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Variations in the Production Capacity in the Norwegian Sea during 1954, 1958 and 1959.

By
Grim Berge.

As part of the Norwegian program in the international cooperation in the ecological studies of the Norwegian Sea, the situation in the water's primary production has been recorded during the following periods: In 1954: May 23rd - June 21st, in 1958: May 1st - June 17th, and in 1959: June 1st - June 30th. The agreement between the periods seems satisfactory for a comparison of the recorded situations. The areas investigated however, (Fig. 1.) differed considerably in the three years with the result that the overlapping in some regions is insufficient for annual comparison to be made.

Some important regions were, therefore, only touched by our observations in 1954 and 1958 (e.g. The East Icelandic Arctic Current). However, for the latter year the Icelandic investigations covered this region, (Thordardottir 1958) at closely the same period as the Norwegian investigations.

Although the information concerning certain regions are deficient for the annual comparisons, the results obtained are informative as to the degree of the variations and tentative conclusions important for the further work may be drawn.

The measurements have been carried out on 100 ml samples, using ^{14}C as indicator on the photosynthetic activity, (Steemann-Nielsen 1952). Two specially adapted techniques have been applied, (Berge 1958):

1. The simulated in situ measurements.
2. The measurements of the production capacity in artifical day-light.

In 1958 and 1959 also the Continous Transparency meter was used for the immidiate indication of the productivity.

Since the aim of this contribution is to discuss the annual variations, only the zero meter observations on the production capacity will be applied. For further information on the subject see Berge (1958, 1961) and Thordardottir (1958).

Fig. 2 demonstrates the recorded situations in the production capacity at the surface for the three years concerned, together with the hydrographical situations in salinity at a depth of 20 meters. Comparisons indicate a close relation ship between the productivity and the hydrography of the water, and the division into the following hydrographically separated production areas can be made:

1. The Norwegian coastal waters.
2. The Norwegian Current with $S^{o}/oo > ca.\ 35.15$.
3. The Atlantic Water with ca $34.95 < S^{o}/oo < 35.15$.
   (Area between 2. and 4.)
4. The Arctic Water with $S^{o}/oo < 34.95$.
   (Area between 6., 5. and 3.)
5. The East Greenland Current.
6. The East Icelandic Arctic Current.
7. The Irminger Current and the Icelandic coastal waters.

The salinity limits for the production areas are aproximate, and seem to differ a little from one year to another, depending on the character and force of the original inflow of Atlantic as well as Arctic waters to this region.

Areas where high production is recorded are characterized by central maximum values which rapidly decrease outwards against the fronts. In the longitudinal direction of the current systems the productions has a slower decrease with no definite borders, the decrease certainly being a result of a continuous reduction of the nutrient supply by the previous growth. In the Atlantic waters the northward limits are also affected by the time delay between the observations, thus possibly resulting in measurements being taken within different stages in the succession of the population. The limits of the production in the longitudual direction of the current systems should therefore not be used as characteristic for the year concerned.

The situation recorded in fig. 2 has some common feature of a low productivity in:

1. the Norwegian coastal waters (area 1),

2. the main Atlantic instream (area 2) and
3. the Arctic waters (area 4).

According to Paasche (1960), the low productivity recorded in these areas is probably caused by the post spring stage in the plankton succession. The variations recorded are small, and with the exception of the main instream to the ocean (area 2), are of minor interest for these studies.

In the Atlantic waters (area 3) the productivity varied considerably in the three years: In 1954 this area was extremely productive with maximum values nearly double of those recorded in 1958. In 1959 the observations made in this area were insufficient, except in the southern part where the results indicate a rather low productions however, were found at the western side of the polar front. A recession of the iceborder since 1954 uncovered a great area of the East Greenland Current (area 5) and in 1958 production values similar to those in the Atlantic water were measured.

The Norwegian investigations covered the East Icelandic Arctic Current (area 6) in 1959. In 1954 one single observation at st. 254 possibly touched this production area. The 20 m observation at this station was definitely very different from the rest of the Arctic stations, both in productivity and plankton content (Paasche 1960). Also, the hydrographical data confirm its close connection with the outer limits of the East Icelandic Arctic Current. The recorded production capacity of 32 $\cdot (10^{-7}$ mg C/l$\cdot$luxH), indicates that the production in this area was very high and similar to the situation recorded in 1959. In 1958, stations 78 and 85 similarily seemed to touch the East Icelandic Arctic Current. Their low production capacity, however, indicates that the production in area 4 this time was rather low, in agreement with Thordardottir's (1958) observation at nearly the same time.

The typical situations in the productivity of these areas can be summarized as follows:

In 1954: A high productivity of the Atlantic waters in area 3, and the East Icelandic Arctic Current (area 6 as indicated by one observation).

In 1958: A moderate productivity in the East Greenland Current (area 5) and the Atlantic waters (area 3). A low production in the East Icelandic Arctic Current (area 6).

In 1959: A high productivity in the East Icelandic Arctic Current (area 6) and a moderate to low productivity in the Atlantic waters (area 3).

Since there are hydrographical connections between the East Greenland Current and the East Icelandic Arctic Current, the recorded situations in the productivity should be excepted to affect each other. Thus, the recession of the iceborder and the appearance of the production area in the East Greenland Stream might reduce the nutrient supply to the East Icelandic Arctic Current and explain the lower productivity observed in this area in 1958. The high production in the East Icelandic Arctic Current in 1954 might partly be explained by the icecover and supposedly low production in the area 5 that year. The high production in area 6 in 1959 should indicate low production in area 5, but observations from this latter area are lacking for that year.

A similar analysis can be made for the production area 3, which hydrographically is mainly a mixture of Atlantic and Arctic waters. In order to graphically illustrate to what degree the production is specific for each area, and what the effects of different degrees of their mixture might have on the production in area 3, a scheme similar to the t/S diagrams in hydrographical analysis has been applied (fig. 3). Since the Arctic waters are characterized by low salinity and low temperature in contrast to the Atlantic component with high salinity and high temperature, a better separation has been obtained by using the products $t \cdot S$ against the corresponding production capacity. (The observations in areas 1 and 7 have not been given the diagram).

The Arctic and Atlantic productions are well separated, as is the mixed production of area 3. Within the Arctic waters two production centers appeared in 1954, corresponding to the East Icelandic Arctic Current (?, one high value) and the area 4. Two areas also appeared in 1958, corresponding to the area 5(The East Greenland Current, high values), and the Arctic waters in area 4 and 6. The two areas in 1959 corresponded to the Arctic waters in area 4 (lower values) and the East Icelandic Arctic Current (area 6). As foreseen, the productivity in area 3 varies between wide limits. These values have been used in the lower part of fig. 3 and show the production in relation to the degree of admixture, using the salinity as an indicator.

The situation in the Arctic and Atlantic waters in 1954 and 1958 were rather similar and the production in area 3 might be considered as different degrees of dilution of the productive area 6 with the areas 2 and 4. However, the data shown in the lower part of fig. 3 do not fit with such a hypothesis. The production in area 3 in 1954 shows an increasing trend with increasing salinity, i.e. the less Arctic water introduced, the higher the productivity. These findings are the opposite of what would be expected from simply a dilution of a rich productive center. In 1958, the productivity in the area 3 is also higher than in either of the admixed waters. It seems thus not possible by a simple formula to calculate the production in area 3 on the basis of information of the productivity of the original waters introduced to this area. It appears that the production in area 3 has a close relation-ship to the situations in the original waters, but the growth controlling factors seem to vary and are not known.

A review of the observed situations in the production capacity are given in table 1 as the arithmetic mean and maximum production capasities recorded within each area. The mean values are very much dependent on the distributions of the observations. The maximum values, therefore, more significantly express the relative size of the productions.

The recorded variations in primary production might have perceptible effects on the feeding resources of herring and thereby on its distribution during the feeding period. Berge (1958) demonstrated the positive relationship between the herring feeding grounds (Marty 1956) and the production centre in the Norwegian Sea. It is, however, not understood whether this relation is a consequence of long time adaptarion to a customarily rich feeding area, or if the herring has the ability in any situation to seek the rich feeding grounds. Simultaneous recording of the herring distribution and the primary production might add further knowledge to this field. An example of such recording made in June 1959 is given in fig. 4. As shown, the production in the East Icelandic Arctic Current was very high in contrast to that of the Atlantic water. The herring are seem to be grouped around the periphery of the rich production area, so these results do not confirm this relation between an area of high productivity and the herring concentrations. However, the occurrence of phaeocystis in the East Icelandic Arctic Current might explain the discrepancy, since it is known that the herring seem to avoid this organism, as discussed by Pavshtiks (1960).

Summary:

1. Seven typical production areas have been delimited. The fronts of these, which are hydrographically limited by the salinity, show variations dependent on the character of the water flowing into the Norwegian Sea.

2. Considerable annual variations in the amount of the prodiction has been recorded in most of the areas. The greatest variation observed was, however, the occurance of a production area in the Arctic waters in 1958 where none existed in 1954.

3. The effect of ice melting in the East Greenland Current on production in the East Icelandic Arctic Current has been discussed.

4. The interaction between the production areas has been analysed by means of a diagram of production vs. temp. x salinity.

5. A table sammarizing the observed maximum and mean production capacities of each of the regions is given.

6. The effect of the changes in production on the distribution of herring is discussed. A map of the relative productivity in 1959 based on the recordings by the Continuous Transparency meter together with the herring recordings is given.

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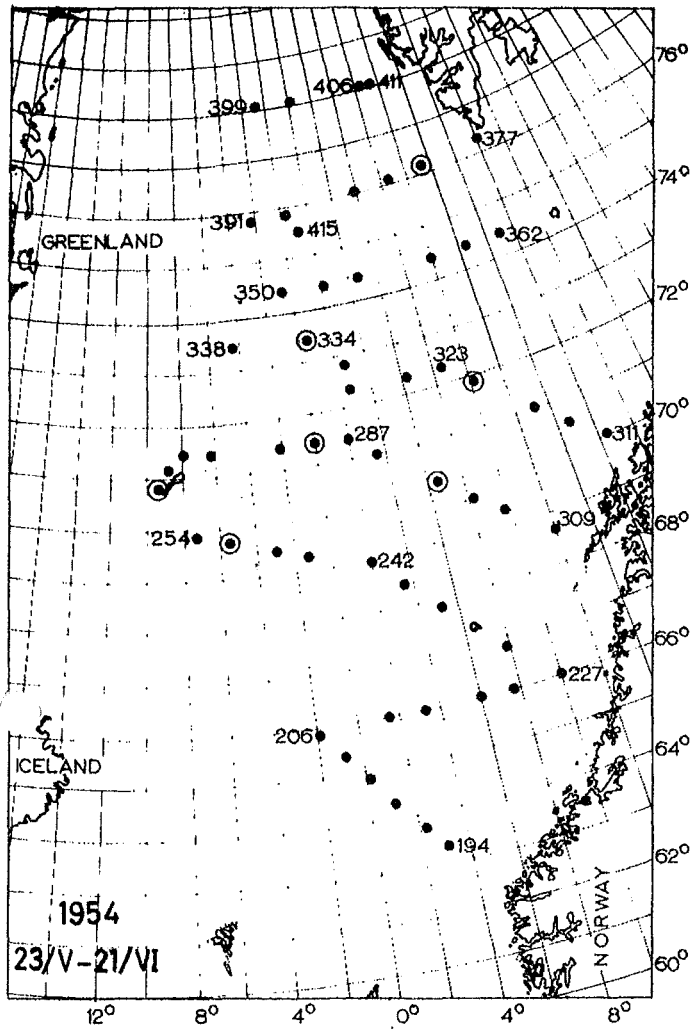
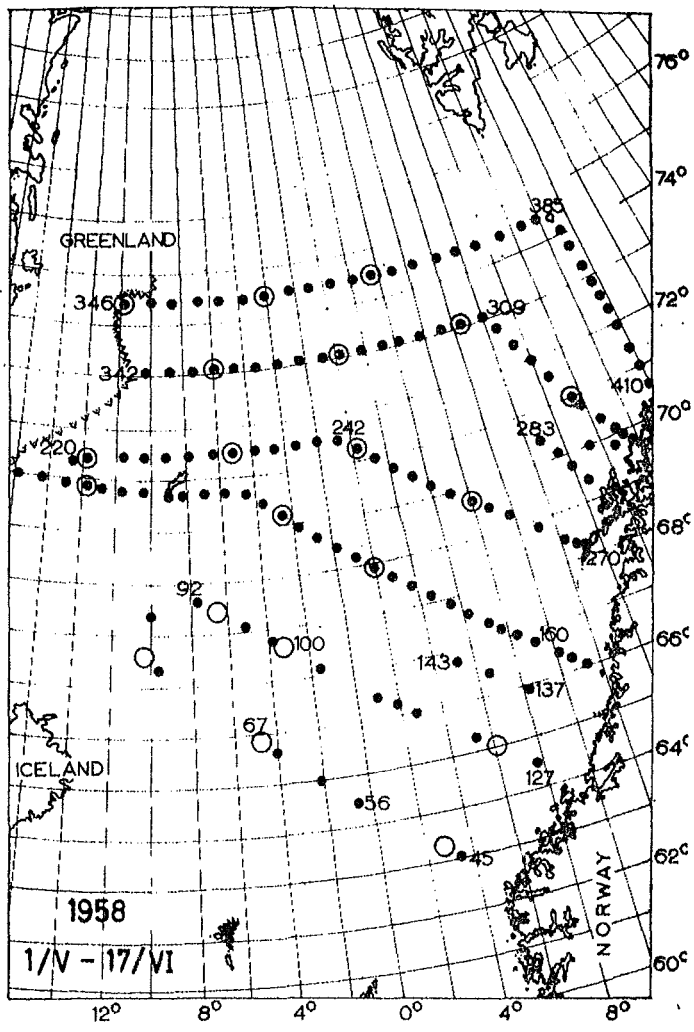
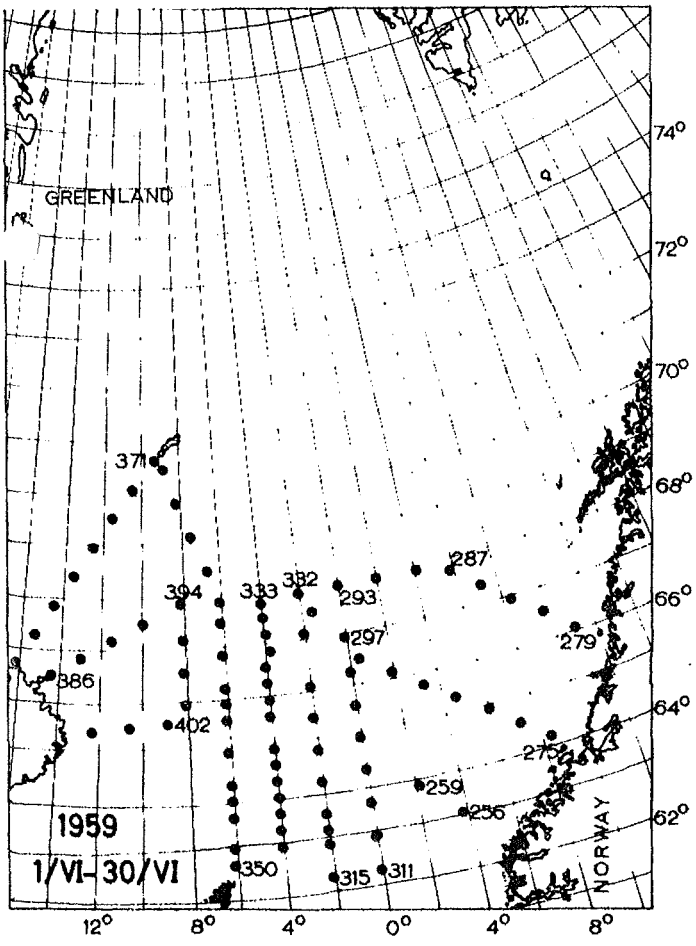






SECTIONS AND STATIONS IN THE NORWEGIAN SEA FOR THE OBSERVATIONS OF THE PRIMARY PRODUCTION IN 1954, 1958 AND 1959.

• - Measurements of the production capacity.
O - Simulated in situ measurements,
vv - Ice border

Fig. 1.

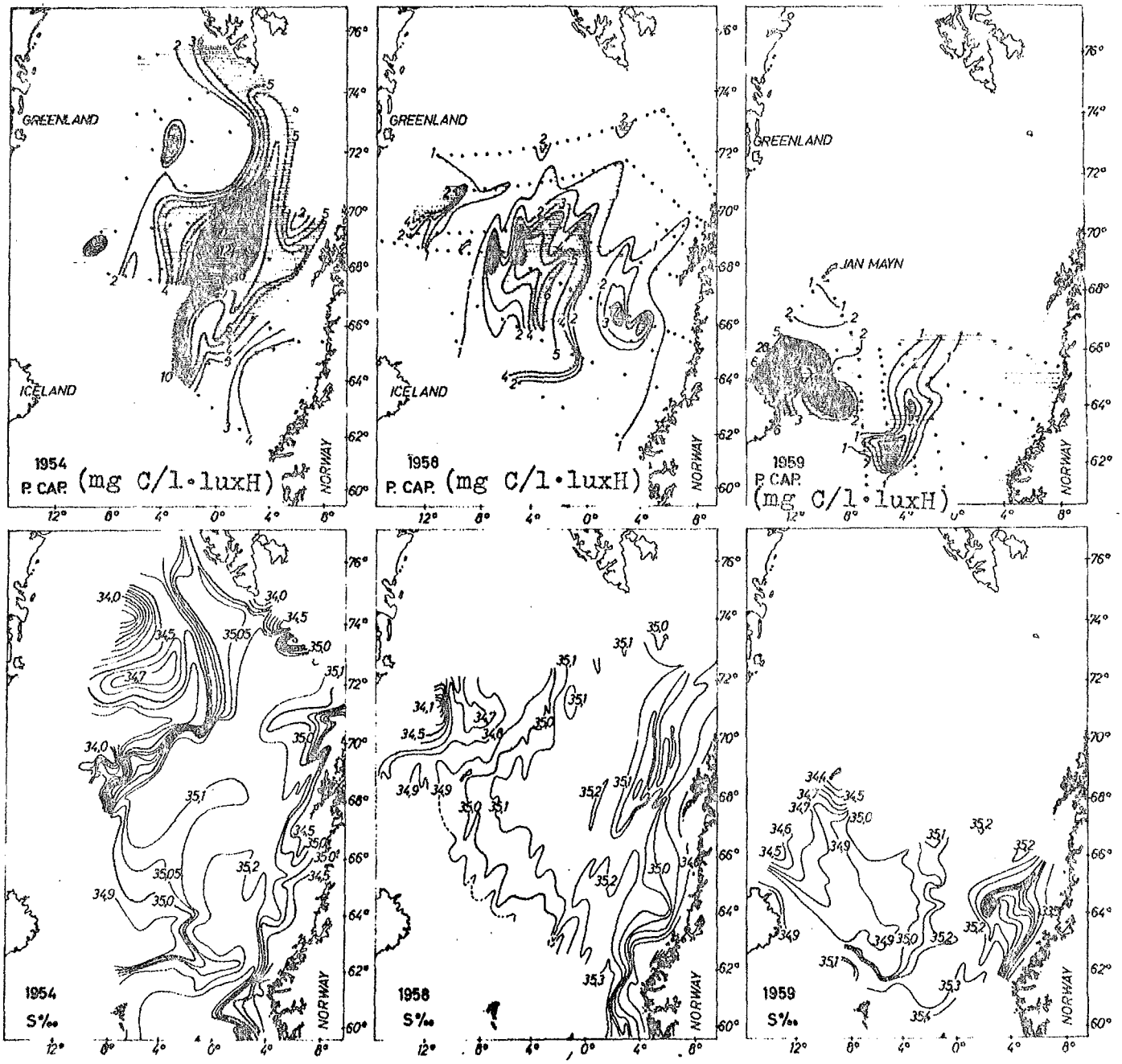
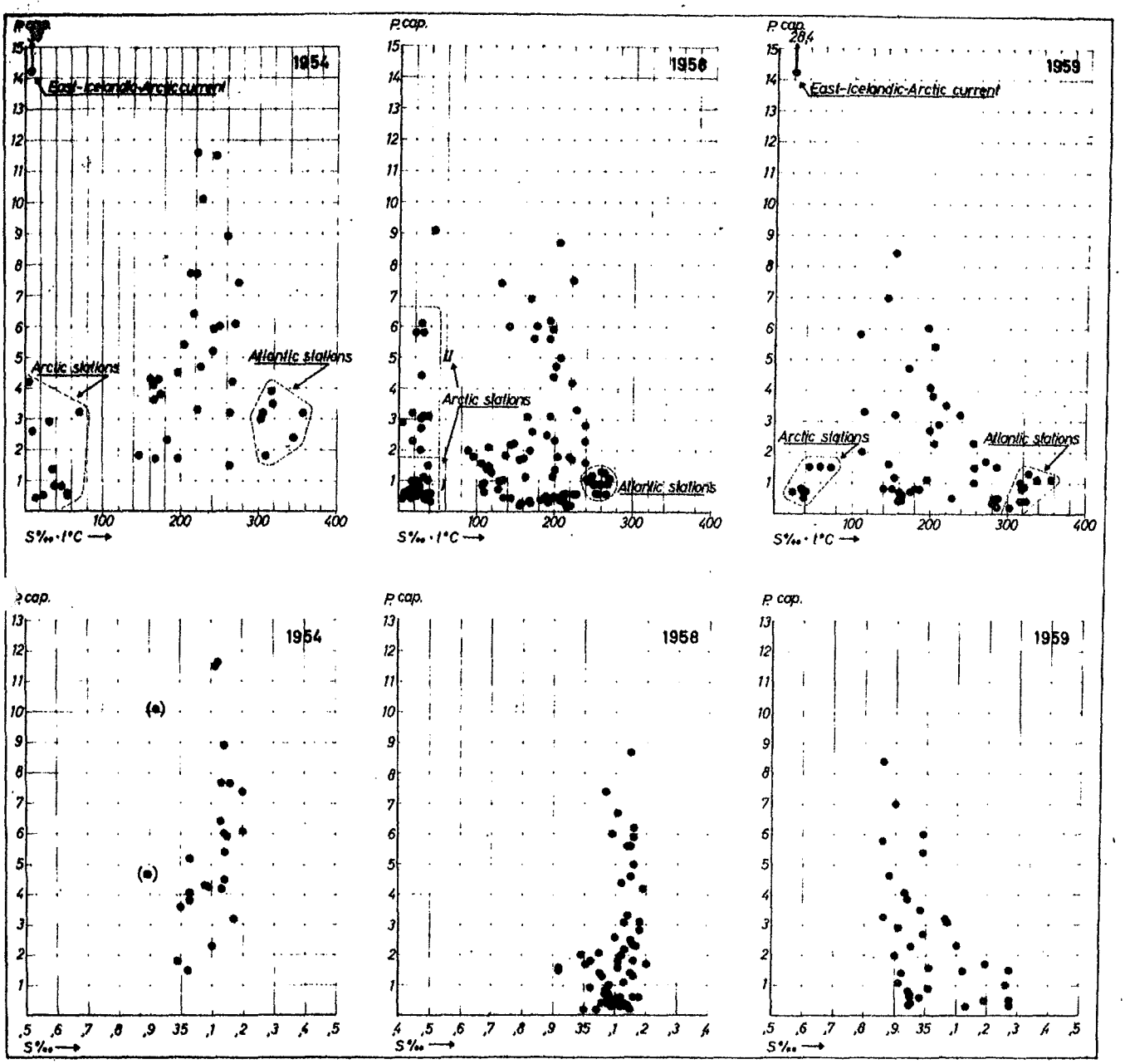


Fig. 2. The production capacity in mg C/l·luxH (all figures $\cdot 10^{-7}$) in the surface, together with the salinity in 20 m.



TOP: CORRELATION BETWEEN PROD. CAP. AND S‰ · t°C IN 0m DEPTH
BOTTOM: CORRELATION BETWEEN PROD. CAP. AND S‰ IN 0m DEPTH
OF THE MIXED WATERMASSES

Fig. 3.

1959

Fig. 4. TRANSPARENCYMETER RECORDINGS AND DISTRIBUTION OF HERRING

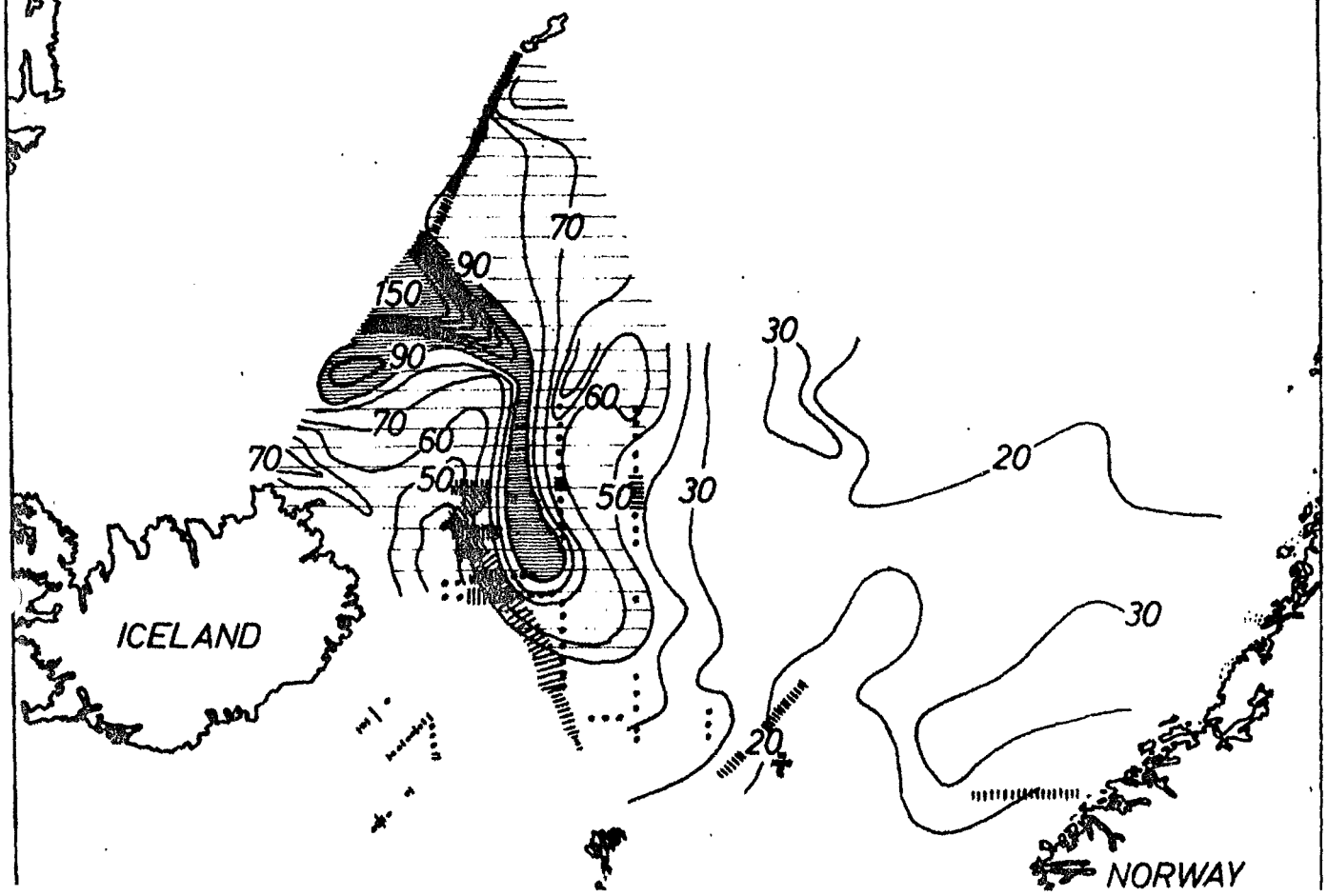


Table 1. Production areas and their production capacity.

		PRODUCTION CAPACITY 0 M DEPTH		
		1954	1958	1959
1.	The Norwegian coastal waters	One value 4.7	Max. 5.9 Average 2.0	One value 0.2
2.	The Norwegian Current with S‰ > ca 35.15	Max. 3.9 Average 3.0	Max. 1.3 Average 0.9	Max. 1.3 Average 0.8
3.	The Atlantic water with ca. 34.95 < S‰ < 35.15. (Area between "2" and the arctic water to the West)	Max. 11.6 Average 5.2	Max. 8.7 Average 2.2	Max. 8.4 Average 2.6
4.	The Arctic water with S‰ < 34.95. (Area between "6", "5" and "3").	Max. 4.2 Average 1.5	I Max. 1.5 I Average 0.7 II Max. 6.1 II Average 3.7	Max. 1.5 Average 1.0
5.	The East Greenland Current.	Covered by ice	Max. 5.8 Average 2.1	No stations
6.	The East-Icelandic-Arctic Current	One value 38.0	No stations (?)	Max. 28.6 Average 5.5
7.	The Irminger Current and the Icelandic coastal waters.	No stations	No stations	Max. 10.3 Average 5.5