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Measurements of the primary production and recordings of the water transparency in the Norwegian Sea during May - June 1958.

Preliminary report

by

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Measurements of the primary production in the Norwegian Sea in June 1954 (Berge 1958) indicated a highly productive area in a mixed water mass with salinities between 34.95 and 35.15 $^{o}/oo$, in the central part of the sea. The arctic water masses in the north-western part and the Atlantic water masses with salinities above 35.15 $^{o}/oo$ in the eastern part, showed nearly no production.

There is reason to believe that great variations in the rate of production occur from one year to another. Taxonomical analyses of phytoplankton from these areas in 1952 and 1953 (Ramsfjell 1957) and 1954 (Paasche 1959) indicate great variations from one year to another both in the qualitative and quantitative composition of the plankton.

The changes are possibly caused by variations in the hydrographical and meteorological conditions. The rate of production in the mixed water masses in the central part of the Norwegian Sea is thus determined chiefly by the state of stability (i.e. the depth of the mixing layer) (Sverdrup 1953), but also the hydrographical and biological conditions in the original water masses should to a certain extent be expected to affect the production.

In June 1954 the area of high production coincided well with the main feeding area of the herring. Since a high primary production is the first requirement for good feeding conditions, a close correlation between the distribution of pelagic fishes and the primary production may be expected. Great variations in the primary production might thus have great effects on the distribution of pelagic fishes.

In order to study variations in the composition of the phytoplankton and the primary production in relation to changes in hydrography and distribution of fish, phytoplankton investigations have been continued together with hydrographical and other biological investigations in the "IGY".

Material and Methods.

From 28. April to 24. June 1958, the area shown in Fig. 1 was investigated. Besides measurements of the primary production and sampling of phytoplankton for taxonomical analysis, investigations were made on hydrography and zooplankton. Experiments were also carried out on methods for immediate indication of the production. As a correlation has shown to exist between the production capacity and the water transparency, (Berge 1958), continuous recording of the water transparency at 5 m level was undertaken. Also Secchi disc readings were made at all stations during the day.

The production measurements were carried out with C^{14} as indicator (Steeman Nielsen 1952) following the technique described by Berge (1958). This technique is based on the correlation between the production (P) and the effective part of the incoming light energy ($\int I_e dt$) (Sverdrup 1953),

$$P = k \cdot \int I_e dt.$$

The correlation factor between P and $\int I_e dt$, is describing the potential production per unit of light energy (prod. capacity). Berge (loc. sit.) stated that the production capacity is a more suitable factor for expressing the relative production than measurements in situ where weather conditions may influence the measurements to a great extent. From knowledte of the light penetration into the sea and a representative $I_e dt$ for the area and time in question, the total production in the euphotic zone may, however, be calculated for an identical average day (Berge loc. sit.).

Together with the measurements of k, photoelectric light measurements, and simulated in situ measurements of P were also made, in order to convert k to total production in the euphotic zone. The latter part of the material is not yet ready for presentation.

Measurements of the production capacity were carried out at the standard depths 0 - 10 - 20 m at 135 stations (729 samples). At the first 74 stations of the cruise samples were taken with an all glass water sampler (Aabye Jensen og Steeman Nielsen 1953), and production experiments were carried out in 100 ml glass stoppered water bottles. Later on a new water sampler was taken into use, in which the samples were drawn directly into the experimental bottles (Fig. 2).

After addition of 1 ml $Na^{14}CO_3$ (type b, Steeman Nielsen 1952) the bottles were placed into an incubator (Fig. 3) for 4-5 hours. The incoming light energy was recorded by a watertight photocell in the incubator combined with a summarizing lux-meter. After filtration through millipore filter (type AA) in a pressfiltering apparatus of special construction (Fig. 4), the filters were dried and kept for Geiger counting ashore.

The production capacity (k) was calculated from the following formula:

$$k = \frac{\text{Counts per min found} \cdot \sum CO_2 \ {}^{mg\ C}/_{l} \cdot 1.1}{\text{Initial counts} \cdot \text{lux-hours}}$$

$\sum CO_2 \ {}^{mg\ C}/_{l}$ were taken from Buch et. al. (1932). The factor 1.1 is correction for discrimination and respiration (Steeman Nielsen 1952).

The transparency meter (Fig. 5) has a tube of plexiglass, 1.5 m in length, diameter 10 cm. A water pump, delivering a continuous water flow through the tube from a depth of 5 m, is placed at the bottom of the ship. At the lower end of the tube a constant light source transmits parallel light beams, and at the upper end the transmission is recorded by a light recording unit. The recording unit consists of a convex lens, an iris blend to exclude slant incident light, and a photo resistance. By use of the iris blend the tube could be made of clear plastic, which has shown to be of great importance to the experiments. The photo resistance (mrk. "PETEWE" dr. ing. W. Heimann, Dotzheim, Germany) has a very high sensitivity and a characteristic (Fig. 6) which makes it very well suited for the purpose: The sensitivity, increasing exponentially with decreasing light makes it almost equally sensitive for variations in turbid water as well as in clear water. During the 3 first weeks of the cruise, a 50 mm dr. Lange-cell (Selén element) was used. Due to the low sensitivity of this cell, however, the results could not be used. Both the light source and the iris blend can be adjusted. By different combinations the sensitivity of the instruments can be varied.

During the latter half of the cruise recordings were made at two different levels of sensitivity.

Results.

The production capacities are shown in Fig. 8. Similar to the conditions in 1954 a production area limited by the 34.95 - 35.15 $^{o}/oo$ isohalines were evidently located in the central part of the Norwegian Sea (Cp. Fig. 9). The production intensities are, however, very different in the two years, the figures in 1954 being 2-3 times higher than those of 1958.

In the arctic water masses N and NW of Jan Mayen the situation was almost the opposite. In 1954 a very low production was measured, while in 1958 the production capacities were 2-3 times higher, corresponding with the intensities found in the central part of the Norwegian Sea that year. The temperature of the arctic water was also higher than usual.

A marked effect of the "time"-factor is demonstrated in 1958, the production capacities within the same water mass decreasing in a south-north direction. This is to be expected as there was an interval of more than two months between the southernmost and northernmost sections.

From the observations on primary production hitherto made in the Norwegian Sea the following conclusions may be drawn:

I. Four areas are distinguished with regard to their rate of production:
   1. Arctic water masses with salinities below 34.95 $^{o}/oo$.
   2. Mixed Atlantic water masses with salinities between 34.95 - 35.15 $^{o}/oo$.
   3. Atlantic water masses with salinities above 35.15 $^{o}/oo$.
   4. The coastal water masses off Norway.

II. Marked variation in the production capacities is observed to occur in the areas 1 and 2.

As the measurements made, only indicate certain situations in the production, one may not be justified to draw any conclusions as to the rate of the annual production. Informations of this kind would require measurements several times a year. However, from the informations obtained, it seems as if regular observations from one selected station within each of the four production areas would be sufficient to keep track with the annual production.

Until more hydrographical data are available, it is of little value to discuss the possible causes of the variations in production. As to the production in the mixed Atlantic water masses, however, very interesting data may evidently be observed in the actual mixing area NE of Iceland.

From stations 200 - 410 recordings of the water transparency were made at two different sensitivity ranges of the transparency-meter. The correlations between the recordings in 5 m (resistance readings in Ohm) and the corresponding prod. capacities in 10 m, for the two sensitivities are whown in Fig. 10. In the second diagram (B) most of the corresponding production capacities during the cruise were very near zero. For the sake of simplisity most of the low values have been omitted.

As very low

production capacities were found in 1958, the figures were not very well fit for the purpose for a general correlation with the water transparency. However, within the range of prod. capacities measured a good correlation was found with the water transparency for values of k above $1 \cdot 10^{-7}$ mg C/1$\cdot$ lux-hour.

From all stations taken ±2 hrs. from noon the Secchi disc readings have been correlated with the recordings of the transparency meter (Fig. 11). In most cases there is evidently a correlation between the readings; discrepancies may chiefly be explained by inaccurate Secchi disc readings, caused by unfavourable weather.

In the Norwegian Sea where the production capacities vary from 0 - $14 \cdot 10^{-7}$ mg C/1 lux-hour, both the Secchi disc readings and transparency measurements give a fairly good and immediate indication of the production. However, the transparency-meter has the following advantages:

1. Recordings are made continuously at a certain level, indicating horizontal gradients in the production.
2. Observations are taken during day and night.
3. The instrument is very little influenced by the weather, except in rough sea, when air bubbles disturb the measurements.

In areas where the research vessels are operating regularly, the instrument presented thus may give valuable information of the production at different times of the year.

Fig. 12 and 13 are based on Secchi disc readings and transparency recordings during May - June 1958. The recordings have been transferred to "plankton units". (20 units correspond with the production capacity in sea water having a transparency half of that of destilled water). The pictures coincide well with the map of the production capacity.

Summary:

Measurements of the primary production were carried out at 135 stations from 28.IV - 24.VI 1958 together with recordings of the water transparency and Secchi disc readings.

The technique for measuring the production capacity is described and pictures are given of the instruments used. A drawing of the transparency meter is given and the principle for its operation explained.

Maps of the production capacities measured in 1954 and 1958, indicate entirely different production intensities during the two years, although the same production areas can be spotted.

The correlation between production capacity and transparency readings is illustrated, and the conclusion is drawn that the instrument may give fairly good information of the production. The Secchi disc readings taken within ±2 hrs. from noon in most cases agree fairly well with the recordings of the transparency. For comparison with the production capacities maps based on Secchi disc readings and the transparency recordings are presented.

References.

Aabye Jensen, E. & Steeman Nielsen, E.: A water-sampler for bio-
1953. logical purposes. J. du Cons., 18 (3).

Berge, G.: The primary production in the Norwegian Sea June
1958. 1954, measured by an adapted ^{14}C technique. Rapp. Cons. Explor. Mer, 144.

Buch, Kr., H.W. Harvey, H. Wattenberg and S. Gripenberg: Über
1932. das Kohlensäuresystem im Meerwasser. Rapp. Cons. Explor. Mer, LXXIX.

Marty, J. J.: Fundamental Stages in the lifecycle of the Atlanto-
1956. Scandian herrings. (In Russian). Trody VNIRO 9.

Paasche, E.: Fytoplanktonet og den biologiske bakgrunn for pri-
1959. mærproduksjonen i Norskehavet i mai og juni 1954. Thesis, Inst. Mar. Biol., University of Oslo.

Ramsfjell, E.: Hovedtrekkene i nannoplanktonets fordeling i Nors-
1957. kehavet og deres hydrografiske bakgrunn. Manuscript, Inst. Mar. Biol., University of Oslo.

Steeman Nielsen, E.: The use of radio-active carbon (^{14}C) for mea-
1952. suring organic production in the sea. J. du Cons., 18 (2).

Sverdrup, H.U.: On conditions for the vernal blooming of phytoplank-
1953. ton. J. du Cons., 18 (3).

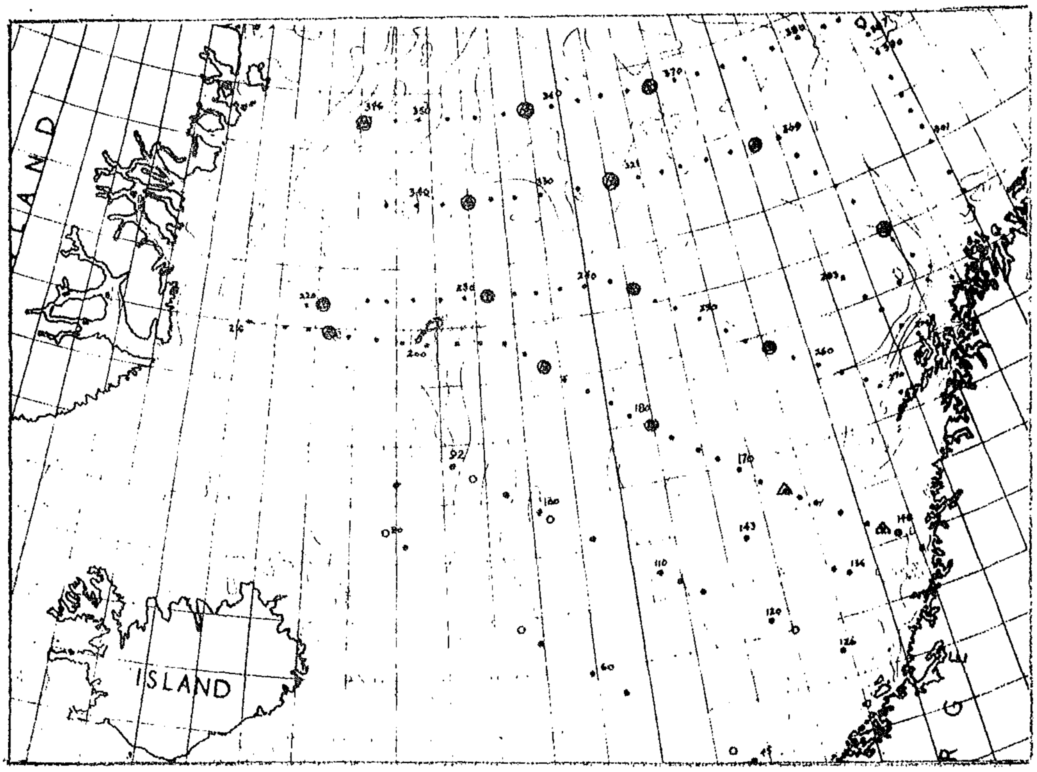


Fig. 1. Sections and production stations in the Norwegian Sea 28/IV - 24/VI 1958.

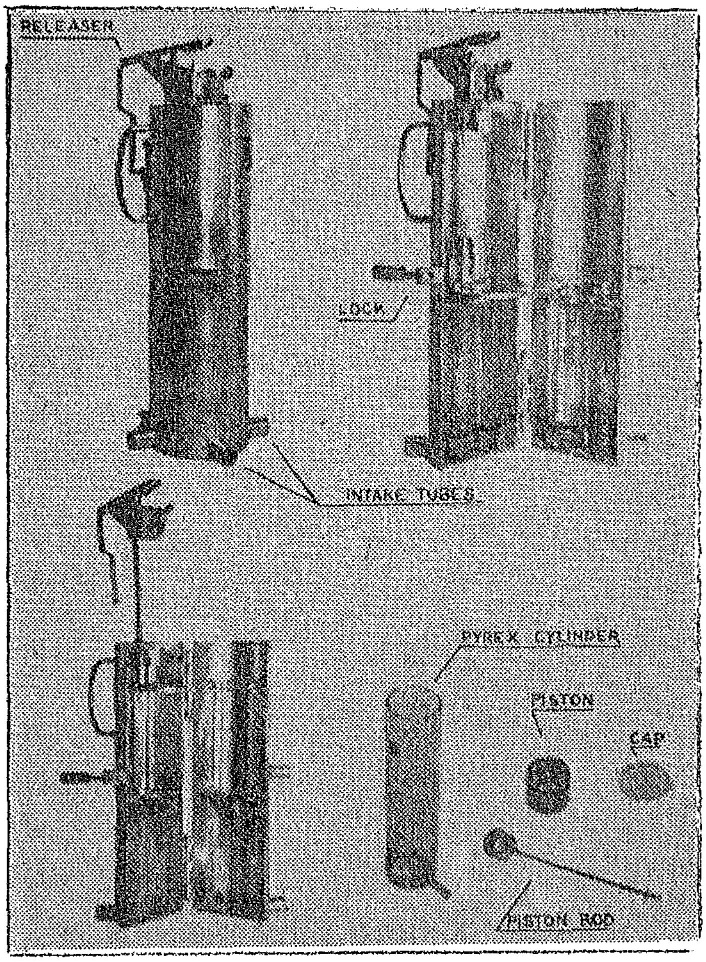


Fig. 2. Water sampler for insertion of 4 production bottles. The bottles are constructed after the syringe principle. A messenger and the weight of the sampler operates the mechanism.

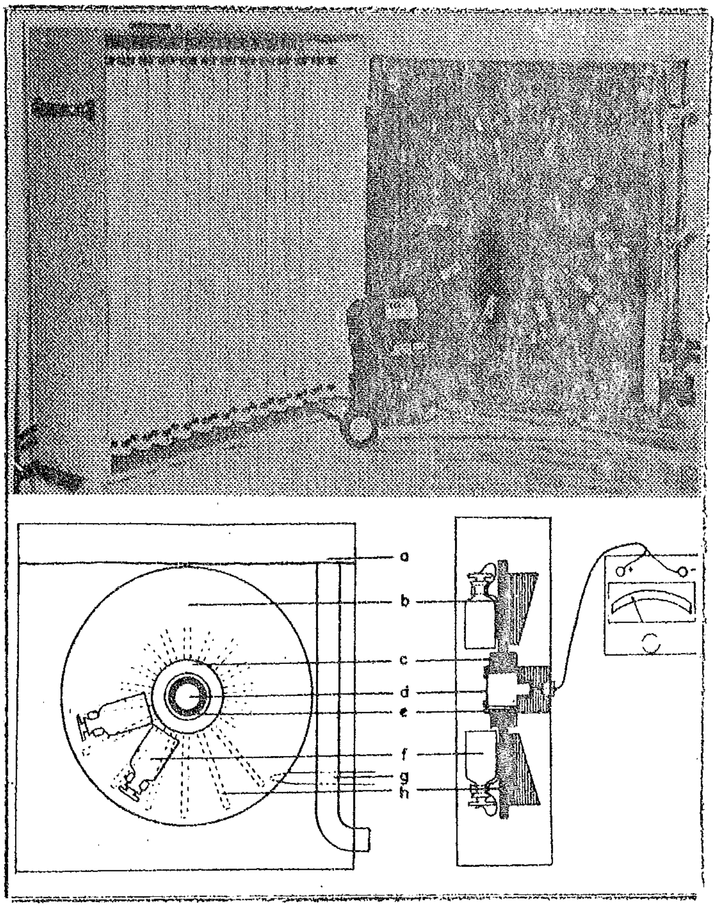


Fig. 3. Apparatus for measuring the production capacity.
Upper part: Light source and incubator with the light recorder.
Lower part: Two vertical sections of the incubator.
a. water over-flow.
b. rotating wheele.
d, photo cell.
f. sample bottle.
g. water inlet.
h. turbine wings.
The waterflow rotates the wheele.

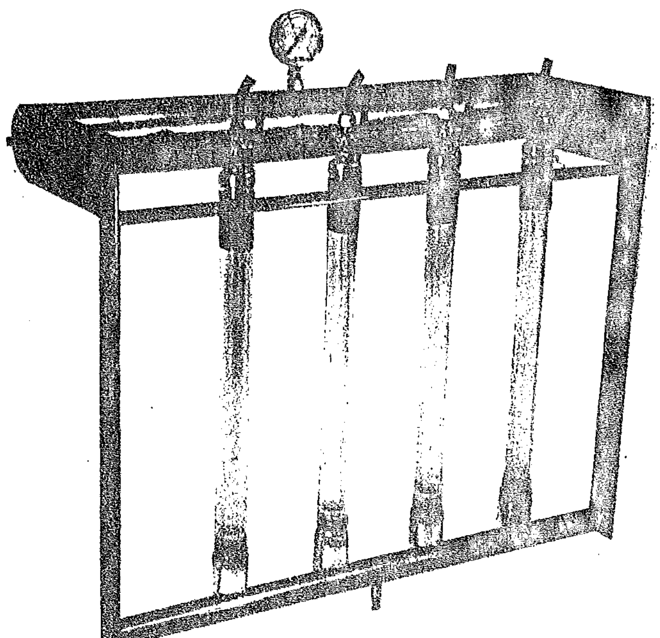


Fig. 4. Pressure filtering apparatus for 4 simultaneous and independent filterings. The pressure is obtained by an air pump.

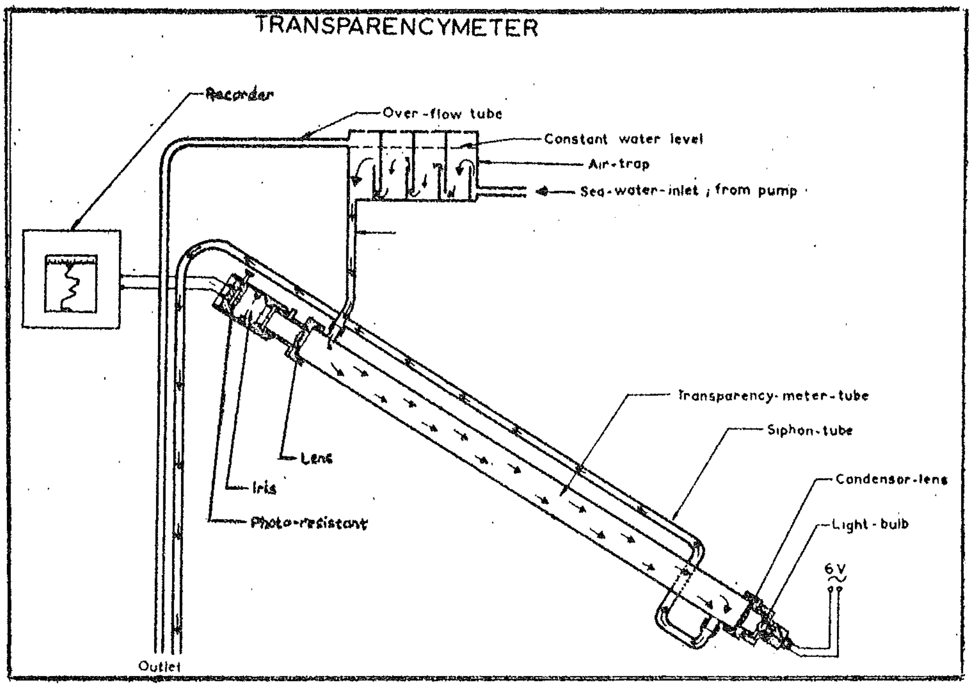


Fig. 5. The transparency-meter. The tube consists of clear Perspex, 1.5 meter long and 10 cm diameter.

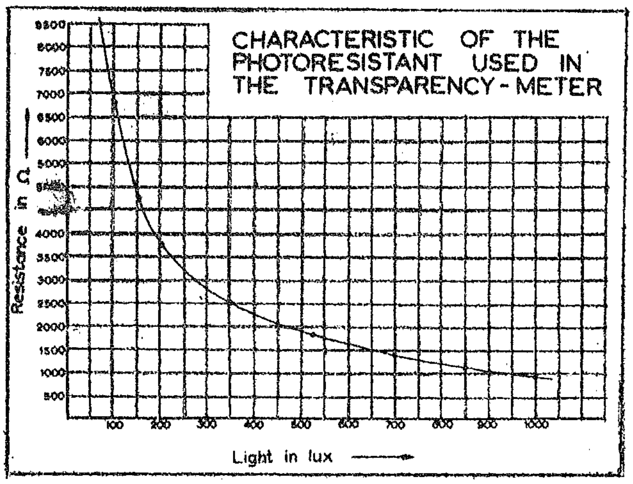


Fig. 6. Characteristic of the photoresistant used in the transparency meter.

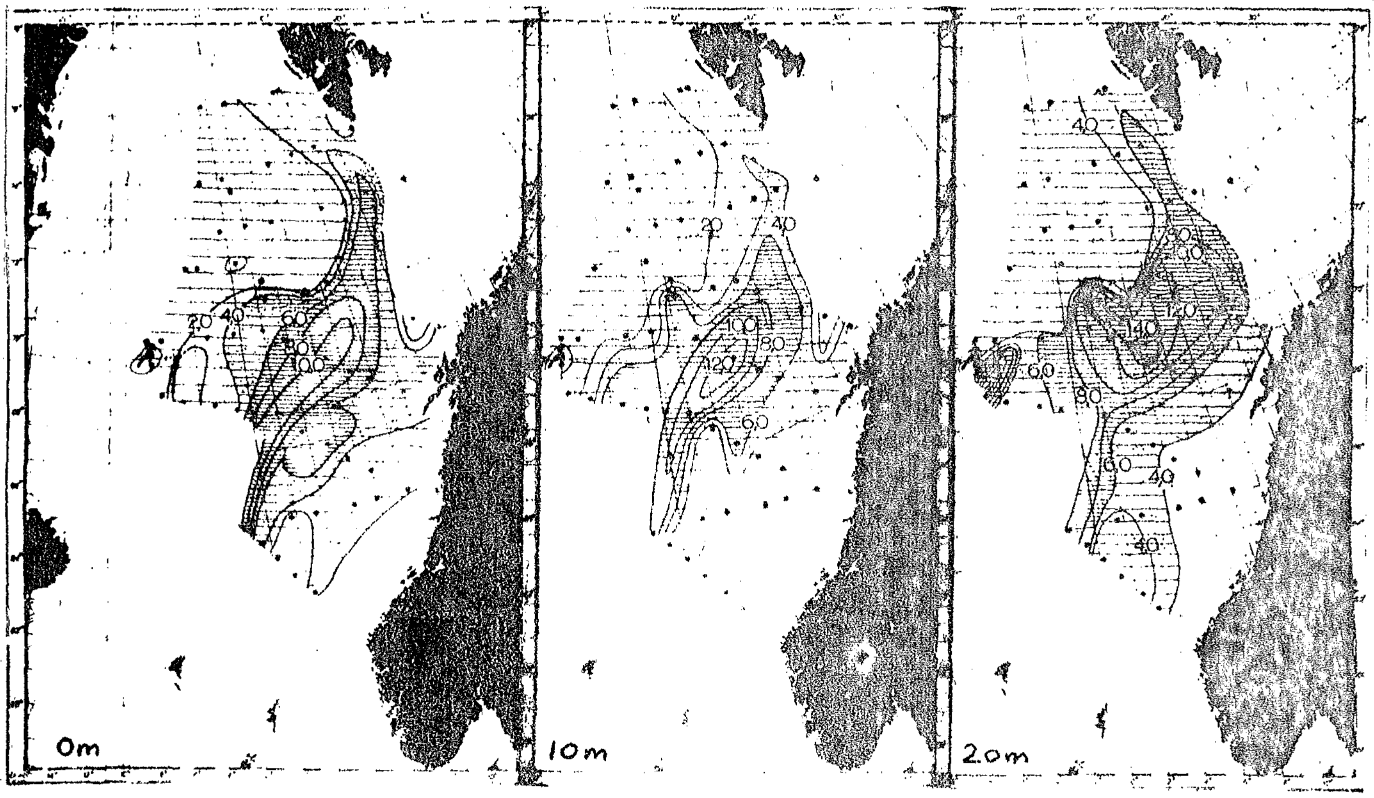


Fig. 7. The production capacity (10^{-7} mg C/litre and lux-hour) 24/V - 25/VI 1954. (Berge 1958).

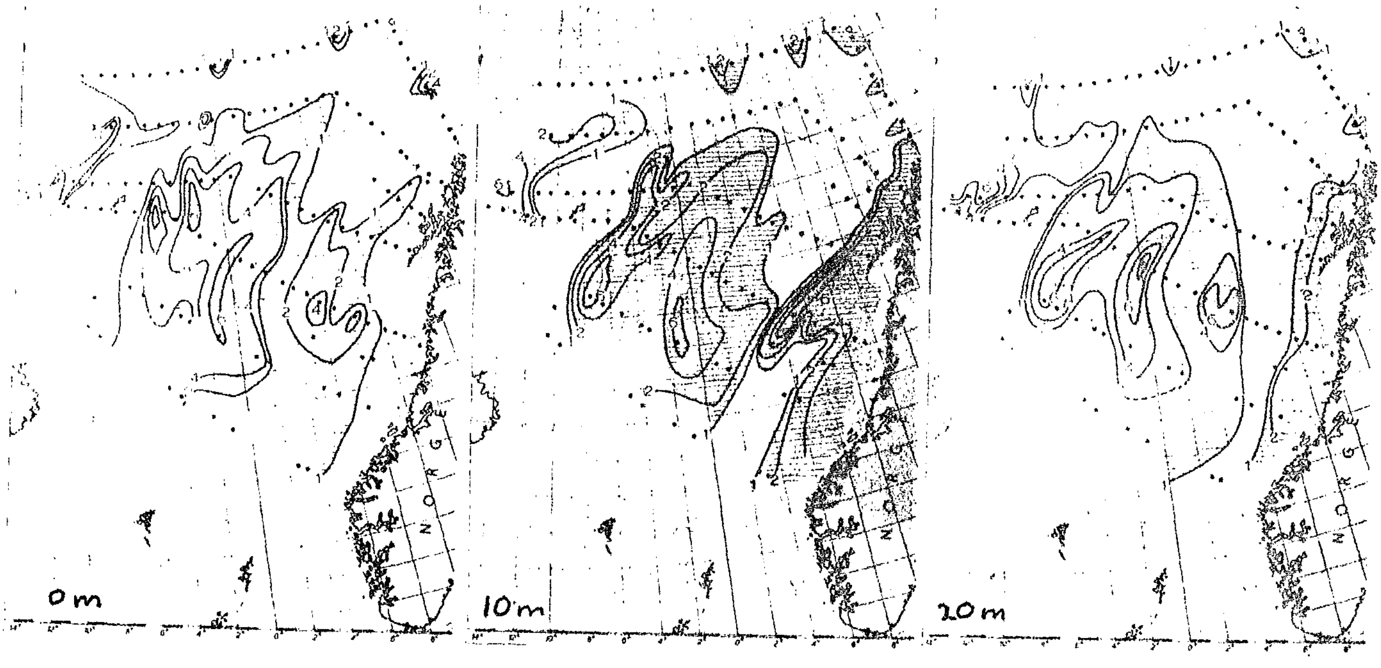


Fig. 8. The production capacity (10^{-7} mg C/litre and lux-hour) 28/IV - 24/VI 1958.

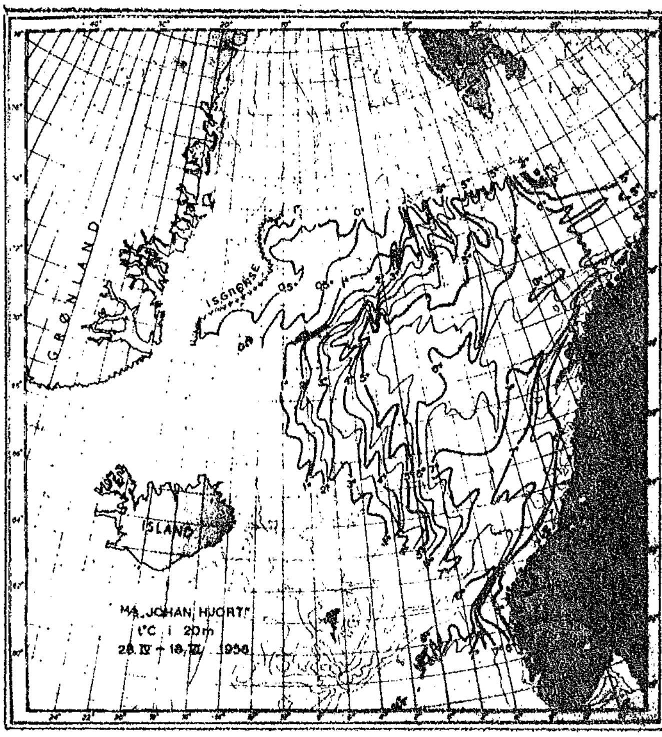


Fig. 9. S °/oo in 20 metres, 28/IV-24/VI 1958. (Eggvin, not published).

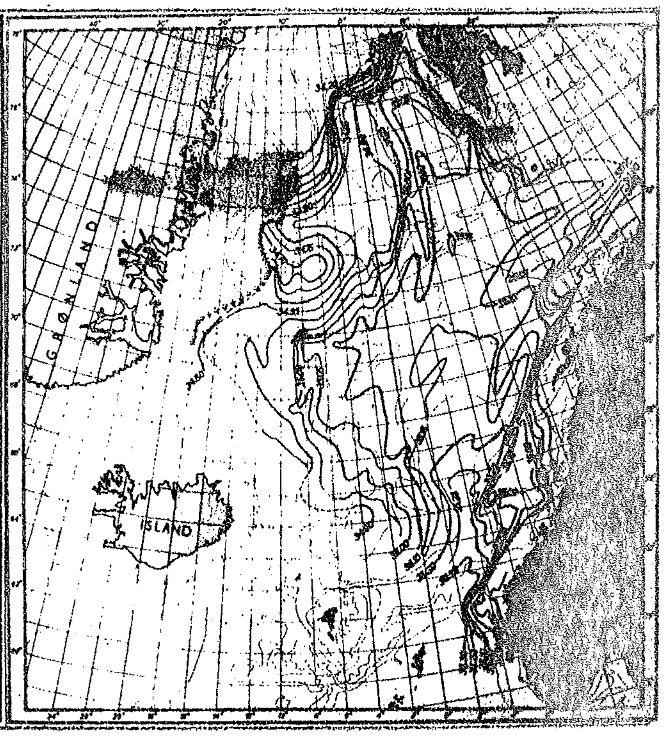
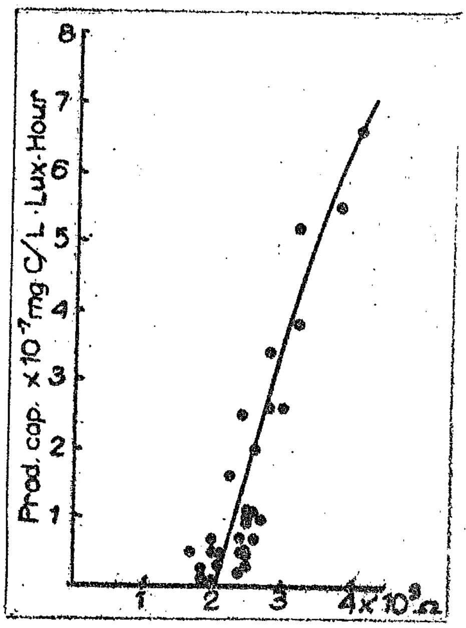


Fig. 9. T °C in 20 metres, 28/IV - 24/VI 1958. (Eggvin, not published).



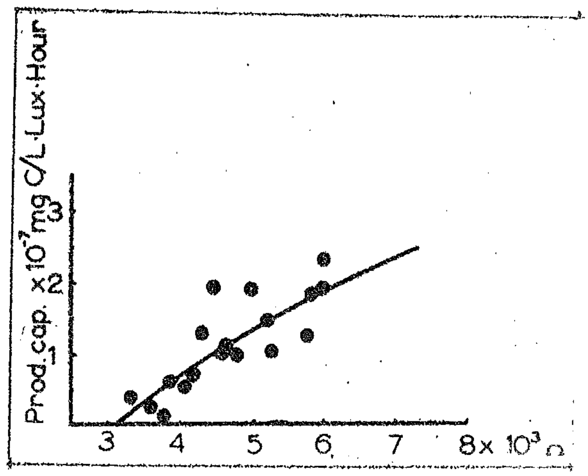


Fig. 10 A. Fig. 10 B.

The correlation between the transparency (recordings in Ohm, 5 m depth) and the production capacity in 10 m. Two different sensitivity ranges of the apparatus.

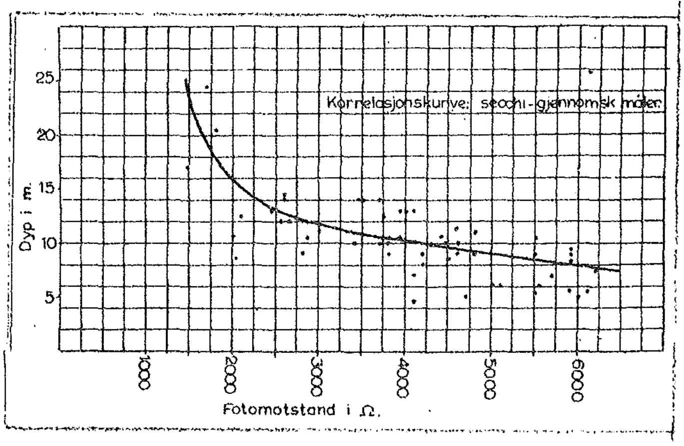


Fig. 11. The correlation between Secchidisc readings in m (only stations between ± 2 hours from noon), and the corresponding transparency recordings in Ohm.

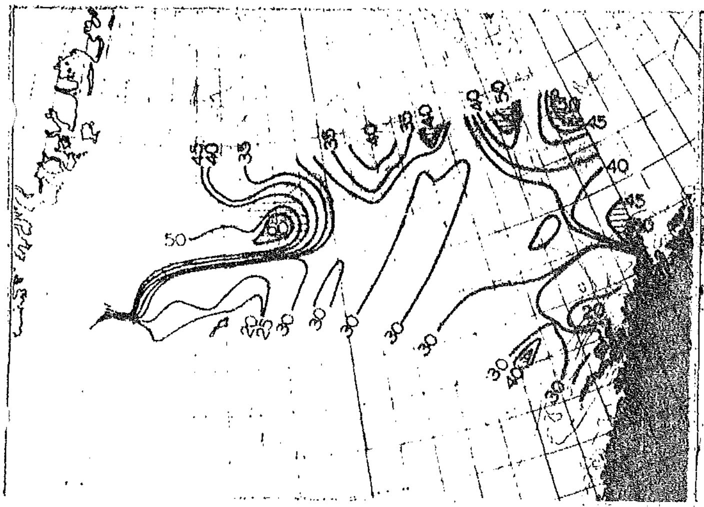


Fig. 12. The transparency recordings 28/IV - 24/VI 1958. The readings are converted to "plankton units". (20 units correspond to ½ the transmission of that in clear water).

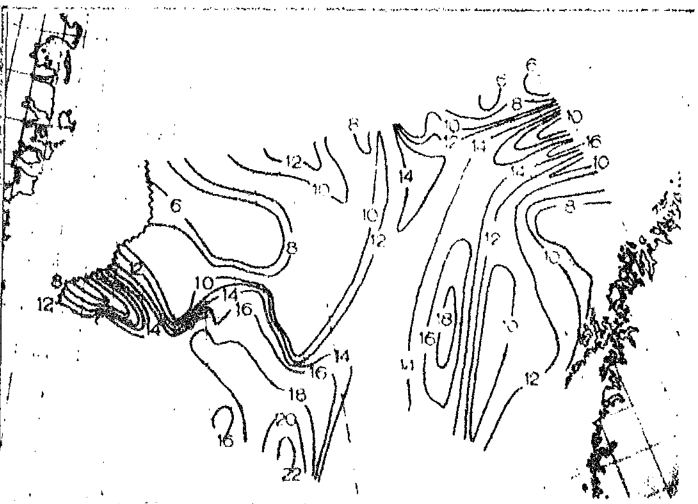


Fig. 13. The Secchidisc readings 28/IV - 24/VI 1958.

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Fig. 8

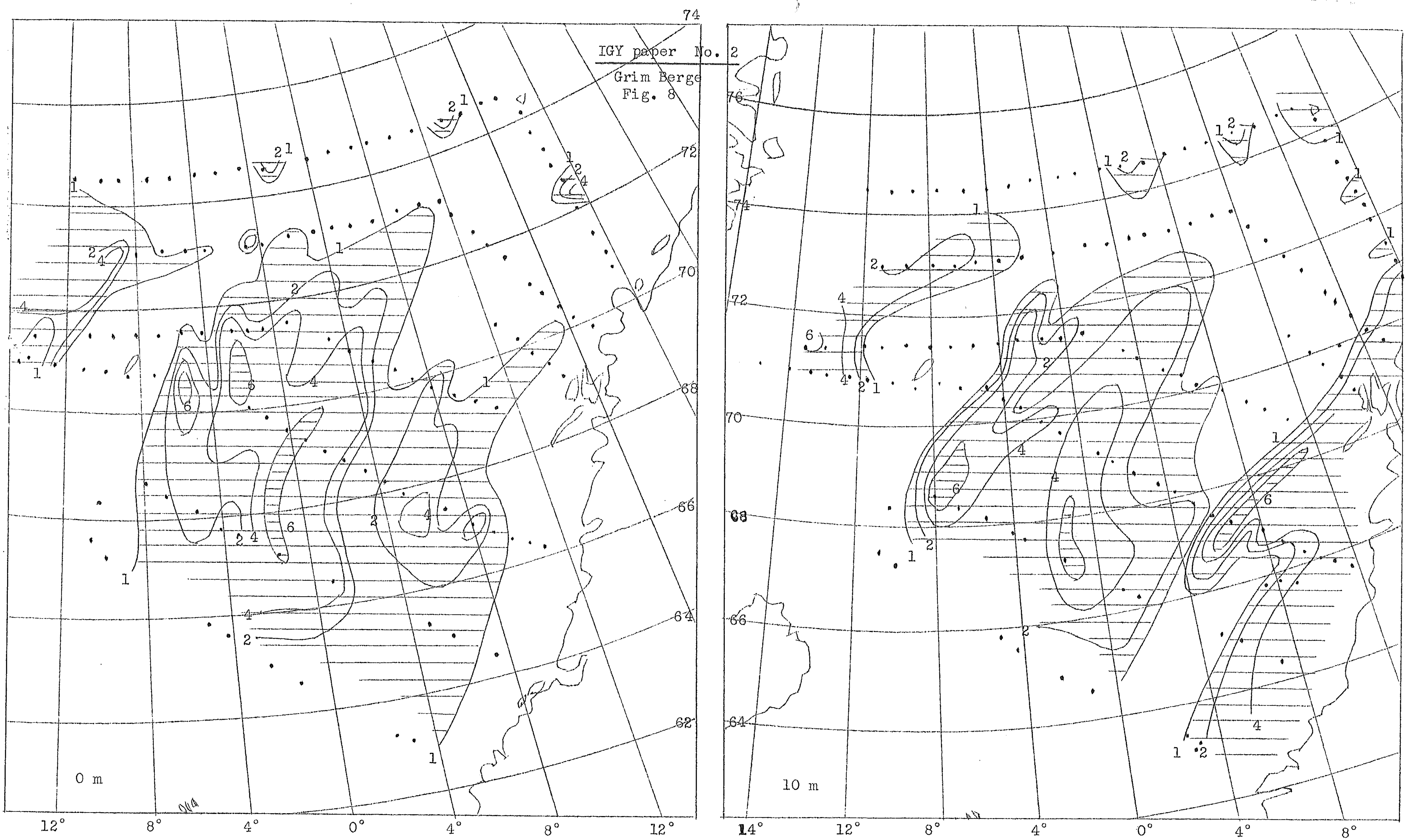

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Fig. 8