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The Oceanic
and Bathypelagic Plankton of the
North-East Atlantic
and its possible significance to Fisheries

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The Oceanic and Bathypelagic Plankton of the North-East Atlantic and its possible significance to Fisheries

INTRODUCTION

The flow of Atlantic water on to the shelf surrounding the British Isles changes the physical and chemical environment, and at the time brings with it a specialised planktonic fauna and flora which mixes with, or displaces, the local plankton and thus alters the biological environment. Such changes may affect the fisheries directly by inducing corresponding changes in fish migrations, shoaling or other behaviour patterns. Indirect results may be even more important because the food supply of the fish is affected. This effect may be relatively rapid for herring and other plankton-feeding fish, or long-term through changes in the slower-growing food supply for the bottom-feeding fish. Almost the entire food supply of fish of all kinds is derived fundamentally from phytoplankton production—not necessarily on the fishing grounds themselves but more often in an area from which the current systems will eventually bring the later stages in the food chain to the fishing grounds. The immediate food supply, and also the potential fertility of a fishing ground, are thus dependent upon the planktonic conditions all the way along the incoming current systems, while these conditions are dependent upon the types and mixing of water masses of various chemical and physical natures even further away. What are these water masses and what are the most important of the biological changes that may affect the commercial fishery? An attempt has been made to find some of the answers to these questions, linking the biological and the physical wherever possible.

The water masses of the north-east Atlantic at different depths have different origins and different planktonic faunas that as a rule can be recognised as such. The situation is complicated by vertical diurnal migrations, so that zooplankton in a lower water mass—its "natural" habitat—during the day may be at the surface or nearer the surface at night, possibly in a water mass with different characteristics and perhaps also moving in a different direction. There are thus numerous examples of bathypelagic species—e.g. myctophids, stomiatids and other lantern fish—to be found at the surface at night, quite unconnected with any upwelling of deep water.

That different water masses have their own recognisable planktonic fauna or flora, according to their physical, chemical, biochemical or biological features has now been well established, and the term "plankton indicator species" has been accepted to denote such characteristic species (Russell, 1935 a, b, 1936, 1939). For most of the organisms concerned the actual limiting factor or combination of factors is not known. Sometimes it may be mainly a simple feature like temperature, salinity or depth; sometimes it may be an unknown such as those which improve growth, facilitate metamorphosis or relate to settling conditions for planktonic larvae (Wilson, 1951; Wilson and Armstrong, 1952, 1954). Recent work by Johnston (1955) and others has shown how important is the co-operation of the biochemist as well as the physical chemist in this work. Pending the answers to these questions, however, the planktonic indicator species can be used to label water masses which may have many characters other than those that limit the indicator organisms, and it is these combinations of factors that ultimately affect the fisheries.

There has been some variation in the definition of "bathypelagic" amongst previous authors but the term is here ascribed to those species whose natural pelagic habitat is below 150-200 m during daylight, i.e. according to Marshall (1954).

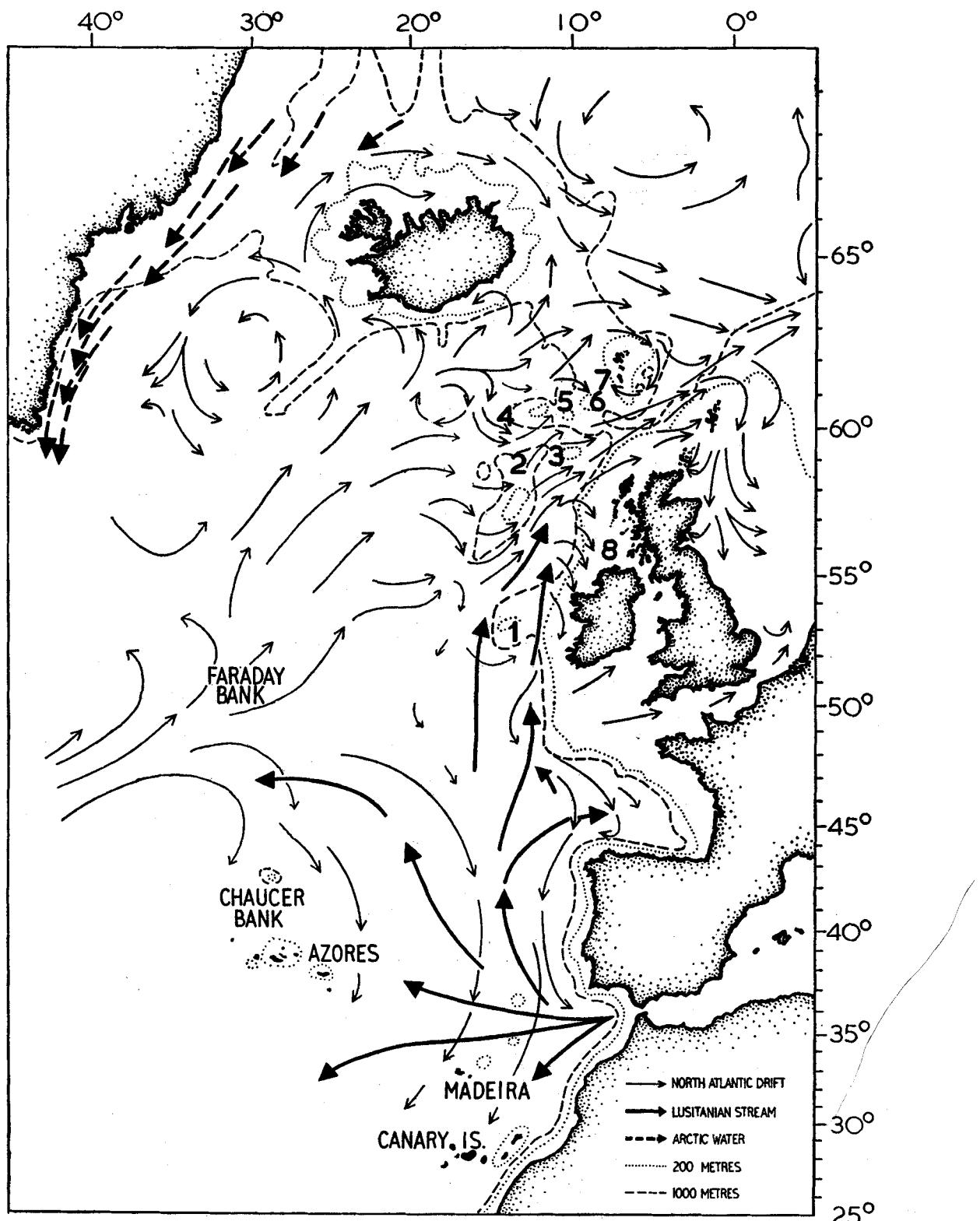


Fig. 1 Chart of the oceanic current systems of the north-east Atlantic based on the works of several authors.

1 Porcupine Bank, 2 Rockall Bank, 3 Rosemary Knoll, 4 Lousy Bank, 5 Bill Bailey Bank, 6 Faroe Bank,
7 Faroe Plateau, 8 Stanton Bank.

The thickness of the arrows is not intended to indicate the strength of the current.

THE CURRENT SYSTEMS

The current systems on the eastern side of the North Atlantic have been fairly well plotted by hydrographers—e.g. Helland Hansen and Nansen (1909), Jacobsen (1929), Tait (1930-37, 1934 and 1957), Vallaux (1936), Hermann and Thomsen (1946), Einarsson and Stefánsson (1953), Tulloch and Tait (1959) etc. A composite figure, reproduced here as Fig. 1, has been taken from various sources including some unpublished data from the cruises of the Scottish research vessels. Although it is not proposed to attempt to give any authoritative picture of the current system in this essentially biological paper, it may be useful to give a brief summary.

The main inflow of the North Atlantic Drift follows a broad path in the open ocean and towards the European shelf it splits into two main sections, one going north-east to the Faroe Channel and the other eastwards along latitude 50°N and again splitting. The main part of the latter goes south between the Azores and the continental shelf, and the other and smaller part turns north along the Irish shelf, ultimately to meet again the northern section which has divided to go on both sides of Rockall. The northern main stream in part continues through the Faroe Channel via the Norwegian Sea to the Barents Sea, giving a branch to the North Sea round the north of Shetland. The remainder of this main northern stream reaches the Icelandic shelf, forming a clockwise eddy round Iceland with an anti-clockwise eddy off the Reykjanes Ridge and a clockwise eddy round Faroe; it overflows near the surface at the Faroe-Iceland Ridge. There are also overflows on to the shelf around the British Isles which affect the Celtic Sea to the south of Ireland, the west Scottish and Irish areas of the shelf in a southerly trend, and the north Scottish shelf, the last tending to continue to the Moray Firth area of the North Sea via the Orkney passages.

The deeper layers have different origins according to whether their greater density is derived from a greater salinity or a lower temperature. The chief source of more saline waters in the north-east Atlantic is the Mediterranean Sea—the deep outflow from it spreads out through the Straits of Gibraltar—and its process of mixing has its own very real significance in the formation of oceanic water masses in the open ocean (Defant, 1955). Although it is usually very well mixed before any part of it reaches the British Isles it can at times be recognised beyond Porcupine Bank to Rockall (Neilsen, 1912) and even in the Faroe-Shetland Channel. Thus Tait (1955) found hydrographic evidence of such water there, for example, in May 1948, August 1951 and November 1952, and Fraser (1955) found planktonic evidence of its effect reaching Shetland in the autumn of 1953. This Mediterranean or Lusitanian influence underlies the open Atlantic water at some 1000 m off Gibraltar, gradually ascending as it moves northwards, so that in due course it overlies the colder bottom arctic water.

Apart from the East Greenland current the arctic water in the Atlantic to the west of the British Isles is all deeply situated. The volume transport in the different paths it takes to reach these latitudes is still rather doubtful and indeed may be very variable, but the important routes are over the Faroe-Iceland Ridge, and between Greenland and Iceland, in the depths between 300 m and the sill depths of about 550 m (Cooper, 1955b; Dietrich, 1956). These cold water masses sink into the depths of the North Atlantic Basin, probably intermittently as large discrete boluses (Cooper, 1955a); in the North Atlantic Deep the currents may normally reach speeds of 9.2 cm/sec or an occasional maximum of 17.4 cm/sec—i.e. 4½-8¾ miles per day (Wüst, 1955). The precise movements of this arctic water are, of course, closely bound up with the bottom topography.

Any deep flow from higher to lower latitudes must be replenished by an opposite flow of warmer surface water, and Cooper (1955b) puts forward the hypothesis that extreme low temperature in the Arctic will result in the cooling and sinking of increased volumes of water, thus giving a greater recruitment of deep water in the North Atlantic. This in turn will lead to an upward displacement of nutrient rich water towards the productive layers in the euphotic zone, especially against continental slopes.

The currents depicted in Fig. 1 can be taken as typical of "average condition" but there are wide variations, both seasonal and annual, which change this pattern. Such variations are due to meteorological conditions, to varying volumes of the different elements comprising the whole and to internal waves at the junction of the water masses. These variations can have far-reaching effects on the ultimate distribution of the inflow over the continental shelf which, of course, carries the chemical and biochemical variations which are revealed by the plankton indicator species.

Further local variations of the general current pattern are caused by topographical features. Some banks rise above the level of the cold bottom water and sufficiently far into the upper layer to affect its course. This effect may be a simple splitting of the main flow, leaving a surface oceanic stream to flow over it, e.g. Lousy Bank (200 m); or the bank may be sufficiently large to cause eddy formation so that part of the body of water above the bank stays there in circulation, e.g. Rockall. When this happens the winter conditions are right for the formation of a cascade (Cooper and Vaux, 1949). The surface layers, cooled by the atmosphere, sink and cascade down the slope to a deeper level, to be replaced by relatively warm surface oceanic water, and so the process is repeated until the atmospheric conditions are sufficiently warmed in the spring.

This, then, is briefly the general hydrographic background on which to fit the oceanic plankton distribution; it will help in the appreciation of the significance of the plankton distribution on the continental shelf and its ultimate significance to the fisheries.

THE CHARACTERISTIC SPECIES OF THE VARIOUS WATER MASSES THAT AFFECT THE SCOTTISH AREA

The main masses are:

- (1) the indigenous North Sea and other indigenous waters,
- (2) the mixed Atlantic and indigenous water that occupies much of the shelf area, including the northern North Sea, the shelf west and north of the British Isles, the Faroe Plateau, the Icelandic shelf, etc.,
- (3) the open Atlantic water—the North Atlantic Drift,
- (4) the Lusitanian stream, containing mixed Mediterranean and sub-tropical Atlantic water,
- (5) the arctic, sub-arctic and boreal water.

Although an attempt to distinguish five water masses has been made, and at times the boundaries between them are clear, particularly as strata, they can and do intermix greatly during their progress as moving masses so that sharp boundaries are rare and the edges diffuse. There are also natural variations in tolerance and preferences in the physiology of the plankton organisms as well as seasonal changes of distribution and diurnal vertical migration, so that there cannot be any very sharply defined list applicable to one water mass, and that alone. Nor can abundance of a particular indicator species be related entirely to the volume of inflow of the water to which it belongs (Farran, 1933); it may have been particularly abundant, or scarce, in the area of origin, or conditions may have been suited to its reproduction en route so that masses of young individuals develop in an area as distinct from the relatively few that have themselves been brought into it. Nevertheless, in spite of these well-known complications, it is possible to use certain organisms as indicators with a reasonable degree of reliability, and to use groups of indicator species as communities or associations with a much greater reliability.

As Russell (1935a) emphasised, to be of value a plankton indicator species must be a *practical* indicator. It must be easily identified, preferably by naked eye on board ship, and short lists of easily recognised forms are of more practical value for this particular work than long lists of possibilities. These will be dealt with in the next section.

Work of this kind has now been done by many workers in different parts of the world, such as—to mention but a selected few—Gran (1902), Ostenfeld (1908), Damas (1909), Russell (1935 a, b, 1936, 1939, 1952), Fraser (1937, 1939, 1949, 1952, 1955), Bigelow (1938), Parker (1939), Allen (1940), Redfield and Beale (1940), Thompson (1942), Clarke, Pierce and Bumpus (1943), Moore (1949), Kändler (1950), Dunbar (1951), Williamson (1952, 1956 a, b), Hela, Moore and Ower (1953), Pierce (1953), Bernard (1955a), Blackburn (1955), Bumpus and Pierce (1955), Wiborg (1955), Abramova (1956) and Hida (1957).

The use of the planktonic larvae of littoral benthos as indicators of the intermixing of coastal water in offshore waters also has its value (Gran, 1902; Russell, 1935a; Rees, 1952, 1954a, b; Kitou, 1956).

Not only are indicators used to define water masses of various marine origins, but also to define

areas affected by land drainage, e.g. Komarovsky (1953) uses the presence of the cladoceran *Podon polyphemoides* to indicate the presence of Nile flood water off the Israel coast.

For the North Sea, English Channel, Irish Sea and the main masses of water mixing with these, the best groups of organisms to use as practical indicators are the Chaetognatha (Russell, 1935 a, b, 1936, 1939; Pierce and Orton, 1939; Fraser, 1937, 1939, 1952), the Thaliacea (Fraser, 1949) and certain groups of copepods and pteropods (Rae, 1953); indeed these same groups have proved to be the best in many other areas with similar characteristics. Out in the open ocean, however, the physical or micro-chemical similarities between adjacent water masses are much closer and it is then practicable to use organisms with much finer tolerance limits, organisms that soon die if transported into slightly changed conditions. Perhaps one of the best groups of indicators in this area is the Siphonophora. Until recently, this group has been regarded as a specialists' group, with much justification, but the work of Totton (1954) and the publication of Plankton Sheets 55-62 by the International Council for the Exploration of the Sea should help to make them familiar to the non-specialist. Other useful groups are the medusae, pteropods, euphausids, Thalicea and pelagic polychaetes, from all of which helpful species can be selected.

The indicator species of the first two main water masses mentioned have already been dealt with elsewhere—see, for example, Russell (1935 a, b, 1936, 1939), Fraser (1937, 1939, 1952), Williamson (1952, 1956 a, b), Rae and Rees (1947) and the literature referred to in these papers. These two water masses are not in the main relevant to this paper and are only summarily dealt with here.

It is emphasised that diagnostic organisms are the main concern of this section of the paper, and not a description of the total plankton content of the water masses.

(1) THE INDIGENOUS WATER OF THE NORTH SEA AND OF OTHER LOCAL AREAS

Russell (1935a) said that the only practical indicator of the indigenous North Sea water is *Sagitta setosa*. Rees, at one time (1949), would have added the form of *Calanus* known as *C. helgolandicus* but on investigating its distribution more fully he found (1955) that this is not so. Rae and Rees (1947) added the copepods *Labidocera wollastoni* and *Isias claviceps*. Williamson (1952) used *S. setosa* to indicate indigenous water in the Irish Sea, as did Pierce and Orton (1939), but excluded *Labidocera* and *Isias*. Barnes (1950) used *S. setosa* in the Clyde area and Fraser (1937 etc.) used it to indicate the presence of indigenous water from the southern North Sea in the northern North Sea. Furnestin (1938) associated it with low salinity water in the Gironde.

Another group which can be used is the medusae (Kramp, 1927, 1959). Care must be taken to distinguish between distributions which can be correlated with the physical or chemical environment in which the organisms thrive or die and distributions which can be correlated with the natural life cycle of the organism. For example, *Obelia* medusae are inevitably restricted to water of coastal associations—whether oceanic coast or not—because the hydroid stage is coastal. Such an organism has an indicator value of its own which can be useful if this point is kept in mind. Similar remarks can be applied to the nauplii and casts of *Balanus balanoides* and to the larvae of many other coastal living Crustacea. There are also, however, many species of neritic medusae such as *Tima*, *Eutonina* etc.—see the paragraphs on distribution (Russell, 1953; Kramp, 1959).

(2) THE MIXED ATLANTIC AND SHELF WATER

For the northern North Sea and in the north and west Scottish areas, this subject has been covered by Fraser (1937, 1939, 1952), Russell (1935 a, b, 1939) and Rae (1949); in the Irish Sea by Williamson (1952) and in the English Channel by Russell (1935 a, b, 1936) and Corbin (1947). *Sagitta elegans* seems to be universally acclaimed on both sides of the Atlantic, as the best single indicator species, as this species appears to require both coastal (or bottom) influence as well as oceanic—see Fraser (1937) and Clarke *et al.* (1943). In an area dominated by coastal water it is thus a good indicator of an admixture of oceanic water (e.g. North Sea, English Channel), but where the water is dominantly oceanic it is an indicator of coastal influence (e.g. west Scottish and Irish coasts, Faroe Islands, Icelandic shelf etc.).

It is an indigenous form requiring certain mixed conditions and its use as an indicator of oceanic inflow is thus of a different category from the Chaetognatha such as *S. lyra*, *S. maxima* and *S. serratodentata* and those other oceanic forms which indicate the presence of oceanic water on the shelf because they themselves have been transported with it. Such indicators will be more appropriately dealt with below.

The copepods used, in a comparable sense to *S. elegans*, to indicate the inflow of Atlantic water to the North Sea are *Metridia lucens* and *Candacia armata* (Rae and Rees 1947). *Calanus finmarchicus* is of special importance: when it is thriving it is rich in oil and forms a rich feeding for herring and other pelagic feeding fish as well as being of high value in the general productivity chain leading to good bottom feeding for fish. In the North Sea *C. finmarchicus* originates partly from indigenous overwintering stocks and is partly brought in from the north in early spring. Its success in the brood of the next generation, in the summer, seems to depend to a large extent on the oceanic element in the water. For example, in the northern North Sea a large inflow of Atlantic water in the autumn often gives rise to conditions the following spring which promote a vigorous growth of *Calanus* (see p. 20). Other organisms rich in protein associated with the "elegans" community are *Thysanoessa inermis*, various species of *Themisto*, *Clione limacina* and *Spiratella* (= *Limacina*) *retroversa*.

Oceanic species are transported to, and can live in, this mixed area on the shelf as long as conditions remain tolerable. Some can survive the winter but do not appear to be able to reproduce in the area—e.g. *Sagitta serratodentata* and the siphonophores *Sulculeolaria* (= *Galettea*) *biloba*, *Dimophyes arctica* and *Physophora hydrostatica*. Others rarely survive the winter but can reproduce before the temperature falls, e.g. *Salpa fusiformis*, *Dolioletta gegenbauri*, but the offspring also fail to survive the winter. Most merely linger in the area until they die out, in the order of their inability to withstand the conditions. Some idea of their tolerance limits is thus a help in assessing the conditions which they indicate. As already mentioned, the number of individuals present need not be dependent upon the volume of water transport. The presence of the less tolerant species will, however, usually mean a greater volume transport because the greater the inflow the less changed will the conditions be for the organisms transported in it, and thus the greater the distance they can be carried and still live.

As a rough guide, the species in Table I have been divided according to three degrees of tolerance. Organisms in the first column are frequent invaders of the northern North Sea and occur almost every year with the oceanic inflow. Those in column 2 are not usually present if the inflow is subnormal and will not be well represented unless it is above average strength. They are, however, fairly frequent in the Faroe Channel. Those in column 3 occur only rarely in the northern North Sea, at times of peak inflow, and are found in the Faroe Channel usually only as isolated specimens.

TABLE I
OCEANIC SPECIES FOUND IN THE MIXED WATER OF THE SCOTTISH SHELF

Frequent	Intermediate	Rare
COELENTERATA		
<i>Dimophyes arctica</i>	<i>Chelophyes appendiculata</i>	<i>Chuniphyes multidentata</i>
<i>Lensia conoidea</i>	<i>Lensia fowleri</i>	<i>Vogtia</i> spp.
<i>Sulculeolaria biloba</i>	<i>Hippopodius hippopus</i>	<i>Nectopyramis</i> spp.
<i>Physophora hydrostatica</i>	<i>Arachnactes larvae</i>	<i>Rosacea</i> spp.
<i>Agalma elegans</i>	<i>Staurophora mertensii</i>	<i>Nausithoe</i> spp.
<i>Laodicea undulata</i>	<i>Pelagia noctiluca</i>	<i>Pantachogon haekeli</i>
<i>Cosmetira pilosella</i>		<i>Halicereas</i> sp.
<i>Phialidium hemisphericum</i>		<i>Periphylla periphylla</i>
		<i>Rhopalonema velatum</i>
CHAETOGNATHA		
<i>Sagitta serratodentata</i>	<i>Sagitta maxima</i>	<i>Sagitta serratodentata</i>
<i>f. tasmanica</i>	<i>Sagitta lyra</i>	<i>f. atlantica</i>
	<i>Eukrohnia hamata</i>	<i>Sagitta hexaptera</i>
		<i>Sagitta zetesios</i>
FOLYCHAETA and NEMERTEA		
<i>Tomopteris septentrionalis</i>	<i>Nectonemertes mirabilis</i>	<i>Lagisca hubrechti</i>
		<i>Vanadis formosa</i>

TABLE I (continued)

	Frequent	Intermediate	Rare
MOLLUSCA			
<i>Clione limacina</i>		<i>Clio pyramidata</i> <i>Clio cuspidata</i> <i>Pneumodermopsis ciliata</i> <i>Tracheloteuthis riseii</i> <i>Taonidium pfefferi</i>	<i>Diacria trispinosa</i> <i>Spiratella helicoides</i> <i>Spiratella helicina</i>
COPEPODA			
<i>Rhincalanus nasutus</i>	<i>Euchaeta hebes</i>		Other species of
<i>Eucalanus elongatus</i>	<i>Gaetanus pileatus</i>		<i>Euchaeta</i>
<i>Pareuchaeta norvegica</i>	<i>Gaidius tenuispinus</i>		<i>Pareuchaeta</i> and
<i>Pleuromamma robusta</i>	<i>Euchirella curticaudata</i>		<i>Euchirella</i>
<i>Euchirella rostrata</i>	<i>Metridia longa</i>		Most other bathypelagic species.
<i>Calanus hyperboreus</i>	<i>Phaenna spinifera</i>		
<i>Oithona spinirostris</i>			
OTHER CRUSTACEA			
<i>Thysanoessa longicaudata</i>	<i>Euphausia krohni</i>		<i>Nematoscelis megalops</i>
<i>Sergestes arcticus</i>	<i>Stylocheiron longicornis</i>		<i>Thysanopoda acutifrons</i>
	<i>Brachyscelus crusculum</i>		<i>Nematobrachion boopis</i>
	<i>Munnopsis murrayi</i>		<i>Stylocheiron elongatum</i>
			<i>Vibilia</i> spp.
			<i>Phronima sedentaria</i>
			<i>Scina</i> spp.
			<i>Ammalopeneus elegans</i>
FISH LARVAE			
<i>Maurolicus mulleri</i>	<i>Bathylagus</i> spp.		<i>Nansenia groenlandica</i>
<i>Myctophum glaciale</i>	<i>Fierasfer</i> spp.		<i>Stomias boa</i>
<i>Gadus poutassou</i>	<i>Paralepis coregonoides</i>		<i>Argyropelecus hemigymnus</i>

Included in this table are oceanic species from habitats ranging from warm to cold water. Those associated with boreal influence are *Metridia longa*, *Calanus hyperboreus* (and to a lesser extent *Pareuchaeta norvegica* and *Pleuromamma robusta*), *Sagitta maxima*, *Eukrohnia hamata* and *Spiratella* (= *Limacina*) *helicina*. In applying this principle it is necessary to remember that boreal water may not come directly from the north but also from the cold water below the warmer north Atlantic Drift by upwelling along the edges of the continental shelf. Some of these, *Calanus hyperboreus* and *Pareuchaeta norvegica* in particular, live also in the cold deep water of the Norwegian Deep and can be distributed from there either by upwelling or by their own vertical migration. *Dimophyes arctica* given as an indicator of boreal water (Fraser, 1952) should now be withdrawn. Although it lives in boreal conditions it is too cosmopolitan in its oceanic distribution to have any reliable boreal significance.

(3) THE NORTH ATLANTIC DRIFT

The North Atlantic Drift (i.e. warm water of 35‰ and over from the open Atlantic but containing none of Lusitanian origin) is the main source of inflow that affects the northern North Sea and Scottish fisheries generally, including those at Faroe and Iceland. Physically it has been dealt with by many hydrographers, and it is the North Atlantic Central water of Cooper (1952, a, b, c). Its passage to the Scottish area, through the Faroe-Shetland Channel in particular, has been described in detail by Tait (1957). It has an oceanic planktonic fauna which enables it easily to be distinguished from the coastal and indigenous waters when it is transported to these areas as described on p. 5. It is not so easy to find species which can be used to define this water in contrast to other oceanic waters present in the north-east Atlantic basin. The two other water masses of significance are: first, the boreal and arctic water which, after overflowing the ridges west and east of Iceland, flows down the slope to the deeps and underlies the other water masses, and second, the Lusitanian stream, a mixture of Gibraltar water with Atlantic water of the Azores area, i.e. south of the North Atlantic Drift. Both of these have characteristic species.

The fauna of the North Atlantic Drift is thus detected negatively by the presence of the cosmopolitan

oceanic species (Table II) without many of the boreal or Lusitanian forms. There will inevitably be some admixture of boreal species, slight in the main stream in the centre of the Atlantic, but becoming greater towards the north and at greater depths, i.e. where the boundary is nearer, because of mixing at the interface and vertical migration of the organisms from one zone to the other. Close to the Lusitanian stream there will also be boundary diffusion but it will not be so great as between the Atlantic and boreal water since the areas of interface are much smaller. Some species—e.g. *Dolioletta gegenbauri*, *Vanadis formosa* and *Rhynchonnerella angelini* are cosmopolitan and thus included in Table II, but are usually more commonly found in the Lusitanian area.

TABLE II
TYPICAL COSMOPOLITAN OCEANIC SPECIES

Siphonophora	Mollusca	Copepoda
<i>Physophora hydrostatica</i>	<i>Euclio pyramidata</i>	<i>Rhincalanus nasutus</i>
<i>Agalma elegans</i>	<i>Euclio cuspidata</i>	<i>Eucalanus elongatus</i>
<i>Dimophyes arctica</i>	<i>Diadria trispinosa</i>	<i>Pleuromamma robusta</i>
<i>Lensia conoidea</i>	<i>Pneumodermopsis ciliata</i>	<i>Euchirella rostrata</i>
<i>Chelophyses appendiculata</i>	<i>Taonidium pfefferi</i>	<i>Euchirella curticaudata</i>
<i>Sulculeolaria biloba</i>	<i>Tracheloteuthis risei</i>	<i>Oithona spinirostris</i>
Medusae	Polychaeta	Other Crustacea
<i>Cosmetira pilosella</i>	<i>Travisiopsis lanceolata</i>	<i>Lepas</i> spp.
<i>Laodicea undulata</i>	<i>Vanadis formosa</i>	<i>Munnopsis murrayi</i>
<i>Halicreas</i> spp.	<i>Rhynchonnerella angelini</i>	<i>Brachyscelus crusulum</i>
<i>Periphylla periphylla</i>	<i>Tomopteris septentrionalis</i>	<i>Meganyciphanes norvegica</i>
	Chaetognatha	<i>Euphausia krohnii</i>
	<i>Sagitta serratodentata</i>	<i>Anchialus agilis</i>
	<i>f. tasmanica</i>	
	<i>Sagitta hexaptera</i>	
	Thaliacea	
	<i>Salpa fusiformis</i>	
	<i>Dolioletta gegenbauri</i>	

(4) THE LUSITANIAN STREAM

The fauna of this stream has been defined (Fraser, 1955) as "that fauna which, originating in the outflow of the Mediterranean, has become modified by admixture with fauna from the area between the Azores and the Bay of Biscay". It thus corresponds to the mixed Central and Gibraltar water of

TABLE III
LUSITANIAN SPECIES IN THE SCOTTISH AREA

Siphonophora	Chaetognatha	Crustacea
<i>Rosacea plicata</i>	<i>Sagitta lyra</i>	<i>Nematocelia megalops</i>
<i>R. cymbiformis</i>	<i>S. serratodentata atlantica</i>	<i>Stylocheiron</i> spp.
<i>Nectopyramis diomedaeae</i>	<i>S. bipunctata</i>	<i>Vibiliia</i> spp.
<i>N. thetis</i>	<i>Krohnitta subtilis</i>	<i>Phronima</i> spp.
<i>Bassia bassensis</i>	Polychaeta	<i>Sapphirina</i> spp.
<i>Vogtia</i> (all species)	<i>Travisiopsis lobifera</i>	<i>Phyllosoma</i> larvae
<i>Hippopodius hippopus</i>	<i>Lagisca hubrechti</i>	Thaliacea
<i>Muggiaea</i> spp.	<i>Sagitella kowalewskii</i>	<i>Cyclosalpa</i> spp.
<i>Eudoxoides spiralis</i>	Mollusca	<i>Ritteriella</i> spp.
<i>Chuniphyes multidentata</i>	<i>Euclio polita</i>	<i>Thalia democratica</i>
<i>Lensia</i> —all species except <i>L. conoidea</i>	<i>Janthina britannica</i>	<i>Thetys vagina</i>
<i>Stephanomia bijuga</i>		<i>Iasis zonaria</i>
<i>Velella velella</i>		<i>Ihlea asymmetrica</i>
Medusae		<i>Salpa maxima</i>
<i>Rhopalonema velatum</i>		<i>Doliolina mulleri</i>
<i>Nausithoe punctata</i>		<i>Doliolum nationalis</i>
<i>Pelagia noctiluca</i>		

Cooper (1952a), and has originated at the depth corresponding to the sill depth of the Straits of Gibraltar, i.e. about 1000 metres. This water spreads out (Defant, 1955) and gradually mixes with the Atlantic water at the interface in the process. The northern part of this fan continues to spread northwards along the edge of the continental shelf and so plays a part in the constituent waters which affect the Scottish area. Its importance varies from year to year. Fraser (1955) gives a list of Lusitanian indicator species to distinguish its fauna from that of the cosmopolitan species which occur in both the Lusitanian stream and the North Atlantic Drift. This list, slightly amended, is repeated here as Table III.

A number of species that are known from the Mediterranean and perhaps the Red Sea are so far unknown from the open Atlantic. It thus might be possible to distinguish between the pure Mediterranean and the mixed Mediterranean and Atlantic water on this basis, but as unmixed Mediterranean water is of little significance to any of the Atlantic fisheries, there is probably not much point in doing so here. On the other hand, the differences between the Mediterranean and Atlantic water flowing into the Mediterranean at the surface will be of real significance in Mediterranean fisheries. Bernard (1956, 1958) in particular has worked on the plankton problem associated with this interchange though largely from his own specialised subject of the phytoplankton, and he finds the Coccolithophore *G. fragilis* to be of special value in this work.

In the region of the Spanish, Portuguese and Moroccan coasts, and probably the whole west African coast to Cape of Good Hope, *Sagitta friderici* exists in the inshore waters whereas *S. bipunctata* is typical of the offshore waters—see details given by Faure (1952), Furnestin (1959), Heydorn (1959) and Fraser (1960b). This is reminiscent of the *S. setosa* *S. elegans* relationship in the North Sea and adjacent waters (but see Colman, 1959).

(5) THE ARCTIC, BOREAL AND COLD DEEP WATER

Boreal, or sub-arctic, water can affect the Scottish fisheries in three ways:

- by direct inflow, either into the area or in such a way that it dams the passage of the inflow from the Atlantic (Tait, 1949);
- by early upwelling after overflowing the Faroe-Iceland Ridge and so entering the area with the North Atlantic Drift;
- as the main source of the underlying deep water which occupies the floor of the whole north-east Atlantic basin; the amount of this is important in determining the amount of Atlantic water that must flow northwards to maintain the balance.

This deep water may have a mixed history and although mainly of arctic and boreal origin it will contain also some element of Atlantic and Lusitanian water (see p. 10). Although moving it is sufficiently stable, homogeneous and of long standing to allow a deep water fauna of its own to develop. The fauna of this water mass is thus composite, consisting of (a) arctic and boreal epiplanktonic species, carried over the sills, which can thrive in the continued cold but deep conditions; and (b) indigenous deep-water species not found in cold surface water of the arctic. Some of the former exist in the deeps throughout the whole tropical area and are found near the surface in the Antarctic—the bipolar epiplanktonic species of Russell (1935a).

Typical examples of the arctic and boreal (not necessarily bipolar) epiplanktonic species found in deep water in lower latitudes are given in Table IV.

TABLE IV
SPECIES CHARACTERISTIC OF ARCTIC OR BOREAL WATER FOUND IN LOWER LATITUDES

<i>Calanus hyperboreus</i>	<i>Dimophyes arctica</i>	<i>Spiratella helicina</i>
<i>Metridia longa</i>	<i>Sagitta maxima</i>	<i>Sergestes arcticus</i>
<i>Pareuchaeta norvegica</i>	<i>Eukrohnia hamata</i>	
<i>Pareuchaeta barbata</i>		

There are also some arctic species which are carried southward with water movement but which do not appear to be able to survive even in cold deep water, probably because the depth factor is limiting.

Of these the most typical is *Oikopleura vanhoffeni*; *Themisto libellula* probably also belongs to this category. Typical examples of the indigenous deep-water species are given in Table V.

TABLE V
SOME SPECIES TYPICAL OF DEEP WATER

<i>Gaetanus pileatus</i>	<i>Amalopenaeus elegans</i>	<i>Sagitta macrocephala</i>
<i>Arietellus plumifer</i>	<i>Hymenodora elegans</i>	<i>S. zetesios</i>
<i>Pontoptilus muticus</i>	<i>Boreomysis microps</i>	<i>Eukrohnia fowleri</i>
<i>Centraugaptilus rattrayi</i>	<i>Eucopia unguiculata</i>	<i>Nectonemertes mirabilis</i>
<i>Augaptilus megalaurus</i>	<i>Cyphocaris anonyma</i>	<i>Spiratella helicoides</i>
and many other copepods (see pp. 40-42)	<i>Scina</i> spp.	<i>Histioteuthis bonelliana</i>

A number of fish, small enough to be caught by plankton nets, can also be classified in this category, such as:

<i>Argyropelecus hemigymnus</i>	<i>Cyclothona microdon</i>	<i>Paralepis coregonoides</i>
<i>Stomias boa</i>	<i>C. braueri</i>	<i>Bathylagus</i> spp.

RECORDS OF RARE OCEANIC SPECIES

Records of large-scale plankton investigations in the north-east Atlantic carried out by the Scottish Home Department, now the Department of Agriculture and Fisheries for Scotland, have added to our knowledge of the distribution of the rarer species. Lists of such records for the period 1947 to 1949 were published by the International Council for the Exploration of the Sea in their Annales Biologiques. Without such lists the records are lost in the notebooks and charts of the laboratory and it is therefore desirable to bring them up to date from time to time so that the records of major interest can be made available. Opportunity is therefore taken to do so here (see Appendix Table 1), for the years 1950 to 1956; a few records of particular interest since 1956 are included in the text.

Unless the list is to be extremely large a limit has to be set, and there is a measure of personal bias in deciding whether or not a species justifies inclusion. This inevitably means that the list cannot itself inform the reader whether species 'A' did not occur at all, or was too common to be included. It is thus necessary to include a supplementary list (Appendix Table 2) of organisms, which occurred too frequently to be included as rare, and so to bridge the gap to those which will be well recognised as common.

The size of mesh in the nets used for this investigation—26 meshes to the inch—means that small organisms are lost through the meshes; for example, copepods of a size smaller than *Calanus finmarchicus* will not be represented and are excluded from these lists. Neritic species, and the planktonic larvae of neritic species are excluded, as also are bottom-living species such as *Spadella*, and many amphipods and cumaceans that are liable to be taken in a plankton net towed near the bottom.

The organisms in this supplementary list (Appendix Table 2) are found fairly frequently over a wide range of the area investigated, usually decreasing in abundance from the Atlantic, the boreal area or Scottish and Irish west coasts, according to their origin, to the Faroe Channel and the northern North Sea east of Shetland.

Several species given in the "rare" records (Appendix Table 1) often occurred at the same station and to save frequent repetition of the station details, the name of each organism is accompanied by only the station numbers at which it was found.

COMMENTS ON THE ORGANISMS LISTED (Appendix Tables 1 and 2)

The precise depth of capture of any individual taken in an open net cannot be ascertained, but a study of the contents of nets from various depths in different water areas and communities soon indicates the general depth distribution of the various organisms. Such a general picture is adequate for the broad principles under consideration as they affect the fisheries, and the information is obtained with consider-

ably less strain on the facilities available both at sea and in the laboratory. The hydrographic data including serial temperatures and salinities are not given here as they can be obtained by those interested from the Bulletin Hydrographique.

Some individual comment on the ecological significance etc. of some of the organisms listed is necessary.

Medusae

Ectopleura dumortieri is a neritic form common in the southern North Sea (Aurich, 1958). It has been included in this list as it is quite uncommon in the northern North Sea and the records of its distribution may be of value. *Leuckartiara octona* is easily the most abundant of the Pandeidae and it is of wide distribution in the waters off the west and north of Scotland and in the northern North Sea. *Neoturris pileata* is fairly common, in the Faroe Channel area in particular. *Laodicea undulata* is one of the commonest oceanic medusae (*Aglantha* excepted) particularly if there is some boreal element in the water. Although frequently brought to the northern North Sea its distribution is too oceanic for it to be an indicator of *Sagitta elegans* water, as Russell (1953) suggests, but it can itself be a very useful indicator of water movements. Kramp (1959) includes it in his list of neritic species but also says it is generally distributed in the Atlantic. In this paper the term neritic is used in a narrower sense than by Kramp.

Staurophora mertensii is normally a boreal form and is most abundant in the Faroe area. It is occasionally found in inshore waters both in the North Sea and in the Hebridean area. Gauld (1952) reported it from the Firth of Clyde. Following Russell (1953), only one species of *Cosmetira*, *C. pilosella*, is recognised from this area. It is an oceanic species, most common to the south of the area frequented by *Laodicea*, and these two medusae rarely occur in the same oceanic sample. The two can thus be useful indicator forms, as they follow separate paths leading to mixing in the northern North Sea in years of big inflow. Normally *Cosmetira* tends to keep close to the Scottish coast and affects the Moray Firth area while *Laodicea* keeps to the north of Shetland and affects the North Sea east of 1°W.

Unless they are caught in good condition it is not easy to distinguish between *Halicreas minimum* and *Haliscera bigelowi*, and specimens taken out of their normal habitat are usually partially disintegrated. As their distribution is essentially similar (Kramp, 1947) they have the same value and have been included together in this list.

Previous to 1955 *Solmaris corona* was regarded as rare in the Scottish plankton but in that year it was widely distributed over a large area from the Hebrides to at least 15°W, to the Faroe Channel and to the north-west of Faroe. This distribution is very similar to that given by Kramp (1959). In 1956 numbers were much reduced although it was still present as far as Shetland. In neither year was it found within the limits of the North Sea, although it was found off the Aberdeenshire coast in 1959. Because of the large number of 1955 stations at which it was reported it has been omitted from the detailed list. It seems to be a species that occurs with spasmodic abundance.

The specimen of *Octophialucium* from S54/488 had 9 radial canals; similar abnormalities have been recorded, see details given in Russell (1953) p. 341 as *Octocanna*.

Nausithoe globigera and *N. atlantica* are grouped together in the list.

The papers by Russell (1957, 1958) describing *Atolla vanhoffeni* and *A. parva* appeared after these identifications were made, and it is thus possible that the records given here as *A. wyvillei* include also those species.

The record of *Tetraplatia volitans* is of particular interest so far north—see Rees and White (1957).

Although taken more recently than 1956 the opportunity is taken here to record also *Ptychogena lactea* Agassiz from the surface at 60°23½'N 7°49½'W on 3rd June 1958, the identification being confirmed by F. S. Russell and by P. L. Kramp to whom I am indebted. This record from the Faroe Channel now widens the distribution of this species to the 'East-Atlantic Boreal' region of Kramp (1959).

Comparing this list with those given by Kramp (1959) it is seen that many species have been known to occur in the area covered by the Scottish research vessels but have not been found by them. This in itself is not surprising, especially as medusae disintegrate rapidly when carried away from their natural habitat. Many blobs of jelly occur in the plankton collections which have probably at one time been medusae but are no longer recognisable.

Few parasitic copepods are found in the plankton of the open ocean although *Caligus rapax* is fairly common in the plankton from inshore waters. The most noteworthy oceanic species is *Nestipus borealis* (Steenstrup and Lütken); this is a shark parasite but the male is found not infrequently in plankton collections over deep water and seems to be distributed over a wide area of the North Atlantic from Porcupine Bank to the Denmark Strait. Another species which might be mentioned here is *Sarcotrete scopeli* Jüngersen which is sometimes taken on its host *Benthosema* (= *Myciophum*) *glaciale* in the plankton nets, and at times with its own epizoic hydroid *Ichthyocodium sarcotretis* Jüngersen. (Jüngersen, 1911, 1913).

Cirripedia

Specimens of *Lepas* are sometimes found attached to stray objects floating in the water, but most frequently to strands of the weed *Ascophyllum nodosum*. *L. fascicularis* is the most common species, but *L. anatifera* and *L. anserifera* also occur.

Isopoda

Although according to the literature *Munnopsis oceanica* and *M. murrayi* have almost identical distributions, only *M. murrayi* has been taken in the collections by the Scottish research ships since detailed lists of oceanic plankton samples have been kept, i.e. since about 1935.

Most of the species of *Eurydice* known to occur in the area have been found, but of these *E. grimaldii* is certainly the most abundant.

Species of *Idothea* are usually directly associated with the coast but *I. balthica*, *I. pelagica* and *I. viridis* have all been found at some distance from the shore, nevertheless in water with a distinctly coastal influence. *I. emarginata* and *I. metallica*, however, are found in the truly oceanic water, although associated with floating clumps of *Ascophyllum*. This perhaps indicates a coastal origin, even if many months previously, and Naylor (1957) suggests an American origin for the British records of *I. metallica* via the Gulf Stream and North Atlantic Drift.

Amphipoda

The common species are listed in Appendix Table II on p. 48. A number of other species occur but never in quantity. *Themisto libellula* is occasionally found north of Faroe, and this species with other arctic forms such as *Onesimus leucopis* and *Thaumatops fabricii* also occur in 'Scotia's' collections from the Denmark Strait, but not in areas affected by warmer water. The commonest bathypelagic species is *Cyphocaris anonyx*. *Phronima sedentaria* is found in its gelatinous case, and each time it has been possible to identify its source it has been the salp *Iasis zonaria*. The record of *Eurisus holmi* is perhaps of special interest as it is usually found much further north and in the Barents Sea. Another specimen was found on 28th January 1960 in an oblique haul from 1200 m at 61°21'N, 3°10'W.

Mysidacea

The large red mysid *Gnathophausia zoea* occurs occasionally, but *G. gigas* has not so far been taken by Scottish research vessels. The most abundant oceanic mysid is *Erythrops erythrophthalma* but as this species is even more common in neritic waters it is excluded from the lists. Of the listed species *Boreomysis microps* and *Eucopia unguiculata* are the commonest and often occur in the same collections. The name *E. unguiculata* W-Suhm is taken as synonymous with *E. hansenii* Nouvel 1942 as used in the I.C.E.S. sheets No. 19 (see Tattersall and Tattersall, 1951). These records extend the northerly known distribution of *Arachnomysis leuckarti*, *Anchialus agilis* and *Katerythrops oceanae*.

Euphausiacea

The southern species *E. krohni*, *N. boopis* and *N. megalops* have all occasionally been recorded in the Norwegian Sea (Østvedt, 1955), as has also the bi-boreal species *T. acutifrons* (Wiborg, 1954). Species that might have been expected in the oceanic samples taken by Scottish research vessels but which have not so far been taken include *Bentheuphausia ambylops* and *Thysanopoda microphthalmalma*.

Decapoda

Adult decapoda are not usually abundant in plankton samples. *Pasiphaea sivado* is the main exception,

and although it is not often present it can be very numerous when it does occur, in such places as the North Channel entrance to the Irish Sea. Of the bathypelagic species the commonest is *Amalopenaeus (Gennados) elegans* which is fairly general in the deep water. *Hymenodora glacialis* and *Acanthephyra* spp. occur much more rarely.

Decapod larvae are frequent, but have not been studied specifically. Phyllosoma larvae of *Palinurus vulgaris* are not taken as frequently as might be expected, which would indicate that larvae from the main areas of abundance of *Palinurus* have already gone to the bottom before being transported so far north, and that the more northerly adults off the west Scottish coasts are not sufficiently numerous to reproduce to any extent (see also Wilson, 1952). It is probable that the small numbers of *Palinurus* found off northern Scotland have been derived from transported larvae, and that they are not self-maintaining stocks; Tambs-Lyche (1958) holds the same opinion about specimens found in Norwegian waters. Lewis (1951) states that larval development requires about six months, during which time larvae can be carried 1000 miles in the Gulf Stream.

Mollusca

Several species of pteropods are listed on p. 48 as being too common to be included in the list, but of these only *Spiratella retroversa* occurs in great abundance. It may occasionally reach about 1 litre in a 15 minutes' haul with a 1 metre net, over the continental shelf in areas where the oceanic influence is distinct. The other species mentioned there and those recorded as rare are all oceanic, but with a wide range from *Euclio limacina*, which is the most tolerant and often thrives and breeds in the northern North Sea, to species like *Peraclis moluccensis*, which is in this area very strictly an oceanic exotic. *P. tricantha* also occurred in Scottish collections in 1948 but not during the period 1950-56. The cold water species *Spiratella helicina* has not been as common as expected from data given in the literature, even in areas where there is distinct evidence of arctic or boreal water. It was never taken in the Scottish collections during the period under consideration here. *Euclio polita* can be regarded as a Lusitanian species, as can *Janthina*. Shells of *Janthina* have been reported washed up on the western coasts of Scotland (Beatson, Nicol and Elton, 1936) but have rarely been found in plankton collections.

The heteropod *Carinaria lamarcki* was found in both 1952 and 1953 further north than in previously published records. *Atlanta* and *Firoloida* have been found off the south-west of Ireland but they have not yet been found in Scottish plankton collections, although occasional dead shells have been taken as far north as the western entrance to the Faroe Channel. On 11th May 1959 a large specimen of *Pterotrachea scutata* was also taken there, 59°44'N, 7°15'W, in a deep haul from 1000 m.

The most abundant cephalopods are the young stages of the commoner pelagic (as distinct from planktonic) species which occur in the oceanic areas, particularly members of the family Gonatidae. Small Cranchidae are also quite frequent, particularly *Tracheloteuthis (Brachioteuthis) riseii* and *Taonidium pfefferi*, and they can add their quota to the indicator value of the community. Records of less common species include *Desmoteuthis hyperboreus*, of which there were three during the years 1950-56, and *Histioteuthis bonelliana*, which was found once only. Stephen (1944) gives details of earlier records, and the apparent recent increase in the numbers of *Taonidium pfefferi* is of interest.

Tunicata

A short section on the appendicularian fauna and its ecological significance is given on p. 37 in the appendix.

A general picture of the occurrence of Thaliacea in the waters affecting the Scottish area was given by Fraser (1949); as this was supplemented in 1952 and in 1955 it does not require much comment here. In this group, more than in any other, emphasis must be drawn to the distinction between those individuals which have themselves been transported into the area and those which have been reproduced within the area because exceptionally high temperature conditions permitted it. Where large numbers of original individuals occur, and have been together a long time, they tend to denude the water of phytoplankton and therefore also of the food supply of copepods and other zooplankton and so exist in relatively pure communities. Recently reproduced individuals have not had time to do this so that swarms in the central North Sea in exceptional years are found with the normal communities of the area

(see Cattley, 1950). The transport of great volumes of denuded water into the late summer herring fishing grounds might have repercussions on the fishery, and indeed if repeated would affect the bottom fauna and so also the food supply of demersal fish. The regeneration of nutrients in this water, and its mixing with indigenous water during the winter months does, however, appear to stimulate good growth of plankton the following spring (see p. 21).

Salpa fusiformis is the commonest species of salp and is of cosmopolitan oceanic distribution in temperate and warm water. It occurs in the Scottish area almost every year, sometimes in small numbers only, but sometimes in dense swarms, e.g. in particular 1920, 1921, 1925 and 1954. *Ihlea asymmetrica* is also at times very common, but this species is less tolerant than *S. fusiformis* and it has a delicate test. It is thus frequently very disintegrated when found in the Scottish area and is usually represented by "nuclei" only (i.e. the concentrated ball containing the stomach etc.) but occasionally with enough of the fragmentary test to show the characteristic muscle bands confirming its identity (Fraser, 1949; Farran, 1906). In 1953, however, many specimens were alive when caught and in excellent condition, and in this year also *Cyclosalpa virgula* and *Ritterella picteti* were found, both first records from so far north (Fraser 1955). *Iasis zonaria* occurs only in isolated instances in this area and has never been abundant. It has a durable test in both solitary and aggregate forms and thus gets carried in recognisable form for long distances. *Thalia democratica*, probably the most abundant salp in the world, is not sufficiently tolerant to withstand the conditions so far north as the Scottish area and, although it occurs off the western end of the English Channel and south-west of Ireland, it rarely penetrates further north. Until 1958 only occasional specimens have been taken by the Scottish research vessels in the Porcupine Bank area and in the Continuous Recorder survey they were caught further north over the deep water west of Scotland in July 1954 and in September 1955 (Rae, 1956, 1957a). Apstein (1894) and Herdman (1888), however, both record it as occurring in immense shoals off the Hebrides towards the end of the last century. Similar shoals were not recorded there again until 1958, when *Thalia* thrived in great numbers in a band extending from the west of Ireland to the Butt of Lewis.

Cyclosalpa bakeri was recorded off the north of Scotland in 1932 and 1937 (Fraser, 1949) and a large *Thetys vagina* was taken in a herring net off Wick in 1929 (Thompson, 1948). Neither of these has been found in the years dealt with here, but a single specimen of *Thetys* was taken on 2nd October 1958 at 53°20'N, 14°40'W. A solitary *Pegea confoederata* was taken at 20 m on 13th November 1958, from 59°24'N 3°45'W.

Of the doliolids, *Dolioletta gegenbauri* is certainly the most abundant, and in fact almost the only species found in the Scottish area and extending frequently into the North Sea (Fraser, 1949; Lucas, 1933; Cattley, 1950). In the open oceanic area it is usually present as the variety 'tritonis', but less so in the small gonozoids reproduced within the area, thus confirming Garstang's (1933) opinion that *D. gegenbauri* and *D. tritonis* are the same species. *D. nationalis*, like *Thalia*, is found off the entrance to the English Channel but rarely penetrates into the Scottish area. Rae (1956) recorded some specimens mixed with *D. gegenbauri* in 1954 west of the Hebrides. This species and *D. mülleri* are quoted by Fraser (1955) as Lusitanian and occurring off the English Channel in 1953, but *D. mülleri* has not so far been found further north.

Pisces

The eggs, larvae and post-larvae of commercial fishes are not dealt with in this paper.

Plankton nets are far from ideal for catching adult pelagic or bathypelagic fish or their later young stages, so that records are likely to be spasmodic and of little practical value. With such frequent sampling they do, however, catch occasional specimens and so widen the known distribution; certain records of interest are therefore listed. Opportunity may be taken to add two 1957 records of *Diploploichthys bifilis* Regan and Trewavas from 61°51'N 23°20'W on 9th April 1957, and from 61°51'N 23°25'W, almost the same place, on 4th July 1957. *Antennarius radiosus* Garman was found at 54°10'N 12°10'W on 5th October 1958 (see Palmer, G. Ann. Mag. nat. Hist., Ser. 13, 3, 149-151).

It is, perhaps, worthy of note that although there are several species of *Argyropelecus* with fairly similar distributions only *A. hemigymnus* has so far been found by Scottish research vessels, and, although *Benthosema* (= *Myctophum*) *glaciale* is very common, *Electrona* (= *Myctophum*) *arcticum* is much more scarce

and other species seem to be rarities. The fish listed as *Nansenia* spp. are mostly *N. groenlandica* but at least one (S.55/723) is believed to be a new species and is to be dealt with by the British Museum. Leptocephali must be very abundant in the North Atlantic yet surprisingly few are caught by the 1 metre plankton nets; the Corbin net with its greater 'D' shaped size of about 3 metre head rope caught up to 6 per $\frac{1}{4}$ hour haul (at 57°38'N 15°14'W, 31/7/56), at 10 fm during the night. Proportionally, this must mean that fish such as *Benthosema glaciale* and the young pelagic stages of *Gadus poutassou*, of which some hundreds are taken yearly in the plankton nets, must be very abundant indeed (see p. 27).

FAUNISTIC RELATIONSHIPS AND THE FISHERIES

The planktonic species which may be used to indicate the presence of the various water masses have already been noted (p. 6). The presence of these organisms can be a valuable label, although they may not themselves have more than a minute significance in the ecological systems involved, and therefore to the fisheries. As mentioned below, however, certain of them do have very pronounced direct effects, but it is the general fauna associated with these labels, and its environment, that has the principal significance.

Research in recent years has more and more emphasised the complicated subtleties of the requirements of different organisms in the phytoplankton (e.g. Provasoli, McLaughlin and Droop, 1957) and the resultant effect on the ecological relationships in the sea (e.g. Lucas, 1956; Wilson, 1951; Johnston, 1955; Collier, Ray and Wilson, 1956; Bentley, 1958, 1960). The major component physical factors, the seasonal temperature and light variations and the dominant currents follow a similar general pattern from year to year so that there is always the basic annual picture of biological succession. The relatively smaller changes in volume transport and the constituent proportions of water masses of different origins are, however, big enough to make distinct differences to the plankton production and so to affect the fisheries. These changes may be merely seasonal, annual or even long-term trends. The phytoplankton is dependent on the organic constituents, often produced by bacteria, as well as on the inorganic nutrient salts and trace elements. It appears that many organisms produce metabolites which may affect the growth of their neighbours, thus resulting in a chain of succession of dominance, although Talling (1957) does not consider this adequately established. The succession of phytoplankton occurs, however, and could result in changes in succession of zooplankton; as these too may complicate their environment with excretions and secretions the whole plankton production could be affected. Specific phytoplankton and zooplankton composition can also be important as the potential food value of the different species may vary, partly because of their chemical constituents, but also because their shape or other physical factors can make them unavailable. Certain phytoplankton organisms, for example, are not suitable food for some planktonic grazing species (Gibor, 1956).

Each water mass, though "labelled" by a few indicator species that may be of greater or lesser importance in the eco-system, has a characteristic fauna often typified by the abundance and condition of many species which are also found in other water masses but in different numbers or in different proportions. The richest production of crustaceous zooplankton in the area round the British Isles—and thus the potential fertility of this area for pelagic fish and, via the bottom fauna, probably also for demersal fish—is not found in any one of the incoming water masses, but where these meet and mix with the local waters. This is no doubt due in part to the different waters having been impoverished of different chemical constituents (both organic and inorganic) during their various histories so that mixing may replenish the fertility of each. Upwelling of nutrient-rich deep water and land drainage each play their important part, adding nutrients, trace elements and metabolites to the euphotic zone in the areas of mixing.

It is thus that the water labelled 'elegans water' contains the richest zooplankton of the water masses around the British Isles, and the greatest crops there of copepods such as *Calanus finmarchicus*, *Pseudocalanus elongatus*, *Centropages typicus*, *Temora longicornis*, *Acartia clausi* and *A. longiremis*, *Candacia armata*, *Oithona spinirostris* and *O. similis* etc., euphausiids such as *Thysanoessa inermis*, *T. raschii* and *Nyctiophanes couchii*, decapod larvae, amphipods, cladocerans etc., all of which are rich in protein content and

often oil content. This rich crop of zooplankton is usually maintained in spite of the abundant predatory fauna that often goes with it. It is preyed upon by the pelagic fish and the planktonic stages of demersal fish and either directly, or indirectly via disintegration, it forms the food of the bottom fauna species which are the major source of food for the demersal fish—this will be dealt with more fully later.

In the oceanic waters, with which this paper is mainly concerned, the zooplankton communities are not themselves usually as rich as the mixed 'elegans' community. An exception is in the rich boreal oceanic conditions of the Norwegian Sea (Wiborg, 1955), only the fringe of which is in the area considered here. This is the area north of the Faroe-Iceland Ridge, where temperature conditions are not normally conducive to the formation of stratified water and there is thus general intermixing of the Atlantic and the boreal water masses, in contrast to the area further south where currents and the continental slopes are responsible for upwelling. In nearly all this northern area there is a great abundance of oily plankton, including *Calanus*, *Meganyctiphanes*, etc., which is of great significance to the Atlantic herring while feeding in this area; further, this rich planktonic fauna with the plankton-feeding capelin and herring is directly or indirectly responsible for the great cod fisheries there. Conditions are similar still further north. Jaschnov (1939) states that in the south-western part of the Barents Sea *Calanus* forms by weight 74-91% of the total plankton. Lednev (1958) states that "variation in the inflow of Atlantic water into the Barents Sea influences the fishery; the rate at which the fish migrate eastward, the distribution and their concentration in certain areas are all affected". Baranenkova (1960) demonstrates a definite relation between an increase in the warm water and the numerical strength of O+ cod and haddock in the Barents Sea.

The warm surface water of the Atlantic inflow is naturally relatively poor in plankton. Ryther and Yentsch (1958) show that productivity at the surface decreases in a seaward direction over the American continental shelf and that the annual rate of carbon fixation is even less in the north central Sargasso Sea than in the most seaward of the Shelf stations; in Long Island Sound, by comparison, the value given is almost five times as great. The surface waters, as they approach the British Isles, contain such organisms as *Agalma*, *Arachnactes*, *Beroe* etc. which can often be seen from the ship's side, but species of good feeding value are rare. The inflow is richer in the sub-surface layers as is typical of most warm waters (Jespersen, 1935; Leavitt, 1935, 1938; Clarke, 1940; Bernard, 1955b). Even as near the surface as 10 metres—the depth chosen to run the Hardy Continuous Recorder—the fauna is much richer, containing an abundance of siphonophores (including in particular *Lensia conoidea*, *Chelophysa appendiculata* and *Sulculeolaria biloba*), medusae such as *Laodicea*, *Cosmetira*, *Turris* etc., *Salpa fusiformis*, *Dolioletta gegenbauri* and a fair crustaceous element, particularly *Acartia longiremis*, *Oithona spinirostris* and patches of *Temora longicornis* and *Centropages hamatus*. Included also are a few of those other organisms which are more abundant at deeper levels (100-300 m), such as *Pareuchaeta norvegica*, *Rhincalanus nasutus*, *Eucalanus elongatus*, *Pleuromamma robusta*, *Gaetanus pileatus*, *Clione limacina*, *Clio pyramidata*, *Tomopteris helgolandicus*, *T. septentrionalis*, several species of *Conchoecia* (Ostracoda) and of fish such as myctophids and post-larval *Gadus poutassou*, *Stomias*, *Paralepis* etc.

Calanus finmarchicus is not usually abundant in this Atlantic plankton at any depth, but swarms in great numbers both on its northern edge, i.e. the interface with the boreal water, and also along its southern edge against and on the continental shelf, i.e. the interface with the indigenous water. Both these *Calanus*-rich areas are of great importance to the fertility of the fishing grounds. The former affects the Icelandic, Faroese, Norwegian and Bear Island areas as well as the northern North Sea, where the fringe may be brought in along the edge of the main inflow east of Shetland. The second affects all the Scottish fishing grounds, from Stanton Bank to the Minch, the shelf area north of Scotland and west of Orkney and Shetland, the Shetland herring fishing grounds and the area to the north-east of the Aberdeenshire coast fished by the Fraserburgh and Peterhead fleets. Dense patches of *Spiratella* (= *Limacina*) also occur with *Calanus* in this band and feeding on this organism by herring gives the familiar 'black gut' condition in contrast to the 'red gut' when *Calanus* predominates. This shelf plankton is normally at its densest in May and June, supplying rich feeding to the north-east herring grounds; but its constitution and distribution are more probably functions of the balance between the physical, chemical and biological components of the water off the edge of the continental shelf in early spring rather than those of the northern North Sea in May and June. However, this water, rich in food material arrives on the fishing grounds in late spring to mix with, rather than replace entirely, the local water in this part of the northern

North Sea. Just as mixing off the shelf produces conditions for excellent growth of *Calanus* so also does mixing in the area of the northern North Sea itself (Fraser, 1937; Rees, 1957) but in order to have the right conditions there, in time for the spring reproduction and growth of *Calanus* which have overwintered there at stage V, the mixing must have occurred earlier. Tait (1937) emphasises that the hydrographic conditions in the Faroe-Shetland Channel determine those in the northern North Sea, and it would thus seem that the oceanic inflow of the previous autumn and winter leaves a legacy conducive to rich growth the following spring, and indeed might continue to be effective for a much longer period. This could account for the trend of increased *Calanus* in the spring in the North Sea from 1947 to 1955 (Glover, 1957, Fig. 7) in association with an increased Atlantic inflow.

Planktonic conditions in this part of the northern North Sea in summer, which are of direct importance in the herring fisheries, may thus depend on either local growth affected by the inflow of the previous year, or the richness of the zooplankton brought in by the mixed inflow of the current year, or both. It must be emphasised again that this richness is associated with mixing of an oceanic element and a local or inshore water and not with the inflow itself. Thus, where the oceanic water itself enters the northern North Sea in a relatively unmixed inflow, conditions will not be right for a rich zooplankton population there until later, after mixing has occurred and there has been time for the succession of growth. Pelagic fish such as herring do not appear to be found in normal quantity when such unmixed oceanic conditions occur. This could be due to the fish leaving the area because of lack of food, to distaste of the water itself (possibly of the same substance which is causing the difference in specific content of plankton) or to the presence of salps or other oceanic species. However this may be, an unmixed influx of oceanic plankton during the herring season would be expected to cause an early end to the Shetland fishery, and indeed the evidence since 1920 strongly suggests that this is so.

The distribution of the main concentrations of different plankton communities in the Shetland area, before the close of the fishery, can be shown to have a positive and direct effect on the distribution of the herring there. In July 1958 "Scotia" investigated this factor. The herring shoals were fairly widely scattered during the first half of July, as was shown by the echograms, in the areas east of Fair Isle, 20 miles east of Sumburgh (South Shetland), 30-50 miles east of Yell (North Shetland), 10 miles north-west of Flugga and between Foula and Shetland. These traces were nowhere particularly dense and large plume traces were few, so this distribution is fully consistent with the spotty distribution of the shoals as found by the commercial vessels. By the second half of July the herring traces were very much more concentrated to the south-east and east of Fair Isle and commercial vessels from Shetland were making excellent catches. At this time echometer traces from other areas were similar to those of early July, nowhere indicating the concentrations found near Fair Isle; few boats were working elsewhere.

During the first half of July the plankton pattern showed four distinct communities; (1) dominant and abundant *Calanus*, only in the Fair Isle area from about $2^{\circ}15'W$ to $0^{\circ}15'E$; (2) mixed *Calanus* with euphausiid furcillia and other zooplankton but also with small jellies, *Cosmetira* and *Laodicea* in the area south of Fair Isle, and with *Pleurobrachia* east of Shetland; (3) *Calanus* with abundant *Spiratella* in the area north and west of Shetland within 25-30 miles of the coast, and with a slight leakage through to the east of Shetland via the north of Fair Isle, i.e. north of the first mentioned community; (4) outside these communities, in the oceanic area, dense quantities of *Salpa fusiformis*. By the second half of July the plankton pattern had changed. Salps had still not penetrated round the north of Shetland to the east side, but the *Calanus-Spiratella* patch had extended round Flugga and southwards into the area east of Shetland as far as $60^{\circ}N$. The *Calanus-Pleurobrachia* community has thus been pushed rather further eastwards in this area but *Calanus* with jellyfish were still present south of the *Calanus* patch near Fair Isle.

It would seem that herring in Shetland waters were fairly widely distributed in early July 1958, but that the shoals were in local patches and thus difficult to fish economically except in the Fair Isle area where catches improved during July. This later concentration in the Fair Isle area coincided with the only area of abundant *Calanus* that was also free of small jellies. It occurred in a relatively stationary patch of water where temperature conditions were more or less homogeneous throughout the water depth, although a thermocline was well marked elsewhere. Thus it seemed that herring aggregated in this area, though it is debatable whether this was due to a positive attraction or to the avoidance of conditions elsewhere.

That the distribution, and therefore the availability for catching, of herring and other pelagic fish can be associated with the production and abundance of their food has long been known—see, for example, the following papers and the references contained therein: Pearcy (1885), Savage and Hardy (1935), Hardy, Henderson, Lucas and Fraser (1936), Fridriksson (1944), Einarsson (1951), Sette (1955), Cushing (1955 a, b, 1956, 1957), Blackburn (1957), Glover (1957), Jakobsson (1958). The relationship is not always a simple one (Lucas, 1936; Manteufel, 1939; Fridriksson, 1944; Cushing, 1956; Glover, 1957), because of the grazing effect of the predators on the prey, but basically it is true to say that the stocks of fish will normally be found where conditions have enabled the food supply to be most plentiful and that they will move out of areas where it is scarce or conditions are otherwise unacceptable. In extremes, great quantities of salps filter the phytoplankton content almost completely as fast as it can be produced over areas off the coasts of the British Isles of as much as 20,000 square miles, so depriving crustaceous zooplankton of their food supply. This community of jelly appears to be little used as food by fish (Thompson, 1942; Fraser, 1949), although in September 1958 cod were reported to be feeding on salps west of Orkney (Fraser, 1960a). In comparison with the richer fat and protein content of crustacea etc. they contain little that can eventually form the food of the bottom-living animals; from this point of view they could have a serious effect on fisheries. That potential effect is subsequently offset, however, by the quickening of the regenerative process of returning nutrients to the water after death and so increasing the plankton production the following spring. The actual presence of such masses of chains of salps, which are by no means confined to the surface (Fraser, 1949), could itself be a physical repellent to pelagic fish. Glover (1957) stresses the importance of associating plankton conditions with shoaling habits and thus with the availability for capture by the fisheries. Salps and conditions associated with salps may have an effect of this type as well as acting as a repellent. This effect of oceanic water is not only felt by adult fish; for example, Huntsman (1920) put forward evidence (p. 332) to show that the 'wrong type' of water may prevent the development of fish eggs and larvae in the Atlantic west of Cape Breton. Rae (1957b) infers from a study of plankton, wind and haddock broods in the North Sea that environmental conditions which may be wind-induced are in a large measure responsible for the success or failure of the broods. This is quite distinct from the actual transport of the larvae by wind-induced currents to unsuitable areas, e.g. Saville (1956).

Corlett (1958) has shown a clear relationship between the plankton of the western Barents Sea and the year-class strength of the Arcto-Norwegian cod, even though this was not found for cod eggs and larvae by Wiborg (1957). That the brood strength is associated with environmental conditions in the widest sense—which affect plankton abundance—is evident from Ottestad (1960) who has shown a relationship between the brood strength of cod at Lofoten and the growth of pine trees in the vicinity.

Morris (1956) found that larval fish associated with mixed conditions were easier to rear in aquarium conditions than those associated with a particular water mass. The relative abundance of larval fish in 'elegans' water, as a typical indicator of mixed conditions as compared with 'setosa' water (Russell, 1940), may thus be more fundamental than the abundance of a suitable food supply. This relationship is not confined to the English Channel but is shown also in the northern North Sea where the boundary between these two types of water is influenced by the inflow from the Atlantic round the north of Scotland and Shetland. Fraser (1961) for example divided the records of plankton samples taken in the northern North Sea by Scottish research vessels according to their *Sagitta* content. He showed that the numbers of larval fish were greater in the mixed water characterised by the presence of *S. elegans* than when this species was replaced by *S. setosa* or absent. This relationship did not apply to early stages of fish eggs, and this suggests that, whatever the reason may be, the mixed water is better for the survival of larvae rather than for egg production. The better survival in 'elegans water' has presumably nothing to do with the actual presence of *S. elegans* and, indeed, as this is a predatory species the effect of its actual presence might be just the reverse. Because the mortality rate of larval fish is dependent upon the combination of a number of factors, the direct relationship between the numbers of North Sea recruits of various fish to the commercial stocks would not be expected to correlate directly with the numbers of *Sagitta elegans* or with the proportion of the North Sea occupied by this species. Haddock, for instance, spawn in the areas in the northern North Sea where *S. elegans* is normally typical and an extension of 'setosa water' northwards but not reaching the haddock spawning grounds would have no effect on the survival of the

brood. Nevertheless Glover and Barnes (1960) state ". . . the summer months during the period 1947-1951 were characterised by typical neritic and North Sea plankton; from 1952 to 1954 there was an invasion of indicators of the mixture of Atlantic oceanic and shelf water; from 1955 to 1958 the shelf plankton dominated the fishing grounds with a scarcity of extreme neritic and oceanic plankton." An assessment of the haddock broods over this period shows 1946 to 1950 to be rather poor, 1951 to 1955 good and 1956 to 1957 extremely bad, and 1958 rather better. Saville (1959) reached a similar conclusion. Using plankton indicators to define the conditions he stressed the importance of mixed conditions, neither neritic nor oceanic, on the success of the broods of haddock in the northern North Sea. Summarising his Table IX it is seen that if less than 25% of the haddock spawning area was free from oceanic and neritic water the index of the survival of the haddock brood was rated at 0·7; 25-50%, 1·4; 51-75%, 4·4; and over 75% free, 6·8.

The differences in survival between these types of water, as shown in the English Channel and North Sea, is all the more important when it is realised that the mixed conditions which favour the fish and their food also favour the production of predatory species. The small coelenterates are the chief offenders, especially *Aglantha*, but also *Cosmetira*, *Laodicea*, other medusae and the siphonophores.

Ctenophores and chaetognaths are also serious predators. *Pleurobrachia* can almost denude great tracts of inshore water of its zooplankton and young fish content (Foerster, 1948 p. 60; Lebour, 1922, 1923; Bigelow, 1910, 1924; Kuhl, 1932; Kamshilov, 1959). In the North Sea area it is at its densest in autumn and less likely to affect the spring fish larvae. *Aurelia*, while in its early stages in the spring, is likely to be a serious predator on young fish, but in its later stages it feeds only on the zooplankton. The large jellyfish, particularly *Aurelia* and *Cyanea* have another important effect in that they can exist in such numbers that fishing in Faroese waters can be spoilt by choking the trawls. Similar serious results occur in the Gulf of Finland (Hela, 1951). Lucas and Henderson (1936) note that good catches of herring are not usually taken where jellyfish abound. Swarms of predatory species (except *Aglantha*) are not so common in the oceanic waters as on the shelf but their abundance in mixed shelf water is linked with the past biological history of the incoming water.

Apart from the Chaetognatha, which are important food organisms for herring, few of the predatory species are themselves useful as food, and this particularly applies to the Coelenterata. *Pleurobrachia* is not usually considered a valuable source of food but is occasionally eaten, probably only if nothing else is available—a not infrequent condition when they swarm. Records of *Pleurobrachia* as food of *Acanthias* and *Cyclopterus* are given by Mortensen (1912), of *Mola* by Bigelow (1924), of West Greenland cod by Hansen (1949) and of mackerel by Scott (1924). *Beroe*, however, is eaten frequently by cod but probably less by haddock (Kiselev, 1960) and also by *Cyanea* (Plotnikova, unpublished). Trawl-caught haddock from the east Scottish coast in June 1958 were sent to the Marine Laboratory at Aberdeen as their stomachs contained a most unusual, orange-coloured food. They had been feeding on the siphonophore *Agalma elegans* with numerous *Calanus* and euphausids entangled in it—it was probably the clumps of the entangled crustacea that attracted the haddock as food, rather than the *Agalma*. However, even if these predators are themselves seldom eaten, they will add to the fertility of the water by excretion and in due course by regeneration of nutrients after death. Indeed Davidson and Huntsman (1926) consider that the products of disintegrating *Aurelia* contribute significantly to the later diatom production. Sudden release of nutrients from decaying organisms (Graham, 1954) or from land drainage can produce the conditions leading to the notorious 'red-tides' (see, for example, Fish and Cobb, 1954) which in some areas, but not in Scottish waters, have a profound effect on local fisheries and indeed, economically, on a wider scale.

Thus the changing planktonic environment will not affect all fish broods or the abundance of the different predatory species in the plankton in the same way; for example the different distributions of *Sagitta elegans* and *S. setosa* and other species of chaetognaths, medusae and siphonophores. Alterations in environment thus affect the larval and post-larval stages of fish and their brood survival. This may be a direct effect of the transport of larvae (see below) but may also occur through the resultant planktonic changes. Food of the right type must be available in sufficient quantity after the larvae hatch (Hjort, 1926) whether there is a "critical period" in their early stages or not (Marr, 1956). Shelbourne (1957a) has suggested that plaice larvae cannot withstand starvation at the period of yolk sac absorption without severely upsetting their osmotic regulation.

Different fish larvae hatch at different times of the year and have different food requirements; for instance post-larval herring feed chiefly on copepods and molluscan larvae (Lebour, 1924; Hardy, 1924; Ogilvie, 1927; Bowers and Williamson, 1951; Bhattacharyya, 1957) while plaice larvae (Shelbourne, 1957b) and lemon sole larvae (unpublished Scottish investigations) feed mostly on Appendicularia. *Oikopleura* is also taken occasionally in masses by adult haddock (Fraser, 1957b).

Although it seems certain that the succession of plankton species and the identity and abundance of the dominant forms are dependent upon the past history of the water, both hydrographically and biologically, the complicated processes that control these features are very far from being adequately understood. It is possible to state with confidence that mixing of the water masses gives rise to conditions of better production of crustaceous zooplankton and thus perhaps better feeding for fish. It is not yet possible to forecast the final outcome of fluctuations in the environment; nor is it possible to state that because of certain factors the diminished food supply or the incidence of predators will or will not become serious elements in young fish mortalities. Another planktonic cause of fish mortality in the egg or larval stages not yet properly assessed, is parasitism by dinoflagellates; for example sardine eggs infected by *Ichthyodinium chabaudii* (Hollande and Cachon, 1952) seem to develop normally, but the young fish which are infected soon die after hatching. In May 1949 many eggs of cod, saithe and ling found by "Scotia" at $63^{\circ}44'N$ $21^{\circ}35'W$ near the south-west coast of Iceland were heavily infected by spores in the perivitelline space. Herring eggs in the Clyde spawning area at Ballantrae Bank in the spring of 1959 were found to be infected by a dinoflagellate similar to *Ichthyodinium*.

A further very important relationship between the plankton conditions and the fisheries concerns the survival and distribution of the bottom fauna, particularly the crustaceans, molluscs and polychaetes and the sandeels and other small fish which will eventually become the food of the demersal fish. It should be again emphasised that the right conditions (see Wilson, 1951; Wilson and Armstrong, 1952, 1954) for the growth of the bottom fauna, both as adults in situ and in the planktonic developmental stages, are dependent upon the biological history of the various water masses that have been mixed and brought into the area where the animals of the bottom fauna are feeding and spawning. Edmondson (1957) points out in this connection that phytoplankton may be much more extensively used as food of such organisms than, because of rapid digestion, the examination of gut content would suggest.

Blacker (1957) has shown that the distribution of benthic animals in the Svalbard south of Spitzbergen is dependent on hydrographic conditions and that stenothermic species in particular can be used to indicate these. The bottom fauna is influenced by the greatly increased average influx of Atlantic water into this area in recent years, and while warmer conditions can play a great part in the extinction of established Arctic species, irrespective of their life history, it is only those Atlantic species with a planktonic stage that can spread rapidly northwards to become established in the new conditions.

Finally, mention should be made of two other possible effects of planktonic environments on fisheries. First, although it is no longer generally accepted that certain animals can use dissolved substances as food as suggested by Pütter (1909), there is support for feeding on lepto-pel (Fox, Isaacs and Corcoran, 1952; Morris, 1955). The amount and type of lepto-pel is of course largely dependent upon the planktonic history of the water, and Gillbricht (1959) says "Das Zooplankton lebt also offenbar von der Zerfallsproduktion einer in ihre Masse längst verschwundenen Phytoplanktonbevölkerung". Secondly, Liston (1956) has shown that the maximum bacterial population in the skin of skate and lemon sole follows the phytoplankton outbursts, and Georgala (1958) found a similar pattern on cod, the supposed connection being the increase in bacteria in the sea with the decomposition of the phytoplankton.

A number of general papers on the environmental hydrographic effects on fisheries have been written, emphasising one aspect or another, but are not quoted above or in the following sections. Of these the recent ones include those by Cooper (1952, a, b, c, 1955b), Hachey (1955), Boden and Kampa (1953), Lee (1952), La Fond (1954, 1955) which in turn quote many others. That many of these hydrographical effects operate through the plankton seems certain and some examples have been quoted. This paper emphasises that these plankton changes may be dependent on conditions outside the fishing grounds themselves.

THE TRANSPORT OF PLANKTONIC STAGES OF FISH

The eggs of most fish and the early stages after hatching are planktonic, so that at these stages they are themselves part of the planktonic environment and subject to the various changes that occur there. Some of the effects of biological changes have already been dealt with in the previous section. The direct physical effect of the environment also has its profound effect on survival (Huntsman, 1920; Sund, 1924; Hjort, 1926).

Walford (1938) discussed the effects of currents on the distribution and survival of the eggs and larvae of haddock on Georges Bank. Sette (1943) investigated the survival of eggs and larvae of mackerel and Chase (1955) discussed wind and temperature relations with brood strength of haddock in the same area. Saville (1956) has considered similar problems at Faroe and also (1959) in the northern North Sea, and Wiborg (1957) for the Arcto-Norwegian cod stock. Carruthers, Lawford, Veley and Parrish (1951) suggested that the brood strength of haddock in the North Sea could be correlated with wind conditions. If, as Rae (1957b) says, the main causative factor in this correlation is the wind induced environmental conditions prior to spawning, it is still probable that wind induced surface currents will have significant effects on the distribution of the planktonic stages.

These, and similar papers show that brood survival varies according to a complexity of factors and that no single factor, biological, hydrographical or meteorological, provides a simple answer.

The hydrography of the fishing grounds in situ is not the concern of this paper and these planktonic relationships with hydrography are mentioned in passing. It is, however, the concern of this paper to consider certain fish larvae in oceanic plankton and to refer to their physical movements as they drift with the accompanying invertebrate fauna over the areas off the Scottish coasts. Schmidt (1909) discussed this problem over the wider area between Iceland and Spain and dealt with the distribution and spawning conditions of seventeen species of Gadidae in great detail. Fraser (1958) discussed the drift of planktonic oceanic fry off the west and north-west of the British Isles from their spawning places to possible areas of settlement, giving approximate distances and duration of transit. He found, as far as the young of commercial demersal fish are concerned, that only Rockall Bank and the Faroe plateau of the oceanic banks in this area can be considered with certainty as self-supporting; Porcupine Bank is doubtfully so, while there is little chance of young fish from spawnings on the other banks remaining to grow into adults on the same banks. Stocks on these must be maintained largely by migration of demersal stages of fish or from drift of larvae from other banks as fry drifted from these will not be entirely lost, though it is certain that many will. From Porcupine Bank larvae might eventually be able to settle on the Irish continental shelf or on Stanton Bank; from Rockall to other outer banks or on the Scottish continental shelf, and from Lousy, Bill Bailey and Faroe Banks on the Faroe plateau or the Scottish continental shelf in the neighbourhood of Shetland or Orkney. This is confirmed to some extent by the presence of small larval haddock taken in oceanic plankton collections over deep water, i.e. away from their spawning grounds, and by the presence of larger young fish at about the limits of the pelagic phase—up to 11 cm—taken in pelagic trawls in the Faroe Shetland Channel and over banks such as Bill Bailey Bank where it seems most unlikely that the fry could remain for several months. Henderson (1954) also reports gadoids, other than *G. poutassou* and other deep-water forms, 30-50 miles beyond the 100 fathom (183 m) line. Clearly the relative success or failure of such fish will depend greatly on variations in the local currents.

The larvae of oceanic fish also drift with the plankton but apart from hake and ling few have as yet much commercial significance to Scottish or other fisheries, except as part of the food cycle. One of the most important of these is *Gadus poutassou*, the blue whiting, which forms one of the dominant foods of the hake (Hickling, 1928). It is largely pelagic, even in the adult stage in the middle and upper layers over great depths, and it spawns beyond the 1000 metre line in relatively warmer waters (Schmidt, 1909). Schmidt also states that the populations of *G. poutassou* at Iceland, at Faroe, in the northern North Sea, in the Norwegian Sea and in other northern waters are the result of larval planktonic drift, presumably followed by a pelagic migration. Henderson (1957) describes the main abundance of the larvae in the area west of the British Isles as occurring in April and May over the deep water east of Rockall and extending north-east to the Faroe Shetland Channel and towards the Faroe-Iceland Ridge. He considers

it likely that the Barents Sea (Boldovsky, 1939) and the Polar Basin populations have originated from a separate but unlocated spawning. Schmidt (op. cit.) points out that the larvae of *G. poutassou* were often associated with *Salpa fusiformis*, and Fraser (1958) also found this, pointing out that the final dispersal of the larvae could probably be depicted from the final distribution of the salps, bearing in mind that the larvae would become less planktonic as they grew older and that the salps could reproduce in transit given suitable conditions. This would mean that, in 1955 at least, the larvae could be carried well into the North Sea, to the Norwegian fjords, to south-west Iceland and Jan Mayen, but not into the Barents Sea. This agrees with the normal distribution of the older fish and supports Henderson's suggestion of a separate spawning for the Barents Sea stock (see also p. 28).

Fraser also deals briefly with the part played by larval drift in the distribution of the hake, another species with deep-water spawning. He says ". . . in this species the planktonic stage is shorter so that although the first general distribution is likely to follow that of *G. poutassou* the final dispersal is much less dependent upon drift than on migration and is therefore less widespread. There is no evidence of hake spawning at Faroe or Iceland, but there is a spring spawning off the Irish coast and a summer spawning off the north of Scotland (Hickling 1928). Following the lead of *G. poutassou* there should be scope for the larvae to be drifted to the south-west of Iceland, but because of the shorter planktonic stage young hake have never been found there although older fish have been taken on rare occasions (Saemundsson, 1949). It can be assumed that these were adult migrants. Hake are, however, occasionally abundant in the deep water east of Shetland; as the distances are so much less, these could possibly be associated with the north Scottish spawning grounds, but the situation is complicated by adult migrations, and Hickling (1928) considers them to belong to a self-contained stock."

Fraser also considers that the drift of planktonic fry of haddock and saithe is responsible for the small stocks of these species in Iberian waters, south of their normal range, where there is no evidence of spawning.

OCEANIC PLANKTON, FISH AND ECHO TRACES

The problem of organisms which are responsible for oceanic scattering layers, whether deep or not, has been considerably debated. Whilst most authors consider small fish, especially those with swim bladders, to be at least an important source of the echo reflections there is a wide range of opinion about how far small planktonic organisms can be responsible. Cushing, Lee and Richardson (1956) have been able to associate echoes with zooplankton at a density of 25 organisms per litre, and phytoplankton of 100,000 cells per litre. Most other authors mention the possibilities of planktonic organisms being in part the cause but emphasize that fish, especially the swim bladders, and gas bubbles associated with the fish are the main cause: e.g. Parrish and Craig (1951), Marshall (1951), Tucker (1951), Hersey and Backus (1954), Kanwisher and Volkman (1955), Backus and Barnes (1957), Weston (1958). There are also instances of large planktonic or pelagic invertebrates being considered as the source; e.g. euphausiids (Moore, 1950), heteropods (Blackburn, 1956), squid and shrimps (Smith, 1954) and penaeid prawns (Gordon and Ingle, 1956). Authors dealing with the commercial side of echo detection have, of course, emphasised the importance of fish themselves—e.g. Hodgson (1950), Burd and Lee (1951), J. Furnestin (1953), Capart (1955), Craig (1955), Cushing and Richardson (1955 a and b) and many others (see Hodgson and Fridriksson, 1955), though few of these deal with oceanic traces.

Whether or not the smaller planktonic organisms will produce an echo depends on their characters and also on the frequency, sensitivity and other characteristics of the echosounder in use. Some attempts were made from the Scottish research vessel "Scotia" in June and July 1955 to locate scattering strata in the upper water layers of the north-east Atlantic west and north-west of the British Isles, and to identify the organisms concerned. The machine in this instance was the Kelvin Hughes MS 24G operating at 30 K/cs. No difficulty was experienced in locating traces. In addition to the usual "plume" traces characteristic of the northern North Sea ribbon traces, both diffuse and well-defined, were found in the oceanic area. Plankton nets towed above, at, and below the depths of both these kinds of traces frequently showed the absence of any correlation between the normal organisms of the plankton and the traces.

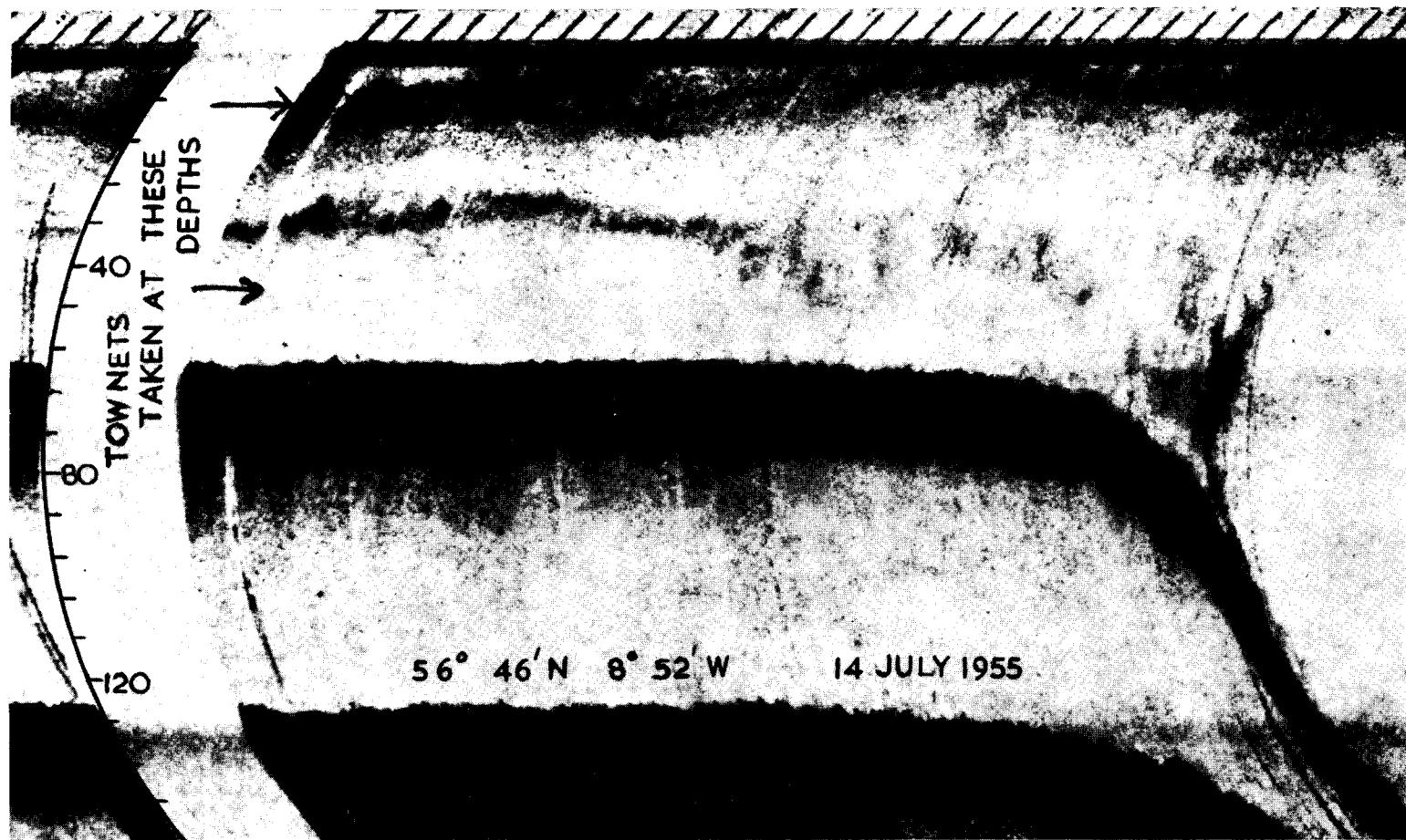


Fig. 2 Echo trace taken by "Scotia" off the west coast of Scotland at $56^{\circ}46'N$, $8^{\circ}52'W$, on 14th July, 1955. The time markings are at two minute intervals and the depth markings at 8 fm. Townets (26 meshes to the inch) were taken at the depths indicated by the arrows. The upper one in the dense trace contained very sparse plankton, the lower one below the trace contained abundant *Calanus* and *Spiratella*. Note the trace upwelling at the edge of the shelf and overflowing on to it at about 30 fm depth. (The dense trace at about 125 fm is a "double echo" of the bottom).

An example in Figure 2 which shows a dense ribbon trace over the shelf and continuing over the deep water. The trace was about 10 fm thick, and at 23-33 fm depth, at $56^{\circ}46'N$ $8^{\circ}52'W$. A one metre townet (26 mesh) towed at the depth of the trace (and it could hardly fail to be at the right place for most of the tow) revealed very little plankton indeed and practically no *Calanus*. A similar net towed quite definitely below the trace at the same time contained dense quantities of *Calanus* and *Spiratella* (= *Limacina*). This collection has been estimated to contain about a quarter of a million *Calanus*. Towed for $\frac{1}{4}$ hour at approximately 2 knots this would represent, under good filtration conditions, only about 1 *Calanus* in $2\frac{1}{2}$ litres. This is so very short of the artificial figure of 25 organisms per litre used experimentally by Cushing and Richardson (1955a) that it is not surprising that no traces were recorded from the *Calanus* population, and it does not mean that traces cannot be obtained from zooplankton. It does mean, however, that the very dense and obvious traces were not caused by *Calanus* or any similar organism. The figure also illustrates a column of echoes arising at the edge of the continental shelf and drifting over it below the main trace—i.e. a trace associated with upwelling.

Diffuse traces were recorded in areas of abundant *Pleurobrachia* in the northern North Sea but not when much denser concentrations of salps occurred in the oceanic area. As these two organisms are largely of a similar consistency and the salps have in addition a dense nucleus, it does not seem reasonable to attribute traces to *Pleurobrachia* if salps cannot produce similar effects. On no occasion during the survey were abundant zooplankton organisms confined to so narrow a depth stratum as that shown by the ribbon trace.

A commercial Icelandic pelagic trawl, fitted with a codend of $\frac{1}{4}$ in. mesh, was used to sample the traces. This revealed the presence of young fish, both by day and by night, in the areas of diffuse traces, especially in the northern North Sea where haddock and whiting of 5-11 cm in length were taken—i.e. pelagic stages too active to be caught by the townets and too small to be taken by commercial gear. Young lemon soles and other small fish were also taken in the plankton nets in the areas of diffuse traces. These observations show no evidence of diurnal vertical migration by the larger young fish which were just as abundant at noon as at midnight at depths of 8-30 fathoms. At sensitivity '4' on the "Kingfisher" as fitted to "Scotia" in July 1955 these young fish caused interference patterns on the cathode ray screen of only about $\frac{1}{2}$ to 1 in. in the Fladen area. At night these fish were joined by larger fish such as whiting up to 25 cm which caused interference patterns of $1\frac{1}{2}$ to 2 in. at the same sensitivity setting.

The Icelandic pelagic trawl with small mesh was also used to investigate dense ribbons traces found in the oceanic regions. Two main behaviour patterns were exhibited by these ribbon traces; one showed little evidence of diurnal migration and from the catches was evidently due to the young of *Gadus poutassou* and the other, which only appeared a short time before midnight and disappeared with the dawn, was attributed to a mixture of oceanic fish, particularly *Benthosema glaciale* with smaller numbers of *Myctophum punctatum*, *Maurolicus mulleri*, *Stomias boa* and *Gonostoma*. Further evidence that these echoes were probably due to fish is provided by the appreciable increase in their depth that occurred when the ship stopped, probably owing to the various ship's noises frightening the fish. Deepenings of as much as 30 fm in 10 minutes were recorded, indicating that this was caused by organisms capable of individual active movements.

Euphausids were not abundant during the trip and the evidence for and against their causing traces was inconclusive; their scarcity, however, suggests that they were not the cause of the traces recorded during the survey in 1955. Of special interest were the hauls taken on Rosemary Knoll on 20th July where prior to midnight the echo traces appeared in two layers—one at 15-20 fm and one at 35-40 fm. The deeper trace sampled just prior to midnight, produced about 80 *G. poutassou* with some scopelids in one haul. The lower trace gradually ascended until the two traces coalesced; a second haul in this mixed trace at about 15 fm also contained about 80 *G. poutassou* with some scopelids, but in addition 84 penaeid prawns, *Funchalia woodwardi*, of 14-16 cm (see Gordon and Ingle, 1956, for full details, with a copy of the echo trace).

The 1955 "Scotia" traces believed to be due to the young stages of *G. poutassou* occurred only to the north of $57^{\circ}N$, east of Rockall. They extended north across Rosemary Knoll, Faroe Bank, thence to the west of Faroe as far as the Faroe-Iceland Ridge and also into the south side of the Faroe-Shetland Channel to the immediate north-west of Shetland beyond the 100 fm line. This is similar to the picture given by

Schmidt (1909) and Henderson (1957) (quoted in the previous section, p. 26). The scopelid traces occurred only in the southern part of the section investigated, south of about 59°30' N.

Henderson says (p. 180) of *G. poutassou*—"Further one cannot disregard the possibility that this widely distributed species, which is by no means the smallest of the gadoids, may yet become exploited commercially. . . ." He refers to the adult stages, but a fishery for the young stages is not beyond the realms of possibility as the numbers of these young stages in the upper oceanic layers in summer must be enormous. Similar remarks also apply to the scopelids. One of the objects of this cruise in 1955 was the preliminary investigation of the industrial potential of these small fish. A possible fishery for young of *G. poutassou* would be confined to the May-July period but would be available throughout the 24 hours. Although a scopelid fishery would extend over a longer period of the year as they are adult fish and not therefore so seasonal in their appearance, it would be limited to the hours of darkness which are so short during the summer. In spite of the great numbers of young *G. poutassou* which were evidently in the area it must be admitted that the catches taken by "Scotia" with the gear then available did not reach commercial proportions. To ensure the success of such a fishery would undoubtedly need, as in other fisheries, gear specially designed for the purpose, presumably with a very small mesh and wide gape. With the appropriate gear there may well be real possibility in poutassou fisheries, for both young and adults, a possibility that might be further improved if accompanied by a method of inducing the fish to congregate in local shoals.

SUMMARY

This paper attempts to clarify our knowledge of the plankton communities in the oceanic waters around the British Isles and their relationship to the fisheries.

The basic current systems are mentioned as the distribution of the communities is dependent upon these currents.

Five types of plankton community are recognised, viz:

- the indigenous North Sea water,
- mixed Atlantic Shelf water,
- the North Atlantic Drift,
- the Lusitanian stream,
- the Arctic, boreal and cold deep water.

Each of these has its own characteristic fauna and an attempt has been made to typify them.

The data gathered over a period of years inevitably includes records that extend the previously known distribution of various species. Those of special interest that would otherwise be lost in the record books of the laboratory have now been brought together to make them available to specialists in their particular fields.

Ecological, taxonomic and other comments are given on the species included in these lists. A short section on the distribution of Appendiculata summarises the unpublished work of Miss S. T. Lindsay who worked as Carnegie scholar in Aberdeen from 1927 to 1930.

The effect of these plankton communities and changes in the communities on the fisheries is dealt with, partly by a review of known effects in various parts of the world, and partly by an assessment of the probable effects in the Scottish area. These act in the following ways.

1. Growth promoting or inhibitory factors due to changes in plankton in turn affect productivity and specific composition.
2. The mixing of water masses with differing organic and chemical content and differing faunas results in an increased abundance of zooplankton, which is directly the food of pelagic fish and indirectly of demersal fish.
3. The distribution of pelagic fish, and therefore to some extent of their availability for capture, is at times directly influenced by their food supply in the plankton.
4. Certain organisms, such as salps and ctenophores may have a repellent effect on migratory pelagic fish. This may be due to an actual positive repellent or to these organisms eating out the

basic food supply of the fish, but the products of their disintegration may have beneficial effects on future productivity.

5. Planktonic predators and parasites, with a planktonic phase or origin, cause mortality in fish eggs and so affect the brood survival.
6. Plankton is the food of larval and post-larval fish and the sufficiency and suitability of the organisms present also affects fish brood survival.
7. The distribution and abundance of the bottom fauna as food for demersal fish is to a large extent based on the distribution and survival of the planktonic larval stages.
8. The organic and bacterial content of the sea water is dependent upon plankton production and disintegration, and this in turn has its effects on the fisheries.

Changes in the oceanic plankton being brought into the fishing grounds on the continental shelf are partly, and sometimes largely, responsible for these effects.

The eggs and planktonic stages of fish are dealt with as plankton organisms and a section is devoted to their distribution by currents in the oceanic areas around the British Isles with an indication of how these can be responsible for the existence of self-supporting fish populations on some isolated banks.

The final section deals with echo traces in the oceanic area and their possible origin in small planktonic fish. Evidence is given to show that concentrations of *Calanus* and other small invertebrate species occurring in their natural numbers in the open sea do not produce echoes on the model of echo-sounder used. Some of the oceanic fish may exist in sufficient numbers to make a fishery but a profitable method of catching them has not so far been devised.

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APPENDIX

THE DISTRIBUTION OF APPENDICULATA IN SCOTTISH WATERS

This section is based on the investigations of Sheila T. Lindsay who worked on the subject in Aberdeen between 1927 and 1930 as holder of a Carnegie Scholarship. The results of her work were never written up for publication but this paper provides an opportunity to publish a resumé of the more important features. (Further details may be obtained if required by application to the Marine Laboratory, Aberdeen).

Three abundant species were found; *Oikopleura dioica* Fol, *O. labradoriensis* Lohmann, and *Fritillaria borealis* Lohmann. Only two other species were found in these particular years; *O. fusiformis* Fol, and *F. pellucida* Busch, although a particular look out was kept for other species which might reasonably be expected to occur. Previous and more recent work show that *O. vanhoffeni* Lohmann is a cold water species which has been recorded from near Shetland (Lohmann 1911) and in the Faroe area (Fraser and Saville 1949). *Appendicularia sicula* Fol and *Fritillaria venusta* Lohmann are warm water species occasionally recorded from the North Sea (Lohmann 1911). Other species occurring in the north-west Atlantic, and regarded by Bückmann (1945) as likely to occur in the Scottish area, are *O. parva* Lohmann, *F. gracilis* Lohmann, *F. tenella* Lohmann and possibly *F. aberrans* Lohmann.

Oikopleura dioica

This species is widely distributed in warm and particularly in temperate waters but is not found in the arctic. It occurs within wide ranges of both temperature and salinity and is generally regarded as being more abundant in inshore waters than in the open ocean (e.g., Berrill, 1950; Forneris, 1957). Nevertheless a study of the seasonal extension of its distribution in the North Sea shows that it is either brought into the area each year from the open ocean, or that it is at least associated with the inflow. Thereafter its multiplication leads to the largest numbers generally being found in the inshore waters as it becomes distributed throughout the central North Sea. The data from the years in question confirm the impression that this species was absent or scarce in January and February, presumably after the previous year's stock had died down. The spring influx of oceanic or mixed water via the north of Shetland and the Orkney passages brought with it the conditions that favoured the growth of *O. dioica* as well as introducing it. By May and June the mixed water, and so therefore the distribution of *O. dioica*, had extended into the whole northern North Sea roughly north of a line from about the Firth of Forth to Bergen excepting the inner extremities of the Firth of Forth and Moray Firth. The next period, July and August showed a very marked increase in numbers in the firths, (large numbers in the Moray Firth, small numbers in the Firth of Forth) although it was still apparently absent off the north-east English Coast. In September and October numbers in the central North Sea were still fairly large, the densest concentrations being then found in the Firth of Forth and off the Danish coast. Numbers in the Shetland area were much reduced but the Orkney area was still densely populated. There were obvious signs of disintegration in November and December.

This pattern of extension fits in with the hydrographic conditions in the North Sea and by rapid reproduction during May to September, when egg formation was apparent in the ovary, the pattern shown would soon develop. *O. dioica*, like *Sagitta elegans* and *Metridia lucens* can thus be regarded in the northern North Sea generally as an indicator of mixed oceanic and coastal water though at a later stage of mixing as the season progresses. This seems true also off the west coast of Scotland; where the mixture of oceanic water with shelf water occurs *O. dioica* achieves its greatest abundance. *O. dioica* does, however, appear to have an indigenous population in the southern North Sea, as it is present on the plaice spawning grounds in the Southern Bight in spring (Shelbourne, 1953).

Oikopleura labradoriensis

According to Lohmann (1900) this species is indigenous in cold and mixed waters and occurs in abundance up to 70°N. It has a wide distribution in the colder parts of the North Atlantic, but occasionally occurs at temperatures up to 11·6°C—though Essenberg (1926) reports specimens from southern California at temperatures between 12·6°-13°C, and in her Table 2 Forneris (1957) gives it a range of -1·36 to 20·10°C. It occurs in the northern North Sea but not in the Baltic, Kattegat, English Channel, or Irish

Sea, and this investigation also shows it to be absent, in the surface waters at least, off the west Scottish coast. Its numbers in the North Sea are small compared with *O. dioica* and it is most common from March to June, thereafter being replaced by *O. dioica* until the late autumn.

From the apparent absence of *O. labradoriensis* in the Faroe-Shetland Channel during the season of major inflow, and from its general distribution in a large part of the northern North Sea even at its period of least abundance, it must be assumed that an indigenous population lives in the North Sea and that some of the summer brood survive to maintain it. There is a suggestion that this population may be augmented by inflow east of Shetland at a time when this might include an admixture of cold water. Unlike *O. dioica*, however, there is no sign of inflow via the Orkney passage, where the current has its origin from the upper layers of the west coast area which is free from boreal influence. Its cold water preference is shown by fairly high numbers south of Faroe (but north of the Wyville Thomson Ridge) where a colder south-flowing current underlies the Atlantic stream.

Its main breeding period is May and from this brood come the high summer concentrations of the northern North Sea. During the period investigated some years were more productive of *O. labradoriensis* than others; 1930 was a peak year, 1928 least productive and 1927 and 1929 intermediate. This is perhaps relevant in the light of the observations of Fraser (1949) showing that 1928 was a peak year for the warm water indicator species *Dolioletta gegenbauri*, although the actual surface temperatures in the area off the Scottish coast (Smed, 1953) indicated slightly subnormal temperatures in 1928 and in 1929 and slightly above normal in 1927 and 1930. The two warm-water Appendiculata referred to below also occurred only in 1928.

Fritillaria borealis

This species is generally known as a cold-water species occurring in abundance in arctic and antarctic seas, but it also occurs in the Mediterranean and off the coast of southern California (Berrill, 1950). It has been divided into sub-species (see Lohmann and Bückmann, 1926 and Bückmann, 1945) and of these *F. b. acuta* occurs in the cold and temperate waters and *F. b. truncata* in warm water. Both are liable to be found in the Scottish area (Bückmann, 1945) but the data in this paper refer only to *F. b. acuta*. *F. borealis* was never abundant in the area south of a line approximately from the Anglo-Scottish border to southern Norway and it is perhaps significant that this is similar to the general division between the communities of *Sagitta elegans* and *S. setosa* (Fraser, 1952). *F. borealis*, like *S. elegans* showed a tendency to be less common in the more open ocean of the Faroe-Shetland Channel, and an oceanic origin cannot be regarded as contributing materially to the North Sea stocks.

Fritillaria reached its greatest numbers—except in certain localities—in March and April, generally dying down in the summer although it never disappeared. When conditions are suitable it can reproduce in quantity and very high figures were recorded in the north Minch in March and April and in the Firth of Forth in June and July. Reproduction appears to take place at any season of the year and ripening gonads were frequently seen in this material in each month from March to October.

Other Species

During 1928, but not in any other year from 1927 to 1930, two southern species, *Oikopleura fusiformis* Fol and *Fritillaria pellucida*, not indigenous to the Scottish area, were taken, but they did not long persist.

O. fusiformis is typical of warm seas but has been reported from the North Sea (Lohmann, 1911; Bückmann, 1926); presumably it occurs with other Lusitanian species which arrive there from time to time in late summer.

F. pellucida is also typical of warm water and, so far as has been ascertained, these records, numerous in early September, are the only ones for the Scottish area, although it is abundant in the Mediterranean and in warm and temperate parts of the Atlantic south of 42°N. The distribution of each of these species in the Scottish area is restricted, mainly because they are much less tolerant to local conditions, so that only exceptionally, as in 1928, do they survive to reach the Faroe-Shetland Channel and thence the North Sea.

APPENDIX TABLES

TABLE I

LIST OF RECORDS OF RARE OCEANIC SPECIES FOUND BY SCOTTISH RESEARCH VESSELS, 1950-56,
AND BY H.M.S. CHALLENGER, APRIL-JUNE, 1953.

Station details are given at the end of the table and are preceded by a letter, 'E' denoting "Explorer" and 'S' "Scotia", and a number indicating the year; stations preceded by the symbol 'Ch' refer to samples taken by H.M.S. Challenger off the entrance to the English Channel in 1953 and reported by Fraser (1955): Ch.53/15-19th April; Ch.53b/25-28th May; Ch.53c/16-23rd June.

Medusae

- Dipurena ophiogaster* Haeckel, E55/544.
Ectopleura dumortieri (van Beneden), E50/491, S53/694, 925, S55/846.
Zanclea costata Gegenbaur, E52/1197, S52/886.
Catablema vesicarium A. Agassiz, S56/296.
Pandeia rubra Bigelow, E50/135.
Bythothiara murrayi Günther, S53/922, 929, S55/936, S56/271.
Tiaranna rotunda (Q. & G.), S53/1698.
Chromatonema rubrum Fewkes, S50/847, S51/312, S54/810, S56/321.
Melicertum octocostatum (M. Sars), E52/1247, 1248.
Dipleurosoma typicum Boeck, S53/586.
Ptychogena lactea Agassiz, (1958, see p. 13).
Octophialucium funeraria (Q. & G.), S54/488, S55/233?
Colobonema sericeum Vanhöffen, S50/855, 867, S51/374, S54/960, S56/321.
Pantachogon haekeli Maas, E50/135, 141, S50/847, 855, 874, S51/312, 363, 364, 371, 374, 375, 604, 688, 695, E52/1196, 1197, 1308, 1314, S53/922, 934, 953, S54/453, 461, 469, 488, 516, 891, 904, 954, 959, 987, S55/727, 840, E56/594, S56/296.
Halicereas minimum Fewkes or *Haliscera bigelowi* Kramp S50/394, 847, 855, 949, S51/275, 363, 364, 375, 688, E52/1162, 1200, 1305, 1314, S52/533, 1377, S53/922, 934, 953, 1611, S54/453, 469, 479, 482, 557, 847, 960, S55/682, 727, 832, 840, 972, E56/586, 594, S56/262, 296, 335, 368.
Aegina citrea Eschscholtz, S53/557.
Aegina spp? S54/879, S55/846.
Aeginura grimaldii Maas, S54/954.
Periphylla periphylla Peron and Lesueur, S50/783, 847, 855, 859, 874, S51/363, 364, 375, E52/1162, 1197, 1308, S53/26, 549, 934, 1597, S54/453, 488, 516, 557, 563, 590, 595, 855, 891, 904, 960, S55/672, 840, E56/594, S56/296, 335.
Nausithoe spp. S50/847, 867, 874, 937, S51/129, 275, 304, 363, 364, 371, 374, 375, 604, 688, 695, E52/1161, 1308, S53/934, 953, 1637, S55/840, E56/474, S56/377.
Atolla wyvillei Haeckel, S50/847, S53/555, 1646, 1648, S55/841, 949, E56/474.
Tetraplatia volitans Busch, E52/1305.

Siphonophora

- Velella velella* (L.), S51/358, E52/1193, 1198, 1203, Ch53/10, S54/906, 979, 989.
Marrus orthocanna (Kramp), S51/688.
Sphaeronectes gracilis (Claus), S54/935, 947, S55/9.
Amphicaryon acaule Chun, (1958, see text).
Nectopyramis spinosa (Sears), S51/363, 371.
Nectopyramis thetis Bigelow, E52/1305, S54/516, 954, S55/721, S56/271, 296, 335.
Nectopyramis diomedea Bigelow, S51/363, S55/948.
Rosacea cymbiformis Delle Chaije, Ch53/7, S53/209, 2277, S54/987, 1338.
Rosacea plicata (Q. & G.), E50/141, 767, S50/855, 867, 874, S51/275, 363, 364, 695, E52/1339, S52/1280, Ch53/9, S53/555, 934, 953, S54/453, 469, 961, S55/41, 69, 936, 948, 972, E56/459, 586, 594, S56/262, 265, 271, 296, 335, 368, 382.
Vogtia glabra Bigelow, S51/364, E52/1305, S53/953, S54/488, 913, 991, E56/466, 471, S56/296.
Vogtia spinosa Haeckel, E50/135, 138, S50/949, S52/1377, 1497, S53/548, 1648, S54/879, 987, 991, 1181, 1188, S55/721, 948, 972, E56/586, S56/278, 321, 382.
Vogtia pentacantha Köllicker, S51/371, E52/1305, S52/1497, S55/840, 948, E56/601.
Vogtia serrata Moser, S56/262, 321, 335.

- Lensia cossack* Totton, S₅₁/337, 377, S₅₄/479.
Lensia fowleri (Bigelow), S₅₁/377, E₅₂/1342, S₅₃/925, S₅₄/456, 696, 935, 949, 953, 960, 986, 988, 1183, 1187, 1188, 1395, 1396, S₅₅/702, 843, 936, E₅₆/567, 586.
Lensia multicristata (Moser), S₅₁/364.
Lensia achilles Totton, S₅₁/371, 374, 375, 385.
Lensia lelouveteau Totton, S₅₁/363.
Lensia ajax Totton, S₅₁/374.
Eudoxoides spiralis (Bigelow), S₅₁/357, Ch₅₃/4, 5, 6, 7, 8, 9, 10, 11, Ch₅₃b/1, 3, 6, Ch₅₃c/6, 8, 10, 12, 13, S₅₃/939, 945, S₅₄/935, 959, S₅₅/66, 201.
Thalassophyes crystallina Moser, S₅₁/375.
Heteropyramis maculata Moser, S₅₁/363.
Bassia bassensis (Q. & G.), E₅₂/1198, Ch₅₃/5, 7, 9, 10, 11, Ch₅₃b/1, 3, Ch₅₃c/8, 10, 13, S₅₃/1661, 1667, 1697, E₅₄/1608, S₅₄/936, 959, 961, 988, S₅₆/315, 328, 330, 337.
Apolemia uvaria (Lamarck), S₅₃/1646, 1648, 1654, 1980, 1990, 1991, 2238, 2274, 2277.

Chaetognatha

- Sagitta lyra* Krohn, S₅₀/775, 783, 845, 867, 874, 922, 927, 932, 937, E₅₁/1417, 1574, S₅₁/364, 374, 377, E₅₂/1161, 1165, 1174, 1195, 1196, 1197, 1212, 1280, 1305, 1311, 1339, S₅₂/1287, 1365, Ch₅₃/7, 8, 9, 10, S₅₃/1597, 1646, 1648, 2288, 2537, S₅₄/879, 935, 949, 953, 960, S₅₅/840, 843, 948, E₅₆/586, 596, S₅₆/371.
Sagitta hexaptera d'Orb., S₅₁/374, E₅₂/1161, S₅₃/929, 2288, S₅₄/482, 949.
Sagitta bipunctata Q. & G., S₅₃/953, S₅₄/379.
Sagitta macrocephala Fowler, E₅₀/135, S₅₀/400, 847, 855, 874, S₅₁/312, 363, 371, 374, 672, 679, 688, E₅₂/1196, S₅₄/453, 456, 469, 488, 849, S₅₅/727.
Sagitta decipiens Fowler (1958, see p. 15).
Eukrohnia fowleri R.Z., E₅₀/135, S₅₀/847, 855, E₅₁/1579, S₅₁/364, 374, 375, 672, 688, E₅₂/1200, 1314, S₅₃/1597, S₅₄/353, 453, 456, 879, 960, S₅₅/727, 840, E₅₆/474, S₅₆/262, 321.
Krohnitta subtilis (Grassi), E₅₀/138, S₅₄/456.

Nemertea

- Nectonemertes mirabilis* Verrill, S₅₀/855, S₅₁/363, 375, S₅₄/488, 879, 954.
Nectonemertes pelagica Cravens and Heath, S₅₅/672.
Pelagonemertes brinkmanni Coe, S₅₄/954.

Polychaeta

- Harmathoe* sp. S₅₃/922.
Lagisca hubrechti (McIntosh), E₅₀/767, S₅₀/783, 847, 855, 874, S₅₁/364, 374, 672, 695, 851, E₅₂/1305, 1318, S₅₃/953, S₅₄/453, 456, 469, 479, 847, 855, 879, 960, S₅₅/233, 840, E₅₆/594, S₅₆/271, 296, 321.
Nectochaeta caroli Fauvel, S₅₄/935.
Lepadorhynchus uncinatus Fauvel, S₅₃/922.
Tomopteris nisseni Rosa, S₅₄/453, 469, S₅₅/971, E₅₆/586.
Tomopteris kerfsteini Greeff, S₅₄/557.
Tomopteris cavalli Rosa, S₅₄/954, S₅₅/363, 545, E₅₆/472.
Tomopteris krampi Wesenberg Lund, S₅₆/321.
Travisiopsis lanceolata Southern, S₅₁/594, S₅₂/825, S₅₃/935, S₅₄/482, 488, 595, 954, S₅₆/296.
Travisiopsis levinseni Southern, S₅₀/855, S₅₁/364, S₅₄/488, S₅₅/233.
Travisiopsis lobifera Levinsen, E₅₀/135, 767, S₅₀/394, 783, 847, 855, 867, S₅₁/364.
Sagitella kowalewskii Wagner, S₅₁/375, E₅₂/1317, Ch₅₃/6, 12, S₅₄/960.
Vanadis formosa Claparède, E₅₀/135, 138, S₅₁/363, 364, 368, 371, 376, 377, 385, 570, 602, E₅₂/1161, 1165, 1200, S₅₂/838, 1502, Ch₅₃/9, S₅₃/298, S₅₄/696, 855, 873, 949, 953, 954, 986, 987, 988, 1396.
Rhynchonerella angelini (Kinberg), S₅₂/1280, 1281, Ch₅₃/10, S₅₄/456.

Ostracoda

- Gigantocypris mülleri* Skogsberg, S₅₁/672, E₅₂/1314, S₅₄/453.

Copepoda

- Megacalanus longicornis* (Sars), S₅₁/363, 371, 695, S₅₄/453, 987, S₅₅/727, E₅₆/474.
Megacalanus princeps (Brady), S₅₁/364.
Bathycalanus richardi Sars, E₅₀/135, S₅₀/847, 855, S₅₁/374, 375, E₅₂/1196, S₅₄/482, 516, S₅₅/727.
Bathycalanus rigidus Sars (1957, 1958, see p. 15).
Eucalanus crassus Giesbr., S₅₀/949, Ch₅₃/5, 8, 10, S₅₃/1697, 2059, S₅₄/456, 935, 949, 953, 960, 961, 962, 981, 986, 1181, 1184, 1188.

- Spinocalanus validus* Sars, S54/855.
Spinocalanus caudatus Sars, 256/296.
Aetidiopsis rostrata Sars, S53/944.
Aetidiopsis multiserrata Sars, E56/474.
Undinopsis similis Sars, S53/922.
Chiridius poppei Giesbr., S53/934.
Chiridiella sp. S55/963.
Gaidius brevispinus (Sars),
Gaidius brevicaudatus Sars, S52/141, S55/936, 941, 971, E56/586, S56/296, 382.
Gaetanus kruppi Giesbr., S54/488, 516, 855, 891, 904, 954, 987, S56/262, 296, 335.
Gaetanus miles Giesbr., S50/867, 874, 949, S51/275, E52/1311, S52/1377, S54/954, S55/832, 941.
Gaetanus curvicornis Sars, S50/874, S51/695.
Gaetanus latifrons Sars, S50/874, S51/371, 374, 695, 749, S54/954.
Gaetanus minor Farran, S51/371, S54/891, 954, S55/660, 672, 721.
Euchirella messinensis (Claus), S51/365, 679, S52/833, S54/479, 960, S55/702, S56/296.
Euchirella bitumida With, S50/54, 219, E52/1196, S53/922, 945, S55/936, S56/262, 368.
Euchirella intermedia With, S51/364, E52/1195, 1314, 1339, S54/949, 960, S55/721.
Euchirella maxima Wolfenden, E50/135, S50/922, S51/599, 679, 688, 695, E52/1195, 1197, S52/876, S54/891, S55/233.
Chirundina streetsi Giesbr., E50/135, 767, S50/64, 394, S51/364, 851, E52/1314, S53/934, S54/954, S55/233, 672, 660, 702.
Undeuchaeta plumosa (Lubbock), S51/365, 375, S55/702.
Undeuchaeta major Giesbr., S50/855, S51/371, 672, S54/595, S55/721, E56/474.
Pseudochirella obtusa (Sars), E50/135, S50/847.
Pseudochirella pustulifera (Sars), S50/847, S51/364, 374, 375, 679, S54/488, 904.
Pseudochirella notocantha (Sars), S50/68.
Euchaeta acuta Giesbr., S51/363.
Pareuchaeta glacialis (Hansen), S50/68, 425, 540, 847, 867, 874, 949, S51/129, 249, 304, 363, 374, 602, 672, 749, S54/352, S55/948, 963, 971.
Pareuchaeta tonsa (Giesbr.), E50/141, S50/949, S51/312, 371, 374, 375, 695, S54/469, 479, 855.
Pareuchaeta hansemi (With), S51/672, S52/1377.
Pareuchaeta scotti (Farran), S50/425, 847, 949, S51/374.
Pareuchaeta bradyi (With), S51/374.
Pareuchaeta barbata (Brady), E50/135, S50/68, 425, 775, 847, 855, S51/249, 363, 364, 599, 672, 749, E52/1196, S52/141, S53/698, S54/352, S55/941, 963, 971, 972, E56/474, 594.
Pareuchaeta sarsi Farran, E50/135, 138.
Pareuchaeta gracilis (Sars), E50/138, 141, S50/855, S54/479, 488, S55/206.
Pseudeuchaeta brevicaudata Sars, S51/304, 364, 602, 679.
Phaenna spinifera Claus, E50/138, E52/1195, 1197, 1342, Ch53c/11, S53/922, S54/935, 949, 1184, S55/841.
Xanthocalanus greeni Farran, S54/904, S55/682.
Onchocalanus trigoniceps Sars, S50/855, S51/364, E52/1196, S54/453, 469, 960, S55/672, S56/296.
Onchocalanus cristatus (Wolfenden), S54/479, S55/727.
Cornucalanus chelifer (Thompson), E50/138, 144, S50/783, 847, 855, S51/364, 371, 375, 567, 594, 602, 672, 688, 695, S52/533, S54/343, 469, 516, 954, S56/296.
Scottocalanus persecans (Giesbr.), S50/54, 219, 855, 867, 874, S51/304, 312, 365, 371, 374, 695, S54/891, 987, S56/296.
Scottocalanus securifrons (T. Scott), S50/53, 54, 227, 845, 867, 949, S51/333, 363, 364, 375, 672, 679, 688, 695, S52/141, 533, S54/469, 1187, S55/702, 721, 936, 941, 963, 971, E56/586, S56/335.
Lophothrix frontalis Giesbr., E50/141, 767, 770, S50/771, 783, 847, 855, 867, 874, S51/304, 312, 363, 364, 371, 374, 375, 672, 695, E52/1162, 1195, 1196, 1197, S52/141, 533, 825, S53/922, 934, 944, 953, S54/469, 488, 516, 855, 891, 954, 960, 987, S55/233, 672, 682, 721, 941, E56/474, S56/262, 270, 321, 335.
Scaphocalanus magnus (T. Scott), E50/767, S50/847, 867, 874, S51/695, S54/954, 960, S56/296.
Scaphocalanus angulifrons Sars, S54/891, S55/971.
Scaphocalanus affinis (Sars), E50/135, S55/672.
Ammalothrix gracilis (Sars), S54/904.
Metridia princeps Giesbr., S50/847, 855, 874, S54/453, 488, S55/672, 682, E56/474, 594.
Metridia macrura Sars, S50/847, S51/374, 375, 688.
Metridia venusta Giesbr., S56/296.
Pleuromamma abdominalis (Lubbock), S51/363.
Pleuromamma xiphias Giesbr., S50/847, S51/363, 364, 371, 374, E52/1195, Ch.53c/9, 10, Ch.53b/4, S54/954, 962, S55/721.
Pleuromamma gracilis (Claus), Ch.53c/10, 11.
Centropages cherchiae Giesbr., S55/862.

- Lucicutia grandis* (Giesbr.), S₅₁/364, 375.
Lucicutia maxima (Steuer), S₅₄/855.
Lucicutia atlantica Wolfenden, S₅₅/672.
Dissita palumboi Giesbr., S₅₁/695.
- Heterorhabdus robustus* Farran, E₅₂/1196, S₅₄/904, 954, S₅₅/672, E₅₆/474, S₅₆/296.
Heterorhabdus norvegicus (Boeck), S₅₁/364, 695, S₅₂/833, 1377, S₅₄/469, 891, 960, S₅₅/672, S₅₆/262.
Heterorhabdus compactus (Sars), S₅₄/954.
Heterorhabdus spinifrons (Claus), S₅₅/721.
Heterorhabdus abyssalis Giesbr., S₅₄/1187.
Heterorhabdus clausi Giesbr., S₅₄/949, S₅₅/721, E₅₆/474.
Hemirhabdus grimaldii (Richard), S₅₀/847, S₅₁/364, 375.
Mesorhabdus brevicaudatus (Wolfenden), S₅₄/855.
Mesorhabdus augustus Sars, S₅₃/698.
- Heterostylites longicornis* (Giesbr.), E₅₀/138, 767, S₅₀/68, 400, 540, 783, 840, 847, 855, 874, S₅₁/249, 304, 363, 364, 374, 375, 599, 672, 679, 688, 695, 749, 851, E₅₂/1195, 1197, S₅₂/1377, S₅₃/922, 934, S₅₄/488, 855, 950, 953, 981, S₅₅/672, 682, 702, 721, 727, 971, 972, E₅₆/474, S₅₆/265, 296, 368.
- Haloptilus oxycephalus* (Giesbr.), S₅₄/904.
Haloptilus bullicheps Farran, S₅₄/855.
- Augaptilus glacialis* Sars, S₅₀/54, 847, S₅₄/954, 959.
Augaptilus longicaudatus (Claus), S₅₁/363, 374, E₅₂/1196, S₅₂/1384, E₅₆/474.
Augaptilus megalaurus Giesbr., E₅₀/767, S₅₀/64, 394, 780, 783, 788, 855, 859, 867, 874, S₅₁/364, 375, 688, 851, E₅₂/1197, 1200, S₅₂/141, S₅₃/934, S₅₄/343, 453, 847, 954, 987, S₅₅/660, 727, 832, 841, E₅₆/594, S₅₆/262, 270, 296.
- Augaptilus anceps* Farran, S₅₁/364, 374.
- Euaugaptilus squamatus* (Giesbr.), S₅₁/688, 695, S₅₃/77, S₅₄/456.
Euaugaptilus magnus (Wolfenden), S₅₃/944, 953, S₅₄/954, S₅₅/672, E₅₆/474.
Euaugaptilus laticeps (Sars), S₅₀/847, 874, S₅₁/375, 672, 679.
Euaugaptilus oblongus (Sars), S₅₀/874, S₅₄/479, 987.
Euaugaptilus bullifer (Giesbr.), S₅₀/847, S₅₄/469, S₅₅/721, 727.
Euaugaptilus affinis Sars, S₅₄/456.
Euaugaptilus filiger (Claus), E₅₀/767, S₅₀/874, S₅₁/374, 375, 688, S₅₃/26, S₅₅/660, S₅₆/296.
Euaugaptilus augustus (Sars), S₅₀/855, S₅₁/364, 570, 599, E₅₂/1197.
Euaugaptilus penicillatus Sars, S₅₀/855, S₅₄/891.
Euaugaptilus hecticus (Giesbr.), S₅₆/262.
- Centraugaptilus rattrayi* (T. Scott), E₅₀/135, 767, S₅₀/847, E₅₂/1162, 1195, 1197, 1311, 1318, S₅₂/1280, 1287, 1377, S₅₃/17, 698, 925, 934, 1597, S₅₄/456, 469, 516, 557, 847, 891, 953, S₅₅/721, 840, S₅₆/262, 271, 368.
Centraugaptilus cuculatus (Sars), S₅₅/727.
Centraugaptilus horridus (Farran), S₅₀/400, 855, S₅₁/275, 312, 695, S₅₃/555, 953, 1597, S₅₅/660, 832, 841.
- Pontoptilus muticus* Sars, E₅₀/135, S₅₀/775, 847, 855, 874, S₅₁/275, 304, 312, 364, 371, 374, 672, 679, 688, 695, E₅₂/1196, 1197, S₅₄/479, 960, 987, S₅₅/840, S₅₆/321.
Pontoptilus robustus Sars, E₅₀/135, S₅₁/312, 364, 371, S₅₂/141, S₅₄/453, 469, 488, 696, 904.
Pachyptilus eurygnathus (Sars), E₅₀/135, S₅₄/479, 488, S₅₅/672.
- Arietellus setosus* Giesbr., S₅₃/553, 919, S₅₄/891, S₅₅/233, 672.
Arietellus giesbrechti Sars, S₅₀/783, 847, S₅₁/363, S₅₆/265, 296.
Arietellus plumifer Sars, E₅₀/144, S₅₀/783, 840, 845, 847, 855, 874, S₅₁/312, 363, 364, 374, 375, 599, 679, 688, 695, 851, E₅₂/1162, 1195, 1196, 1305, 1308, 1314, 1317, S₅₃/17, 26, 922, 925, 934, S₅₄/343, 453, 469, 479, 482, 488, 557, 855, 891, 904, 954, 961, 987, S₅₅/672, 682, 721, 727, 840, 941, E₅₆/474, 594, S₅₆/262, 321, 368.
- Paraugaptilus buchanani* (Wolfenden), S₅₂/141.
Phyllopus impar Farran, S₅₀/855, S₅₁/363, 371, 375, 851, S₅₄/488.
Phyllopus helgae Farran, E₅₀/141, S₅₀/874, S₅₅/672, S₅₆/262, 296.
- Sapphirina augusta* Dana, Ch.53b/4.
Sapphirina nigromaculata Claus, Ch.53b/6, 7, Ch.53c/11.
Sapphirina scarlata Giesbr., S₅₁/387, Ch.53c/6, 8, 13, 14.
Sapphirina ovatolanceolata Dana, Ch.53b/5.
Sapphirina opalina Dana, Ch.53c/11.
Sapphirina spp. S₅₅/848.
- Nesippus borealis* (♂) (Steenstrup and Lutken), E₅₂/1199, 1305, S₅₂/18, 133, S₅₃/332, 554, 917, 935, S₅₄/475, 479, 480, 482, 549, 615, 885, 988, S₅₅/702, E₅₆/464, S₅₆/330.
Sarcotretes scopeli Jungersen, S₅₄/376, 582, S₅₅/233, 766.

Cirripedia

- Lepas fascicularis* Ellis & Sol., S₅₁/604, E₅₂/1193, E₅₄/1265, S₅₅/700, 710.
Lepas anserifera L., S₅₁/589, 682, E₅₆/431.
Lepas anatifera L., S₅₁/589, S₅₄/333.

Isopoda

- Munnopsis murrayi* Walker, S₅₀/847, 855, S₅₁/363, 364, 371, 375, 679, 695, S₅₄/488.

Amphipoda

- Lanceola serrata* Bov., S₅₀/847, S₅₄/453.
Lanceola loveni Bov., E₅₀/767, S₅₁/364.
Lanceola sp. S₅₄/954.
Mimonectes steenstrupi Bov., E₅₂/1309, S₅₄/460, 474.
Parascina fowleri Stebbing, E₅₀/135, 138, S₅₀/64, 855, 867, 874.
Scina oedicarpus Stebbing, S₅₁/304, 364, 371, 374, 375, 599, 602, 672, 688, 695.
Scina crassicornis (Febr.), S₅₂/1377, S₅₃/934.
Scina marginata (Bov.), S₅₅/971.
Scina tullbergi (Bov.), S₅₄/904, 949.
Scina rattrayi Stebbing, E₅₀/767, S₅₀/783, 847, 855, S₅₄/847, S₅₅/672, 721, 840, 936, 941, S₅₆/271.
Scina borealis (Sars), S₅₁/672, 679, 695, 851, E₅₂/1305, S₅₄/453, 891, S₅₆/271, 296.
Vibilia borealis Bate & West., S₅₄/1394.
Vibilia propinqua Stebbing, S₅₄/932, 936, 981.
Vibilia pyripes Bov., S₅₃/924, S₅₄/960, 986, 988, 990, 1181, 1184, 1188.
Thaumatops fabricii Stebbing, S₅₄/557.
Phronima sedentaria Forsk., S₅₁/368, S₅₃/2274, S₅₄/946, 949, 962, 986, 1176, 1188, 1366, 1394, S₅₅/723, 753.
Themisto libellula (Mandt), S₅₀/425, S₅₄/352, 378.
Euprimnus macropus (Guerin), S₅₀/859, 874, S₅₁/375, 377, 851, S₅₄/949, 953, 981, 987, 1395.
Brachyscelus crusculum Sp. Bate, S₅₁/695, E₅₂/1311, S₅₄/696, 879, 949, 981, 1188.
Paralycaea gracilis Claus, S₅₄/1394, 1395, 1396.
Onesimus leucopis (Sars), S₅₄/623.
Cyphocaris anonyma Boeck, S₅₀/64, 783, 847, 855, 874, S₅₁/275, 364, 375, 672, 679, 695, E₅₂/1200, 1314, S₅₂/1280, S₅₃/922, 944, S₅₄/479, 488, 904, 954, 960, S₅₅/233, 672, 682, E₅₆/474, 594, S₅₆/321.
Eusirus holmi Hansen, S₅₂/610, also in 1960 (see text).

Mysidacea

- Gnathophausia zoea* W-Suhm, S₅₁/364, 695, S₅₄/879, 904.
Eucopia unguiculata W-Suhm, E₅₀/135, S₅₀/855, S₅₁/312, 364, 375, 672, 679, 688, 695, S₅₄/453, 469, 482, 960, S₅₅/672, 721, 840.
Eucopia grimaldii Nouvel, S₅₀/855, S₅₁/375, E₅₆/474.
Anchialus agilis Sars, S₅₃/282, E₅₆/604, S₅₆/31, 328.
Katerythrops oceanae Holt & Tatt., S₅₀/874.
Meterythrops picta Holt & Tatt., S₅₀/847, 855, 874, S₅₁/375, 679, S₅₄/453, 469, 891, S₅₅/233, E₅₆/594.
Boreomysis microps Sars, S₅₀/847, 855, 874, S₅₁/304, 364, 375, 672, 679, 688, S₅₄/479, 482, 516, 904, 954, S₅₅/233, S₅₆/321.
Arachnomysis leuckarti Chun, E₅₂/1162, S₅₂/1281.

Euphausiacea

- Euphausia krohni* (Brandt), E₅₀/144, S₅₀/28, 32, E₅₂/60, S₅₂/1287, S₅₄/453, 469, 935, 949, 950, 953, 954, 960, 962, 987, 990, 1181, 1184, 1187, S₅₅/936, E₅₆/465, 466.
Thysanopoda acutifrons Holt & Tatt., S₅₀/867, S₅₁/312, 375, 688, S₅₂/141, S₅₄/453, 488, 595, 873, 878, 879, S₅₅/233, 721.
Nematobrachion boopis Calman, S₅₁/594, S₅₄/879, 891, S₅₆/270, 296.
Nematoscelis megalops Sars, E₅₂/1317, S₅₃/2288, S₅₄/879, S₅₆/262.
Stylocheiron elongatum Sars, S₅₀/400, 874, S₅₂/876, S₅₄/595, 879, 891, 949, 960, E₅₆/586.
Stylocheiron longicorne Sars, E₅₀/144, E₅₂/1162, 1305, 1311, 1318, 1321, 1342, S₅₃/934, 953, S₅₄/456, 949, 950, 953, 981, S₅₆/270.
Stylocheiron maximum Hansen, S₅₂/1280, S₅₄/953, S₅₆/321.

Decapoda

- Amalopenaeus elegans* Smith, E₅₀/135, S₅₀/847, 855, 867, 874, S₅₁/304, 312, 364, 371, 375, 688, E₅₂/1196, 1197, 1311, S₅₂/533, S₅₃/922, 934, 944, S₅₄/453, 479, 482, 488, 516, 855, 879, 904, 960, 987, S₅₅/672, 721, 727, 840, 941, 972, E₅₆/594, S₅₆/262, 296, 321, 335, 382.

Hymenodora glacialis Buch., S52/593, 925, S54/352.

Acanthophyra spp., S54/855, 873, 878, 891, 953, 954, 961, 986, 991, S55/727, S56/270, 377.

Bythocaris simplicirostris Sars, S51/602.

Palinurus (*Phyllosoma* larvae), S53/1593, 1672, S56/327.

Parapaspheaa sulcatafrons Smith, S54/904, E56/474.

Mollusca—Gasteropoda

Peraclis moluccensis Tesch., E56/594.

Spiratella helicoides (Jeffreys), E50/135, S50/847, 855, S51/695, E52/1200, S54/479.

Euclio cuspidata (Bose), E50/135, 141, 767, S50/54, 783, 855, 867, 874, 922, S51/129, 374, 376, E52/1162, 1311, S52/876, 1280, S53/17, 919, 945, 953, 1611, S54/343, S55/201, 843, 848, 949, 971, E56/466, 595, 634, S56/262, 278, 368.

Euclio polita (Pfeffer), Ch.53/9, 10, S53/1597, S54/453, 488, 876, 891, 949, 950, 963, S55/941, E56/474, 475.

Diacria trispinosa (Lesueur), E50/138, 767, S50/783, 847, 855, S51/907, 910, E52/1161, 1200, S52/1280, S53/935, S54/456, 461, 878, 891, 946, 949, 950, 953, 959, 961, 962, 991, 1184, 1188.

Carinaria lamarckii Peron & Les., E52/1196, S54/950, 953.

Pterotrachea scutata Gegenbaur, (1959, see text).

Janthina sp., S53/947.

Mollusca—Cephalopoda

Desmoteuthis hyperborea Steenstrup, S55/723, S56/296.

Histioteuthis bonelliiana (Ferussac), S50/874.

Taonidium pfefferi Russell, E52/1200, 1756, S52/536, 615, 902, 972, S53/915, 922, 925, 929, S54/453, 456, 461, 479, 488, 508, 590.

Cranchia spp., S54/879, S55/201.

Tunicata—Thaliacea

Cyclosalpa virgula (Vogt), S53/934, 945.

Ritteriella picteti (Apstein), Ch.53/9.

Thalia democratica (Forskål), S51/382, 383.

Iasis zonaria (Pallas), Ch.53c/10, 13, S53/932, 1657, 1724, S54/454, 990, 1184, S56/321.

Pegea confoederata (Forskål), (1958, see text).

Thetys vagina (Tilesius), (1958, see text).

Doliolina mülleri Krohn, Ch.53c/6.

Doliolum nationalis Borgert, Ch.53c/5, 6, 7, 8, 9, 10, 12, 13, 14.

Pisces

Argyropelecus hemigymnus Cocco, E50/135, 144, S50/219, S51/304, S52/1280, S53/922, S54/343, 453, 469, 960, S55/233, 832, 936, 972, E56/586, S56/262, 271, 368.

Stomias boa (Risso), E50/601, S50/845, 859, 867, S51/304, E52/1161, Ch.53/9, S54/453, 456, 488, 595, 904, 1188, S55/201, 723, E56/586.

Nansenia spp. S53/695, 919, 929, S54/456, 696, 891, S55/723.

Bathylagus spp. E50/138, S50/394, S51/364, E52/1195, 1197, 1200, 1342, S52/876, S53/915, 919, 934, 935, S54/453, 456.

Paralepis coregonoides Risso, E50/135, 138, 767, S51/323, 377, E52/1162, 1195, 1196, 1197, 1200, 1317, S52/876, S54/453, 456, 482, 873, 891, S55/206.

Myctophum humboldti (Risso), E52/1193, S54/454, S55/723.

Myctophum punctatum (Rafinesque), E52/1193, S54/454, S55/227.

Lampanyctus pusillus (Johnson), S55/723.

Lampanyctus nigrum (Günther), S54/479.

Lampanyctus iselini Parr, S54/904.

Lampadena braueri Zugmayer, S54/904.

Lycodonus flabellicauda Jensen, S56/279.

Melamphaës beanii Günther, S50/855, E56/474.

Melamphaës eurylepis Holt & Byrne, S54/904.

Melamphaës spp. S54/453, 891.

Fierasfer spp. S53/694, 2207, 2280, 2428, E54/1279, 1284, 1775, S54/935, E55/872, 1503, 1511, 1516, 1519, 1662, 1684, 1710 (eggs S54/1234).

Antennarius radiosus Garman, (1958, see text).

Diplolynchus bifilis Regan and Trewavas, (1957, see text).

Leptocephali E52/1161, 1162, S52/876, S54/1181, 1187, S55/204, 823, S56/262, 296. 321,

POSITIONS OF STATIONS GIVEN IN APPENDIX TABLE I

(1 METRE NON-CLOSING NETS USED EXCEPT WHERE INDICATED BY *)

Haul No.	Date	Position	Depth (m)	Haul No.	Date	Position	Depth (m)		
E50/				S51/ C'td.					
135	27 Mar.	56°50'N	9°50'W	1000-0	382	30	53°25'N	13°43'W	20
138	27 "	"	"	250	383	30	"	12°11'W	100
141	27 "	"	9°30'W	600-0	385	30	53°04'N	"	0
144	27 "	"	"	250	387	30	"	"	100
491	7 June	61°01'N	1°45'E	20	567	16 Aug.	59°31'N	7°05'W	250
601	20 July	59°31'N	7°05'W	200-0	570	16	59°44'N	7°15'W	1000-0
767	28 Aug.	56°50'N	9°30'W	800-0	589	20	61°48'N	9°06'W	0
770	29 "	"	9°02'W	110-0	594	20	62°15'N	9°30'W	500-0
				599	21	62°04'N	10°48'W	250	
				602	21	62°36'N	12°03'W	750-0	
				604	21	63°13'N	13°40'W	0	
				672	29	62°07'N	16°06'W	1750-0	
				679	30	61°11'N	14°14'W	1000-0	
				682	30	60°18'N	12°20'W	0	
				688	31	59°50'N	11°24'W	1100-0	
				695	31	58°49'N	9°26'W	1700-0	
				749	20 Sept.	60°35'N	8°00'W	900-0	
				850	14 Oct.	59°31'N	7°05'W	50	
				851	14	"	2°10'W	250	
				907	29	61°08'N	"	250-0	
				910	29	61°01'N	1°36'W	100	
E52/									
60	19 Jan.	58°11'N	2°55'W	30-0					
1161	9 June	56°50'N	9°30'W	20					
1162	9	"	"	280					
1165	10	"	"	20					
1174	12	"	56°20'N	7°46'W	100				
1193	12	"	55°30'N	10°21'W	0				
1195	12	"	"	250					
1196	12	"	"	1000-0					
1197	13	"	55°28'N	9°42'W	700-0				
1198	13	"	"	0					
1199	13	"	"	20					
1200	13	"	"	250					
1203	13	"	55°26'N	8°54'W	0				
1212	13	"	55°35'N	7°46'W	60				
1247	15	"	54°38'N	5°14'W	20				
1248	15	"	"	100					
1280	22	"	56°41'N	6°40'W	75				
1305	24	"	58°38'N	8°21'W	500-0				
1308	24	"	58°53'N	8°50'W	1000-0				
1309	24	"	"	0					
1311	24	"	"	250					
1314	25	"	59°36'N	7°11'W	1000-0				
1317	25	"	"	250					
1318	25	"	59°27'N	6°52'W	700-0				
1321	25	"	"	250					
1339	26	"	60°16'N	4°33'W	500-0				
1342	26	"	"	250					
1756	29	"	61°01'N	2°30'W	165				
E51/									
1417	14 July	59°31'N	7°05'W	250					
1574	24 "	61°14'N	2°40'W	750-0					
1579	24 "	61°08'N	2°10'W	250					
S51/									
129	19 May	59°17'N	6°53'W	500-0	S52/				
249	1 June	61°21'N	3°10'W	1000-0	18	11 Feb.	61°34'N	7°20'W	150-0
275	16 "	59°17'N	6°53'W	580-0	133	19	61°42'N	4°51'W	0
304	19 "	59°45'N	11°12'W	1250-0	141	19	61°21'N	3°10'W	1200-0
312	19 "	58°46'N	9°18'W	1650-0	533	10 May	59°44'N	7°15'W	960-0
323	21 "	57°40'N	9°27'W	100	536	11	59°56'N	7°27'W	250
333	23 "	"	15°11'W	250	593	19	61°21'N	3°10'W	1260-0
337	23 "	56°25'N	14°16'W	250	610	20	62°24'N	1°00'W	1500-0
357	28 "	54°15'N	12°51'W	250-0	615	20	61°53'N	"	250
358	28 "	54°15'N	13°42'W	0	825	21 June	61°35'N	4°15'W	900-0
363	28 "	"	14°32'W	1000-250*	833	22	61°21'N	3°10'W	1350-0
364	28 "	"	"	2120-0	838	22	61°08'N	2°10'W	100
365	29 "	"	16°15'W	250-0	876	6 July	59°17'N	6°53'W	550-0
368	29 "	"	17°03'W	0	886	6	60°12'N	7°40'W	600-0
371	29 "	"	"	1000-250*	902	7	61°48'N	9°06'W	100
374	29 "	53°53'N	15°32'W	2100-0	925	11	64°00'N	6°35'W	2000-0
375	29 "	"	"	1000-250*	972	18	61°14'N	2°40'W	100
376	30 "	53°41'N	14°44'W	250-0					
377	30 "	53°34'N	14°12'W	250-0					

Haul No.	Date	Position		Depth (m)	Haul No.	Date	Position		Depth (m)
S52/C'td.					S53/C'td.				
1280	4 Nov.	59°17'N	6°53'W	550-0	1646	18	60°12'N	1°18'W	100
1281	4 "	59°31'N	7°05'W	150-0	1648	20	60°30'N	3°09'W	205-0
1287	9 "	60°23½'N	7°49½'W	150-0	1654	22	58°51'N	7°35'W	100
1365	17 "	61°54'N	5°45'W	150-0	1657	23	58°28'N	8°27'W	180-0
1377	18 "	61°21'N	3°10'W	1900-0	1661	23	57°57'N	9°17'W	0
1384	18 "	61°08'N	2°10'W	100	1667	24	57°11'N	9°10'W	180-0
1497	8 Dec.	60°30'N	1°57'W	190-0	1672	25	56°45'N	8°38'W	20
1502	8 "	61°01'N	1°30'W	100	1697	31	58°06'N	13°50'W	20
Ch.53/					1698	31	"	"	100
4	16 Apr.	48°10'N	7°23'W	60	1724	16 Sept.	59°25'N	3°25'W	20
5	16 "	48°06'N	8°24'W	60	1980	17	59°40'N	2°00'W	95
6	16 "	48°05'N	9°56'W	60	1990	18	"	1°00'W	20
7	17 "	47°59'N	12°02'W	60	1991	18	"	"	100
8	17 "	47°54'N	12°56'W	60	2059	20	58°25'N	2°32'W	60
9	17 "	47°31'N	14°51'W	60	2207	12 Nov.	58°05'N	0°40'W	100
10	18 "	46°58'N	16°15'W	60	2238	13	58°25'N	0°20'W	20
11	18 "	47°07'N	16°35'W	60	2274	15	59°15'N	0°30'W	134-0
12	19 "	47°16'N	17°52'W	60	2277	15	59°40'N	"	125-0
Ch.53b/					2280	15	"	"	100
1	25 May	47°50'N	17°40'W	60	2288	19	59°17'N	6°53'W	600-0
3	26 "	47°40'N	13°58'W	60	2428	10 Dec.	57°25'N	1°20'W	60-0
4	26 "	47°32'N	12°20'W	60	2537	19	58°50'N	1°00'W	108-0
5	27 "	47°33'N	9°57'W	60	E54/				
6	27 "	48°03'N	9°12'W	60	1265	5 Aug.	61°01'N	3°00'E	0
7	27 "	48°30'N	8°04'W	60	1279	6	"	0°00'	20
Ch.53c/					1284	6	"	1°00'W	20
5	20 June	47°45'N	8°48'W	150	1608	28 Oct.	58°35'N	3°49'W	38-0
6	20 "	47°22'N	9°30'W	150	1775	19 Nov.	58°30'N	0°30'W	121-0
7	20 "	47°92'N	10°06'W	150	S54/				
8	21 "	46°45'N	11°41'W	150	333	16 Apr.	58°50'N	6°26'W	0
9	21 "	"	12°18'W	150	343	17	59°31'N	7°05'W	500-250-100
10	21 "	"	13°22'W	150	352	21	63°45'N	6°35'W	1000-0
11	22 "	"	15°26'W	150	353	21	63°18½'N	250-0	250-0
12	22 "	"	16°15'W	150	376	22	61°28'N	3°42'W	250
13	22 "	"	17°28'W	150	378	23	61°21'N	3°10'W	1200-0
14	23 "	46°46'N	19°37'W	150	379	23	61°14'N	2°40'W	250-0
S53/					453	13 May	58°07'N	10°10'W	1180-0
17	10 Feb.	59°17'N	6°53'W	550-0	454	13	"	"	0
26	10 "	59°44'N	7°15'W	950-0	456	13	"	"	250
77	17 "	62°00'N	6°12'W	110-0	460	14	57°52'N	12°12'W	0
209	17 Mar.	58°30'N	5°45'W	0	461	14	"	"	20
282	4 April	61°01'N	0°48'W	0	469	15	58°44'N	15°18'W	1000-0
292	5 "	"	0°44'W	100	474	15	59°43'N	16°42'W	0
332	7 "	62°30'N	7°54'W	150	475	15	"	"	20
548	11 May	59°17'N	6°53'W	250-0	479	16	60°32'N	17°55'W	1200-0
549	12 "	59°44'N	7°15'W	0	480	16	"	"	0
553	12 "	59°56'N	7°27'W	20	482	16	"	"	250
554	12 "	"	"	250	488	16	62°08'N	20°18'W	1200-0
555	12 "	"	"	600-0	508	17	63°00'N	25°10'W	500
557	12 "	59°59'N	6°52½'W	20	516	17	"	27°20'W	500
586	23 "	61°21'N	3°10'W	650-0	549	21	64°00'N	"	500
694	13 June	60°12'N	4°18'W	20	557	22	64°30'N	28°25'W	500
695	13 "	"	"	100	563	22	"	26°15'W	220
698	13 "	60°28'N	5°03'W	920-250*	582	29	65°00'N	27°20'W	300
915	27 "	62°08'N	20°18'W	250	590	29	65°30'N	28°25'W	300
917	27 "	61°21'N	19°03'W	0	595	29	65°00'N	"	500
919	27 "	"	"	250	615	30	65°30'N	33°57'W	0
922	28 "	60°32'N	17°55'W	700-0	623	31	64°38'N	35°15'W	500
925	28 "	"	"	250	696	12 June	59°31'N	7°05'W	250
929	28 "	59°43'N	16°42'W	250	810	6 July	60°02'N	4°30'W	145
932	28 "	58°44'N	15°18'W	0	847	9	60°23½'N	7°49½'W	880-0
934	28 "	"	"	250	849	10	60°12'N	7°40'W	20
935	28 "	"	"	700-0	855	10	59°44'N	7°15'W	900-0
939	29 "	57°34'N	13°46'W	20	857	10	59°31'N	7°05'W	250
944	29 "	57°52'N	12°12'W	1000-300*	873	14	58°32'N	8°50'W	250
945	29 "	"	"	0	876	15	58°40'N	9°18'W	0
953	30 "	58°07'N	10°10'W	700-0	878	15	"	"	250
1593	13 Aug.	58°50'N	6°26'W	115-0	879	15	"	"	920-0
1597	14 "	59°17'N	6°53'W	590-250*	885	17	59°31'N	10°43'W	250-0
1611	14 "	60°45'N	8°08'W	890-0	891	17	59°45'N	11°12'W	1200-0
1637	17 "	61°08'N	2°10'W	250					

Haul No.	Date	Position		Depth (m)	Haul No.	Date	Position		Depth (m)
S54/ C'td.									
898	17 "	60°56'N	13°28'W	250-0	682	8 "	59°54'N	14°15'W	1000-400*
904	19 "	61°20'N	14°22'W	1200-0	700	9 "	59°02'N	9°08'W	0
906	22 "	58°18'N	12°32'W	0	702	9 "	56°46'N	8°52'W	250
913	22 "	57°58'N	11°40'W	250	710	14 "	56°51'N	9°24'W	1100-0
932	15 Aug.	52°40'N	10°40'W	20	721	15 "	56°59'N	10°00'W	20
934	16 "	53°04'N	12°11'W	250-0	723	15 July	57°22'N	12°10'W	1100-0
936	16 "	53°14'N	12°57'W	0	727	17 "	59°12'N	10°09'W	20
946	17 "	53°34'N	14°12'W	250-0	753	20 "	60°35'N	4°30'W	1000-0
947	17 "			0	766	22 "	59°17'N	6°53'W	625-0
949	17 "	53°41'N	14°44'W	250	832	30 Aug.	59°44'N	7°15'W	1050-0
950	18 Aug.	53°53'N	15°32'W	250	840	31 "	59°06'N	7°27'W	250-0
953	18 "	54°05'N	16°18'W	250	842	31 "	60°12'N	7°40'W	250-0
954	18 "			1200-0	843	31 "	60°23 $\frac{1}{2}$ 'N	7°49 $\frac{1}{2}$ 'W	20
959	18 "	54°28'N	18°00'W	250	846	1 Sept.	60°35'N	8°00'W	250-0
960	18 "			1200-0	848	1 "	61°28'N	3°42'W	20
961	19 "	55°00'N	17°00'W	250-0	862	5 "	59°17'N	6°53'W	580-0
962	19 "			250-0	936	3 Nov.	59°44'N	7°15'W	1000-0
979	21 "	57°04'N	12°46'W	0	941	4 "	60°35'N	8°00'W	980-0
981	21 "			250	948	4 "	60°45'N	8°08'W	250-0
986	21 "	57°00'N	12°00'W	250	949	4 "	61°35'N	4°15'W	1040-0
987	21 "			1200-0	963	7 "	61°21'N	3°10'W	1130-0
988	21 "			250-0	971	7 "	61°14'N	2°40'W	840-0
989	21 "			0	972	7 "			
990	21 "			20					
991	21 "			250					
1176	14 Oct.	58°50'N	6°26'W	0					
1181	14 "	59°17'N	6°53'W	600-0					
1183	14 "			20					
1184	14 "			250					
1187	15 "	59°31'N	7°05'W	250-0					
1188	15 "	59°44'N	7°15'W	1000-0					
1234	26 "	59°30'N	1°00'W	0					
1338	15 Nov.	55°15'N	1°00'W	115-0					
1366	16 "	57°45'N	0°30'W	100-0					
1394	8 Dec.	61°01'N	1°00'E	100					
1395	13 "			1°36'W					
1396	13 "	61°08'N	2°10'W	250-0					
E55/									
544	28 May	58°30'N	1°30'W	100					
872	4 July	60°43'N	0°30'W	110-0					
1503	31 Oct.	59°15'N	1°30'W	95					
1511	31 "	58°45'N		115-0					
1516	31 "		0°30'W	125-0					
1519	31 "	58°30'N		105-0					
1662	1 Dec.	57°45'N	1°00'W	91-0					
1684	2 "	58°45'N	0°00'	135-0					
1710	5 "	58°15'N	2°00'W	20					
S55/									
9	15 Feb.	58°50'N	6°26'W	20					
41	26 Mar.	58°46'N	7°35'W	0					
66	28 "	59°30'N	6°20'W	0					
69	28 "			180					
201	23 Apr.	59°31'N	7°05'W	250					
204	24 "	59°59'N	7°27'W	0					
206	24 "			250					
227	30 "	62°34'N	12°47'W	0					
233	30 "	62°45'N	14°56'W	1100-0					
363	17 May	61°21'N	3°10'W	1150-0					
545	26 June	60°47'N	2°30'W	220-0					
660	5 July	63°05'N	11°42'W	400-200*					
672	7 "	60°32'N	11°10'W	1000-?*					
S55/ C'td.									
682	8 "	59°54'N	14°15'W	1000-400*					
700	9 "	59°02'N	9°08'W	0					
702	9 "	56°46'N	8°52'W	250					
710	14 "	56°51'N	9°24'W	1100-0					
721	15 "	56°59'N	10°00'W	20					
723	15 July	57°22'N	12°10'W	1100-0					
727	17 "	59°12'N	10°09'W	20					
753	20 "	60°35'N	4°30'W	1000-0					
766	22 "	59°17'N	7°40'W	250-0					
832	30 Aug.	59°17'N	6°53'W	625-0					
840	31 "	59°44'N	7°15'W	1050-0					
842	31 "	59°06'N	7°27'W	250-0					
843	31 "	60°12'N	7°40'W	250-0					
846	1 Sept.	60°23 $\frac{1}{2}$ 'N	7°49 $\frac{1}{2}$ 'W	20					
848	1 "	60°35'N	8°00'W	250-0					
862	5 "	61°28'N	3°42'W	20					
936	3 Nov.	59°17'N	6°53'W	580-0					
941	4 "	59°44'N	7°15'W	1000-0					
948	4 "	60°35'N	8°00'W	980-0					
949	4 "	60°45'N	8°08'W	250-0					
963	7 "	61°35'N	4°15'W	1040-0					
971	7 "	61°21'N	3°10'W	1130-0					
972	7 "	61°14'N	2°40'W	840-0					
E56/									
431	8 Aug.	57°25'N	0°55'E	0					
459	22 "	59°31'N	7°05'W	250					
464	23 "	59°56'N	7°27'W	0					
465	23 "			20					
466	23 "			250					
471	24 "	60°23 $\frac{1}{2}$ 'N	7°49 $\frac{1}{2}$ 'W	250					
472	24 "	60°45'N	8°08'W	250-0					
474	30 "	62°25'N	14°12'W	1475-0					
475	30 "	62°42'N	14°43'W	250-0					
567	22 Oct.	60°32'N	3°32'W	400-0					
586	11 Nov.	59°17'N	6°53'W	545-0					
594	11 "	59°44'N	7°15'W	1000-0					
595	11 "	59°56'N	7°27'W	250-0					
596	11 "	60°12'N	7°40'W	250-0					
601	12 "	60°35'N	8°00'W	250-0					
604	12 "	60°54'N	8°16'W	100-0					
634	18 "	61°21'N	3°10'W	1200-0					
S56/									
31	4 Apr.	61°01'N	0°00'	0					
262	18 July	59°17'N	6°53'W	800-0					
265	18 "	59°31'N	7°05'W	250					
270	18 "	59°54'N	7°15'W	250					
271	18 "			800-0					
278	18 "	60°23 $\frac{1}{2}$ 'N	7°49 $\frac{1}{2}$ 'W	250					
279	18 "			900-0					
296	21 "	60°54'N	12°10'W	800-0					
315	23 "	59°12'N	10°00'W	0					
321	24 "	59°01'N	9°25'W	800-0					
327	28 "	58°27'N	8°00'W	100					
328	29 "	57°44'N	9°05'W	0					
330	29 "			25					
335	30 "	57°40'N	10°50'W	800-0					
337	30 "	57°40'N	10°50'W	15					
368	6 Aug.	60°25'N	4°35'W	800-0					
371	6 "	60°50'N	3°45'W	100-0					
377	7 "	60°50'N	2°35'W	100					
382	7 "	61°27'N	2°25'W	800-0					

TABLE II

MODERATELY COMMON ORGANISMS EXCLUDED FROM APPENDIX TABLE I

Medusae

- Leuckartiara octona* (Fleming)
Neoturris pileata (Forskål)
Laodicea undulata (Forbes and Goodsir)
Staurophora mertensii Brandt
Mitrocomella polydiademata (Romanes)
Cosmetira pilosella Forbes
Halopis ocellata Agassiz
Phialidium hemisphericum (L.)
Rhopalonema velatum Gegenbaur
Solmaris corona (Kerf. and Ehlers)
Pelagia noctiluca (Forskål)

Siphonophora

- Hippopodius hippocampus* (Forskål)
Lensia conoidea (Kerf. and Ehlers)
Sulculeolaria (*Galletta*) *biloba* (Sars)
Dimophyes arctica (Chun)
Chelophyes appendiculata (Eschscholtz)
Agalma elegans (Sars)
Nanomia cara (Delle Chiaje)
Physophora hydrostatica Forskål

Chaetognatha

- Sagitta serratodentata* Krohn
S. maxima (Conant)
S. zetezios Fowler
Eukrohnia hamata R.-Z.

Polychaeta

- Tomopteris helgolandica* Greeff
Tomopteris septentrionalis Quart.

Ostracoda

- Conchoecia borealis* Sars
C. haddoni Brady and Norman
C. elegans Sars
C. daphnoides (Claus)
Halocypris globosa (Claus)

Copepoda

- Calanus hyperboreus* Kröyer
Eucalanus elongatus Dana
Rhincalanus nasutus Giesbrecht
G. tenuispinus Sars
Gaidius affinis Sars
Gaetanus pileatus Farran
G. kruppi Giesbrecht
Euchirella rostrata (Claus)
E. curticaudata Giesbrecht
Pareuchaeta norvegica (Boeck)
Euchaeta hebes Giesbrecht
Metridia longa (Lubbock)
Pleuromamma robusta (Dahl)
Anomalocera patersoni Templeton

Amphipoda

- Themisto* spp. (except *T. libellula*)
Hyperia spp.
Hyperoche medusarum (Kröyer)
Hyperoides longipes Chevreux

Euphausiacea

- Meganyctiphanes norvegica* (M. Sars)
Thysanessa inermis (Kröyer)
T. longicaudata (Kröyer)
T. raschii (M. Sars)
Nyctiphantes couchii (Bell)

Decapoda

- Sergestes atlanticus* M.-Edw.
S. articus Kröyer
Pasiphaea sivado (Risso)

Mollusca

- Spiratella retroversa* (Fleming)
Clione limacina (Phipps)
Euclio pyramidata (L.)
Pneumodermopsis ciliata (Gegenb.)
Gonatus spp.
Tracheloteuthis riseii Steenstrup

Fish

- Benthosema glaciale* (Reinhardt)
Electrona arcticum (Lütken)
Maurolicus mulleri (Gmelin)
Cyclothona spp.