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by

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FAO INDICATIVE WORLD PLAN FOR
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Area Reviews on Living Resources of the World's Ocean

Draft for Comment

NORTHEAST ATLANTIC

1. TOPOGRAPHY

1.1 The area treated here is the same as the ICES statistical area; that is, from Cape Farewell at the northwest and Novaya Zemlya at the northeast to the latitude of Gibraltar (36°N) in the south. For subsequent analysis it is convenient to consider five major subdivisions: northern waters (sub-areas I, II, V and XIV of ICES); the North Sea plus the Skagerrak and Kattegat (sub-area IV and division IIIa); south and west of the British Isles (VI and VII); the Baltic, plus the Belts (divisions III b, c and d) and southern waters between 36°N and 48°N (VIII and IX).

This breakdown agrees very closely with that of the North East Atlantic Fisheries Commission; the first and last areas correspond to NEAFC Regions I and III respectively, and the second and third of the present areas correspond to Region II of NEAFC. The Baltic lies outside the NEAFC area.

1.2 The continental shelf in the northern area consists of (i) the long eastern coast of Greenland; most of this is ice-covered and the productive area is relatively quite small; (ii) the area round Iceland; this is variable in extent, reaching up to around 50 miles from the coast, with the particularly large areas of Faxa Bay and Breda Bay on the west coast. The total area out to the 100 fm contour is around 125,000 km sq. (iii) the area round Faroes, including the Faroe Bank, which is separated from the shallow waters round the islands by a channel deep enough to form a barrier to the movement of demersal fish. The total area is about 17,000 km sq.; (iv) the west and north coasts of Norway (from 62°N). This is a narrow and generally rocky shelf. Trawling is possible in a few areas, the most important being the very narrow grounds in the north off Lofoten; (v) the Barents Sea - this is a very large area ca 1,300,000 km. sq., bounded by Spitsbergen, Franz Joseph Land and Novaya Zemlya, of which the north-eastern part is generally ice-covered for much of the year, and has limited production. For fishery purposes the important parts are the south-eastern part of the Barents Sea (part of the sub-area I of ICES) and the Bear Island-Spitsbergen Shelf (division II b), which is separated from the south-eastern part by a moderately deep Bear Island Channel (ca 600 m.).

As considered here, and as defined for purposes of fishery statistics, the North Sea and adjacent waters are bounded in the south at 51°N, in the northwest at 4°W and 62°N (i.e. lines running a little west and north of the Orkneys and Shetlands), and lines at the southern end of the Kattegat joining Zealand to the coasts of Jutland and Sweden. The approximate area of shelf less than 200 m (which includes all this area except a small part in the northwest, and a deep channel off the Norwegian coast) is about 550,000 km sq. in the North Sea proper (Fairbridge, 1966, gives an area of 575,000 km. sq. for an area which includes the Norwegian deep water, but excludes the area to the west of the Orkneys). South of the Dogger Bank the water is shallow (less than 80 m.), but gradually deepens northwards from the Dogger Bank to 100 fms and more. The Skagerrak and Kattegat contain a further area of about 40,000 km.sq.

The other waters round the British Isles can be divided into (i) the isolated Rockall Bank (ICES region VI b, area within 200 m about 12,000 km.sq.); (ii) the west coasts of Scotland and Ireland to 54°30'N (VI a, about 100,000 kg.sq.), which includes both the area of generally rocky and uneven bottom, between the Hebrides and Scottish mainland, and the fairly wide (about 90 km) and rather smoother shelf between the Hebrides and the edge of the continental shelf; (iii) the shallow (ca 50 m.) Irish Sea (division VII a, about 100,000 km.sq.); (iv) the west coast of Ireland, including the partially isolated Porcupine Bank - between 54°N and 52°30'N (divisions VII b and c). The shelf deepens rapidly to 100 m, but is fairly wide between 100 and 200 m; total area to 200 m is around 30,000 km.sq.; (v) the British Channel (division VII f, about 12,000 km.sq.); (vi) the English Channel (divisions VII d and e), which has an area of about 75,000 km.sq., and an average depth of some 50 m; (vii) the area southwest of Ireland (divisions VII g, h, j, k), where there is a wide shelf, mostly between 100 and 200 m; the total area is about 170,000 km.sq.

The total area of the Baltic is about 420,000 km sq. All of it is shallow (average ca 50 m), and the Gulfs of Bothnia and Finland, and other areas are ice-covered for much of the winter. Much of Skagerrak is moderately deep (7,500 m).

The southern waters area, south of 48°N, can be split into the part off the French coast, on the east side of the Bay of Biscay, where the continental shelf is moderately wide - about 100 n.ml., giving a total area of shelf out to 200 m of 100 km.sq., and the very much narrower shelf along the Spanish and Portuguese coasts about 40 k... wide, and an area of 60,000 km.sq.

2. HYDROGRAPHY

2. The hydrography of the area is dominated by the North Atlantic Current and its offshoots, which bring warm water over most of the northern parts of the area (Schott 1942). The warm Irminger Current flowing anti-clockwise along the south of Iceland is separated from the Greenland coast by cold East Greenland Current. The north and east coasts of Iceland are also covered by predominantly cold water from the East Iceland Current.

The longest extension of the North Atlantic Current after passing the Faroes goes northward along the west coast of Norway, and divides into two arms, one northwards to the west coast of Spitsbergen and the other along the north coast of Norway. These two currents cover much of the western and southern parts of the Barents Sea with relatively warm (ca 4°C) and productive water.

Atlantic water flowing round the north of the Shetlands forms the main current into the North Sea, with a smaller inflow between Shetland and Scotland and also from the English Channel. These, with the generally strong tidal movements produce a complex, but generally anti-clockwise circulation within the North Sea. South of the Dogger the water column is mixed for the whole year, but in the north a thermocline forms in the summer.

With its narrow and shallow entrance the Baltic is cut off from major oceanic influences. Inflow of fresh water is very large(about 2% of the total volume) so that the salinity is low, varying from 25-30 ^{o}/oo on the bottom in the Belts, to 5 ^{o}/oo or less on the surface in the Gulf of Bothnia and the Gulf of Finland. Outflow of low salinity water on the surface is balanced by inflow of higher salinity on the bottom. Some major changes in the total productivity of the Baltic may be linked with changes in the inflow of water from the North Sea (reference?).

3. PRIMARY PRODUCTION

Studies of primary production have been made by a large number of authors using a variety of methods in different parts of the area. A detailed review will not be attempted here, especially as many of the studies have been made in inshore coastal and estuarine waters where there are likely to be large real differences in annual primary production, and individual observations may be far from typical of the whole area. A chart of primary production throughout the world (Hela and Laevastu 1962) suggests that the Northeast Atlantic especially in the area between Faroes and Iceland contains some of the most productive areas of the world. Variations of productivity within the area might be best studied by examination of plankton standing crop (e.g. from plankton recorder data), rather than by extensive direct measurement of production.

In the North Sea, Steele (1965) considered that the annual production was in the range 50-150 gC/m.sq/year and used a figure of 100 gC/m.sq/year. Cushing (personal communication) considers the possible range is as wide as 44-200. For the present purpose a figure of 100 gC/m.sq/year will be used. This gives a total fixation of carbon of 55 x 10^6 tons per year. (550 x 10^6 tons wet weight, if carbon is 10% of wet weight)

Russian estimates (Bogdanov, pers. comm.) for Barents Sea is of an annual production of 1200 x 10^6 tons wet weight of phytoplankton (approximately 1000 g/m sq/year).

4. SECONDARY PRODUCTION

4.1 Zooplankton

The regular plankton recorder surveys carried out by Edinburgh Oceanographic Laboratory give very good information on the distribution and abundance in the area covered - the North Sea and the Atlantic from Iceland and west Norway in the north to Ushant in the south. These surveys give the distribution in terms of number per unit volume just below the surface and therefore cannot be used to give quantitative estimates of the abundance per unit area unless assumptions are made concerning the vertical distribution of the organisms concerned. However, they do provide much the best presently available data on the distribution of plankton in the area.

The distribution of copepods, probably the most important element in the zooplankton, is given by Colebrook et al (1961). The most important elements are Acartia spp. (up to 1000+ individuals per sample - 3 m cu); Calanus finmarchicus (300+ per sample) and Para- and Pseudocalanus.spp. (1000+ per sample). To estimate total standing crop in weight there should be an adjustment for the different size;

Para- and Pseudocalanus are about one third the length (and therefore about one thirtieth the weight) of Calanus (Cushing and Vucetic 1963), and Acartia is also smaller than Calanus.

Allowing for these differences in size the largest average standing crops are in the oceanic areas off the west coast of Norway and parts of the area between Iceland and Faroes, with more than 300 Calanus per sample. If it is assumed that the average weight of the individual is that of a stage IV, and using the length of 2.3 mm, and quoted length-weight relation of Kamshilov (1951) given (for the North Sea) by Cushing and Vucetic, the average wet weight is around 0.25 mg. The total weight in the area of greatest standing crop is then > 75 mg/sample, or > 25 mg/m^3, or (if the surface density applies to a depth of 100 m), > 2.5 g/m^2.

Slightly lower standing crop (100-300 Calanus/sample or perhaps 0.8-2.5 g/m^2) were found in the northern North Sea, other parts of the area southeast of Iceland, west of Scotland, and (allowing for a proportionally greater contribution of other copepods) south of Ireland.

In other parts of the area studied (southern North Sea, and west of Ushant), the standing crop, particularly of Calanus was low - even allowing for the larger numbers of other species, probably not more than equivalent to 50 Calanus per sample, or 0.4 g/m^2 wet weight.

These are standing crops. There are several generations each year, so that the production will be several times the standing crop. For instance the data of the number of Calanus caught during the later cruises reported by Cushing and Vucetic, during which recruitment of stage I Calanus was small, gives an instantaneous mortality rate of 0.3 per 10 days or 11.0 per year. If this was the average mortality rate throughout the year then the production would be 11 times the standing crop. Taking 10 as a convenient approximate figure - which may not be constant over the whole area considered - estimates of annual copepod production of from 4 to over 25 g/m^2 wet weight are obtained.

More detailed studies of zooplankton standing crop (though usually not of production) have been made for particular areas, especially in the North Sea and English Channel. (These have not yet been examined in detail). Steele (1965), using results of the Aberdeen Laboratory, derives estimates of Calanus production in the northern North Sea of a minimum of 6.4 gC/m^2 per year. This is equivalent of ca 65 g/m^2 wet weight - considerably greater than that obtained above. Apart from possible real differences due to place or time of sampling the discrepancies may be because the plankton recorder underestimates the true abundance, or incorrect values of mean weight of individuals used here.

For other parts of the Northeast Atlantic Russian sources (Bogdanov, personal communication) give for the Barents Sea a total zooplankton biomass of 40-42 x 10^6 tons and (assuming 2-3 generations per year) an annual production of 100 x 10^6 tons wet weight. For the area of 1,400,000 km sq., these figures are equivalent to an average standing crop of ca 30 g/m^2 and production of 70 g/m^2 wet weight. The conversion factor from standing crop to production may be too low. For example, if there are 2 generations per year the standing crop is likely to be considerably less than the production of one generation unless there is considerable overlap between generations and there is little mortality among one generation until the next generation is well grown.

Against this, some of the important elements in the Barents Sea zooplankton may have only one generation per year.

(Data on zooplankton standing crop and production in the Baltic and the southern areas will be presented following further literature research).

4.2 Benthos

Though quantitative work on benthos has a long history in the area (Petersen 1918, Blegvad 1930), there have been comparatively few recent studies, particularly on production. As pointed out by Steele (1965) estimation of production is made more difficult by the wide range in the ratio of standing crop; production for different elements in the bottom fauna. Steele derives an estimate for annual production in the North Sea of 5 gC/m sq. or perhaps 50 g/m sq.wet weight (ignoring shells of molluscs, etc.).

In the Baltic estimates of benthos standing crop have been made for the whole area (Zenkevitch 1963) as follows:

Area	Total biomass (thousand tons)		Density (g/m sq)
North of Gulf of Bothnia	9		0.2
South of Gulf of Bothnia	1,200		12.4
Gulf of Finland	1,200		57.0
Gotland Basin	3,500		25.0
Southern Baltic	4,600		60.0
TOTAL	10,509	Average	31.5

The figure for the southern Baltic is the same as that given by Demel and Mulitsky (1955).

Assuming that the mean duration of life of the benthos is one year these figures might be taken as equal to the annual production. (Further data on benthos production are available in the literature, and should be examined).

5. FISH[1/]

5.1 The fisheries

The fisheries of the area include some of the oldest in the world. The North Sea was the cradle of modern trawling, and intense trawling has been carried on in all parts of the area for a considerable period. The area most recently exploited has been the East Greenland area, first by German trawlers in 1950, and later by some other countries. Successively in different parts of the region the trend has been first for an increase in fishing, followed by a stabilization as catch rates drop and the increased effort is diverted to more distant waters.

[1/] Crustaceans, and molluscs (other than cephalopods) are being examined in a separate review and are not considered here.

While trawling is the most important gear for demersal species other important fisheries for cod and other fish are carried on by other gears, especially in northern Norway (particularly Lofoten), and Iceland. Here purse seines have been recently introduced, in addition to, and partly in replacement of, other gears, hand and longlines and gill nets. Especially in the North Sea Danish seining, both by the Danish (anchor) and Scottish (fly-dragging) methods are important for plaice, cod, haddock and whiting. In southern waters bull (pair) trawls are used .

Herring fisheries off Iceland, Norway and in the North Sea, are among the most important and longest established, but recent developments have changed the nature of the fisheries. In the North Sea, the traditional drift net was slowly replaced by trawl fishing (both bottom trawls, and particularly most recently, pelagic trawls) until, in 1964, the Norwegians developed purse-seining in the open northern North Sea. The major part of the catch is now taken by purse-seine. Also the northern stocks, off Iceland and Norway, and in the high seas between, are now mainly exploited by purse seine, but there is an important USSR fishery with drift net in the open Atlantic.

In the southern areas there have been fewer changes in the pelagic fisheries; the most important remains that for young pilchard (sardine).

An important development within the last ten years has been the growth of fishery specifically for fish meal. Apart from the growth of fisheries on species already exploited (herring, sprats, mackerel), new fisheries have started, especially in the North Sea, for species previously unfished - Ammodytes, Trisopterus esmarkii, etc. These are largely caught by small-meshed trawls, and which has caused some difficulties in management through the incidental catches of other species - haddock, whiting, etc.

5.2 Statistics

Statistics of catches in the area (including some adjacent waters - West Greenland, Northwest Africa) and some data on fishing effort have been collected and published by ICES since 1906. The general statistics are given in the annual Bulletin Statistique, while in the last few years detailed statistics of catches and effort by small areas, and also length compositions, have been issued in the Statistical Newsletter for certain stocks. These statistics are outstanding both in detail and in the length of time covered. Until 1964 catches of non-member countries of ICES were not included; the most important are the catches of East Germany especially in the Baltic. For some countries the reported area of capture corresponds to the area in which the port of landing is situated, and not where fishing was actually carried out. This has lead, for example, to a serious underestimation of Spanish fishing off the west coast of the British Isles. The summary statistics for the year 1962-66 are given in Appendix 1.

5.3 Stock assessment

Detailed studies have been carried out for some stocks - the demersal stocks of the northern area, and the herring - by working groups set up by ICES to advise the North East Atlantic Fisheries Commission (NEAFC). For the demersal stocks the conclusions have been quite clear, but considerable doubt still remains concerning the precise status of the herring stocks. Another ICES group is now considering the North Sea stocks; assessments have been made also by individual scientists. Little work has, however, been published concerning the southern stocks, or those to the west of the British Isles. The present state of knowledge of the stocks in the various areas is given below.

5.4 Northern Area (Greenland to Barents Sea)

(a) Separation of stocks

Deep water maintains the separation of the major demersal stocks (cod, haddock, plaice and possibly coalfish) - those at Iceland (but there is significant movement of cod between Iceland and East and West Greenland), the northeast Arctic (Barents Sea, Bear Island-Spitsbergen, and northwest Norway), and Faroes (where the stocks on Faroe Bank are largely separate from those round the Islands). There is some interchange of coalfish between these areas, and with the stocks round the north of Scotland (ICES 1965 a). The separation of redfish stocks is not known, particularly regarding the relation of the stocks now exploited on the continental shelves with the large number of larvae found over deep water (Henderson 1965), though it is probable that the stocks in the northwest are separate from the others.

There are separate groups of herring with both spring and summer spawning. Spring spawning in the area occurs off the west coast of Norway, south Iceland, and on the Faroe plateau. Summer spawning occurs mainly along the south and west coasts of Iceland. Though separate at spawning time they mix on the feeding grounds north and east of Iceland. Herring from the Atlanto-Scandian stock of herring also spawn on the north-eastern and northern edges of the North Sea Shelf, and off the north and west of Scotland (ICES 1966 b, Annex II). When caught on these grounds they will appear in the total catch statistics for the North Sea or west of Scotland, but they are quite distinct from the North Sea stocks.

With these exceptions there is probably little movement into or out of the area.

(b) Demersal stocks in the northeast

Cod and haddock

The state of the cod and haddock stocks in the northeast has been reviewed by the ICES Arctic Working Group (ICES 1966 b, Annex I). This showed that both stocks had been greatly affected by fishing, and thatincreased average catches could be achieved only by reducing the amount of fishing, or by protection of the small fish (e.g. use of larger effective mesh size by trawlers). The actual average catch will depend on the recruitment; for cod this appears to be related to the parent stock, with maximum recruitment possibly occurring at an intermediate parent stock (Garrod 1966). Between 1945 and 1963 the average cod catch was 800,000 tons. These catches include an element from the reduction in standing crop as well as from current production, but allowing for better management, the possible annual catch from year-classes with the same average strength as those in the fishery between 1945 and 1963 (i.e. those from about 1937 to 1958) is in the range 800,000 - 1,000,000 tons. If, however, the stock/recruitment curve has the dome shape suggested by Garrod, then if the adult stock is maintained at the level giving the greatest average year-class, the year-class strength might be 25% above the 1937-58 average. This, unless there are other density-dependent effects, e.g. reduced growth such as suggested by Ponomarenko, 1967, would give possible average catches of 1 to 1.25 million tons. Also, if adequate management measures are not introduced, and the adult stock remains at this present low level, then average recruitment may also remain very low, and average catches be perhaps no more than 300,000-500,000 tons.

Less is known concerning the state of the haddock stocks; but the available evidence suggests that with proper management average catches could be rather higher than the recent average, say, a potential 200,000 tons.

Coalfish

The state of the saithe (coalfish) stocks has been examined by the ICES coalfish working group (ICES 1965 a). This could not reach any very precise estimates of the effect of fishing. Unlike the cod and haddock, whose main area of feeding and growth is the Barents Sea, it appears that the main area for juvenile coalfish is along the western Norwegian coast, where they are fished by purse seines. Catches fluctuate considerably, largely due to real changes in abundance (year-class strength) (Olsen 1966). These fluctuations tend to mask any relation between catch per unit effort and effort. Estimates of total mortality coefficient average around 0.5-0.6; estimates of fishing mortality from tagging are 0.2-0.3 (ICES) though the age-composition of Polish catches in 1967 (Draganik 1967) suggested a higher total mortality of 0.99. This suggests that moderate increase in fishing, from the level of the early 1960s, would give increased yield. An examination of Beverton and Holt's (1964) yield tables for $E = {}^{F}/(F + M)) = 0.4-0.5$ suggests that the fishing effort might be as much as double, though this probably would only increase the catch by perhaps 30-50%. The average landings from 1954-63 were 14,000 tons in region I, 106,000 tons in region II, 800 tons in IIb. A rough estimate of the potential average catch is therefore 120,000 x 1.4 = 175,000 tons. The fact that increased abundance is correlated with reduced growth (Olsen 1966) suggests that food is a limiting factor.

Redfish

Less is known of the redfish stocks. Catches since 1951 have fluctuated between 109,000 tons (in 1959) and 26,000 tons (in 1962), with an average of 62,000. The decline from the 1959 peak suggests that fishing has seriously reduced the stocks, though the magnitude of the decline may be due more to reduced effort than reduced catch per unit effort. The supposition that the stocks are fairly heavily fished is supported by the analysis of Sorokin (1964) based on changes in the sex ratio. Potential average annual catches may be in region 50-100,000 tons.

Other exploited demersal species

The only other demersal species the subject of a specific fishery is the Greenland halibut, fished in deep water. This probably accounts for the major part of the catches of various Pleuronectiformes reported landed by Norway from region IIa which have increased from 10,000 tons in 1962 to 17,500 tons in 1965. The substantial catches of 'halibut' reported by USSR in the Bulletin

Statistique - 5,000 tons in IIb, and 11,000 in IIa in 1965 - are probably not true halibut, but also Greenland halibut. There are no good data for stock assessment though in view of the probably long life of the fish it is doubtful if the average potential yield is very high. Possibly the large Norwegian catches are from an accumulated stock and cannot be maintained. A figure of 20,000 to 40,000 tons might be guessed. A somewhat less specialized fishery is that for plaice in the Barents Sea, especially off the North Russian coast, off Cape Kanin. This was the first stock exploited in the area (Atkinson 1908), and specialist English skippers make occasional trips specifically for plaice. The stock is probably heavily exploited (Gulland 1964) and the potential yield, with proper management, is rather above the recent average. This is difficult to establish exactly because in the USSR statistics plaice are combined with other flatfish, and sometimes recorded in the Bulletin Statistique as 'plaice' and sometimes as 'other Pleuronectiformes'. This potential is probably at most 5-10,000 tons.

Halibut catches, assuming the reported USSR catches are mainly Greenland halibut, are small, ca 4,000 tons. No appreciable increase seems possible.

A variety of other demersal species, ling, tusk, catfish (wolffish), etc. are landed, mainly caught incidentally to the cod fisheries, to a total of ca 50,000 tons. These are all large and long-lived and are probably quite heavily fished. It is unlikely that any great increase can be achieved.

(c) Demersal stocks in the northwest (Faroes to East Greenland)

The state of the major stocks at present exploited has been reviewed by the ICES north-western working group (ICES 1966 a). This group which was chiefly concerned with the probable effects of increase in trawl mesh size concluded that these stocks are generally heavily fished, in agreement with other published studies by individual scientists, e.g. Russel (1942), Parrish and Jones (1953), Jonsson (1960), Gulland (1961), Jones (1966) and by the previous ICES group (ICES 1962).

Cod and haddock at Iceland were considered to be so heavily fished that further increase in fishing would not increase the long-term average catch, though such a small increase might result from a moderate decrease in effort. Small increases would be achieved by better protection of young fish, e.g. by using a larger mesh size. This might raise the average annual catch to around 500,000 tons of cod, and perhaps 75-100,000 tons of haddock, depending on the strength of year-classes. There is some evidence that a reduced adult stock of Icelandic cod results in smaller year-classes (Jonsson 1966); if so, proper management might result in rather greater yields than above, and more particularly without management there is likely to be a further decline in catches.

Cod and haddock at Faroes (including both the Faroes Banks and Plateau stocks) are also heavily fished, but changes in fishing effort were not explicitly considered by the ICES group. Jones (1966) concluded that a moderate decrease in effort would give a slight increase in yield of cod, and the same is probably true of haddock. Average catches slightly above the recent average should be possible, say 35,000 tons of cod, and 25,000 tons of haddock, though actual catches in any year, particularly of haddock, will depend greatly on the strength of the year-classes.

The cod stocks at East Greenland are less heavily fished, but the total stock is probably small and potential catches are unlikely to be much greater than recent catches, possibly as much as 25,000 tons.

The state of the coalfish stocks is, as noted for the north-eastern area, less well known (ICES 1965 a). They are probably less heavily exploited than cod or haddock, but tagging experiments off North Iceland, which gave 30% recaptures in the local purse-seine fishery within 12 months (Jonsson and Jones 1965) suggest at least a locally high fishing rate. Probably increased fishing, especially on the larger fish - the fish caught for tagging in the purse-seine fishery were nearly all between 40 and 62 cm (1964), or 40 and 68 cm (1965), while the offshore English and German trawl catches, at least in 1955-9 ranged up to 120 cm, with males around 70-80 cm (ICES 1965 a, Fig. 9) - would give some increase in average catches, possibly as much as 50-100% above the recent level, i.e. perhaps up to 100,000 tons at Iceland, and 20,000 tons from Faroes.

The ICES group considered that fishing had caused a real decline in redfish stocks at Iceland and East Greenland. Total catches from Iceland declined from a peak of 170,000 tons in 1951 to 70,000 tons in 1961, though they have recovered to 114,000 tons in 1965. Some of these changes are directly due to changes in effort (Icelandic fishing for redfish has decreased greatly, while the attention of German trawlers has to some extent been diverted from redfish to cod), so it is by no means certain that 170,000 tons is more than can be maintained as a long-term average annual catch though for a long-lived fish such as the redfish the annual yields from the accumulated stock present when the fishery starts may be appreciably greater than the potential average catch over a period. Probably the greatest average catch would be taken with an effort rather greater than the present (1965), and would be in the range 150-200,000 tons: the potential yields from East Greenland and Faroes may be 30-50,000 tons and 10,000 tons respectively. These estimates only refer to the grounds presently exploited on the continental shelves - down to 200-300 fms. Judging by distribution of larvae there are redfish over the ocean depths which may provide large additional catches.

Other demersal species - plaice, lemon sole, halibut, catfishes (wolffish), ling, tusk - make smaller contributions to the demersal catch, some (e.g. plaice, halibut) supporting specialized fisheries. Most of these show signs of heavy fishing, at least at Iceland (Gulland 1961), and catches could be increased by better management. Such increases would be only moderate, perhaps increasing the total catch of these species from the figures of 55,000 tons in 1965 to perhaps at most 75,000 tons.

(d) Herring

The Atlanto-Scandian herring stocks have shown great fluctuations including a long-term cycle of the order of 100 years during the several centuries that they have been exploited. Some of these are certainly due to year-clss changes; weak year-classes from 1951 to 1958 led to a decline in catches, which recovered when the strong 1959 year-class recruited to the fisheries. The absolute level of catches in any future year therefore depends more on the (atpresent unpredictable) strength of year-classes, than on the amount of fishing. Estimates of the stock size of the Norwegian spring-spawning stock from tagging and direct acoustic counting suggests that in the 1950s fishing took about 10-20% of the stock (and thus accounted for about half the total deaths). Fishing effort on this stock has since increased, and it appears that the fishing is at least as heavy on the other elements of the Atlanto-Scandian herring - the Icelandic spring and summer spawners (ICES 1966 b).

It is therefore unlikely that any substantial increase in average yield per recruit can be achieved by increased fishing and some minor increase might be achieved by suitable management, e.g. protection of the small fish (now caught in the smasild fishery), or a slight reduction in fishing on the most heavily fished elements. The actual catch will depend on year-class strengths; at recent levels these have resulted in annual catches of around 1.5 million tons.

(e) Capelin

Substantial catches of capelin are taken both at Iceland (50,000 tons in 1965) and northern Norway and USSR (220,000 tons in 1961 and up to ca 500,000 tons in 1967, but only 3,700 tons in 1962). Knowledge of the fishery has been reviewed by Moller and Olsen (1962) and Olsen (1964). The often very large fluctuations in catches are due in part to year-class fluctuations, and partly to changes in the timing and place of the migration to the inshore spawning areas where they are caught. There appears to be very large post-spawning mortality though some fish may spawn twice (Prokhorov 1960), so that fishing has little effect on the stock coming to spawn in the immediately following year. The proportion of the spawning stock taken by the fishery is not known, nor is anything known of the possible stock/recruitment relationships. Olsen (1964) has estimated the abundance of the spawning stock in relative terms, but this cannot as yet be expressed in actual tons of fish.

(f) Other resources

Most of the species caught incidentally when fishing for the other species (cod, redfish, etc.) have already been considered. Probably the biggest resource among trawl-caught fish is the long rough dab, which is caught in moderate numbers (up to ca 200 kg in trawl hauls over most of the area).

Cod is the main large predatory fish in the area. Stomachs of smaller cod contain mainly invertebrates (reference ?); larger cod also eat invertebrates but also fish - including small cod, capelin, herring, polar cod (Boreogadus saida) etc. Most of these species have already been considered above, and the data do not suggest the existence of any large unknown potential. Nor is the probable quantity eaten of capelin or herring (say 10% of 10 times the present production of cod, equals 1 to $1\frac{1}{2}$ million tons) so very much larger than the present catches of these species as to suggest that they are greatly under-exploited.

In the Barents Sea detailed surveys of young fish have been carried out internationally - in 1965 by USSR and Norway and in 1966 and 1967 by USSR, Norway and UK (Anon. 1965, 1966, 1967).
Though designed primarily for surveying the abundance and distribution of 0-group herring and cod, information is given on other species. The surveys were carried out by echo-survey, supplemented by pelagic trawling. The 1966 results are presented as charts of the distribution. 0-group cod, haddock and saithe were scarce, occurring only at scattered individual stations and were not contoured; herring were more abundant occurring along the north Norwegian coast, and in a few stations near Bear Island and were contoured at one level of abundance. In contrast four species - redfish, capelin, long rough dab and polar cod - were sufficiently abundant over a wide enough area to be contoured at two levels of abundance. 0-group fish of some other species were found in smaller numbers - including catfish, Lumpenus, Cottidae and Myctophidae. The

results must be interpreted with some caution because of the very great year-to year fluctuations, at least for some species, e.g. cod, as shown by the USSR surveys of young cod carried out over the last 20 years. It is believed that the relative scarcity of cod, herring and haddock is due to 1966 being a poor year, likely to lead to extremely poor 1966 year-classes, rather than representing the normal average abundance of these species. The very low strength of the 1965 and 1966 year-classes of cod is shown clearly in the later catches of 1 and 2 year old fish in later trawl surveys (Nizovtsev 1967). Thus, for example, the surveys of cod larvae (in May only) and of O-group fish on the bottom in winter, reported by Baranenkova (1966) for the 1959, 1960 and 1961 year-classes, though not comparable quantitatively with the present surveys, do produce distribution charts looking very like those for capelin etc. in the 1966 surveys. Comparison of the numbers in 1966 of O-group cod, haddock and coalfish with those of redfish, capelin, long rough dab and polar cod is therefore likely to give a misleading impression of the abundance of the latter. More interesting may be a comparison of redfish with the other three.

Redfish were by far the most abundance pelagic echo-scatterers in the western Barents Sea. This dominance may be compared with the dominance of larval redfish found in the plankton between Newfoundland and Iceland (Henderson 1965), though it is clear that in the present area these young fish come from a stock that is presently exploited. An examination of the quantitative distribution of larval redfish in the south-eastern Barents Sea, and comparisons with the larval numbers in the western Atlantic and with the commercial catches in both areas may give a better measure of the potential new resources, if any, represented by the larval redfish over the oceanic depths. A comparison with redfish, based on larval and O-group catches, may however underestimate the potential yield of capelin and other species. Redfish are very longlived, and the fishing mortality to give the greatest long-term yield is likely to be low. Thus the proportion of the stock taken each year for optimum harvesting, and hence probably also the ratio of potential yield/larval or O-group abundance, is small. Also the estimate of potential yield of redfish is not a very precise one.

However, it seems unlikely that the O-group/potential yield ratio differs so much between species, and that the real potential yield of redfish differs so much from its estimated value, that the potential yield of capelin differs by more than an order of magnitude from the figure of 50-100,000 tons estimated for redfish. Therefore it is possible that 500,000 tons of capelin reported for the Norwegian spring season of 1967 (which was in fact limited by processing capacity, not by catching capacity) may be approaching the potential of the stock. The potential for long rough dab, a quite long-lived species, and for polar cod, are probably rather less than for capelin.

The joint survey also recorded echo-traces from larger fish. Apart from the species already considered, adult blue whiting were recorded along the eastern boundary of the Norwegian Sea. No quantitative estimate can be given of the magnitude of this resource .

In the north-western area there have not been similar published surveys of young fish. Joint echo-surveys for herring have covered wide areas to the north and east of Iceland, and apparently most of the traces recorded could be considered as herring (e.g. Malmberg et al 1965, 1966). However, large concentrations of Micromesistius poutassou were found off the east coast on at least one occasion in 1965. Incidental trawl catches have included this species and occasional catches of argentines. Norway pout are common at Faroes, and west and south Iceland (Raitt 1966a, Saemundsson 1949, Kotthaus and Krefft 1957).

There is no comprehensive published survey of the quantitative distribution of eggs and larvae. G.C. Williams (personal communication), in analyzing the data collected by Einarsson has found that round Iceland long rough dab eggs and larvae were very abundant, around twice as abundant as any other fish.

These egg and larval data would suggest the presence of four possibly substantial under-exploited stocks - Gadus poutassou, argentines, Norway pout and long rough dab. There is no good ground for quantitative estimate, but a rough comparison with other catches suggests that potential yields of each species are probably within an order of magnitude of 100,000 tons.

5.5 North Sea

(a) Separation of stocks

The North Sea is large and partly enclosed; including the Skagerrak there is little interchange to the east (Baltic, Belts). Some fish move through the Straits of Dover, notably the Downs herring which spawn in the Eastern Channel, though spending most of their life in the North Sea. This stock is now small, but analysis of past data should include Channel herring catches in the North Sea; otherwise the interchange at the southern end is probably small enough to ignore.

At the north, deep water and narrowness of the shelf along the Norwegian coast limits appreciable movement of demersal fish along the West of Norway. There is, however, evidence of greater movement of some species, including haddock along the Scottish north coast, and of interchange with stock there, and to the west of Scotland, but in total this is not a large proportion of the North Sea catches or production. Movement of pelagic fish is probably much more extensive. Catches of Atlanto-Scandian herring along the Norwegian coast have been included in past statistics of the North Sea fisheries, but should be excluded from consideration of the production of the North Sea. The past statistical data for herring (probably also mackerel) should be therefore treated with care.

Within the North Sea populations of most of the important species can be divided into two or more distinct stocks, e.g. herring (Cushing and Bridger 1966), plaice (de Veen 1962), sole (ICES 1965 b), cod (Bedford 1966) and whiting (Knudsen 1964, Hannerz 1964 and Prims 1966). For herring it is clear that the major stocks must be assessed separately, but for the others, or at least the plaice, it is possible that there are sufficient similarities in the pattern of exploitation for the stocks of each species within the North Sea to be treated as a single unit (Gulland, in press).

(b) Flatfishes

Plaice - very good knowledge. "Overfished" in the 1930s but fishing in terms of both total effort and effective size at first capture probably now gives close to the greatest average annual yield, which is about 100,000 tons. Total production is limited more by numbers of recruits than by supply of food to adults, judged by the moderate changes in growth with changes in stock abundance (Wimpenny 1953, Beverton and Holt 1957, Gulland in press).

Sole - very good knowledge. Fishing is probably close to optimum. Actual yield subject to fluctuations, and tending to increase over the past 50 years (ICES 1965). Potential average annual yield is 15-20,000 tons.

Dab - moderate knowledge. There is no fishery specifically for dabs, which do not grow to a large size. Any extension of fishing for small dabs would almost certainly involve destruction of small plaice, and an overall loss in yield. Much of the production going into dabs is therefore inaccessible at present, though this production is probably very much larger than the reported catches (ca 6,000 tons). (Fishermen often suggest that scientists should kill off the dabs to give a better production of plaice).

Other flatfish (turbot, lemon sole, etc.) - moderate knowledge. Probably in a similar state to plaice and sole, i.e. present catches (16,000 tons) close to maximum.

(c) Gadoids

Cod - good knowledge. "Overfished" in the 1930s (Graham 1948), less heavily fished now, at least in central North Sea (MAFF), but still apparently heavy, and probably too heavy, fishing on the small cod in some western areas (Bedford 1966, Symonds and Raitt 1966, Symonds and Raitt 1967). The average catch could probably be increased by more rational fishing; the 1965 catch (195,000 tons) was, however, much above the recent average, and was probably the greatest ever taken. This high catch was probably due to transient effects, particularly some good year-classes. It is doubtful if even with proper management this catch could on the average be maintained. The potential average annual yield is possibly 150,000 tons.

Haddock - good knowledge. Has undergone long-term fluctuations (e.g. the catch declined from over 200,000 tons in 1920 to 50,000 tons in 1950, due mainly to a drastic reduction, probably from natural causes, in the stock in the southern part of the North Sea). There are also large fluctuations in year-class strength, a recent (1962) year-class being outstanding, giving the near-record catches of 220,000 tons in 1965 (Jones 1966). Better management, especially better protection of the young fish, e.g. by a larger mesh size, would increase the average catch, probably by between 40% and 100% (Parrish and Jones 1953, ICES 1956). The greatest average sustainable yield might be 100-200,000 tons, but the catch in one year, or over a short period might be very different. Reduction of growth rate for strong year-classes suggests that haddock are using a good proportion of the available food (Beverton and Holt 1957), but by no means all of it (see section 6.2).

Norway Pout (Trisopterus esmarkii) - some knowledge (Raitt 1966a). Fishery based on one or two year-classes, with no clear evidence of the effect of fishing. Catches have fluctuated, with peak in 1963 (185,000 tons) with 1965 catches under 70,000 tons. (Some at least of these fluctuations are due to effort changes (Raitt in press)). No useful estimate of potential yield. There seems, on the basis of very few years, to be negative correlation between year-classes of Norway pout and haddock.

Saithe (Coalfish) - moderate knowledge. Generally, at least until recently, less heavily fished in Northeast Atlantic than cod or haddock, but signs of fishing now becoming apparent (ICES 1963). Probably moderate further increase in catches possible; possible yield perhaps 100,000 tons (North Sea stocks probably closely linked with West of Scotland and Norwegian coast stocks).

Whiting - moderate knowledge. Probably moderately to heavily fished, and only moderate increase in catches possible. Yield perhaps 150,000 tons.

Other large gadoids (hake, ling, pollack, tusk) - moderate knowledge. All probably moderately to heavily fished, some slight expansion in catches possible. 1965 catches: hake 3,600, ling 10,500; pollack 3,200; tusk 2,500; total 19,800 tons. Potential yield is perhaps 25,000 tons).

Other small gadoids (blue whiting, pout whiting) - some knowledge (Raitt 1966 b). Present catches for meal are probably a small fraction of potential yields, though the main potential is outside the North Sea.

(d) Other demersal species

There is a poor knowledge of any of these. Several species (catfishes, anglers, redfish etc.) are caught in small numbers by trawl, and by analogy with cod, haddock, etc., are probably heavily fished. 1965 catches were catfish 1,800 tons; anglers (monk) 4,700; redfish 500; breams 200; total 7,200 tons. The potential annual yield of all these combined is probably less than 10,000 tons.

Gurnards occur frequently in small numbers in trawl catches; landings are probably only a fraction of actual catch. Like dabs, they are not very attractive commercially in some countries for human consumption, nor do they occur in sufficient concentrations as a basis of industrial fishery. The potential yield is much higher than the 700 tons landed.

Sandeels - moderate to poor knowledge. Fishing is very localized, and in small areas the effect of fishing can sometimes be detected, but the present fishery covers only a part of the whole North Sea (Macer 1966). The potential yield is probably considerably greater than the present catches of 100-150,000 tons.

(e) Pelagic fish

Herring - moderate to good knowledge. There is considerable scientific argument about the precise state of the stock particularly regarding the long-term effects of fishing; but fishing clearly is a major cause of mortality in the stocks in the southern North sea, though it is not agreed by scientists whether it has also affected the recruitment. With the recent increased fishing in the northern North Sea the fishing effort on the stocks is probably approaching the level where any further increase in effort will give no appreciable increase in the average annual catch. 1965 catches, including the Skagerrak, were 1,470,000 tons, but this probably includes some Atlanto-Scandian herring (perhaps 5%). The potential yield is probably less than 2 million tons, perhaps1,500,000 tons. It should be noted that the stock of herring spawning in the southern North Sea and eastern English Channel, which used to provide catches of over 200,000 tons, has declined to negligible proportions. If this stock does not recover the total North Sea potential will be reduced. Some scientists believe that this total is no more than 900,000-1,000,000 tons. Year-class fluctuations are less important than in the Atlanto-Scandian herring.

Sprat - moderate knowledge. Fishing is localized and coastal. The recent increase in catch (75,000 tons in 1965) compared with 21,000 tons in 1953) seems due in part to a real increase in stock or at least the availability to the fishermen. In some areas, e.g. Wash, the stocks are moderately heavily fished, but in others a large increase in catch may be possible. The potential yield is almost certainly subject to wide natural fluctuations, but under present circumstances is probably at least 150,000 tons. Estimates from egg surveys (Johnson, personal communication) of the stock size in the North Sea is from 65-650,000 tons. The potential yield might be half this.

Tunas - moderate knowledge. Only bluefin caught, and only in small quantities, potential yield not more than a few thousand tons.

Mackerel - moderate to poor knowledge. There was a very large increase in catch in 1965 (200,000 tons) and still more in 1966 (500,000 tons) - compared with 120,000 in 1964, and 40,000 tons in 1953, due to the rapid expansion in the Norwegian purse seine fishery. The stocks were certainly underexploited before 1963.

Horse mackerel - poor knowledge. Present landings of 5,000 tons probably well below the present catch, because of discards, and even further below sustainable yield. This fish is rarely sought deliberately by the fishermen.

(f) Others

Dogfish, skates, rays, etc. - variable knowledge, good for picked dogfish. The northern stock of dogfish (which is caught also in West of Scotland and Norway coast areas) is overexploited. Probably by analogy with cod and plaice the other species of commercial importance which are mainly caught by trawl are also heavily exploited. Because of the small number (3-15) of young produced per female the dogfish stocks are particularly susceptible to overfishing (Holden 1967). The potential yield from all these stocks is probably not much, if at all, larger than present catches (36,000 tons) - say at most 50,000 tons.

Unsorted and unspecified - some 150,000 tons of unsorted fishes were landed in 1965. Most of these were herring for industrial purposes.

(g) Other evidence of resources

The most recently published results from trawl surveys are by Sahrhage (1964), giving the results of surveys in the summers of 1959 and 1960 (results of surveys in the winters of 1962 and 1963 will be published late in 1967). The distribution and abundance of the major commercial species agree well with the data from commercial catches, but certain species occurred in quantity in the survey, but not in the commercial landings. The most frequent were as follows:

Long rough dab (Hippoglossoides platessoides) - catches of several thousand per haul north of the Dogger.

Blue whiting (Micromesistius poutassou) - large numbers (up to 3,000 per haul) along the edge of the Norwegian deep water.

Argentines (Argentina silus and A. sphyraena) - up to 1,000 per haul in northern North Sea (north of 57°).

Horse mackerel (Trachurus trachurus) - up to 2,300 per haul in southern area (south of 56°N), and smaller numbers along the Scottish coast.

The surveys also confirmed the considerably greater abundance of gurnards than is suggested by the small quantity landed. Scottish research vessel surveys in the northern North Sea agree with this list of species, but show common dab and gurnard as also common (Parrish, personal communication).

Though no full echo-survey of the North Sea has been published, both research and commercial vessels run their echo-sounder while working or on passage in the North Sea and there has been no suggestion of any substantial quantity of traces which cannot be ascribed to the well known pelagic species - herring, mackerel, etc.

Extensive data are available on egg and larval distribution, including a few general research surveys, special surveys on certain species (especially plaice), and plankton recorder surveys.

In qualitative terms these show that the abundance species are either the fish (herring, cod, haddock, plaice, etc.) which have long been exploited for human consumption, or the smaller fish (sandeels and Trisopterus esmarkii) for which special fisheries for industrial purpose have recently been developed. No large quantities of eggs or larvae have been found of species which are as yet not exploited.

Further analysis of these data is desirable to determine a quantitative relation, if only rough, between eggs or larvae and sustainable yield. Henderson (1961) gives data on the distribution of larvae in plankton recorder catches round the British Isles (excluding the Irish Sea and English Channel). These data are summarized in Table 1, which also gives data on catches in 1965. The data are in the form of average number or larvae per sample within each area. Assuming perfect filtration each sample corresponds to $3m^3$. The size of most areas was 1 degree of latitude by 2 degrees of longitude, i.e. approximately 4,000 sq.n.ml or 14,000 sq. km. The data give the distribution of larvae at 10 m (the depth of sampling), and if it is assumed that the larvae are equally distributed down to 100 m, then the number per m^2 will be $\frac{100}{3}$ x number per sample, i.e. the total number in each area will be equal to:

$$\text{number per sample } \frac{100}{3} \times 14{,}000 \times 10^6 = 4.7 \times 10^{11}$$

(more precise estimates may be obtained by correcting for different sizes of the areas and using different estimates of the depth to which the larvae are dstributed). Plates XXX to XXXIII of Henderson's paper can now be used to estimate the mean number of larvae present during the year (except for Stomias boa ferox and Gadus poutassou which are mean numbers present in March, April and May), by adding up the numbers in each area.

These figures are given in Table 1 (the clupeoids to the southwest of England were presumed to be pilchards, and elsewhere herring and sprat, and the figures for G. poutassou and S. ferox have been divided by four to correct for being present for only one quarter of the year), expressed as average numbers present in the area. Also given are the 1964 catches from the area (regions IV, VI and VII of ICES), and the tons caught per 10^9 larvae.

Table 1

Catch of fish and estimated number of larvae from the waters round the British Isles

	Larvae x 10^{-11}	Catch thousand tons	Tons per 10^9 larvae	Notes
Clupeoids	118.9	1451	122	
(Herring and sprats)	104.9	1448	138	
(Pilchard)	14.0	3	2	Not fished intensively in area
Ammodytes	73.7	129	18	Only fished in southern North Sea
Mackerel	57.4	112	20	Lightly fished - 1965 catch was much larger
<u>Micromesistius poutassou</u>	41.1	-	-	Not fished
Coalfish	12.4	74	60	Catches could probably be increased
Common dab	8.2	5	6	Not exploited; only large specimens among incidental catches landed
Whiting	6.8	137	201	
Plaice	6.4	120	188	
<u>Stomias b. ferox</u>	4.6	-	-	Not fished
Witch	2.3	2	9	
Cod	1.9	158	832	Larvae probably underestimated
Lemon Sole	1.0	11	110	

For most of the species believed to be fully exploited catches are fairly constant in the range 100-200 tons per 10^9 larvae. This relation suggests sustainable yields of 300,000 tons of blue whiting; 350,000 tons of sandeels; and 550,000 tons of mackerel. Most of the larvae of blue whiting and mackerel were outside the North Sea.

Taken together the various data suggest that apart from certain species (horse mackerel, blue whiting, etc.) occurring mainly at the boundaries, including macrurids and others in the deep water (ca 500 m and deeper) in the north, which may be best considered in other areas, there are no major unexploited species in the North Sea. Catches and landings of some species - sandeels, long rough dab, gurnard - might be expanded.

(h) Molluscs and crustaceans

In 1965 the catches from the North Sea were 70,600 tons of crustaceans (including 47,800 tons of shrimps), and 150,000 tons of molluscs (including 135,000 tons of mussels). Virtually the whole catch is taken in coastal waters and may be considered separately from the production of the main, offshore, part of the North Sea. Knowledge of offshore resources from benthos surveys is comparatively good; none of the numerous molluscs seems at present commercially attractive, and the only attractive crustaceans are Pandulus borealis (in deep water) and Nephrops. 1965 catches of these species were 15,000 tons, and are probably capable of moderate expansion, possibly to 50,000 tons. These resources are considered in detail elsewhere.

5.6 Waters to the west of the British Isles

(a) Stock separation

The physical characteristics of the region do not provide clear boundaries to the stocks. There are significant interchanges with stocks both to the north, round the north of Scotland (certainly for haddock, and probably other demersal stocks - but not Norway pout (Raitt 1965) - dogfish, and to some extent herring), and to the south (e.g. the adult pilchards found in the English Channel in the summer may migrate from south of Ushant). Interchange with the North Sea through the Straits of Dover does not seem to be large - North Sea herring move into the eastern channel to spawn and there is some movement of small local stocks of demersal fish, e.g. cod (Bedford 1966) and of pilchard and anchovy into the North Sea in summer. Within the region some divisions of stocks are known - most of the fish stocks in the Irish Sea seem to be separate from those outside - but for most species the possible stock separation in the area open to the Atlantic from the north of Scotland to Ushant have not been studied in detail. The statistics for this region are also not as good as in other parts of the ICES area; as noted earlier part of the Spanish catch recorded in regions VIII and IX probably comes from this region. Also there are some doubts about the precise location of some other catches and generally poor statistics of fishing effort. Mainly for these reasons there are few good assessments of the stocks in this region.

(b) Demersal stocks

The hake was studied in detail by Hickling before and just after the war (Hickling 1934, 1946), who showed that it was overfished. Subsequent events have done nothing to throw doubt on this conclusion, though detailed analysis has been difficult because of statistical shortcomings. Average catches could be increased by suitable management measures (less fishing, and better protection of small fish), probably to appreciably above the present level. The latter is now known. Reported catches from the region (excluding Spain) were, in 1965, 20,000 tons. If Spanish catches were as much again, this would suggest potential average catches of 50,000 tons.

The major haddock catches in the region come from the West of Scotland. These include an element of fish moving from the North Sea (Jones 1959). A recruitment of larger fish from the North Sea may account in part for the rather larger size of haddock from the westerly grounds compared with the North Sea (e.g. Anon. 1962 ca) but the difference may also in part be due to less fishing on these grounds as well as possibly to a faster growth. Changes in catch per unit effort of haddock by British vessels during and just after the war did not fit in with expected changes in a heavily fished stock, though changes in fishing tactics, following the recovery of the hake stocks, may have had an important effect. Probably the west coast haddock is less heavily fished than the hake, or the haddock in the North Sea. However, in view of the local concentrations of Scottish seiners inshore, which fish mainly for haddock, it is unlikely that the stocks are not at least moderately heavily fished. Probably, therefore, the average catch of haddock from the West of Scotland grounds could be at best only increased to a moderate extent, though it is not known whether this would require a restriction of fishing, or a moderate expansion. Recent catches are, as in the North Sea, very high because of the outstanding 1962 year-class. Potential annual catches from average recruitment are probably around 15,000 tons.

In the other areas of the region where haddock are caught (south and west of Ireland), even less is known of the state of the stocks. There is no intense local fishery corresponding to the Scottish seining in the Minches, so probably the effect of fishing is less. Probably therefore average catches could be increased by greater fishing.

The <u>cod</u> fisheries are probably in a similar condition regarding both exploitation, and state of knowledge, as the haddock. As judged by tagging returns (53% recapture) (Beverton <u>et al</u> 1959), the fishing intensity in the Irish Sea is at least locally very high. Potential average annual catches are probably not much above the present - say 50,000 tons - and to catch this would require about the present effort.

The <u>whiting</u> fishery in the north-western part of the Irish Sea has been studied in detail by an international working group - the only one to date which has dealt with problems of stock assessment in this region (Garrod <u>et al</u> 1965, Garrod and Gambell 1965). They showed that in the local County Down fishery, fishing is so intense that total catches would be increased by the use of a larger mesh size. However, this is only a local fishery, mainly on immature fish. The mature fish move out of the area and the fishing mortality on the mature stocks is not known, nor is the proportion of the total recruitment to the adult stocks coming from the County Down fishery. Thus it is possible that the average total catch of whiting might be increased by more fishing on the adult fish - though these appear to be more dispersed than the immature, and less able to support an economic fishery - combined with some regulation of the immature fishery. Similar considerations probably also apply to other parts of the region - there is an intense fishery in the Clyde which corresponds to that off County Down (Garrod and Gambell 1965). In this area too the absence of old, large fish from catches is believed to be due as much, if not more, to emigration as to heavy local fishing. This suggests that catches of the larger fish, which are probably dispersed in the Irish Sea and to the west of Scotland,might be increased.

There is no suggestion of major unexploited stocks, though most probably catches to the west of Ireland could be increased. Probably the potential average catch is slightly above the present - say 50,000 tons, with overall not much change in effort, though more on the older fish and less on the younger would be necessary.

The saithe (coalfish) caught in the northern part of the region are connected with the stocks further north. Except that there is no local purse-seins fishery for medium-small fish, similar remarks apply; the average catch would probably be increased by increased fishing, but probably not to any great extent (say to 30,000 tons).

Ling, though mainly caught incidentally by trawlers, is probably at least moderately heavily fished, with no great potential increase in the average catch.

Various flatfishes (lemon soles, sole turbot) are caught in moderate quantities throughout the region. Though not studied in detail there is some evidence that these stocks are moderately heavily fished.

Williams (1965) found percentage returns of soles tagged in the Irish Sea (17%) and Bristol Channel (12%) which are not much less than the 17-23% found with similar tags (Peterson discs) in the heavily fished North Sea (Williams 1963). It is improbable that the present catches of flatfish (33,000 tons in 1965) can be greatly increased - possibly to 40,000 tons, by increased fishing on some stocks and better management of others.

Several other demersal fish are caught in small quantities. Spiny dogfish probably come from the same stock as the North Sea (see above); stocks of conger eel and angler monk are probably small; the sea bream probably are connected with stocks further south and will be discussed later.

(c) Pelagic fish

The herring fisheries to the west of Scotland have been reviewed most recently by Saville et al (1965). They found no clear evidence of heavy fishing, and concluded that much of the fluctuations of catches between 27 and 108,000 tons before the war, and 33-78,000 since the war, were due to changes in effort and not in stock. Surveys of adults and larvae by British research vessels have suggested quite a large stock in this area (Cole 1966). The total number of larvae found (1.26×10^{12}) was about the same as found in the southern North Sea in 1947-8, when catches in that area were about 200,000 tons, not including catches from the same stock in the central North Sea. Average catches in this area, including the grounds to the west of the Hebrides, can almost certainly be increased by more fishing, possibly to around 200,000 tons.

Burd and Bracken (1965) have studies the Dunmore stock off southeast Ireland, and concluded it is heavily fished, with a potential annual catch of 12-15,000 tons. The herring stocks in the Irish Sea are probably in a similar state, and not much more than the present catch, i.e. ca 10,000 tons, can be taken. It is not known whether the present very small catches from off the west coast of Ireland can be increased.

The mackerel stocks are related to those supporting the rapidly developing Norwegian fishery in the northern North Sea, and any catch in the present region would to some extent be at the expense of the potential yield in the North Sea. The same probably also applies to the pilchard which migrate into the English Channel (and sometimes also the southern North Sea) from southern waters. Sprat catches are at present small, but could be appreciably increased.

(d) Other evidence of resources

Incidental catches, by trawlers and others, of fish other than those now mainly exploited are not common in shallow water, less than ca 200 m. In deeper water a wide range of species are caught, some in fair quantities. These include fish which might reasonably be used for human consumption - argentine, breams, etc., as well as less attractive fish - macrurids, etc. Since, at these depths (between say 200 and 1,000 m) the bottom slopes steeply, the total area concerned, and therefore probably the potential yield is not great.

Besides bottom fish, echo-traces in midwater, probably of fish, are frequent along the edge of the continental shelf, and over the oceanic banks from the Shetlands to soutwest of Ireland, though no detailed surveys appear to have been made. Some may be of herring, but other possible species include blue whiting (M. poutassou), mackerel, argentines, Gadiculus and myctophids, etc. Blue whiting appears to be the main food of the hake (Hickling 1927), particularly medium hake. Larval studies (see section 5.5 on North Sea), suggest sustainable yields of 300,000 tons of blue whiting from the area to the west of Scotland and Ireland. Some research trawling for this species has been done (Raitt 1967). Not as much is known of the more southern area west and southwest of Ireland. More species occur, but more are acceptable to and used by the French and Spanish vessels fishing this water, than to the British trawlers, which mainly fish further north. Probably there are lightly exploited stocks, but no more than further north.

In the shallower areas - between the Hebrides and the Scottish mainland, in the Irish Sea and Bristol Channel - there is less evidence of unexploited stocks of moderate sized fish. Stomach contents of larger fish, some data on incidental catches and egg surveys suggest that the most promising stocks are sandeels and sprats. Johnson (personal communication) estimated from sprat egg surveys that there were 30-55,000 tons of adult sprats off the south coast of Ireland in 1959-60, and 65-650,000 tons in the North Sea, and possibly as much again in other British waters. The biggest catches of sandeel larvae in the plankton recorder surveys (Henderson 1961) occurred off the north coast of Scotland, and in the northern approaches to the Irish Sea (the Irish Sea itself was not included in the plankton recorder surveys). The estimation of potential catches from larval catches by plankton recorder data has already been discussed for the North Sea. The resources of some species may be underestimated by this method. For instance, argentines, or silver smelts (Argentina spp.) have bathy-pelagic eggs, which do not appear in surface hauls, though there may be a considerable resource (Wood and Raitt 1963), and Russian trawlers have reportedly been fishing for argentines in 1967. Danish vessels have also been fishing for Norway pout off St. Kilda (Raitt, in press).

In the English Channel a survey of pilchard eggs was carried out by Cushing (1957), who estimated that there were 10^{10} mature pilchards in the Channel. He assumed a mean length of 20.5 cm, which, using Lopez (1963) data, corresponds to a weight of 65 gm; the weight of the stock can thus be estimated as 650,000 tons. Bridger (1965) carried out extensive studies of the possible development of pilchard fishing in the southwest approaches to the Channel, including the detailed echo-surveys. Most of the identified traces were of pilchards, but horse mackerel, anchovies, sprats and garfish were also found.

As a first estimate of the potential yield from this stock, which as adults is virtually unexploited, a figure of 0.4 x M x standing stock might be used. M, the natural mortality coefficient, is not known; fish up to 10 years old are found (Bridger 1965), which suggests a value of M of around 0.5. This gives a potential yield of 130,000 tons.

5.7 Baltic and adjacent areas

(a) Separation of stocks

The fish in the Baltic proper form clearly separate stocks from those in the North Sea, but those in the Belts are intermediate and probably mix to some extent with those in the Kattegat.

(b) Demersal stocks

The state of the demersal stocks in the Baltic was reviewed by an ICES special scientific meeting in 1957. The conclusion was that the demersal stocks (cod, plaice, flounder and dabs) were all heavily fished (see ICES 1959, especially papers by Jensen, Kandler and Thurow, Mulicki, Rutkowicz, Otterlind, Dementjeva, Zemskaya). This conclusion has been supported by later investigations, e.g. Bagge (1966) and Cieglewicz (1963) found high fishing rates on flounder from tagging, and Otterlind (1967) and Jensen (1967) observed a decline in the average age and size of cod.

The actual yield depends very critically on environmental factors. Thus the vast increase of cod catches from the low level of the 1920s to well above 100,000 tons seems due to the greater salinity, especially on the spawning ground and the same changes have reduced the flounder stocks (Dementjeva 1963, ICES 1959). Short-term predictions may be made from environmental conditions (Lablaida and Lishev 1964), but unless environmental conditions can be predicted, such forecasts can be made into the future for at most the average lifespan of the individual fish. On the assumption that there are no major changes in the environment, then the potential catches, with the proper management measures, such as those outlined by ICES (1959), in force, the potential average annual catch from region III is rather above the present (1962-5) level, e.g. 200,000 tons of cod, and 50,000 tons of various flatfishes (mainly plaice and flounders).

(c) Pelagic fish

No detailed analysis of the effect of fishing on the herring or sprat stocks appears to have been published. Analysis of statistics is made difficult by the absence of USSR, Polish and East German catches from many of the volumes of the ICES statistics. Also small herring and sprat are not always kept distinct (Elwertowski and Popiel 1963). There are some signs of heavy fishing, e.g. decline in catch per trap-net in the Gulf of Parnu coinciding with an increase in the number of traps (Dementjeva 1957). Possibly not much further increase in average catch can be achieved, but detailed studies are required. As for the demersal catches, the actual catch in any future year depends on environmental factors; recent catches have averaged 275,000 tons; the potential average catch may be 300-400,000 tons. Lishev and Uzars (1967) considered the interaction between cod and sprat herring. There are significant negative correlations between the catches, particularly between the catch of cod, and the catch of sprat in the following year. This is blieved to be due to predation by cod - sprat makes up some 30% (by weight) of the food of cod over 26 cm. The estimated weight of sprat eaten, apparently by those cod which were subsequently caught in the Soviet Gotland fishery, was some 46,000 tons annually. The total consumption must be much higher, probably of the same order as the total sprat catch. The intense cod fishery presumably therefore has some beneficial effect on stocks and catches of sprat and also herring, though the effect on catches cannot as yet be measured quantitatively. There is no evidence that the fishery for sprat or herring has any measurable effect on cod stocks or catches.

(d) Other resources

There are no indications of large stocks of fish of species other than those already exploited. Echo-surveys by Lindquist (1964) off the Swedish west coast revealed no traces other than those believed to be sprat, or small herring. There are resources of molluscs and crustaceans, but these are being considered separately.

5.8 Southern waters

(a) Demersal fish

The population dynamics of the demersal stocks in this area (from Ushant to the Straits of Gibraltar) have not been studied in such detail as those further north. To some extent this is due to shortcomings in the statistics (little data on fishing effort and inadequate data on area of capture). As noted above (section 5.5) some of the catches recorded in the Bulletin Statistique as coming from this area in fact come from the grounds to the west and southwest of the British Isles.

Hake is the most important demersal species. The stocks have probably been heavily fished for a long time (Letaconnoux 1951). Very small hake are caught in some areas - Meriel-Bussy (1966 a) reported a modal length of 10-14 cm on catches in November, and Rodriguez (1963) found a mode of 15 cm, and about 25% by number of "non-commercial" hake in experimental trawling inthe Bay of Biscay. This may be contrasted with a modal length of 50-60 cm in the landings at Fleetwood by English trawlers fishing to the west of Scotland. Since the growth of hake in the two areas is not vastly different (Meriel-Bussy 1966 b), a difference of length of four times, and in weight of perhaps 50 times - and even more in value - shows that the benefit from adequate management of the hake stocks could be very large. The difference between catches by different groups of vessels landing at La Rochelle is shown clearly by Meriel-Bussy (1967). The deep-sea trawlers land approximately equal quantities of five out of the six size categories, but few of the smallest size; the landings by small vessels (artisans) contain some 60% of the smallest categories, while the short-lived gill-net fishery, apparently based on a limited stock of old fish (Guero and Meriel-Bussy 1967) consisted of 90% of large hake. The potential yield is difficult to estimate with any precision. The recorded catch in 1965 from ICES regions VIII and IX was 95,000 tons but some of this (perhaps, as suggested in section 5.5, 20,000 tons) was in fact caught further north so that the real catches might be only 75,000 tons. The potential catch is likely to be substantially bigger, and may well be 100,000 tons, but probably not very much more.

The other important demersal species (breams, flatfishes, etc.) are probably also heavily fished. Letaconnoux (1948) found after the war a big increase in the catch per count of trawlers fishing out of La Rochelle for nearly all species; however, the area of fishing was not given in detail, and was probably at the northern edge of the present area, and including part of ICES region VII. There is no reason to suppose that the catches of those species presently exploited can be increased substantially; any increase is more likely to result from better management than from increased fishing.

The is little evidence concerning possible demersal stocks other than those at present exploited. Rodriguez (1963) gives data of catches with small meshed trawls in the southeast corner of the Bay of Biscay; the major species were hake, pout (G. luscus), blue whiting (M. poutassou), angler, squid and octopus.

(b) Pelagic fish

The most important pelagic species is the sardine (pilchard). The available statistics up to 1956 have been reviewed by Riedel (1960). The total catch has fluctuated between 150,000 and 220,000 tons since 1940 - and probably in the same range since at least 1927 if allowance is made for the Spanish catch, the statistics of which were not available for the period 1927-40. Riedel believed that the fishing effort, in terms of manpower, boats and general technical progress, has increased over the period; the lack of any appreciable increase in total landings indicated that the level of effort in the 1920s and 1930s represented a balance between fishing input and abundance (i.e. gave not much less than the maximum average annual catch). Since 1956 there has in fact been a slight increase to between 220,000 and 250,000 tons in the total sardine catches - mainly from Portugal, while the French catch has tended to decrease. There have not been more recent published studies concerning the effect of fishing on these stocks, but it appears that Riedel probably underestimated the potential yield, which is probably at least 250,000 tons, and might well be higher.

The ICES statistics include some 100,000 tons of various clupeoids; some of these may be sardines, but the total includes anchovies, and possibly a few sprats. Horse mackerel (ca 100,000 tons) and mackerel (ca 30,000 tons) are also important, but for none of these species are there published studies on which estimates of the potential yield can be based. It is probable that the former at best are less heavily fished than the sardine, and catches can be moderately increased (see below concerning eggs and larvae).

Tuna (bluefin, albacore and bonito) are caught in the area, but these stocks are being considered in a separate study, dealing with the tuna stocks of the world as a whole. Similar specialized studies are also being made of the crustacean, and molluscan resources.

(c) Eggs and larvae

The distribution of these in the Bay of Biscay during 1964 has been described by Arbault and Boutin (1967). Four surveys were made with a Hensen net in February, May, August and November. By far the most abundant larvae were sardines; anchovy eggs were as abundant as sardine eggs, but anchovy larvae were comparatively scarce. Eggs and larvae of hake, horse mackerel, dragonet (Callionymus lyra) and mackerel were rather less abundant - of the order of one-tenth of the abundance of sardines and anchovy. Other species were even less abundant. This suggests that there are no important stocks other than considered above. Also, the low number of eggs and larvae of horse mackerel and mackerel relative to sardines suggests that either the potential of these species is not much greater than the present catches, or that the potential of sardine is appreciably greater than present catches.

6. DISCUSSION

6.1 Summary

The estimates of potential catches made in the previous section have been summarized in table 2. Question marks, and brackets plus question marks denote increasing degrees of uncertainty in the estimates. Where it is quite impossible to make any reasonable estimate, the probable order of magnitude has been indicated, i.e. x 10, between 10,000 and 100,000, x 100, between 100,000 and 1,000,000 tons.

Two totals have been given for each area; the first (A), including only those stocks for which an actual estimate of potential yield (however imprecise), has been given. The second total (B), includes those stocks for which only an order of magnitude figure is available. In calculating these totals (and the relevant species totals) potential catches entered in table 2 as (x 10) have been taken as 30,000 tons, and (x 100) as 300,000 tons. All totals have been rounded off.

The potential catches in each major area have also been summarized in table 3. For comparison with estimates of primary production, and of the production at other trophic levels, the species of fish have been classified as zooplankton eaters (the pelagic fish, excluding tuna, squid, sandeels, Norway pout, blue whiting and other small demersal fish) and the rest. This division, denoted in the table as 'pelagic' and 'demersal' is somewhat arbitrary and does not correspond exactly to first and second stage predators. Many of the forms of the zooplankton consumed are predators - euphausids, larval fish, etc., while much of the production of large predatory fish, such as cod, comes from small zooplankton consumed when small.

Table 2. Potential yields from the ICES area (in thousands of tons)

	I, II NE Arctic	Va, XIV Iceland	Vb Faroes	IV + IIIa North Sea	VI, VII Westerly	VIII, IX Biscay & Portugal	III bcd Baltic & Belts	Total	Actual Catch 1965
Plaice	7	10	+	100	10	2	40	170	144
Long rough dab	(200)?	(200)?	(x1)?	(x10)?	-	-	-	400	No data
Other flatfish	50	20	5	60	40	20?	10	200	155
Cod	1,000	525	35	150	50	2	200	2,000	1,289
Haddock	200	75	25	150	15	-	-	465	490
Hake	-	-	-	5	50	100	-	150	121
Saithe	175	100	20	100	30	-	-	425	379
Whiting	-	3	+	150	50	5	-	200	187
Norway pout	-	(x10)?	(x10)?	(100+)?	(x10)?	(x10)?	-	(200)	77
Blue whiting	(x10)?	(x10)?	(x10)?	(f)	(300)?(f)	(x100)?	-	(500)	No data
Other large demersal	50	60	15	30	30	100?	-	300	217
Redfish	75	200	10	-	-	-	-	300	201
Other small demersal	(500)?(c)	(x10)?(d)	(x10)?(d)	(100)?(b)	(x100)?(d)	(x100)?(d)	-	(1,000)	(57)(i)
Sandeels	-	(x10)?	(x10)?	(350)?	(100)?	(x10)?	-	(500)	141
Capelin	500+?	(x100)?	-	-	-	-	-	(1,000)	274
Argentines	-	(x10)?	(x10)?	-	(x10)?	-	-	(100)	-
Horse Mackerel	-	-	-	(x10)?	(x100)?	150+?	-	(500)	122
Herring	800(a)	700(a)	15(a)	1,500	200	-	250?	3,500	3,376
Pilchard	-	-	-	++	(130)	250+	-	400	229
Sprat	-	-	-	(250)?	(250)?	+	100?	600	165
Anchovy	-	-	-	++	++	(x100)?	-	(300)	No data
Tunas	-	-	-	5?(g)	++(g)	70+(g)	-	70	76
Mackerel	-	-	+	550?(e)	(e)	50+?	-	600	297
Dogfishes	5?	1	1	25	15?	10?	-	60	51
Skates	5?	2	+	20	25?	10?	-	60	43
Squid	(x10)?	(x10)?	(x10)?	(x10)?	(x10)?	(x100)?	-	(1,000)?	16
Total (A)	3,550	1,900	125	3,625	1,300	750	600	(15,000)	8,795(h)
Total (b)	3,600	2,200	250	4,000	2,800	2,000	600		

Notes (Table 2)

+ Probably less than 1,000 tons
++ Uncertain, but small, probably only a few thousand tons
(a) Atlanto-Scandian herring. A total for all areas of 1.5 million tons is split rather arbitrarily between the regions
(b) Pout whiting, gurnards, etc.
(c) Mainly polar cod (Boreogadus saida)
(d) Includes argentines
(e) Mackerel resources of III a, VI and VII included in North Sea
(f) Blue whiting resources of North Sea included in VI and VII
(g) Discussed in detail in chapter dealing with world tuna resources
(h) Includes 298,000 tons of various and unsorted fish
(i) Unspecified gadoids, probably including blue whiting

Single underlining: moderately heavily fished, but increased fishing likely to give some increase in catch
Double underlining: heavily fished, any increase in catch will come from better management, and not from increased fishing

Table 3. Potential and actual yields from each area of the NE Atlantic, and potential yields per unit area

	Region							
	I, II NE Arctic	Va, XIV Iceland	Vb Faroes	IV,IIIa North Sea	VI, VII Westerly	VIII,IX Biscay& Portugal	III Baltic	Total
Area (000 km²)	1,300	150	25	600	500	160	420	
Potential catches (000 tons):								
Pelagic	1,850	1,000	130	3,200	1,950	1,700	350	
Demersal	1,750	1,200	120	800	350	300	250	
	3,300	2,000	250	4,000	2,300	2,000	600	15,000
Kg per hectare:								
Pelagic	14	67	52	53	39	106	8	
Demersal	13	80	48	13	7	18	6	
	27	147	100	66	46	124	14	
Ratio: Pelagic/Demersal	1.0	1.8	1.1	4.0	5.6	5.8	1.3	
1966 Catches:								
Pelagic	1,921	658	10	1,872	211	588	532	
Demersal	1,032	675	86	1,011	270	210	251	
TOTAL	2,953	1,333	96	1,882	481	798	783	

Also shown in the table are the areas of bottom less than 200 m in each area, and the estimated potential yields expressed as kg per hectare. If 10% of the weight of fish is carbon, then these figures should be divided by 100 to give the yield as gC/m^2. They should be divided by 10 to give it as $tons/km^2$.

These figures should be treated with some reserve, and have in fact been rounded off to the first or second significant figure, and so may not correspond precisely with additions from Table 2. Some general comments and conclusions may be made.

From north to south (excluding the Baltic) there is a fairly steady reduction in the proportion of demersal fish, relative to the pelagic fish. This may well be related to the nature of the productive cycle, which is very highly seasonal in the north, but more uniform throughout the year in the south.

The magnitude of the potential yield per unit area is quite variable. Some of this variation is no doubt due to errors in the estimates, but some is real. Thus the low figure for the Baltic, and probably also the Barents Sea, are due to areas of very low primary production in these regions - the Gulf of Bothnia, and north-eastern Barents Sea. In regions with narrow continental shelves the figures are probably misleading in that much of the fish production comes from primary production occurring off the continental shelves. This may occur to a large extent at Iceland, Faroes and Biscay and Portugal. It is probably less important in the westerly region, despite the long boundary between the shelf and the deep ocean, because much of the fish production occurs in more or less enclosed waters - English Channel, Irish Sea and the Minches. Making allowance for these factors the consistency between the figures is fairly good.

6.2 Comparison of potential fish yields and primary production

Because of the probability of unknown contributions from primary production from off the continental shelf, as noted above, only for the North Sea and the Baltic may a direct comparison between primary production and fish potential be possible. For the North Sea this has been reviewed by Steele (1965). His figures for fish yield are slightly different from those derived here. His are of total fish production, not only that part of the production that is, or could be, taken by man. The figures were actually calculated as the weight of fish dying, by multiplying the catch by the ratio of total to fishing mortality; this is clearly equal in a steady state situation to the production of fish of commercial size. This should give an underestimate of the actual production of fish, because omitted from the calculation are fish which die before reaching commercial size, and fish from unexploited stocks. The analyses here suggest the latter are not very large. However, fish yield, in the sense that he uses it, should be greater than used here because Steele's case refers to the yield to all consumers of fish, not just to man. In even the best managed fishery there must be 'losses' to other predators, disease, etc. Allowing for losses both before and after reaching the optimum size at first capture, the total fish production is likely to be at least 50% greater than the potential yield.

For these reasons the near coincidence between the estimates of fish yield (0.81 gC/m^2 here, and 0.77 gC/m^2 by Steele) is just a coincidence, especially as Steele used too low a figure (3.3×10^5 km^2) for the area of the North Sea, and his yield should be nearer 0.6 gC/m^2. From the assessments made in this report the fish yield in his sense may be estimated as around 1.2 gC/m^2.

However, the differences are not great when considering the order of magnitude of the difference between primary production and fish yield. In particular the area taken for the North Sea does not affect at all the arguments put forward by Steele.

As he points out, if a 10% reduction is assumed at each trophic level then the production of herbivores is 10% of the primary production (100 gC/m^2/year), and i.e. 10 gC/m^2; working from the other end, the production of the food eaten by the fish 10 times the yield, i.e. 6-12 gC/m^2. On this assumption if the production figures are right then fish must eat herbivores, and must also be the main consumer of herbivores. Neither of these is true, and the production figures are not likely to be greatly in error. That for primary production might, at the very worst, be too low by a factor of two; the potential fish production must at least be as great as the average recent catches, which, for demersal fish in particular, are not much less than the estimates of potential yield given here. It is interesting that since Steele drew attention to the remarkable constancy of demersal catches over the past 50 years (400,000 tons $\pm$ 20%), there has been a rapid increase to 650,000 tons in 1964 and 750,000 tons in 1965. This increase may be due to different reasons in different stocks, but the increase in haddock catches is due largely to the outstanding 1962 year-class. The history of this and other outstanding year-classes of haddock, suggests that at its normal abundance the haddock stock does not fully use its available food resources. There is a reduction in growth in a good year-class, but this is by no means enough to counterbalance the increased numbers. The total weight increment, and presumably also the food consumption, is much greater for strong year-classes.

From this, therefore, it follows that the efficiency of transfer from one trophic level must be more than 10%, or the 12% maximum found in experiments by Slobodkin (1959). Explanations for this have been then suggested by Steele, who, following MacArthur (1955), believes that the efficiency in higher latitudes may be higher because the productive cycle is seasonal. This is important for the present studies of the world fish potential in that estimates of the potential in tropical or sub-tropical waters based on temperate fish potential, and the relative primary production may give too high figures. Regarding the North Sea estimates of fish potential, the comparison with primary production, suggests that probably no large fish potential has been omitted. (It has been drawn to my attention since writing this section that estimates of primary production using the C_{14} technique made in the period 1958-66 are probably too low, and should be increased by a factor of 1.45. This will reduce the discrepancy to some extent).

In the Barents Sea, estimates of production of phytoplankton made by Russian scientists (Bogdanov, personal communication) are of total production of 1.2×10^9 tons, or about 1,000 g/m^2 (net weight). This (assuming 10% carbon) is about the same primary production per unit area as the North Sea, but the estimates of fish production are about one-third - i.e. more nearly in accordance with a reduction of 10% at each trophic level, with the major demersal species - cod, haddock, etc., being three stages removed from the primary production. However, if the efficiency increases with latitude then the Barents Sea should be more productive than the North Sea. Possible explanations include (i) the estimate of primary production is too high; (ii) the estimate of fish potential is too low; (iii) the efficiency in the Barents Sea is lower than the North Sea; (iv) most of the production in the Barents Sea ends in blind alleys - forms such as jelly-fish, starfish, etc., which are at present unsuitable directly or indirectly for harvest by man. Some indication that the production of cod is limited by the original primary production is given by the observation of Ponomarenko (1967) that the growth rate of cod has increased, apparently due to the reduced abundance of the present stock. The biggest changes are among the young (less than 4-year-old) fish, which suggests that the supply of food to the older fish is less limiting.

In the Baltic the estimates of production are 34×10^6 tons phyto- and zooplankton (Bogdanov, personal communication) and 10×10^6 benthos. If fish are respectively 2 and 1 trophic level removed, and dividing these figures by 10^2 and 10^1 gives a potential fish yield of 340,000 plus 1,000,000 tons. This is well above the estimates in table 3; the same possible explanations exist as for the Barents Sea of which the possibility of much of the benthos production being unsuitable for consumption by fish seems particularly likely. This emphasizes the need for qualitative as well as quantitative studies of production.

6.3 Needs for further study

Too much of the estimates of potential yield presented here are very tentative, so that it is a truism to say that much further research is needed in all the branches of fishery science involved. Certain particular items can be distinguished as needing special attention. These include:

(a) Primary production - a more detailed review of available published and unpublished data, including a review of the comparability of different methods. Further observations in some areas or seasons. Examination of the possibility of using rapid methods of estimating productivity, e.g. from 'greenness' of plankton recorder material (though greeness is a measure of standing crop, not, directly, of production).

(b) Zooplankton and benthos - further studies generally, especially as regards production, as opposed to standing crop.

(c) Stock assessment - more studies generally, but particularly for those stocks with long-established fisheries, and which have had sometimes extensive biological research, without explicit stock assessment studies, e.g. sardine.

(d) Eggs and larvae - general studies on the likely precision achieved by using eggs or larvae as quantitative measures of the potential yield. Examinations of the variation of the ratios standing crop of larvae: standing crop of adults: potential. Do the large numbers of eggs and larvae from some species (long rough dab, oceanic redfish) really indicate large potential? The carrying out, if necessary, in certain areas of surveys of eggs and larvae specifically aimed at stock assessment.

(e) Acoustic methods - further use in appropriate areas of these methods of resource survey.

All the above apply in particular to those stocks/areas where there appears to be a considerable underexploited resource - blue whiting, argentines, sandeels, capelin, especially round Iceland, horse mackerel, pilchard in the English Channel, sprats to be west of the British Isles, anchovy and squids.

The discussion in the previous section shows that the simple model of food chains in the sea, with tow or more distinct trophic levels from primary production to fish, and a 10% loss at each step, gives a poor representation of reality, at least in the North Sea. Also the production of fish, especially demersal fish, may be much closer to the limit of production at the later stages of the ...

food chain set by the total primary production than is suggested by the simpler models of fish population dynamics. These facts are important not only for the present type of study, but also for problems of fisheries management. There is therefore an urgent need for further research in this field.

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Appendix Tables. Summary of recent statistics

Table I. Catches by species

CATCH OF SELECTED SPECIES IN THE ICES AREAS

Quantity = metric Tons

SPECIES	AREAS	1962	1963	1964	1965	1966
Capelin	I Barents Sea	3 514	34 738	19 675	202 891	279 975
	IIa Norwegian Sea	-	-	-	21 462	109 013
	Subtotal	3 514	34 738	19 675	224 353	388 988
	Va Iceland Grounds	-	1 078	8 640	49 735	124 934
	Total	3 514	35 816	28 315	274 088	513 922
Halibut	I Barents Sea	1 494	2 694	24 083	1 781	1 346
	IIa Norwegian Sea	3 378	2 473	2 874	13 707	7 732
	IIb Spitsbergen and Bear Island	828	1 008	2 494	5 137	3 305
	Subtotal	5 700	6 175	29 451	20 625	12 383
	Va Iceland Grounds	4 924	4 653	3 759	4 060	2 647
	Total	10 624	10 828	33 210	24 685	15 030
Lemon Sole	Va Iceland Grounds	2 567	2 879	2 352	2 560	1 542
	IV N.C.S. North Sea	4 630	3 791	4 793	5 683	6 134
	VII (VII a + f, b + c, g - k, d + e)	417	271	4 557	5 089	6 468
	Total	7 614	6 941	11 702	13 332	14 144
Plaice	Va Iceland Grounds	11 411	9 658	9 368	10 898	11 875
	IV N.C.S. North Sea	87 419	107 062	110 368	96 927	100 130
	VII (VII a + f, b + c, g - k, d + e)	5 170	5 656	7 169	9 069	10 804
	Total	104 000	122 376	126 905	116 894	122 809
Sole (Common)	IV N.C.S. North Sea	26 841	26 131	11 299	16 966	31 769
	VII (VII a + f, b + c, g - k, d + e)	2 901	2 768	4 164	5 048	3 737
	Total	29 742	28 899	15 463	22 014	35 506
Cod	I Barents Sea	510 409	508 859	230 844	202 855	264 646
	IIb Spitsbergen and Bear Island	218 041	110 526	75 355	80 139	54 866
	IIa Norwegian Sea	199 346	184 561	162 039	198 399	237 922
	Subtotal	927 796	803 946	468 238	481 393	557 434
	Va Iceland Grounds	386 422	409 376	434 510	393 552	357 397
	Vb Faroes Grounds	24 230	24 136	25 127	27 127	22 936
	IV N.C.S. North Sea	89 558	105 921	121 550	179 469	219 702
	VI N.W. Coast Scotland N. Ireland, Rockall	10 065	14 370	24 137	24 222	18 651
	IIIb, c, d, Baltic, The Sound and Belt Sea	151 103	146 831	128 111	128 349	158 711
	Total	1 589 174	1 504 580	1 201 673	1 234 112	1 334 831

SPECIES		AREAS	1962	1963	1964	1965	1966
Haddock	I	Barents Sea	147 796	111 191	55 833	68 580	75 729
	IIb	Spitsbergen and Bear Island	3 762	1 053	1 169	1 429	1 986
	IIa	Norwegian Sea	32 222	33 228	29 906	36 201	51 935
		Subtotal	183 780	145 472	86 908	106 210	129 650
	Va	Iceland Grounds	119 603	102 562	99 247	99 127	60 141
	Vb	Faroes Grounds	27 149	27 569	19 491	18 407	18 762
	IV	N.C.S. North Sea	52 419	59 398	198 706	221 700	268 958
	VI	N.W. Coast Scotland N. Ireland, Rockall	10 732	16 864	29 251	33 015	31 816
		Total	393 683	351 865	433 603	478 459	509 327
Hake	VI	N.W. Coast Scotland N. Ireland, Rockall	8 878	8 215	7 909	8 370	6 652
	VII	(VII a + f, b + c, g - k, d - e)	21 131	17 320	12 038	33 345	8 435
	VIII	Bay of Biskay	46 853	51 752	47 058	17 805	33 003
	IX	Portugal Coast	45 355	49 924	57 659	57 017	56 030
		Total	122 217	127 211	124 664	116 537	104 120
Ling	I	Barents Sea	1 094	2 661	1 131	5	11
	IIb	Spitsbergen and Bear Island	7	14	23	14	3
	IIa	Norwegian Sea	11 868	6 747	7 059	9 342	5 486
		Subtotal	12 969	9 422	8 213	9 361	5 500
	Va	Iceland Grounds	12 117	10 492	10 374	10 658	10 032
	IV	N.C.S. North Sea	4 512	8 115	10 247	10 024	9 807
	VI	N.W. Coast Scotland, N. Ireland, Rockall	4 422	6 449	8 362	8 821	9 010
		Total	34 020	34 478	37 196	38 864	34 349
Norway Pout	IV	N.C.S. North Sea	156 960	166 827	82 669	59 342	52 737
		Total	172 731	185 722	109 720	77 423	??
Saithe	I	Barents Sea	10 929	20 809	53 968	16 149	10 479
	IIb	Spitsbergen and Bear Island	403	143	994	884	921
	IIa	Norwegian Sea	109 375	127 675	142 544	168 567	191 575
		Subtotal	120 707	148 627	197 506	185 600	202 975
	Va	Iceland Grounds	50 385	48 449	60 417	60 107	52 168
	Vb	Faroes Grounds	10 454	12 693	21 893	22 181	25 497
	IV	N.C.S. North Sea	22 276	27 571	55 102	68 907	86 927
	VI	N.W. Coast Scotland N. Ireland, Rockall	7 159	6 609	13 59[illegible]	18 395	18 509
		Total	210 981	243 949	348 5[illegible]4	355 190	386 076

SPECIES	AREAS	1962	1963	1964	1965	1966
Tusk	I Barents Sea	807	648	931	423	249
	IIb Spitsbergen and Bear Island	100	331	99	55	12
	IIa Norwegian Sea	20 096	17 078	20 819	21 432	16 660
	Total	21 003	18 057	21 849	21 910	16 921
Whiting	IV N.C.S. North Sea	68 967	98 653	91 528	106 694	155 153
	VI N.W. Coast Scotland N. Ireland, Rockall	8 612	10 541	8 612	19 304	18 787
	VII (VII a + f, b + c, g - k, d + e)	26 071	25 756	26 071	27 207	27 207
	Total	103 650	134 950	126 211	153 205	201 147
Redfishes	I Barents Sea	8 621	10 753	40 030	6 333	6 383
	IIb Spitsbergen and Bear Island	14 746	15 429	11 273	4 467	3 280
	IIa Norwegian Sea	12 198	15 750	14 874	29 055	25 125
	Subtotal	35 565	41 932	66 177	39 855	34 788
	Va Iceland Grounds	75 277	90 132	95 160	113 796	106 627
	XIV East Greenland	27 228	36 838	41 092	36 403	23 191
	Total	138 070	168 902	202 429	190 054	164 606
Sand Eels	IV S.C.S. North Sea	110 041	162 134	128 501	130 802	161 110
	Total	110 041	162 134	128 501	130 802	161 110
Horse Mackerel	VII Bay of Biscay	47 204	47 671	51 694	48 507	43 035
	IX Portugal Coast	56 826	69 223	69 690	62 547	53 475
	Total	104 030	116 894	121 384	111 054	96 510
Herring	I Barents Sea	95 401	93 153	7 869	123 041	174 892
	IIa Norwegian Sea	505 783	622 969	861 664	1 045 845	1 344 894
	Va Iceland Grounds	650 508	507 703	625 141	624 040	482 615
	Vb Faroes Grounds	6 618	23 060	14 514	4 391	8 618
	IV N.C.S. North Sea	678 515	805 301	932 046	1 230 315	1 038 851
	VI N.W. Coast Scotland N. Ireland, Rockall	63 699	53 949	69 720	66 385	93 147
	VII (VII a + f, b + c, g - k, d + e)	37 226	29 543	20 753	23 385	38 306
	IIIb, c, d Baltic, The Sound and Belt Sea	177 045	214 852	216 001	214 916	232 709
	IIIa Kaggegat and Skagerrak	116 771	159 988	273 603	238 923	152 449
	Total	2 331 566	2 510 518	3 021 311	3 571 241	3 566 481
Pilchard	VIII Bay of Biscay	51 440	49 141	47 139	39 543	37 566
	IX Portugal Coast	176 617	170 546	204 191	184 798	168 985
	Total	228 057	219 687	251 330	224 341	206 551

SPECIES	AREAS	1962	1963	1964	1965	1966
Sprat	IV N.C.S. North Sea	31 312	67 668	70 812	76 180	106 577
	III b, c, d Baltic, The Sound and Belt Sea	62 732	61 045	80 818	73 598	70 254
	Total	94 044	128 713	151 630	149 778	176 831
Tunas	VIII Bay of Biscay	54 674	47 658	51 834	50 743	40 689
	IX Portugal Coast	10 887	18 090	10 305	14 281	14 064
	Total	65 561	65 748	62 139	65 024	54 753
Mackerels	IV N.C.S. North Sea	66 285	55 402	79 390	151 721	505 134
	IIIa Kattegat and Skagerrak	12 747	17 666	35 607	56 745	24 594
	Subtotal	79 032	73 068	114 997	208 466	529 728
	VII (VIIa + f, b + c, g - k, d - e)	20 230	24 560	22 778	16 562	41 205
	VIII Bay of Biscay	12 368	15 871	16 923	21 627	25 881
	IX Portugal Coast	18 729	10 713	11 776	34 140	18 244
	Total	130 359	124 212	166 474	280 795	615 058
Dogfishes	IV N.C.S. North Sea	30 437	34 366	21 638	26 108	23 414
	IIa Norwegian Sea	6 797	4 850	3 527	2 418	1 593
	Total	37 234	39 216	25 165	28 516	25 007
Rays & Skates	IV N.C.S. North Sea	9 588	10 683	10 982	10 037	8 233
	VI N.W. Coast Scotland N. Ireland, Rockall	3 714	3 910	4 787	4 317	3 905
	VII (VII a + f, b + c, g - k, d + e)	21 765	21 994	21 344	17 641	16 019
	VII Bay of Scotland	6 862	5 920	6 732	5 921	5 787
	Total	41 929	42 507	43 845	37 916	33 944
Unsorted	IV N.C.S. North Sea	23 100	49 564	154 034	136 127	56 523
	VII (VII a + f, b + c, g - k, d + e)	29 788	33 794	33 393	37 757	22 816
	VII Bay of Scotland	28 517	28 580	35 321	15 670	30 485
	IX Portugal Coast	36 731	46 441	49 291	36 731	47 712
	Total	118 136	158 379	272 039	226 285	157 536

Table II. Catches by Sub-Areas

CATCH BY SUB-AREAS IN THE ICES AREA

			1962	1963	1964	1965	1966
I	Barents Sea	Pelagic	132 734	129 589	28 882	326 572	459 936
		Demersal	718 346	681 362	427 994	313 894	383 942
		Total	821 080	810 951	456 876	640 466	843 878
IIa	Norwegian Sea	Pelagic	510 775	625 167	862 355	1 073 757	1 460 079
		Demersal	426 660	418 872	422 796	518 385	581 311
		Total	937 435	1 044 039	1 285 151	1 592 142	2 041 390
IIb	Spitsbergen and Bear Island	Pelagic	2 228	1 044	1 320	1 426	1 476
		Demersal	245 793	135 066	93 565	94 090	66 504
		Total	248 021	136 110	94 885	95 516	67 980
Total (I + IIa + IIb)		Pelagic	615 737	755 800	892 557	1 401 755	1 921 491
		Demersal	1 390 799	1 235 300	944 355	926 369	1 031 757
		Total	2 006 536	1 991 100	1 836 912	2 328 124	2 953 248
Va	Iceland Grounds	Pelagic	657 406	514 386	643 366	683 240	615 413
		Demersal	707 496	730 594	754 304	734 638	637 336
		Total	1 364 902	1 244 980	1 397 670	1 417 878	1 252 749
XIV	East Greenland	Pelagic	424	1 169	1 895	1 562	42 724
		Demersal	46 216	62 369	79 696	57 019	37 299
		Total	46 640	63 538	81 591	58 581	80 023
Total (Va + XIV)		Pelagic	657 830	515 555	645 261	684 802	658 137
		Demersal	753 712	792 963	834 000	791 657	674 635
		Total	1 411 542	1 308 518	1 479 261	1 476 459	1 332 772
Vb	Faroes Grounds	Pelagic	7 867	24 417	15 661	5 335	10 368
		Demersal	77 431	80 712	91 683	92 982	85 863
		Total	85 298	105 129	107 344	98 317	96 231
IV	N.C.S. North Sea	Pelagic	919 640	1 145 780	1 367 575	1 733 169	1 871 524
		Demersal	590 876	690 258	773 900	858 801	1 010 652
		Total	1 510 516	1 836 038	2 141 475	2 591 970	2 882 176
VI	N.W. Coast Scotland N. Ireland, Rockall	Pelagic	72 051	60 462	79 017	75 883	101 403
		Demersal	64 620	79 931	127 167	133 378	125 386
		Total	136 671	140 393	206 184	209 261	226 789
III	Baltic, The Sound and Belt Sea, Kattegat and Skagerrak	Pelagic	474 077	564 573	648 346	624 817	531 988
		Demersal	270 026	254 496	237 475	223 087	251 347
		Total	744 103	819 069	885 821	847 904	783 335

			1962	1963	1964	1965	1966
VII	(VIIa + f, b + c, g - k, d + e)	Pelagic	96 080	100 303	94 626	89 890	109 903
		Demersal	121 386	123 245	140 803	171 484	144 835
		Total	217 466	223 548	235 429	261 374	254 738
VIII	Bay of Biscay	Pelagic	268 217	250 066	296 831	301 412	238 403
		Demersal	120 088	136 428	138 027	115 552	129 095
		Total	388 305	386 494	434 858	416 964	367 498
IX	Portugal Coast	Pelagic	343 431	343 194	379 109	388 986	349 392
		Demersal	66 903	71 938	78 069	81 681	80 671
		Total	410 334	415 132	457 178	470 667	430 063

Note: For the purpose of this table, Demersal and Pelagic are defined in terms of the FAO species groups. Demersal includes all Flounders, Cods, Redfishes etc (except Sand-eels) and Sharks. Pelagic includes Capelin, Sand-eels, Herrings, Jacks, Tunas, Mackerels and Unsorted.

Table III. Total Catch by Species Groups

ICES TOTAL CATCH BY FAO SPECIES GROUPS

	1962	1963	1964	1965	1966
GRAND TOTAL	7 003 831	7 318 566	7 826 180	8 747 905	9 352 822
Demersal Total	3 518 246	3 538 541	3 380 314	3 418 722	3 539 769
Flounders	279 724	289 341	312 149	299 504	310 996
Cods	2 855 359	2 842 772	2 632 025	2 706 469	2 857 537
Redfishes etc (1)	265 446	282 138	314 693	311 682	272 662
Sharks	117 717	124 290	121 447	101 067	98 574
Pelagic Total	3 485 585	3 780 025	4 445 866	5 329 183	5 813 053
Capelin	3 768	35 816	28 315	274 088	513 937
Jacks, Mullets	120 015	138 486	151 304	142 502	114 699
Sand-eels	140 105	184 234	132 038	140 989	180 635
Herrings	2 784 768	2 960 083	3 559 989	4 099 691	4 107 408
Tunas	75 454	66 384	68 946	76 175	60 921
Mackerels	157 223	143 266	182 297	297 638	627 167
Unsorted	204 252	251 756	322 977	298 100	208 286
Crustaceans (2)	126 950	151 468	134 639	124 959	128 907
Molluscs (2)	262 238	243 490	292 327	307 068	390 751

(1) Except Sand-eels

(2) Not included in total. A Review of the Resources of these groups are contained in seperate sections of the IWP study.

REFERENCES

Arbault, S. and N. Boutin, Oeufs et larves de poissons téléostéens dans le Golfe
1967 de Gascogne en 1964. ICES Plankton Comm., Paper L11

Atkinson, G.I., Notes on a fishing voyage to the Barents Sea in August 1907.
1908 J.mar.biol.Ass.U.K., 8:71-98

Bagge, O., Tagging of flounder in the western Baltic, the Belt Sea and the Sound
1966 in 1960-62. ICES Baltic-Seas Comm.Meeting 1966, Doc. B1:8 p. (mimeo)

Baranenkova, A.S., Notes on the condition of formation of the Arcto-Norwegian
1965 tribe of cod of the 1959-61 year classes during the first year of life. Spec.Publs int.Commn NW.Atlant.Fish, 6:397-410

Bedford, B.C., English cod tagging experiments in the North Sea. ICES Gadoid
1966 Fish Comm.Paper G9:9 p. (mimeo).

Beverton, R.J.H., J.A. Gulland and A.P. Margetts, Whiting tagging: How the tag
1959 return rate is affected by the condition of fish when tagged. J.Cons. perm.int.Explor.Mer, 25(1):53-7

Beverton, R.J.H. and S.J. Holt, Tables of yield function for fishery assessment.
1964 FAO Fish.tech.Pap., (38):49 p.

Belgrad, H., Invertebrates in the Kattegat with special reference to plaice food.
1930 Rep.Dan.biol.Stn, 36 p.

Bridger, J.P., The Cornish Pilchard and its fishery. Lab.Leafl.Fish.Lab.Lowestoft,
1965 (9):17 p.

Burd, A.C. and J. Bracken, Studies on the Dunmore herring stock. 1. A population
1965 assessment. J.Cons.perm.int.Explor.Mer, 29(3):277-301

Cieglewicz, W., Flounder migrations and mortality rates in the southern Baltic.
1963 Baltic-Belt Seas Comm. Doc.78:7 p. (mimeo)

Colebrook, J.M., D.E. John and W.W. Brown, Contribution towards a plankton atlas
1961 of the North-eastern Atlantic and North Sea. 2. Copepoda. Bull.mar. Ecol., 5(42):90-7

Cushing, D.H., The number of pilchards in the channel. Fishery Invest.,Lond.(2),
1957 21(5):27

Cushing, D.H. and J.P. Bridger, The stock of herring in the North Sea and changes
1966 due to fishing. Fishery Invest.,Lond.(2), 25(1):123

Cushing, D.H. and T. Vucetic, Studies on a Calanus patch. 3. The quantity of food
1963 eaten by Calanus finmarchicus. J.mar.biol.Ass.U.K., 43(2):349-71

Dementjeva, T.F., Researches in the USSR on Baltic herring and cod. J.Cons.perm.
1957 int.Explor.Mer, 22(3):309-21

Dementjeva, T.F., Changes in the stock of commercial fish in the Baltic under the
1963 influence of oceanological factors. Okeanologiia, 5 p.

de Veen, J.F., On the existence of sub-population of plaice in the southern North
1962 Sea. ICES Near Northern Seas Comm.Doc. 94:6 p. (mimeo)

Draganik, B., Age-composition and rate of growth of saithe (Pollachius vivens)
1967 caught in February-March off the Norwegian coast. ICES Demersal Fish (Northern)Comm.Paper F2

Elwertowski, J. and J. Popiel, Recruitment to the herring stock in the southern
1963 Baltic. Rapp.P.-v.Réun.Cons.perm.int.Explor.Mer, 154:242-8

Fairbridge, R.W., The encyclopedia of oceanography. New York. Reinhold Publ.C.
1966

Garrod, D.J., Stock and recruitment data for Arcto-Norwegian cod. ICES Gadoid
1966 Fish Comm.Paper G8:8 p. (mimeo),

Garrod, D.J. and R. Gambell, Whiting of the Irish Sea and the Clyde. Fishery
1965 Invest.,Lond.(2), 24(3):64

Garrod, D.J., R.Gambell and J.P. Hillis, The whiting fisheries of the Irish Sea.
1966 Co-oper.Res.Rep.int.Comm.Explor.Sea,(B), 1964:8-20

Glowinska, A., Changes in the hydrographical conditions in the southern Baltic
1966 1902-1965. ICES Annual Meeting 1966

Graham, M., Rational fishing of cod of the North Sea. London, Edward Arnold, 112 p.
1948

Gulland, J.A., Fishing and the stocks of fish at Iceland. Fishery Invest.,Lond.(2),
1961 23(4):52

__________, The abundance of fish stocks in the Barents Sea. Rapp.P.-v.Réun.
1964 Cons.perm.int.Explor.Mer, 155:126-37

__________, Recent changes in the North Sea plaice fishery. J.Cons.per.int.
(in press) Explor.Mer

Hannerz, L., Regional and annual variations in the growth of whiting (Gadus
1964 merlangus L.). Rep.Inst.mar.Res.Lysekil(Biol.), 14:64 p.

Hela, I. and T. Laevastu, Fisheries hydrography. London, Fishing News (Books)
1962 Ltd., 137 p.

Henderson, G.T.D., Contributions towards a plankton atlas of the North-Eastern
1961 Atlantic and the North Sea. 5. Young fish. Bull.mar.Ecol., 5(42): 105-11

__________, Redfish larvae in the North Atlantic. Spec.Publs int.Commn NW.
1965 Atlant.Fish., (6):309-16

Hickling, C.F., The natural history of the hake. Fishery Invest.,Lond.(2), 10(2)

__________, The hake and the hake fishery. London, Edward Arnold and Co.,
1935 142 p.

__________, The recovery of a deep sea fishery. Fishery Invest.,Lond.(2),
1946 17(1):1-59

Holden, M.J., Spurdogs. Lab.Leafl.Fish.Lab.Lowestoft, (16):23 p.
1967

ICES, International Fisheries Convention, 1946. Report of the Ad hoc Committee
1957 J.Cons.perm.int.Explor.Mer, 23:7-37

__________, Contributions to special scientific meeting. Measures for improving
1959 the stock of demersal fish in the Baltic. Rapp.P.-v.Réun.Cons.perm.
int.Explor.Mer, 147:96 p.

__________, North-western working group. Report of meeting in Copenhagen 27
1962 February-6 March 1961. Co-oper.Res.Rep.int.Comm.Explor.Sea, 1:31 p.

__________, Report of the coalfish working group. Co-oper.Res.Rep.int.Comm.
1965a Explor.Sea, 6:23 p.

__________, Report of the working group on sole. Co-oper.Res.Rep.int.Comm.
1965b Explor.Sea, 5:125 p.

__________, Liaison committee report 1964, (B), 59 p.
1966a

__________, Liaison committee report 1965, (B), 187 p.
1966b

__________, Report of the North-western working group, ICES, Gadoid Fish Comm.
1966c Doc.G1:40 p. (mimeo)

Jensen, A.J.C., Danish investigations on the cod at Borneholm. ICES Demersal
1967 fish (Northern) Comm.Doc. F26

Jones, B.W., The cod and the cod fishery at Faroe. Fishery Invest.,Lond.(2),
1965 24(5):32 p.

Jones, R., A method of analysis of some tagged haddock returns. J.Cons.perm.int.
1959 Explor.Mer, 25(1):58-72

__________, Post war changes in the North Sea stock of haddock. ICES Gadoid
1966 Fish Comm.Doc. G20:2 p. (mimeo)

Jonsson, J., On the mortality of the Icelandic stock of cod during the years
1960 1930-60. ICES Gadoid Fish Comm.1960, Doc.133:3 p. (mimeo)

Jonsson, J., Abundance, recruitment and growth in the Icelandic stock of cod.
1966 ICES Gadoid Fish Comm.1966, Doc. G13;3 p.. (mimeo).

Jonsson, J. and B.W. Jones, Anglo-Icelandic coalfish tagging experiments at
1965 Iceland, 1964-5; a progress report. ICES Gadoid Fish Comm.Doc 82
4 p. (mimeo)

Knudsen, H., Studies on whiting (Merlangus merlangus L. in the North Sea, Skagerrak
1965 and Kattegat. Medd.Danm.Fisk.Havundersøg., 4(1/7):95-136

Kotthaus, A. and G. Krefft, Fischfaunen Liste der Fahrten mit FFS Anton-Dohrn nach
1957 Island-Gronland. Ber.dt.wiss.Komm.Meeresforsch., 24(3):169-91

Letaconnoux, R., Effets de la guerre sur la constitution des stocks des poissons.
1948 Rapp.P.v-Réun.Cons.perm.int.Explor.Mer, 122:55-62

__________, Considérations sur l'exploitation du stock de merlu depuis 1937.
1951 Rev.Trav.Off.(scient.tech.)Pêches Marit., 16(1/7):72-89

Lindquist, A., Zur fischerei hydrographie der sprotte (Curpea sprattus)
1964 an der Schwedischen west küste. Rep.Inst.mar.Res.Lysekil.(Biol.),
15:87 p.

Lishev, M.N. and D.V. Uzars, Some data on the relations between the stocks of cod,
1967 sprat and herring in the Eastern Baltic. ICES Pelagic Fish (North) Comm.
Doc.H17 (mimeo)

Lopez, J., Edad de la sardina (Sardina pilchardus Walb) de Barcelona.
1963 Investigación pesq., 23:133-57

MacArthur, R., Fluctuations of animal population and a measure of community
1955 stability. Ecology, 36(3):533-6

Macer, C.T., Sand-eels (Ammodytidae) in the South-western North Sea; their
1966 biology and fishery. Fishery Invest.,Lond.(2), 24(6):55

Malmberg, S.A., I. Hallgrímsson and J. Jakobson, (Eds.) Report of the joint
1965 Segdisfjordur meeting, held 20-23 June 1965. ICES Herring Comm.Doc. 141:
10 p. (mimeo)

Malmberg, S.A., T. Thordardottier, and H. Vilhjalmsson, (Eds.) Report on the joint
1966 meeting on the Atlanto-Scandian herring distribution, held at Akureyri,
June 12-14, 1966. ICES Herring Comm. Doc.H18:6 p., (mimeo)

Meriel-Bussy, M., Le merlu du golfe de Gascogne. Répartition bathymétrique
19661 saisonnière et composition du stock. ICES Gadoid Fish Comm.Doc. G18:
6 p. (mimeo)

__________, La croissance de merlu dans le golfe de Gascogne. ICES Gadoid Fish
1966b Comm. 1966, Doc.G17:2 p. (mimeo)

Meriel-Bussy, M., 1967 La pêche du merlu à La Rochelle. Analyse statistique de 1966. ICES Demersal Fish (Southern) Comm. Doc G10

Moller, D. and S. Olsen, 1962 Norwegian capelin investigation. ICES Distant Northern Seas Comm.Doc.34:10 p. (mimeo)

Nizovtsev, G.P., 1967 Soviet investigations on young cod of the O, I, II and III age-groups in the Barents Sea. ICES Demersal Fish (Northern) Comm.Paper F:17

Olsen, S., 1964 Abundance estimates of Barents Sea capelin. ICES Distant Northern Seas Comm.Doc.119: 5 p. (mimeo), also issued as Fisk.Dir.Skr.(Havunders), 13(8):76-82

__________, 1966 Density-dependent growth in saithe. ICES Gadoid Fish Comm.1966, Paper G2:6 p. (mimeo)

Otterlind, G., 1967 On the status of the Baltic cod fishery and cod stock. ICES Demersal Fish (Northern) Comm.Doc. F33

Parrish, B.B. and R. Jones, 1953 Haddock bionomics. 1. The state of the stocks in the North Sea 1946-50 and at Faroe 1914-50. Mar.Res., 1952(4):1-27

Petersen, C.G.J., 1918 The sea bottom and its production of fish food. Rep.Dan.biol. Stn, 25 p.

Ponomarenko, V.P., 1967 Reason of changes in the rate of growth and maturation of the Barents Sea cod. ICES Demersal Fish (Northern) Comm.Paper F:16

Prokhorov, V.S., 1960 Post-spawning survival of the Barents Sea capelin. ICES Distant Northern Seas Comm.Doc. 165:5 p. (mimeo)

Quero, J.C. and P. Meriel-Burrey, 1967 La pêche du merlu au filet maillant sur les côtes françaises de l'Atlantique et plus particulièrement à La Rochelle. ICES Demersal Fish (Southern) Comm.Paper G11

Raitt, D.S., 1939 The rate of mortality of the haddock of the North Sea stock 1919-1938. Rapp.P.-v.Réun.Cons.perm.int.Explor.Mer, 110:65-79

Raitt, D.F.S., 1965 The stocks of Trisopterus esmarkii (Nilsson) of north-west Scotland and in the North Sea. Mar.Res., (1):24 p.

__________, 1966a Synopsis of biological data on the Norway pout Trisopterus esmarkii (Nilsson) 1855. FAO Fish.Synops., (33):pag.var.

__________, 1966b Synopsis of biological data on the blue whaling Micromesistius poutassou (Risso) 1810. FAO Fish.Synops., (34):pag.var.

__________, 1967 Further observations on the population dynamics of Norway pout: the effect of the poor 1963 year class in the North Sea. ICES Committee Meeting 1967. Doc.F:30

Raitt, D.F.S., On the distribution, age and abundance of Trisopterus esmarkii
(in press) (Nilsson) in the North Sea. Mar.Res.

Raitt, D.F.S. and D.J. Symonds, The Scottish cod fishery in the North Sea. Mar.Res.,
1967 (5):24 p.

Riedel, D., Sardine production off the Atlantic coast of Europe and Morocco since
1960 1920. In Proceedings of the World Scientific Meeting of the Biology of Sardines and Related Species. Rome, FAO, pp. 877-911

Rodriguez, D.O., et al., Experiencias sobre selectividad de artes de arrastre en
1963 el golfo de Vizoaya, ICES Comparative Fish.Comm., abril 20-30, 1963

Russel, E.S., The overfishing problem. Cambridge, Univ.Press, 130 p.
1942

Rutkowicz, S., The result of investigations on the stock of cod in the southern
1963 Baltic 1946-1960. Pr.morsk.Inst.ryb.Gdynia

Sahrhage, D., Uber die Verbreitung der Fischarten in der Nordsee. 1. Juni-Juli
1964 1959 und Juli 1960. Ber.dt.wiss.Kommn Meeresforsch., 17(3):165-278

__________, Uber die Verbreitung der Fischarten in der Nordsee. 2. Januar 1962
1967 und 1963. Ber.dt.wiss.Kommn Meeresforsch., 19(2):66-175

Saemundsson, B., Marine pisces. Zoology Iceland, 4(72):1-150
1949

Saville, A., B.B. Parrish and I.G. Baxter, Review of herring fisheries and stocks
1965 off the west coast of Scotland. ICES Herring Comm.Doc. 154:8 p. (mimeo)

Schott, G., Geographie des Atlantischen Ozens. Hamburg, Boysen, 438 p.
1942

Slobodkin, L.B., Energetics in Daphnia pulex populations. Ecology, 40:232-43
1959

Sorokin, V.P., On a possible method of calculating the absolute abundance of the
1964 commercial populations of Sebastes mentella Travin in the Barents Sea. Rapp.P.-v.Réun.Cons.perm.int.Explor.Mer, 155:255-6

Steele, J., Some problems in the study of marine resources. Spec.Publs int.Commn
1965 NW.Atlant.Fish., (6):463-76

Symonds, D.J. and D.F.S. Raitt, Preliminary report on Scottish cod tagging
1966 investigations, 1962-4. ICES Gadoid Fish Comm.Paper G21:4 p. (mimeo)

U.K. MAFF, Fish stk record, 1961:57 p.
1962

__________, Rep.Dir.Fish.Res., Lowestoft, 1965:90 p.
1966

Williams, T., Tests of efficiency of various kinds of tags and methods of attachment
1963 on plaice, cod, sole and whiting. Spec.Publs int.Commn NW.Atlant. Fish., (4):156-63

_____________, Movements of tagged soles in the Irish Sea and Bristol Channel.
1965 ICES Near Northern Seas Comm.Doc. 87 (mimeo)

Williams, T. and J. Prime, English whiting tagging experiments in the North Sea.
1966 ICES Gadoid Fish Comm.Paper G10:3 p. (mimeo)

Wimpenny, R.S., The plaice. London, Edward Arnold, 145 p.
1953

Wood, R.J. and D.F.S. Raitt, Preliminary investigations on the biology of the
1963 greater silver smelt - Argentina silver (Ascanius). ICES Atlantic Comm. Doc. 128 (mimeo)

Anon, Preliminary report of the joint Soviet-Norwegian investigation in the Barents
1965 Sea and adjacent waters, September 1965. ICES Herring Committee, Distant Northern Seas Comm.Doc. 161:5 p. (mimeo)

Anon, Preliminary report of the joint international 0-group fish survey on the
1966 Barents Sea and adjacent waters, August/September 1966. ICES Herring Committee and Gadoid Fish Comm. 9 p. (mimeo)