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

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ABSTRACT

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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.

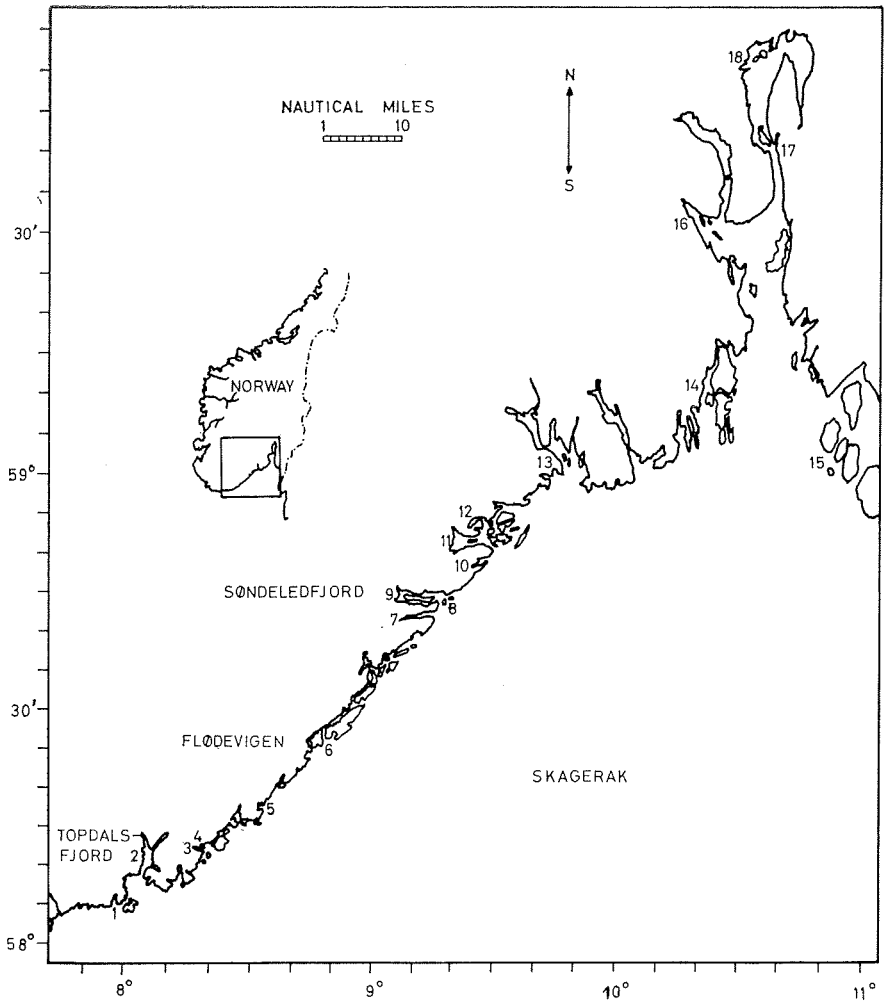

Fig. 1. Districts investigated. 1) Torvefjord, 2) Topdalsfjord, 3) Steindalsfjord, 4) Vestre Vallesvær, 5) Bufjord, 6) Flødevigen, 7) Sandnesfjord, 8) Søndeledfjord, 9) Risør Skerries, 10) Stølefjord, 11) Kilsfjord, 12) Soppekilen, 13) Langesund, 14) Vrengen—Tjøme, 15) Hvaler, 16) Holmestrand, 17) Drøbak,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

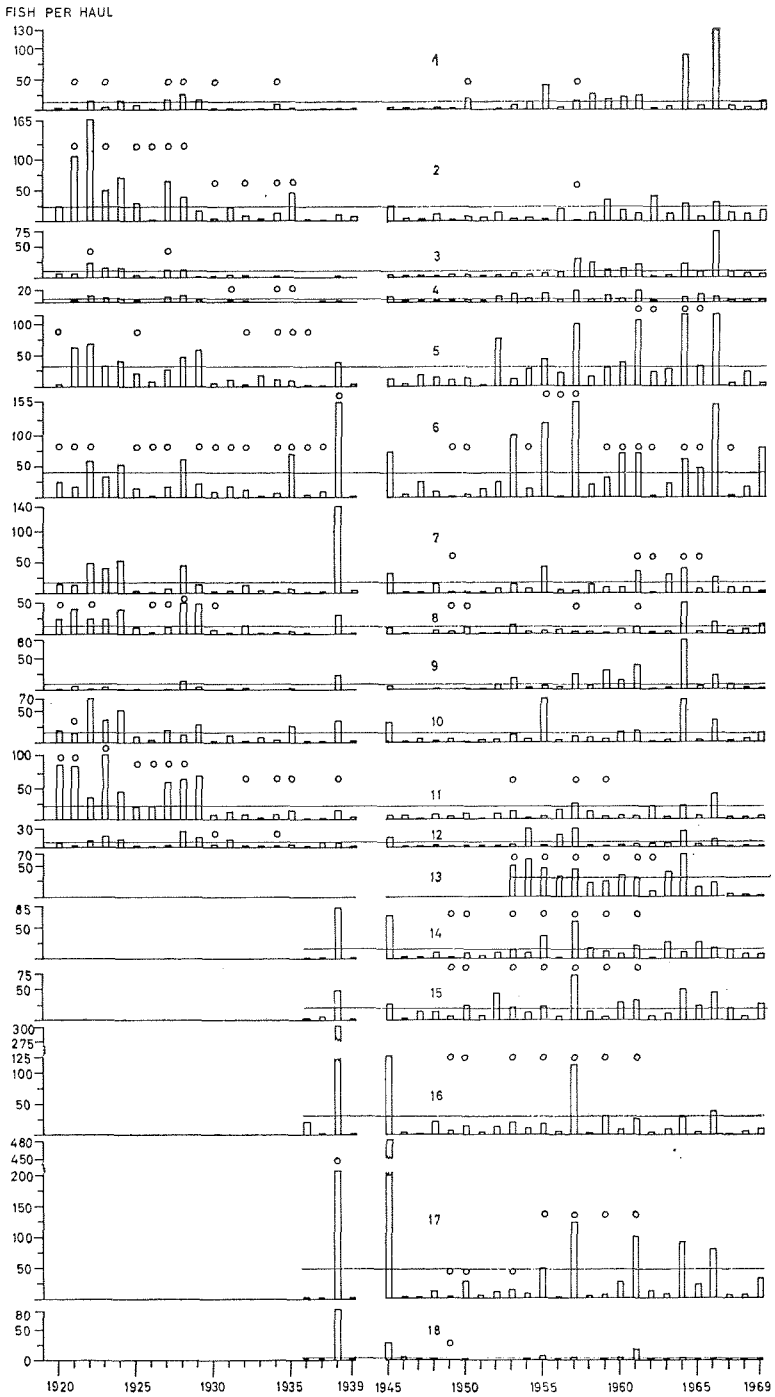

Fig. 2. 0-group cod per seine haul in the different districts. Average catch for each district is indicated. Liberation of cod larvae is marked by an open circle above the column. Districts numbered as in Fig. 1.

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.

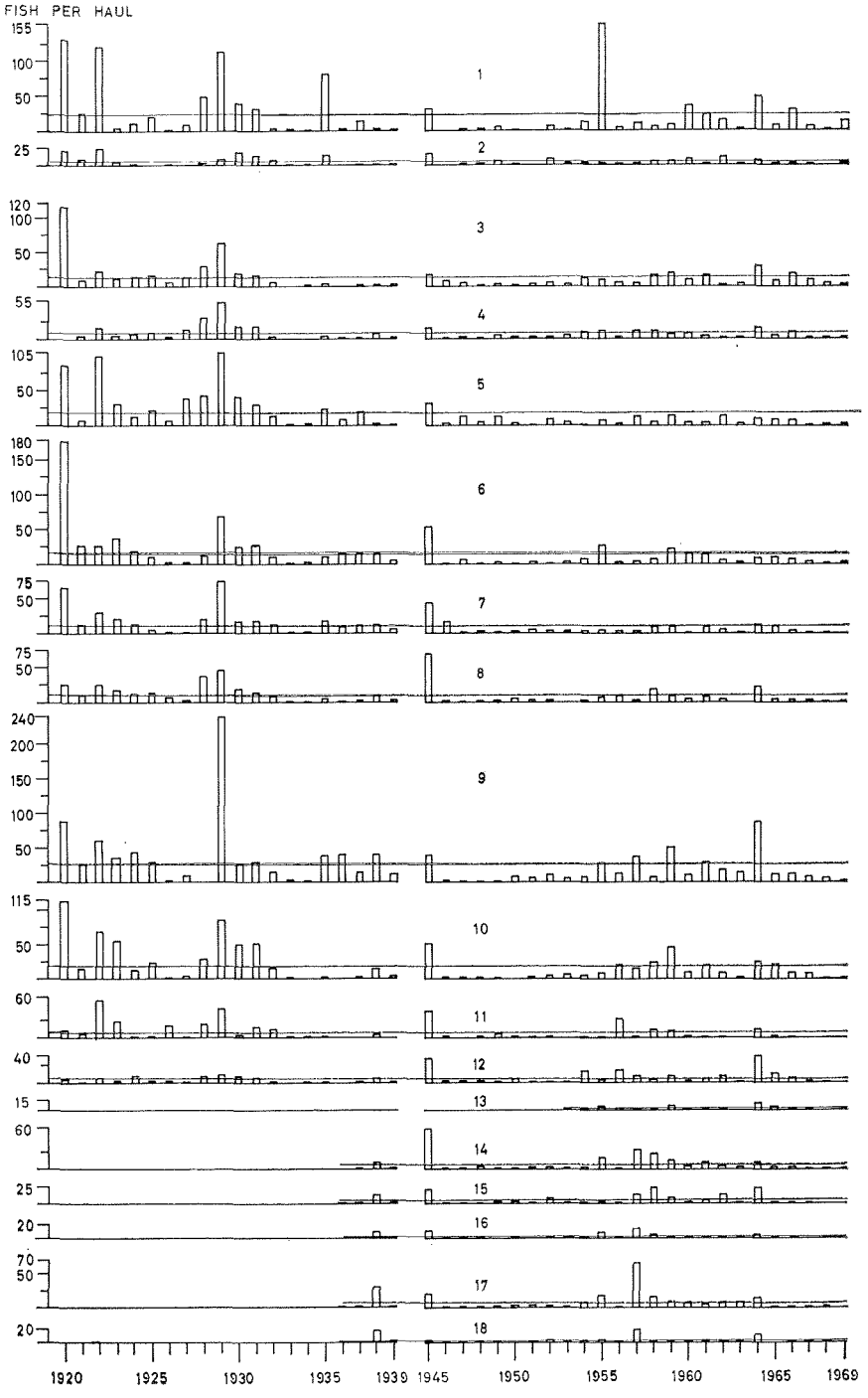

Fig. 3. 0-group pollack per seine haul in the different districts. Average catch for each district is indicated. Districts numbered as in Fig. 1.

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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