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COMPARATIVE ANALYSIS OF YEAR-CLASS STRENGTH AMONG FISH STOCKS IN THE NORTH ATLANTIC

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ABSTRACT

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A comparative analysis of year-class strength among stocks of abundant fish species (herring, cod, haddock, saithe, redfish and capelin) in the North Atlantic is given with a view to discussing whether covariation in year-class strength exists among species living in the same region and among stocks of the same species in different regions.

It is suggested that fish stocks of the same species living in regions distinctly separated from each other are independent and apparently no covariation in year-class strength exists among them. Even in neighbouring regions no apparent covariation could be found. Not all the species living in the same region produce numerous broods in the same year. Indications were found that the total number of 0-group fishes produced varied from year to year. It is tentatively concluded that the variation in total 0-group abundance did not vary to the same extent as the variation of the abundance of each of the species.

INTRODUCTION

In the present paper a comparative analysis of year-class strength in self contained stocks of abundant fish species, herring, cod, haddock, saithe, redfish and capelin, in the North Atlantic will be given. A similar analysis was made by TEMPLEMAN (1965) with the view to discussing whether covaration in year-class strength exists among stocks of cod, haddock and herring living in different regions. This investigation also includes an analysis of year-class strength among fish species living in the same region.

More than one self contained stock (ANON. 1960) of each species may exist in the same region. Even if the fish stocks are self contained, a mingling of individuals from separated stocks may take place both within and between regions, especially during the feeding migration. Taking into account the general system of water currents in the North Atlantic

(Fig. 1) and the subdivision of fish species into large groups or populations, self contained fish stocks from five regions will be considered:

A) fish stocks which have their spawning grounds along the Norwegian coast, with nursery and feeding areas in the Barents Sea and the Norwegian Sea;
B) stocks which have their spawning grounds in western and north-western part of the North Sea with nursery and feeding areas in the North Sea;
C) stocks which are spawning at South and West Iceland with nursery and feeding areas around Iceland and the Irminger Sea;
D) stocks which have their spawning, nursery and feeding grounds off West Greenland;
E) stocks which are inhabiting the banks off Canada and northern USA.

Generally a fish stock has separated spawning, nursery and feeding areas. The young drift with the current from the spawning to the nursery area (denatant movement). From the nursery area the juveniles usually recruit to the adult stock on the feeding area. The spawning migration

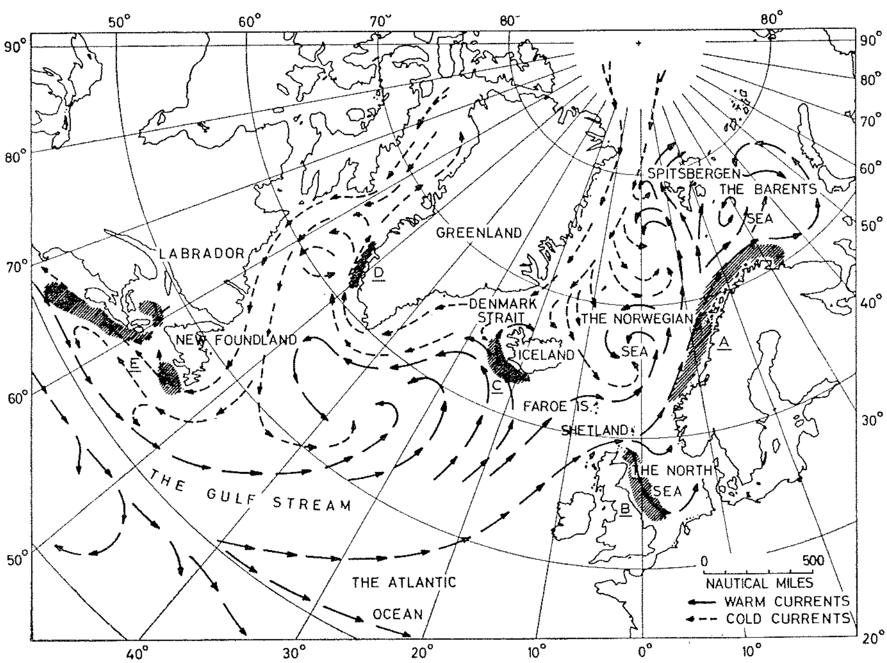

Fig. 1. The general surface water currents in the North Atlantic. Adapted from Mosby (1960). The diagonal shadings indicate some of the main spawning grounds in different regions.

from the feeding to the spawning grounds is against the current, (contranatant movement). Some of the stocks migrate via a wintering area on their way to the spawning grounds. The spent fish return to the feeding area with the current (Harden Jones 1968).

Special attention is paid to the drift migration phase of the young since this may be the most critical-period in a fish's life. Many species are drifting in the same watermasses simultaneously during the larval and postlarval stages, and during this period it is likely that there is a great competition for food. In order to understand the mechanism of year-class fluctuations of fish stocks within a region, research is needed on the interrelationship among species, e.g. time and location of spawning, drift pattern of the larvae and feeding behaviour of both the adults and the progeny. Knowledge about such interrelationships is necessary since a species cannot be studied in isolation, but must be investigated together with its biotic and abiotic environment.

The drift migration of the young is especially pronounced for fish in boreal regions. For most of the species the first part of this phase, when eggs and larvae are drifting passively with the current, lasts six to eight months for instance in region A). During this part of the life cycle the 0-group fish might be carried 500—800 nautical miles or even farther by the current (Dragesund 1970a, 1970b). The return migration from the nursery areas through the adult feeding area and farther on to the spawning grounds may take from three to eight years, for some species even longer, depending on their growth and maturing rate. To maintain their position within a region the older fish must undertake active and compensatory movements in the direction opposite to larval drift. This movement takes place usually in connection with the spawning migration, but both contranatant and denatant periodic migrations take place also during the adolescent stages.

In the present investigations two main questions are raised:

1) Does a covariation in year-class strength among stocks of the same species exist in neighbouring regions? Do the haddock stocks for instance in regions A), B) and C) produce abundant broods the same years?

2) Is the total number of recruits produced by all species in the same region varying from year to year?

MATERIAL AND METHODS

The major part of the material is obtained from:

1) records of age compositions from pre-recruit and adult stocks;
2) acoustic surveys of 0-group fishes.

YEAR-CLASS STRENGTH ESTIMATES BASED ON ANALYSIS OF PRE-RECRUITS AND ADULTS

Estimates of year-class strength for adults are complicated by the wide range of ages over which individuals of a given year-class attain sexual maturity. The most simple method used for estimating relative year-class strength is to compare the frequency distribution of the different year-classes in the exploited stocks. This method is used for Norwegian spring spawning herring combined with estimates on the adult stock size (ANON. 1970a, DRAGESUND 1970a). For cod and haddock the data are from ICES and ICNAF working group reports where the estimates are mainly based on pre-recruits (ANON. 1970a, 1970b, GRAHAM 1969). For other species information has been placed at my disposal by colleagues at research institutes in England (JONES, personal communication), Scotland (PARRISH, personal communication), Iceland (JAKOBSSON, personal communication) and USSR (BENKO, personal communication). Due to the diffculties in obtaining comparable abundance indices year-class strength at age ≥ 3 years is indicated by grading it 1) very poor, 2) poor, 3) average, 4) strong and 5) very strong.

ACOUSTIC SURVEYS

0-group fish surveys in the Barents Sea have shown that many fish species occur pelagically, i.e. in the upper 100 metres of water in late summer and early autumn, and that it is possible from acoustic surveys combined with fishing by pelagic trawl to estimate year-class strength at an age of five to six months (DRAGESUND, MIDTTUN and OLSEN 1970). The 0-group fish investigations were started in 1959 (DRAGESUND 1970b), but prior to 1963 only herring were studied. Because of the promising results obtained for herring, other species were later included. The major laboratories conducting fisheries research in the Barents Sea took a joint initiative to carry out surveys and to expand the work to include all the commercially most important species; herring, cod, haddock, saithe, redfish, capelin, polar cod and long rough dab.

In order to obtain a more precise quantitative estimate of the total abundance of 0-group fish, and to reduce the element of subjectivity in the evaluation and classification of the echo sounder paper-recordings, an electronic echo integrator was developed to work in conjunction with

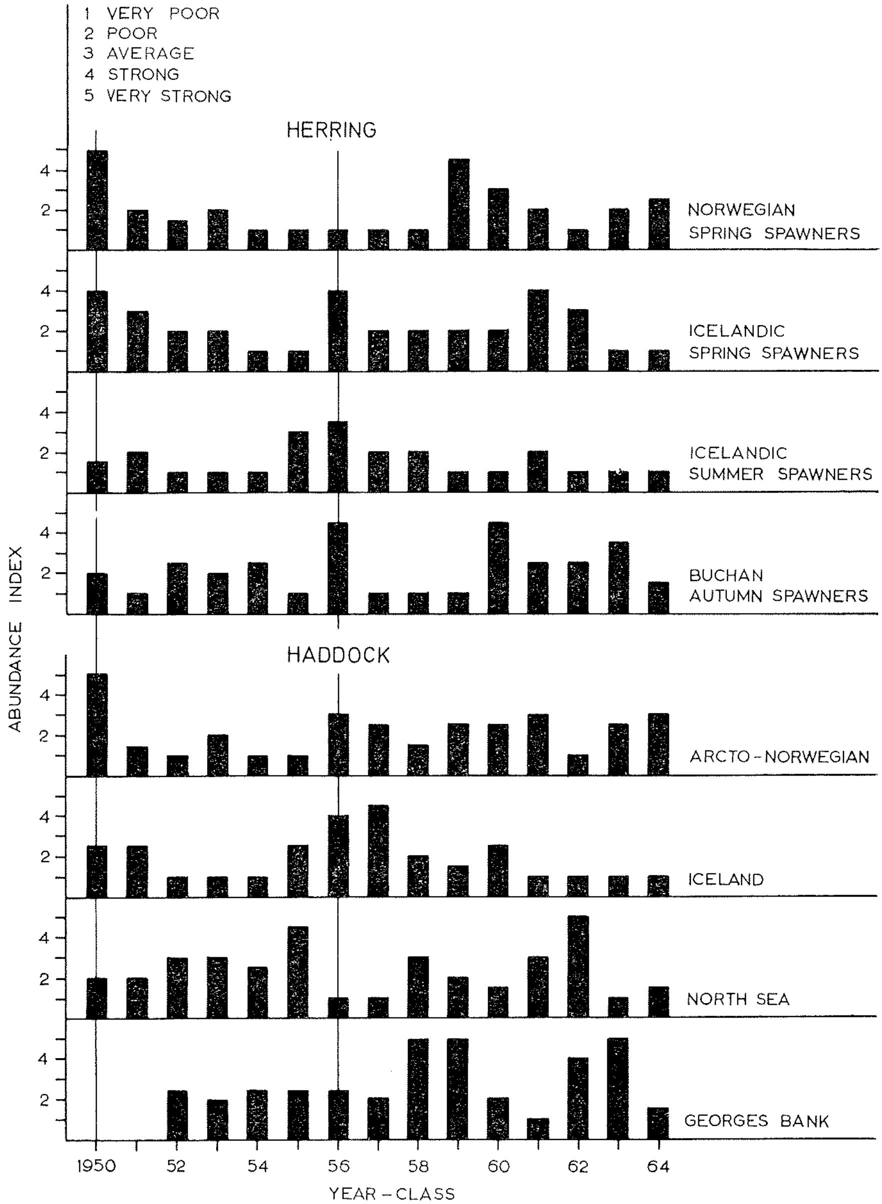

Fig. 2. Year-class strength at age $\geq$ 3 years of herring and haddock in different regions. The abundance estimates are indicated by grading year-class strength in, 1) very poor, 2) poor, 3) average, 4) strong and 5) very strong.

the acoustic research equipment onboard the Norwegian research vessels «G. O. Sars» and «Johan Hjort» (Dragesund and Olsen 1965). The echo integrator was first used during a cruise in the Barents Sea in

August—September 1963, and its technical performance proved to be successful. To facilitate comparison between years the sum of signal voltages per five nautical miles were plotted on charts, and isolines for equal levels of echo abundance were drawn.

RESULTS AND DISCUSSION

Fig. 2 shows year-class strength at age $\geq$ 3 years of herring and haddock in different regions. No apparent covariation in year-class strength among stocks of herring in the three neighbouring regions A), B) and C) could be found. The 1950 broods for example, were strong in Norwegian and Icelandic spring spawners, but not in Icelandic summer and in Buchan (North Sea) autumn spawners. The broods of 1956 were strong in all the herring stocks except in the Norwegian spring spawning herring.

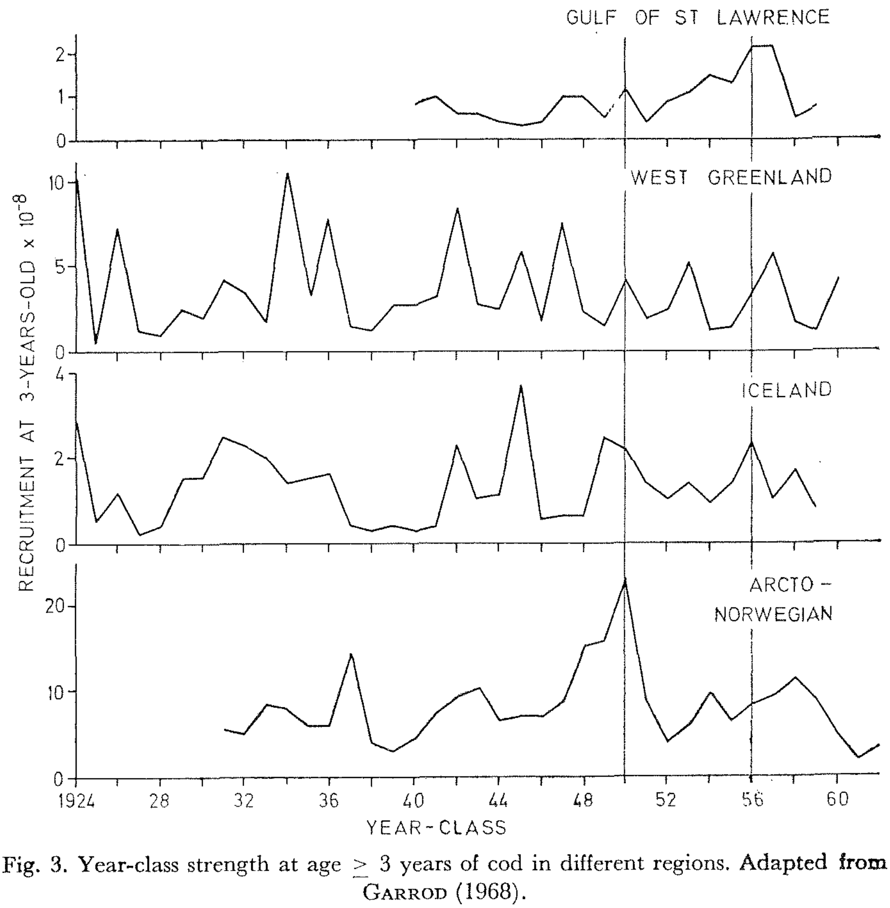

Fig. 3. Year-class strength at age $\geq$ 3 years of cod in different regions. Adapted from GARROD (1968).

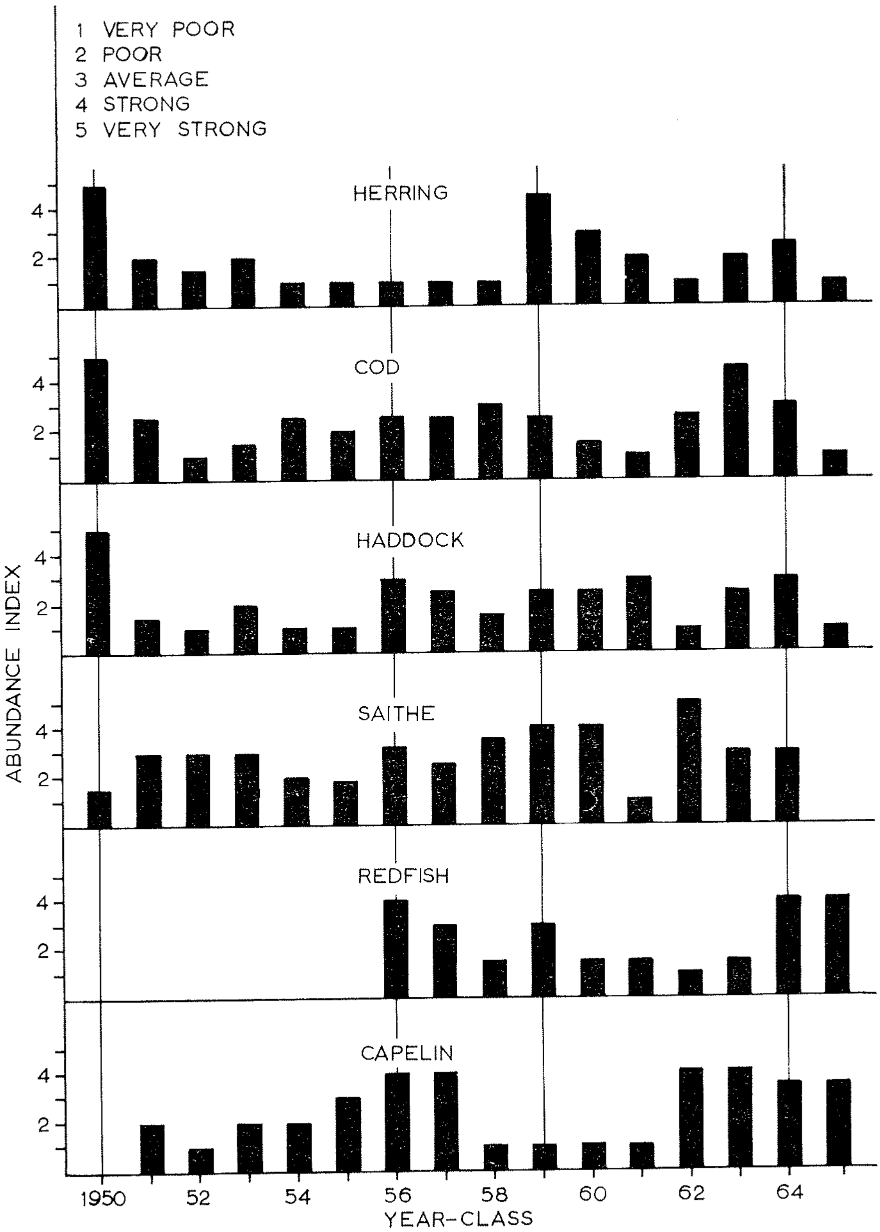

Fig. 4. Year-class strength at age ≥ 3 years for different species spawning at the Norwegian coast, region A). Year-class strength is grouped as, 1) very poor, 2) poor, 3) average, 4) strong and 5) very strong.

In the haddock stocks the 1950 broods were strong in the Arcto-Norwegian stock, but average or poor in the Icelandic and North Sea stocks. The broods of 1956 were average and strong in two stocks and very poor in one. Comparing also the year-class fluctuations of the Georges Bank haddock in region E) with haddock stocks living in regions A), B) and C) no covariation could be found.

Fig. 3 shows absolute recruitment in numbers of 3 year old fish in each year-class for different cod stocks in the North Atlantic (GARROD 1968). There was apparently no covariation in year-class strengths among the different stocks. The 1950 year-class was strong in the Arcto-Norwegian and in the Icelandic stocks whereas in the Northwest Atlantic stocks (Gulf of St. Lawrence and West Greenland) the year-class was about average in strength. The 1956 year-class was strong in the Gulf of St. Lawrence and Icelandic stocks, whereas in the other two stocks it was of average strength. In each of the stocks there seem to be periods of successful year-classes. In the Gulf of St. Lawrence stronger year-classes of cod were produced during the years 1955—1957 than in the period prior to these years. In the Arcto-Norwegian stock rich year-classes occurred in 1948—1950 whereas in the following years (1951—1956) relatively poor year-classes were produced. No apparent trend can be seen in the periodicity of these fluctuations.

In order to discuss the second question raised, year-class strength at age $\geq$ 3 years of six species; herring, cod, haddock, saithe, redfish and capelin spawning at the Norwegian coast i.e. in region A) is compared (Fig. 4). Unfortunately no data are available for redfish in the early 1950s. During the period 1950—1965 there was a clear tendency towards rich year-classes of several species, but not all the stocks produced abundant broods in the same years. However, in some years e.g. in 1950, 1956, 1959 and 1964 rich broods occurred in several stocks. This was the case for herring, cod and haddock in 1950, for capelin, redfish and partly saithe and haddock in 1956. In 1959 again a rich year-class of herring was produced, and the same was the case for saithe. In 1964 most of the broods were rich or average in strength.

To extend the series of observations and to compare year-class strength at an earlier stage, the abundance estimates from the 0-group fish surveys in the Barents Sea are considered. Fig. 5 summarizes the estimates of year-class strength at the 0-group stage of the different species investigated. Looking at the period 1963—1969 it will be seen that year-class strength of herring has been very poor except for the 1963 and 1964 year-classes which were of poor and average strength respectively. The year-class strengths of cod and haddock have varied, being very strong for cod in 1963 and average or strong in 1964 and 1969. Poor

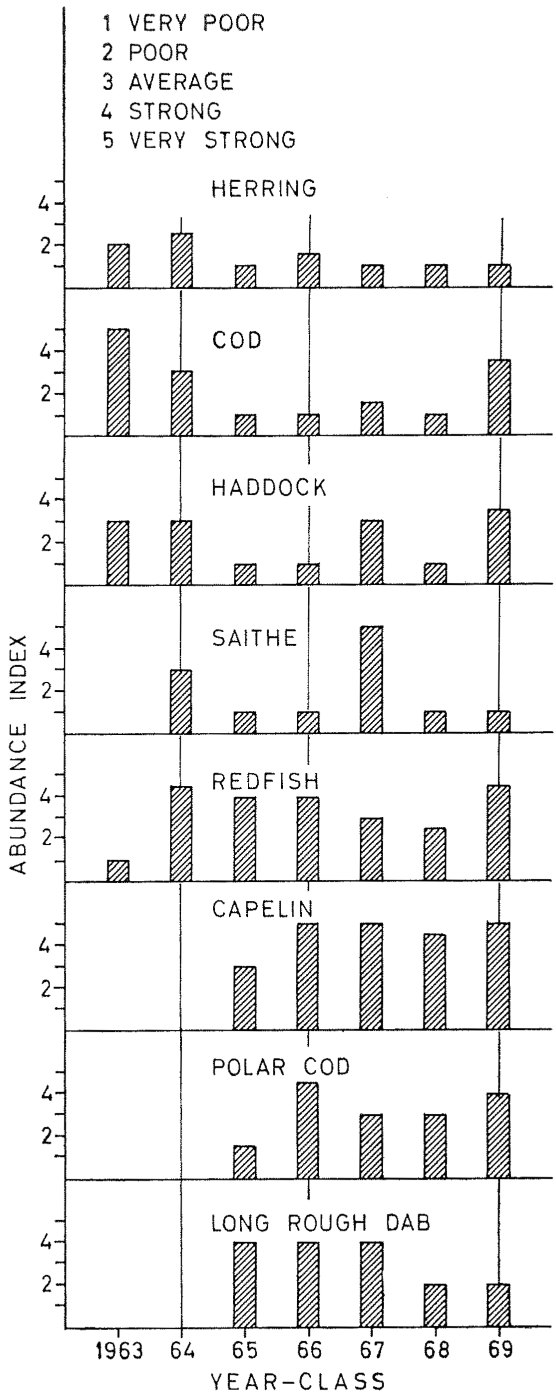

Fig. 5. Year-class strength measured at the 0-group stage for different species in region A). Year-class strength is grouped as, 1) very poor, 2) poor, 3) average, 4) strong and 5) very strong.

year-classes of cod were produced in 1965—1968. A similar trend in variation was found for haddock. The saithe followed the same variations as haddock except for the 1969 year-class. Redfish and capelin have been the dominating species during the years 1964—1969 with average or strong year-classes. It should also be noted that the stocks of polar cod and long rough dab have produced strong year-classes in some of the years during this period.

In order to compare year-class strength at the 0-group stage with subsequent year-class strength, the echo abundance of 0-group herring, cod, haddock and capelin is plotted against year-class strength at age $\geq$ 3 years grouped as very poor, poor, average, strong and very strong (Fig. 6). The 0-group echo abundance indices for herring are from DRAGESUND and NAKKEN (1970), for cod and haddock from HYLEN and DRAGESUND (1970), and for capelin they are derived from BENKO *et al.* (1970). A very close correlation is found between the two independent estimates of year-class strength, and it is concluded therefore, that the abundance indices of 0-group fish obtained from the acoustic surveys give a fairly good estimate of year-class strength.

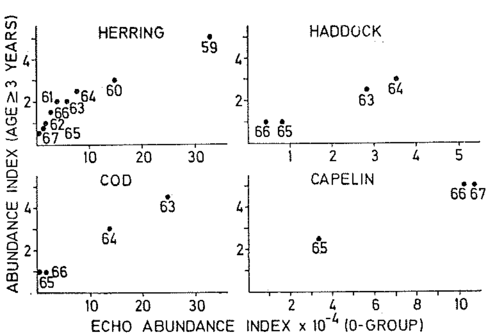

Fig. 6. Relationship between year-class strength at the 0-group stage and subsequent stages (age $\geq$ 3 years) for herring, haddock, cod and capelin in region A.)

The echo integrator readings showing the total echo abundance of 0-group fishes are given in Fig. 7. In 1963 only the central part of the Barents Sea was covered. Because of the differences in target strengths of the various species and echoes from other organisms than fishes, such as medusae, some caution must be used in interpretation, but it is sug-

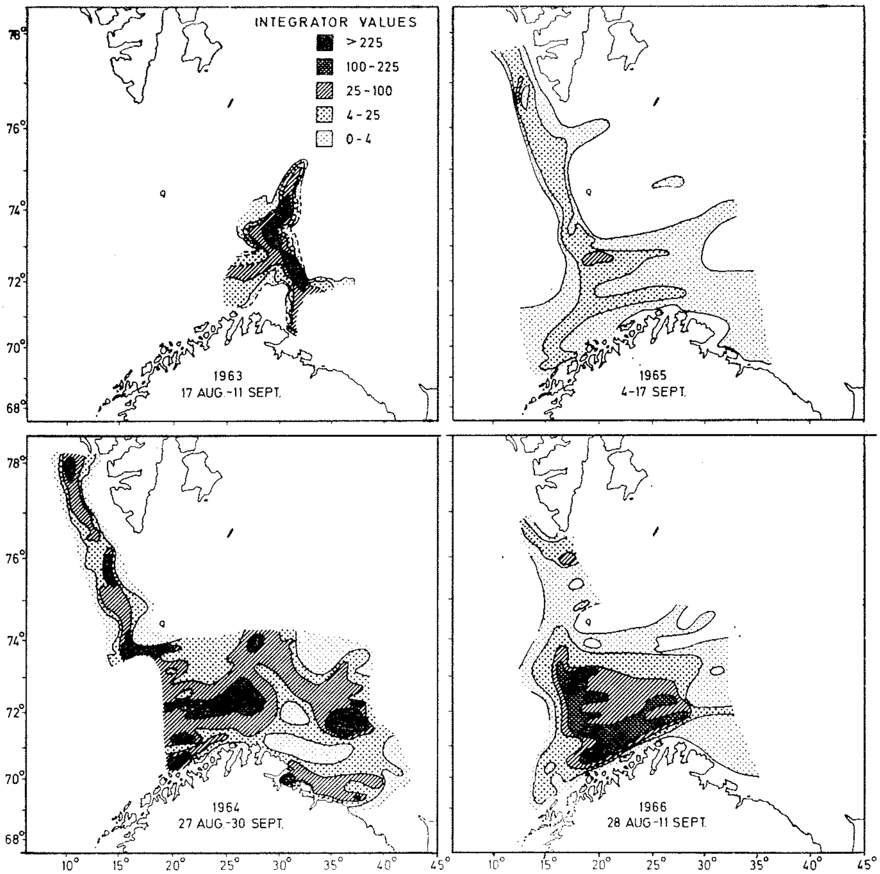

Fig. 7. Echo abundance distribution as determined by the echo integrator during the surveys in 1963—1966. Equal levels of abundance are indicated by isolines.

gested that the total echo abundance varied from year to year. This is particularly pronounced when comparing the years 1964 and 1966 with 1965. However, the number of fishes might have been underestimated in 1965 compared with 1964 as long rough dab were numerous that year. This species as well as capelin have a lower target strength than the gadoids and herring which both had very low abundances in 1965.

No firm conclusion can be drawn concerning the variation in number of 0-group fishes from year to year, and more research has to be done in this field. However, it is tentatively concluded that the variation in the total number of 0-group fishes did not vary to the same extent as the variation in number of each of the species. One possible explanation might be that there are interrelationships among species so that when the mortality of the progeny of fishes spawning earlier is high, then the progeny of species spawning next has a better chance of survival.

To illustrate the interrelationship among species the main spawning centres of saithe, haddock, cod, herring, redfish and capelin are mapped out (Fig. 8). The surface water currents are also shown in the figure. Plotting the spawning area against time of spawning (Fig. 9) it will be seen that spawning in region A) usually takes place comparatively later in the year for stocks spawning at the northern part of the coast. Due to the denatant movements of eggs and larvae and the difference in spawning time, all species will gradually mingle during the larval and postlarval phases.

To demonstrate a characteristic distribution of saithe, haddock, cod, herring, redfish and capelin at the 0-group stage 1967 has been chosen (Fig. 10). The 0-group herring had a restricted distribution with very low abundance. Similarly cod was recorded in a relatively small area, and no dense echo recordings were obtained. The abundance of 0-group haddock and redfish was estimated to be average in strength, whereas saithe and capelin were very abundant over relatively large areas.

The variation in total 0-group abundance is in one way or another related to the biotic and abiotic environmental conditions during the drift migration phase. The interrelationship among species is probably of great importance for the mechanism governing recruitment e.g. the

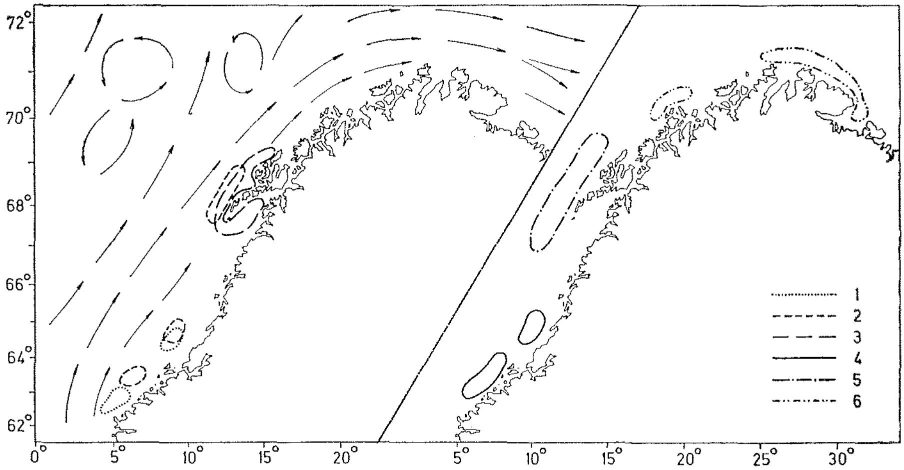

Fig. 8. Main spawning centres for, 1) saithe, 2) haddock, 3) cod, 4) herring, 5) redfish and 6) capelin in region A). The surface water currents are also shown in the figure.

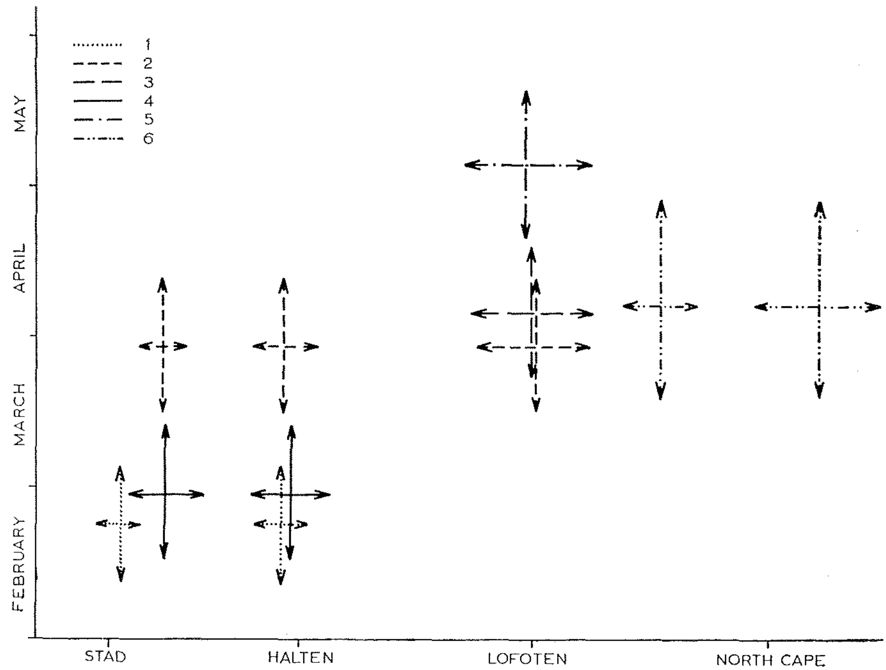

Fig. 9. Time of spawning in relation to spawning area. Legend as in Fig. 8.

predator effect. Gadoid fishes like saithe and haddock feed heavily on herring eggs (DRAGESUND and NAKKEN 1970), and later in the larval and post-larval phases both 0-group cod and haddock feed on 0-group herring and redfish (WIBORG 1960). Since there is a close correlation between 0-group abundance and subsequent year-class strength, it is likely that the relative proportion among year-class strength of the different species is established at a very young age, most likely during the larval and postlarval stage. It is unlikely that this proportion will be significantly changed later in life even though the carrying capacity in a region might be higher for some of the adult stocks. Recent investigations have shown that the stock size of herring has been of a much higher level than at present (DRAGESUND and NAKKEN 1970). It is likely therefore, that region A) has a far greater capacity at least for keeping the adult stock of herring at a higher level than at present.

The fact that not all the species produce numerous broods in the same year suggests that favourable conditions do not exist in a region for all the species to produce numerous year-classes. Lie (1966) has shown that the spawning time of *Calanus* varies from one year to another along the coast of Norway. The coincidence in time therefore between the occurrence of suitable food and hatching of fish larvae may be an important

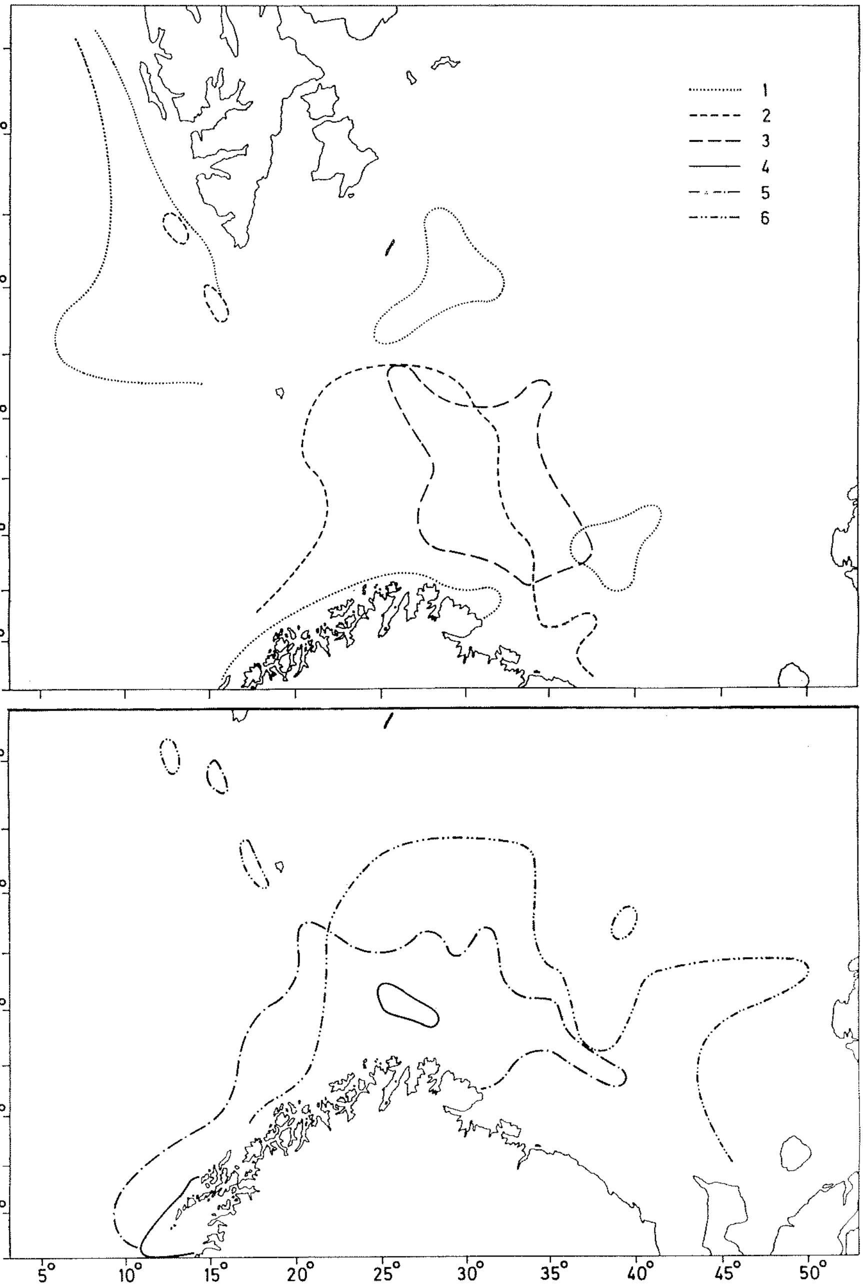

Fig. 10. Distribution of 0-group fishes in region A) during August—September 1967. Legend as in Fig. 8.

factor controlling year-class strength. The relationship between the spawning stock size (the spawning potential) and the resulting year-class is therefore often completely masked due to the great fluctuations in year-class strength that usually occur in boreal and subarctic regions. One is still left in doubt about the relative importance of the stock size and other conditions in determining year-class strength of fish stocks.

Knowledge of the pre-recruitment stocks therefore is essential in attempts to predict and control fisheries, and the advantage of knowing year-class strength for all species in a region before they are subject to fishing is obvious. This becomes even more important if the question of regulating the different stocks arises, and if a system of catch quota has to be introduced. So far the regulation has been concentrated too much on single species, and species of less commercial importance have been neglected. It is necessary to consider all species and estimate the total number of recruits produced in a region and try to find out its total capacity for producing recruits.

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REFERENCES

ANON. 1960. Proceedings of the joint scientic meeting of ICNAF, ICES and FAO on fishing effort, the effect of fishing on resources and the selectivity of fishing gear. *Spec. Publs. int. Comm. NW. Atlant. Fish., 1960* (2): 1—45.

— 1970a. Report of the working group on Atlanto-Scandian herring. Copenhagen 21st—25th April 1969. *Coop.Res.Rep.Ser.A.Int.Coun.Explor.Sea, 17*:1—43.

— 1970b. Reports of the North-east Arctic fisheries working group. Copenhagen, 4th—14th December 1967 and Copenhagen, 13th—17th January 1969. *Coop.Res.Rep.Ser.A.Int.Coun.Explor.Sea, 16*:1—60.

BENKO, YU. K., DRAGESUND, O., HOGNESTAD, P. T., JONES. B. W., MONSTAD, T., NIZOVTSEV, G. P., OLSEN, S. and SELIVERSTOV, A. S. 1970. Distribution and abundance of 0-group fish in the Barents Sea in August—September 1965—1968. *Coop.Res.Rep.Ser.A.Int.Coun. Explor.Sea, 18*:35—76.

DRAGESUND, O. 1970a. Factors influencing 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 haregus* 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.Hav-Unders., 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.

DRAGESUND, O. and NAKKEN, O. 1970. Relationship of parent stock size and year-class strength in Norwegian spring spawning herring. *ICES/FAO/ICNAF Stock and recruitment symp., Aarhus, 1970* (20): 1—17, 10 figs. [Mimeo.]

GARROD, D. J. 1968. Stock and recruitment relationship in four North Atlantic cod stocks. *Coun.Meet.int.Coun. Explor.Sea, 1968* (F:14): 1—6, 1 tab., 3 figs. [Mimeo.]

GRAHAM, H. W. 1969. XII. United Research Report, 1968. *Redbook int. Comn. NW. Atlant. Fish., 1969* (Part 2): 121—180.

HARDEN JONES, F. R. 1968. *Fish migration.* Edward Arnold Ltd., London. 325 p.p.

HYLEN, A. and DRAGESUND, O. 1970. Recruitment of young Arcto-Norwegian cod and haddock in relation to parent stock size. *ICES/FAO/ICNAF Stock and Recruitment Symp., Aarhus 1970* (19): 1—15, 22 figs. [Mimeo.]

LIE, U. 1966. Dyreplankton fra faste stasjoner langs norskekysten i årene 1963—1965. *Fiskets Gang, 52*: 736—740.

MOSBY, H. 1960. Havet. Pp. 13—42 in ROLLEFSEN, G. ed. *Havet og våre fisker 1.* J. W. Eides forlag, Bergen.

RICKER, W. W. 1954. Stock and recruitment. *J.Fish.Res.Bd Can., 11*: 559—623.

TEMPLEMAN, W. 1965. Relation of periods of successful year-classes of haddock on the Grand Bank to periods of success of year-classes for cod, haddock and herring in areas to the North and East. *Spec. Publs int. Comn. NW. Atlant. Fish., 1965* (5): 523—533.

WIBORG, K. F. 1960. Investigations on pelagic fry of cod and haddock in coastal and offshore areas of northern Norway in July—August 1957. *FiskDir.Skr.Ser. HavUnders., 12*(8): 1—18.

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