson Ridge.

REMARKS. The four specimens collected measured from 33 to 35 mm in disk diameter (cf. the size frequency distribution in Mortensen (1933)).

Homalophiura tesselata (Verrill, 1894)

See: Koehler, 1898 : 37, pl. 7, figs 34, 36; 1909 : 156, pl. 25, figs 12–13; Mortensen, 1927 : 231–232.

SAMPLES. AT 144 (2), AT 151 (1), AT 154 (2), AT 171 (3), ES 176 (1), AT 181 (1), ES 184 (1). SWT 18 (4). [1785–1845 m to 2264 m]

DISTRIBUTION. *H. tesselata* has previously been found throughout the N Atlantic; 458–3720 m.

The present records, which extend the distribution of this species to the Rockall Trough, are all from St. 'M' (*c.* 2200 m depth) or the adjacent Hebridean Slope and lie within the bathymetric range quoted (Mortensen, 1927). *H. tesselata* remains unknown beyond the N. Atlantic (Cherbonnier & Sibuet, 1973).

Amphiophiura convexa (Lyman, 1878)

See: Lyman, 1878 : 84, pl. 3, figs 83, 84; 83, pl. 3, figs 85, 86 (as *A. bullata*); Mortensen, 1927 : 231.

SAMPLES. ABD 3 (juvenile, 1), ES 10 (10). [1997–2540 m]

DISTRIBUTION. This species may have a cosmopolitan distribution in the abyssal of the world ocean; 2160–5280 m in Atlantic (Cherbonnier & Sibuet, 1973).

REMARKS. Specimens were collected from two stations in the Rockall Trough. Cherbonnier & Sibuet (1973) found specimens possessing certain characteristics of both *A. convexa* and *A. bullata* (Wyville Thomson, 1873) suggesting that these are conspecific; they note that both have a nearly identical distribution in the Atlantic. *Amphiophiura convexa* was first recorded in the Pacific.

Amphiophiura saurura (Verrill, 1894)

See: Koehler, 1898 : 40, pl. 6, figs 19–21; Mortensen, 1927 : 231; 1933 : fig. 49, pl. 3, figs 9, 10.

SAMPLE. ES 112 (11). [1900 m]

DISTRIBUTION. Previously collected in the Bay of Biscay but unknown in British Seas. Although apparently uncommon, Mortensen (1933) suggests that this species has a wide distribution in the N Atlantic deep sea; 848–2167 m. The depth of the present record on the Feni Ridge falls within this range.

? Stegophiura macrartha H. L. Clark, 1915

See: H. L. Clark, 1915 : 315, pl. 19, fig. 7, 8.

SAMPLE. ES 112 (1). [1900 m]

DISTRIBUTION. Previously recorded only once before off Georgia (NW Atlantic) at a depth of 424 m.

This find on the Feni Ridge represents the first record in the eastern Atlantic and extends the bathymetric range to 1900 m.

Ophiocten gracilis (G. O. Sars, 1871)

See: Paterson, Tyler & Gage, 1982: 115–117.

SAMPLES. ES 4 (juveniles, 3315), ES 5 (juveniles, 265), ES 10 (juveniles, 43400), ES 12 (juveniles, 1240), ES 18 (juveniles, 4441), ES 20 (7465), ES 22 (6761), ES 23 (5665), ES 27 (juveniles, 3), SBC 46 (juveniles 3), ES 54 (juvenile, 1), SBC 58 (juveniles, 33), ES 59 (juveniles, 2281), SBC 60 (? juvenile) 1), SBC 64 (juvenile, 1), SBC 65 (juveniles, 21), SBC 66 (57), SBC 67 (26), SBC 68 (juveniles, 11), ES 69 (9946), ES 90 (10), AT 90A (1), ES 111 (juvenile, 1), ES 99 (? 6; juveniles, 1627), ES 111 (juvenile, 1), ES 115 (312), ES 129 (juveniles, 5), ES 135 (juveniles, 16562), ES 137 (juveniles, 35), AT 141 (2), ES 147 (juveniles, 10263), ES 164 (juveniles, 417), ES 169 (juvenile, 1), ES 172 (juveniles, 1694), ES 176 (juveniles, 10380), ES 178 (147), ES 180 (juveniles, 8), ES 184 (juveniles, 650), AT 1 (77). [704–2925 m]

DISTRIBUTION. The synonomy and status of species of the genus *Ophiocten* have recently been revised by Paterson, Tyler & Gage, (1982). Identifications of populations of *O. gracilis* previously have been confused both with the shallow arctic species *O. sericeum* (Forbes) and with *O. abyssicolum* (Forbes) which is re-defined as a lusitanian species, the Atlantic distribution of which becomes increasingly submerged northwards, and does not appear to extend into the Rockall Trough (Paterson *et al.*, 1982).

We have found adults (2·50–4·75 mm disk) of *O. gracilis* only from upper bathyal depths on the Hebridean slope (stations ES 20, ES 22, ES 23, SBC 66, SBC 67 in the north Rockall Trough at 1040 m depth (ES 90) and on the Hebridean Seamount at 1000 m depth (ES 115). The remaining records listed above refer only to post larvae of this species found in samples from greater depths where a massive but non-viable settlement occurs from pelagic larvae probably originating from the upper slope populations (Gage & Tyler, 1981*a*), Semenova, Mileikovsky & Nesis (1964) and Tyler & Gage (1982*b*), show that a form of *'Ophiopluteus ramosus'* which Geiger (1963) and the above authors indicate to be abundant in the surface zooplankton in spring in parts of the N Atlantic, is most probably the pelagic larval stage of this species. We suggest that *O. gracilis* may have a ribbon-like distribution along the upper continental slope, and on submerged banks around the 1000 m depth level, around the N Atlantic.

REMARKS. The evidently high population densities (Semenova *et al.*, 1964; Gage & Tyler, 1981*a*) suggest that *O. gracilis* might be extensively preyed on by bottom feeding fish: remains of this species are identifiable and commonly found in stomachs of demersal fish trawled on the Hebridean slope (Mauchline & Gordon, personal communication).

Close-up bottom photographs taken at around 1000 m on the Hebridean slope only rarely show brittle stars (A. J. Southward, Marine Biological Association, Plymouth, personal communication). Possibly the individuals of this abundant population are shallow burrowers, or lie with the mottled coloured disk closely pressed against the sediment or with a dusting of particles covering it. The markedly long oral and arm tube-feet of this species may be associated with a microphagous feeding mechanism.

Ophiocten hastatum Lyman, 1878

See: Paterson, Tyler & Gage, 1982: 117–119.

SAMPLES. ES 6 (9; ? [juveniles] 4), ES 10 (1; ? [juveniles] 2), ES 27 (1; ? [juvenile] 1), ES 31 (1), ES 52 (2), ES 55 (1), ES 56 (2; ? [juvenile] 1), AT 107A (10), ES 111 (1), AT 119 (1), AT 121 (187), ES 129 (1), ES 137 (4; ? [juvenile] 1), ES 140 (7), ES 143 (? 4), ES 147 (7), ES 152 (2), ES 164 (? 1), ES 185 (5). OTSB 51001 (1). [2000 m to 2921 (? 2925) m]

DISTRIBUTION. This species may now be regarded as cosmopolitan in distribution, with a bathymetric range in the lower abyssal from 1130 to 5000 m, but concentrated on the lower abyssal zone. Paterson, Tyler & Gage (1982) in re-examining species of the genus *Ophiocten* have found no significant differences between *O. hastatum* and *O. latens,* records of the latter being confined to the Atlantic.

Ophiura affinis Lütken, 1858

See: Süssbach & Breckner, 1911 : 244–247; Mortensen, 1927 : 244–245, fig. 132.

SAMPLE. ES 113 (10). [168 m]

DISTRIBUTION. Although not apparently recorded previously on Rockall Bank this record is not unexpected in view of the known distribution in the NE Atlantic and around the British Isles (e.g., Farran, 1913; Mortensen, 1927; D'yakonov, 1954; Ursin, 1960); 8–550 m.

Ophiura carnea Lütken, 1858

See: Mortensen, 1927 : 243, fig. 131.

SAMPLES. ES 2 (1), AT 194 (1). [630–2857 m]

DISTRIBUTION. *Ophiura carnea* is an eastern Atlantic species found from Norway south to the Bay of Biscay, previously collected also from the upper Porcupine Seabight by the *Helga* from 215 m to *c.* 400 m (Farran, 1913); 50–1260 m.

The present records are the first for this species in the Rockall Trough, that from the Anton Dohrn Seamount, AT 194 in 630 m depth, is well within the previously recorded range; the one from ES 2 in 2857 m depth represents a considerable extension to the known bathymetric range.

Ophiura irrorata (Lyman, 1878)

See: Lyman, 1882 : 47, pl. 5, figs 7–9; Mortensen, 1933 : 86–87, fig. 48.

SAMPLES. AT 151 (2), AT 175 (1), AT 177 (1), AT 181 (1), AT 191 (59), AT 192 (220), AT 195 (1), AT 198 (1). [1862–2220 m]

DISTRIBUTION. This is a cosmopolitan abyssal species; Mortensen (1933) gives the known bathymetric range as 600–4315 m.

A few specimens were found in Agassiz hauls at St. 'M'. However, hauls on two positions on the Feni Ridge yielded by far the largest samples indicating a more numerous develop-

ment of the population there. All specimens agreed with Mortensen's (1933) description of *O. irrorata* sensu stricto. When compared with localities worked on the eastern side of Rockall Trough, the small numbers or apparent absence of this species seems striking. Possibly, *O. irrorata* is associated with conditions, such as strong bottom currents, that are best developed on Feni Ridge.

REMARKS. The colour of fresh specimens is a pale pink with a dark blue-purple colouration where the stomach shows through the dorsal and ventral disk. The tube feet on the arms are a pale orange colour which immediately distinguishes them from the bright red tube feet of *O. ljungmani* when found in the same haul.

Ophiura imprudens (Koehler, 1906)

See: Koehler, 1907 : 256, pl. 18, figs 9–10.

SAMPLE. ES 113 (6). [168 m]

DISTRIBUTION. This species has only been recorded once before, off the Azores; 560 m.

The present record from Rockall Bank of this evidently rare species is somewhat shallower at 168 m.

Ophiura ljungmani (Lyman, 1878)

See: Mortensen, 1927 : 240–242, fig. 130.

SAMPLES. ES 2 (55), ABD 3 (? 7), ES 4 (1464), ES 6 (1439), ES 8 (? 36), ES 10 (juveniles, 6120), ES 12 (548), ES 14 (32), ES 15 (243), ES 20 (juvenile, 1), ES 27 (170), ES 28 (25), ES 31 (25), ES 32 (1) ES 34 (1164), SBC 46 (3), ES 52 (53), ES 53 (15), ES 54 (1), ES 55 (851), ES 56 (688), ES 57 (921), SBC 58 (5), ES 59 (425), SBC 60 (juveniles, 4), SBC 68 (juvenile, 1), ES 69 (juveniles, 2), ES 99 (juveniles, 8), AT 107A (2), ES 111 (205), ES 112 (44), ES 118 (201), AT 119 (2), AT 121 (640), ES 129 (512), ES 135 (973), ES 137 (787), AT 138 (2), AT 139 (8), ES 140 (1056), AT 141 (50), ES 143(107), AT 144 (3), ES 147 (965), SBC 150 (4), AT 151 (8), ES 152 (360), AT 153 (47), AT 154 (12), ES 164 (530), AT 167 (49), ES 169 (323), AT 171 (17), ES 172 (270), AT 175 (15), ES 176 (289), AT 177 (35), ES 180 (291), AT 181 (35), ES 184 (352), ES 185 (74), AT 186 (25), ES 190 (73), AT 191 (65), AT 192 (38), AT 195 (21), ES 197 (5), AT 198 (1), ES 200 (1). SWT 11 (2), SWT 13 (2). [1050 m to 3425–3500 m]

DISTRIBUTION. Commonly occurring throughout the N Atlantic; 309–4070 m (Cherbonnier & Sibuet, 1973).

Ophiura ljungmani was abundant in samples taken at the Permanent Station (2900 m), becoming less numerous at shallower stations where *Ophiomusium lymani* became abundant, although adult specimens were found as shallow as 1632 m on the Hebridean slope. At the latter position, the bottom haul also included adults of *Ophiocten gracilis* occurring near the lower end of the bathyal range of the breeding population. The deepest record of *Ophiura ljungmani* was from 3425–3500 m in the Porcupine Seabight.

REMARKS. The colour of fresh specimens is pale rose to white, with conspicuously bright red tube feet. The stomach shows through the disk as a dark blue-purple colouration.

REPRODUCTION. *Ophiura ljungmani* has separate sexes in roughly equal proportions. Study of the gametogenic cycle shows a marked seasonal periodicity with rapid vitellogenic growth in autumn and maximum development and probable spawnout by late January/early February at the Permanent Station (Tyler & Gage, 1979, 1980). These authors suggest that egg size (max. 90 μm) and fecundity (up to 5700 eggs per individual) indicate planktotrophic larval development.

Analysis of disk-size frequencies from the Permanent Station indicates low survival of the annually recruited postlarvae and a high though constant rate of mortality amongst older year classes. The time series studied at the Permanent Station also suggests both a seasonal growth pattern, with maximal growth in spring, and a variation in year-class strength (Gage & Tyler, 1981*b*). Reproductive maturity is thought to be reached in the third year at a disk

diameter of 3·5–4·0 mm with individuals thereafter reproducing annually (Tyler & Gage, 1980).

Ophiura ophiura (Linnaeus, 1758)

See: Süssbach & Breckner, 1911 : 238–241 (as *O. ciliaris*); Mortensen, 1927 : 236–238, fig. 128 (as *O. texturata*).

Sample. ES 23 (1). [704 m]

Distribution. Previously recorded all round the coasts in British seas; 0–200 m.

The presence of this well-known coastal species on the upper Hebridean Slope represents a surprising extension of its known bathymetric range.

Subfamily **OPHIOLEPIDINAE**

Ophiomusium lymani Wyville Thomson, 1873

See: Mortensen, 1927 : 253–254, fig. 138.

Samples. ES 4 (153), ES 10 (juveniles, 13), ES 12 (32), ES 14 (10), ES 15 (juveniles, 33), ES 18 (1), ES 20 (juveniles, 4), ABD 24 (1), ES 34 (15), SBC 68 (1), AT 68A (1), AT 107A (192), AT 114 (42), AT 138 (8), AT 139 (14), AT 141 (juveniles, 14), AT 144 (1686), ES 147 (juveniles, 2), AT 151 (233), AT 153 (610), AT 154 (369), AT 157 (3), AT 161 (119), SBC 166 (juvenile, 1), AT 167 (944), AT 169 (juvenile, 1), AT 171 (1565), AT 175 (735), ES 176 (402), AT 177 (1245), AT 181 (1711), ES 182 (140), ES 184 (1174), AT 186 (1027), AT 191 (64), AT 192 (714), AT 195 (1434), ES 197 (308), AT 198 (724), ES 200 (192). SWT 10 (505), SWT 11 (1), SWT 16 (3), SWT 17 (6), SWT 18 (129), SWT 32 (35). [810–2921 m]

Distribution. *Ophiomusium lymani* is now known to have a cosmopolitan distribution; 130–3435 m. It was first described by Wyville Thomson (1873) from dredgings by the *Porcupine* in the Rockall Trough. Elsewhere this species has been recorded from between 700 m and 4700 m and at temperatures varying from 2° to 9°C (Cherbonnier & Sibuet, 1973).

Adult specimens in our samples were taken over a wide area and in depths from 810 m on the Hebridean Slope to 2540 m in the central Rockall Trough. Postlarvae of this species are distinctive and easily recognised (see Schoener, 1967); they were common in epibenthic sled hauls taken between these depths and were also found in hauls down to 2921 m depth in the vicinity of the Permanent Station. This suggests that postlarvae dispersed to depths significantly greater than about 2500 m do not survive to adulthood.

Remarks. The numbers of specimens collected in Agassiz hauls at different depths indicate that the population is best developed around the 2000 m isobath in Rockall. At St. 'M', the population density visible in close-up bottom photographs is a little less than 1 m^{-2} (Dr A. J. Southward, personal communication). Size frequencies from Agassiz hauls at this station show a marked dominance by adults, with a postlarval peak apparent from the fine-meshed epibenthic sled hauls. Although finding no seasonal pattern in oogenesis from comparison of oocyte size frequencies in samples taken at different times of the year, Gage & Tyler (1982) interpret differences in the relative size of the postlarval peak in spring and summer samples as evidence for a seasonal recruitment to the population. A model age structure consisting of two fast growing juvenile year classes with a slowing of growth on attaining reproductive maturity at *c.* 20 mm disk diameter and a consequent 'stacking up' of adult year classes is deduced from study of a time series of disk-size frequencies in large samples of *Ophiomusium lymani* from St. 'M'.

Heavy mortality is thought only to apply to post-larvae; the relatively heavily calcified body and large size of adults protecting them from heavy predation. However, a small percentage (*c.* 2–5%) of specimens show healed, or partially healed, lesions usually in the dorsal interradial area. They may be caused by attacks from biting predators, probably fish. Subsequent regeneration of the wound may give rise to 'monstrous' specimens sometimes found.

Bottom photographs and submersible observations (Barham, Ayer & Boyce, 1967; Wigly & Emery, 1967; Grassle, Sanders, Hessler, Rowe & McLellan, 1975) indicate that this species moves over, or nestles into, the sediment surface without burrowing. Some photographs show the disk raised well clear of the sediment, supported by the proximal part of the arms. Barham *et al.* (1967) suggested that *O. lymani* is a filter feeder; however, the absence of obvious ciliary tracts, long spines and arm podia equipped with mucus producing glands as found in other brittle stars known or likely to filter feed, such as members of the families Amphiuridae, Ophiactidae, Ophiotrichidae and Ophiocomidae (see Fell, 1966 and Reese, 1966 for reviews of pre-1965 literature; Fontaine, 1965; Pentreath, 1970; Warner & Woodley, 1975) seem to render a filter feeding mode of nutrition unlikely for *Ophiomusium lymani.* Preliminary study of the stomachs of specimens from St. 'M' has yielded few recognisable contents, the stomachs of most of 100 specimens examined appearing empty. However, fragments of mysid uropods and small gastropod shells were found along with polychaete setae, indicating that *O. lymani* may rather be an opportunistic scavenger or carnivore.

Discussion

For many relatively well known species that are also abundant in our samples a bathymetric range of adults is recorded that is somewhat narrower than that known over its full range. This is not unexpected considering the comparatively small area of the present study compared to the full geographical range of the deep-sea distribution of a species, when, as seems likely, these distributions are determined chiefly by the temperature of water masses (Ekman, 1953). Examples include the asteroid *Porcellanaster ceruleus* and the ophiuroids *Ophiacantha bidentata, Ophiactis abyssicola, Ophiura ljungmani* and *Ophiomusium lymani.* In addition there are many uncommon species known from great depths to the south that are recorded in the Rockall area at somewhat shallower depth. Examples include the ophiuroids *Ophiotrema alberti, Ophiacantha crassidens* and the asteroids *Pteraster reductus, Hoplaster spinosus.* This may be explained in terms of the general trend towards progressive submergence of the cold, deep ocean water, expressed as a trend to tilting of isotherms in longitudinal sections of the Atlantic Ocean (Wüst, 1936), that is related to the continual formation of deep water from the polar oceans. The species *Ophiacantha cuspidata* provides an illustration of this trend towards an increasingly submerged distribution towards lower latitudes, which is analogous to the bipolar-equatorial submergence seen in distributions of many coastal species in the Atlantic that are described by Ekman, 1953. Mortensen (1927, 1933) cites records made by the *Ingolf* of *O. cuspidata* from SW of Iceland in 1461 m depth, and by the *Challenger* at 785 m depth in the S Atlantic off Ascension Island; while the present records from the Rockall Trough at 55°12′N in 1900 m fall between these depths and the *Princesse Alice* record at 42°53′N in 2460 m off the Azores (Koehler, 1909).

Topographic boundaries such as the Wyville Thomson Ridge give rise to locally sharp step-like increases in the physical gradient where cold arctic water enters the Atlantic deep sea by a process of intermittent overflow (Ellett & Roberts, 1973). The southerly route of this overflow is thought to lie along the sedimentary feature, Feni Ridge, which describes a sinuous path along the eastern margin of the Rockall Bank. The consequent latitudinal difference in hydrographic regime on the west and east sides of Rockall Trough may well be connected with differences seen in the echinoderm fauna around the 2000 m level (Table 1).

Although, as shown in Table 1, more samples have been taken on the east side, a considerably richer echinoderm fauna appears in the few samples taken in the west. Some species recorded there were not taken at all in the east around St. 'M' and the adjacent lower Hebridean slope despite the relatively intense sampling effort made in this area. Many of the species recorded only in the west are uncommon and have, as already discussed, only been previously taken in deeper water to the south. Other more common species, such as *Ophiura irrorata,* appear to be far more numerous on Feni Ridge.

Table 1 Distribution of species on west and east sides of the Rockall Trough. *species present only as juveniles; †probable suspension feeders (see text).

Species taken only from west (on Feni Ridge at 1600–2190 m depth, 5 hauls)	Species common to both areas	Species taken only from east side (on St. 'M' or adjacent Hebridean Slope at 1600–2200 m depth, 23 hauls)
Heliometra glacialis	*Porcellanaster ceruleus*	*Rhizocrinus lofotensis*
		? *Hathrometra sarsi*
**Psilaster andromeda*	*Bathybiaster vexillifer*	*Dytaster insignis*
Evoplosoma scorpio	*Plutonaster bifrons*	*Pectinaster filholi*
**Pteraster reductus*	*Benthopecten simplex*	*Hoplaster spinosus*
†*Asteroschema inornatum*	*Pseudarchaster parelii*	**Paragonaster subtilis*
†*Ophiotrema alberti*	*Hymenaster membranaceus*	†*Asteronyx loveni*
†*Ophiacantha crassidens*	*Ophiacantha bidentata*	*Homalophiura tesselata*
†*O. cuspidata*	†*Ophiactis abyssicola*	
†*O. simulans*	†*Amphilepis ingolfiana*	
Amphiophiura saurura	*Ophiochiton ternispinus*	
? *Stegophiura macrarthra*	*Ophiura ljungmani*	
Ophiocten hastatum	*Ophiura irrorata*	
	Ophiomusium lymani	

It is tempting to account for the presence of these species as essentially abyssal elements that find the cooler water overflowing from the Arctic to their liking. However, hydrographic data given by Ellett & Martin (1973) although showing some east–west tilting of deep-water temperature and salinity isopleths indicates that this explanation may be insufficient: samples from the Permanent Station at 2900 m where the bottom water generally is as cool as in shallower water to the west on Feni Ridge have not yielded the missing species.

It seems more likely that hydrographic conditions other than temperature may also be important in the west. Since overflow is thought to be associated with fast bottom currents and high turbidity (Jones, Ewing, Ewing & Eittreim, 1970), it seems possible that the richer fauna may reflect the better feeding conditions, particularly for microphagous suspension feeding, in the nepheloid layer at the benthic boundary. Hence, it may be significant that six out of the eleven species found as adults only from the Feni Ridge are likely, on morphological criteria, to be suspension feeders (Table 1). However, one difficulty with this explanation is that the apparently higher species richness of echinoderm groups covered by the present account on Feni Ridge is also associated with physical conditions that, because of the episodic nature of overflow, are more variable than elsewhere. Although admittedly we are dealing with only a fraction of the total benthic fauna, the present data do not accord with the stability-time hypothesis invoked by Sanders (1968, 1969) to explain why species richness in the supposedly stable environment of the deep sea appears to be higher than in comparable coastal habitats where conditions for life are more variable. It is interesting to note that results from two other studies of deep-sea faunas (Rex, 1973; 1976; Thistle, in press) do not fit in with the prediction of a simple positive relationship between increasing physical stability and species richness. Furthermore, the results of intensive sampling in the Bay of Biscay indicate that species diversity of asteroids on the lower continental slope decreases with increasing depth after a maximum at 2200 m (Sibuet, 1977), despite a presumed increasing physical stability with increasing depth. Rex (1981) has re-analysed data available from the NW Atlantic to show a parabolic response of species diversity of both macrofauna and megafauna to depth, with maxima at levels from 1900 m to 2800 m.

The present study also demonstrates a greater geographic and bathymetric range of juveniles and post-larvae of some relatively abundant species compared to the adult range. Juven-

iles of the following species of sea star have been identified over a wider bathymetric range than adults: *Plutonaster bifrons, Pectinaster filholi, Pseudarchaster parelii* and *Hymenaster membranaceus.* Juveniles and post-larvae of brittle stars usually are smaller than those of sea stars. However, Gage & Tyler (1981*a*) have shown that a massive non-viable settlement of the upper bathyal brittle star *Ophiocten gracilis* occurs seasonally over a wide area of the Rockall Trough. The easily recognisable post-larvae and juveniles of *Ophiomusium lymani* also are found in samples from a wider range of depths than adults. Post-larvae are typically found in small numbers in epibenthic sled hauls from the Permanent Station (*c.* 2900 m) at a depth several hundred metres deeper than the lower limit of adults. We suggest that the probably demersal lecithotrophic larvae are dispersed by currents to areas sometimes inimical to adult survival. Post-larvae of other ophiuroid species have also been identified in the Permanent Station samples; one of these being an ophiacanthid, probably *Ophiacantha bidentata,* that probably is derived from an adult population in shallower water, since no adult ophiacanthid species has as yet been collected from the Permanent Station.

Summary

Four species of sea lily, forty species of sea star and thirty-six species of brittle star are identified from recent extensive sampling conducted by the Scottish Marine Biololgical Association from R.R.S. *Challenger* in the deep sea area lying to the west of the British Isles. The following species have not previously been recorded from the British seas.

Crinoidea	*Thaumatocrinus jungerseni*
Asteroidea	*Hyphalaster inermis*
	Pseudarchaster gracilis
	Paragonaster subtilis
	Pteraster sp. aff. *P. acicula*
	Hymenaster gennaeus (provisionally)
	H. rex
	Freyella spinosa
	F. sexradiata
	Hydrasterias sexradiata
Ophiuroidea	*Astrodia tenuispina*
	Asteroschema inornatum
	Ophiotrema alberti
	Ophiomyces grandis
	Ophiacantha cuspidata
	O. simulans
	O. aculeata
	Ophiolimna bairdi
	Amphiura otteri
	A. griegi
	Amphilepis ingolfiana
	Homalophiura tesselata
	Amphiophiura convexa
	A. saurura
	? *Stegophiura macrarthra*
	Ophiocten hastatum [Hoyle (1884) records this species but under the name *O. sericeum*]
	Ophiura irrorata
	O. imprudens

Ophiura imprudens is known from only one specimen from the Azores and *Ophiacantha aculeata* only from N America and SW Iceland.

Extensions of bathymetric range are recorded (in metres) for the following:

	Upper limit	Lower limit
Crinoidea		
Thaumatocrinus jungerseni		2734–3425 (3500)
Heliometra glacialis		1358–1900
Asteroidea		
Luidia ciliaris		400–650 (805)
Plutonaster bifrons		2500–2965
Psilaster andromeda		1853–2965
? Radiaster tizardi		1320 (? 1630)–2540
Paragonaster subtilis	2455–(1785) 1845	
Plinthaster dentatus		2117–2190
Evoplosoma scorpio		*c.* 1600–1900
Pteraster reductus	1920–1900	
Hymenaster gennaeus		2245–2500 (2500)
H. rex		2285–2910
Henricia abyssicola	*c.* 930–168	
Brisinga endecacnemos		2200–2220
Freyella spinosa		4060–4810
Stichastrella rosea		1150 (? 1330)–1632
Zoroaster fulgens		3660–4810
Ophiuroidea		
Astrodia tenuispina		3300–3425 (3500)
Asteroschema inornatum		1480–1900
Ophiotrema alberti	3785–1862	
Ophiacantha aculeata		2510–3425 (3500)
Ophiolimna bairdi		2600–2910
Amphiura otteri		1425–2892
A. griegi		300–810
Amphipholis squamata		740–1330
Amphiophiura convexa	2160–1997	
? Stegophiura macrarthra		424–1900
Ophiura carnea		1260–2857
O. imprudens	560–168	
O. ophiura (syn. *O. texturata*)		200–704

In this list the depths given are the minimum possible extensions of the previously known bathymetric limits. Figures in brackets give the maximum possible from the depth range of hauls (fish trawlings only) although of course specimens may not have been taken throughout the depth range of the tow.

For some of the more abundantly occurring species from fine-meshed epibenthic sled hauls, the records demonstrate a wider bathymetric distribution of juveniles and post-larvae than of adults, suggesting that externally developing larvae often are dispersed to areas where they do not survive to adulthood.

In general, records of adults of the most abundantly occurring species cluster well within the vertical range recorded over their, often circumoceanic, known distribution. This may reflect a trend towards progressive submergence of isotherms in the deep ocean from high to low latitudes.

Despite a concentration of sampling effort to the east, comparison between the east and west sides of Rockall Trough has indicated that a richer echinoderm fauna, particularly of filter feeding species, is present in the west on Feni Ridge. This may be related to a greater availability of suspended food in the west associated with the passage of fast-flowing turbid water at the benthic boundary as a result of overflow from the Faroe Channel over the Wyville Thomson Ridge.

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References

Barham, E. G., Ayer, J. J. & Boyce, R. E. 1967. Macrobenthos of the San Diego Trough: photographic census and observations from the bathyscaphe, *Trieste*. *Deep-Sea Res.* **14**: 773–784.

Blake, D. B. 1981. A reassessment of the sea-star orders Valvatida and Spinulosida. *J. nat. Hist.* **15**: 375–394.

Bruun, A. F. & Wolff, T. 1961. Abyssal benthic organisms: Nature, origin, distribution and influence on sedimentation. pp. 391–397. *In:* M. Sears [Ed.] *Oceanography*. American Association for the Advancement of Science Publ. 67. Washington D.C.

Carpenter, P. H. 1884. Crinoidea. 1. The stalked crinoids. *Rep. scient. Results. Voy. Challenger.* (Zool.) **11** (32): 1–440.

Cherbonnier, G. 1969. Echinodermes récoltés par la "Thalassa" au large des côtes ouest de Bretagne et du Golfe de Gascogne (3–12 Août 1967). *Bull. Mus. natn. Hist. nat., Paris* (2) **41** (1): 343–361.

—— 1970. Echinodermes récoltés par la "Thalassa" au large des côtes d'Espagne et du Golfe de Gascogne (18–25 Octobre 1968). *Bull. Mus. natn. Hist. nat., Paris* (2) **41** (5): 1266–1277.

—— **& Sibuet, M.** 1973. Résultats scientifiques de la campagne Noratlante: astéroides et ophiurides. *Bull. Mus. natn. Hist. nat., Paris* (3) Zool. No. 76: 1333–1394.

Clark, A. H. 1913. On a collection of recent crinoids from the waters about Ireland. *Scient. Invest. Fish Brd Ire.* **191** (24): 1–5.

—— 1923. Crinoidea. *Dan. Ingolf-Exped.* **4** (5): 1–58.

—— **& Clark, A. M.** 1967. A monograph of the existing crinoids. 1 (5). *Bull. U.S. natn. Mus.* **82** (1) 5: 1–860.

Clark, A. M. 1970*a*. Notes on the family Amphiuridae. *Bull. Br. Mus. nat. Hist.* (Zool.) **19** (1): 1–81.

—— 1970*b*. Echinodermata: Crinoidea. *Marine Invertebrates of Scandinavia*. No. 3. 55 pp. Oslo: Universitetsforlaget.

—— 1977. Notes on deep-water Atlantic Crinoidea. *Bull. Br. Mus. nat. Hist.* (Zool.) **31** (4): 157–186.

—— 1980. Crinoidea collected by the *Meteor* and *Discovery* in the North-East Atlanatic. *Bull. Br. Mus. nat. Hist.* (Zool.) **38** (4): 187–210.

—— 1981. Notes on Atlantic and other Asteroidea. 1. Family Benthopectinidae. *Bull. Br. Mus. nat. Hist.* (Zool.) **41** (3): 91–135.

—— 1982. Notes on Atlantic Asteroidea. 2. Luidiidae. *Bull. Br. Mus. nat. Hist.* (Zool.) **42** (3): 157–184.

Clark, H. L. 1915. Catalogue of recent ophiurans. *Mem. Mus. comp. Zool. Harv.* **25** (4): 165—376.

—— 1923. The echinoderm fauna of South Africa. *Annals S. Afr. Mus.* **13**: 221–435.

—— 1941. Reports on the scientific results of the *Atlantis* Expeditions to the West Indies. The echinoderms (other than holothurians). *Mem. Soc. cubana Hist. nat.* **15** (1): 1–54.

Danielssen, D. C. & Koren, J. 1884. Asteroidea. *Norske Nordhavs-Exped.* Zool. **11**: 1–118.
Döderlein, L. 1900. Zoologische Ergebnisse einer Untersuchungsfahrt des deutschen Seefischerei-Vereins nach der Bäreninsel und Westspitzbergen. *Wiss. Meeresunters.* (Helgoland) N.F. **4** (2): 195–248.
Downey, M. E. 1970. Zorocallida, new order, with notes on the Zoroasteridae. *Smithson. Contr. Zool.* No. 64: 1–18.
—— 1973. Starfishes from the Caribbean and the Gulf of Mexico. *Smithson. Contr. Zool.* No. 126: 1–158.
—— 1981. A new goniasterid seastar, *Evoplosoma scorpio* (Echinodermata: Asteroidea), from the northeastern Atlantic. *Proc. biol. Soc. Wash.* **94** (2): 561–563.
D'yakonov, A. M. 1950. [Sea stars of the Soviet Union.] *Opred. Faune SSSR* **34**: 1–199. [In Russian] [Transl. 1968. Israel Program for scientific translations. **1922.** 183 pp. Jerusalem.]
—— 1954. [Ophiuroidea of the Soviet Union.] *Opred. Faune SSSR* **55**: 1–136. [In Russian] [Transl. 1967. Israel Program for scientific translation. **1880.** 123 pp. Jerusalem.]
Ekman, S. 1953. *Zoogeography of the Sea.* 417 pp. Sidgwick & Jackson, London.
Ellett, D. J. & Martin, J. H. A. 1973. The physical and chemical oceanography of the Rockall Channel. *Deep-Sea Res.* **20**: 585–625.
—— **& Roberts, D. G.** 1973. The overflow of Norwegian deep sea water across the Wyville Thomson Ridge. *Deep-Sea Res.* **20**: 819–835.
Farran, G. P. 1913. The deep water Asteroidea, Ophiuroidea and Echinoidea of the west coast of Ireland. *Scient. Invest. Fish Brd Ire.* **1912** (6): 1–66.
Fell, H. B. 1946. The embryology of the viviparous ophiuroid *Amphipholis squamata* (D. Ch.) *Trans. R. Soc. N.Z.* **75** (4): 419–464.
—— 1960. Synoptic keys to the genera of Ophiuroidea. *Zool. Publs Vict. Univ. Wellington* No. 26: 1–44.
—— 1966. The ecology of Ophiuroids. pp. 129–143. *In* Boolootian, R. A. [Ed.] *Physiology of the Echinodermata.* Interscience, New York.
Fontaine, A. R. 1965. The feeding mechanisms of the ophiuroid *Ophiocomina nigra. J. Mar. biol. Ass. U.K.* **45**: 373–385.
Gage, J. D. 1975. A comparison of the deep-sea epibenthic sledge and anchor-box dredge samples with the van Veen grab and hand coring by diver. *Deep-Sea Res.* **22**: 693–702.
—— **Lightfoot, R. H., Pearson, M. & Tyler, P. A.** 1980. An introduction to a sample time-series of abyssal macrobenthos: methods and principle sources of variability. *Oceanol. Acta* **3**: 169–176.
—— **& Tyler, P. A.** 1981*a*. Non-viable seasonal settlement of larvae of the upper-bathyal brittle star *Ophiocten gracilis* in the Rockall Trough abyssal. *Mar. Biol.* **64**: 153–161.
—— & —— 1981*b*. Re-appraisal of age composition, growth and survivorship of the deep-sea brittle star *Ophiura ljungmani* from size structure in a sample time series from the Rockall Trough. *Mar. Biol.* **64**: 163–172.
—— **&** —— 1982. Growth and reproduction of the deep-sea brittle star *Ophiomusium lymani* Wyville Thomson. *Oceanol. Acta* **5**: 73–83.
Geiger, S. R. 1963. *Ophiopluteus ramosus* between Iceland and Newfoundland. *Nature, Lond.* **198**: 908–909.
Gordon, J. D. M. 1979. Seasonal reproduction in deep-sea fish. pp. 223–229. *In* Naylor, E. & Hartnoll, R. G. [Eds] *Cyclic phenomena in marine plants and animals.* Pergamon Press, Oxford.
Grassle, J. F., Sanders, H. L., Hessler, R. R., Rowe, G. T. & McLellan, T. 1975. Pattern and zonation: a study of the bathyal megafauna using the research submersible *Alvin. Deep-Sea Res.* **22**: 457–481.
Grieg, J. A. 1921 [& 1932]. Echinodermata. *Rep. scient. Results Michael Sars N. Atlantic deep Sea Exped.* **3** (2): 1–47.
Halpern, J. A. 1970. Goniasteridae (Echinodermata: Asteroidea) of the Straits of Florida. *Bull. mar. Sci.* **20**: 193–286.
—— 1972. Pseudarchasterinae (Echinodermata: Asteroidea) of the Atlantic. *Proc. biol. Soc. Wash.* **85** (30): 359–384.
Hartman, O. 1963. Submarine canyons of southern California. 2. Biology. *Allan Hancock Pacif. Exped.* **27** (2): 1–424.
—— **& Barnard, J. L.** 1958. The benthic fauna of the deep basins off southern California. *Allan Hancock Pacif. Exped.* **22** (1): 67.
Hessler, R. R. & Jumars, P. A. 1974. Abyssal community analysis from replicate box cores in the central north Pacific. *Deep-Sea Res.* **21**: 185–209.
—— **& Saunders, H. L.** 1967. Faunal diversity in the deep-sea. *Deep-Sea Res.* **14**: 65–78.

Hoyle, W. E. 1884. Report on the Ophiuroidea of the Färoe Channel, mainly collected by H.M.S. *Triton* in August, 1882. *Proc. R. Soc. Edinb.* **12**: 707–730.

Jones, E. J. W., Ewing, M., Ewing, J. I. & Eittreim, S. 1970. Influences of Norwegian Sea overflow water on sedimentation in the northern North Atlantic and Labrador Sea. *J. Geophys. Res.* **75**: 1655–1680.

Kawaguchi, K. & Mauchline, J. 1982*a*. Biology of myctophid fishes (family Myctophidae) in the Rockall Trough, northeastern Atlantic Ocean. *Biol. Oceanogr.* **1**: 337–373.

—— 1982*b*. Biology of the sternoptychid fishes (family Sternoptychidae) in the Rockall Trough, northeastern Atlantic Ocean. *Biol. Oceanogr.*

Kemp, S. W. 1905. The marine fauna of the west coast of Ireland. 3. *Ann. Rep. Fish. Ireland* 1902–3. (2) App. 6: 176–206.

Koehler, R. 1896. Note preliminaire sur les ophiures des premieres campagnes de la *Princesse Alice. Mem. Soc. zool. France.* **9**: 241–253.

—— 1898. Echinides et ophiures provenant des campagnes du yacht *L'Hirondelle. Result. Camp. scient. Prince Albert I.* **12**: 1–78.

—— 1907. Ophiures, *Exped. scient. Travailleur–Talisman* **8:** 245–311.

—— 1909. Echinodermes provenant des campagnes du yacht *Princesse Alice. Result. Camp. scient. Prince Albert I.* **34**: 1–317.

— 1924. *Les echinodermes des mers d'Europe.* 360 pp. Paris: Librarie Octave Doin.

Laubier, L. & Sibuet, M. 1979. Ecology of the benthic communities of the deep North East Atlantic. *Ambio spec. Rep.* **6**: 37–42.

Lieberkind, I. 1935. Asteroidea. 1. Porcellanasteridae. *Dan. Ingolf-Exped.* **4** (10): 1–37.

Ludwig, H. 1897. Die Seesterne des Mittelmeeres. *Fauna Flora Golf. Neapel.* **24**: 1–491.

Lütken, C. F. & Mortensen, T. 1899. Reports on an exploration off the west coasts of Mexico, Central and South America and off the Galapagos Islands. 25. The Ophiuridae. *Mem. Mus. comp. Zool. Harv.* **23** (2): 97–208.

Lyman, T. 1878, 1879. Ophiuridae and Astrophytidae of the exploring voyage of H.M.S. *Challenger.* 1 & 2. *Bull. Mus. comp. Zool. Harv.* **5** (7): 1–168 [1878]; 6 (2): 17–83 [1879].

—— 1882. Ophiuroidea. *Rep. scient. Results Voy. Challenger* (Zool.) **5**: 1–386.

—— 1883. Report on the results of dredging, in the Caribbean Sea in 1878–79 and along the Atlantic coast of the United States during the summer of 1880, by the U.S. Coast Survey Steamer *Blake.* Report on the Ophiuroidea. *Bull. Mus. comp. Zool. Harv.* **10** (6): 227–287.

Madsen, F. J. 1961. The Porcellanasteridae. A monographic revision of an abyssal group of sea-stars. *Galathea Rep.* **4**: 33–174.

Marenzeller, E. von 1893. Berichte der Commission für Erforschung des östlichen Mittelmeeres: Zoölogische Ergebnisse. 1. Echinodermen. *Denkschr. Akad. Wiss. Wien.* Math.-nat. Cl. **60**(2): 1–24.

Marine Biological Association. 1957. *Plymouth Marine Fauna.* Ed. 3. 457 pp. Plymouth.

Menzies, R. J., George, R. Y. & Rowe, G. T. 1973. *Abyssal Environment and Ecology of the World Oceans.* 488 pp. John Wiley, New York.

Mortensen, T. 1920. Notes on some Scandinavian echinoderms, with descriptions of two new ophiurids. *Vidensk. Meddr dansk naturh. Foren.* **72**: 45–79.

—— 1927. *Handbook of the echinoderms of the British Isles.* 471 pp. Oxford University Press, London.

—— 1933. Ophiuroidea. *Dan. Ingolf-Exped.* **4** (8): 1–121.

Ockelmann, K. W. & Muss, K. 1978. The biology, ecology and behaviour of the bivalve *Mysella bidentata* (Montagu). *Ophelia* **17** (1): 1–93.

O'Connor, B. 1981. Some echinoderms from the west coast new to the Irish fauna. *Ir. Nat. J.* **20** (6): 247–249.

Pain, S. L., Tyler, P. A. & Gage, J. D. 1982*a*. The reproductive biology of *Hymenaster membranaceus* Wyville Thomson from the Rockall Trough, N.E. Atlantic, with notes on *H. gennaeus* H. L. Clark. *Mar. Biol.* **70**: 41–50.

——, —— & —— 1982*b*. The reproductive biology of the deep-sea asteroids *Benthopecten simplex, Pectinaster filholi* and *Pontaster tenuispinus. J. exp. mar. Biol. Ecol.* **65**: 195–211.

Paterson, G. L. J., Tyler, P. A. & Gage, J. D. 1982. The systematics and zoogeography of the genus *Ophiocten* (Echinodermata: Ophiuroidea) in the North Atlantic Ocean. *Bull. Brit. Mus. nat. Hist.* (Zool.) **43** (3): 109–128.

Pawsey, E. L. & Davis, S. M. 1924. Report on exploratory voyages to Lousy Bank and adjacent areas. *Fishery Invest., Lond.* (2) **7** (2): 1–20.

Pawson, D. L. 1978. Some aspects of the biology of deep-sea echinoderms. *Thalassia jugosl.* **12** (1) [1976]: 287–293.

Pentreath, R. J. 1970. Feeding mechanisms and the functional morphology of podia and spines in some New Zealand ophiuroids (Echinodermata). *J. Zool. Lond.* **161** : 395–428.
Perrier, E. 1884. Mémoire sur les etoiles de mer recueillies dans la Mer des Antilles et le Golfe de Mexique. *Nouv. Archs Mus. Hist. nat. Paris* (2) **6** : 127–276, 10 pls.
—— 1894. Stellerides, *Expéd. scient. Travailleur—Talisman.* 1–431.
Reese, E. S. 1966. The Complex Behaviour of Echinoderms. pp. 157–218. *In* Boolootian, R. A. [Ed.] *Physiology of Echinodermata.* Interscience, New York.
Rex, M. A. 1973. Deep-sea species diversity: decreased gastropod diversity at abyssal depths. *Science* **181** : 1051–1053.
—— 1976. Biological accommodation in the deep-sea benthos: comparative evidence on the importance of predation and productivity. *Deep-Sea Res.* **23** : 975–987.
—— 1981. Community structure in the deep-sea benthos. *Ann. Rev. Ecol. Syst.* **12** : 331–353.
Rice, A. L., Aldred, R. G., Darlington, E. & Wild, R. A. 1982. The quantitative estimation of the deep-sea megabenthos: a new approach to an old problem. *Oceanol. Acta* **5** : 63–72.
Roberts, D. G. 1975. Marine geology of the Rockall Plateau and Trough. *Phil. Trans. R. Soc.* **A 278** : 447–509.
Roux, M. 1976. Découverte dans le Golfe de Gascogne de deux éspèces actuelles du genre cénozoique *Conocrinus* (Echinodermes, Crinoides pédonculés). *C. r. hebd. Séanc. Acad. Sci., Paris* (D) **238** (7): 757–760.
—— 1978. Ontogénèse, variabilité et évolution morphofonctionelle du pédicule et du calice chez les Millericrinida. *Geobios* **11** (2) : 213–241.
Rowe, G. T. & Staresinic, N. 1979. Source of organic matter to the deep-sea benthos. *Ambio Special Rpt* No. 6 : 19–23.
Sanders, H. L. 1968. Marine Benthic Diversity: a comparative study. *Am. Naturalist* **102** : 243–282.
—— 1969. Benthic marine diversity and the Stability-Time Hypothesis. pp. 71–81. In: *Diversity and Stability in Ecological Systems,* Brookhaven Symposia in Biology. No. 22.
Schoener, A. 1967. Post-larval development of five deep-sea ophiuroids. *Deep-Sea Res.* **14** : 645–660.
Semenova, T. N., Mileikovsky, S. A. & Nesis, K. N. 1964. The morphology, distribution and seasonal incidence of the ophiuroid larva *Ophiocten sericeum* (Forbes) S.L. in the North-West Atlantic, Norwegian Sea and Barents Sea plankton [In Russian.] *Okeanologija, Mosk.* **4** : 669–683.
Sibuet, M. 1976. Le genre *Hymenaster* (Asterides) dans L'Ocean Atlantique. *Bull. Mus. natn. Hist. nat. Paris.* (Zool.) No. 256 : 305–324.
—— 1977. Repartition et diversité des echinodermes (holothurides—asterides) en zone profonde dans le Golfe de Gascogne. *Deep-Sea Res.* **24** : 549–563.
—— **& Cherbonnier, G.** 1972. Description de stades juvéniles de *Plutonaster bifrons* (Wyville Thomson). *C.r. hebd. Séanc. Acad. Sci., Paris* (D) **275** : 2515–2518.
Sladen, W. P. 1882. Asteroidea dredged during the cruise of the *Knight Errant* in July and August 1880. *Proc. R. Soc. Edinb.* **11** : 698–707.
—— 1889. Asteroidea. *Rep. scient. Results Voy. Challenger.* (Zool.) **30** : 1–935.
Süssbach, S. & Breckner, A. 1911. Die Seeigel, Seesterne und Schlangensterne der Nord- und Ostsee. *Wiss. Meeresunters.* (Kiel) N.S. **12** : 167–300.
Thistle, D. (in press). The stability-time hypothesis as a predictor of diversity in deep-sea soft-bottom communities: a test. *Deep-Sea Res.*
Thomson, C. W. 1872. On the crinoids of the *Porcupine* deep-sea dredging expeditions. *Proc. R. Soc. Edinb.* **7** : 764–773.
—— 1873. *The Depths of the Sea.* 527 pp. Macmillan, London.
—— 1874. On the Echinoidea of the 'Porcupine' deep-sea dredging expeditions. *Phil. Trans. R. Soc.* **6** : 719–756.
Thorson, G. 1936. The larval development, growth and metabolism of Arctic marine bottom invertebrates compared with those of other seas. *Meddr Grønl.* **100** (6) : 1–55.
Tyler, P. A. & Gage, J. D. 1979. Reproductive ecology of deep-sea ophiuroids from the Rockall Trough. pp. 215–222. *In* Naylor, E. & Hartnoll, R. G. [Eds.] *Cyclic phenomena in marine plants and animals.* Pergamon Press, Oxford.
—— **&** —— 1980. Reproduction and growth of the deep-sea brittlestar *Ophiura ljungmani* (Lyman). *Oceanol Acta* **3:** 177–185.
—— **&** —— 1982*a*. The reproductive biology of *Ophiacantha bidentata* (Echinodermata: Ophiuroidea) from the Rockall Trough. *J. mar. biol. Ass. U.K.* **62** : 45–56.
—— **&** —— 1982*b*. *Ophiopluteus ramosus* Mortensen 1898, the larval form of *Ophiocten gracilis* (Sars, 1871) (Echinodermata: Ophiuroidea). *J. mar. biol. Ass. U.K.* **62** : 485–486.

Tyler, P. A. & Pain, S. L. 1982*a*. The reproductive biology of *Plutonaster bifrons, Dytaster insignis* and *Psilaster andromeda* (Asteroidea: Astropectinidae) from the Rockall Trough. *J. mar. Biol. Ass. U.K.* **62**: 869–887.

—— & —— 1982*b*. Observations of gametogenesis in the deep-sea asteroids *Paragonaster subtilis* and *Pseudarchaster parelii* (Phanerozonia: Goniasteridae). *Int. J. invert. Reprod.* **5**: 269–272.

——, —— **& Gage, J. D.** 1982*a*. The reproductive biology of the deep-sea asteroid *Bathybiaster vexillifer. J. mar. biol. Ass. U.K.* **62**: 57–69.

——, —— & —— 1982*b*. Gametogenic cycles in deep-sea phanerozoan asteroids from the NE Atlantic. *Proc. Int. Echinoderms Confr. Tampa, 1981,* pp. 431–434. Balkema, Rotterdam.

Ursin, E. 1960. A quantitative investigation of the echinoderm fauna of the central North Sea. *Meddr Danm Fisk. og Havunders.* N.S. **2.** No. 24: 1–204.

Verrill, A. E. 1884. Notice of the remarkable marine fauna occupying the outer banks off the south coast of New England. 9. *Am. J. Sci.* (3) **23**: 213–220.

—— 1899. Revision of certain genera and species of starfishes with descriptions of new forms. *Trans. Conn. Acad. Arts Sci.* **10:** 145–234.

Warner, G. F. & Woodley, J. D. 1975. Suspension-feeding in the brittle-star *Ophiothrix fragilis. J. mar. biol. Ass. U.K.* **55**: 199–210.

Wigly, R. L. & Emery, K. O. 1967. Benthic animals, particularly *Hyalinoecia* (Annelida) and *Ophiomusium* (Echinodermata), in sea-bottom photographs from the continental slope. pp. 235–249. *In* Hersey, J. B. [Ed.] *Deep-Sea Photography.* The Johns Hopkins Press, Baltimore.

Woodley, J. D. 1975. The behaviour of some amphiurid brittle-stars. *J. exp. Mar. Biol. Ecol.* **18**: 29–46.

Wüst, G. 1936. Schichtung und Zirkulation des Atlantischen Ozeans. Die Stratosphäre des Atlantischen Ozeans. *Wiss. Ergebn. dt. atlant. Exped. 'Meteor'.* **6** (1): 108–288 [English transl. Al-Ahram Center for Scientific Translations, Emery, W. J. [Ed.] 1978, 112 pp. Amerind, New Delhi.]

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