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RECRUITMENT OF YOUNG ARCTO-NORWEGIAN COD AND HADDOCK IN RELATION TO PARENT STOCK SIZE

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INTRODUCTION

Variations in abundance of recruits in the Arcto-Norwegian cod and haddock stocks have been described by Hjort (1914), Rollefsen (1930, 1954), Sund (1924, 1936), Hylen (1962) and Garrod (1968). The relative strengths of poor and rich year-classes in the cod stock measured at age $\geq$3 years were found to be in the order of 1:20 for cod and haddock in the period 1946-1968. Also the time interval between the appearence of rich year-classes in these stocks can be relatively long in some periods even more than ten years (Anon. 1970).

The causes of the variation are not known, but current hypothesis concentrate on possible variability of parental factors and of environmental conditions in the sea shortly after hatching. Since Hjort (1914) demonstrated the great fluctuations in year-class strength of fish stocks in the Northeast Atlantic the general view has been that within the range of stock size variations studied, the numerical strength of a year-class is independent of the size of the parent stock in fish species with high fecundity. The evidence supporting this concept of stock size and recruitment has been reviewed by Beverton and Holt (1957). Recently this theory has been challanged by data from North Atlantic cod and haddock stocks (Garrod 1966, 1968, Anon. 1968a, 1969a). Garrod found evidence for a decrease in recruitment with decreasing parent stock size for Arcto-Norwegian cod and claimed that the declining trend in recruitment that has been observed in this stock, is assiciated with an increasing fishing effort. He assumed that if the spawning stock remains stable it will on the average produce enough young to replace the average of its constituent year-classes.

In the present investigations the series of observations is too short to give firm conclusion of the relationship between the parent stock size (the spawning potential) and the subsequent abundance of the resulting year-class. The paper attempts to present relative estimates of year-class strengths at the O-group stage (i.e. about 6 months of age) of Arcto-Norwegian cod and haddock and to correlate these with subsequent year-class strengths in the young adolescent phases. Abundance estimates of the 1963-1969 year-classes are used to discuss the relationship between recruitment of young Arcto-Norwegian cod and haddock in relation to the parent stock size.

MATERIAL AND METHODS

0-group fish surveys

Joint investigations were carried out during the period 1965-1969 by labatories conducting fisheries research in the Barents Sea in order to estimate year-class strength at the 0-group stage (Anon. 1965a, 1966, 1967, 1969b, 1969c). Prior to this period (in 1963 and 1964) data are available from surveys conducted by Institute of Marine Research, Bergen (Dragesund and Olsen 1965, Dragesund 1970b). The 0-group survey in 1963 was restricted to the Barents Sea (Figs. 1 and 8), and data from the USSR young fish survey in 1963/64 to the Bear Island/Spitsbergen area were taken into consideration (Nizovtsev 1964, 1968a and Baranova 1964). The basic technique employed in the 0-group surveys was echo sounding and sampling with midwater trawl (Dragesund and Olsen 1965, Dragesund, Midttun and Olsen 1970).

Experience has shown that if the Barents Sea surveys for 0-group fish are carried out from late August to early September, the fish are large enough to be detected. They are pelagically distributed and occur generally in the upper 100 metres of water. During the dark period the 0-group fishes form more or less uniform scattering layers. When concentrations are not too dense single individuals can be distinguished. In day-time, however, the fish cluster together forming either small schools or discontinous layers of schooling concentrations.

In general the identification of 0-group fish from the echo reording paper alone is not possible. However, in the Barents Sea surveys it has been possible to distinguish between several types of recordings which have been identified by midwater trawling. In theis area, therefore, analysis of echo recordings combined with frequent sampling with fishing gears seems to be possible for establishing the geographical distribution of 0-group fish in August-September.

The catching gear used by all participating vessels was a small meshed pelagic midwater trawl with headline and footline of 18,3 m, sideline of 15,3 m and mesh size from 100 mm (wings and square) graded down to 8 mm (cod end). The catchability of the trawl was tested by intership comparisons carried out during the surveys. The depth of trawling was checked by a depth recorder attached to the trawl.

0-group echo abundance

A simple counting method can be applied as long as the single fish can be distinguished on the echo paper. In dense layers and in schools this method can not be used on standard echo sounder equipment the 0-group fish are most frequently recorded as multiple echo traces. Exact measurement of multiple echoes is possible, but somewhat sophisticated instrumentation is necessary. However, Dragesund (1970b) has shown that fairly reliable relative abundance estimates could be obtained by visual classification or grading of paper recordings of multiple scatters in 1) very scattered, 2) scattered, 3) dense and 4) very dense echo recordings.

The best conditions for estimating abundance exists during the dark period when the fish fry occur in more or less continuous scattering layers. Since the surveys are carried out also in day time, a conversion factor between day and night recordings was established by frequently surveying the same area both by day and by night.

The abundance of 0-group fish is a function of the area of the horizontal distribution, the vertical extension and the density of the scattering layer. In the present investigations the area of distribution of 0-group cod and haddock together with the density of the echo recordings (the echo abundance) have been used to study the variation in abundance from year to year. The results of some preliminary experiments on 0-group herring (Dragesund 1970b) gave a ratio of the order 1:10 between catch in numbers in a scattering layer by night of density 1) and 2) compared with that of density 3) and 4), which might be the correct order of magnitude for other species too. Indices of total echo abundance, were therefore estimated by multiplying the area of dense recordings by a factor of 10 and adding these estimates to those of the area with scattered recordings. The vertical extension of the scattering layer varied. This feature is not taken into account and might give a bias in the abundence indices.

Young fish surveys

The USSR Polar Institute of Marien Fisheries and Oceanography has since 1946 made yearly surveys of young cod and haddock to determine annual recruitment to the Arcto-Norwegian cod and haddock stocks. A 25 m bottom trawl inserted with a cotton net in the cod end has been used for sampling (Baranenkova 1957). The cover net was 6-8 m long with 10 mm mesh size. Ages were determined from otoliths.

The number of fish in each age-group caught per hour trawling is taken as abundance index. The indices are obtained by dividing the total catch in number of different age-groups in the Barents Sea and the Bear Island/ Spitsbergen areas by the respective hours trawling during the survey period. The abundance indices for cod (Nizovtsev 1966, 1967, 1968b, 1968c, 1969 and Nizovtsev and Trambachev 1969) and haddock (Baranova 1966, 1967, 1968a, 1968b and 1969) are given separately for each year-class at an age c

0+ (i.e. from age 6-13 months), 1+ and 2+ for the Barents Sea and for the Bear Island/Spitsbergen areas respectively. These two regions have different areas. Consequently the catch per hour fishing in the two regions is not directly comparable in terms referring to the total stock. It is therefore necessary to weight the abundance indices for the two regions in order to combine the data. As supposed by Garrod (1967) the catch per unit effort data for the two regions can be combined by supposing that the Bear Island/Spitsbergen "stock" was distributed over an area equivalent to that of the Barents Sea "stock". The weighed abundance indices for the Bear Island/Spitsbergen areas are therefore estimated by dividing the catch per unit effort figures by 3,54, which is the ratio between the Barents Sea and the Bear Island/Spitsbergen areas.

The year-class strength in numbers at 3 years of age have been estimated by virtual population analysis (Anon. 1965b) by assuming a natural mortality rate of M= 0,30 for cod and M= 0,20 for haddock (Anon. 1969a, 1970 and Hylen and Eide 1969). A fishing mortality rate of F= 0,80 for older cod and haddock is applied in the calculations. This method gives only the numerical strength of the 1963 and 1964 year-classes in the period studied. However, by comparing the abundance indices from the USSR young fish surveys in the period 1946-1964 the respective year-class strengths at 3 years of age for the same year-classes, the numerical strength of the 1965-1968 year-classes might be given (Anon. 1969a, 1970 and Hylen and Eide 1969).

The virtual population analysis gives estimates of the absolute numerical strength of each age-group each year. When a maturation ogive is applied to the estimated age composition of the stock for each year, estimates of the spawning stock size and its age composition are obtained. The spawning potential can be estimated from the estimated age-composition when the fecundity is known. Fecundity data for cod and haddock in the Northeast Arctic are insufficient, but the fecundity is assumed to be approximately propotional to the weight of the fish, and the total weight of the parent stock is used as an index of the spawning potential. According to Botros (1959) the suggested fecundity/weight relationship underestimates the true relationship as far as cod is concerned.

RELATIONSHIP BETWEEN MEASURES OF YEAR-CLASS ABUNDANCE

Cod

The echo abundance indices of 0-group cod distributed north of 67^{0}N are estimated for the year-classes 1963-1969 (Figs. 1-7). These indices are plotted against the abundance indices at 0+, 1+ and 2+ years of age respectively (Fig. 15). A correlation is indicated between the echo abundance of O-group cod and the abundance at O+. No correlation could be found for O-group echo abundance and the other measures of year-class abundance estimated from the young fish surveys. This is mostly caused by the low abundance indices of the 1963 year-class at 1+ and 2+ (Fig. 15B-C). In Fig. 15D the O-group echo abundance is plotted against the numerical strength at 3 years of age, obtained from the virtual population analysis. The numerical strengths of the year-classes 1965-1968 can not be measured from this analysis, since they have not yet been available in the fishery for long enough time. However, it is no doubt that they are very poor year-classes, and a correlation between the two measures of year-class strength is suggested.

Haddock

The relationship between O-group echo abundance indices of haddock and the abundance at O+, 1+ and 2+ is shown in Fig. 16. No correlation was found between the O-group abundance and the abundance at O+, whereas correlations are observed between O-group abundance and year-class strength at subsequent stages. (Fig. 16B-C). Excluding the year-class of 1967 a correlation is also indicated between O-group abundance and subsequent year-class strength at 3 years of age (Fig. 16D).

Relationship between parent stock size and subsequent year-class strength.

Cod

Virtual population analysis give for each year estimates of the numerical strength of each age-group in the stock. By applying a maturation ogive to these numbers an estimate of the spawning stock size is obtained. Garrod (1967) used a maturaton ogive derived from the relative number of first time spawners (Rollefsen 1954) by a method described by Gulland (1964). Rollefsen found first time spawners up to 14 years of age, but first time spawners have in the last 3-5 years only been represented by a small number at 13 years of age and none at 14 years of age (unpublished Norwegian data). A similar maturation ogive to that given by Garrod (1967) has been drawn (Fig. 17), starting with 100% maturation at 13 years of age and ending with 2% mature fish in age-group six. When applying this maturation ogive on the absolute numerical stock composition the age distribution of the spawning stock can be estimated for the period 1963-1969. These age-distributions are similar to those obtained from the otolith samples of long line catches of spawning cod (Fig. 18). However, the older age-groups are more abundant in th estimated spawning stock than in the samples of long line catches.. The purse seine catches which are expected to be more representative for the spawning stock than long line catches (Rollefsen 1956 and Hylen 1962) consisted of older fishes. It is therefore suggested that the absolute numerical estimated composition of the spawning stock is fairly good.

A propotional relationship between weight and fecundity is assumed. This implies propotional relationship between spawning potential and the weight of the stock. When estimating the weight of the spawning stock the same age/weight relationship is used as by the North-East Arctic Fisheries Working Group. The absolute size of the parent stock in hundreds of metric tons is plotted against subsequent year-class strength at about 6 months of age (Fig. 19). A relatively small variation in parent stock size has been observed in this period. The year-classes 1963, 1964 and 1969 were the most abundant year-classes. A relationship between the parent stock size and the abundance of the resulting year-class at 6 months of age may exist for the most abundant year-classes in the period studied, but not for the other group of year-classes.

Haddock

The numerical strength of each age group each year in the period 1963-1969 is estimated by using virtual population analysis. A maturation ogive estimated from material sampled in the Barents Sea (Sætersdal 1954) during autumn 1953 (Fig. 17) was applied to the absolute numerical stock size when calculating the age composition of the spawning stock. Otolith readings of Norwegian data taken from research vessel catches during winter and spring on the spawning migration along the coast from Malangen to Røst, show none first time spawners among the age-groups 10 and older and very few of the 3 years old fish (unpublished Norwegian data). These informations are in good agreement with Sætersdal's findings (Fig. 17). These calculations give an age composition of the spawning stock each year in the period 1963-1969 which agree fairly good with the age compositions (Fig. 20) of the German landings from the area Røst-Malangen during January-April 1963-1968 (Meyer 1969) and the age-distribution in Norwegian long line catches from the area Malangen-North Cape during February 1969 (unpublished Norwegian data). Both the German and the Norwegian landings are expected to be mostly mature haddock on spawning migration.

Also for haddock fecundity is assumed to be proportional to the weight of the fish, which implies that the spawning potential is proportional to the parent stock size. Estimates of the parent stock size is obtained by using the same age/weight relationship as by the North-East Arctic Working Group. In Fig. 21 the parent stock size is plotted against the abundance of the resulting year-class at 6 months of age. A relationship may exist under certain conditions within the period considered. However, under other conditions the effect of the spawning stock size is ruled out.

DISCUSSION

When estimating the echo abundance of the 1963 year-class of cod and haddock a scattered distribution of O-group fish was assumed for the areas around Bear Island and along the Spitsbergen coast (Figs. 1 and 8). High abundance indices of cod for this year-class were found in the young and adolescent phases (Nizovtsev 1968a) and at least some of the areas might have been populated with dense concentrations of O-group fish. The O-group echo abundance might therefore be underestimated.

The figures for catch per unit effort are compararable from one year-class to another, when the same relative amount of the year-classes at 0+, 1+ and 2+ years of age are at the bottom each year during the young fish survey. However, some year-classes migrate to the bottom later in the year than others, and a bias may be introduced in the 0+ abundance indices. Few specimens of the 1947 year-class were caught with bottom trawl as late as December 1947 in the eastern Barents Sea, but in December 1948 a great number of this year-class was caught together with O-group cod of the 1948 year-class (Baranenkova 1957). Diurnal, vertical migration of O-group cod (Baranenkova et.al. 1963) and of 1, 2 and 3 years old haddock (Woodhead 1964) will affect the abundance indices in the young fish surveys. These might be responsible for some of the variations observed in Figs. 15 and 16. On the other hand a reduced abundance of the 0+ group relative to the O-group echo abundance might be caused by small predators as 1, 2 and 3 years old cod (Ponomarenko 1961). Variation from year to year in discarding small fish at sea by trawlers (Hylen 1967 and 1969), is a factor which might cause some variation in the data presented in Figs. 15D and 16D. This is not taken into account in the virtual population analysis. At present only the numerical strength of the 1963 and 1964 year-classes of cod and haddock can be estimated with some confidence. Now firm conclusion of the relationship between the O-group abundance and the year-class strength at 3 years of age can therefore be drawn from the available data. However, if a close correlation exists between the echo abundance of O-group cod and haddock and the numerical strength of the year-classes at the beginning of their third year of life, an estimate of the year-class strength can be given the same year as it is spawned. When alinear regression between the O-group abundance and the year-class strength at 3 years of age is assumed, the 1969 year-class of cod and haddock is expected to be represented in the sea at the beginning of 1972 with about 680 and 730 millions of cod and haddock respectively (Figs. 15D and 16D). Applying the same method for the 1967 year-class of haddock this year-class is expected to be represented in the sea by about 420 millions of fish at 3 years of age. However, since the 0+ abundance is low in the young fish survey (Fig. 16A), the year-class might have been reduced by predators in this stage, or it might have been reduced due to unfavourable environmental conditions. It is known from the 0-group survey in 1967 that 0-group saithe were numerous west of Bear Island and off the Spitsbergen coast, up to about 80°N (Anon. 1967). The progeny may have been transported northwards from the spawning areas at Viking Bank, off Møre and Halten Bank. A northward transport of haddock eggs and larvae from the same areas may also have taken place, and the 1967 year-class in the Barents Sea might have got a significant number of postlarval fish from the spawning areas mentioned. These fish might be exposed to more extreme environmental conditions than they are adapted to, and the natural mortality rate during the 0-group bottom stages may have been higher than those of the Arcto-Norwegian haddock. This may explain the low abundance of the 1967 year-class (Fig. 16A). On the other hand this year-class was relatively numerous in catches taken along the Finnmark Coast and in the Barents Sea during a Norwegain trawl survey in May 1970.

When estimating the numerical spawning stock size one maturation ogive for cod and one for haddock were applied for the whole period 1963-69. Long and short term changes will therefore introduce bias in the estimated spawning stock age compositions (Rollefsen 1954). These may be responsible for the disagreement between the relative strength of some year-classes in the estimated spawning stock and those in the catches of spawning fish, as observed for the 1956 and 1959 year-classes of cod and of the 1964 year-class of haddock (Figs. 18 and 20). However, the agreement is fairly good for the period studied.

The age/fecundity relationships are not known for Arcto-Norwegian cod and haddock and a linear regression between the weight and the fecundity is assumed. This assumption implies a proportionality between parent stock size in metric tons and spawning potential. However, this method may give an underestimate of the spawning potential (Botros 1969). Data of parent stock size and subsequent year-class strength are available only for a limited number of years (Figs. 19 and 21). The relationship indicated for cod and haddock are similar to that found for Norwegian spring spawning herring (Dragesund 1970a). These studies suggest a relationship between spawning potential and 0-group abundance for cod, haddock and herring, when the conditions for the progeny are favourable. Under less favourable conditions the effect of spawning potential is ruled out. However, an assosiation in time between the variables, spawning stock, recruitment, fishing, effort and some undetected trends in the environment cannot be avoided in the methods used to demonstrate a stock/recruitment relation. A slightly different approach is made by Garrod (1968) and Anon. (1969). This approach is based on the assumption that if the stock is to remain stable the spawning stock should in average produce enough young to replace the average of its constituent year-classes. When the potential spawning stock is reduced by fishing, the recruitment can be held constant by a corresponding increase in the survival of the progeny. This is expressed (Anon. 1969a) as by $S = (^{R}3/R_{sp}) \cdot e^{F}$ or $\log_e S = {}^{R}3/R_{sp} + F$. Using the age groups 7-13 and 5-11 to represent the spawning stocks of cod and haddock respectively, R_{sp} denotes the average numerical strength at 3 years of age of the year-classes in the parent stocks. R_3 is the year-class strength of the resulting generation at 3 years of age. F is the mean fishing mortality rate per year-class summed over 3-9 and 3-7 years for cod and haddock respectively, and S is a survival index from the eggs stage to 3 years old fish. The relationship $\log_e S = F$ represents the hypothesis that recruitment is independent of the spawning potential (Fig. 22). Recruitment is held constant by increased survival rate of eggs and larvae as the spawning stock is reduced. The replacement rate $(^{R}3/R_{sp})$ for the year-classes up to 1964 are calculated from year-class strengths given by virtual population analysis. For recent year-classes estimates have been obtained from Figs. 15D and 16D, assuming a linear regression between 0-group echo abundance and numerical year-class strength at 3 years of age. Since the late fifthies only 5 of 11 year-classes of cod and 8 of 13 year-classes of haddock have replaced its constituent year-classes (Fig. 22). A great variation is observed in the data, and a longer series of observations are necessary to establish a relationship.

SUMMARY

1. The relationship between the 0-group echo abundance of Arcto-Norwegian cod and haddock (i.e. about 6 months of age) of the 1963-1969 year-classes and the abundance at subsequent stages of the same year-classes (at 0+, 1+ and 2+ years of age) and between the 0-group abundance and the numerical strength at 3 years of age were analysed. (Figs. 15 and 16). 0-group echo abundance indices were obtained from combined acoustic and fishing surveys (Figs. 1-14). Abundance indices at 0+, 1+ and 2+ were taken from the USSR young fish surveys. The numerical year-class strengths at 3 years of age were estimated by virtual population analysis. Correlations were indicated between

the abundance of O-group cod and the abundance at O+ and betweenthe O-group abundance and the numerical strength at 3 years of age. For haddock correlations were indicated between the O-group abundance and the abundance at 1+, 2+ and the numerical year-class strength at 3 years of age.

2. Variation in O-group abundance was studied in relation to the parent stock size in metric tons (assumed proportional to spawning potential). Relationships were suggested for cod and haddock between the parent stock size and the strengths of the resulting generations at the O-group stage in years when the conditions for the progeny were favourable (Figs. 19 and 21). The effect of the parent stock size in determining the year-olass strength was ruled out in years with less favourable conditions.

3. The survival from the egg stage to 3 years old fish was studied in relation to the fishing mortality rate per year-class in the spawning stock (Fig.22). These investigations suggests that since the late fifthies only 5 of 11 year-classes of cod and 8 of 13 year-classes of haddock have replaced its constituent year-classes.

REFERENCES

Anon. 1965a. Preliminary report of the joint Soviet-Norwegian investigations in the Barents Sea and adjacent waters September 1965. Coun. Meet. int. Coun. Explor. Sea, 1965 (161): 1-5, 10 figs. [Mimeo]

Anon. (Gulland, J.A.) 1965b. Estimation of mortality rates. Anex to Arctic Fisheries Working Group. Report of meeting in Hamburg 18-23 January 1965. Coun. Meet. int. Coun. Explor. Sea, 1965 (3): 1-9. [Mimeo]

Anon 1966. Preliminary report of the joint international 0-group fish survey in the Barents Sea and adjacent waters August/September 1966. Coun. Meet. int. Coun. Explor. Sea, 1966 (H:23): 1-9, 13 figs. [Mimeo]

—— 1967. Preliminary report of the international 0-group fish survey in the Barents Sea and adjacent waters August/September 1967. Coun. Meet. int. Coun. Explor. Sea, 1967 (H:31): 1-8, 14 figs. [Mimeo]

—— 1968a. North-East Arctic Fisheries Working Group. Report of the meeting at Copenhagen, December 4th-14th 1967. Coun. Meet. int. Coun. Explor. Sea, 1968 (F:19): 1-10, 14 tables, 7 figs. [Mimeo]

—— 1969a. North-East Arctic Fisheries Working Group. Report of the meeting at Copenhagen, January 13th-17th 1969. Coun. Meet. int. Coun. Explor. Sea, 1969 (F:2): 1-21, 8 figs, 1 Appendix (3 pages). [Mimeo]

—— 1969b. Preliminary report of the 0-group fish survey in the Barents Sea and adjacent waters in August-September 1968. Coun. Meet. int. Coun. Explor. Sea, 1969 (F:33): 1-4, 13 figs. [Mimeo]

—— 1969c. Preliminary report of the 0-group fish survey in the Barents Sea and adjacent waters in August-September 1969. Coun. Meet. int. Coun. Explor. Sea, 1969 (F:34): 1-5, 15 figs. [Mimeo]

—— 1970. Report of the meeting of the North-East Arctic Fisheries Working Group Copenhagen, January 14th-16th 1970. Coun. Meet. int. Coun. Explor. Sea, 1970: 1-15, 1 Appendix. [Mimeo]

Baranenkova, A.S. 1957. Foreløpig meddelelse om den kvantitative utbredelse av yngel av torsk og hyse i Barentshavet. Trydy murmansk biol. Sta., 3: 148-158. [In Russian]

Baranenkova, A.S., Drobysheva and Ponomarenko, I.Ja. 1963. Vertical migration and feeding of 0-group cod in the Barents Sea in September-October. Coun. Meet. int. Coun. Explor. Sea, 1963 (84): 1-6. [Mimeo]

Baranova, Z. 1969. Soviet investigations on young haddock of the 0, I, II and III age groups in the Barents Sea. Annls.biol., Copenh., 25: 124-125.

Baranova, Z.P. 1964. Results of determining the abundance of young haddock in the Barents Sea in winter 1963/64. Mater. ryb. Issled. Sever. bass., 4 : 18-21. [In Russian.]

—— 1966. Soviet investigations on young haddock (0-3 age-groups) in the Barents Sea. Annls biol., Copenh., 21: 91-92.

—— 1967. Soviet investigations on young haddock on the 0, I, II and III groups in the Barents Sea in 1964/65. Annls biol., Copenh., 22: 92-94.

—— 1968a. Soviet investigations on young haddock of the 0, I, II and III age-groups in the Barents Sea. Annls biol., Copenh., 23: 108-109.

Baranova, Z.P. 1968a. Soviet investigations on young haddock of the 0, I, II and III age-groups in the Barents Sea. Annls biol., Copenh., 23: 108-109.

—— 1968b. Soviet investigations on young haddock of the 0, I, II and III age-groups in the Barents Sea. Annls biol., Copenh., 24: 102-103.

Beverton, R.J.H. and Holt, S.J. 1957. On the dynamics of exploited fish population. Fishery, Invest., Lond., Ser. 2, 19: 1-533.

Botros, G.A. 1959. A comparative study on the fecundity of Norwegain and Baltic cod. Coun. Meet. int. Coun. Explor. Sea, 1959 (19): 1-15. [Mimeo.]

Dragesund, O. 1970a. Factors in fluencing year-class strength of Norwegian spring spawning herring. (Clupea harengus Linné) FiskDir . Skr. Ser. HavUnders., 15: 381-450.

—— 1970b. Distribution, abundance and mortality of young and adolescent Norwegian spring spawning herring (Clupea harengus Linné) in relation to subsequent year-class strength. FiskDir Skr. Ser. HavUnders., 15: 451-556.

Dragesund, O. and Olsen, S. 1965. On the possibility of estimating year-class strength by measuring echo-abundance of 0-group fish. FiskDir . Skr. Ser. HavUnders., 13 (8): 48:62.

Dragesund, O., Midttun, L. and Olsen, S. 1970. Methods for estimating distribution and abundance of 0-group fish. Coop. Res. Rep. Ser. A, int. Coun. Explor. Sea,18 : 25-34.

Garrod, D.J. 1966. Stock and recruitment data for Arcto-Norwegian cod. Coun. Meet. int. Coun. Explor. Sea, 1966 (G:8): 1-5, 1 table and 4 figs. [Mimeo.]

—— 1967. Population dynamics of the Arcto-Norwegian cod. J. Fish. Res. Bd. Canada, 24: 145-190.

—— 1968. Stock and recruitment relationship in four north Atlantic cod stocks. Coun. Meet. int. Coun. Explor. Sea, 1968 (F:14): 1-6, 1 table and 3 figs. [Mimeo.]

Gulland, J.A. 1964. The abundance of fish stocks in the Barents Sea. Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer, 155: 126-137.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer, 20: 1-228.

Hylen, A. 1962. Notfisket i Lofoten. Fiskets Gang, 48: 581-587.

—— 1967. On the estimation of cod and haddock discarded by trawlers using different chapers. Coop. Res. Rep. Ser. B, 1966: 65-76.

—— 1969. Discarding of fish in North-East Atlantic. Coop. Res. Rep. Ser. B, 1968: 56-58.

Hylen, A. and Eide, P. 1969. Yield curves for Arctic cod and haddock. Coun. Meet. int. Coun. Explor. Sea, 1969 (F:19): 1, 2 figs. [Mimeo.]

Meyer, A. 1969. German investigations of Arcto-Norwegian haddock. Annls biol., Copenh., 25: 125-126.

Nizovtsev, G.P. 1964. Results of determining the abundance of young cod in the Barents Sea in the autumn-winter period of 1963/64. Mater. ryb. Issled. Sever. bass., 4: 14-17.. [In Russian]

—— 1966. Soviet Researches on the 0, I, II and III age-groups of young cod in the Barents Sea. Annls biol., Copenh., 21: 78-79.

—— 1967. Soviet investigations on young cod of 0, I, II and III age-groups in the fishing areas I and IIa. Annls biol., Copenh., 22: 76,77.

Nizovtsev, G.P. 1968a. The results of young cod registration in the Barents Sea during autumn-winter 1966/67. Mater. ryb. Issled. Sever. bass., 12: 13-19. [In Russian.]

—— 1968b. Soviet investigations of young cod of the 0, I, II and III age-groups in the Barents Sea in 1966. Annls biol., Copenh., 23: 102-104.

—— 1968c. The result of young cod registration in the Barents Sea during autumn-winter 1966/67. Mater. ryb. Issled. Sever. bass., 12: 13-19. [In Russian.]

—— 1969. Soviet investigations on young cod of the 0, I, II and III age-groups in the Barents Sea. Annls biol., Copenh., 25: 112-114.

Nizovtsev, G.P. and Trambachev, M.F. 1969. Soviet investigations on young cod of the 0, I, II and III age-groups in the Barents Sea. Coun. Meet. int. Coun. Explor. Sea, 1969 (F:13): 1-3. [Mimeo.]

Ponomarenko, I. Ja. 1961. On possible influence on feeding of cod fry upon their abundance. Trudy.Soveshch. ikhtiol. Kom., 13: 301-306. [In Russian.]

Rollefsen, G. 1930. Observation on cod eggs. Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer, 150: 31-34.

—— 1954. Observations on the cod and cod fisheries of Lofoten. Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer, 136: 40-47.

—— 1956. Introduction. Rapp. P.-v. Cons. perm. int. Explor. Mer, 140 (Part I): 5-6.

Sund, O. 1924. Snow and survival of cod fry. Nature 113: 163-164.

—— 1936. The fluctuations in the European stocks of cod. Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer, 101 (3): 1-18.

Sætersdal, G. 1954. Some investigations on the Arcto-Norwegian haddock. Coun. Meet. int. Coun. Explor. Sea, 1954 (47): 1-9, 12 figs. [Mimeo.]

Woodhead, P.M.J. 1964. Diurnal changes in trawl catches of fish. Rapp. P.-v. Cons. perm. int. Explor. Mer, 155: 35-44.

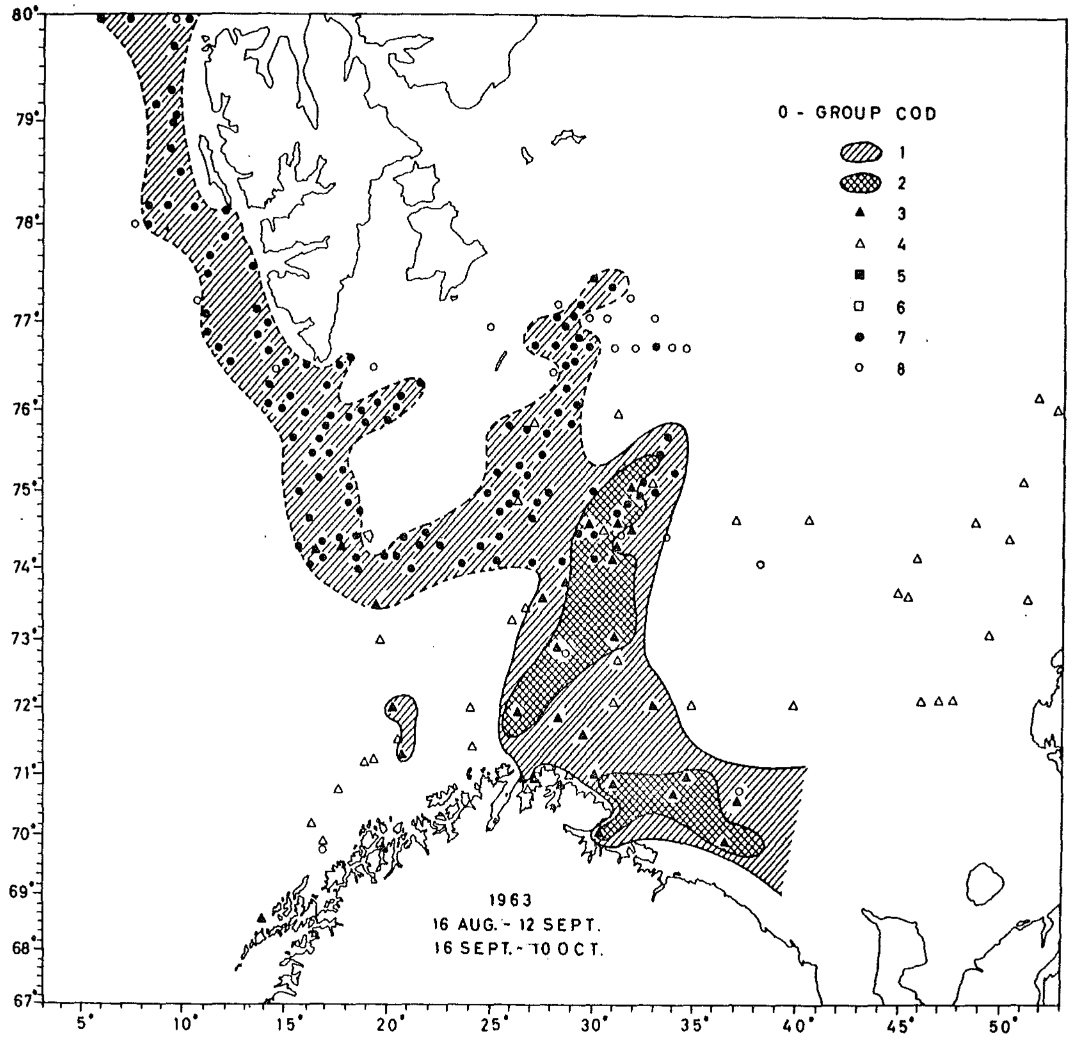

Fig. 1. Distribution of 0-group cod in the autumn of 1963, (1) scattered, (2) dense consentration, (3) 0-group cod caught by midwater trawl with cover net, (4) 0-group cod not observed in midwater trawl catches, (5) 0-group cod caught by purse seine catches, (7) 0-group cod caught by bottom trawl with cover net, (8) 0-group cod not observed in bottom trawl catches.

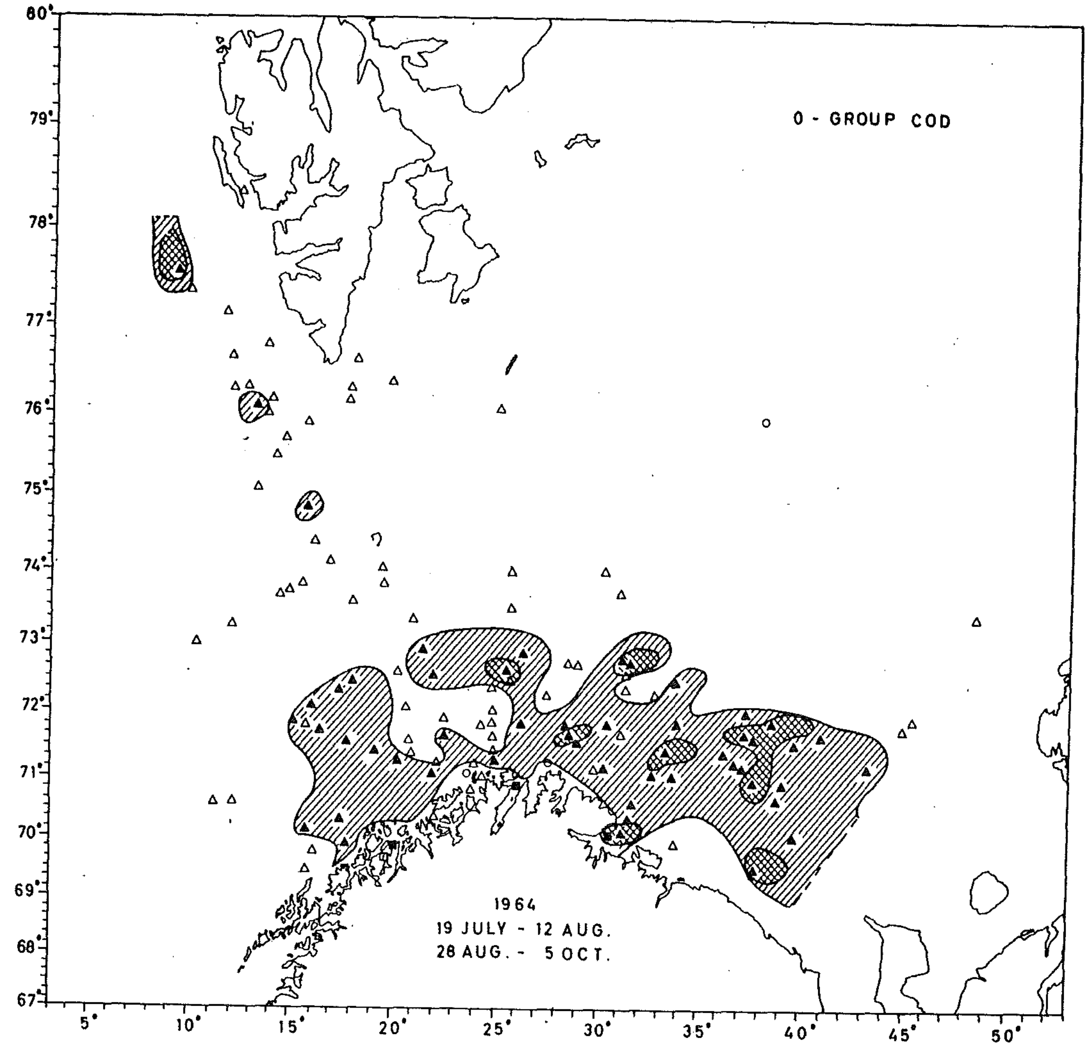

Fig. 2. Distribution of 0-group cod in the autumn 1964. Legend as in Fig. 1.

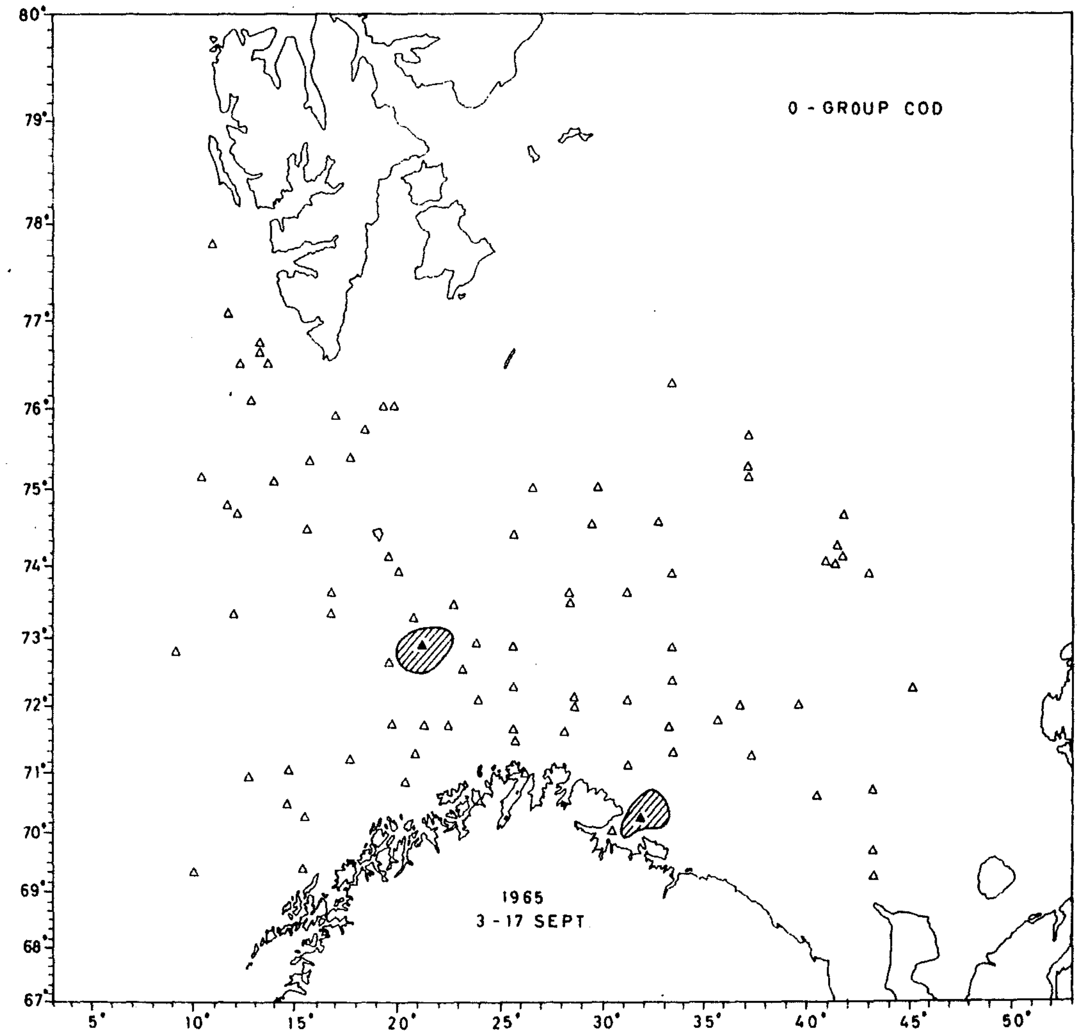

Fig. 3. Distribution of 0-group cod in the autumn 1965.
Legend as in Fig. 1.

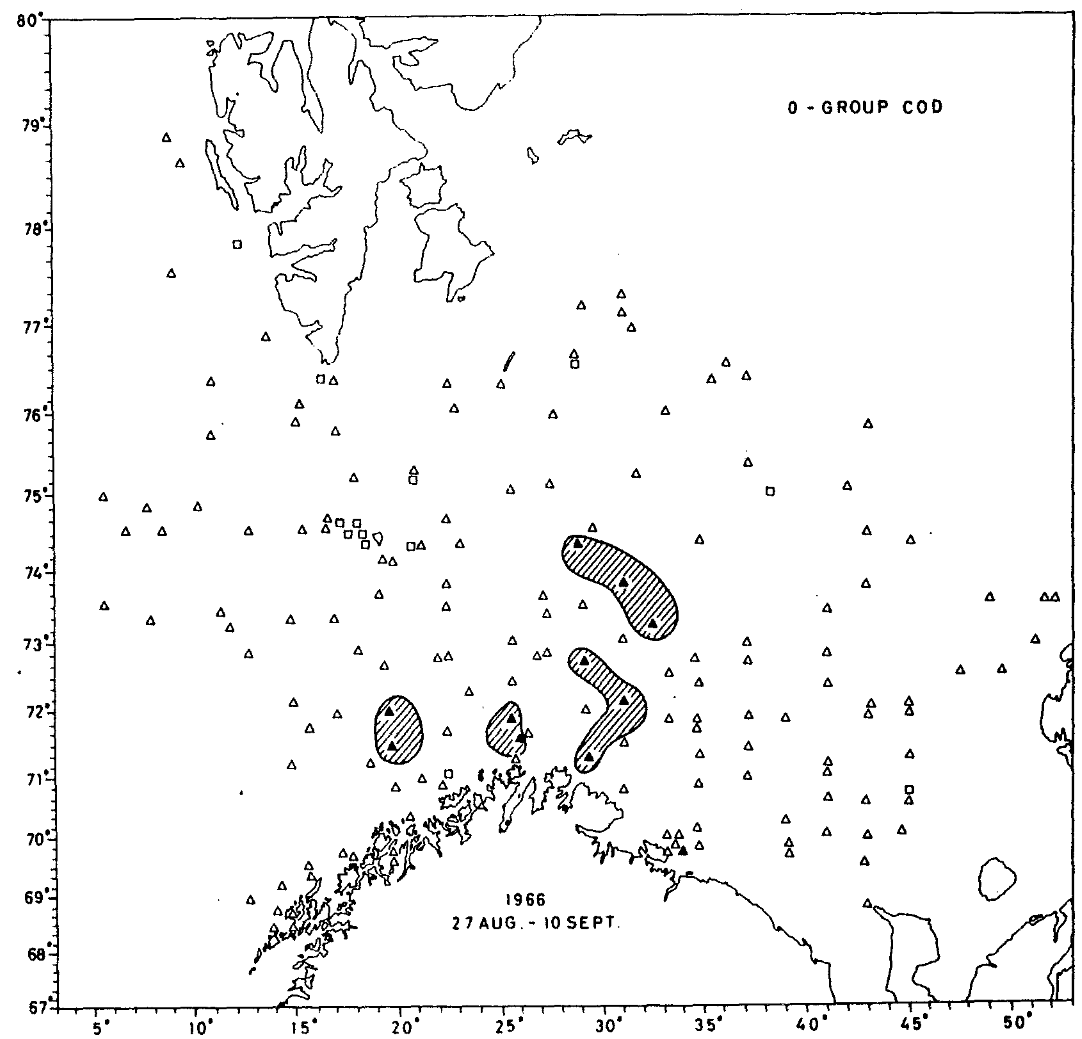

Fig. 4. Distribution of 0-group cod in the autumn 1966.
Legend as in Fig. 1.

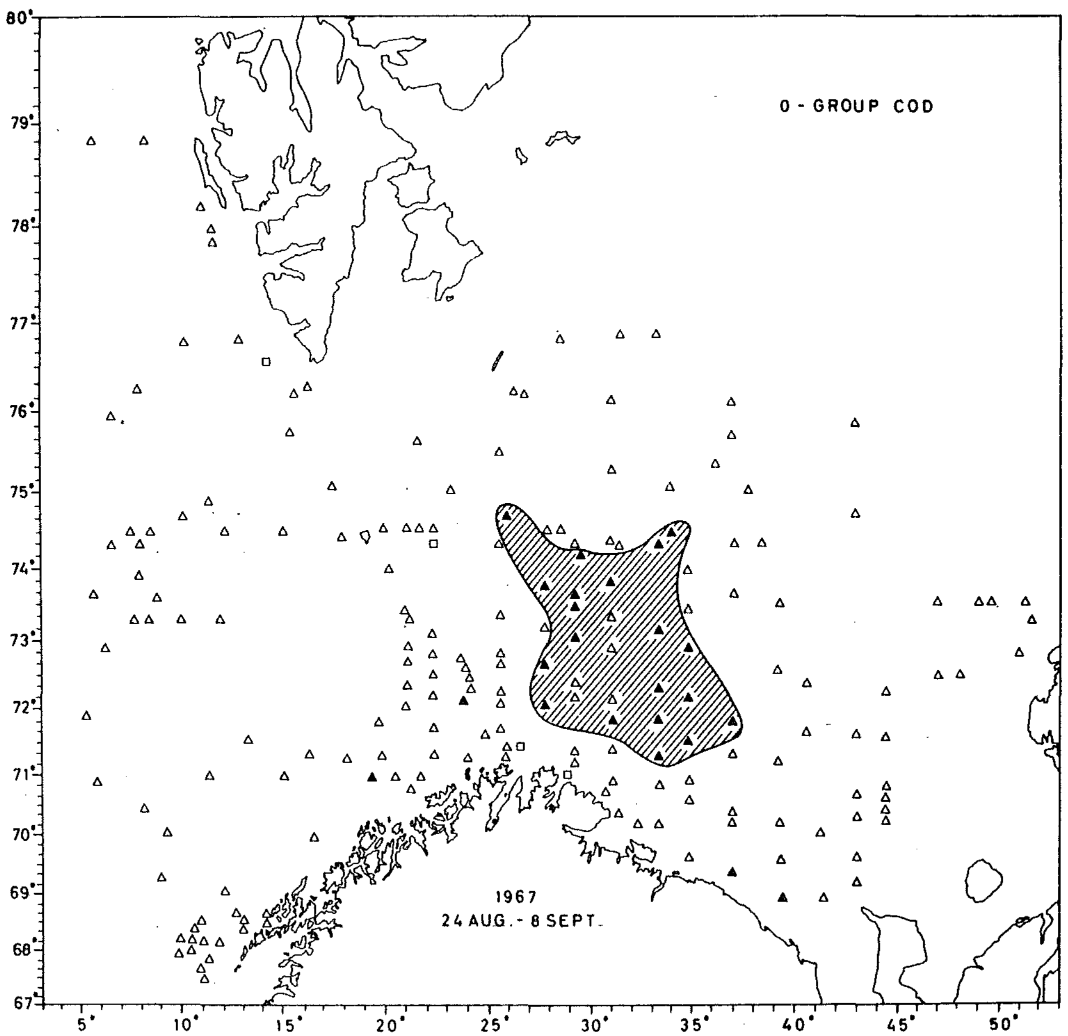

Fig. 5. Distribution of 0-group cod in the autumn 1967. Legend as in Fig. 1.

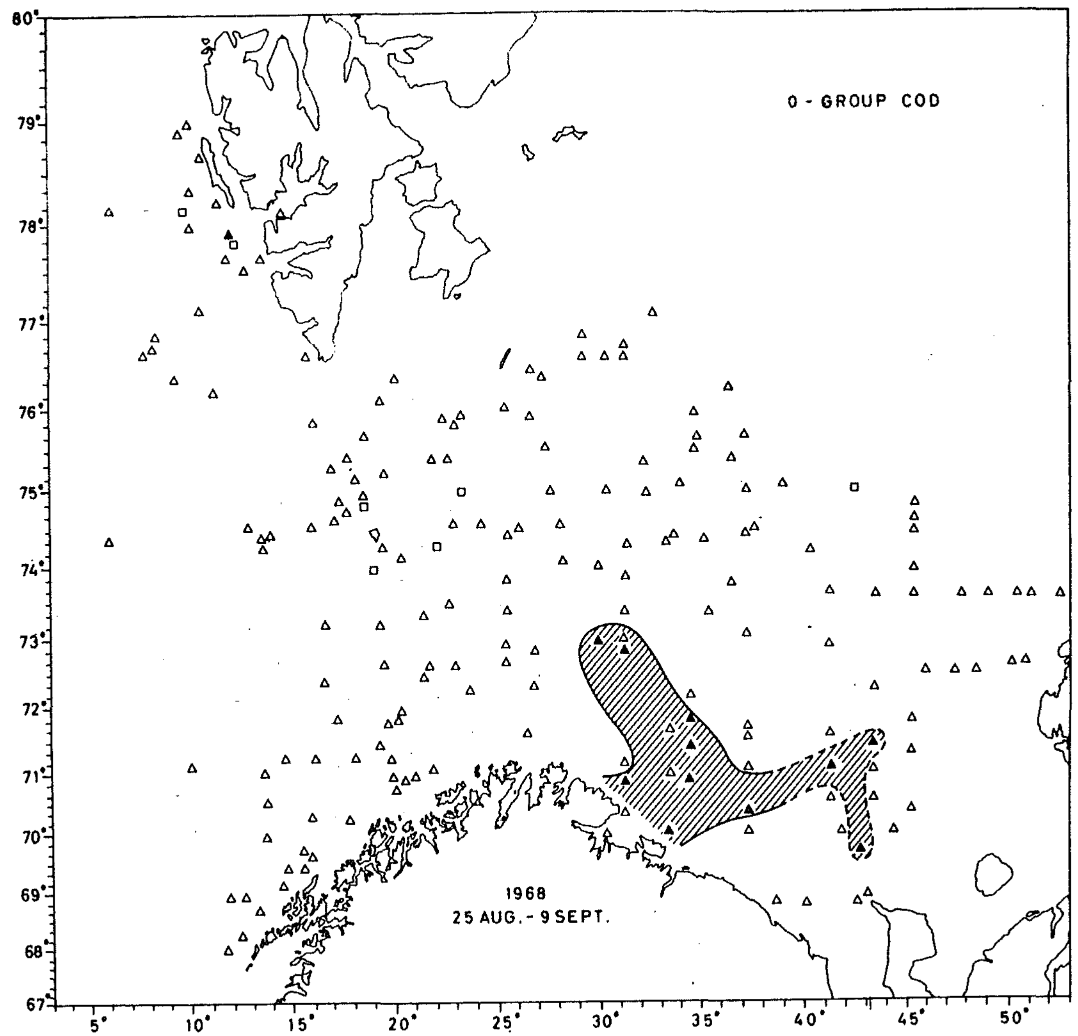

Fig. 6. Distribution of 0-group cod in the autumn 1968. Legend as in Fig. 1.

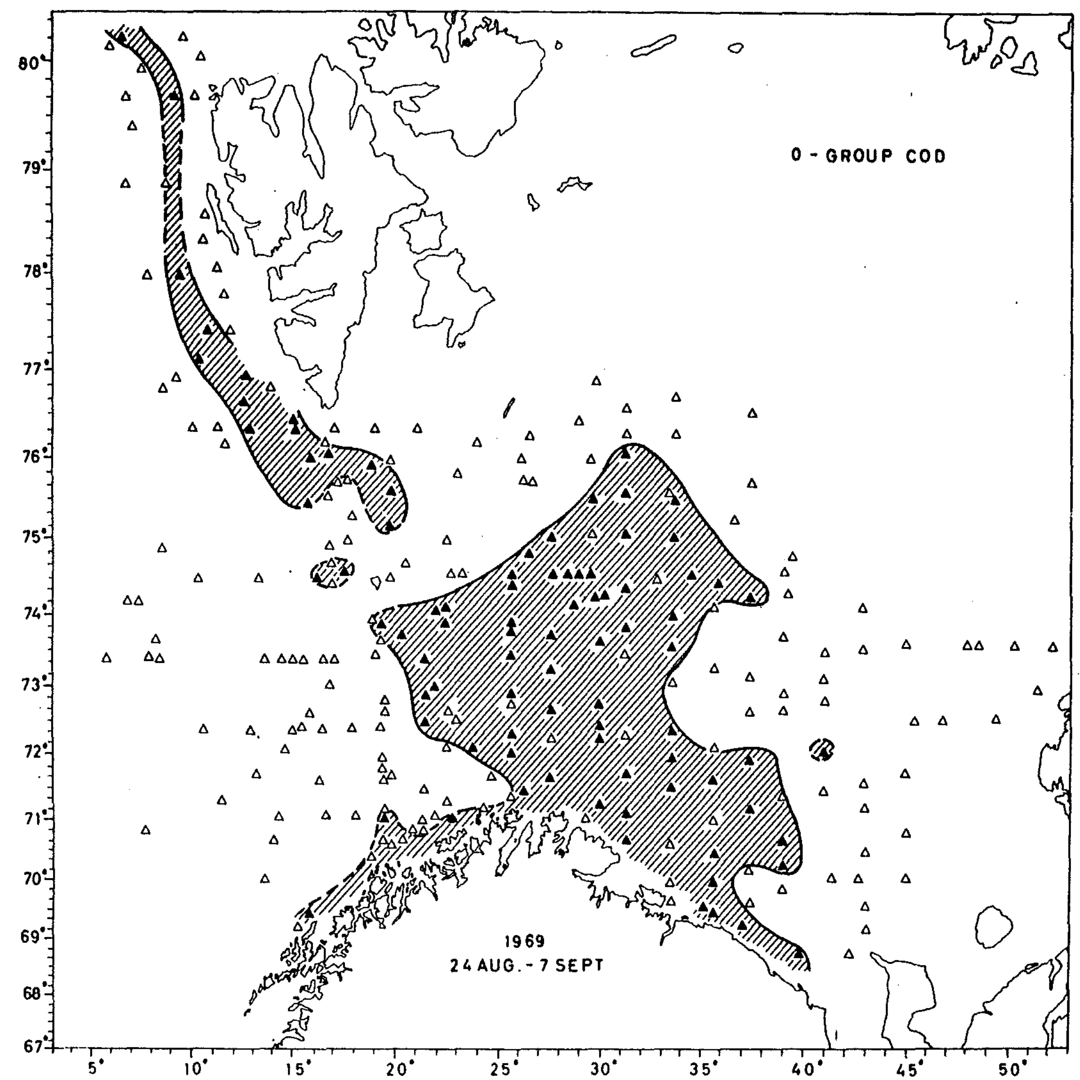

Fig. 7. Distribution of 0-group cod in the autumn 1969. Legend as in Fig. 1.

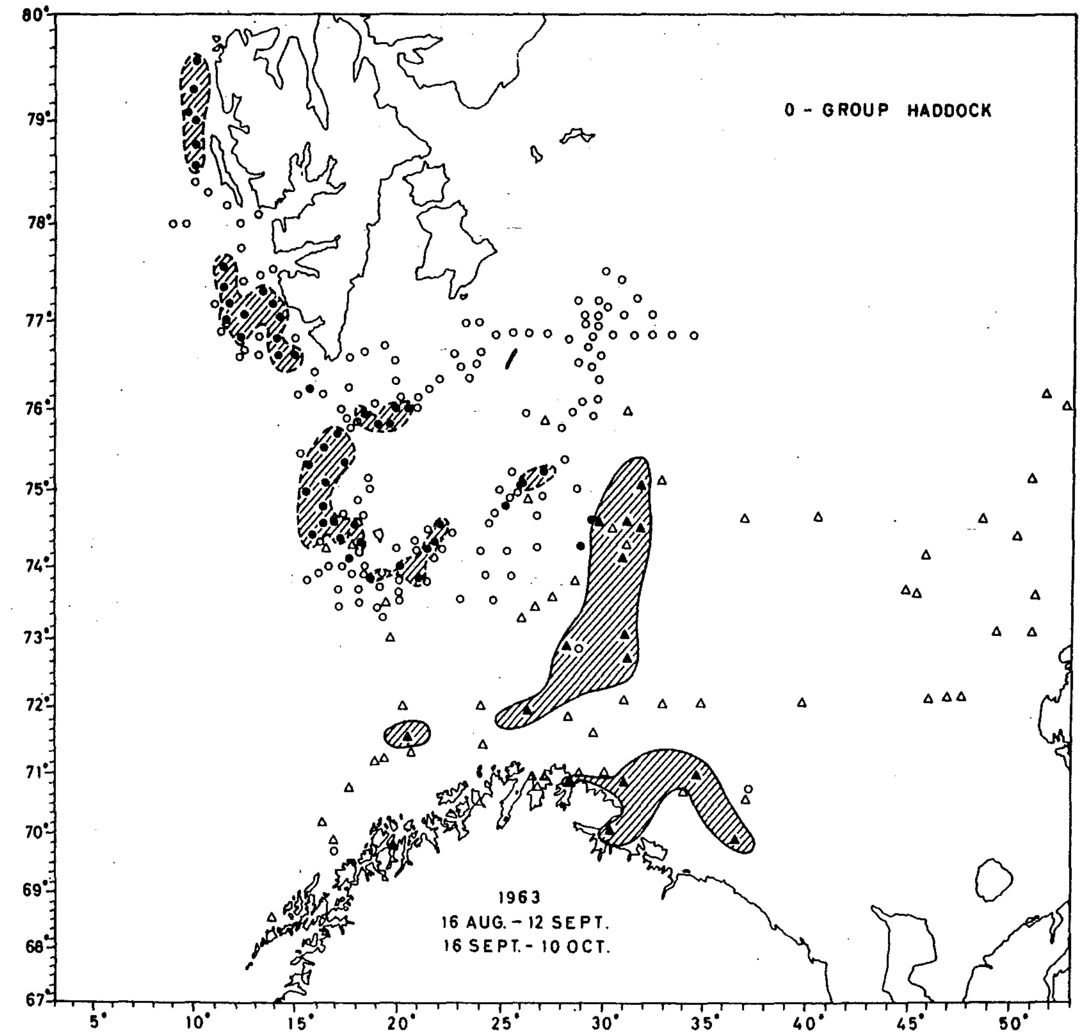

Fig. 8. Distribution of 0-group haddock in the autumn 1963. Legend as in Fig. 1.

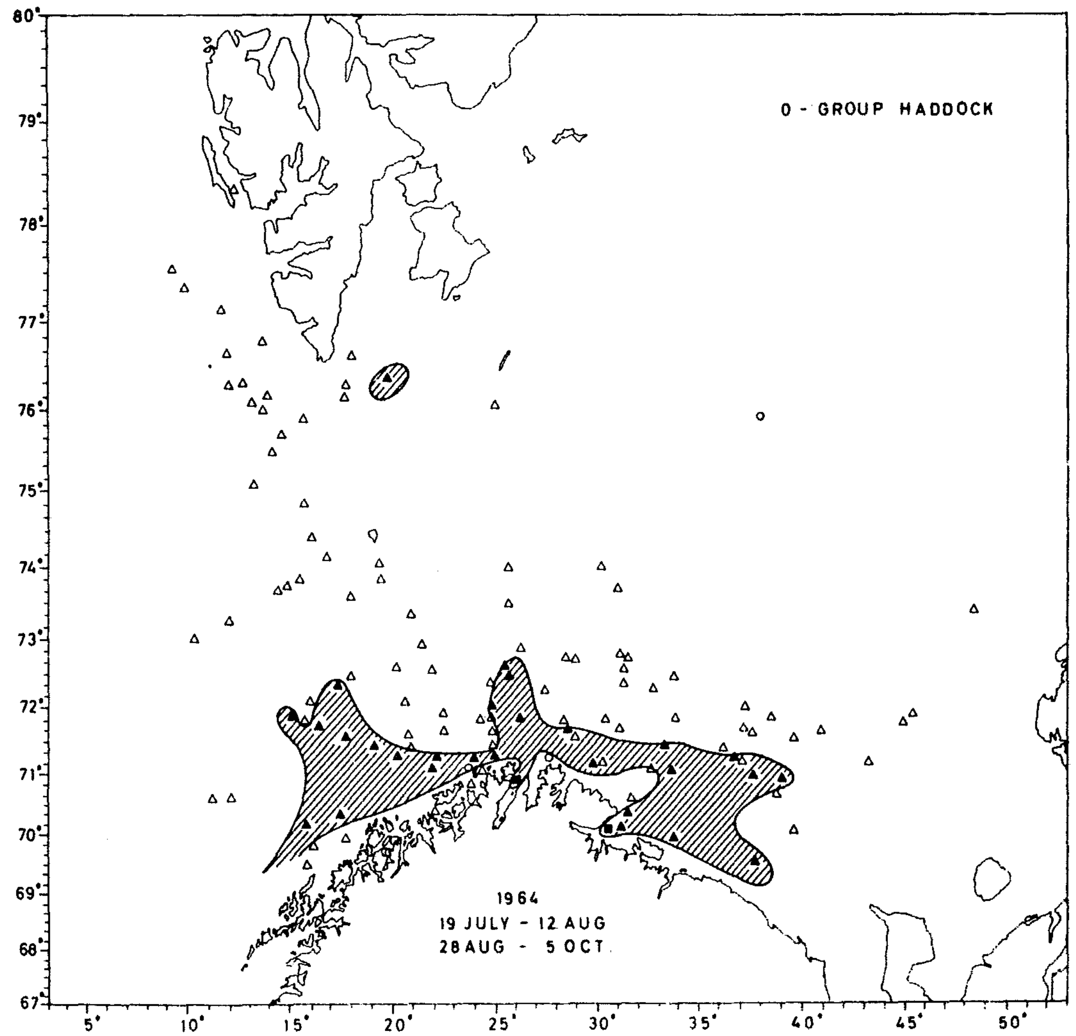

Fig. 9. Distribution of 0-group haddock in the autumn 1964. Legend as in Fig. 1.

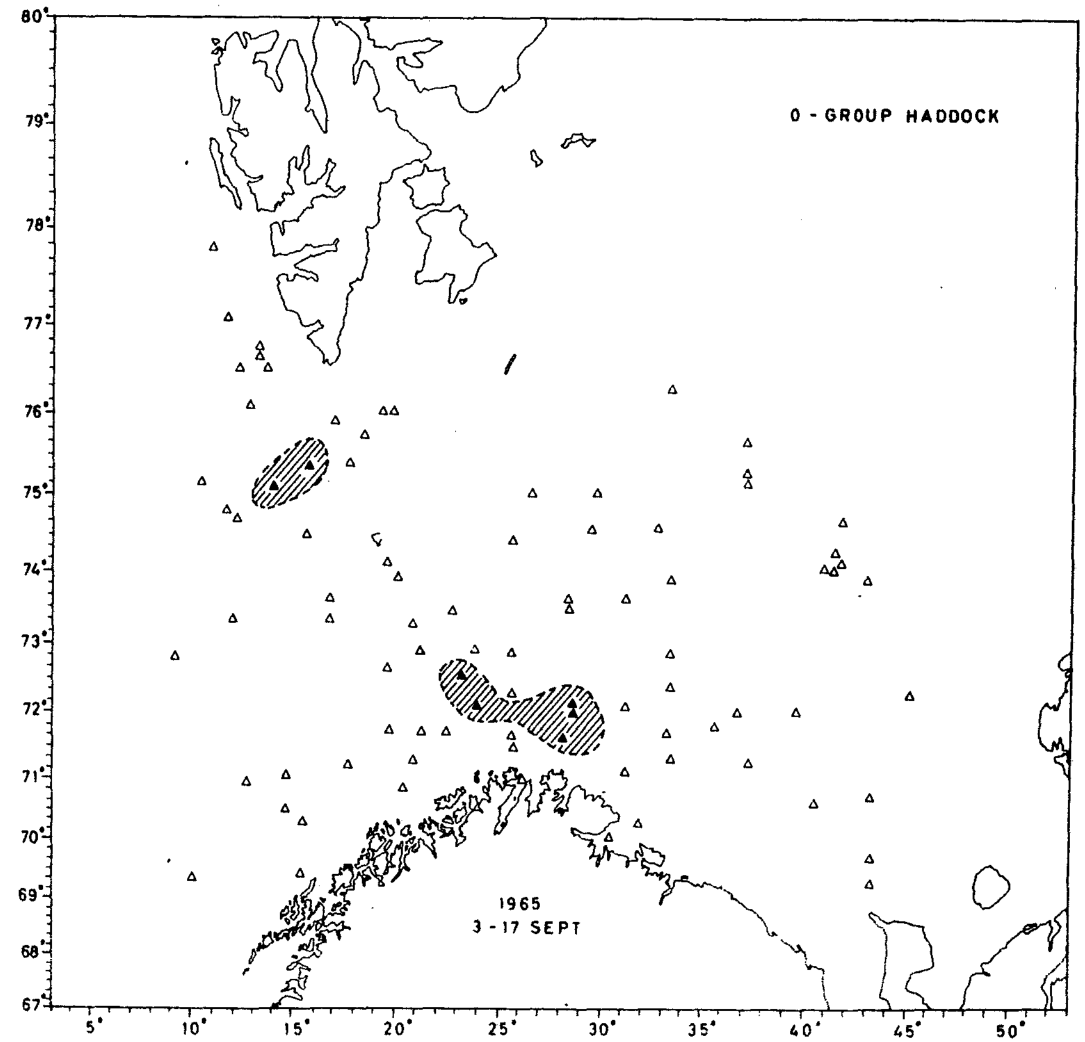

Fig. 10. Distribution of 0-group haddock in the autumn 1965. Legend as in Fig. 1.

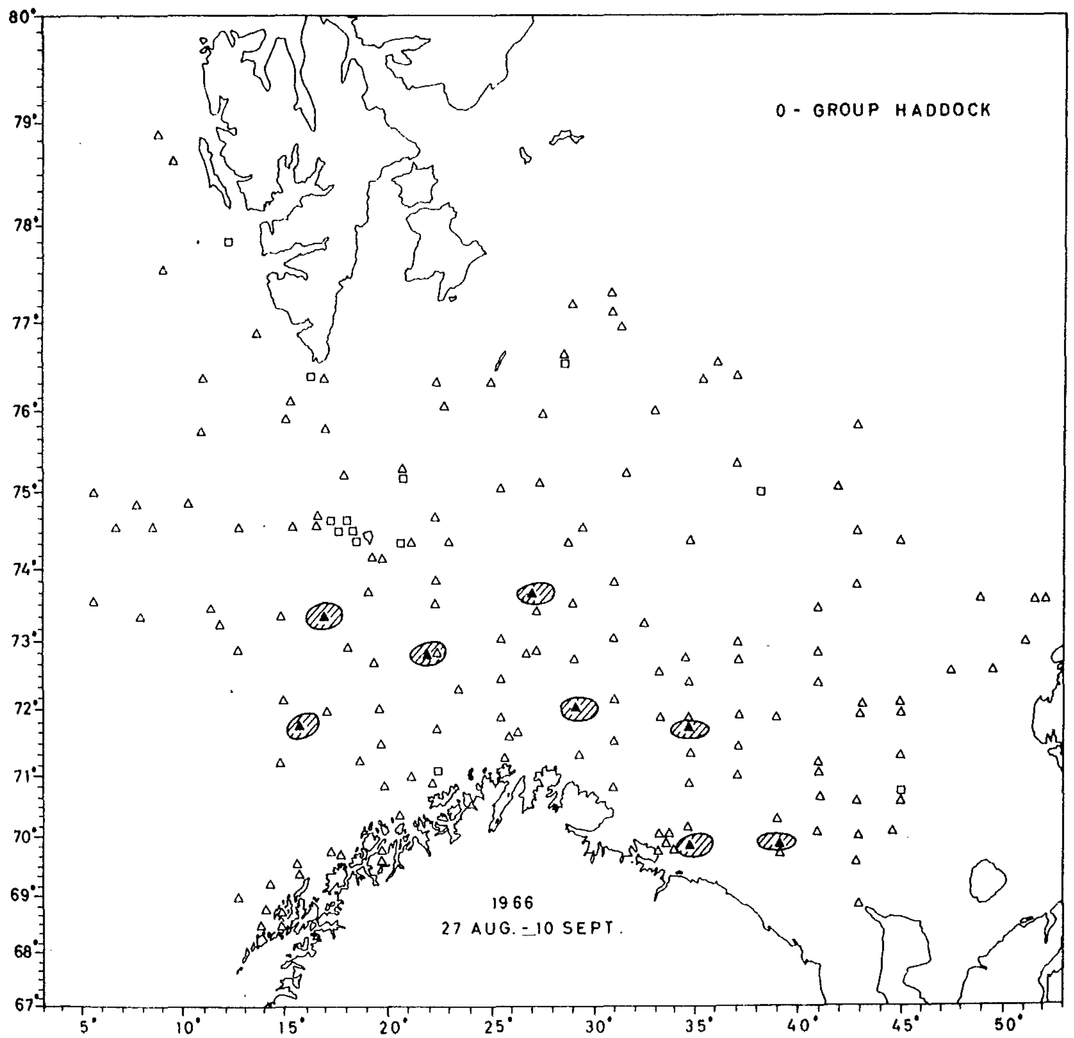

Fig. 11. Distribution of 0-group haddock in the autumn 1966.
Legend as in Fig. 1.

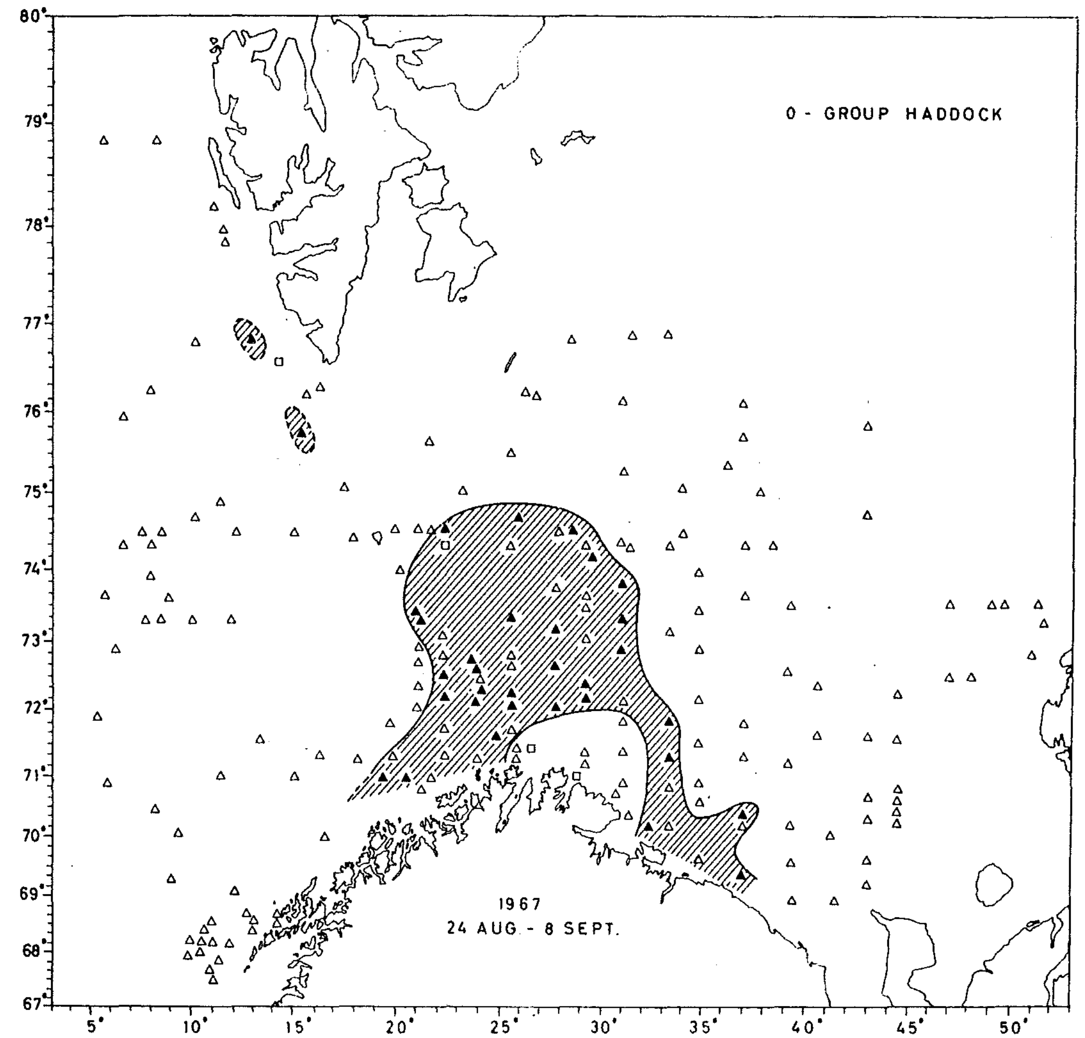

Fig. 12. Distribution of 0-group haddock in the autumn 1967.
Legend as in Fig. 1.

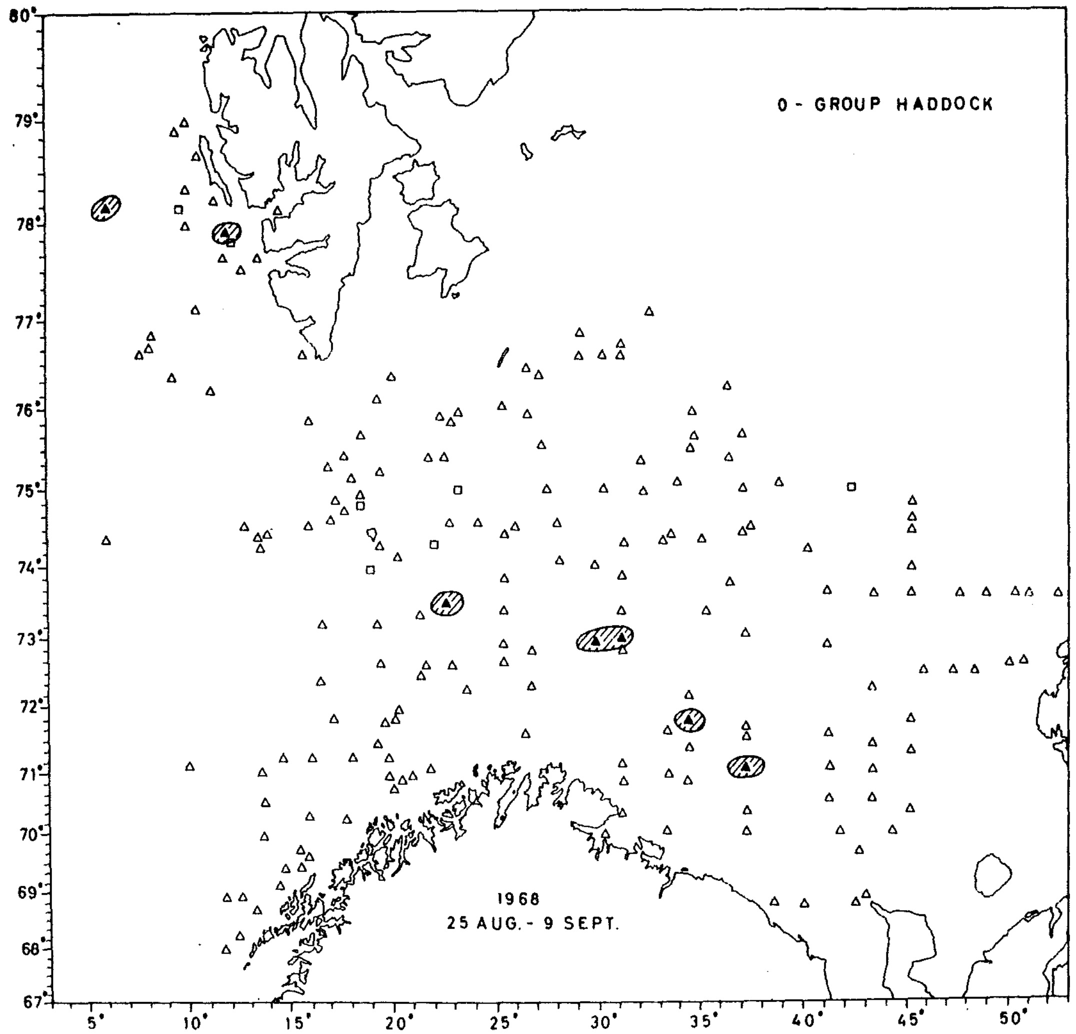

Fig. 13. Distribution of 0-group haddock in the autumn 1968. Legend as in Fig. 1.

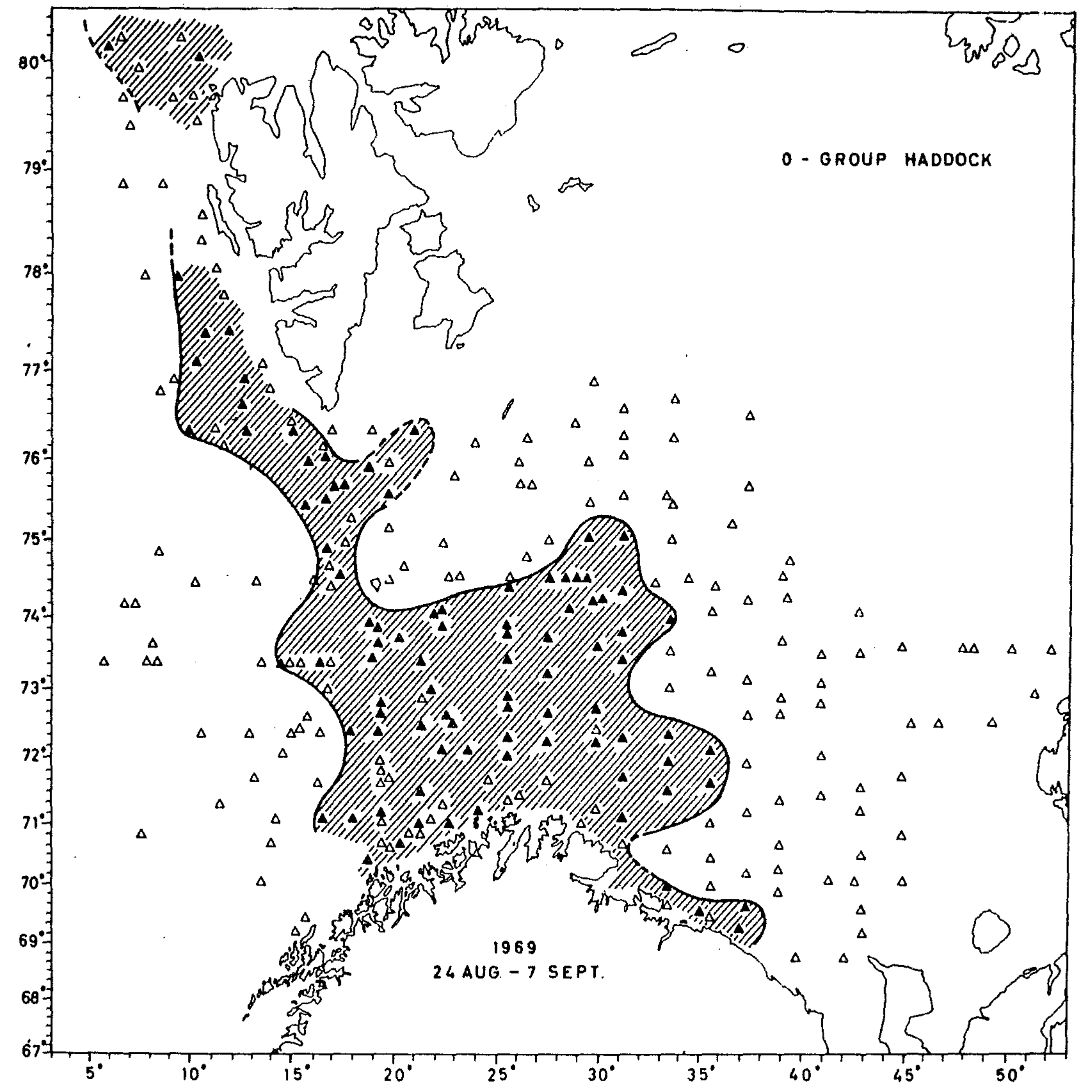

Fig. 14. Distribution of 0-group haddock in the autumn 1969. Legend as in Fig. 1.

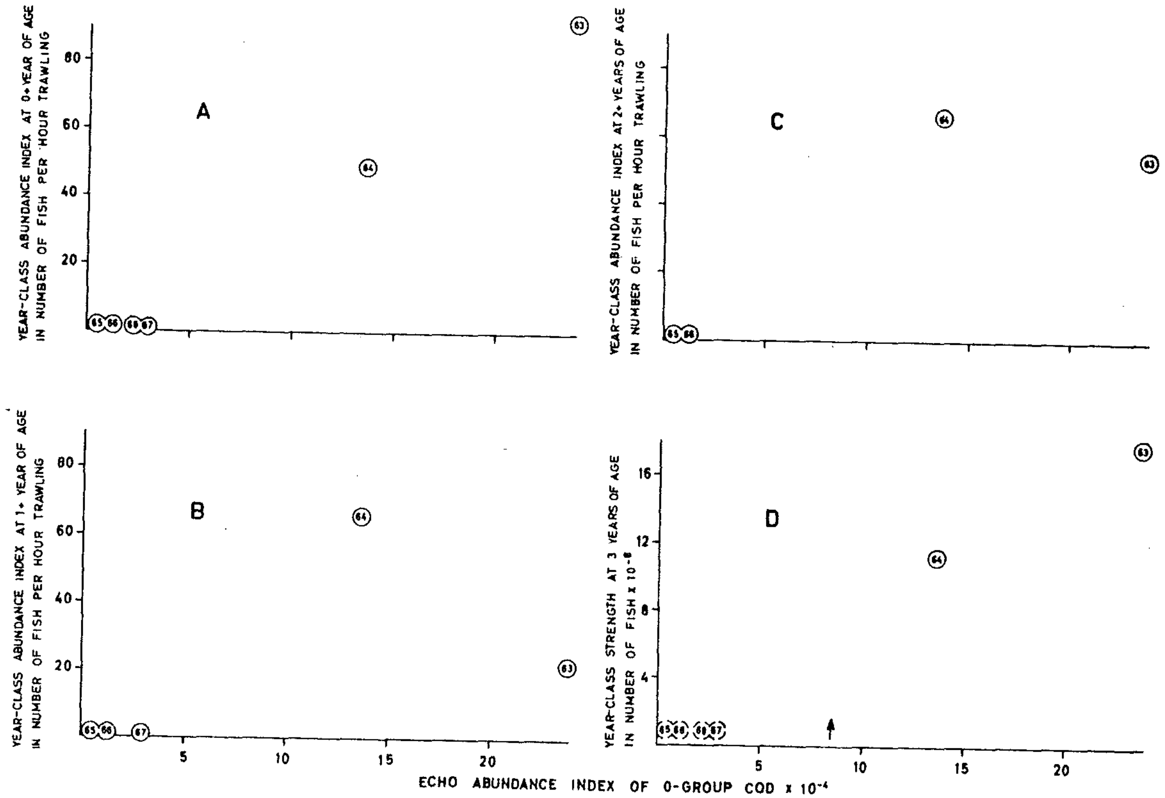

Fig. 15. Relationship between echo abundance index for 0-group cod and (A) at 0+ year of age for the year-classes 1963-1968, (B) at 1+ year of age for the year-classes 1963-1967, (C) at 2+ years of age for the year-classes 1963-1966 and (D) the absolute numerical strenght at 3 years of age for the year-classes 1963-1968. The respective year-classes are indicated inside the circles. Arrow show the 0-group echo abundance index for the 1969 year-class.

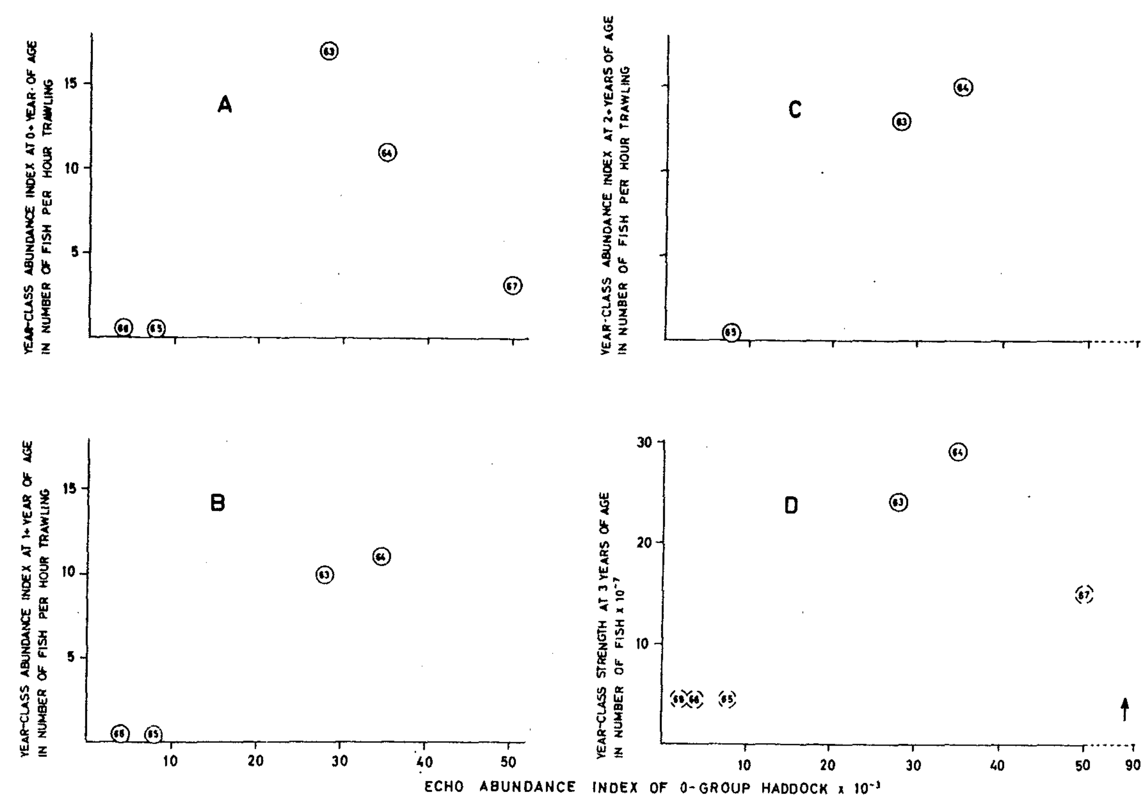

Fig. 16. Relationship between echo abundance index for 0-group haddock and (A) at 0+ year of age for the year-classes 1963-1967, (B) at 1+ year of age for the year--classes 1963-1966, (C) at 2+ years of age for the year-classes 1963-1965 and (D) the absolute numerical strength at 3 years of age for the year-classes 1963-1968. The respective year-classes are indicated inside the circles. Arrows show the 0-group echo abundance for the 1969 year-class.

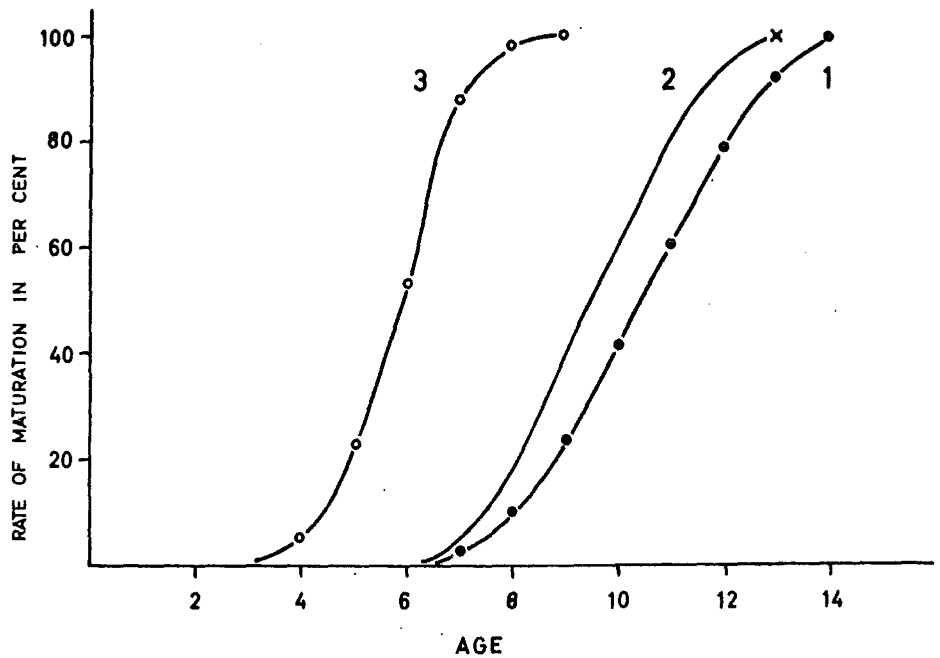

Fig. 17. Maturation ogives for Arcto-Norwegian cod, (1) for the period 1941-1953 (Rollefsen 1953, Garrod 1967), (2) for recent years and (3) for Arcto-Norwegian haddock in 1953 (Sætersdal 1954).

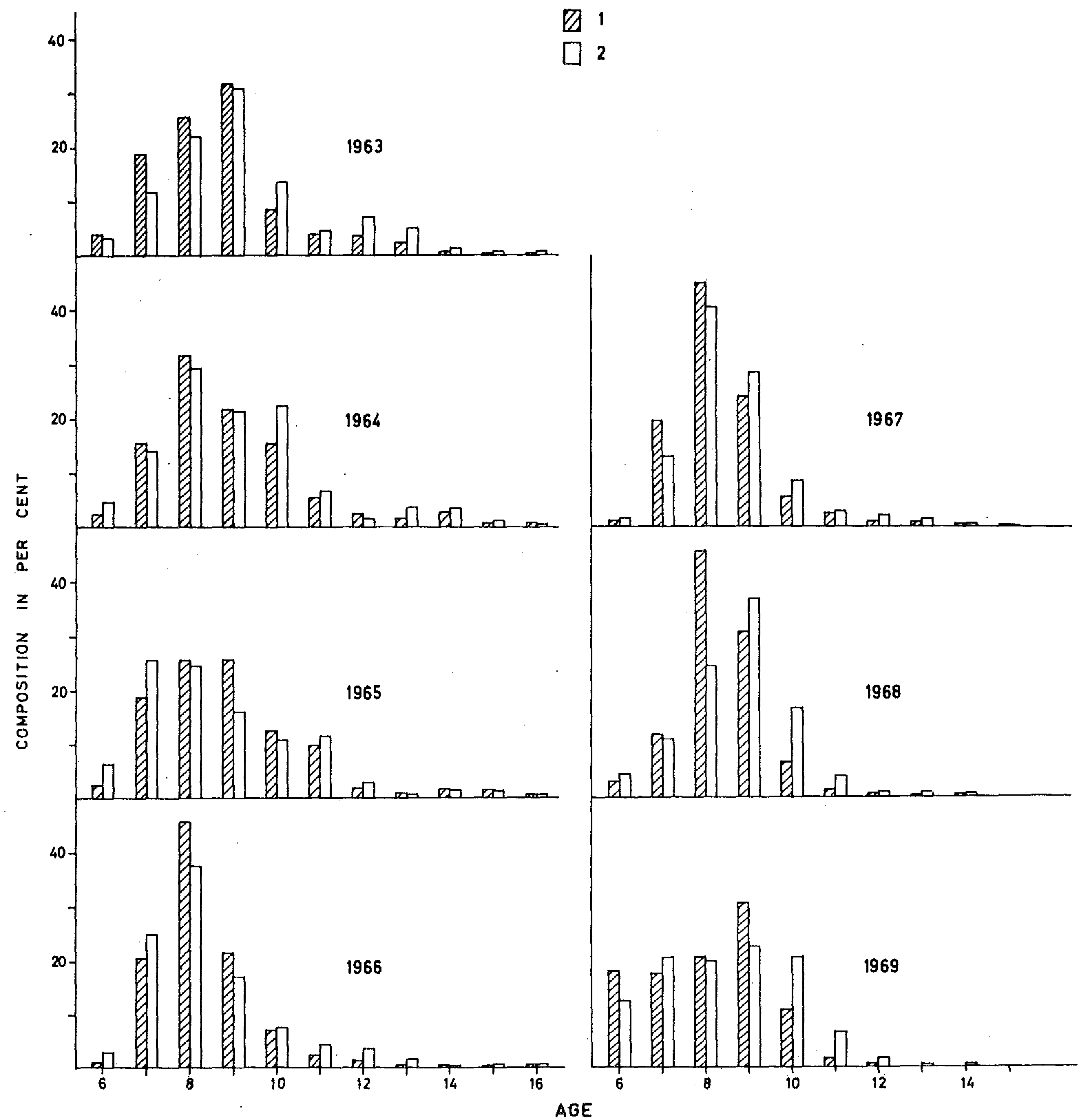

Fig. 18. Age compositions of spawning Arcto-Norwegian cod in the period 1963-1969, (1) long line catches from Lofoten during spawning season, (2) calculated from estimated absolute numerical stock size.

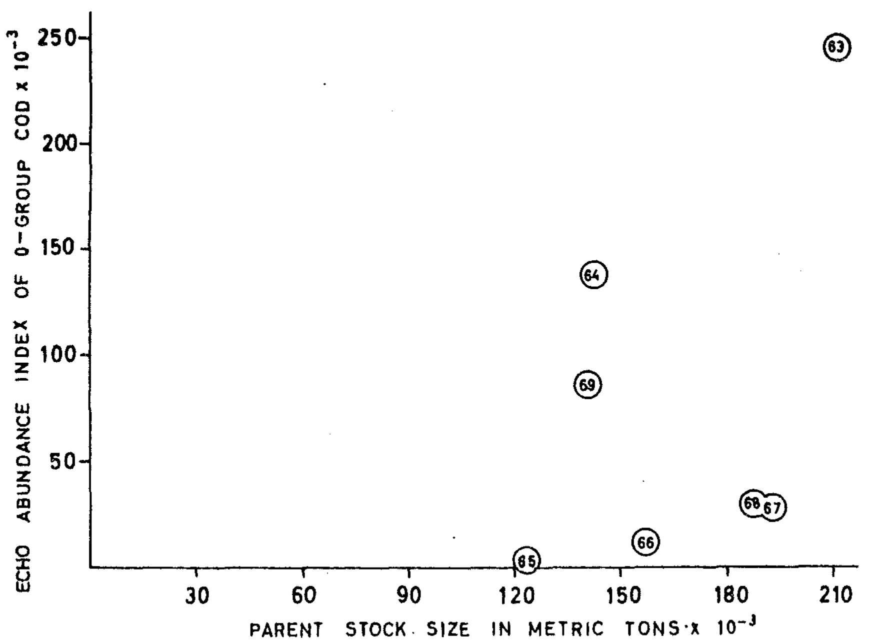

Fig. 19. Relationship between parent stock size of cod and the 0-group abundance index. The respective year-classes are indicated inside the circles.

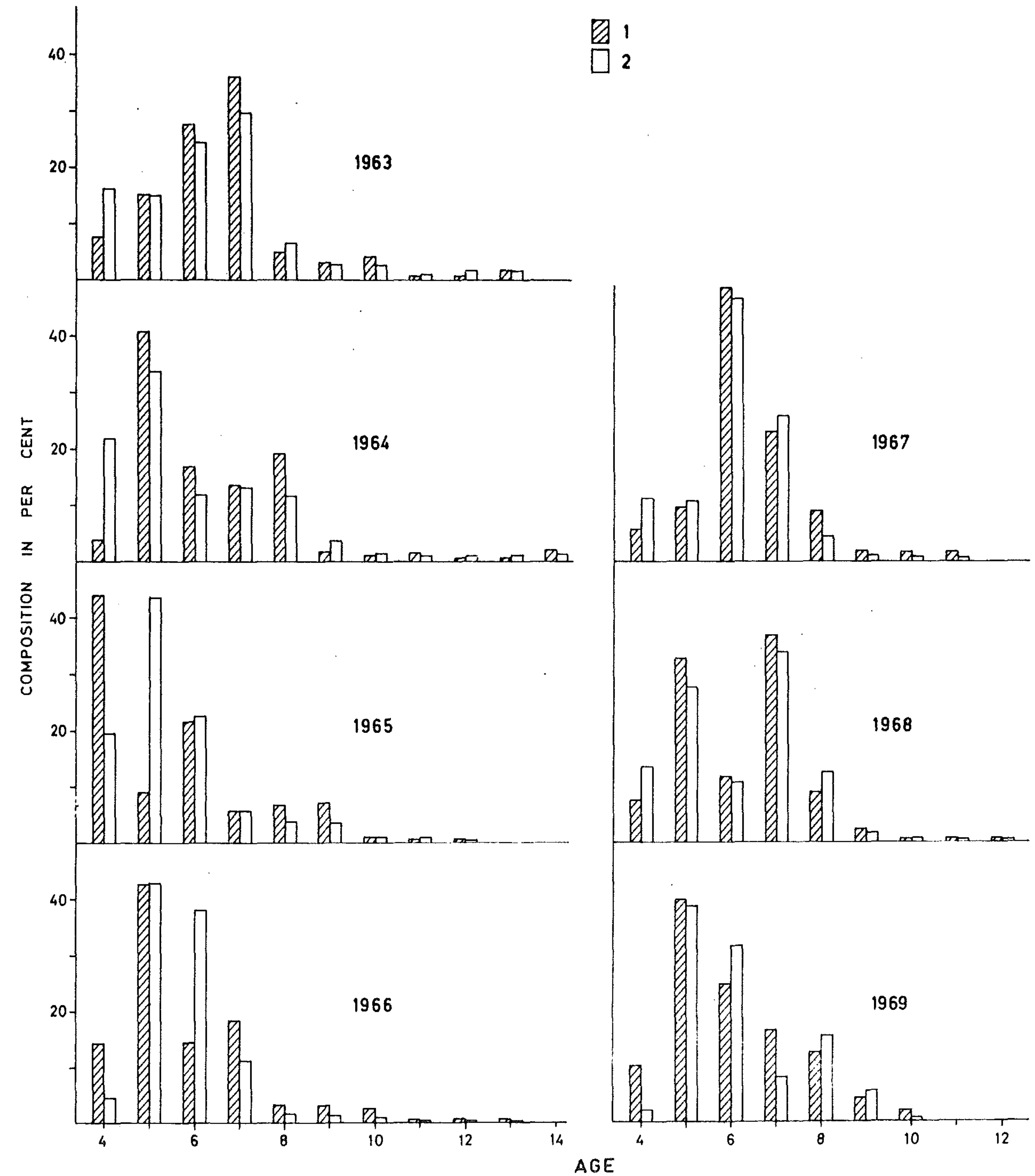

Fig. 20. Age compositions of spawning Arcto-Norwegian haddock in the period 1963-1969, (1) German trawl landings from Røst-Malangen during January-April 1963-1968 and Norwegian long line landings from Sørøya area during January-February 1969, (2) calculated from estimated absolute numerical stock size.

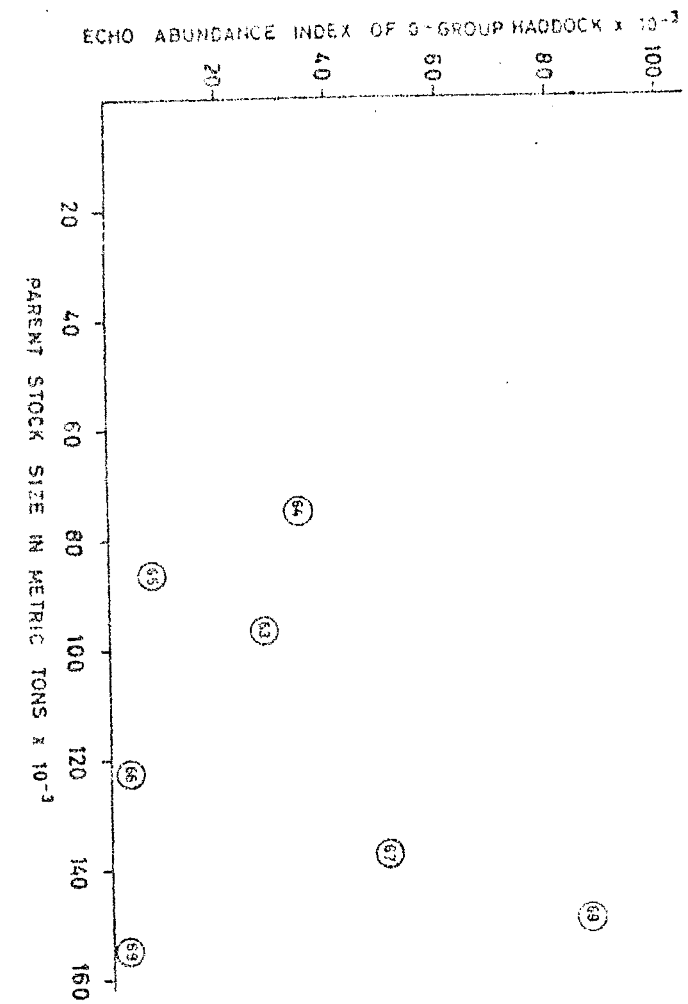

Fig. 21. Relationship between parent stock size of haddock and the 0-group abundance index. The respective year-classes are indicated inside the circles.

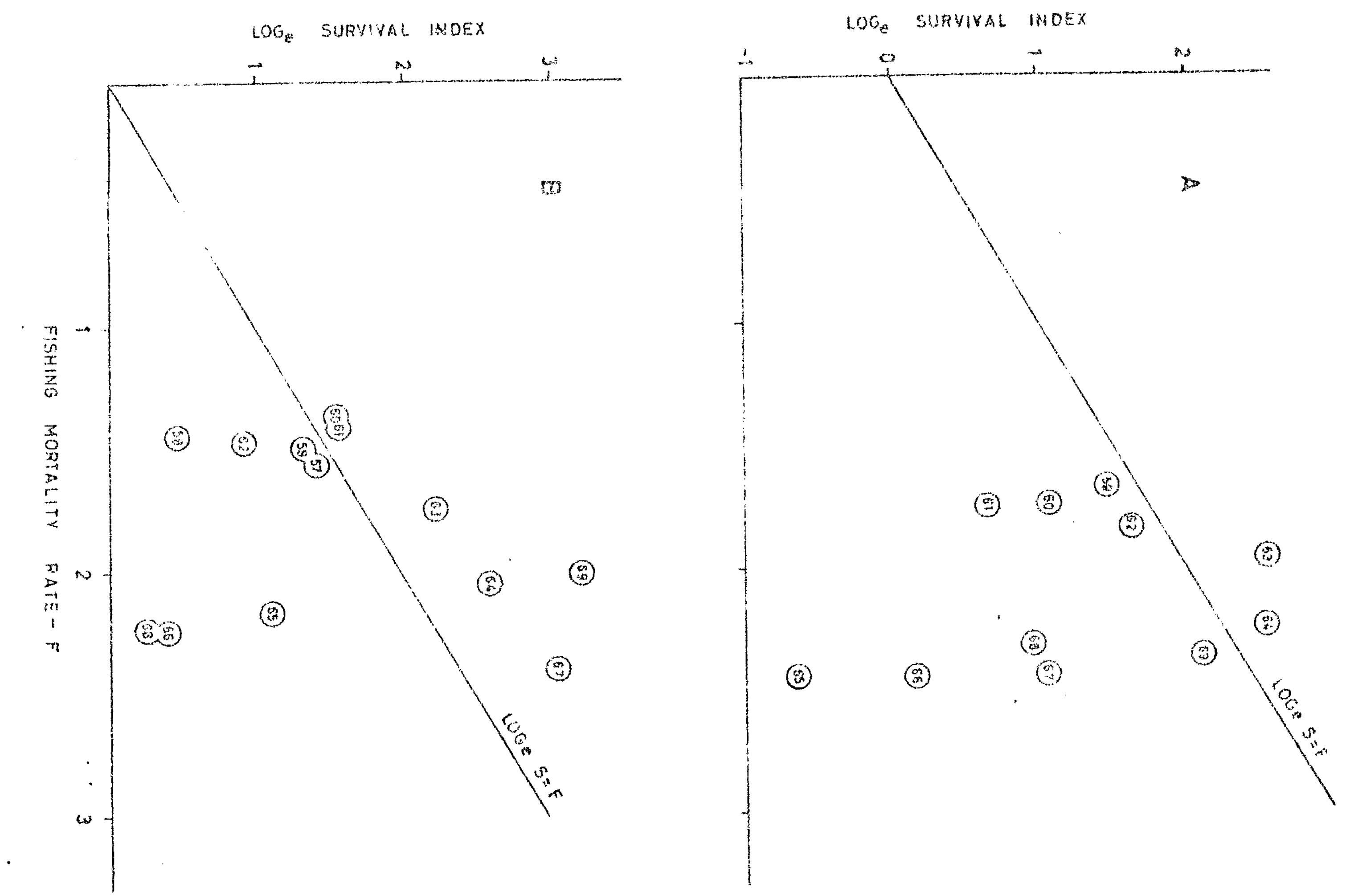

Fig. 22. Relationship between fishing mortality rate per year-class in the spawning stock and the natural logarithm of survival index from the egg stage to 3 years old fish, (A) cod and (B) haddock. The respective year-classes are indicated inside the circles.