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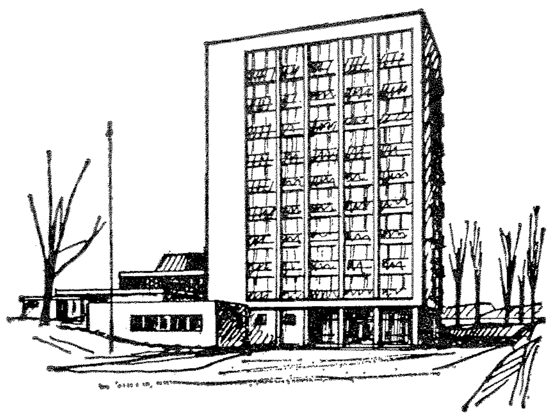

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COMPARATIVE ANALYSIS OF YEAR-CLASS STRENGTH AMONG FISH STOCKS IN THE NORTH ATLANTIC

By

OLAV DRAGESUND

Institute of Marine Research, Bergen

ABSTRACT

DRAGESUND, O. 1971. Comparative analysis of year-class strength among fish stocks in the North Atlantic. *FiskDir. Skr. Ser. HavUnders., 16*: 49—64.

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 northwestern 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

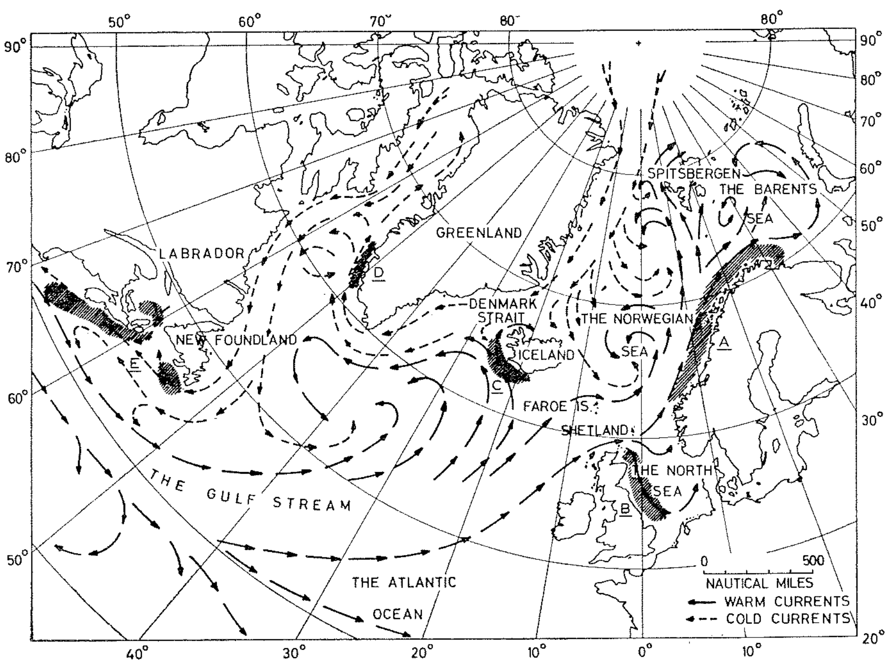

Fig. 1. The general surface water currents in the North Atlantic. Adapted from Mosby (1960). The diagonal shadings indicate some of the main spawning grounds in different regions.

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

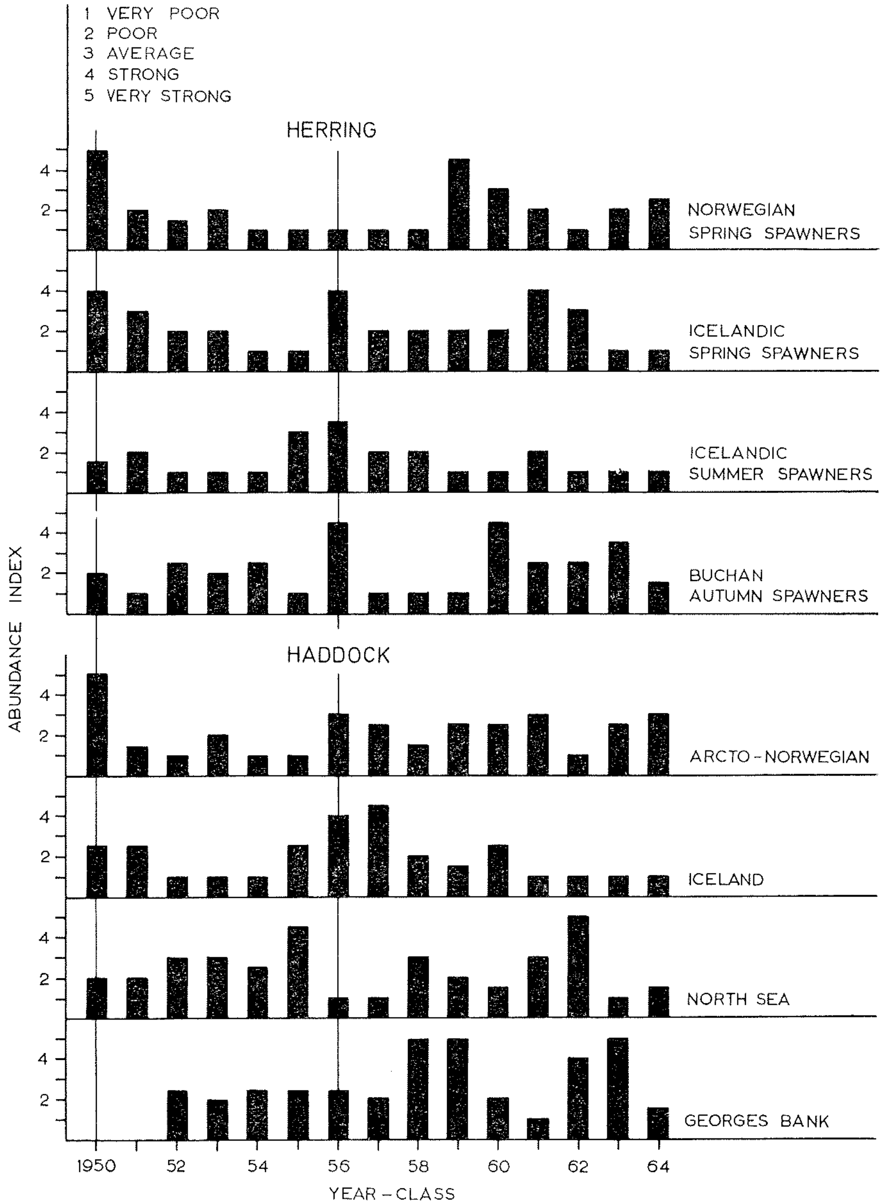

Fig. 2. Year-class strength at age $\geq$ 3 years of herring and haddock in different regions. The abundance estimates are indicated by grading year-class strength in, 1) very poor, 2) poor, 3) average, 4) strong and 5) very strong.

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 ≥ 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.

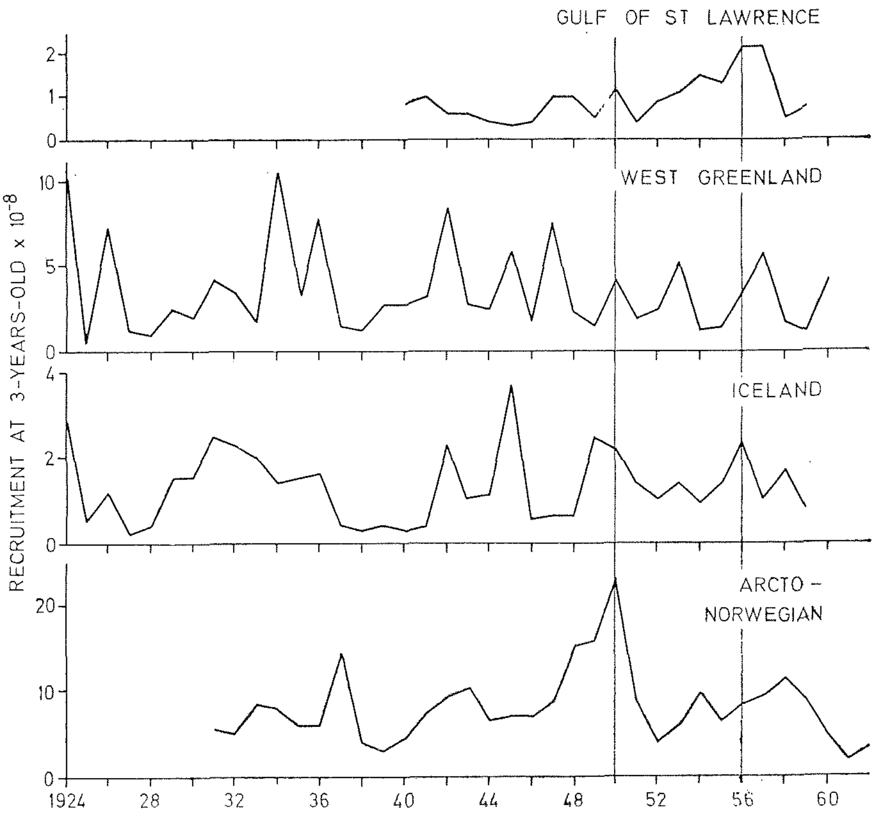

Fig. 3. Year-class strength at age ≥ 3 years of cod in different regions. Adapted from GARROD (1968).

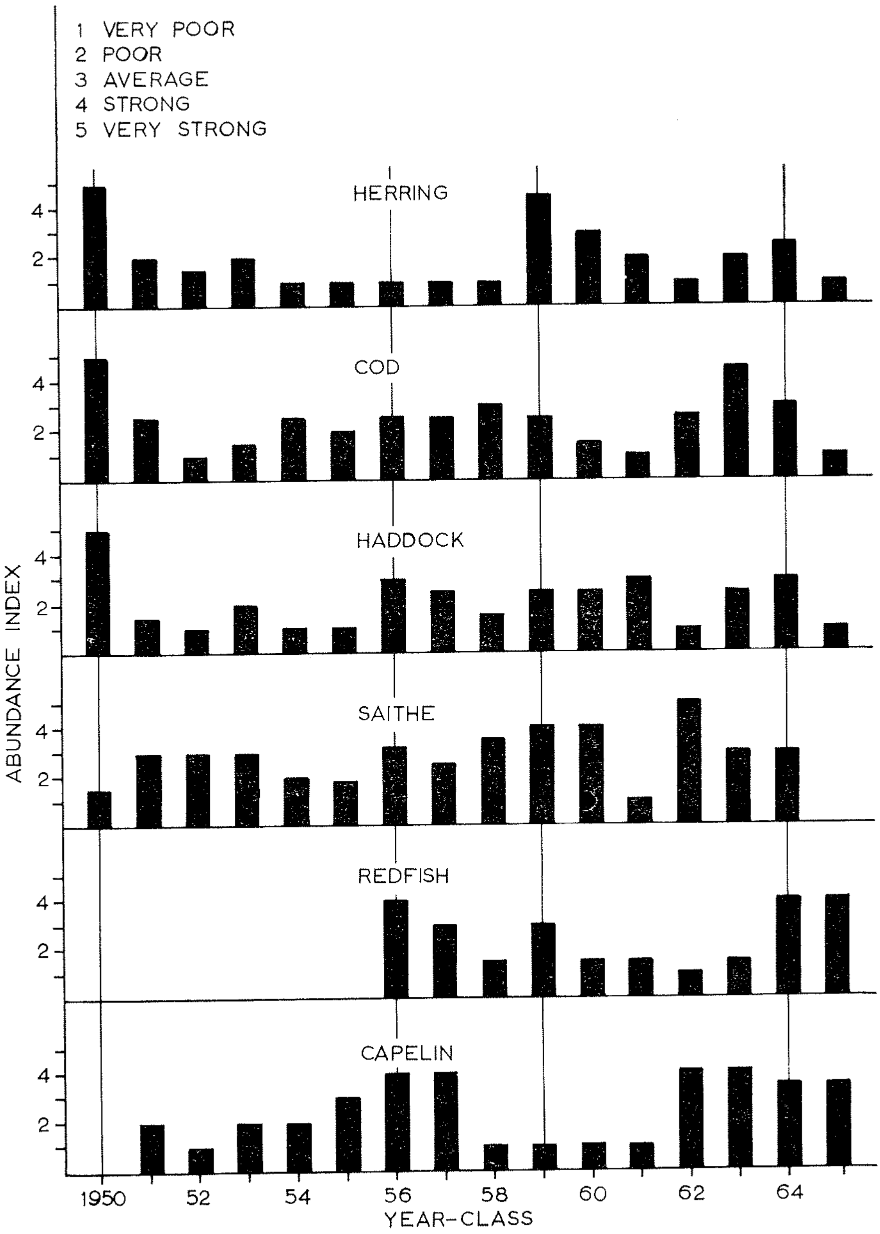

Fig. 4. Year-class strength at age ≥ 3 years for different species spawning at the Norwegian coast, region A). Year-class strength is grouped as, 1) very poor, 2) poor, 3) average, 4) strong and 5) very strong.

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

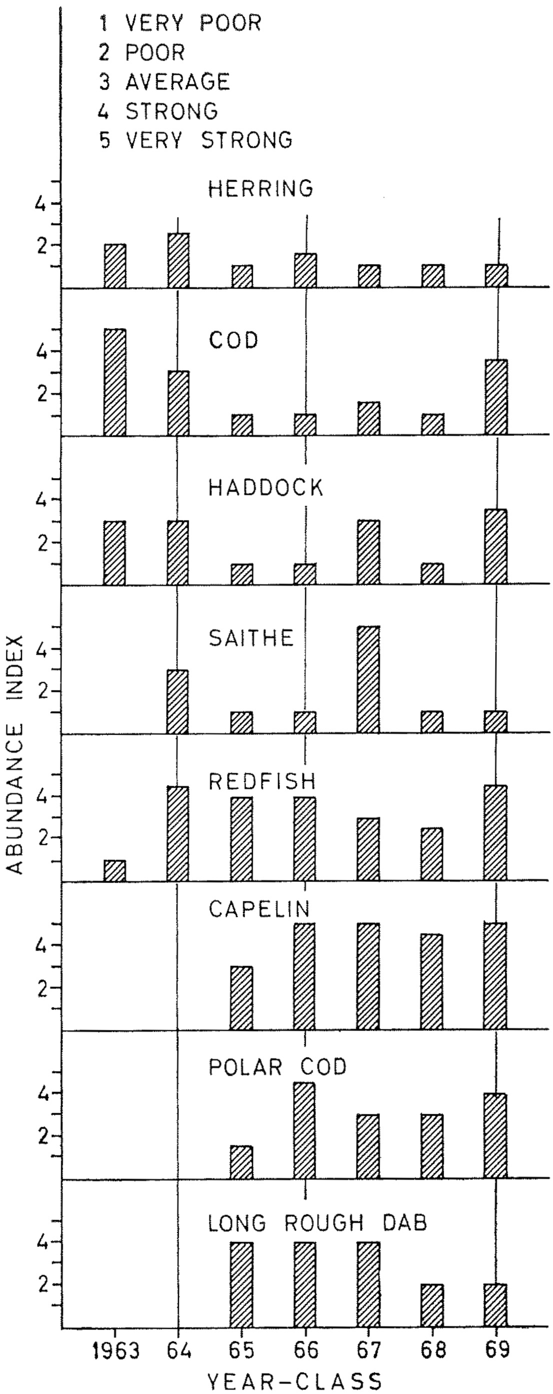

Fig. 5. Year-class strength measured at the 0-group stage for different species in region A). Year-class strength is grouped as, 1) very poor, 2) poor, 3) average, 4) strong and 5) very strong.

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.

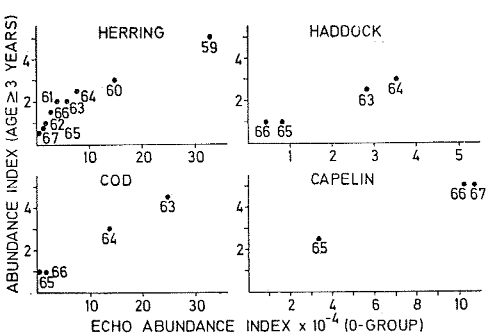

Fig. 6. Relationship between year-class strength at the 0-group stage and subsequent stages (age $\geq$ 3 years) for herring, haddock, cod and capelin in region A.)

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-

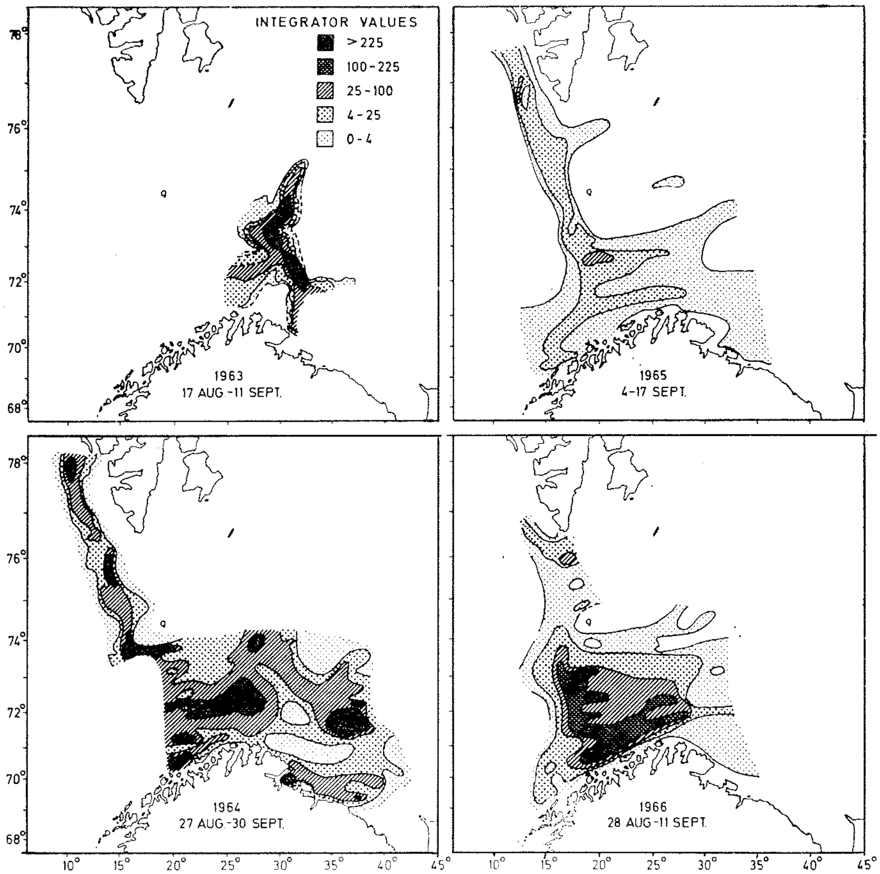

Fig. 7. Echo abundance distribution as determined by the echo integrator during the surveys in 1963—1966. Equal levels of abundance are indicated by isolines.

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

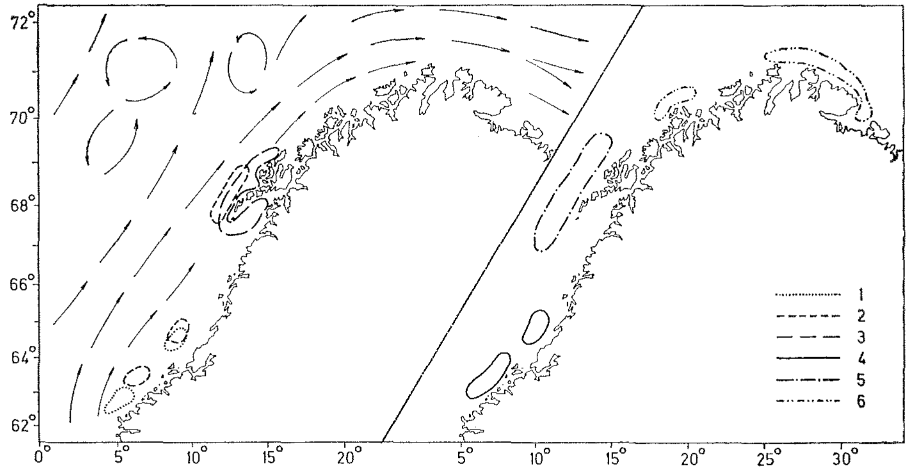

Fig. 8. Main spawning centres for, 1) saithe, 2) haddock, 3) cod, 4) herring, 5) redfish and 6) capelin in region A). The surface water currents are also shown in the figure.

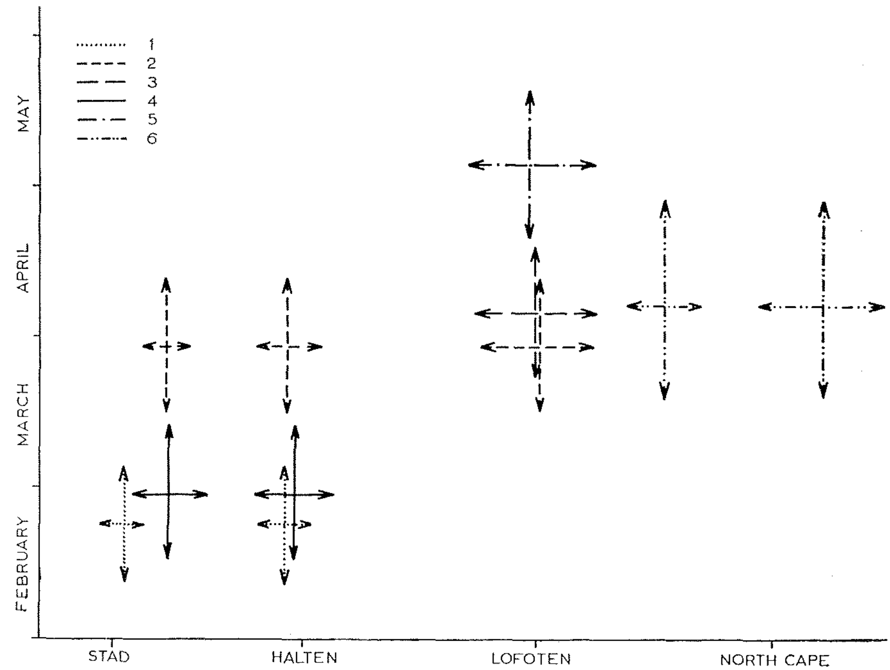

Fig. 9. Time of spawning in relation to spawning area. Legend as in Fig. 8.

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

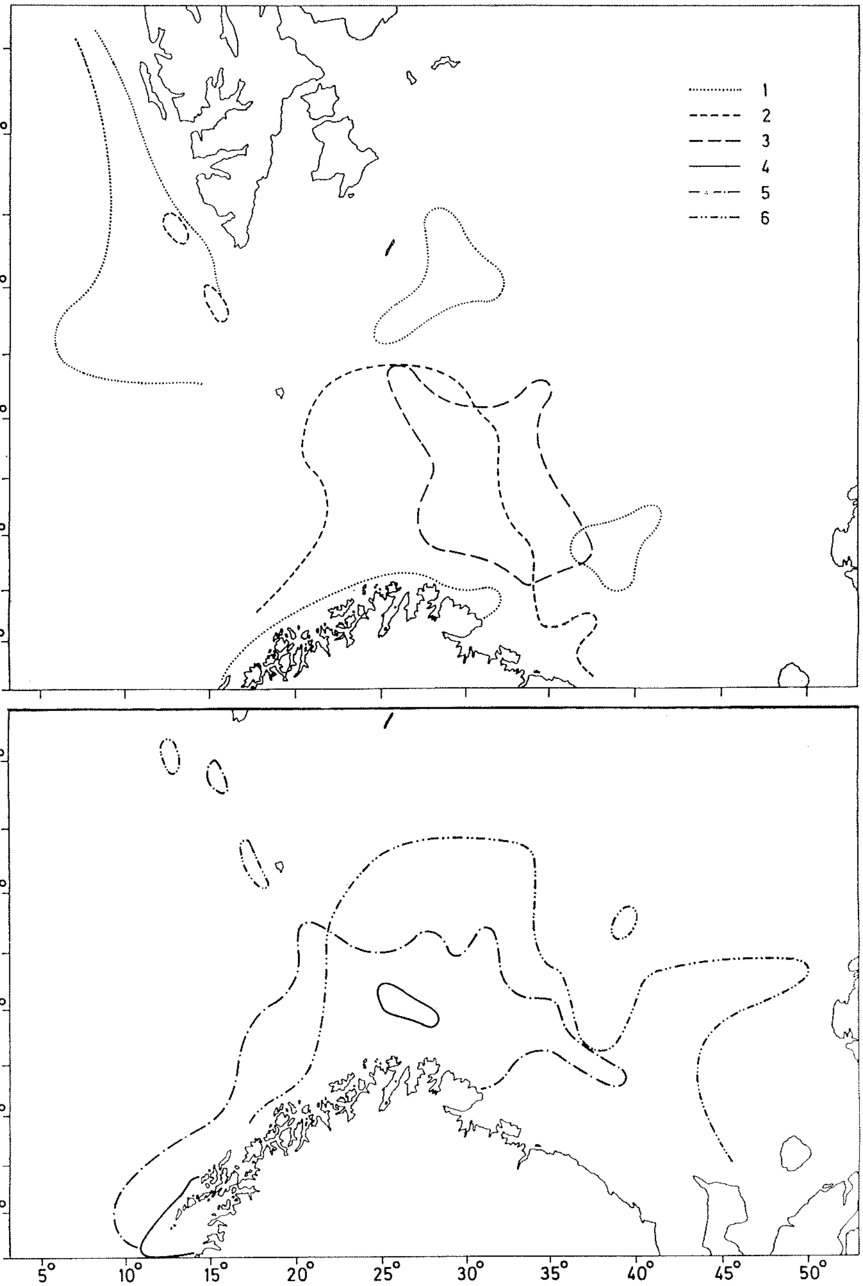

Fig. 10. Distribution of 0-group fishes in region A) during August—September 1967. Legend as in Fig. 8.

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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FLUCTUATIONS IN YEAR-CLASS STRENGTH OF COD AND POLLACK IN SOUTHEASTERN NORWEGIAN COASTAL WATERS DURING 1920-1969

By

STEIN TVEITE

Statens Biologiske Stasjon Flødevigen

ABSTRACT

TVEITE, S. 1971. Fluctuations in year-class strength of cod and pollack in southeastern Norwegian coastal waters during 1920—1969. *FiskDir. Skr. Ser. HavUnders., 16*: 65—76.

From 1920 a small beach seine has every September—October (except 1940—1944) been worked at selected localities along the Norwegian Skagerack coast. The catch per beach seine haul of 0-group cod agree fairly well with catch per trap per week of the same year-class as I-, II-, III- and IV-group and may thus be used as estimate of the strength of each year-class. There are two marked periods with rich year-classes, one before 1930 and one after 1950. In the intermediate period the only rich year-classes were 1938 and 1945. The fluctuations are generally similar in all districts. There has been increase in relative abundance in the most open areas compared to the more landlocked ones. By the present method no effect of the liberation of cod larvae has been revealed.

The catch per beach seine haul of 0-group pollack is less reliable as estimates of year-class strength. Two rich periods, however, one before 1931 and one after 1953, are shown by the material. In the last period the average relative number is below that of the first period. Again, 1938 and 1945 are the only years in the intermediate period which gave rich broods.

Covariation between year-class strength of pollack and cod excist to some extent, but not all years with rich year-classes of one of the species showed a similar year-class strength of the other species.

INTRODUCTION

Along the Norwegian Skagerack coast small gadoids and other fish species have been sampled at a number of selected localities by a small meshed beach seine each autumn since 1917. Parts of the extensive material collected have been dealt with before (LØVERSEN 1946 b, DANNEVIG 1949, 1954, 1959, DANNEVIG 1963). In some years during the period great quantities of cod larvae from Flødevigen hatchery have been liberated in the same area. LØVERSEN (1946 b), DANNEVIG (1959) and DANNEVIG (1963) discussed the fluctuations in year-class strength measured as number of 0-group and 1-group cod caught by beach seine in relation to the cod larvae liberated and the possibility of augmenting heavily exploited stocks of cod by artificial propagation.

The present paper describes variations in year-class strength measured by using the catch in a beach seine of 0-group cod, *Gadus morhua* L. and pollack, *Pollachius pollachius* (L). This method of estimating year-class strength is discussed later in relation to year-class strength measured as catch per trap per day. Possible covariations in year-class strength of the two species as well as factors (including artificial propagation) of importance for the strength of the year-class are looked for.

MATERIAL AND METHODS

The field work was performed during September—October. The total area covered is divided into 18 districts as shown in Fig. 1. Within each district were selected localities for operating the beach seine. Each district contain from two to nine such localities, and only localities examined throughout the entire period are considered here.

In districts 1—12 the sampling program was carried out during the whole period from 1917 to 1969; in district 13 (the Langesund district) from 1953 to 1969; in districts 14—18 (the Oslo fjord) from 1936 to 1969. There were no investigations from 1940 to 1944. In the years 1917—1919 the sampling was not carried out on all the localities used in later years and the results from these years are therefore omitted.

Up to 1961 a seine made of cotton was used. It was 38.0 m long and 3.8 m deep, and the mesh size was 14 mm stretched mesh. From 1962 a nylon seine of the same size and construction was used. No comparative experiments with the two seines were performed, but as no special change in number per seine haul and no special difference in length distribution of the fish caught in the two seines was found after 1961, the seines were considered to have the same fishing power.

The hauls were exactly taken at the same localities and covered the same areas each year. The seine was never operated by an entirely new crew in two successive years.

In each haul the numbers of different fish species were counted, and lengths were measured for cod, pollack, whiting, *Merlangus merlangus* (L) and coalfish, *Pollachius virens* (L). When the age-groups of cod were difficult to separate by length distributions, otoliths were used for age determination. Pollack was usually well separated in age-groups by length.

In Topdalsfjord and Søndeledfjord (Fig. 1) fishermen collected the biological samples from commercial catches taken by traps during the years 1922—1942. Near Biological Station Flødevigen (Fig. 1) fishing by two traps at fixed position started in 1924.

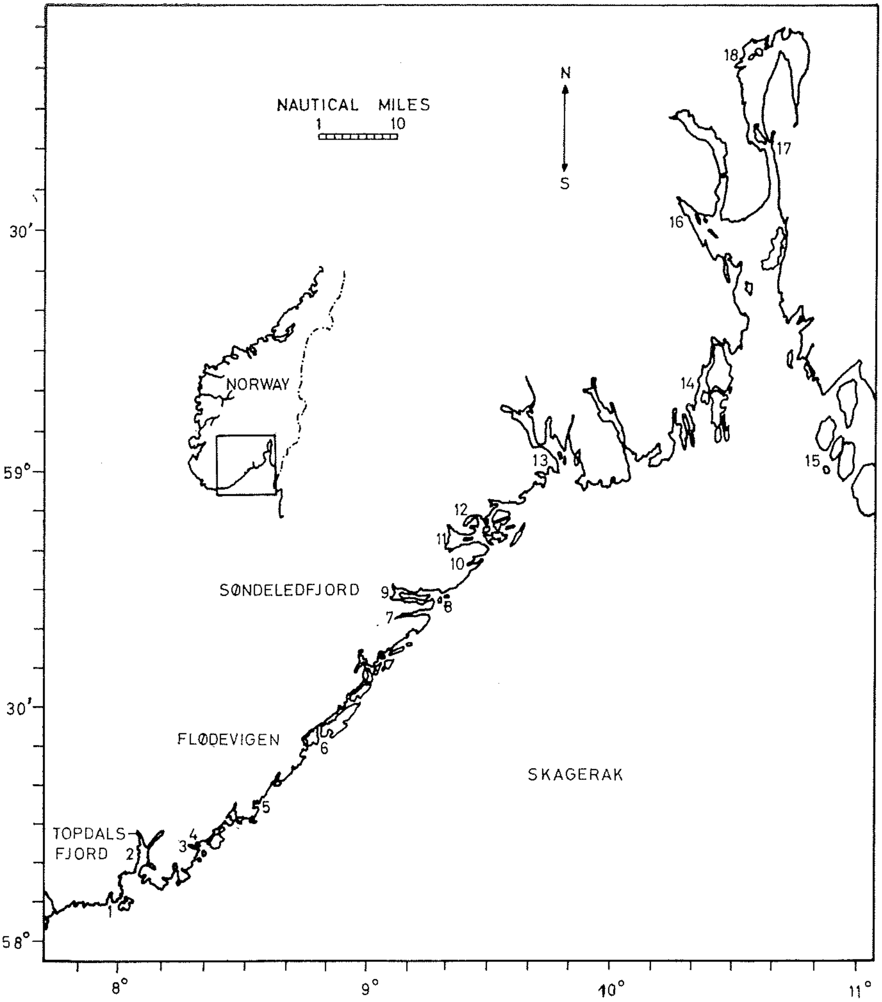

Fig. 1. Districts investigated. 1) Torvefjord, 2) Topdalsfjord, 3) Steindalsfjord, 4) Vestre Vallesvær, 5) Bufjord, 6) Flødevigen, 7) Sandnesfjord, 8) Søndeledfjord, 9) Risør Skerries, 10) Stølefjord, 11) Kilsfjord, 12) Soppekilen, 13) Langesund, 14) Vrengen—Tjøme, 15) Hvaler, 16) Holmestrand, 17) Drøbak, 18) Nærsnes—Bygdøy.

The age of the trap caught cod was usually determined from otoliths, occasionally from scales. The age of the pollack was determined from scales. A few fish were grouped into year-classes by length only.

RESULTS

COD

The catches of 0-group cod per seine haul are shown in Fig. 2, and an average for each district is indicated.

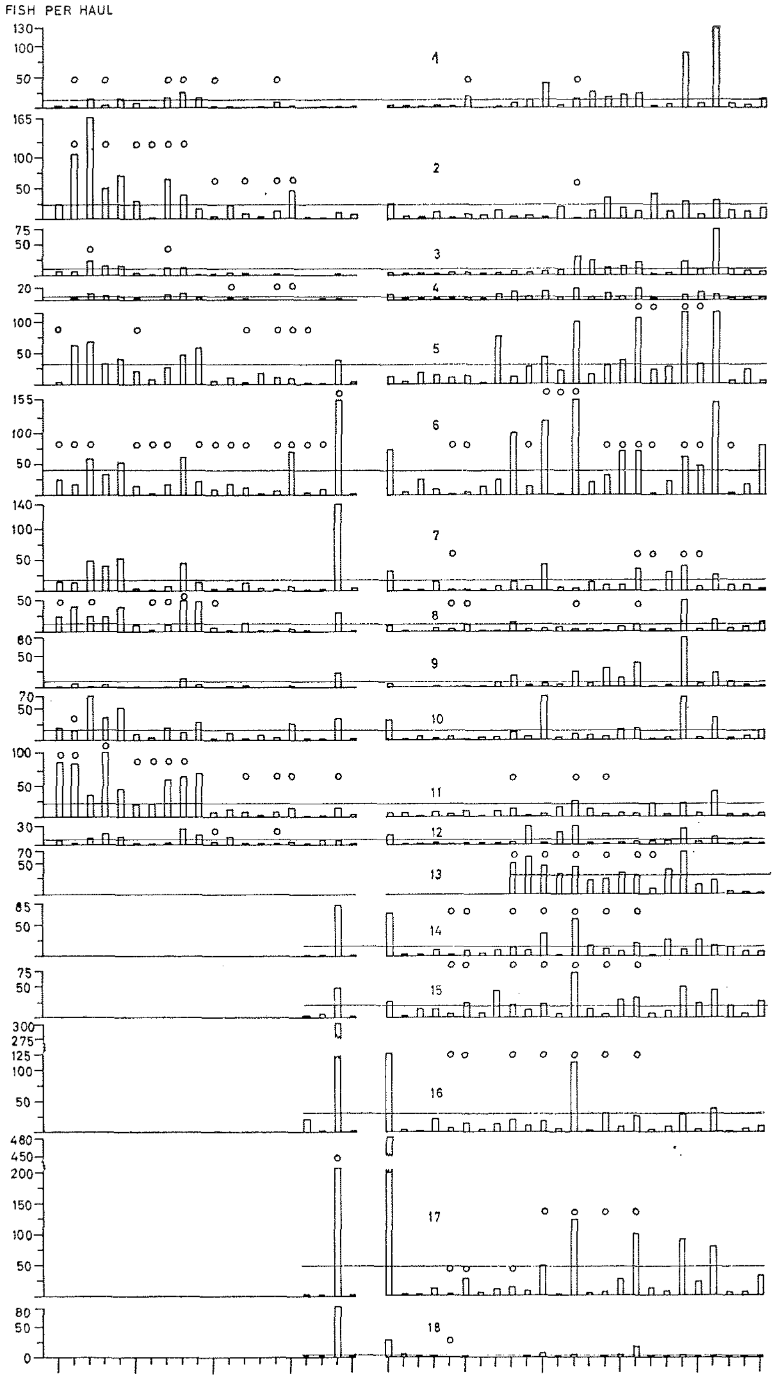

Fig. 2. 0-group cod per seine haul in the different districts. Average catch for each district is indicated. Liberation of cod larvae is marked by an open circle above the column. Districts numbered as in Fig. 1.

Table 1. Average number of 0-group cod per seine haul in five periods.

District	Periods				
	1920—29	1930—39	1945—54	1955—64	1965—69
1 Torvefjord	10.5	1.9	4.8	23.6	32.6
2 Topdalsfjord	56.8	11.8	8.2	17.9	16.3
3 Steinsdalsfjord	9.5	1.0	3.1	13.6	19.7
4 Vestre Vallesvær	5.9	0.4	4.4	8.2	4.8
5 Bufjord	36.1	9.3	18.0	50.8	34.9
6 Flødevigen	30.5	28.4	27.0	55.2	58.5
7 Sandnesfjord	24.3	18.3	8.4	19.6	9.6
8 Søndeledfjord	27.3	5.6	4.6	9.1	9.6
9 Risør Skerries	3.1	2.9	3.8	20.6	8.0
10 Stølefjord	25.8	8.4	6.8	20.0	12.1
11 Kilsfjord	59.7	6.8	5.9	11.6	11.7
12 Soppekilen	9.8	4.9	6.9	10.6	4.4
13 Langesund area				35.6	10.0
14 Vrengen—Tjøme			12.4	18.9	14.5
15 Hvaler			16.9	24.2	20.7
16 Holmestrand			21.9	24.2	11.4
17 Drøbak			56.6	42.3	29.2
18 Nærsnes—Bygdøy			3.2	3.4	1.3

By analysis of variance, the number of cod per beach seine haul has been found to be significantly influenced by both year and district ($P < 0.001$), quite apart from random variations and sampling errors.

Table 1 shows the average number of 0-group cod per seine haul calculated for four periods of 10 and one of 5 years. High catches per haul occurred mostly in the first and fourth period, and only 1938, 1945 and 1966 gave high catches in the other periods (Fig. 2). The averages for the ten years periods tended to be lower in the periods 1930—39 and 1945—54 than in the periods 1920—29 and 1955—64 except in the district Risør Skerries where a slightly lower average was found in the first period than in the period 1945—54 and at Drøbak where the best period was 1945—54. In three landlocked fjords at the Skagerack coast, Topdalsfjord, Søndeledfjord and Kilsfjord, a marked higher average of cod per haul was found in the first 10 years period than in any later period while in the more open fjords, Torvefjord, Flødevigen and Risør Skerries, the two last periods were the best ones (Table 1).

Of 29 years with investigations in the entire area clear differences in year-class strength in the different parts of the coast were only found in 1938, 1958 and 1959. In 1938 large numbers of cod were found east of Bufjord (district 5) while comparatively few were found farther west. In the two other years the higher numbers were found west of Bufjord.

Table 2. Relative numbers of 0-group cod caught in districts with and without liberation of cod larvae. See text for further explanation.

Year	Districts with liberation		Districts without liberation	
	Number of districts	Relative number	Number of districts	Relative number
1920	4	115	7	69
1921	5	135	7	140
1922	3	240	9	226
1923	3	148	9	180
1925	4	64	8	50
1926	4	20	8	8
1927	6	135	6	87
1928	4	213	8	267
1930	5	37	7	12
1931	2	66	10	56
1932	4	26	8	45
1934	7	35	5	9
1935	5	87	7	45
1938	4	274	13	372
1949	8	12	9	22
1950	8	75	9	35
1953	6	97	12	113
1955	6	149	12	158
1957	10	228	8	222
1959	7	56	11	115
1961	9	168	9	197
1962	4	28	14	63
1964	3	250	15	328
1965	3	85	15	72

Cod larvae were liberated in the districts where sampling by beach seine was carried out in years indicated by an open circle above the columns in Fig. 2. The figure shows no marked correlation between the catches of 0-group cod per haul and the liberation of cod larvae. In Table 2 the relative numbers of 0-group cod caught by beach seine in areas with and without liberation of larvae are compared. To have comparable figures, average number of 0-group cod per seine haul for the two periods 1920—1935 and 1936—1965 were calculated for each district, and for each district and year the numbers of 0-group cod caught per seine haul were converted to per cent of these averages. In some years considerably more 0-group cod were caught in districts with liberation of larvae (the same year) than in districts without liberation. However, in other years opposite results were obtained, and the average of the relative numbers for all years were nearly the same in both cases. In Table 3 the average number of cod per haul for years with liberation is com-

Table 3. Average number of cod per seine haul in years with and without liberation of cod larvae.

District	Number of years with liberation	Average number of cod per haul	Number of years without liberation	Average number of cod per haul
1. Torvefjord............	8	11.3	37	12.9
2. Topdalsfjord	11	32.9	34	19.6
5. Bufjord	10	31.3	35	28.7
6. Flødevigen	28	36.3	17	40.2
7. Sandnesfjord..........	5	17.0	40	16.7
8. Søndeledfjord	10	14.2	35	10.6
11. Kilsfjord	14	38.1	31	11.8
13. Langesund	6	34.8	11	28.3
14. Vrengen—Tjøme	7	21.2	22	14.6
15. Hvaler	7	25.8	22	17.8
16. Holmestrand	7	32.2	22	28.0
17. Drøbak	8	67.3	21	38.7

pared with the average for years without liberation. Torvefjord and Flødevigen had, on the average, higher numbers of cod per haul for the years without liberation. In most of the districts, however, the two averages were more or less at the same level. As a source of variation in year-class strength, the liberation of cod larvae could not be significantly separated from other natural sources by the analysis of variance.

To compare the catches of the 0-group of a year-class in the beach seine and the later catches of the same year-class in the traps, the correlation coeffcients (*r*) between catch per seine haul and catch per trap per week of the same year-class as I-, II-, III-, and IV-group were calculated for the three areas where biological data was sampled from the trap catches. In Table 4 the coeffcients are given together with the significance levels (*P*) at which the values of *r* can be separated from zero. All coeffcients are statistical significant. In Topdalsfjord and Søndeledfjord there are fewer observation pairs, but both numerical value of *r*

Table 4. Correlation coefficients (*r*) between number of 0-group cod per beach seine haul and cod per trap per week of the same year-class as I-, II-, III- and IV-group and corresponding significance levels (*P*).

District	Year-classes	*r*	Value of *P*
2. Topdalsfjord	1923—1938	0.78	0.001
6. Flødevigen	1923—1963	0.37	0.02
8. Søndeledfjord......	1921—1938	0.70	0.002

Table 5. Average number of 0-group pollack per seine haul in five periods.

Area	Periods				
	1920—29	1930—39	1945—54	1955—64	1965—69
1. Torvefjord	48.4	17.7	6.9	31.5	12.4
2. Topdalsfjord	7.6	6.0	4.2	5.2	1.5
3. Steindalsfjord	30.6	5.3	7.1	12.6	9.6
4. Vestre Vallesvær	16.0	5.5	5.2	8.1	4.1
5. Bufjord	45.1	14.5	9.1	8.5	5.2
6. Flødevigen	38.2	13.0	8.2	10.9	4.2
7. Sandnesfjord	25.0	11.3	8.9	6.1	3.1
8. Søndeledfjord	20.2	7.0	9.3	9.5	3.0
9. Risør Skerries	53.5	22.5	9.0	30.0	8.8
10. Stølefjord	41.2	14.9	8.2	18.6	8.9
11. Kilsfjord	17.8	4.5	5.9	7.5	1.0
12. Soppekilen	5.8	3.4	7.0	11.5	5.3
13. Langesund area				4.1	1.6
14. Vrengen—Tjøme			9.5	12.8	2.7
15. Hvaler			4.6	10.3	1.3
16. Holmestrand			2.1	4.8	0.2
17. Drøbak			5.1	16.2	1.0
18. Nærsnes—Bygdøy			1.5	4.4	0.1

and the significance level indicates a stronger correlation in these fjords than in Flødevigen.

POLLACK

The beach seine catches of pollack were also on average high before 1931, then low till 1953 except in 1938 in the Oslofjord district and in 1945 along the whole coast. After 1953 there have been more above average catches (Fig. 3). Variations between periods are not so evident as for cod, but the period 1920—29 had on average higher catches per haul than 1955—64 (Table 5). Only Soppekilen district has a higher average catch per haul in the period 1955—64 than in the period 1920—29.

By analysis of variance the number of 0-group pollack per seine haul is found to be significantly influenced by year and district.

No significant correlation between year-class strength estimated from beach seine catches of 0-group pollack and trap catches of older fish was found.

The catches of I-group pollack in the beach seine were incidental, probably because the pollack at this age schools in water deeper than normally fished by seine.

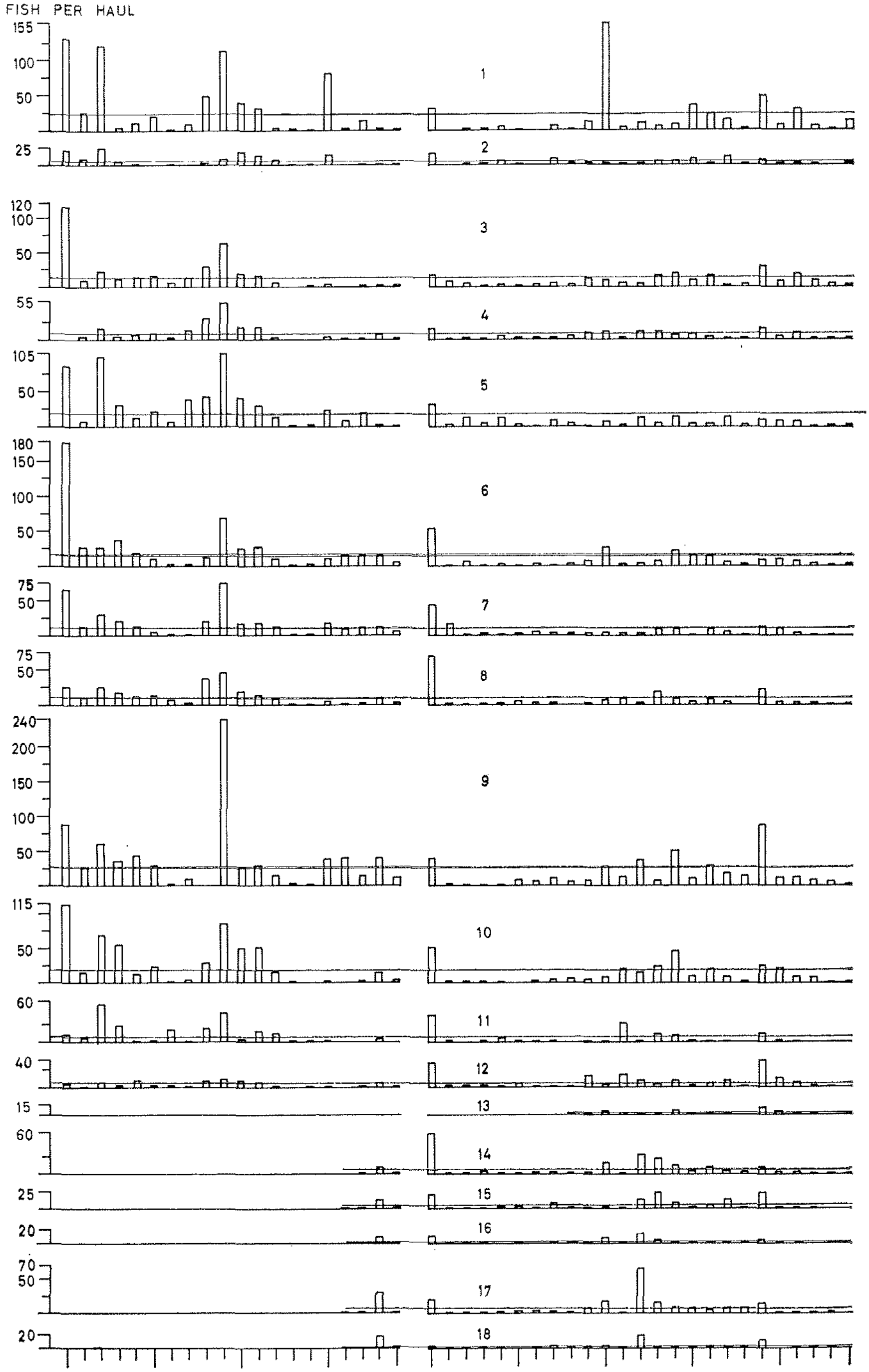

Fig. 3. 0-group pollack per seine haul in the different districts. Average catch for each district is indicated. Districts numbered as in Fig. 1.

DISCUSSION

Some of the one year old cod are caught in traps in deeper water, but some stay in the littoral region and are caught in the seine together with the 0-group. Dannevig (1963) found high correlation between quantities of I-group cod caught by beach seine and the quantities of 0-group cod caught the previous year.

Comparison between the 0-group catches and the trap catches of I- to IV-group cod the following years showed that the beach seine 0-group catches gave a relatively good estimate of the year-class strength (Table 4). The lower correlation coeffcient in Flødevigen is probably due to the trap sampling method used there, namely two traps at fixed depth and place all the year round. The efficiency of the traps may thus vary from year to year depending on temperature in the depths of the traps (Dannevig 1966). The fishermen in Topdalsfjord and Søndeledfjord used more traps (10—20 in Søndeledfjord and 5—10 in Topdalsfjord), and to get as big catches as possible, they placed the traps at the depths where the greatest concentrations of cod usually is found. These catches are therefore expected to be representative for the abundance of 1 to 4 year old cod.

Thus there is a good correlation between the catch of 0-group cod and the catch of I-group cod per seine haul (Dannevig 1963) and between 0-group cod per seine haul and I- to IV-group cod per trap per week. The year-class strength of cod may therefore be considered to be determined by the 0-group stage, and the catch per beach seine haul in the autumn is a good estimate of their relative strengths.

No statistical evidence was found for using the catch per beach seine haul of 0-group pollack compared with older age groups as an estimate of year-class strength. This is probably due to the method of sampling the older fish, the fishermen being more interested in the cod. However, the catch per beach seine haul of 0-group pollack varies significantly from year to year, and it is therefore suppodsed that the catches give indications of fluctuations in year-class strength.

Of the ten years with high catch per haul of 0-group pollack, seven years also gave a high catch per haul of cod. The conditions required to give rich year-classes may therefore be similar for cod and pollack, but small variations in the marine environment may influence the two species differently. For example the main spawning is somewhat later for the pollack than for the cod, and consequently the larvae of the two species may experience different food conditions.

If the year-class strength of cod measured by cod per beach seine haul is followed along the coast, it is found that the year-classes 1936, —39,

—46, —47, —48, —49 and —51 all showed year-class strength below average in all the fjords (Fig. 2). This shows that factors which cause poor survival of cod larvae at least have influenced some year-classes in all the districts investigaed. The strength of the rich year-classes varied more between districts than the strength of the poor ones, and therefore factors which cause favourable conditions for survival of cod larvae appears to be of a more local character.

Temperature influences the spawning time of cod (DANNEVIG 1959) and also the incubation time and growth of the larvae (DANNEVIG 1948, SHELBOURNE 1964). The stock size of many of the food organisms will probably also depend on the temperature. Thus the temperature during the spawning and hatching season is thought to be an important factor for determining the strength of the individual year-classes. POULSEN (1944) found a correlation between the year-class strength of cod in the Kattegat and the temperature in March—May. It has not been possible to find any correlation between the year-classes on the Norwegian Skagerack coast and the average temperatures measured every day at 0 m, 1 m and 15—20 m at Flødevigen. There may be a tendency for poor year-classes in years with great fluctuations in the temperature measured at a depth of 15—20 m, independent of the average value of the temperature.

It is known that the cod in the investigated area is relatively stationary (LØVERSEN 1946 a, DANIELSSEN 1969), and each fjord probably has its own stock (DANNEVIG 1966). Also the composition of ichtyoplankton is so different inside and outside the skerries that currents presumably bring about little exchange of spawning products (DANNEVIG 1922). The year-class strengths in each district are therefore dependent of the local spawning.

The observed decrease in year-class strength on sheltered localities in relation to more open localities might have been caused by a secondary pollution due to over-fertilization by sewage in sheltered localities and a positive effect of the fertilization in greater dilution in the more open areas.

Pollution might well have caused the reduction of cod in the inner Oslofjord (Ruud 1968). However, a similar effect can not be seen from the year-class strength of 0-group pollack in the Oslofjord. DANNEVIG (1959) suggested that this may be due to the late spawning when the polluting material, probably dangerous to the fish eggs and larvae, is more rapidly converted to harmless compounds.

The year-classes 1964 and 1966 showed that rich year-classes of cod still occur although not as rich in the most landlocked districts as in earlier years.

In years like 1950 there appeared to be more cod in the districts where larvae were liberated, but other years show the opposite result. In Table 2 half of the 24 years show better results in the districts where larvae were liberated. A comparison between years with liberation and years without liberation for the same districts shows a higher number of cod per haul in years with liberation for ten of the 12 districts (Table 3). However, by analysis of variance any effect of liberation of cod larvae can not be significantly separated from random variations. Thus it can be concluded that any positive effect of the artificial propagation has not been revealed by the beach seine method.

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