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# Estimation of the Brood-Strength-Fluctuations in the Cod in the Barents Sea Area

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The fluctuation in the Arcto-Norwegian stock of cod has been the subject of intensive investigations (Sund, Rollefsen and others). These investigations have been based mainly on observations of the mature part of the stock: the skrei. It is, however, of considerable interest to extend such investigations to younger age-groups.

Besides the Lofoten fishery we have another Norwegian seasonal cod fishery: the spring-cod fishery in Finmark during the months April to June. By an analysis of length measurements from a series of years Sund has shown that this fishery is based on the immature part of the Arcto-Norwegian cod population.

That the skrei and the spring-cod belong to the same population can also be shown by comparing the yield-per-effort curves of the two fisheries. Figure 1 shows that there is a difference of 3 to 4 years in the fluctuations of the two curves. This is in accordance with the difference in average age of the spring-cod and the skrei.

The age-distribution of samples of cod from the spring-cod fishery is influenced by a number of factors, the most important of which are probably the following four:

1) The selection when sampling the catches
2) The selection by the gear used
3) The rate of mortality and maturity in the spring-cod population
4) The recruitment of the various year-classes to the shoals of spring-cod migrating to the Finmark area.

The selection by sampling can be excluded by sampling total catches when this is possible.

The dominating gear in the spring-cod fishery is the long-line. The selective effect of this gear is probably one of size only. Figure 2 shows typical length-distribution curves of catches taken by trawl and by long-lines at the Finmarken banks in May 1953. Probably neither of these represent the true length-distribution of the population, but we may assume that the trawl-catch gives us by far the best idea of it. For the purpose of determining the brood-strength variations it is, however, not necessary to know the true size- or age-distribution of the population. If the selective effects of the different gears are always the same, it is sufficient to compare catches from the same gear. The selectivity of the long-lines in respect of fish size is probably constant. But if the size/age - relationship in the population changes, the selectivity of the long-lines with respect to age will also change. Such changes can, however, be detected by means of growth studies.

Changes in the mortality and age at first maturity may undoubtedly lead to significant changes in the age-distribution. Nothing is known of the mortality rate at present, but the age at first maturity can be determined in Lofoten.

Regarding point 4) it must be/ presupposed that the recruitment to the spring-cod population occurs according to a definite law as a fairly constant percentage of each age-group of the total cod population, and consequently is proportional to the strength of the various year-classes.

Several other factors may influence the age-distribution. For instance, there seems to be a selection with depth as catches from shallower waters usually contain a higher proportion of younger fish than those from deeper waters. This especially concerns the three- and four-year-old fish, and these age-groups have been omitted in the following calculations.

It must also be mentioned that in the spring-cod catches there is always some intermingling of skrei returning from the spawning migration. These mature fish, can, however, be removed from the material if the state of the gonads is observed.

This reasoning leads to the conception of an average "normal" age-distribution of the spring-cod, influenced mainly by changes in the rate of mortality and maturity. By comparing each year's age-distribution with the average distribution for a series of years it is possible to get an estimate of the strength of each year-class in relation to the adjacent ones, that is, an estimate of the fluctuations above and below the average strength of the year-classes in these years. A change in this average can not be observed unless the relative strength of the year-classes can be related to the yield and the fishing intensity in the corresponding years.

The yield of the spring-cod fishery is known. The fishing intensity is a variable that is dependent upon the number of fishermen engaged in the fishery, the gears and methods used, the weather conditions, and probably several other less important factors, the influence of which we have no means of evaluating. The influence of the weather conditions has been omitted in this preliminary investigation. The gears and methods can be considered as being constant in the relevant period. However, in the latest years the trawl has been introduced as a new gear in this fishery, and an increasing use of this apparatus may complicate future calculations. In the following calculation the number of fishermen has been used as a measure of the fishing intensity; and accordingly, the yield per fisherman, as a measure of the abundance.

The first period of age-observations covers the years 1934 to 1939 and comprises a total of 2361 observations. Table 1 shows the yield in kilos per fisherman of each year-class in the age-steps 5 to 10 years and the average yield of each age-group in the years 1934 to 1939. Furthermore, Table 1 shows the total yield of each yearclass as a percentage of the sum of the average yield in the corresponding age-groups. Rollefsen has for a series of years used a similar method in evaluating the brood-strength-fluctuations in the skrei population in Lofoten. For comparison his data are listed in Table 1. The two sets of data cover the same year-classes, but the calculations are not based on corresponding average and are, therefore, not directly comparable. A more independent expression of the mere fluctuations of the year-classes can be formed by calculating the quotients between each year-class and the preceding one. These quotients (listed in Table 1) show that the year-classes 1929 to 1932 fluctuate in almost exactly the same way in the two sets of data.

Such close agreement is a strong indication that our observations of the fluctuations in the strength of the year-classes 1929 to 1932 are reliable both in the Lofoten and in the Finnmarken material. That the strength of these year-classes, when related to the respective averages used, are not the same, can be explained by the fact that the averages, as has been mentioned before, do not correspond. In the Lofoten material each of the year-classes has been observed during six years, while in the Finnmarken material the observational period varies from one to six years.

In order to facilitate the comparison, one of the "reliable" year-classes 1929-1932 can be used as a common standard. In Table 1 the strength of the 1930-year-class in the Finnmarken data has been made equal to the Lofoten observation and the rest of the Finmarken data recalculated in accordance with this. The results is illustrated in Figure 3. The year-classes 1929 to 1932 agree closely, while as a whole the "Finnmarken year-classes"1924 to 1928 are smaller than those from 1933 and 1934 are larger than the "Lofoten ones". The lack of agreement is in itself not unexpected, because the number of Finnmark, observations of these year-classes are small. The tendency of the disagreement is more difficult to explain. The relative underrating of the earliest year-classes in Finmark may be caused by a change in age at first maturity. According to Rollefsen the average age at first maturity of the Lofoten skrei increased abt. 1/2 to 3/4 year in the years 1938 to 1940. The overrating of the latest year-classes may actually be a sort of underrating of the same year-classes in Lofoten, caused by an increased mortality in the stock of spring-cod, possibly as a result of the heavy increase in the trawl fishery in these years.

There is also some information on line-caught cod from the Spitsbergen-banks: a total of 3915 observations covering the years 1937 to 1939. This material has been treated in the same way as that from Finnmarken, but as the fishing intensity in this area was unknown, no measure of abundance has been used when calculating the strength of the year-classes. Table 1 shows the strengths of the year-classes as percentages of the average 1937 to 1939 and, for comparison with the Lofoten material, recalculated with the 1930 year-class equal to the Lofoten 1930-year-class. The result is illustrated in Figure 3. In the case of the year-classes 1928 to 1931 there is seen to be a fair agreement between the calculations from Lofoten and Finmark.

It thus seems possible to obtain a true picture of the relative strength of the year-classes from observations taken in the feeding area of the Arcto-Norwegian cod population. Besides having a sufficient number of age-observations, it will be necessary to observe those factors which, in addition to the strength of the year-classes, may influence the age-distribution of the samples, such as growth rate, mortality rate and age at first maturity.

As the spring-cod fishery provides us with an approximate measure of abundance, observations from this fishery seem to be best suited for these calculations. But material from the trawl fishery from all the different fishing banks in the area may, besides its specific value, also be of great help in the evaluation of the brood-strength variations. For the last few years such material has been collected by the research ship "G.O.Sars", and this sampling will be continued in addition to the sampling from the spring-cod fishery.

As an appendix will be mentioned the preliminary results of the brood-strength calculations which are based on observations from the spring-cod fishery in the years 1949, 1950, 1952 and 1953 (see Figure 4). It must, however, be emphasized that, due to the insufficient material, the columns in Figure 4 only give an indication of the relative strength of the year-classes, especially in the cases of the year-classes 1939 to 1941 and 1946 to 1948.

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Fig. 1. The yield of the spring cod fishery in tons per man and the Lofoten fishery in number of fish per man.

Fig. 2. Length distributions of catches from trawl and from long-lines. Finnmarken May 1953.

Fig. 3. Relative strength of the yearclasses 1924 to 1934 as observed in Lofoten 1932-1947, in Finnmarken 1934-1939 and at Spitsbergen 1937-1939, cf. Table 1.

Fig. 4. Indication of the relative strength of the yearclasses 1939 to 1948 as observed in the spring cod fishery in 1949, 1950, 1952 and 1953. Black columns denote most reliable observations.

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## Table 1.

Spring cod fishery. Yield in kilos per fisherman of each year-class at the available ages in the interval 5 - 10 years, and the total yield as per cent of the average in the years 1934-1939 compared with observations from Lofoten (Rollefsen) and Spitsbergen.

| Finnmark. Yield in kilos per fisherman | | | | | | | Finnmark 5-10 years | | Lofoten 8-13 years | | Finnm. recalc. 1930 equal | Spitsbergen 4-11 years | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year /Age class | 5 | 6 | 7 | 8 | 9 | 10 | % of average | Quot. 1925 1924 etc. | % of average | Quot. | | % of average | 1930 equal |
| 1924 | | | | | | 8 | 16 | 2,32 | 34 | 1,18 | 18 | | |
| 1925 | | | | | 39 | 44 | 37 | 1,22 | 40 | 2,00 | 41 | | |
| 1926 | | | | 187 | 63 | 32 | 45 | 0,91 | 80 | 1,25 | 50 | | |
| 1927 | | | 233 | 165 | 80 | 43 | 41 | 1,98 | 100 | 1,16 | 46 | 28 | 35 |
| 1928 | | 428 | 342 | 509 | 173 | 71 | 81 | 1,64 | 116 | 1,29 | 90 | 81 | 101 |
| 1929 | 373 | 488 | 1177 | 471 | 313 | 105 | 133 | 1,22 | 150 | 1,21 | 149 | 129 | 161 |
| 1930 | 495 | 1001 | 909 | 754 | 346 | | 162 | 0,44 | 181 | 0,48 | 181 | 145 | 181 |
| 1931 | 64 | 374 | 664 | 322 | | | 72 | 0,93 | 78 | 0,95 | 80 | 58 | 72 |
| 1932 | 128 | 360 | 579 | | | | 67 | 2,31 | 74 | 1,62 | 75 | 98 | 122 |
| 1933 | 417 | 1029 | | | | | 155 | 0,93 | 120 | 0,94 | 173 | 90 | 112 |
| 1934 | 466 | | | | | | 144 | | 113 | | 161 | 120 | 150 |
| Average | 324 | 613 | 651 | 401 | 169 | 51 | | | | | | | |

Average sizes within the market categories and whole landings and average sizes of 50% selection 1929 - 1938.

| | mark.cat. I | | 50% select. | | mark.cat. II | | 50% select. | | mark.cat. III | | 50% select. | | mark.cat. IV | | whole landings | | 50% mark. selection | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm. | kg. | cm. | kg. | cm. | kg. | cm. | kg. | cm. | kg. | cm. | kg. | cm. | kg. | cm. | kg. | cm. | kg. |
| Gadus callarias (S | 83,0 | 4.94 | 73,8 | 3,7 | 63,7 | 2,23 | 59,5 | 1,9 | 41,0 | 0,62 | ←—— | | 35,1 | 0,37 | 49,1 | 1,48 | 34,2 | 0,33 |
| (N | 87,6 | 4,98 | 78,7 | 3,7 | 68,2 | 2,33 | 56,8 | 1,3 | 57,5 | 1,23 (extra large 115 12) | | | | | 78,2 | 3,63 | 45,6/60,0 | 1,2/2,0 +) |
| " aeglefinus (S | 59,9 | 1,69 | 56,5 | 1,46 | 51,7 | 1,05 | 52,3 | 1,18 | 43,5 | 0,66 | 43,5 | 0,67 | 38,1 | 0,43 | | | | |
| ( | | | | | | | market category V: | | | | 37,6 | 0,43 | 29,6 | 0,19 | 30,5 | 0,23 | 22,5 | 0,10 |
| (N | 68,5 | 2,66 | 62,9 | 2,28 | 58,5 | 1,60 | 50,1 | 1,17 | 47,6 | 0,92 | 40,1 | 0,58 | 39,5 | 0,49 | 58,5 | 1,82 | 38,3 / 42,2 | 0,51/0,64 +) |
| " merlangus (S | 42,0 | 0,56 | ——→ | | 32,8 | 0,26 | - | - | - | - | - | - | - | - | 33,7 | 0,29 | 23 | 0,08 |
| (N | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 46,4 | 0,80 | 45,0 | 0,69 |
| " virens | 85,0 | 4,48 | 75,2 | 3,24 | 68,2 | 2,11 | - | - | - | - | - | - | - | - | 80,9 | 3,91 | 45 | 0,8 |
| " pollachius | 72,1 | 2,62 | 66,1 | 2,5 | 57,6 | 1,47 | 57,8 | 1,40 | 50,6 | 1,18 | - | - | - | - | 65,5 | 2,02 | " | " |
| Molva molva | 105,4 | 5,69 | 70,5 | 1,7 | 57,7 | 1,11 | ←—— | | 55,8 | 0,84 | - | - | - | - | 94,3 | 4,52 | > 50 | 0,8 |
| " byrkelange | 99,3 | 3,46 | 64,9 | 0,71 | 59,6 | 0,76 | - | - | - | - | - | - | - | - | 93,5 | 2,88 | > 60 | 0,7 |
| Merluccius merl. | 88,4 | 3,43 | 82,7 | 3,8 | 70,3 | 2,02 | 68,1 | 2,2 | 51,1 | 0,92 | - | - | - | - | 58,0 | 1,26 | 35 | 0,3 |
| Brosmius brosme | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 59,6 | 2,02 | 40 | 0,7 |
| Sebastes marinus | 45,2 | 1,35 | 36,5 | 0,72 | 35,8 | 0,62 (S.vivipar; | | | 25,8 | 0,31 | (extra large; | | 70,4 | 5,12 | 41,2 | 1,28 | 32,4 | 0,54 |
| Anarrhichas lupus (S | 69,2 | 2,71 | 61,1 | 1,81 | 47,7 | 0,93 | - | - | - | - | - | - | - | - | 62,0 | 1,73 | 38 | 0;4 |
| + minor (N | 87,7 | 5,55 | 67,6 | 2,49 | 62,5 | 1,78 | - | - | - | - | - | - | - | - | 70,5+89,6 | 2,4+2,6 | 50 | 1,0 |
| Lophius piscatorius | 95 | 4,1 | 68 | 3,3 | 64 | 3,0 | ←—— | | 44 | 1,0 | - | - | - | - | 79 | 3,8 | 40 | 0,8 |
| Cyclopterus lumpus | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 44,0 | 3,61 | - | - |
| Trigla gurn. + corax | occasionally category "large" mainly with Tr.corax | | | | | | | | | | | | | | 28,3 | 0,20 | 20 | 0,08 |
| Trachinus draco | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 26,3 | 0,11 | 20 | 0,08 |
| Pleuronectes (S | 47,9 | 1,12 | 50,7 | 1,23 | 40,8 | 0,67 | 40,1 | 0,55 | 33,7 | 0,38 | 33,7 | 0,35 | 26,5 | 0,20 | | | | |
| ( | market category V: | | | | 23,2 | 0,13) | living plaice mostly cat.IV; | | | | | | 25,9 | 0,16 | 27,8 | 0,21 | 24,5 | 0,14 |
| platessa (N | mark.cat.III: | | | | 49,5 | 1,30 | 44,9 | 1,03 | mark.cat. III/IV; | | | | 35,1 | 0,43 | 37,5 | 0,58 | 28 | 0,28 |
| " limanda | 31 | 0,29 | - | - | 24 | 0,15 | - | - | - | - | - | - | - | - | 25,0 | 0,16 | 22 | 0,14 |
| " flesus | 38,9 | 0,56 | 35,7 | 0,44 | 31,6 | 0,30 | 29,9 | 0,27 | 27,4 | 0,21 | - | - | - | - | 30,6 | 0,30 | 24 | 0,15 |
| " cynoglossus | 45,2 | 0,60 | 44,7 | 0,59 | 39,4 | 0,38 | 37,4 | 0,31 | 32,6 | 0,20 | - | - | - | - | 37,3 | 0,35 | 24,0 | 0,07 |
| " microcephalus | 37,9 | 0,56 | 35,0 | 0,49 | 30,6 | 0,32 | - | - | - | - | - | - | - | - | 35,0 | 0,49 | 24 | 0,16 |
| Solea vulgaris | 35,5 | 0,39 | 36,0 | 0,44 | 30,2 | 0,24 | 30,0 | 0,24 | 27,5 | 0,16 | 25,5 | 0,14 | 24,3 | 0,12 | 30,9 | 0,25 | 25 | 0,13 |
| Drepanopsetta plat. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 42,0 | 0,72 | 35 | 0,6 |
| Lepidorhombus whiff. | 48,8 | 0,87 | 44,2 | 0,68 | 35,6 | 0,38 | - | - | - | - | - | - | - | - | 36,4 | 0,48 | 25 | 0,12 |
| Hippoglossus hippogloss. | 176,8 | 38,5 | 117,5 | 18,2 | 82,5 | 6,14 | 73,1 | 3,7 | 58,5 | 1,98 | 50,8 | 1,20 | 44,3 | 1,05 | 67,9 | 3,24 | 30 | 0,31 |
| Reinhardtius hippogloss. | similar to the foregoing | | | | | | | | | | | | | | 58,8 | 2,19 | " | " |
| Scophthalmus maxim. | 64,9 | 6,10 | 51,0 | 2,6 | 52,5 | 2,50 | 47,3 | 2,0 | 43,8 | 1,62 | 42,0 | 1,4 | 36,9 | 1,22 | | | | |
| | | | | | | (market category V: | | | | | 30,8 | 0,65 | 28,4 | 0,34) | 46,8 | 2,22 | 24 | 0,27 |
| Rhombus laevis | 55,1 | 2,48 | 50,8 | 1,86 | 45,5 | 1,32 | 39,3 | 0,90 | 31,3 | 0,39 | 35,9 | 0,66 | 27 | 0,25 | | | | |
| | | | | | | (market category V: | | | | | ←—— | | 23 | 0,15) | 40,8 | 0,78 | " | " |
| Scomber scombrus | 40 | 0,6 | 37 | 0,4 | 33 | 0,24 | ←—— | | 28 | 0,13 | " | - | - | - | 32,2 | 0,26 | - | - |
| Orcynus thynnus | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 261 | 230 | - | - |
| Raja ssp. | 104,9 | 5,67 | 92,0 | 4,39 | 84,6 | 3,20 | - | - | - | - | - | - | - | - | 90,6 | 3,78 | 50-75 | 0,9 - 2,5 |
| Acanthias vulg. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 67,4 | 0,86 | 40-60 | 0,17- 0,6 |
| Isurus cornubicus | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 217 | 80 | - | - |

S = Southern region, mainly North Sea.

N = Northern regions.

An arrow means that one market category not extends beyond the size range of the neighbouring one.

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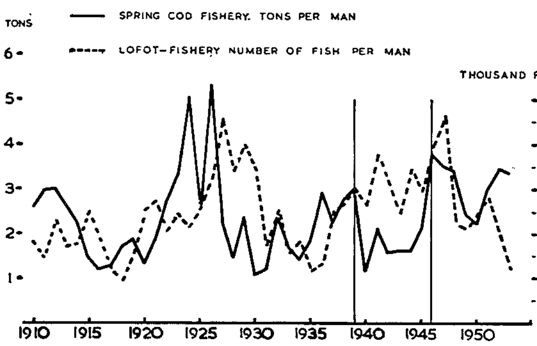


Fig. 1.

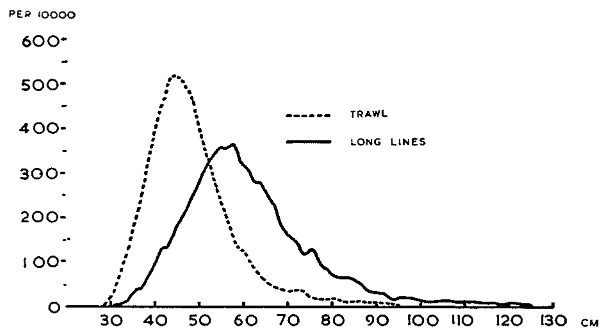


Fig. 2.

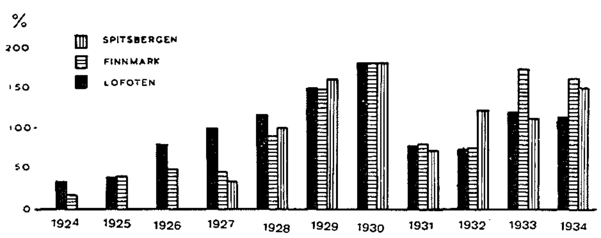


Fig. 3.

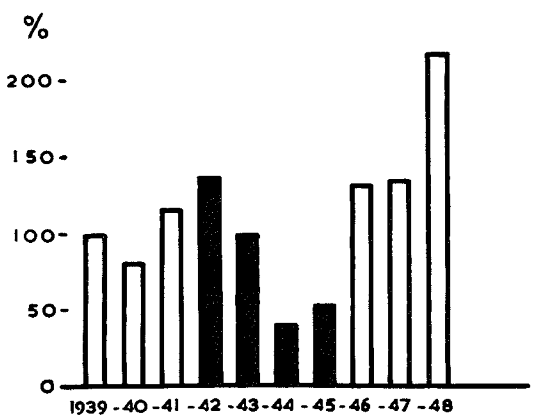


Fig. 4.