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INTRASPECIFIC VARIATIONS IN SIZE, BUOYANCY AND GROWTH OF EGGS AND EARLY LARVAE OF ARCTO-NORWEGIAN COD, Gadus morhua L., DUE TO PARENTAL AND ENVIRONMENTAL EFFECTS

By

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INTRODUCTION

An increase in the proportion of first-time spawners in the population of Arcto-Norwegian cod spawning in Lofoten has been observed during the last years (Hylen & Dragesund 1970). Fewer eggs, therefore, are spawned from each fish, since the number of eggs in correlated to the size of the mother fish (Botros 1962). The quantitative relation between eggs and larvae and the succeeding yearclasses of cod is disputed, and will not be considered here.

The changing size - structure of the spawning population might also effect the quality of the eggs and larvae. For Norwegian spring-spawning herring Hempel & Blaxter (1967) found eggs of lower weight from the first-time spawners. Similar works on species with pelagic eggs are conflicting (Grauman 1965, Heincke & Ehrenbaum 1900). For Argentine anchovy Engraulis anchoita Hubbs & Marini, the positive correlation between size of mother fish and egg size is clearly demonstrated, but no variation in survival is found for larvae hatched from small and big-sized eggs, (de Ciechomski 1966). For Baltic cod, however, a positive correlation between size of mother fish, eggsize and larval survival was found (Grauman 1964).

MATERIAL AND METHODS

The material was collected in Lofoten during March and April in 1969 and 1970.

In 1969 spawning cods were caught on 18 and 31 March with purse seine. The cod were kept live in a commercial well-boat.

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In 1970 the material was caught 12 March with danish seine and 10 April with purse seine.

Eggs were artificially fertilized and measurements were made at the 2-cell stage. Data on length, weight and maturity stage were collected from the parents together with the otoliths for determination of age, spawning zones and type (Rollefsen 1933).

For diameter measurements a Watson eyepiece was used, and the neutral buoyancy of the eggs was determined by suspending eggs in water of different salinities (Sundnes et al. 1965). The neutral buoyancy is expressed in per mille salinity as no difference in thermal expansion could be traced between seawater and cod eggs. The measure error is about $\pm$ 0.5 per mille salinity.

Eggbatches from 15 Arcto-Norwegian cods fertilized in March and April were transported by air to a hatchery at the Institute of Marine Research, Bergen. The total length of the larvae at 50 %-hatching and subsequent length measurements on starved larvae were made up to the time mass mortality occured. The water in the hatchery was pumped from a depth of 130 m and the plankton content is assumed to be negligible. Food particles were never found in the stomachs of the starved larvae.

During both seasons naturally spawned eggs were collected with Clarke-Bumpus plankton sampler and Zaitzev surface sampler in the Lofoten area.

All measurements on eggs and larvae were made on live material.

RESULTS

Fig. 1 shows the intraspecific variation in egg size for the total 1969 material, together with eggsamples from the sea. The total size range for the artificially fertilized eggs is almost the same as for egg sampled at sea. The diameter range for individual fish, however, is smaller than for eggs sampled at sea.

Fig. 1 gives the impression that egg size is independent of the size of mother fish. During the investigation, however, it became obvious that both the eggs in the ovary and the newly hatched larvae were effected by non-parental factors. Fig. 2 shows the observed reduction in egg volume when eggs were taken at different times from the same cod. During 14 days this reduction reached 24 %.

Due to this fact it is important to compare cod females in the same stage of gonad ripeness to detect parental effects. The ordinary maturity scale is not suitable for this purpose, and in practise it is very difficult to obtain comparable material.

The reduction in egg size with time is also reflected on the egg population in Lofoten as shown in Fig. 3. The reduction becomes more significant when the last eggsample in both seasons is divided in eggs older or younger than stage E_1, where the fish larvae is easily recognized (Rollefsen 1929). The younger eggs, spawned late in the season, are significantly smaller both years. The reduction in egg volume during 1969 and 1970 is 13 and 11 %, respectively. The egg volume seems to be somewhat smaller, about 6 %, in 1970 than in 1969. The length distribution of spawning cod at the end of March in both years are given on Fig. 3 (top).

Fig. 4 shows the effect on growth of starved larvae from eggs developed at different temperatures. The experiments were made on eggs from coastal cod, from Western-Norway, and the temperature during egg development was controlled throughout the whole period from fertilization to mass mortality occured. The high temperature for one of the groups was given at the early period of egg development, and both groups hatched at the same temperature, about 3.7°C. Irrespective of egg size the larvae from eggs developed at the low temperature were significantly greater. On the other hand, the small larvae from high temperature group had a faster growth and reached about the same maximum length. The survival of starved larvae from the high-temperature group seems to be somewhat better, although the mean egg size is low, Table 1.

Table 1. Data on mother fish, egg size and growth and survival of starved larvae from egg developed at different temperatures. Coastal cod from Western-Norway.

No. of fish	Length of fish, cm	Egg diam., mean, mm	Egg developm., days	Egg developm., temp.	Temp., larvae period	Survival of starved larvae, days	Larvae, length at hatching, mm
4	61	1,375	22	3,4	3,7	14	4,65
4	74	1,310	15	5,3	3,7	19	3,58

Within the two temperature groups there is a significant correlation between egg size and larvae length at 50 %-hatching, shown in Fig. 5. This correlation holds also for the maximum length of starved larvae.

The neutral buoyancy of egg batches from different Arcto-Norwegian cod females are given in Table 2.

Table 2. Data on neutral buoyancy, expressed in $^{o}/oo$ Salinity, of eggs from Arcto-Norwegian cod.

	March			April		
	Buoyancy, mean, $^{o}/oo$ S	Buoyancy, range, $^{o}/oo$ S	No. of measurem.	Buoyancy, mean, $^{o}/oo$ S	Buoyancy, range, $^{o}/oo$ S	No. of measurem.
1969	31,5	29,5-34,2	25	31,1	29,7-32,2	30
1970	30,5	29,8-31,0	5	31,0	29,9-31,9	13

A few egg batches had neutral buoyancy corresponding to salinities higher than those found in the surface layer in Lofoten. The salinity at 1 meter depth during 1969 was about 33 per mille. The cod females which produced these eggs of high density had stayed for some days in the well-boat and showed signs of stress (high serum osmolarity, which effects the specific gravity of the eggs in the ovary). Eggs from running cod females stripped immediately after being caught always had a specific gravity lower than sea-water, as shown by the 1970 material in Table 2. The neutral buoyancy of cod eggs is not affected by parental factors.

The influence of the low specific gravity of cod eggs on the vertical distribution of the eggs at different weather conditions is illustrated in Fig. 6.

On Fig. 7 the size of eggs from Arcto-Norwegian cods of different age are shown together with the age-distribution of cod investigated during 1969 and 1970. The range of gonad ripeness is supposed to be the same for all age groups. Again, the difference between March and April is significant for all age groups. The effect of age on egg size seems to be negligible. The somewhat smaller eggs observed from six-year old fish in April is doubtfull, since very few specimens were investigated.

No correlation was found between first-time spawners at different age and the egg size. The egg size of fast and slow growing cod females does not seem to vary, and the egg size seems to be independent of natural variation in the condition factor.

Size of eggs, length at 50 %-hatching, growth and survival of starved larvae from 15 Arcto-Norwegian cods are outlined in Fig. 8. The material is too small to give conclusive results. The temperature conditions during the first 4-5 days are also somewhat uncertain due to the lack of temperature-controlled equipment during collection and transportation from Lofoten to Bergen.

As shown in Fig. 8 the temperature was raised at hatching for some of the egg batches collected in April, and this affects the larvae length at hatching and the growth of starved larvae. The material from March showed a significantly longer survival compared to the April group. This gives the impression that larvae of the larger sized eggs of this group have a longer life span when starved. Within this group, however, the larvae with longest life span comes from the cod female with smallest eggs.

DISCUSSION

The intraspecific variation in size of cod eggs was demonstrated by Williamson (1895). Some authors have tried to split the variation in size of pelagic fish eggs into parental and non-parental effects, but the relative importance of these effects are disputed (Heincke & Ehrenbaum 1900, Earll 1880, de Ciechomski 1966). It is now generally stated that the egg size decreases during the time of spawning (Hiemstra 1962, Wiborg 1960). However, this reduction has been explained as a double effect of 1) a long spawning period for individual fish (Grauman 1965, Mayenne 1940, Sorokin 1957) and 2) the arrival of larger fish early in the season (Sund 1938) which are assumed to spawn larger eggs (Earll 1880, Heincke & Ehrenbaum 1900). The present material indicates that for the Arcto-Norwegian cod the first assumption holds (Fig. 2), but not the last (Fig. 7). The material of 6-year old fish is too small to conclude that this age-group produce smaller eggs than the other age-groups in April. In fact 6-year old spawning coastal cod in Lofoten have eggs of "normal" size in April, (not shown in Fig. 7).

The tendency for larger cod to start spawning early in the season (Sund 1938) can probably be responsible for the irregularity in the reduction of egg volume in 1969 (Fig. 3). As the length distribution shows the chances for "grouped" spawning is larger in 1969.

The pronounced effect of temperature during egg development on larval length at hatching is known for Gadus macrocephalus (Forrester & Alderdice 1966). The combined effect of temperature during egg development on length of larvae at hatching and the survival of starved larvae, (Fig. 4., Table 1) may influence the egg and larvae population in Lofoten. The Arcto-Norwegian cod spawn in water between 4 and 6 ^{o}C, and the depth of the water layer with this temperature vary from year to year. The eggs, however, develop in the upper layer. Under special conditions the majority of eggs are even found in the upper centimeters, (Fig. 6, Table 2). The temperature of the surface layer is more variable from year to year than the actual spawning depth. No data exists on the distribution of temperature of the upper centimeters of the surface layer. In Table 3 some data from 4 meter depth off Stamsund are given. 1960 and 1966 represents the extremes during the years 1937-1970.

Table 3. Temperature, Lofoten, 4 meters depth.

	March Temp. °C	April Temp. °C
Average 1945 -65	3.3	3.5
1960	4.5	5.2
1966	1.3	1.8

The calculated time of egg development in 1960 and 1966 is 17 and 30 days, respectively. The delayed appearance of cod larvae in cold seasons due to the long period of egg development, tends to bring the larval population closer in time to the start of the primary production.

The difference in temperature between 1960 and 1966 is greater than the difference in the experimental groups, (Table 1). This means that in 1960 the majority of larvae should be small at hatching and have somewhat longer survival during starvation. In the cold year 1966 the larvae should hatch at a greater length, but have a shorter survival when starved. The adaptive significance of these facts is not known.

The egg size affects the larvae length at hatching (Fig. 5), as also found for Engraulis anchoita (de Ciechomski 1966). The maximum larval length of starved larvae is probably also effected, Fig. 5 and 4.

Larvae kept at higher temperature after hatching show a faster growth than larvae kept at lower temperature, but the maximum size of starved larvae seems to be the same for the two groups (Fig. 8).

As mentioned earlier the present material on larvae from Arcto-Norwegian cod is too scanty to give reliable conclusions on the survival of larvae from eggs of different size or from different time in the spawning season. Controlled experiments in large scale during the whole spawning period are needed to answer these questions.

SUMMARY

1. An intraspecific variation in the size of eggs spawned by Arcto-Norwegian cod was found. This variation is mostly an effect of the long spawning season. A female cod has running eggs for a long period and the first eggs spawned are the largest.

   No correlation was found between egg size and age of mother fish (Fig. 7).

2. The length of larvae at hatching is positively correlated with egg size and the same is true for the maximal length obtained by the starved

larvae. The material indicates a positive correlation between survival of starved larvae and egg size, but the material on Arcto-Norwegian cod larvae is too small to give a reliable conclusion.

3. The neutral buoyancy of cod eggs corresponds to a specific gravity lower than the seawater in which they are spawned. During calm weather, therefore, the eggs will be found in the surface layer. The neutral buoyancy of eggs from Arcto-Norwegian cod is not affected by age of mother fish.

4. The temperature during egg development affects the length of larvae at hatching and the growth and survival of starved larvae very significantly. Small differences in temperature during egg development will easily mask the effect of egg size on the larvae.

   Different temperatures after hatching affects the rate of growth of the newly hatched larvae.

REFERENCES

Botros, G.A., 1962. Die Fruchtbarkeit des Dorsches (Gadus morhua L.) in der westlichen Ostsee und den westnorwegischen Gewässern. Kieler Meeresforschungen 18: 67-80.

de Ciechomski, J.Dz., 1966. Development of the larvae and variations in the size of the eggs of the Argentine anchovy, Engraulis anchoita Hubbs & Marini. J. Cons. perm. int. Explor. Mer. 30 (3): 281-90.

Earll, R.E., 1880. A report on the history and the present condition of the shore cod-fisheries of Cape Ann, Massachusetts together with notes on the natural and artificial propagation of the species. Rep. U.S. Fish. Comm. for 1878, 6: 685-740.

Forrester, C.R., & D.F. Alderdice, 1966. Effects of salinity and temperature on embryonic development of the Pacific cod (Gadus macrocephalus). J. Fish. Res. Bd. Canada 23 (3): 329-340.

Grauman, G.B., 1964. The importance of the size of the eggs of the Baltic cod for survival of foetuses. Coun. Meet. int. Coun. Explor. Sea (F: 85).

Grauman, G.B., 1965. Changes in the egg size of cod (Gadus morhua callarias L.) within the spawning period. Coun. Meet. int. Coun. Explor. Sea (47).

Heincke, F. & E. Ehrenbaum, 1900. Eier und Larven von Fischen der deutschen Bucht. II. Bestimmung der schwimmenden Fischeier und die Methodik der Eimessungen. Wiss. Meeresunters. abt. Helgoland 3: 127-333.

Hempel, G. & J.H.S. Blaxter, 1967. Egg weight in Atlantic herring (Clupea harengus L.). J. Cons. perm. int. Explor. Mer. 31 (2): 170-95.

Hiemstra, W.H., 1962. A correlation table as an aid for identifying pelagic fish eggs in plankton samples. J. Cons. perm. int. Explor. Mer. 27: 100-108.

Hylen, A. & O. Dragesund, 1970. Recruitment of young Arcto-Norwegian cod and haddock in relation to parent stock size. Coun. Meet. int. Coun. Explor. Sea (19): 1-14.

Mayenne, V.A., 1940. Über die Ursachen der Schwankungen in der Eigrösse bei den Knochenfischen. Compt. Rend. Dok. Akad. Sci. U.S.S.R. 28 (7).

Rollefsen, G., 1929. Torskeegg med deformerte fostre. Årsberet. vedk. Norg. fisk. 2: 1-12 (In Norwegian).

Rollefsen, G., 1933. The otoliths of the cod. FiskDir. Skr. Ser. Hav-Unders. 4 (3): 1-14.

Sorokin, V.P., 1957. Ovogenesis and annual development of the ovaries of cod (Gadus morhua morhua L.). Trudy PINRO 10: 125-160 (In Russian).

Sund, O., 1938. The stock of cod in 1937. FiskDir. Skr. Ser. Hav-Unders. 5 (7): 48-49.

Sundnes, G., H. Leivestad & O. Iversen, 1965. Buoyancy determination of eggs from the cod (Gadus morhua L.). J. Cons. perm. int. Explor. Mer. 29: 249-52.

Wiborg, K.F., 1960. Investigations on eggs and larvae of commercial fishes in Norwegian coastal and offshore waters in 1957-58. FiskDir. Skr. Ser. HavUnders. 12 (7): 1-27.

Williamson, H.Ch., 1895. On the variation in size of certain pelagic ova. 13th annual report of the Fish. bd. Scotland 3: 271-75.

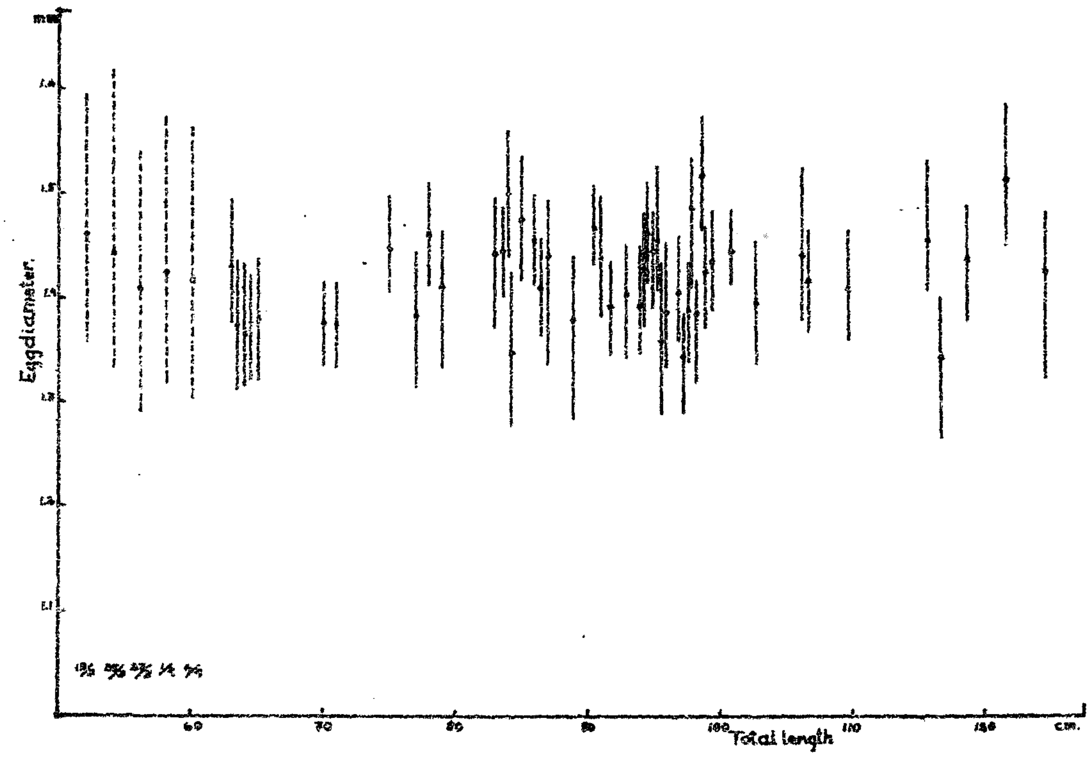

Fig. 1. Mean diameter and range of cod eggs 1969.
———o——— Artificially fertilized, different females.
---- ● ---- Samples from the sea.

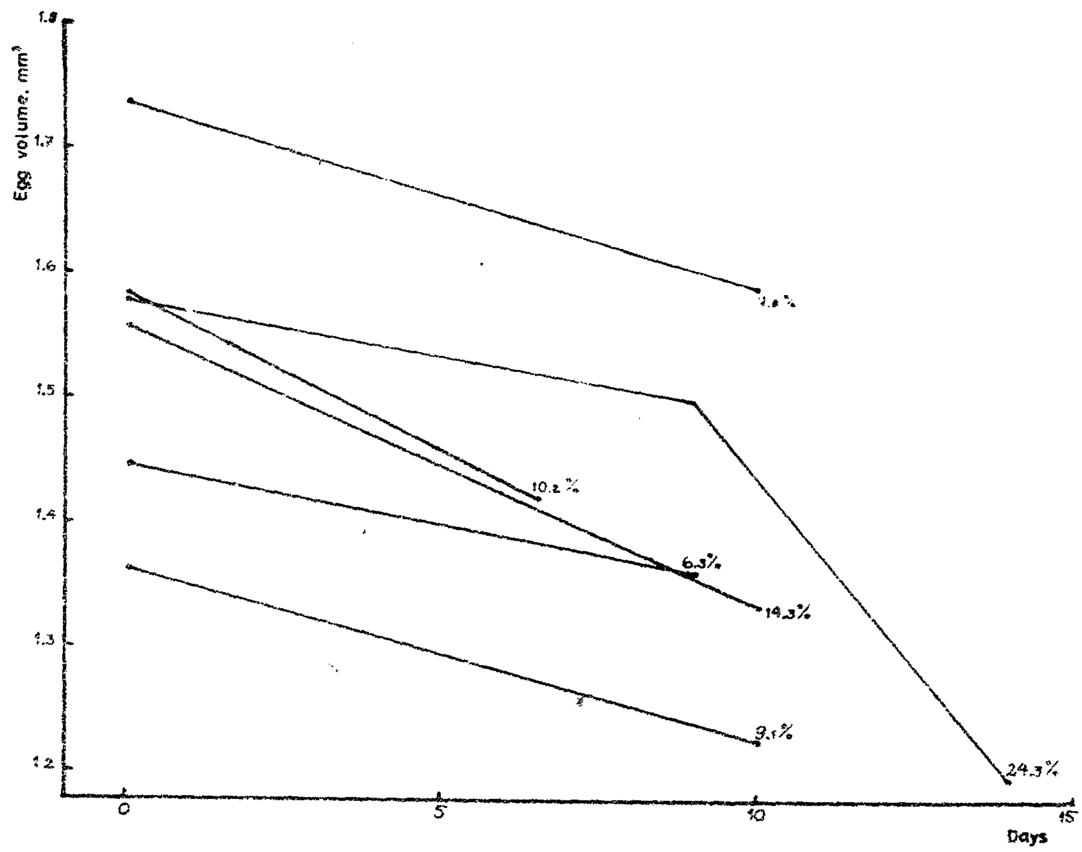

Fig. 2. Reduction of mean volume of cod eggs from separate females. Artificially fertilized.

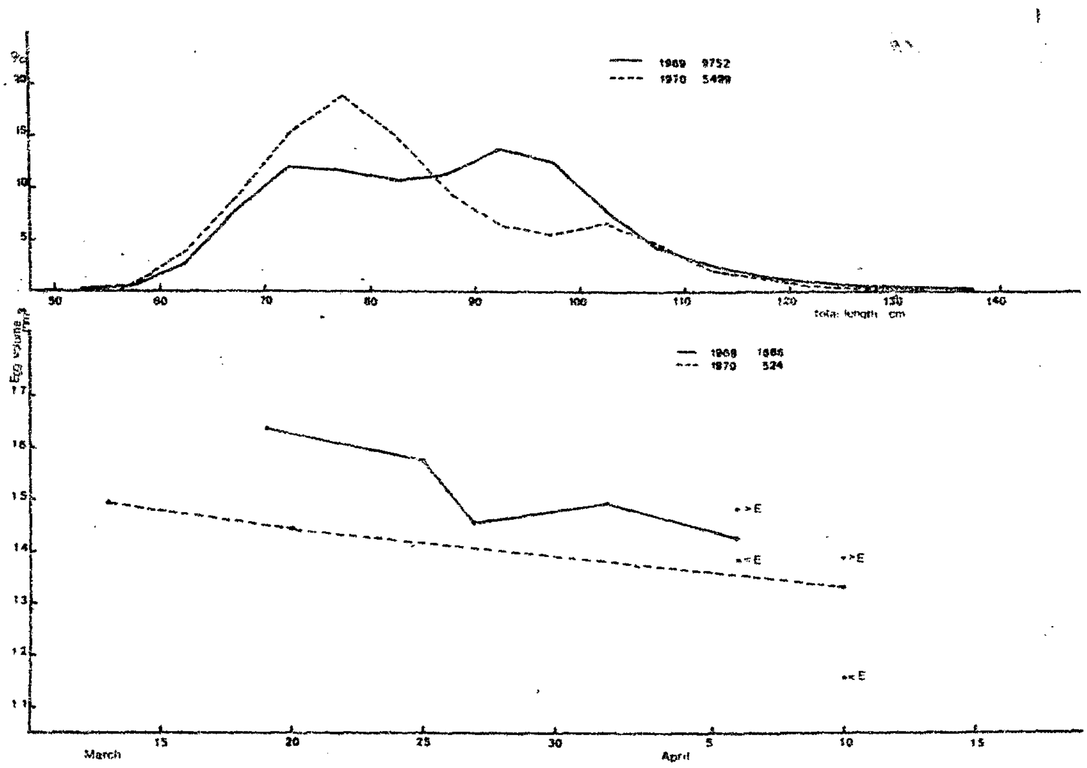

Fig. 3. Length distribution of spawning cod in Lofoten.
March 1969 and 1970. (Top)
Mean volume of cod eggs in samples from the sea, Lofoten.
March - April 1969 and 1970. (Bottom)

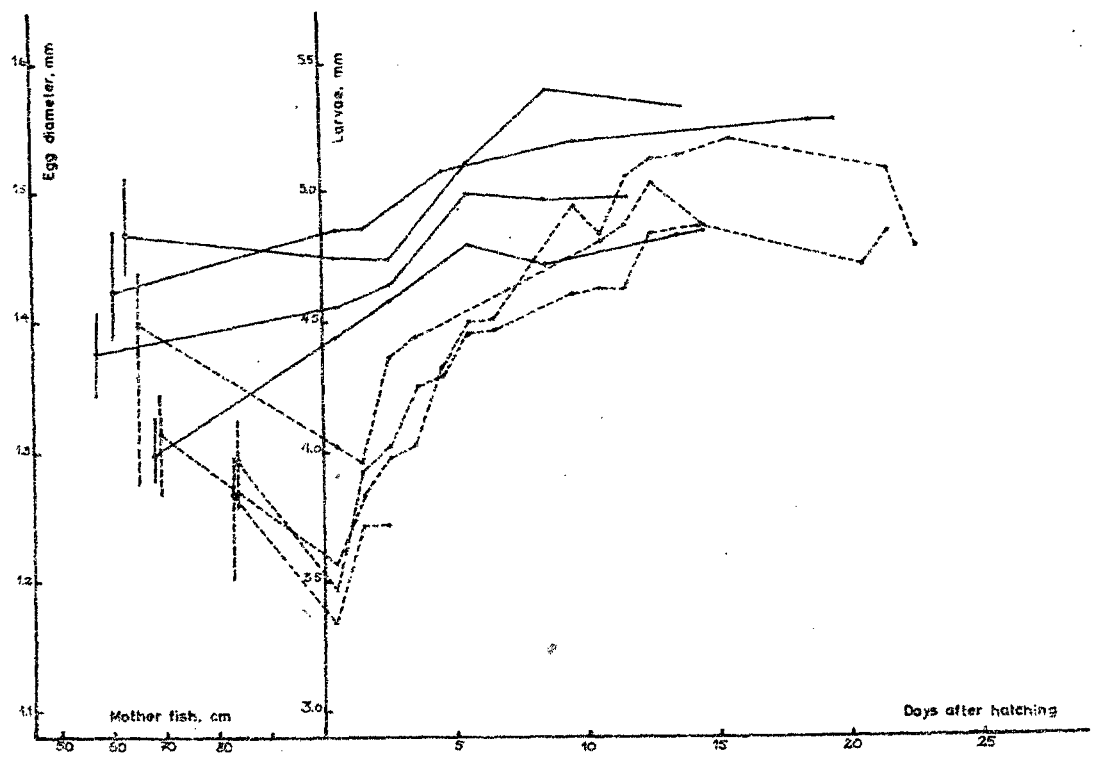

Fig. 4. Growth of starved larvae from eggs developed at different temperatures.
——— 3.4°C (22 days to hatching.)
----- 5.3°C (15 days to hatching.)

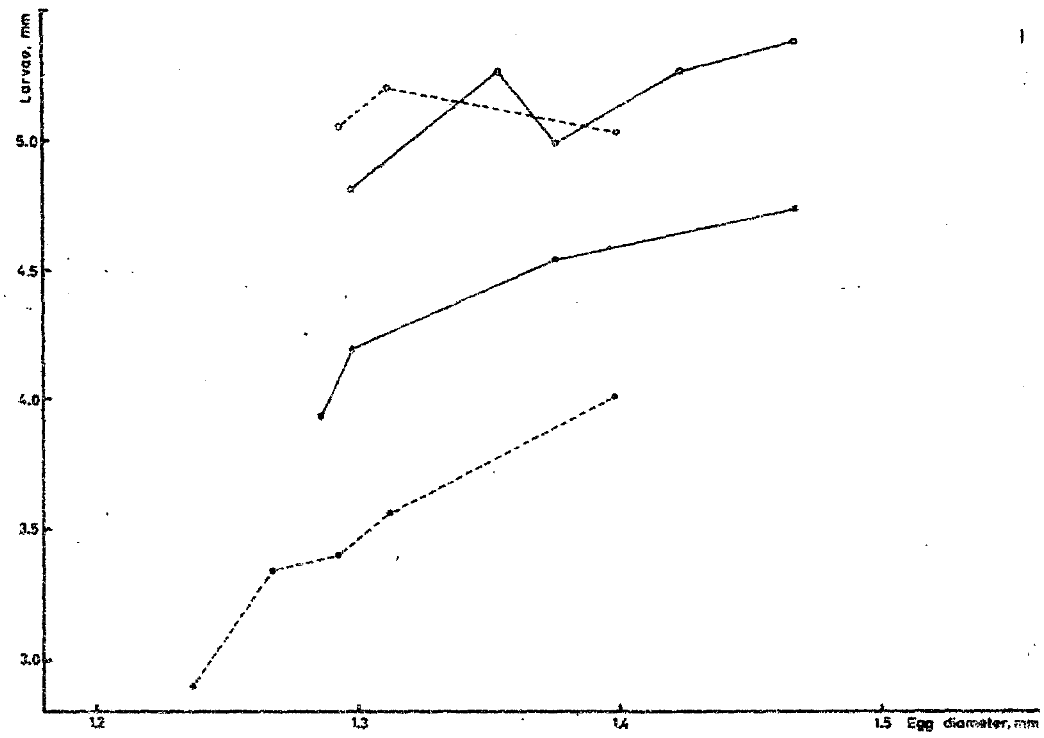

Fig. 5. The length of cod larvae at 50%-hatching from eggs of different diameters, developed at 5.3°C, • ----- •, and 3.4°C, • ——— •.
Maximum length of starved larvae from eggs of different diameter developed at 5.3°C, o ----- o, and 3.4°C, o ——— o.

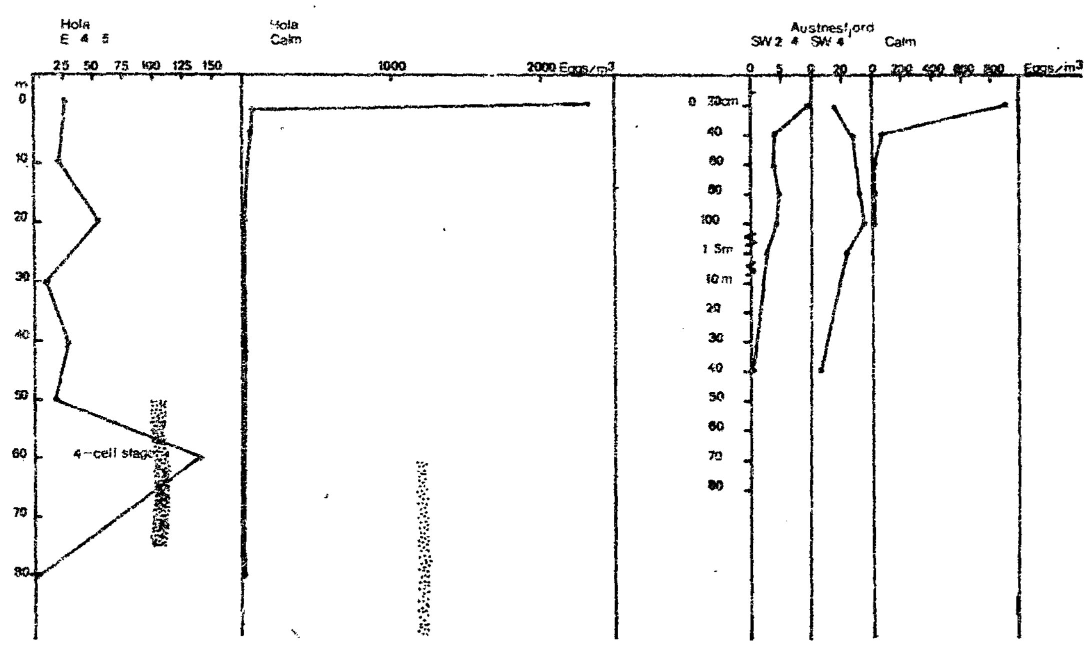

Fig. 6. Vertical distribution of cod eggs in Lofoten at different weather conditions.
Left: Høla, Clarke-Bumpus sampler.
Right: Austnesfjord, Zaitzev surface sampler and Clarke-Bumpus sampler.

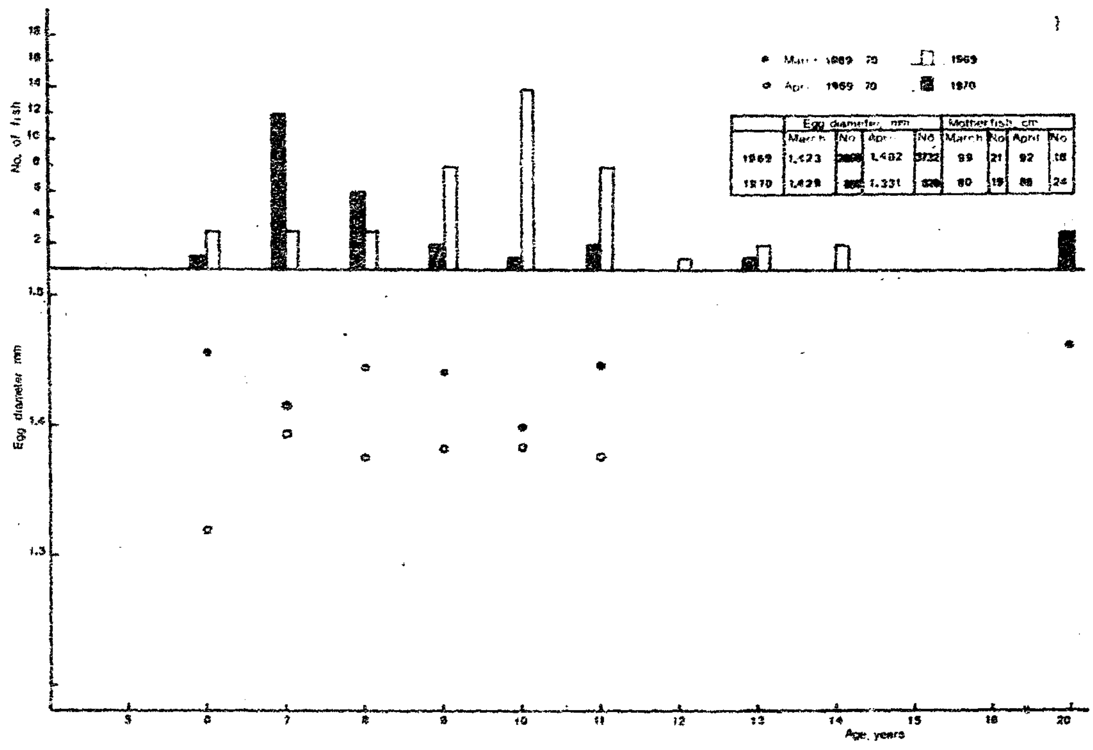

Fig. 7. Egg diameter of Arcto - Norwegian cod at different age in March and April 1969 - 70. (Age distribution of cod females used for egg measurements and tabulated data of investigated material inserted at top.)

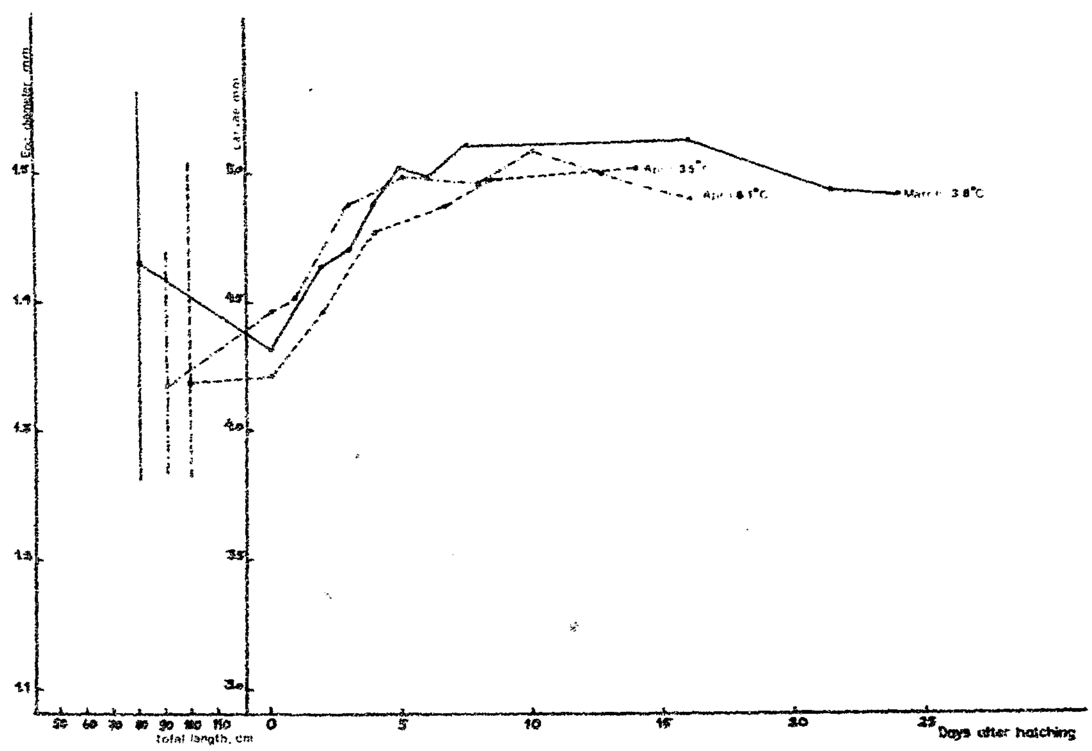

Fig. 8. Egg diameter and growth of starved larvae of 15 Arcto - Norwegian cods, March and April 1970. Temperature during egg development, 3.7°C.