International Council for
the Exploration of the Sea.

C.M. 1961.
Herring Symposium
No. 43.

# Catch, Effort and Composition of the Norwegian Winter Herring Fishery

by

O.J.Østvedt

Institute of Marine Research, Bergen.

The Norwegian winter herring fishery is based on pre-spawning and spawning concentrations of Atlanto-Scandian herring along the Norwegian west coast in January, February and March.

Throughout its history the fishery has been characterized by short and long term fluctuations. Devold ( 1961 ) has given a review of the long term fluctuations and has shown how these may be explained by changes in the migration pattern of the herring, a theory which perhaps may be verified in the present century.

The aim of the present paper is to describe the changes in catch and effort in the Norwegian winter herring fishery during the postwar period and to discuss the causes of the declining catches after 1957.

When sampling to obtain age and length data from the winter herring fishery began in 1907, Hjort ( 1914 ) was able to show that the size of the year-classes varied widely. According to Lea ( 1930 ) the difference in numerical strength of the year-classes could be as much as one to one hundred. One rich year-class ( e.g. that of 1904 ) could increase the yield of the fishery and dominate the catches for several years. From these results it was concluded that fluctuations in the yield of the herring fisheries is caused by natural variations in size of the Year-classes.

In analysing age data from the winter herring fishery the prespawning ( "Large Herring" ) and the spawning ( "Spring Herring" ) have often been treated as separate stocks ( Runnstrøm, 1941 ). The results of the herring investigations ( age, growth, vertabrae counts and tagging experiments ) during the last decade and also the recent changes in the migration pattern, confirm that the Norwegian winter herring fishery is exploiting one single stock.

## Catch and effort

Figure 1. shows the total catch of Atlanto-Scandian herring in the Norwegian Sea ( including the east and north coasts of Iceland ) since 1925. Because the catches of herring in these areas mainly consist of adult herring, the figures should be fairly representative for the total exploitation of the adult stock of Atlanto-Scandian herring. In the post-war period the catches have increased rapidly to approximately twice the pre-war level. Until 1958 the Norwegian catch dominated, but it has since decreased to less than 50 % of the total catch. This reduction in the yield of the herring fishery in Norway is due to the failing winter herring fishery only. The landings from the Norwegian herring fishery off Iceland have even increased the last years, and in 1960 the catch was about 0.7 million hl. or the same as the output from the winter herring fishery in 1961. This year the catch of summer herring is expected to reach about 1.0 million hl.

The catch data from the winter herring fishery for the years 1925-61 are given in Table 1. The numbers have been calculated from the age and weight composition. Since the composition of the catches changes during the season it was found necessary to split the data and calculate the number of herring landed in periods of two weeks. The older spawners appear early in the season and leave the spawning grounds before the recruit-spawners. At the end of the season the catches may consist exclusively of recruit-spawners.

The peak catch before 1940 was reached in 1938 with 5.3 million hl. After 1947 the catches showed an increasing trend until 1956 with a top catch of

12.3 million hl. Since 1957 the catches have declined rapidly, amounting to only 0.7 million hl. in 1961.

The gears used in the winter herring fishery are gill-net, purse-seine and land-seine. Table 2. shows the catch statistics for the different gears since 1925. The catch for drift-nets in the Table also includes the catch by set-nets, in the pre-war period the total landings by drift-net were always larger than the landings by purse-seine. After 1946 the landings by purse-seine increased rapidly, and in 1956 70.8 % of the herring catch was landed by this gear. During the last years the land-seine have been of minor importance.

A crude effort statistic for the winter herring fishery is given in Table 3. For the purse-seine fishery the number of vessels seems to be the best measure of fishing effort available. Im the season of 1957, the year after the record catch, 599 purse-seiners participated in the fishery, but the number has dropped to only 254 in 1961. Figure 2. shows the catch by purse-seine plotted against the number of vessels. It appears that until 1956 the catch increased with increasing effort. After 1957 however, the available population has shifted to a much lower level.

The number of drifter has decreased since 1950, from 2032 to only 789 in 1961. During the 1950's several drifters changes to purse-seine, but the reduction during the last years in due to the small catches. Figure 3. shows the catch by drift-net plotted against the number of vessels and indicates that the available population in the years 1954-57 have been larger than the average for the period 1946-60. In the drift-net fishery there is a large variation in fishing intensity and fishing power of the vessels. It has therefore been supposed that the number of landings would give a best measure of effort. The number of landings has been calculated from the mean catch per day per vessel from information given by approximately 20-25 % of the fleet. It is stressed however, that the number of landings is not always identical with the number of shots. During the last seasons when the catches have been small, one landing may have included catches from two or more shots.

Since 1946 there has also been a rapid growth in fishing efficiency, for purse-seiners as well as for drifters, due to technical advances in gear and in fish location methods. Thus, in 1946 less than 10 % of the fleet was fitted with echo-sounders, while to-day almost every vessel has an echo-sounder and nearly all the purse-seiners have an ASDIC in addition. The fishing efficiency therefore must be higher in 1960 than it was in 1946. It is difficult, if not impossible however, to adjust for this increasing efficiency.

## Catch per unit effort

Figures 4 and 5. show the catches in hl, number of herring and number of herring per unit effort by purse-seine and drift-net respectively. As previously mentioned, the catches by purse-seine increased rapidly after 1946 and in 1954-56 the catches were on an average, four times the pre-war level ( 1935-40 ). The catches per unit effort ( number of vessels ) show that the large increase in the total landings by purse-seine mainly was an effect of increased effort.

The drift-net landings also increased after 1947 compared with the pre-war level, but they do not show an increasing trend in the fifties. As figure 5. indicates, the number per landings shows only small variations. However, both sets of data of catch per effort for purse-seine and for drift-net agree in showing a relatively high level in 1948 and 1950, a slight decrease in 1951-53, an increase in 1954-56 and after 1957 a definite declining trend.

If the estimated catch in numbers per unit effort is used as an abundance index, it seems that the stock available to the fishing fleet for the last four years has been considerably reduced. The purse-seine catch per effort shows a reduction to about one fifth of the 1954-56 level, while the drift-net data show a reduction to only one-half. It is likely that the true value of the reduction in stock abundance from 1954-56 lies between these two estimates.

## Estimation of total mortality

The age-composition for the years 1946-60 are shown in Tables 4 and 5. as number per vessel for the purse-seine fishery and as number per landing for the drift-net fishery. These Tables list a few immature fish which occasionally occur in the catches, mainly as two, three or four years old. Since the samples for age have been collected mainly from the purse-seine catches all samples had to be lumped together irrespective of the gear used. This infers that the

estimated age-composition for the drift-net catches are slightly biased, giving larger numbers of the younger age groups, mainly immature herring which usually not is retained by the drift-net. The numbers grouped under " ? " in the Tables are herring with regenerated scales or scales which could not be used for age determination. This group have a higher mean length than the rest of the samples, showing that it is dominated by herring from the older age groups.

Individuals from one year-class may attain maturity at an age between three and nine years. Only older age groups which are fully recruited should therefore be used for estimation of mortality rates. However, this difficulty is avoided by using the spawning-group composition. In the spawning-group composition the variation in year-class strength is diminished because each spawning-group consists of several different year-classes. In Tables 6 and 7 are given the spawning-group composition as number per unit effort for purse-seine and for drift-net.

Table 8. shows the estimated total instantaneous mortality coefficients from the data in Tables 4 to 7 for each year-class and spawning-class in successive years of life between 1946 and 1960. For comparison the mortality coefficients for the age groups seven to twelve years are also included in the Table.

There is a large variation in the values of the mortality coefficients. The value for the spawning-groups II/III are often negative or very small, while the values for the I/II group are unexpectedly large. It has always been noticed that the number of second time spawners in the samples are small compared with the number of I. and III. spawners. So far it has not been possible to deduce whether the small numbers of II. spawners should be attributed to misinterpretation of the spawning rings on the scales or if the II. spawners are less available to the fishing fleet due to a migration pattern different from the other groups.

It appears from Table 8. that during the period 1946 to 1960 the estimated total instantaneous mortality coefficients have fluctuated widely. In some years there is also a larg difference in the estimated values for purse-seine and drift-net. For the years 1949/50 and 1953/54 the mortality coefficients are negative or nought for both gears. It is known from fishery reports that the availability was high in 1950 and 1954. In 1950 the fishing was stopped for one week because of insufficient capacity of the herring meal-and oil factories.

In 1957 and 1958 the availability was low, due to late arrival of the herring and shifting to more northern spawning grounds. In addition, the weather was very stormy and especially unfavorable for the purse-seine fishery. The estimated values of mortality coefficients also show a much larger value for the purse-seine than for the drift-net.

The mortality coefficients for the age groups shown in Table 8, are much smaller in value than the corresponding values for the spawning groups. This result may be expected if some of the age groups involved have not been fully recruited.

The variations in the mortality coefficients from year to year may be diminished by grouping the data. The number per effort in Tables 6 and 7. have been grouped in three periods; 1946/50, 1951/55 and 1956/60. Figure 6 shows the logarithm of the numbers plotted against spawning-group number. The slope of the line fitted to the plots for the period 1956/60 gives an estimate of 0.25 as the total mortality coefficient. The plots of the first period (1946/50) fall on about the same line, while the plots for the period 1951/55 show an increase of the older spawning groups. This may have been caused by the rapid increase in efficiency of the fishing effort which may give larger catches per unit effort than those obtained in the preceding years.

The estimated total mortality coefficients shown in Table 8. and Figure 6 do not suggest any change in total mortality since 1946. The increase in total mortality caused by higher effort in the 1950's may have been to small to be calculated from the present data due to the large fluctuations in availability.

Recruitment

Since 1946 only four year-classes with above averagge abundance have entered

the winter herring fishery. These are the year-classes 1943, 1944, 1947 and 1950.

The total number per unit effort in the life-span of a year-class should give an estimate of the numerical strength of the year-class, provided the unit of effort has not changed considerably during the period. Table 9. shows the total sum of the numbers per unit effort for the age groups 2-10 years of the year-classes 1943 to 1951. Because of the increasing efficiency the youngest year-classes are probably overestimated. The data show that the ratio between the smallest and the largest year-class, 1949 and 1950 repectively, is one to fifteen. The year-classes 1943 and 1944 give a ratio of about one to one, but give a ratio of about one to two when compared with the 1950 year-class.

As mentioned above the year-class 1950 has dominated the fishery since 1954 and even in 1961 accounted for nearly 60 % of the catch.

It appears from Tables 6 and 7. that since 1957 the recruitment has been low. In 1960 less than 3 % of the spawning stock were recruit-spawners compared with 34 % recruit-spawners in 1955. Since 1946 there have been two periods with high recruitment, 1948-49 and 1954-57. In the first period the year-classes 1943 and 1944 were recruited, while in the last period the 1950 year-class dominated.

A rich year-class usually has a wider range of age at first spawning than a poor year-class. The 1950 year-class thus made up a substantial part of the recruit-spawners even in 1958 and 1959. The year-classes subsequent to 1945 have showed an increasing mean age at their first spawning, while the mean age had decreased for all the year-classes after 1934 ( Øtsvedt, 1958 ). The 1950 year-class had a mean age at first spawning of 7.7 years for herring of the northern growth type compared with 5.1 for the 1945 year-class. This explains the large number of recruit-spawners in 1957.

As shown in Tables 6 and 7. the reduction in numbers per effort since 1957 has been much greater for the recruit-spawners than for any of the other spawnings groups. Figure 7. shows the relationship of catch of recruits per effort on total catch per effort for purse-seine and drift-net. When we compare the figures for the two gears it can be seen that there is a significant difference, with the purse-seine fishery showing a high relationship between catch of recruits and total catch. Thus it seems that the recruit-spawners are more available to the purse-seiners than are the other spawning groups. A possible explanation might be due to difference in schooling behaviour and migration to more sheltered waters. For the drift-net fishery the gear selection may reduce the catches of recruit-spawners. A consequence of this is that high catches for the purse-seine fishery can only be expected in years with high recruitment. If this holds true it explains the much greater decline in catch per effort for the purse-seine fishery as compared with the drift-net fishery ( Figures 4 and 5). An index of stock abundance of the purse-seine fishery based on catch per effort will therefore tend to be greater in years with high recruitment and lower in years with low recruitment.

The year-classes 1951 to 1956 which until 1960 were recruited to the winter herring fishery are all very small. Echo-surveys along the Norwegian coast and in the Barents Sea have indicated that the 1957 and 1958 year-classes are below average in size, while the 1959 year-class may be above average (Dragesund, 1961). It is therefor expected that recruitment will also be low in the 1962 season.

## Conclusion

The above data indicate that increasing catches per unit effort in the winter herring fishery usually coincide with the recruitment of rich year-classes to the spawning stock.

During the last four years the recruitment has been very low due to a series of year-classes which are below average in size. It seems fair to conclude therefore that the declining catches of winter herring mainly resulted from depletion of the spawning stock, because of low recruitment and not because of higher mortality rates due to increased effort.

In the last years the pattern of migration has changed, causing late arrival of the herring and a shifting to more northern spawning grounds. This changes have undoubtedly reduced the availability and have therefore accelerated the reduction in the catches of winter herring.

The recent long series of small year-classes may have been due to the shifting to other spawning grounds which may have been less favorable to the broods.

## References


Devold, F., 1961, The life history of the Atlanto-Scandian herring. Herring symposium, contrib. No. 40.

Dragesund, O., 1961. Norwegian immature herring investigations in 1959. Ann.biol., Copenhague,16 (1959): 170-171.

Hjort,J., 1914. Fluctuations in the great Fisheries of Northern Europe. Rapp. Cons. Exlor. Mer., 20.

Lea, E., 1930. Mortality in the tribe of the Norwegian herring. Rapp. Cons. Explor. Mer., 30: 100-117.

Runnstrøm,S.1941. Racial analysis of the herring in Norwegian waters. Rep. Norw. Fish. Invest. 6(7) : 1-110.

Østvedt,O.J. 1958. Some consideration concerning the homogeneity of the Atlanto-Scandian herring. Rapp.Cons. Explor. Mer., 143(2) : 53-57.

Table 1. Norwegian Winter Herring. Total catch, 1925 - 61.

| Year | Hl. Thousands of hl. | Tons. | Numbers Millions of herring. |
|---|---|---|---|
| 1925 | 2503 | 250 263 | - |
| 26 | 2550 | 254 980 | - |
| 27 | 2817 | 281 776 | - |
| 28 | 3006 | 300 642 | - |
| 29 | 3435 | 343 532 | - |
| 1930 | 4750 | 474 973 | - |
| 31 | 3054 | 305 446 | - |
| 32 | 3648 | 364 799 | - |
| 33 | 3298 | 329 835 | - |
| 34 | 1108 | 110 771 | - |
| 35 | 4312 | 401 012 | - |
| 36 | 5196 | 483 227 | - |
| 37 | 3430 | 318 981 | - |
| 38 | 5338 | 496 428 | - |
| 39 | 4435 | 412 426 | - |
| 1940 | 4400 | 409 220 | - |
| 41 | 2306 | 214 475 | - |
| 42 | 2725 | 253 404 | - |
| 43 | 2456 | 228 419 | - |
| 44 | 3227 | 300 085 | - |
| 45 | 3759 | 349 600 | - |
| 46 | 3846 | 357 633 | 1302 |
| 47 | 5315 | 494 270 | 1755 |
| 48 | 8813 | 819 583 | 3130 |
| 49 | 6103 | 567 467 | 2251 |
| 1950 | 8294 | 771 306 | 2999 |
| 51 | 9548 | 888 006 | 2880 |
| 52 | 8822 | 820 471 | 2614 |
| 53 | 7205 | 670 084 | 2096 |
| 54 | 11744 | 1092 230 | 3554 |
| 55 | 10381 | 965 413 | 3559 |
| 56 | 12321 | 1145 859 | 3960 |
| 57 | 8555 | 795 582 | 2906 |
| 58 | 3713 | 345 294 | 1144 |
| 59 | 4477 | 416 360 | 1278 |
| 1960 | 3227 | 300 111 | 921 |
| 61 | 742 | 69 006 | - |

Table 2. Norwegian Winter Herring. Catch by years, 1925-61.

| Year | Purse - seine | | | Drift - net | | | Land - seine | |
|---|---|---|---|---|---|---|---|---|
| | Hl. Thousands of Hl. | Numbers Millions of herring. | % of total catch. | Hl. Thousands of Hl. | Numbers Millions of herring. | % of total catch. | Hl. Thousands of Hl. | % of total catch |
| 1925 | 450 | - | 18.0 | 1755 | - | 70.1 | 298 | 11.9 |
| 26 | 529 | - | 20.8 | 1607 | - | 63.0 | 414 | 16.2 |
| 27 | 595 | - | 21.1 | 2031 | - | 72.1 | 191 | 6.8 |
| 28 | 790 | - | 26.3 | 1656 | - | 55.1 | 560 | 18.6 |
| 29 | 1268 | - | 36.9 | 1210 | - | 35.2 | 597 | 27.9 |
| 1930 | 1600 | - | 33.7 | 2235 | - | 47.0 | 915 | 19.3 |
| 31 | 1308 | - | 42.8 | 1302 | - | 42.7 | 444 | 14.5 |
| 32 | 1462 | - | 40.0 | 1593 | - | 43.7 | 593 | 16.3 |
| 33 | 1509 | - | 45.8 | 1083 | - | 32.8 | 706 | 21.4 |
| 34 | 289 | - | 26.1 | 773 | - | 69.7 | 46 | 4.2 |
| 35 | 1898 | - | 44.0 | 1602 | - | 37.2 | 812 | 18.8 |
| 36 | 2349 | - | 45.2 | 1719 | - | 33.1 | 1128 | 21.7 |
| 37 | 1293 | - | 37.7 | 1971 | - | 57.5 | 166 | 4.8 |
| 38 | 2180 | - | 40.8 | 2797 | - | 52.4 | 361 | 6.8 |
| 39 | 1797 | - | 40.5 | 2460 | - | 55.5 | 178 | 4.0 |
| 1940 | 1747 | - | 39.7 | 2536 | - | 57.6 | 117 | 2.7 |
| 41 | 751 | - | 32.6 | 1532 | - | 66.4 | 23 | 1.0 |
| 42 | 701 | - | 25.7 | 1986 | - | 72.9 | 38 | 1.4 |
| 43 | 797 | - | 32.5 | 1526 | - | 62.1 | 133 | 5.4 |
| 44 | 1084 | - | 33.6 | 1829 | - | 56.7 | 314 | 9.7 |
| 45 | 1463 | - | 38.9 | 1906 | - | 50.7 | 390 | 10.4 |
| 46 | 1450 | 491.1 | 37.7 | 2373 | 803.4 | 61.7 | 22 | 0.6 |
| 47 | 2488 | 821.2 | 46.8 | 2763 | 912.5 | 52.0 | 64 | 1.2 |
| 48 | 3526 | 1251.9 | 40.0 | 4526 | 1608.6 | 51.4 | 761 | 8.6 |
| 49 | 3179 | 1172.7 | 52.1 | 2524 | 931.8 | 41.4 | 400 | 6.5 |
| 1950 | 4228 | 1529.5 | 51.0 | 3092 | 1118.6 | 37.3 | 974 | 11.7 |
| 51 | 5531 | 1667.4 | 57.9 | 3888 | 1171.8 | 40.7 | 129 | 1.4 |
| 52 | 5335 | 1581.8 | 60.5 | 3425 | 1014.5 | 38.8 | 62 | 0.7 |
| 53 | 4634 | 1347.8 | 64.3 | 2446 | 710.8 | 33.9 | 125 | 1.8 |
| 54 | 7870 | 2381.6 | 67.0 | 3783 | 1144.6 | 32.2 | 91 | 0.8 |
| 55 | 6681 | 2291.8 | 64.4 | 3601 | 1235.0 | 34.7 | 99 | 0.9 |
| 56 | 8720 | 2803.8 | 70.8 | 3568 | 1144.7 | 28.9 | 33 | 0.3 |
| 57 | 4905 | 1665.5 | 57.3 | 3600 | 1223.5 | 42.1 | 50 | 0.6 |
| 58 | 1871 | 576.9 | 50.4 | 1833 | 564.9 | 49.4 | 9 | 0.2 |
| 59 | 2207 | 630.1 | 49.3 | 2265 | 647.0 | 50.6 | 5 | 0.1 |
| 1960 | 1775 | 506.7 | 55.0 | 1452 | 414.3 | 45.0 | - | - |
| 61 | 278 | - | 37.5 | 464 | - | 62.5 | - | - |

Table 3. Norwegian winter herring. Fishing effort.

| Year | Purse-seine | Drift-net. | | |
|---|---|---|---|---|
| | Number of vessels | Number of vessels | Mean catch per day per vessels/hl | Number of Landings |
| 1946 | 273 | 1866 | | |
| 47 | 261 | 1876 | 101.9 | 27100 |
| 48 | 312 | 2032 | 120.0 | 37700 |
| 49 | 350 | 1955 | 110.4 | 22900 |
| 1950 | 385 | 2045 | 122.2 | 25300 |
| 51 | 434 | 1975 | 124.3 | 31300 |
| 52 | 474 | 1885 | 108.3 | 33600 |
| 53 | 482 | 1587 | 125.8 | 19400 |
| 54 | 492 | 1460 | 157.1 | 24100 |
| 55 | 549 | 1435 | 120.4 | 29900 |
| 56 | 561 | 1321 | 121.2 | 29400 |
| 57 | 599 | 1408 | 126.1 | 28500 |
| 58 | 593 | 1413 | 89.7 | 20400 |
| 59 | 564 | 1297 | 96.9 | 23400 |
| 1960 | 439 | 1162 | 72.1 | 20100 |
| 61 | 254 | 789 | - | - |

Table 4. Norwegian Winter Herring. Age-composition, number per purse-seiner in thousands.

| Age/Year | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | - | - | - | 2 | 3 | - | 4 | 4 | 7 | 1 | - | 5 | - | - | - |
| 3 | 20 | 64 | 37 | 138 | 330 | 9 | 44 | 113 | 65 | 61 | 31 | 11 | 5 | 4 | - |
| 4 | 80 | 466 | 634 | 249 | 220 | 444 | 65 | 54 | 1217 | 262 | 249 | 206 | 10 | 15 | 3 |
| 5 | 77 | 131 | 1260 | 928 | 220 | 198 | 663 | 115 | 159 | 1958 | 293 | 119 | 59 | 16 | 18 |
| 6 | 122 | 125 | 110 | 888 | 648 | 185 | 149 | 404 | 261 | 113 | 2528 | 156 | 46 | 84 | 14 |
| 7 | 75 | 206 | 89 | 65 | 745 | 583 | 223 | 88 | 533 | 178 | 114 | 1571 | 64 | 57 | 75 |
| 8 | 234 | 100 | 111 | 52 | 92 | 680 | 414 | 118 | 133 | 240 | 196 | 51 | 491 | 87 | 40 |
| 9 | 383 | 327 | 85 | 75 | 101 | 77 | 407 | 335 | 203 | 70 | 231 | 72 | 25 | 528 | 58 |
| 10 | 49 | 589 | 307 | 55 | 121 | 86 | 80 | 402 | 446 | 169 | 108 | 67 | 34 | 25 | 671 |
| 11 | 124 | 90 | 450 | 133 | 97 | 101 | 85 | 56 | 460 | 230 | 176 | 43 | 33 | 37 | 19 |
| 12 | 229 | 162 | 65 | 273 | 214 | 105 | 103 | 77 | 84 | 139 | 207 | 61 | 22 | 50 | 44 |
| 13 | 86 | 361 | 157 | 44 | 413 | 258 | 100 | 82 | 91 | 42 | 97 | 76 | 21 | 21 | 47 |
| 14 | 34 | 102 | 233 | 72 | 62 | 351 | 165 | 83 | 119 | 58 | 46 | 41 | 17 | 26 | 17 |
| 15 | 19 | 54 | 112 | 129 | 106 | 57 | 235 | 183 | 105 | 74 | 58 | 14 | 11 | 24 | 12 |
| 16 | 6 | 34 | 48 | 34 | 192 | 116 | 55 | 195 | 167 | 81 | 69 | 17 | 6 | 10 | 15 |
| 17 | - | 21 | 20 | 19 | 43 | 152 | 72 | 60 | 207 | 92 | 84 | 21 | 7 | 6 | 10 |
| 18 | 2 | 1 | 8 | 4 | 21 | 16 | 114 | 82 | 79 | 55 | 79 | 28 | 7 | 8 | 6 |
| 19 | 1 | 3 | - | 5 | - | 6 | 27 | 81 | 67 | 62 | 31 | 19 | 5 | 4 | 4 |
| 20 | - | - | - | 11 | 5 | - | 4 | 19 | 49 | 31 | 30 | 8 | 3 | 3 | 6 |
| 21 | - | 1 | - | - | - | -2 | 1 | 4 | 6 | 7 | 16 | 6 | 2 | 2 | 4 |
| 22 | - | - | - | - | - | - | - | 1 | 6 | 6 | 6 | 1 | - | 1 | 1 |
| 23 | - | - | - | 1 | - | - | - | 1 | - | 1 | - | - | - | 1 | 1 |
| ? | 257 | 307 | 286 | 164 | 342 | 415 | 326 | 239 | 375 | 244 | 349 | 183 | 103 | 111 | 90 |
| Total | 1798 | 3144 | 4012 | 3351 | 3973 | 3841 | 3336 | 2796 | 4839 | 4174 | 4998 | 2779 | 972 | 1116 | 1155 |

Table 5. Norwegian Winter Herring. Age-composition, number per drift-net landings.

| Age /Year | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 4 | - | 22 | 32 | - | 38 | 46 | 66 | 7 | - | 77 | - | - | - |
| 3 | 686 | 390 | 1672 | 3676 | 83 | 421 | 1479 | 643 | 599 | 245 | 182 | 123 | 9 | 5 |
| 4 | 4993 | 6745 | 3026 | 2447 | 4326 | 626 | 711 | 11946 | 2592 | 1942 | 3186 | 279 | 368 | 60 |
| 5 | 1402 | 13395 | 11266 | 2447 | 1933 | 6380 | 1510 | 1564 | 19371 | 2279 | 1842 | 1696 | 389 | 318 |
| 6 | 1336 | 1170 | 10786 | 7213 | 1799 | 1430 | 5289 | 2564 | 1124 | 19694 | 2407 | 1309 | 2081 | 244 |
| 7 | 2203 | 950 | 786 | 8277 | 5690 | 2149 | 1149 | 5228 | 1763 | 888 | 24270 | 1828 | 1406 | 1338 |
| 8 | 1070 | 1183 | 629 | 1020 | 6636 | 3991 | 1546 | 1303 | 2375 | 1524 | 789 | 13985 | 2145 | 711 |
| 9 | 3498 | 902 | 913 | 1123 | 748 | 3918 | 4387 | 1988 | 696 | 1799 | 1112 | 745 | 13068 | 1030 |
| 10 | 6303 | 3268 | 689 | 1348 | 840 | 766 | 5268 | 4369 | 1676 | 840 | 1035 | 975 | 628 | 12005 |
| 11 | 959 | 4788 | 1620 | 1075 | 984 | 813 | 732 | 4515 | 2274 | 1371 | 663 | 941 | 927 | 333 |
| 12 | 1734 | 695 | 3319 | 2383 | 1029 | 991 | 1005 | 822 | 1378 | 1612 | 944 | 627 | 1235 | 781 |
| 13 | 3867 | 1663 | 537 | 4601 | 2518 | 959 | 1072 | 888 | 418 | 755 | 1172 | 608 | 530 | 831 |
| 14 | 1092 | 2472 | 878 | 688 | 3419 | 1592 | 1088 | 1166 | 575 | 361 | 628 | 490 | 650 | 294 |
| 15 | 583 | 1191 | 1563 | 1182 | 556 | 2263 | 2392 | 1029 | 732 | 456 | 214 | 299 | 585 | 219 |
| 16 | 365 | 507 | 410 | 2134 | 1130 | 532 | 2552 | 1635 | 806 | 541 | 274 | 167 | 244 | 274 |
| 17 | 221 | 218 | 227 | 474 | 1479 | 696 | 794 | 2033 | 910 | 656 | 319 | 196 | 141 | 174 |
| 18 | 7 | 88 | 48 | 229 | 153 | 1095 | 1077 | 776 | 545 | 619 | 432 | 191 | 188 | 100 |
| 19 | 37 | - | 57 | - | 58 | 259 | 1067 | 660 | 609 | 241 | 298 | 132 | 107 | 70 |
| 20 | 4 | - | 4 | 59 | - | 35 | 247 | 477 | 308 | 231 | 130 | 93 | 81 | 100 |
| 21 | 15 | - | - | - | 19 | 9 | 46 | 71 | 67 | 116 | 98 | 54 | 60 | 65 |
| 22 | - | - | - | - | - | 6 | 15 | 71 | 57 | 37 | 18 | 10 | 38 | 20 |
| 23 | - | - | 4 | - | - | - | 15 | - | 10 | - | 7 | 10 | 21 | 25 |
| 24 | - | - | - | - | - | - | 15 | - | - | - | 3 | - | - | - |
| ? | 3292 | 3042 | 2231 | 3806 | 4038 | 3136 | 3134 | 3680 | 2415 | 2728 | 2828 | 2931 | 2748 | 1617 |
| Total | 33671 | 42667 | 40687 | 44214 | 37438 | 32105 | 36636 | 7494 | 41307 | 38935 | 42928 | 27689 | [illegible]549 | 20614 |

Table 6. Norwegian Winter Herring. Spawning-groups, number per purse-seiner in thousands.

| Age/Year | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 205 | 384 | 1290 | 1083 | 317 | 425 | 346 | 277 | 890 | 1417 | 1366 | 821 | 179 | 126 | 25 |
| II | 116 | 148 | 380 | 556 | 621 | 90 | 234 | 114 | 204 | 677 | 583 | 212 | 94 | 119 | 105 |
| III | 317 | 275 | 164 | 181 | 599 | 757 | 78 | 168 | 223 | 192 | 1178 | 499 | 105 | 120 | 150 |
| IV | 330 | 436 | 175 | 92 | 175 | 433 | 429 | 63 | 214 | 119 | 169 | 351 | 194 | 98 | 133 |
| V | 191 | 490 | 321 | 109 | 148 | 147 | 321 | 378 | 116 | 99 | 120 | 57 | 129 | 199 | 113 |
| VI | 119 | 288 | 420 | 168 | 179 | 137 | 122 | 296 | 500 | 152 | 115 | 34 | 28 | 121 | 220 |
| VII | 70 | 172 | 188 | 226 | 279 | 172 | 101 | 136 | 353 | 238 | 177 | 46 | 22 | 27 | 124 |
| VIII | 60 | 104 | 126 | 125 | 317 | 289 | 127 | 102 | 170 | 127 | 201 | 68 | 23 | 30 | 28 |
| IX | 29 | 84 | 104 | 50 | 163 | 282 | 190 | 129 | 126 | 78 | 103 | 70 | 24 | 25 | 22 |
| X | 22 | 68 | 72 | 24 | 73 | 126 | 186 | 202 | 163 | 89 | 89 | 37 | 17 | 30 | 16 |
| XI | 8 | 34 | 47 | 21 | 42 | 41 | 90 | 226 | 226 | 115 | 78 | 29 | 11 | 21 | 17 |
| XII | 2 | 23 | 18 | 9 | 24 | 18 | 48 | 85 | 185 | 103 | 103 | 28 | 10 | 12 | 12 |
| XIII | 2 | 8 | 12 | 8 | 14 | 10 | 22 | 40 | 77 | 95 | 86 | 26 | 6 | 7 | 7 |
| XIV | - | 5 | 4 | 4 | 4 | 9 | 17 | 13 | 22 | 21 | 31 | 18 | 4 | 4 | 5 |
| XV | - | - | 1 | 1 | 2 | 1 | 10 | 11 | 14 | 7 | 5 | 6 | 3 | 3 | 3 |
| XVI | 1 | 1 | - | - | 1 | - | 6 | 4 | 11 | 5 | 3 | 1 | 1 | 2 | 3 |
| XVII | - | - | - | 1 | 1 | - | 2 | - | 4 | 3 | 1 | - | - | - | 1 |
| XVIII | - | 1 | - | 1 | - | - | - | - | 3 | 1 | 1 | - | - | - | 1 |
| XIX | - | - | - | - | - | - | 1 | 1 | - | 2 | - | - | - | - | - |
| ? | 326 | 623 | 690 | 692 | 1014 | 904 | 1007 | 551 | 1338 | 633 | 589 | 476 | 122 | 172 | 170 |
| Total | 1798 | 3144 | 4012 | 3351 | 3973 | 3841 | 3336 | 2796 | 4839 | 4174 | 4998 | 2779 | 972 | 1116 | 1155 |

Table 7. Norwegian Winter Herring. Spawning-groups, number per drift-net landings.

| Groups/Year | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 4114 | 13721 | 13157 | 3522 | 4137 | 3329 | 3634 | 8730 | 14013 | 10642 | 12688 | 5098 | 3115 | 443 |
| II | 1579 | 4040 | 6755 | 6913 | 875 | 2247 | 1500 | 2004 | 6692 | 4544 | 3270 | 2681 | 2936 | 1886 |
| III | 2937 | 1740 | 2201 | 6664 | 7380 | 750 | 2206 | 2187 | 1896 | 9177 | 7705 | 3000 | 2970 | 2687 |
| IV | 4668 | 1867 | 1122 | 1949 | 4220 | 4130 | 830 | 2104 | 1177 | 1316 | 5421 | 5520 | 2432 | 2373 |
| V | 5247 | 3416 | 1328 | 1548 | 1431 | 3092 | 4959 | 1137 | 983 | 932 | 874 | 3686 | 4932 | 2020 |
| VI | 3085 | 4464 | 2035 | 1988 | 1339 | 1174 | 3881 | 4909 | 1512 | 898 | 523 | 789 | 2987 | 3925 |
| VII | 1845 | 1997 | 2747 | 3111 | 1677 | 972 | 1784 | 3469 | 2358 | 1378 | 716 | 618 | 679 | 2209 |
| VIII | 1111 | 1334 | 1520 | 3530 | 2821 | 1225 | 1330 | 1672 | 1251 | 1565 | 1049 | 642 | 735 | 493 |
| IX | 900 | 1109 | 607 | 1810 | 2751 | 1823 | 1696 | 1237 | 773 | 803 | 1081 | 686 | 624 | 398 |
| X | 727 | 764 | 297 | 818 | 1227 | 1791 | 2649 | 1606 | 886 | 690 | 565 | 490 | 735 | 284 |
| XI | 369 | 507 | 258 | 470 | 399 | 861 | 2964 | 2224 | 1140 | 605 | 446 | 309 | 517 | 303 |
| XII | 240 | 191 | 105 | 273 | 176 | 459 | 1119 | 1817 | 1017 | 799 | 439 | 299 | 299 | 215 |
| XIII | 89 | 125 | 83 | 158 | 99 | 209 | 526 | 759 | 943 | 673 | 396 | 181 | 179 | 119 |
| XIV | 55 | 37 | 48 | 43 | 93 | 161 | 165 | 216 | 207 | 241 | 284 | 103 | 107 | 95 |
| XV | 4 | 13 | 17 | 20 | 10 | 95 | 144 | 141 | 70 | 37 | 99 | 78 | 60 | 55 |
| XVI | 15 | - | - | 8 | - | 57 | 52 | 108 | 54 | 24 | 11 | 15 | 47 | 45 |
| XVII | - | - | 4 | 8 | - | 16 | 5 | 41 | 30 | 10 | - | 10 | 9 | 20 |
| XVIII | 7 | - | 4 | - | - | - | 5 | 25 | 10 | 10 | 7 | - | 13 | 10 |
| XIX | - | - | - | - | - | - | 15 | - | 23 | - | 7 | - | - | - |
| ? | 6679 | 7342 | 8399 | 11281 | 8803 | 9714 | 7172 | 13108 | 6272 | 4591 | 7347 | 3484 | 4273 | 3034 |
| Total | 33671 | 42667 | 40687 | 44214 | 37438 | 32105 | 36636 | 47494 | 41307 | 38935 | 42928 | 27689 | 27649 | 20614 |

Table 8. Estimated total instananeous mortality coefficients for different pairs of years, spawning-groups and age-groups from drift-net (D) and purse-seine (P).

| Spawnings-groups | | I/II | II/III | III/IV | IV/V | V/VI | Mean | Age-groups | 7/8 | 8/9 | 9/10 | 10/11 | 11/12 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Years | | | | | | | | | | | | | | |
| 1947/48 | D | 0.02 | -0.09 | 0.45 | 0.31 | 0.17 | 0.17 | | 0.62 | 0.17 | 0.07 | 0.28 | 0.32 | 0.29 |
| | P | 0.01 | -0.11 | 0.45 | 0.31 | 0.16 | 0.16 | | 0.62 | 0.17 | 0.07 | 0.27 | 0.32 | 0.29 |
| 1948/49 | D | 0.71 | 0.61 | 0.44 | 0.34 | 0.52 | 0.52 | | 0.41 | 0.26 | 0.27 | 0.70 | 0.36 | 0.40 |
| | P | 0.84 | 0.74 | 0.58 | 0.48 | 0.65 | 0.66 | | 0.54 | 0.39 | 0.44 | 0.84 | 0.50 | 0.54 |
| 1949/50 | D | 0.64 | 0.01 | 0.12 | -0.39 | -0.40 | 0.00 | | -0.26 | -0.60 | -0.39 | - 045 | -0.39 | -0.42 |
| | P | 0.55 | -0.07 | 0.03 | -0.48 | -0.49 | -0.09 | | -0.34 | -0.67 | -0.48 | - 0.56 | -0.48 | -0.51 |
| 1950/51 | D | 1.39 | -0.06 | 0.46 | 0.31 | 0.21 | 0.46 | | 0.22 | 0.31 | 0.29 | 0.31 | 0.04 | 0.23 |
| | P | 1.26 | -0.20 | 0.32 | 0.17 | 0.08 | 0.33 | | 0.09 | 0.17 | 0.16 | 0.18 | - 0.08 | 0.10 |
| 1951/52 | D | 0.61 | 0.16 | 0.58 | 0.31 | 0.22 | 0.38 | | 0.36 | 0.52 | -0.02 | 0.03 | - 0.01 | 0.18 |
| | P | 0.60 | 0.14 | 0.57 | 0.30 | 0.18 | 0.36 | | 0.34 | 0.54 | -0.04 | 0.01 | - 0.02 | 0.16 |
| 1952/53 | D | 0.80 | 0.02 | - 0.11 | - 0.19 | - 0.22 | 0.06 | | 0.33 | -0.09 | -0.30 | 0.05 | - 0.21 | - 0.04 |
| | P | 1.11 | 0.32 | 0.22 | 0.12 | 0.08 | 0.37 | | 0.64 | 0.22 | 0.01 | 0.36 | 0.10 | 0.27 |
| 1953/54 | D | 0.59 | - 0.37 | 0.05 | - 0.31 | 0.01 | -0.01 | | -0.13 | -0.25 | 0.00 | 0.16 | - 0.12 | - 0.07 |
| | P | 0.31 | 0.41 | - 0.24 | - 0.62 | - 0.27 | -0.08 | | -0.42 | -0.54 | -0.24 | - 0.14 | - 0.40 | - 0.35 |
| 1954/55 | D | 0.26 | 0.06 | 0.62 | 0.76 | - 0.29 | 0.28 | | 0.79 | 0.63 | 0.17 | 0.65 | 1.19 | 0.69 |
| | P | 0.27 | 0.06 | 0.63 | 0.77 | - 0.27 | 0.29 | | 0.80 | 0.64 | 0.18 | 0.66 | 1.20 | 0.70 |
| 1955/56 | D | 1.12 | - 0.31 | 0.36 | 0.23 | 0.09 | 0.30 | | 0.15 | 0.28 | -0.19 | 0.19 | 0.34 | 0.15 |
| | P | 0.89 | - 0.54 | 0.13 | - 0.01 | - 0.15 | 0.06 | | -0.09 | 0.04 | -0.43 | - 0.04 | 0.10 | - 0.08 |
| 1956/57 | D | 1.18 | - 0.53 | 0.52 | 0.41 | 0.58 | 0.44 | | 0.12 | 0.31 | 0.55 | 0.24 | 0.37 | 0.32 |
| | P | 1.86 | 0.16 | 1.21 | 1.09 | 1.26 | 1.12 | | 0.80 | 1.00 | 1.24 | 0.92 | 1.06 | 1.00 |
| 1957/58 | D | 1.55 | 0.09 | 0.34 | 0.39 | 0.10 | 0.49 | | 0.55 | 0.06 | 0.13 | 0.10 | 0.06 | 0.18 |
| | P | 2.17 | 0.70 | 0.94 | 1.00 | 0.71 | 1.10 | | 1.16 | 0.71 | 0.75 | 0.71 | 0.67 | 0.80 |
| 1958/59 | D | 0.55 | - 0.11 | 0.21 | 0.11 | 0.21 | 0.20 | | -0.16 | 0.07 | 0.17 | 0.05 | - 0.27 | - 0.03 |
| | P | 0.41 | - 0.25 | 0.07 | - 0.03 | 0.07 | 0.05 | | -0.30 | -0.07 | 0.00 | - 0.08 | - 0.42 | - 0.17 |
| 1959/60 | D | 0.50 | 0.09 | 0.22 | 0.18 | 0.23 | 0.24 | | 0.68 | 0.73 | 0.09 | 0.64 | 0.17 | 0.46 |
| | P | 0.18 | - 0.24 | - 0.11 | - 0.14 | - 0.11 | - 0.08 | | 0.36 | 0.41 | -0.24 | 0.28 | - 0.17 | 0.11 |
| Mean. | D | 0.76 | - 0.03 | 0.33 | 0.19 | 0.11 | | | 0.28 | 0.18 | 0.00 | 0.23 | 0.14 | |
| | P | 0.80 | 0.09 | 0.37 | 0.23 | 0.15 | | | 0.32 | 0.23 | 0.11 | 0.26 | 0.18 | |

Table 9. Total catch in million fish and number per effort of the year-classes 1943-1951, age-groups 2 - 10 years.

| Year-class | Total catch in million fish | Catch / effort | |
|---|---|---|---|
| | | Purse-seine number/vessel in thousands | Drift-net number/landings |
| 1943 | 3,546.3 | 4,886 | 58,266 |
| 1944 | 2,983.2 | 4,052 | 44,347 |
| 1945 | 1,057.1 | 1,404 | 15,025 |
| 1946 | 832.3 | 1,104 | 11,470 |
| 1947 | 2,244.3 | 2,914 | 30,130 |
| 1948 | 760.4 | 933 | 10,189 |
| 1949 | 492.4 | 585 | 6,870 |
| 1950 | 8,015.5 | 9,081 | 115,856 |
| 1951 | 899.1 | 1,047 | 14,000 |

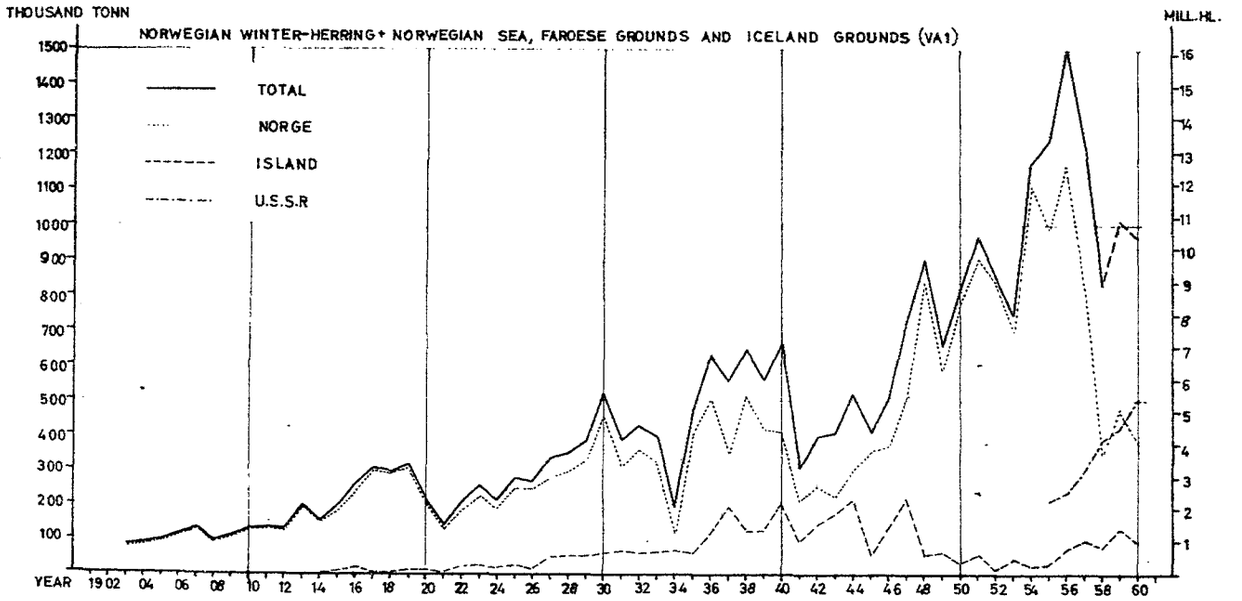



Figure 1. The catch of Atlanto-Scandian herring by countries.

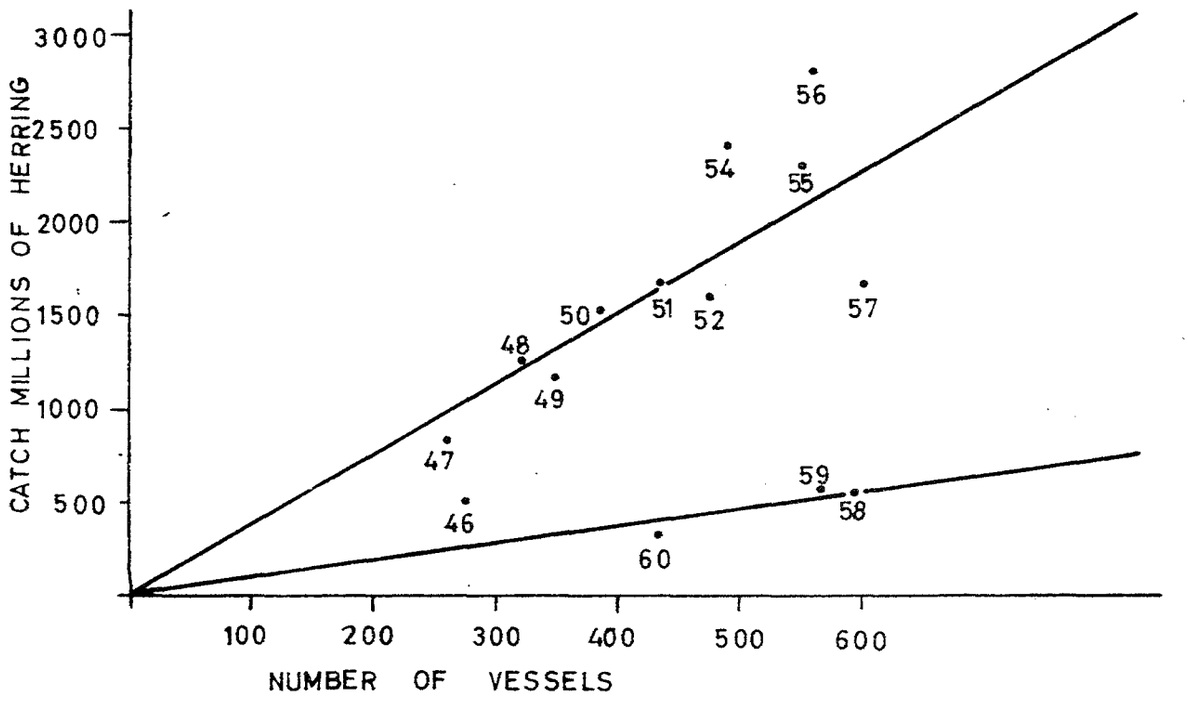



Figure 2. Purse-seine fishery .Relation between number of vessels and catch .

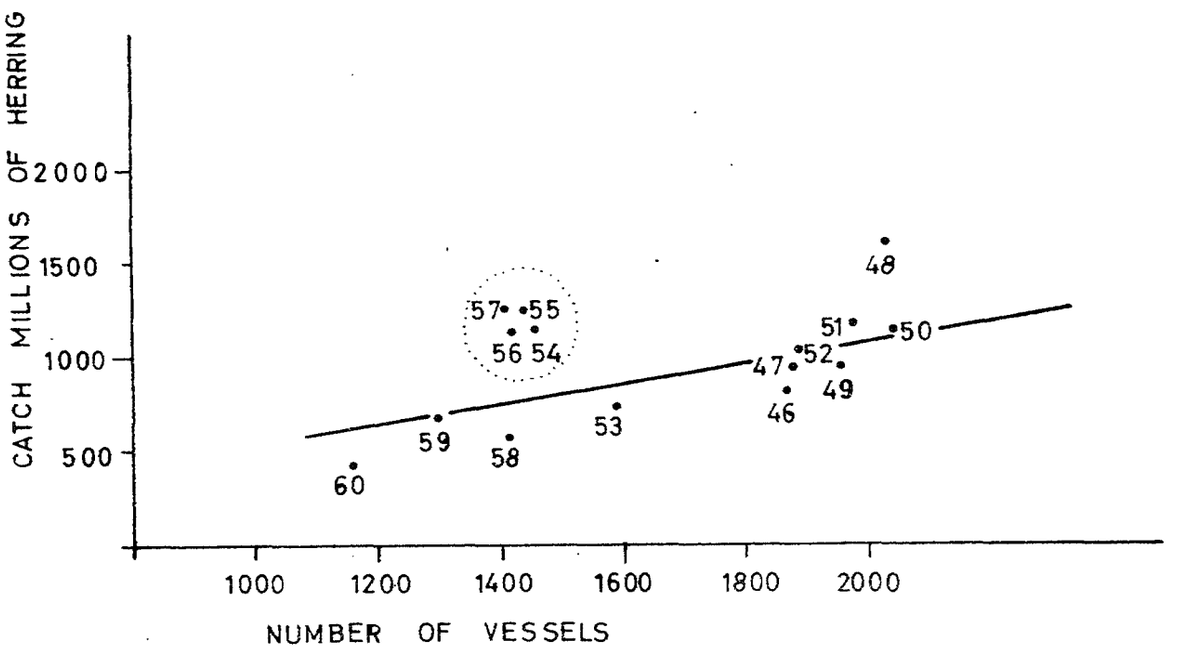



Figure 3. Drift-net fishery . Relation between number of vessels and catch.

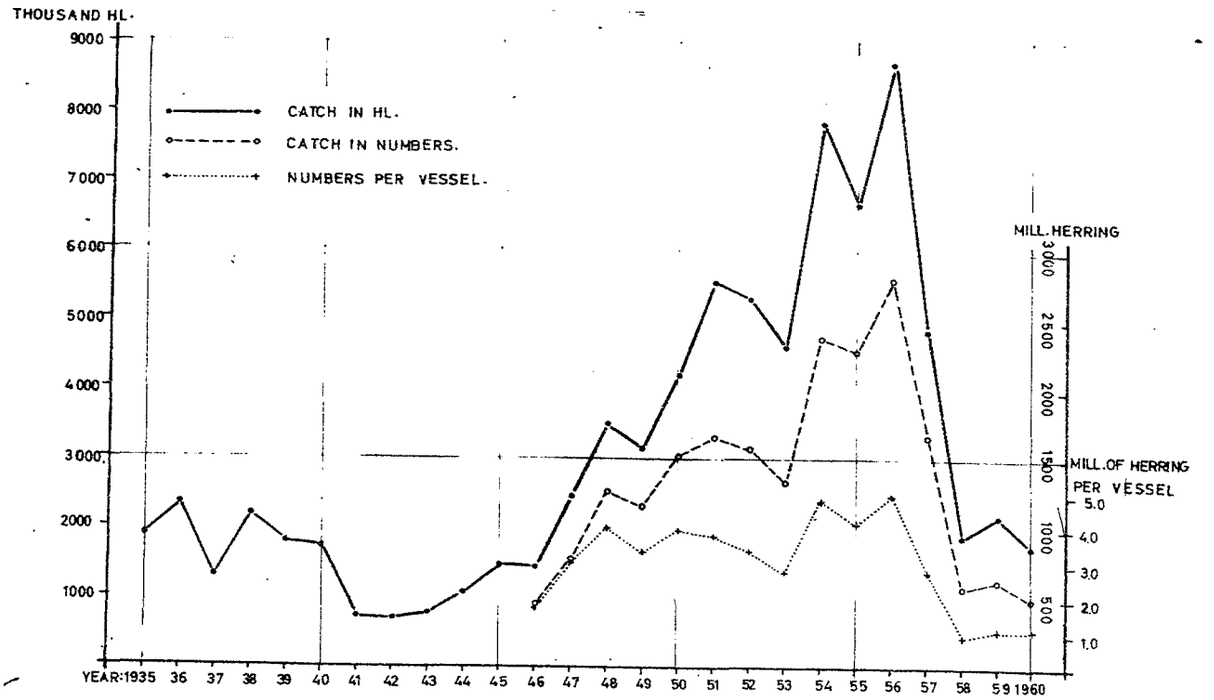



Figure 4. Purse-seine fishery . Catch in hl , number and number per effort .

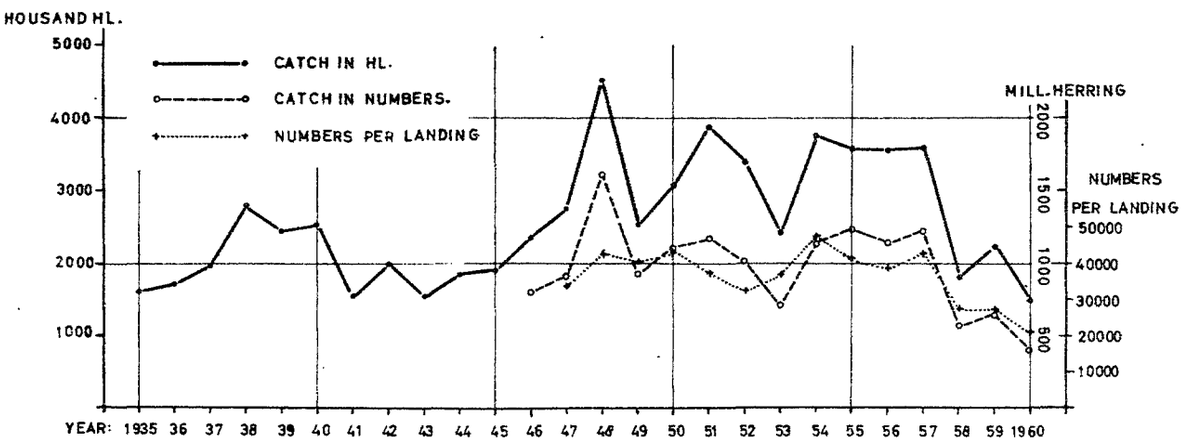



Figure 5. Drift-net fishery . Catch in hl , number and number per effort .

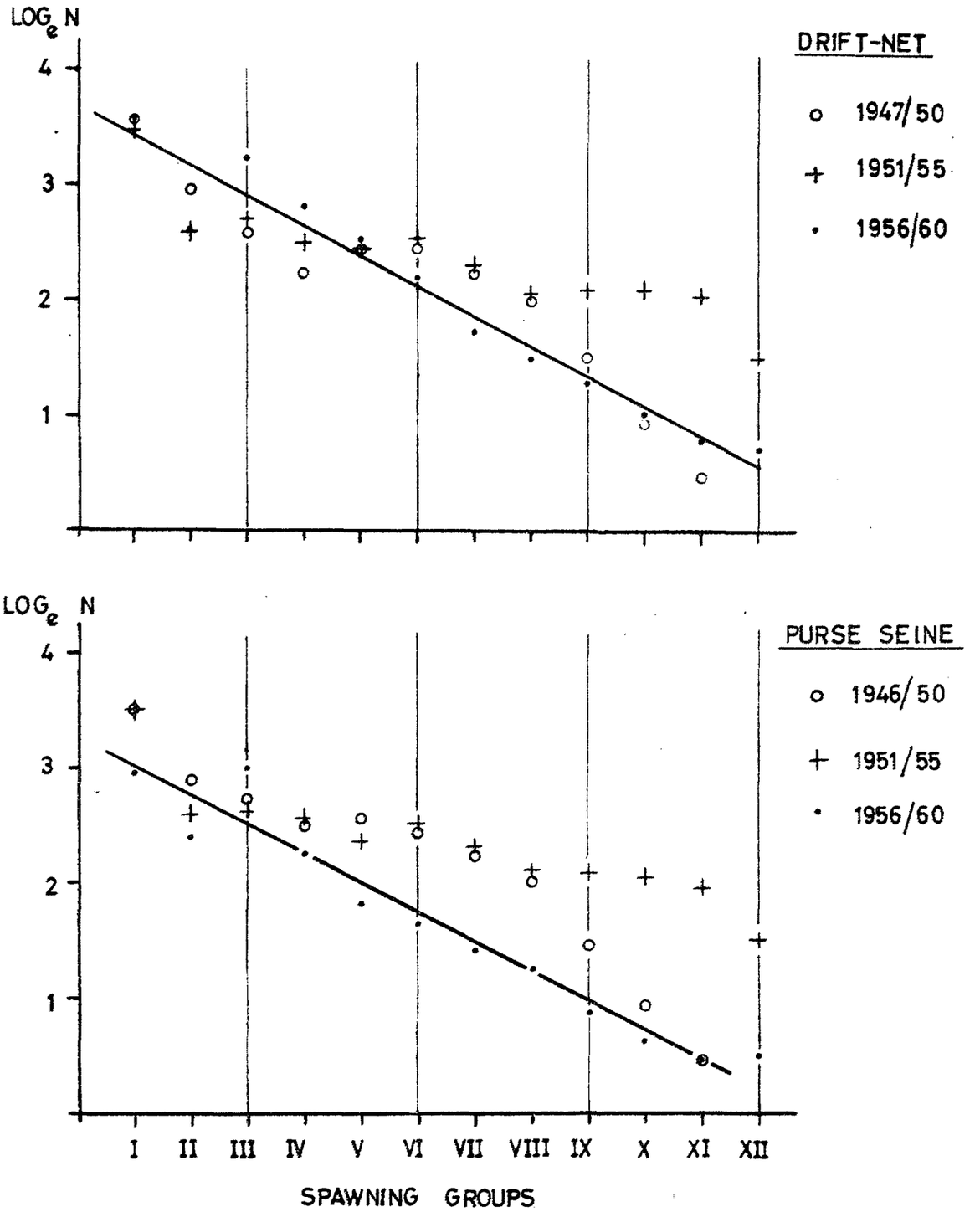
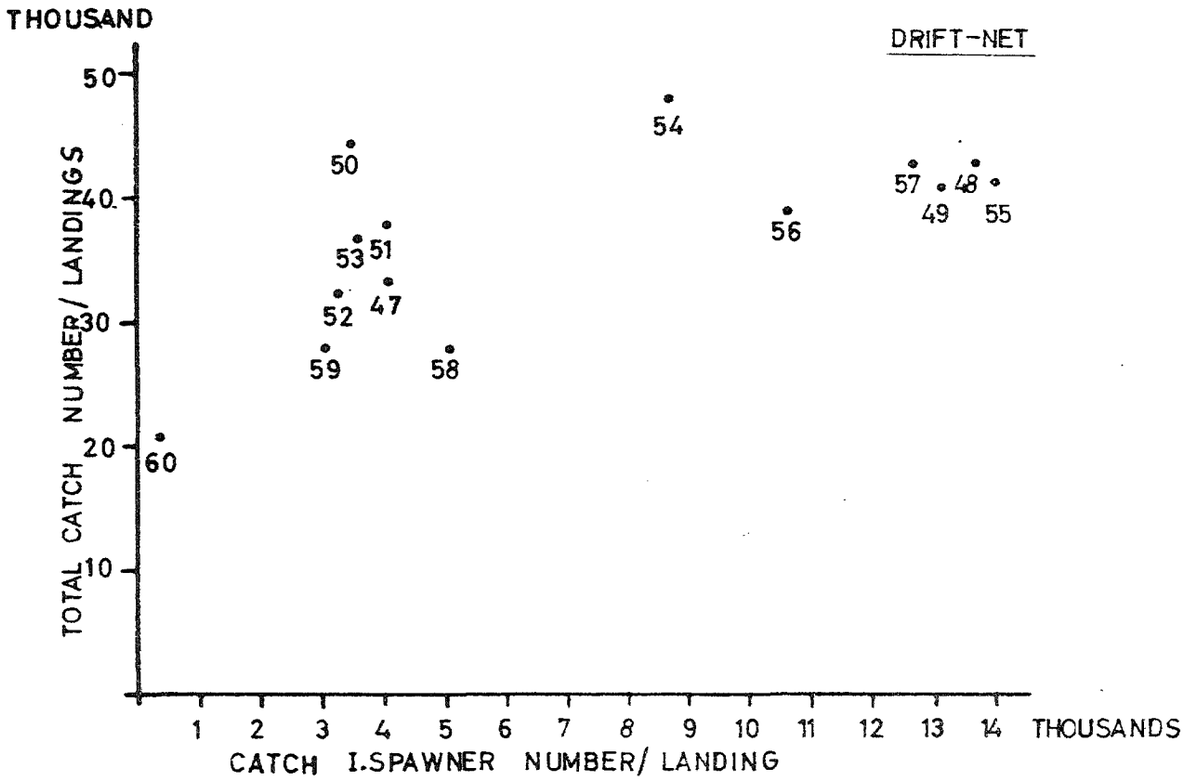



Figure 6. Spawning group composition of winter herring 1947/50, 1951/55 and 1956/60.



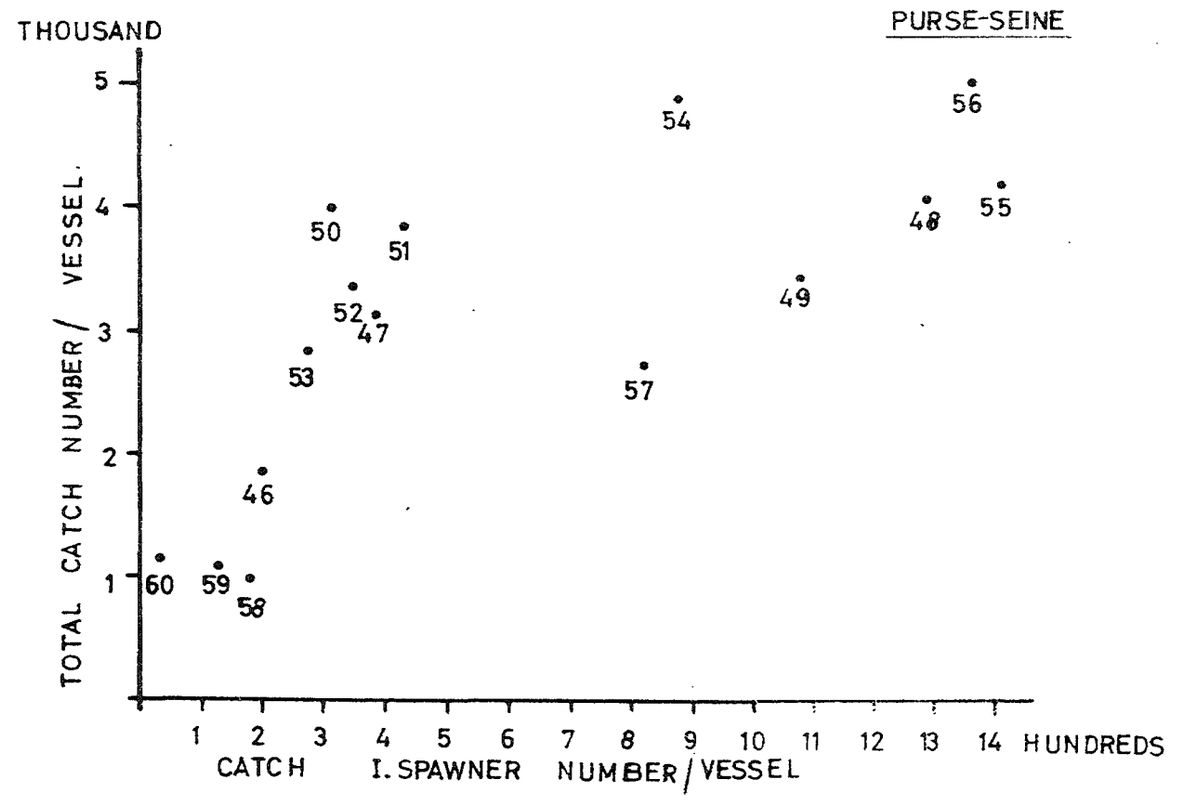




Figure 7. Relation between total catch per effort and catch per effort of I. spawners for purse-seine and drift-net.