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A Note on the Fisheries Resources of the ICES Area

by

Biology Branch, Fisheries Division, Food and Agriculture Organization of the United Nations

INTRODUCTION

In a paper presented to the 42nd Meeting of the International Council for the Exploration of the Sea, an account was given to the Council of FAO plans for the development of a programme to survey the living aquatic resources of the world. That paper reported the Organization's views, at that stage, of its responsibility in respect of natural resources, and after indicating the types of international action which the Organization might undertake and offering a definition of the world survey, a request was made for collaboration between the International Council and FAO. Since presentation of that paper, the Secretariat has been able to make some further development of its ideas on this matter and has had the advantage of discussions with a great many of the active workers in this field. The purpose of the present paper is to report these further developments to the Council and, in a somewhat more practical way than was possible at the time of the first paper, to indicate the kind of information which the Secretariat is assembling and the kind of collaboration which the Organization would like to have with the Council.

The scope and objectives of the resources survey

The first paper to the Council listed five principal categories of elements which it was thought were involved in resources survey. It is worthwhile to repeat these elements here:

1. Comprehension of the relevant special properties of living resources and of the purpose of a survey as a guide to further human action with respect to these resources;

2. knowledge of the uses of different kinds of organic products and of the possible means of obtaining them so that the scope of the survey can be narrowed to practicable limits;

production under current modes of exploitation, but it is the material out of which will be constructed the greater account of these resources. The second will permit of interim evaluations of different areas and it will be combined with the first as and when we become possessed of reliable estimates of the efficiency of conversion of material and transfer of energy between successive links in natural food chains.

The notes which follow give a preliminary indication of the kind of treatment of data which is contemplated, applied to the particular circumstance of the ICES area. It is in two parts, the first of which summarizes oceanographic data and the second examines certain statistics of commercial operations and presents some theoretical discussion of the possibilities of treatment of these statistics. The submission of this material is in accordance with the proposals made in the note on this project submitted to the Council's last meeting. The Division hopes that it may have the Council's comment on this material in respect of:

1. The schedule of data being assembled;
2. the sources of data to which reference has been made or could be made;
3. the accuracy of data;
4. the arrangements that could be made to assist in interpretation of those data in the sense of the survey plan.

"NATURAL" REGIONS OF THE ICES AREA

The administrative division of the North Atlantic between the International Council for the Exploration of the Sea, and the International Commission for the North West Atlantic Fisheries, is shown in Figure 1. The classification of oceanic areas which the Biology Branch of the FAO Fisheries Division proposes to employ (Kesteven and Holt 1955) is also shown on this diagram. Neither of these systems corresponds to the classifications which have been made on oceanographic considerations and for the purposes of the survey programme it seems desirable at least to examine the division into the so-called natural regions and to consider whether it would be preferable to use that classification. One consequence of such a decision would be that ICES and ICNAF might need to be consulted concurrently in respect of certain shared regions. The "natural" regions of the North Atlantic are shown in Figure 2. The ICES regions are listed, with brief characterization, below.

I. Atlantic Arctic Region

This is synonymous with the "High Arctic" of Ekman (1935) and with Schott's (1942) natural and biological "Arctic" regions.

The region is covered with ice for the greater part of the year. It has no importance for fisheries. The arctic bottom water and intermediate water originates in great part from this area.

II. North Atlantic Subpolar Region

This region is synonymous with Ekman's "Low Arctic", with Schott's natural "North Atlantic Subpolar Region" and with his biological "Arctic region".

the mixing zones between the East Greenland the the Irminger Currents and between the Labrador Current and the Gulf Stream. The organic production is high, especially to the west and soutwest of Iceland. These areas are important feeding grounds for the fish which use the Icelandic Shelf for spawning.

IIIc Norwegian Sea, Faeroes Waters

The warm surface water of this region originates from North Atlantic Drift Current whose Northern branches are here called the Faroes-Shetland current and the Norwegian current. The Norwegian current forms a counter-clockwise gyral in the Norwegian Sea. This area includes the Norwegian Shelf (with an area of 93.000 km^2 and mean depth of 200-300 m.) and part of the Iceland-Faeroes Shelf and Wyville-Thompson Ridge which has a total area of 115.000 km^2 with mean depth of 200-300 m. The average sill depth of the Wyville-Thompson Ridge is about 450-500 m. and the greatest depth is 575 m. The surface temperature in winter is between 0 to 7°C. and in summer is between 5 and 12°C. The mean surface salinity is around 35‰, being somewhat lower near the coasts. The summer surface phosphates are medium to high. The highest summer phosphates originate from the mixing of the East Iceland current with the North Atlantic Drift Current east of Iceland, and from the mixing of waters around the ridges, the Faeroes Islands, the Jan Mayen Shelf, and partly on the Lofoten Shelf. The basic organic production is high, especially on the edges of these shelves. Somewhat lower production takes place in the Norwegian gyral area with its 'old' surface water.

IIId North Sea Waters

This area is a part of the Northwest European Shelf, the total area of which is 1.050.000 km^2 and the mean depth less than 100 m. The area of the North Sea is 575.000 km. and of the English Channel 75.000 km^2, the mean depths are 94 and 54 m. respectively. The Atlantic water flows in through the English Channel on the south and from around the Shetland Isles on the north. After mixing, the low salinity Baltic water flows out along the Norwegian coast. The average temperature of the surface water is between 2° and 6°C. in winter and 13°to 17°C in summer. The surface salinity is on the average between 33‰ and 34.5‰. The summer surface phosphates are low, 0 - 0.2 µg at /L, and the winter phosphates are around 0.5µg.at /L. Owing to the generally high stability of the water, the phosphates are brought to the surface mainly during the autumn turn-over. The basic organic production is medium. Since all the area is shallow, the spawning grounds and the benthos make the area one of the most important fishing grounds in the North Atlantic.

IIIe Baltic Sea Waters

The Baltic Sea is one of the largest brackish water bodies in the world. Since the oceanographical and biological problems in brackish water differ considerably from those of oceanic waters, and numerous new factors enter into the picture, this region is not discussed here.

must eventually be made in interpreting available data.

The result of an attempt to estimate the annual basic organic production in the North Atlantic is presented in Figure 5. This is a more detailed presentation after Fleming and Laevastu (MS); the same factors having been considered. Some of the earlier estimations of basic organic production in the area are summarized in Table 3.

Although considerable work has been done on the benthos biomass for most of the ICES fishing grounds, there remains a need for a summary of the data in the form of maps. An example of the representation of the quantitative distribution of benthos biomass is presented in Figure 6 which relates to the Barents Sea. Some data on the size of benthos biomass in the North Atlantic are presented in Table 1.

ECOLOGICAL AND FOOD RELATIONS OF THE PRINCIPAL MARINE BIOLOGICAL GROUPS IN THE NORTH ATLANTIC

The preceding sections have related to the oceanographic and especially the biological characterization of the ICES area and of the sub-areas into which it can be divided. The eventual discussion which we wish to have is of the total production of various links in the food chain in each of these sub-areas, leading to an examination of the use of such production made by man. In order to pursue this line of discussion, it is next necessary to consider quantitative measures of the relations between the various elements of these systems.

(a) Water content

The following figures relate to biomass (wet weight). For calculations the following mean values for water content are taken: Plankton 85%, Benthos soft organic tissues 80%, Fish 75%, Organic matter of sediments 65%. Water content in deep water sediments (globigerina ooze, diatomaceous, ooze etc.) 50%; shallow water sediments 40% (Vinogradov, 1953, Sverdrup, Johnson, Fleming, 1949).

(b) Food coefficients

McGinitie (1949) estimates the food coefficient to be 1:10 between every pair of links in the food chain. Some refinement of this coefficient is proposed in the following paragraphs.

Zooplankton 1:15 This value is arrived at from values given by Gauld (1951/53) Jaschnov (1939) and others, and from consideration of the variation of the food coefficient from season to season because of the availability of the food. In middle and high latitudes, most aquatic animals have a limited growth period in each year and in the other seasons the food they can get seems at best only for maintenance and they may even have to go completely hungry.

Although the bacteria and colourless flagellates are important food boundary for benthos in quantity.

Published statistics indicate that the relation between demersal and pelagic catches in shallow areas is on the average 1:3 whilst only pelagic fish are taken in deep areas (the migrating demersal fish are not considered). Whether these indications correspond closely to the natural situation is a matter yet to be determined. Although large numbers of pelagic fish are present in shallow areas, such fish do not necessarily spend all their life there but at least they use the area as spawning ground.

From (1) calculations of the filtration capacity of zooplankton, (2) grazing rates and the relations between standing crop of phyto- and zooplankton, (3) estimates of the amount of substances assimilated by zooplankton, and (4) the relative life length of organisms, it is calculated that about 65% of the annual phytoplankton production must pass through the digestion of zooplankton. The rest is used for reproduction and sinks after death to the deeper layers or to the bottom, where it degenerates. This means that 1 g. of annual phytoplankton production (wet weight) gives a maximal 0.043 g. of annual zooplankton production. One g. of standing crop of zooplankton must then correspond to 23 to 115 g. of annual phytoplankton production, depending on the latitude, the average number of generations being 1-5. In the case of two generations, the value is 46 g.

It is estimated that at the most about 30-60% of zooplankton is used as food for fish, considering (1) the reproduction rate, (2) the extensive depth distribution of zooplankton, and (3) the suitable and the preferred food items in respect of plankton spectrum. Using 40% as mean value, 1 g. of annual zooplankton production corresponds then to 0.04 g. of annual pelagic fish production. Assuming that in the North Atlantic, the zooplankton standing crop reproduces itself on the average twice (two generations) (Wiborg, 1954), 1 g. of standing crop of zooplankton then would correspond roughly to 0.08 g. of annual production of pelagic fish. An average standing crop of zooplankton in the North Atlantic (0.1 g/m^3), integrated over 200 m. depth range, could in a year produce 1.6 g of pelagic fish under one square meter of surface.

There is roughly 40% of calcareous and chitinous matter and 60% of organic soft tissues in the average biomass of benthos. About 50% of the soft organic matter is estimated to be available as fish food, and assuming 70% of it is used by demersal fish it results that 1 g of benthos biomass satisfies the special food requirement of 0.084 g of annual production of demersal fish, considering the food spectrum given earlier in this paper. One g of standing crop of demersal fish corresponds then to 11.9 g of benthos biomass, 3.5 g of pelagic fish and 1.5 g zooplankton per annum. Most of the above-described relations are represented in Tables 4 and 5.

STANDING CROPS OF MARINE BIOLOGICAL GROUPS IN DIFFERENT NORTH ATLANTIC AREAS AND THEIR RELATIONS TO THE PRESENT COMMERCIAL CATCH OF FISH

As shown in previous chapters, we must consider not only the annual basic organic production but also numerous other factors, in

Benthos on the continental shelf	14×10^{11} kg.**
Benthos outside the continental shelf	0.27×10^{11} "
Plankton on the continental shelf	8×10^{11} "
Plankton outside the continental shelf	4×10^{11}

Altogether, $25 - 30 \times 10^{11}$ kg., exclusive of fish and mammals. Steemann-Nielsen (1952) estimates a total net production of 1.5×10^{10} tons carbon per year in the sea. The estimation by Rabinowitch (1945) is about one order of magnitude higher. Riley (1949) estimates the average standing crop of fish in the oceans to 0.9 g/m^2 which would give 3.2×10^{11} kg. fish in the oceans as a whole.

Considering the above estimations and the discussions in earlier chapters, the standing crops of fish within certain broad limits have been estimated as follows:

1. <u>On the Continental Shelf</u>

   $40^oN - 75^oN$ }
   $40^oS - 65^oS$ } Latitudes

   0.6 g/m^2 demersal fish

   1.4 g/m^2 pelagic fish

   40 N - 40 S latitudes

   0.2 g/m^2 demersal fish

   0.7 g/m^2 pelagic fish

2. <u>Oceanic</u>

   North and South from 40^oN and S latitudes respectively

   1.0 g/m^2 pelagic fish

   $40^oN - 40^oS$ latitudes

   0.4 g/m^2 pelagic fish

In order to test how the values, estimated for food relations in the earlier chapters fit to the experimental values for fish population studies, a calculation is made for the Icelandic waters. Using the values for experimental fishing for Faxa and Breida Bays (Fridriksson, 1948) and estimating that the trawl covers ca 150,000 m^2 per hour and catches 50%

** there must be a typographical error in the Zenkevich paper where tons are given in place of kg.

COMMERCIAL CATCH OF ICES AREA CONSIDERED IN RELATION TO RESOURCES SURVEY

We now consider the harvest at present derived from the resources in terms of fish catch, arguing backwards to estimates of potential sustainable increase in harvest as each limiting factor is removed (in resource survey we consider only the biological factors and their direct relation to properties of fishing gear).

For this purpose we select the unit fish stock as a part of the resource susceptible to separate treatment. The stock is thus considered as a partial system, and the method of procedure is to attempt to link this with the other elements of the ecosystem (the environment of the stock), considering each relation in turn. We find that we may usefully group certain elements together (as we did when we considered benthos, pelagic fish, demersal fish and so on) and in particular we shall find that we have to give special consideration to the problem of describing the simultaneous exploitation of several species by the same fishing units.

The fundamental properties of the fish stock that we seek to describe are:

(a) Its identity and general location - its existence as an independent population; the bounds of its distribution;

(b) The behaviour exhibited by the individuals or groups of individuals (schools) composing it; as by changes of habitat at certain stages in the life history migrations within the general area of distribution; local movement in response to various stimuli; and other forms of activity;

(c) Its magnitude.

ICES area studies under (a) are well advanced and it should not prove difficult to make summary maps of unit stocks - this needs doing. Property (b) determines the accessibility of that part of the resource to the available fishing equipment (gear, vessels) and although findings of studies are important to resources survey, the subject is of marginal interest, belonging partly to the resources survey and partly to the exploitation programme. Analysis of property (c) is the central problem.

Similar procedures can be followed for dealing with line and other fisheries, but there is a further difficulty in reconciling the alternative catch-isopleth diagrams that might be drawn for a particular stock with the possibility of being exploited by different types of gear, for which the relations of selectivity to size of fish are different. For example, whereas with a trawl or other "bag" net such as a seine, the fishing mortality coefficient is, to a first approximation, constant at all ages of fish above a certain age at first capture - which is determined either by the pattern of recruitment or by the size of mesh - Rollefsen's (1953) and other data indicate that this is not so for hook and line gear, but that the instantaneous fishing mortality coefficient may vary in a curvilinear manner (possibly exponentially) with age of fish. The same is undoubtedly true of entangling nets, such as drift gill nets and trammels. We see then that in general the mortality coefficient is some function - but probably usually a rather simple function - of the size or age of fish; that each kind of fishing unit has a characteristic function; and that for trawls this is of the simplest possible kind. Now it is possible to define an amount and selectivity of one kind of fishing (say trawling) that will result in the same sustained catch and have roughly the same effect on the stock magnitude as any given amount and selectivity of another kind of fishing (say lining with a given size of hook). It is thus possible to transform any one isopleth diagram referring to one kind of gear to an equivalent one for some standard fishing method, and it is convenient to take trawling as the standard.

In this way we can, for the purposes of resource appraisal, define standard exploitation conditions in biological terms so that the sustained catch may be used as a basic measure of stock productiveness.

Before passing to the next stage of the argument it should be mentioned that there are many ways of simplifying the procedures of drafting an isopleth diagram and subsequent operations. A paper dealing with this matter is in preparation; the matter is of considerable importance if the appraisal methods we are describing are to be used in a general survey of world resources. It is sufficient here to say that simplification can be achieved at several levels - some standardization of methods of observation and presentation of data, compilation and critical revision of data on special subjects such as growth of fish, mathematical approximation, and short cuts in computation and plotting.

On to isopleth diagrams of steady catch, other summary curves may be drawn indicating certain aspects of the contour pattern. The most important of these is the eumetric fishing curve, showing the best selectivity of the gear for each particular fishing mortality and from which may be deduced the eumetric catch curve giving the maximum steady catch as a function of the amount of eumetric fishing. In the other line (shown dotted in diagrams A and B), adjustment of selectivity may be limited for technical or other reasons, and for each age at first liability to capture we impose the best fishing mortality. (On this curve lie all points of "maximum sustainable catch" obtained when only the variations of <u>amount</u> of fishing is considered as a factor governing

t_ρ = age of fish at recruitment

λ = fishable life span

Ω_0, Ω_1, Ω_2, and Ω_3 are

+1, -3, +3 and -1 respectively

When λ is large and t_ρ small, as may often be assumed, this approximates to

$$r \simeq R\, W_\infty\, 6K^3 \Big/ \prod_{n=0}^{3} \left[M + nK \right]$$

The other quantity is the asymptote, the yield, and it is found to be given by

$$y = R e^{M t_\rho}\, W_\infty (3K)^3 M^{M/K} \Big/ (M + 3K)^{3 + M/K}$$

y and r are linked by the approximate relation

$$C_u = y \sqrt{\frac{1 - e^{-2rF/y}}{1 + e^{-2vrF/y}}}$$

where C_u is the eumetric steady catch, and v is a constant lying between zero and unity.

It will be seen that the equation for y (and also indeed that for r) contains only parameters referring to the recruitment, growth and mortality of fish in the stock, all of which factors are measurable, and it would seem that measurement of these factors and their use to compute yield would be an important part of any survey and appraisal work. It might be argued that for this population model these parameters have been assumed to be constant, and since it is expected that for example growth rate is in reality dependent on the density of the stock, our deductions would be invalid. However, we suggest that this first approximation might be taken as a working basis from which to develop more comprehensive methods of estimation, and in addition they seem to help in sorting out the kind of data we need to analyse, and link up widely different kinds of observation. It is an advantage to use terminology and methods that are applicable equally to marine and inland resources, and to cultural practices as well as simple exploitation of wild stocks. Further, we would hope that in doing this we may diagram, choosing again for preference the particular contour passing through the reference point of observation. The lines intersect, cutting the diagram into segments in some of which there is universal improvement in all characteristics, and in others there is universal detriment; whilst in others one characteristic is improved to the detriment of one or both others.

Two examples are given here of this procedure (figures A and B, but see also Kesteven and Holt (1955)), the material being taken from Beverton and Holt (in press), and referring to the plaice and the haddock stocks of the North Sea. As it happens, in both these cases, the curve for average weight of fish, used as an index of "quality" coincides almost exactly with the lower part of the curve for magnitude of catch. The two "optimum" lines are shown to indicate relief on the diagrams, and to provide an opportunity of marking in the yield.

Such diagrams can be the basis for technical, economic and social evaluations by suitable transformation of the co-ordinates. Thus, F is proportional to standard fishing intensity, and catch and effort can be converted to value and cost to obtain curves for net economic gain. Diagrams for different stocks can be compared to show conditions under which more valuable species begin to decline in yield in relation to less valuable species. Again, diagrams for different types of fishing, for example, line and trawl, may be compared by superposing them directly or transforming first into cost-value diagrams. All this, of course, concerns the evaluation of operations under current conditions of exploitation, but we may indicate the values of both yield and the ratio Y/F which show the limits of economic production sustainable with current exploitation methods. Then, as information becomes available, similar contour lines might later be drawn to indicate the effects of certain types of intervention, such as transplantation, predator control, and so on.

We believe that diagrams such as these will serve as a first attempt to reduce to simple terms the essential information about the magnitude of the exploited stocks that is obtainable from the records of fishing operations and catch and from special research projects. As presented, they refer only to single species populations, but similar presentations can be made for mixed populations; the procedure is then considerably more complex but not different in principle.

Consideration of the situation where more than one species is taken by the same gear provides an example of this procedure, and incidentally illustrates the practical value of distinguishing yield from catch as we have done. Figure C shows a combination of the plaice and haddock evaluation diagrams. Here, since the relation between codend mesh size and t is different for the two species, the scale of the selectivity axis has for both been transformed to mesh size. The fishing mortality coefficient is expressed in relative instead of absolute terms, so that the two reference points of observed state, O, coincide at unity. In this case only the two characteristics, of catch, and catch per unit effort, have been plotted. Again we see that the diagram is cut into several sectors showing different degrees of advantage or disadvantage (see figure legend). In this diagram not all possible combinations are distinguished, but certain groups of segments have been blended, to show the general

BIBLIOGRAPHY

ANNON, 1934 - Rapp. Cons. Explor. Mer, 89(II):47

ATKINS, W.R.G. 1923 - The hydrogen ion concentration of sea water in its relation to photosynthetic changes. Part II. J. Mar. biol. Ass. U.K., 13:93-118

ATKINS, W.R.G. and M, PARKE 1951 - Seasonal changes in the phytoplankton as indicated by chlorophyll estimations. J. Mar. biol. Ass. U.K., 29(3):609-618

BEVERTON, R.J.H. 1953 - Some observations on the principles of fishery regulation. J.Cons.int. Explor.Mer, 19(1):56-68

BEVERTON, R.J.H. and HOLT, S.J. 1955 - On the dynamics of exploited fish populations Fish.Invest., London.

BIGELOW, H.B. and SEARS, M. 1939 - Studies of the waters of the continental shelf, Cape Cod to Shesapeake Bay. III A volumetric study of the zooplankton. Mem. Mus. Comp. Zool. Harvard Coll. 54(4):182-378

BLEGVAD, H. 1915 - Food and conditions of nourishment among the communities of invertebrate animals found on or in the sea bottom of Danish waters. Rep. Danish biol. Sta., 22:3-88

BLEGVAD, H. 1930 - Quantitative investigations of bottom invertebrates in the Kattegat with special reference to the plaice food. Rep. Danish biol. Sta., 36:3-56

BROTSKAJA, V.A. and ZENKEVICH, L.A. 1939 - Quantitative study of the bottom fauna of the Barents Sea. Trans. Inst. Mar. Fish and Oceanogr. USSR, 4(8):5-126

BUCH, K. 1952 - The cycle of nutrient salts and marine production. Rapp. Cons. Explor. Mer, 132:36-46.

BUCH, K. 1954 - Physikalische und chemische Verhältnisse in Beziehung zur biologischen Aktivität im Wasser des südwestlichen Schärenmeeres von Finnland. Havsforskn. Inst. Skr. Helsingf., 159:36pp.

GRAN, H.H. 1929 - Investigation of the production of plankton outside the Romsdalsfjord 1926-27. Rapp. Cons. Explor. Mer, 56:112 pp.

HAGMEIER, A. 1951 - Die Nahrung der Meerestiere. Beziehungen der Ernährung zur Verbreitung der Arten und der Gemeinschaften der Bodentiere. Handbuch der Seefischerei Nordeuropas, 1(5b):177-212

HALLDAL, P. 1953 - Phytoplankton investigations from weathership "M" in the Norwegian Sea 1948-49. Sci. Results of Mar. biol. Res., 38:91 pp.

HARVEY, H.W. 1950 - On the production of living matter in the sea off Plymouth. J. Mar. biol. Ass. U.K., 29(1):97-137

HENTSCHEL, I.E. 1936 - Über das Winterplankton im süden von Island. Rapp. Cons. Explor. Mer, 99:1-33

IDELSON, M.S. 1934 - Materials for the quantitative evaluation of the bottom fauna of the Barents, White and Kara Seas No. 7. Distribution of the benthos biomass in the southern Barents Sea. The influence of different factors on the density of the sea bottom population. Trans. Oceanogr. Inst. (Russian), 3(4) Ref: J. Cons. Explor. Mer (1935 - 10(2):206-207

JASCHNOV, W.E. 1939 - Plankton productivity of the south-western part of the Barents Sea. Trans. Inst. Marin. Fish. and Oceanogr. USSR, 4:221-224

JASCHNOV, W.E. 1939 - Reproduction and seasonal variations in the distribution of different stages of Calanus finmarchicus in the Barents Sea. Trans. Inst. Mar. Fish. Oceanogr. USSR, 4:225-244

JESPERSEN, P. 1944 - Investigations of the food of the herring and the macroplankton round the Faroes. Medd. Danm. Fisk. og Havunders., Ser. Plankton. 3(7):1-43

JESPERSEN, P. 1954 - On the quantities of macroplankton in the North Atlantic. Medd. Danm. Fisk. og Havunders. Ny serie. 1(2):12 pp.

JOHNSON, R. 1952 - Chemical observation, North Sea. Ann. biol. Copenhague, 9:99

KÄNDLER, R. 1955 - An account of the knowledge concerning the response of the plaice to environmental factors. U.N. Gen. Assembly. Intern. Techn. Conf. on the Conservation of the Living Resources of the Sea, Rome, Apr. 1955

RILEY, G.A. 1941 - Plankton Studies. III. Long Island Sound. Bull. Bingham oceanogr. Coll. 7(3):93 pp.

ROLLEFSEN, G. 1953 - The selectivity of different fishing gear used in Lofoten J. Cons. int. Explor. Mer, 19(2):191-4

SCHAEFER, M.B. 1954 - Fisheries Dynamics and the concept of maximum equilibrium catch. Proc. Gulf Caribb. Fish. Inst. 6th Ann. Sess.

SCHOTT, G. 1942 - Geographie des Atlantischen Ozeans. Boysen, Hamburg, 438 pp.

SEGERSTRÅLE, S.V. 1933 - Studien über die Bodentierwelt in Südfinnländischen Küstengewässern. Comment. biol., Helsingf., 4(8 and 9)

SPÄRCK, R. 1929 - Preliminary survey of the results of quantitative bottom investigations in Iceland and Faroe waters. Rapp. Cons. Explor. Mer, 57:28 pp.

SPÄRCK, R. 1935 - On the importance of quantitative investigation of the bottom fauna in marine biology. J. Cons. int. Explor. Mer, 10(1):3-19

SBÄRCK, R. 1936 - Review on the Danish investigations on the quantitative composition of the bottom fauna in Iceland and East Greenland waters. Rapp. Cons. Explor. Mer, 99:5 pp.

SPÄRCK, R. 1948 - Bottom investigations Rapp. Cons. Explor. Mer, 120:32-33

STEEMANN-NIELSEN, E. 1954 - On organic production in the oceans. J. Cons. int. Explor. Mer, 19(3):309-328

STEEMANN-NIELSEN, E. 1952 - The use of radio-active carbon (C^{14}) for measuring organic production in the sea. J. Cons. int. Explor. Mer, 18(2):117-140

STEFANSSON, U. 1952 - Hydrographic conditions in the Iceland Sea, 1951. Ann. biol., Copenhague, 8:27-30

SVERDRUP, H.U., M.W. JOHNSON and R.H. FLEMING 1949 - The Oceans, their physics, chemistry and general biology. Prentice-Hall, N.Y., 1087 pp.

VINOGRADOV, A.P. 1953 - The elementary chemical composition of marine organisms. Sears Found. for Mar. Res., N.Haven, 647 pp.

TABLE I

Standing crops of benthos biomass in the North Atlantic and adjacent waters

Locality and Depth	Community and other Remarks	g/m^2	Author
North Sea	Venus gallina comm.		Anon. I 1934
	Nucula nitida var.	30 - 130	
	Tellina fabula var.	5 - 10	
	Echinocardium cordatum var.	- 500	
	Aonides var.	10	
North Sea		500	Petersen, Jensen, 1911
North Sea		244	Moiseev, 1955
North Sea Helgoland Bay	Macoma comm.	7 - 31	Hagmejer, 1925 (acc. Spärck, 1935)
	Syndosmya comm.	105	
	Venus comm.	25 - 28	
	Amphiura comm.	98 - 233	
Kattegatt		35	Petersen, Jensen, 1911
Kattegatt	Venus comm.	27 - 101	Belgvad, 1930
	Amphiura comm.	139 - 220	
	Haloops comm.	55	
Off Plymouth		100	Harvey, 1950
Baltic Sea		15	Petersen, Jensen, 1911
Southern Finland Waters	Gyttja bottom	25 - 206	Segerstrale, 1935
European Seas		20 - 250	Moiseev, 1955
Barents Sea		100	" "
Barents Sea	Edges of banks and continental shelf	100 - 500	Filatova, 1938
	Greatest part of the Barents Sea	50	
	Deeper parts against Atlantic	10	

TABLE 2

Standing crops of plankton biomass in the North Atlantic Ocean
(Zooplankton mainly on the basis of Hensen net catches).

Locality	Season	mg/m³	Author	Remarks
Zooplankton				
Skrova	IV-VIII 1949	32		Roughly calculated assuming 9 m³ filtered and 1 m/ displ. vol. = 50 mg biom.
	1950	63		
	1951	118		
Eggum	IV-VIII 1949	49		
	1950	184		
	1951	196		
Norwegian Sea, Weather Station "M"	IV-VIII 1950	46	After Wiborg, 1954	
	1951	38		
Norwegian Continental Shelf		280 - 560		Maximum
Outer part of Norwegian Cont. Shelf		180 - 280		Maximum
Off Plymouth	Average	37 - 80	Harvey, 1950	Recalculated assuming 70 m. depth
North Sea	"	55	Wimpenny, 1953	Recalculated assuming 50 m. depth
European Seas	"	50 - 140	Moiseev, 1951	
Barents Sea	"	140	Taschnov, 1939	
	Summer	230		
	Winter	50		
S.W. North Sea	Febr. March	152-357	Krey, 1953	
Phytoplankton				
Off Plymouth	Average	115 - 135	Harvey, 1950	Recalculated assuming 70 m. depth
" "	June (min.)	21	Atkins and Jenkins 1953	Recalculated
	April (max.)	400		
Barents Sea	Vegetative period 0-30 m.	500 - 600	Zenkevich, 1947	
S.W. North Sea	Febr. March	8.1-103	Krey, 1953	

TABLE 2(a) (Contd.)

Locality	Season	Authority	Plankton biomass in mg/m^3
Cape Cod to Chesapeake Bay	Feb. 1930-1932		320
	April 1929-1930		400
	May 1929-1932		640
	June 1929-1932		560
	July 1929-1931		640
	October 1931		320
Martha's Vineyard	Sept. - Oct. 1935	Clarke and Finn (1932)	32
	Nov. - Dec. 1935		560
	Jan. - March 1936		720
	April - June 1936		96
	July - August 1936		72
Gulf of Maine	July - August 1913 1916	Bigelow (1926)	280
	March 1920		160
	April 1932	Fish and Johnson (1937)	560
	May 1932		272
	June 1932		168
	August - Sept. 1932		128
	September 1933	Redfreld (unpublished data)	168
	October 1933		104
	December 1933		136
	January 1934		96
	March 1934		40
	April-May 1934		128
	May-June 1934		208
	June-July 1934		256
	September 1934		400
Bay of Fundy	April 1932	Fish and Johnson (1937)	32
	May 1932		152
	June 1932		160
	August - Sept. 1932		72
Nova Scotia, Newfoundland Shelf	May 1915	Huntsman (1919)	360
	June 1915		200
	July 1915		270
Gulf of St. Lawrence	May - June 1915	Huntsman (1919)	200
	August 1915		200
West Greenland	August 1924	Stormer (1929)	136

TABLE 4

Food coefficient, spectrum and average utilization by different marine biological groups

Biological Group	Average food Coefficient	Average food Spectrum	% of utilization	Biological Turnover	Remarks
Bacteria colourless flagellates		Organic detritus Bacteria (dissolv. organic matter)			
Phytoplankton			65	15-50% daily	
Zooplankton	1:15 (1:20 with bacteria)	80% zooplankton 20% bacteria and flagellates	30 - 60 mean (40)	1-5 yearly	
Pelagic fish I stage carniv.	1:10	100% zooplankton	20	1 a year	
II stage carniv.	1:8	80% I stage carniv. 20% zooplankton			
Demersal fish	1:10	50% benthos 35% I stage carniv. fish 15% zooplankton	(15)		
Benthos	1:6	45% org. detritus 20% zooplankton 20% phytoplankton 15% other benthos	70 of org. soft tissues		60% organic soft tissues in biomass

TABLE 6(a)

The relation of annual basic production to the commercial catch of fish in ICES area
(preliminary values)

ICES Sea Division	Area	Statistical Area nr.	Estimated total fishing area in 1000 km^2	Area 400 m. depth in 1000 km^2	Total in 1000 tons		Relation Pelagic/ Demersal
					Pelagic	Demersal	
Distant Northern Seas	Barents Sea	I		(830	16	352	0.05
	Spitzbergen Bear Island	IIb		(	-	76	-
	Norwegian Sea	IIa	1920	90	626	515	1.22
	Island Gr.	Va	410	(115	62	724	(0.08
	Faeroes gr.	Vb	180	(	-	64	(
	East Greenland	XIV	780	60	-	(194)	
				1095	704	1925	
Transition areas and Baltic Sea	Skager., Katteg., Sounds	IIIa-c	90	90	123	168	0.73
	Baltic Sea	IIId	390	390	(67)	(46)	1.46
			480	480	190	214	

TABLE 6(b)

The relation of annual basic production to the commercial catch of fish in ICES area (preliminary values)

Statistical Area nr.	Gram/m^2		Commercial catch in phytoplankton equivalents g biom. per m^2		Average basic organic production in g phytoplankton biomass/m^2/year	% of basic organic prod. removed by commercial catch	
	Pelagic	Demersal	Pelagic	Demersal		Pelagic	Demersal
I		(0.52)		(1070)	5600		
IIb							
IIa	0.33 [7.0]	0.27 [5.7]	190 [4000]	450 [11.700]	4600		
Va	0.11 [0.54]	1.3 [6.9]	65 [310]	2650 [14.200]	14.000	0.5 [2]	ca20 [ca100]
Vb							
XIV					3700		
		[1.8]		[3700]	ca 5200		[ca 70]
IIIa-c	1.4	1.9	805	3900	3700	22	105
IIId							

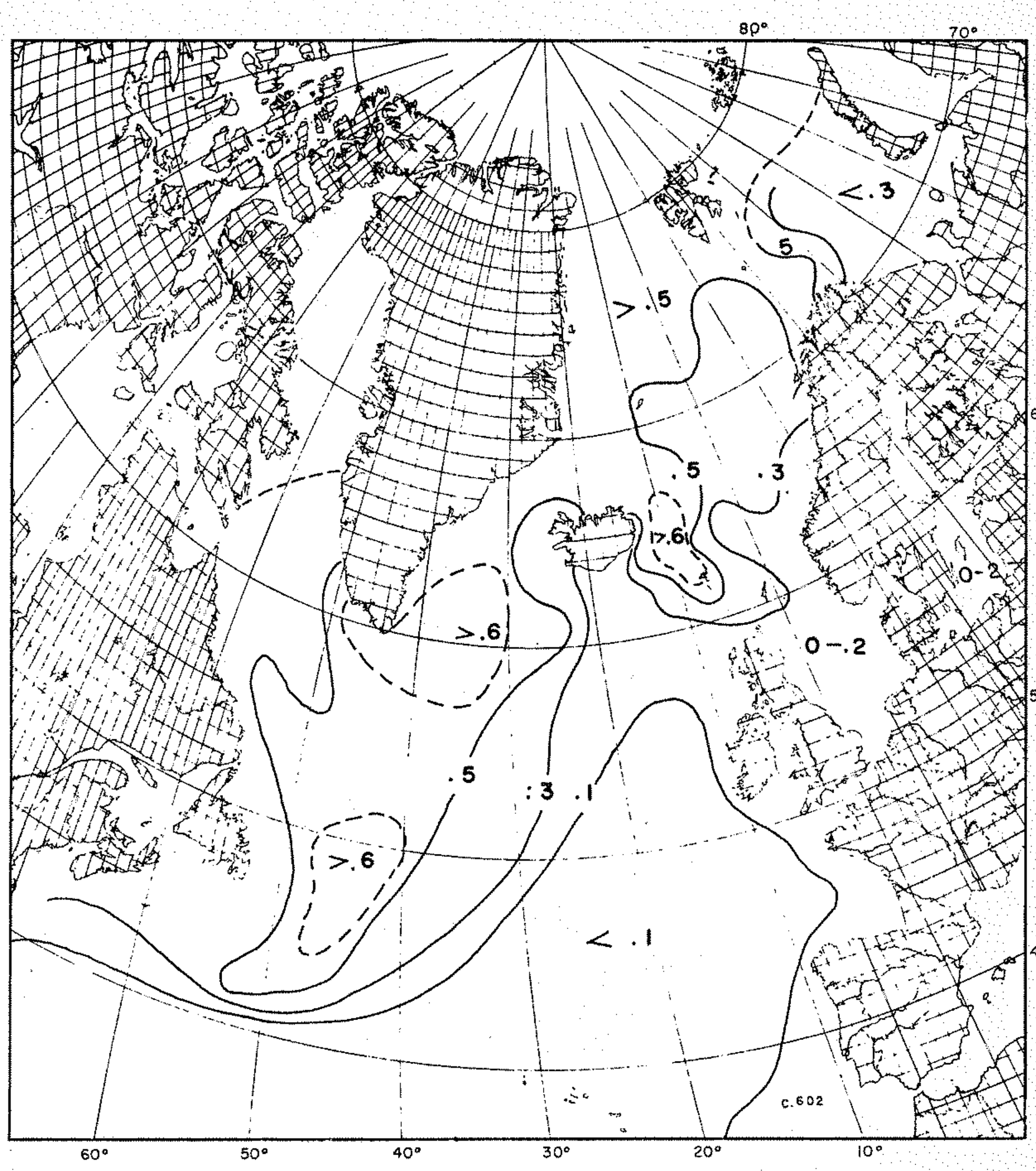

Figure 8

Average distribution of phosphates in the surface waters in the North Atlantic Ocean in late summer (μg.at./L)

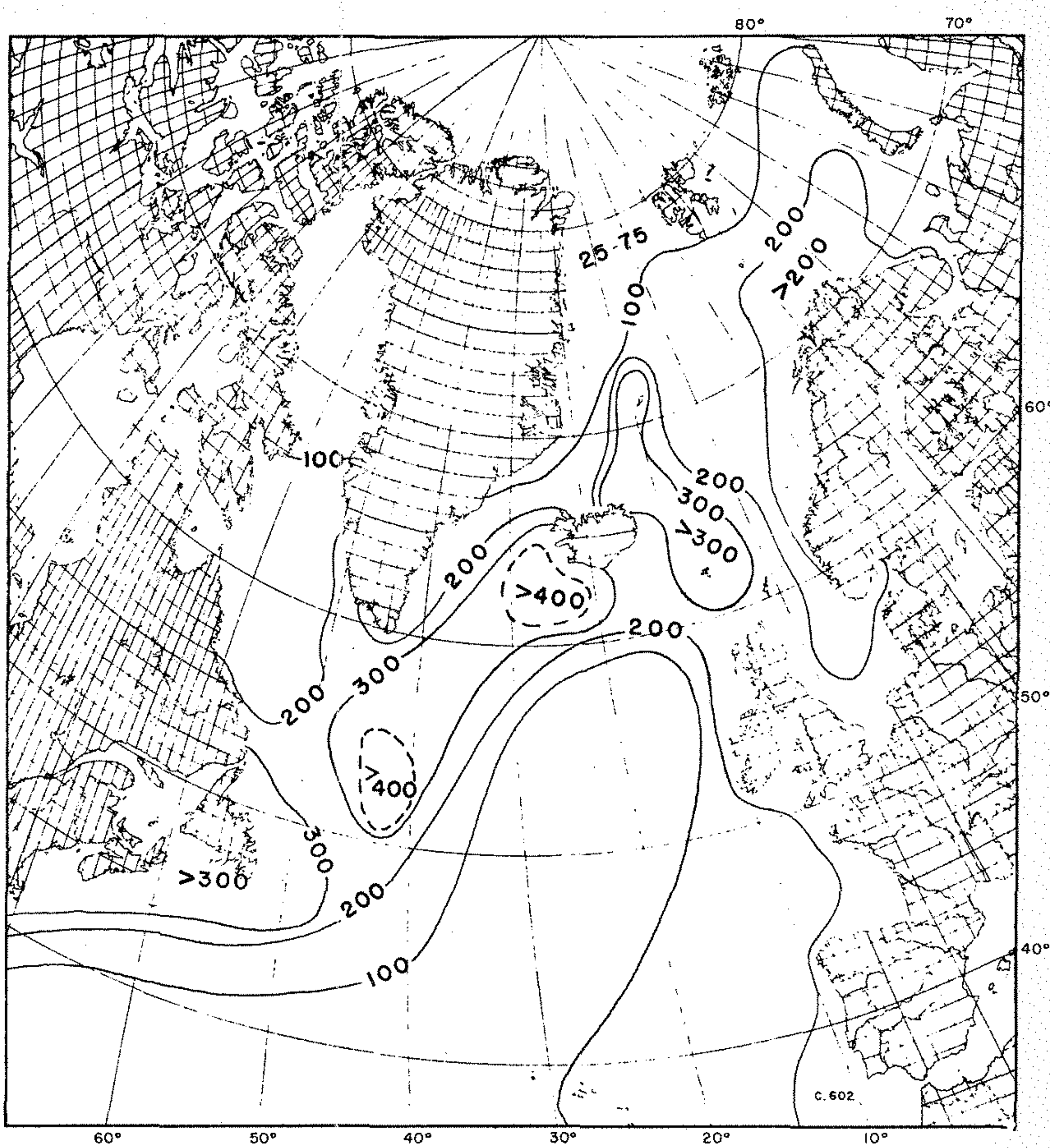

Figure 9

Estimation of average standing crop of zooplankton biomass in the North Atlantic Ocean in summer (mg/m³)

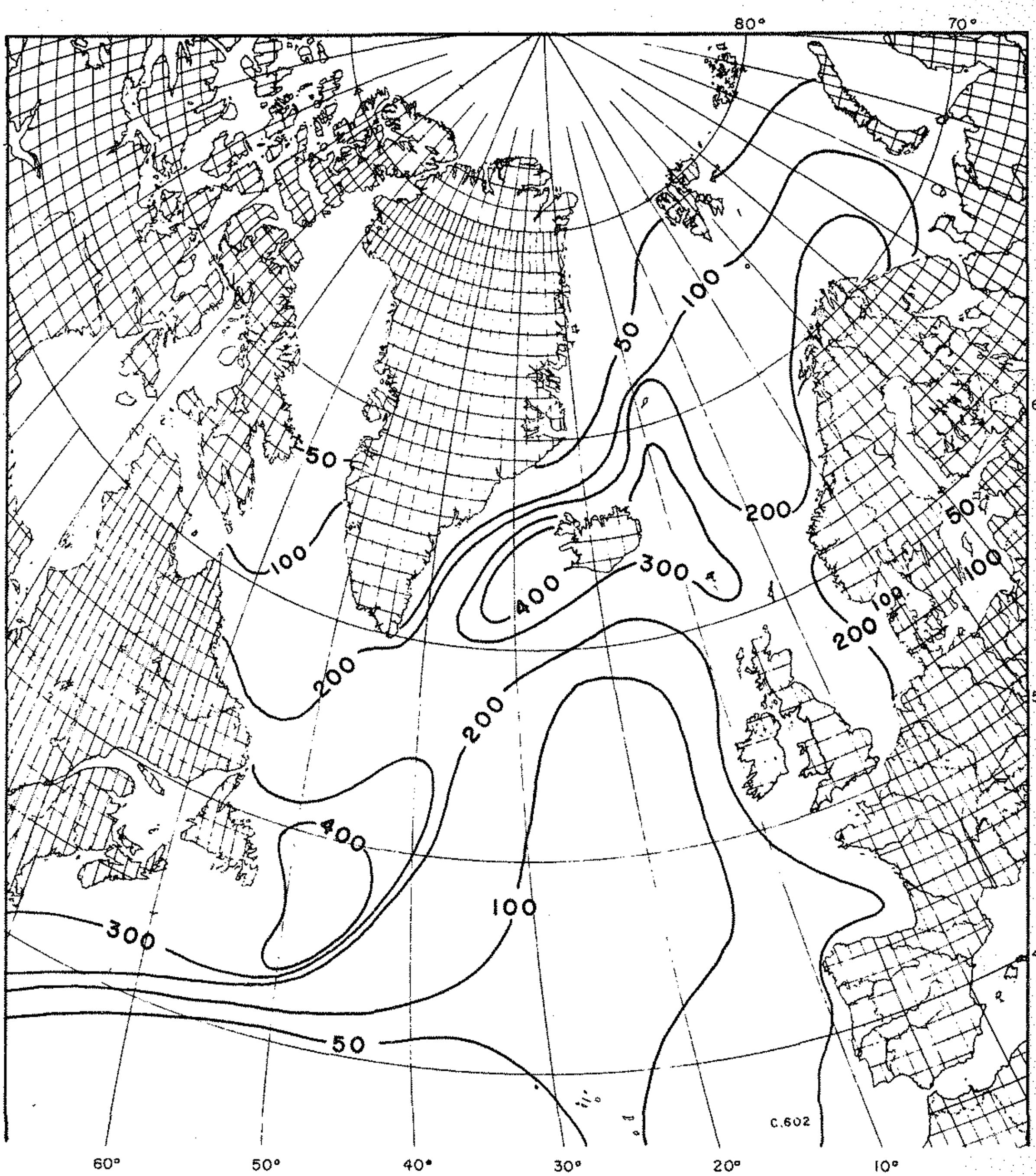

Figure 10

Estimation of annual basic production in the North Atlantic Ocean (g Carbon/m^2/year)

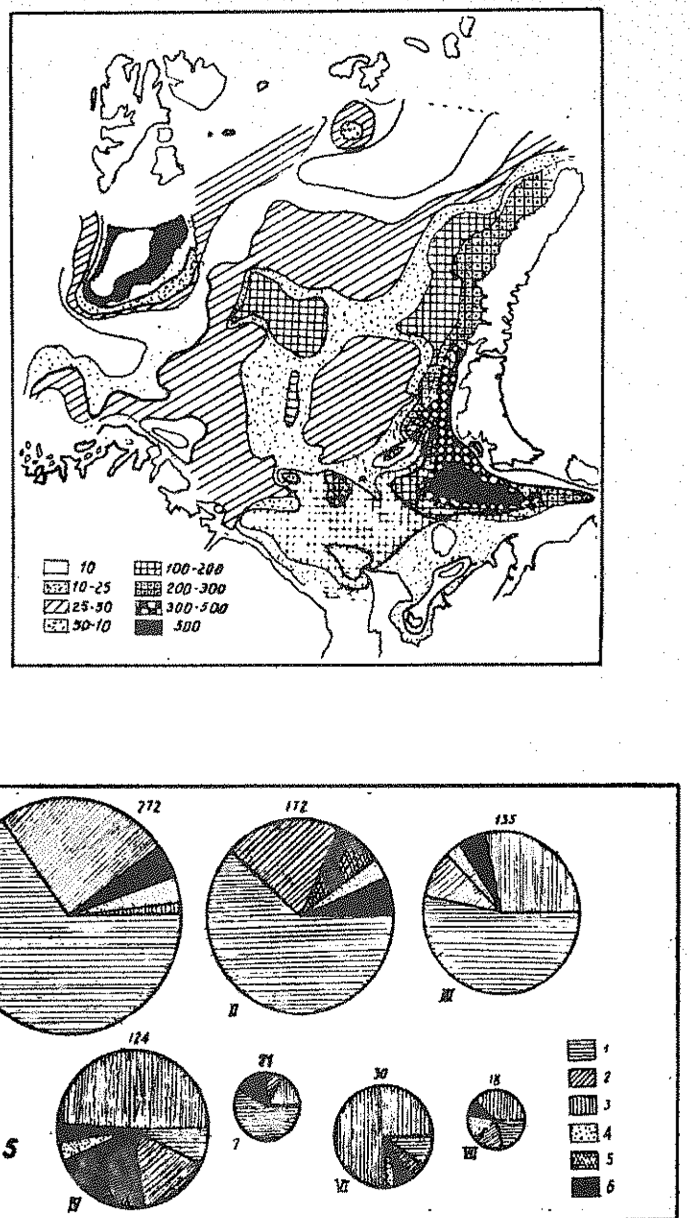

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Figure 11

Distribution of benthos biomass in Barents Sea (g/m^2) and the composition of principal groups (after Brotski, Zenkevich and Filatova)

I Petroski Region, Barents Sea

II Karinski Region

III Central part of Barents Sea

IV Northern part of Barents Sea

V White Sea

VI and VII Karskoi Sea

Arabic numbers indicate the average biomass in g/m^2

1. Bivalves	4. Crustacea
2. Polychaeta	5. Gephyrea
3. Echinoderms	6. Others

EVALUATION DIAGRAMS FOR NORTH SEA PLAICE, PLEURONECTES PLATESSA.

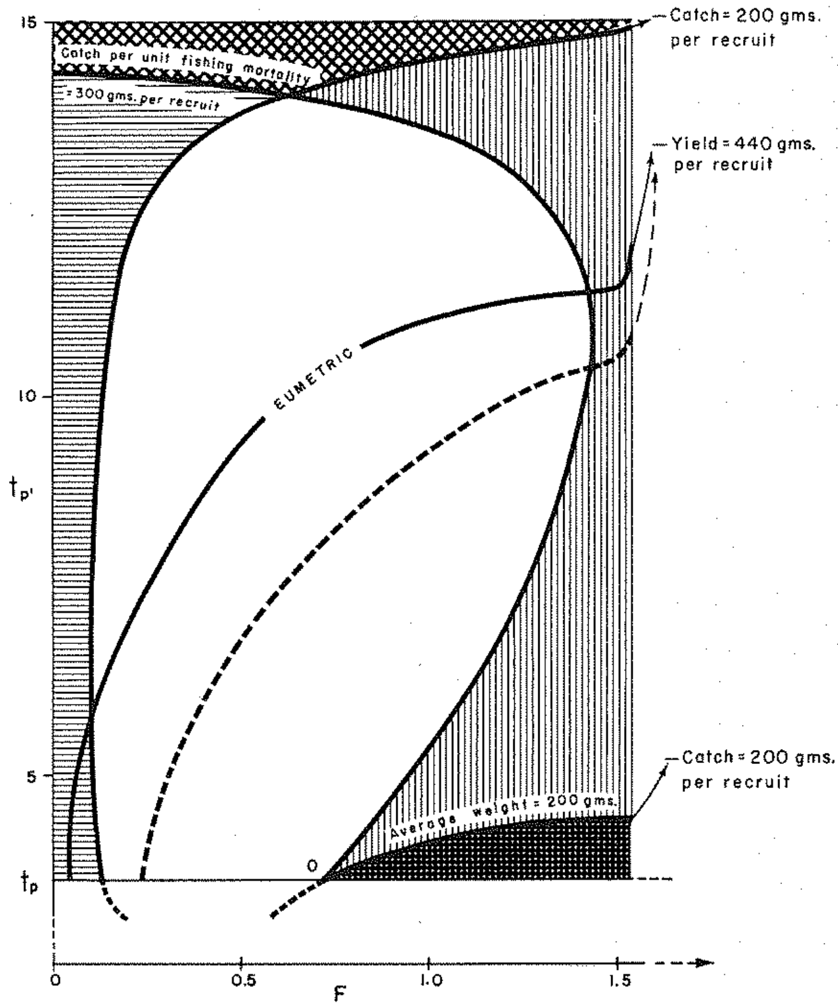

FIG. A

(blank)	REGION OF BOTH INCREASED YIELD AND INCREASED YIELD PER UNIT EFFORT
(cross-hatched)	COMBINATION OF FISHING INTENSITY AND SELECTIVITY GIVING BOTH A DECREASED YIELD AND A DECREASED YIELD PER UNIT EFFORT
(vertical lines)	INCREASED YIELD BUT DECREASED YIELD PER UNIT EFFORT
(horizontal lines)	REGION OF DECREASED YIELD BUT INCREASED YIELD PER UNIT EFFORT
(solid dark)	ALSO DECREASE IN AVERAGE SIZE OF FISH

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EVALUATION DIAGRAMS FOR NORTH SEA HADDOCK, GADUS CALLARIAS.

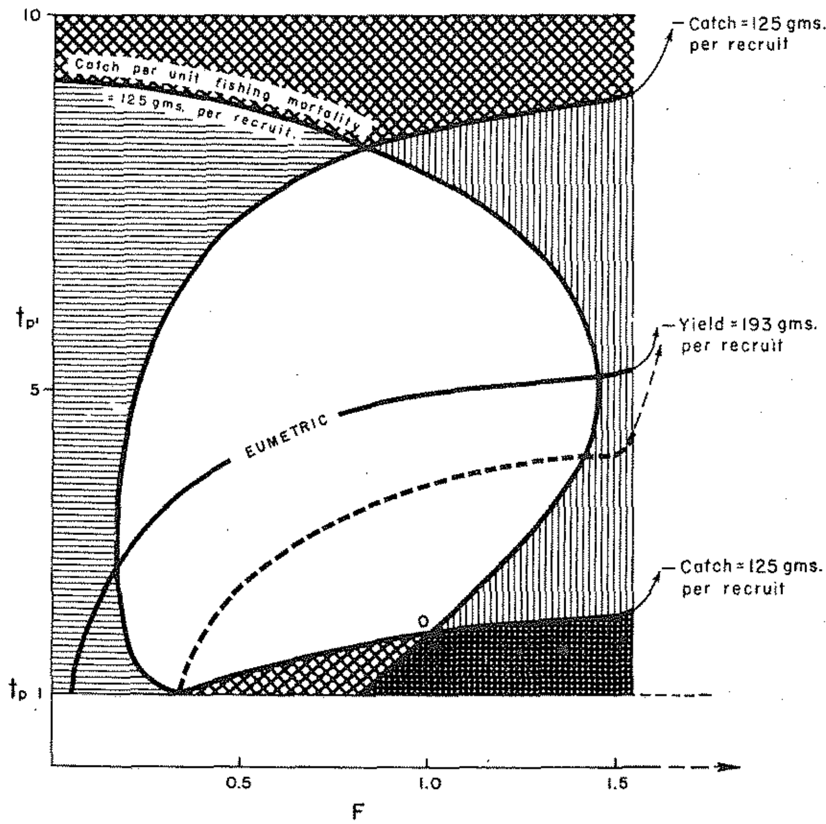
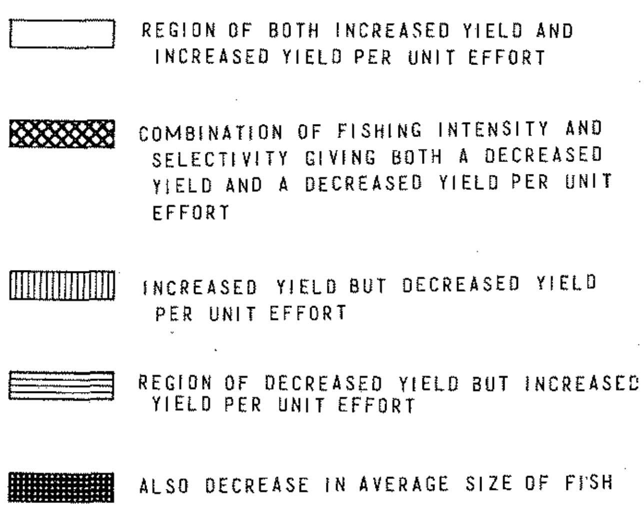


FIG. B



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COMBINED EVALUATION DIAGRAMS FOR PLAICE α HADDOCK.

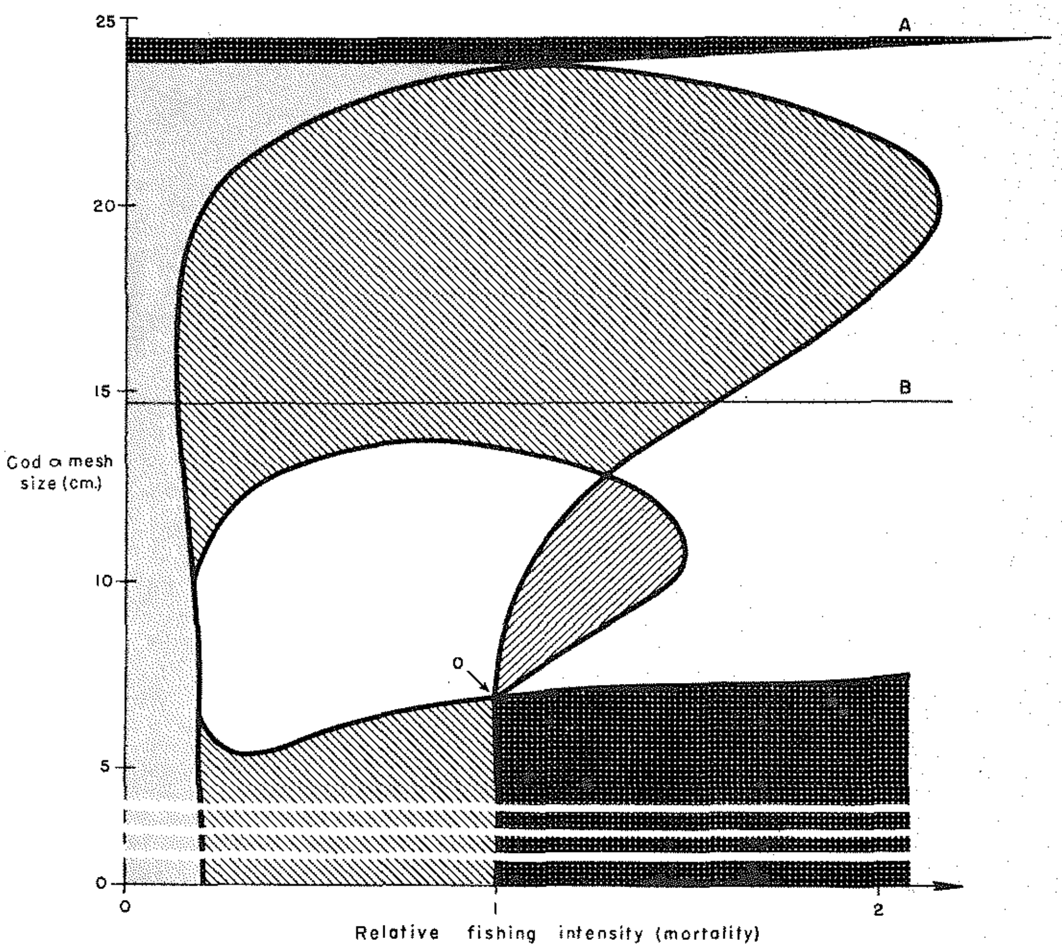

FIG. C

YIELD OR CATCH PER UNIT EFFORT INCREASES FOR BOTH SPECIES

YIELD OR CATCH PER UNIT EFFORT DECREASES FOR BOTH SPECIES

CHARACTERISTICS OF PLAICE CATCH IMPROVED AT EXPENSE OF HADDOCK

CHARACTERISTICS OF HADDOCK CATCH IMPROVED AT EXPENSE OF PLAICE

EITHER DECREASED YIELD OR CATCH PER UNIT EFFORT FOR ONE OR BOTH SPECIES

C. 633