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# On the Reasons of Correlation Between Recruitment Dynamics of Some Commercial Fish Populations in the Northwestern Atlantic Ocean (NAFO Subareas 2-4) and Probability of Forecasting the Trends in Dynamics of Their Biomass for Several Years Ahead

V. A. Rikhter

Atlantic Scientific Research Institute of Marine Fisheries and Oceanography (AtlantNIRO)
5 Dm. Donskoy Str., Kaliningrad, 236000 Russia.
Tel. 007 0112 22 55 47, Fax: 007 0112 21 99 97, E-mail: atlant@baltnet.ru

## Abstract

The comparative analysis of recruitment dynamics of nine commercial fish populations (stock units) and water temperature in the Northwestern Atlantic (NAFO Subareas 2-4) has been carried out. It was found that the occurrence of weak generations in seven populations (2J+3KL, 3NO, 4VxW cod, 3LNO American plaice, 4TVW haddock, 4VWX+5Zc pollock, 4VWX silver hake) coincided with the periods of strong and rather long fall of temperatures, while in two populations (2J+3KLMNO Greenland halibut, 3LNO yellowtail flounder) the inverse process was observed. The assumption was made, that the reason of reliable correlation between recruitment dynamics of stock units under consideration was the identical (or opposite) reaction to interannual fluctuations of water temperature. The attempt was made to obtain the general idea on the trends of fishing and spawning biomass dynamics of respective populations during the first decade of the new century.

## Introduction

Researches in 2001 have been allowed to find statistically significant correlation between recruitment dynamics of several fish populations, including those belonging to different species and living in significant distance from each other (Rikhter *et al.*, 2001). At the same time the assumption was made that the reliable relationship availability could be explained with similar (or opposite) reaction to the environment condition changes. In the above-mentioned work, the idea also appeared on the possibility of forecasting the trends in fishing and spawning biomass dynamics of considered populations for a few years ahead (within the nearest decade). Thus, actually the subject of researches in above field was formulated.

## Materials and Methods

Eight stock units with statistically significant correlation between recruitment dynamics revealed earlier (Rikhter *et al.*, 2001) became the subject of researches. The information on year-class abundance at appropriate age (recruitment) was obtained from NAFO and CSAS Research Documents (Bowering *et al.*, MS 2000; Frank *et al.*, MS 1997; Lilly *et al.*, MS 1999; Mohn *et al.*, MS 1998; Morgan *et al.,* MS 1999; Neilson *et al.*, MS 1999; Stansbury *et al.*, MS 1999; Walsh *et al.*, MS 1999). In addition to the above-mentioned eight populations represented by species of medium- and long-term life cycle (Greenland halibut, flounders, cod, pollock), Scotian silver hake was also considered (4VWX) while retrospective estimates of hake abundance were taken from Showell (MS 1997). The recruitment age data for considered populations are available in Rikhter *et al.* (2001). The data on long-term temperatures fluctuations on the shelf of the southern Labrador, Grand Bank and Scotian Shelf are taken from Drinkwater *et al.* (MS 2001). The above information was used in comparison of the trends in year-classes recruitment dynamics of considered populations and water temperature in Subareas 2-4. For this purpose the basic periods of warming, cooling and respective year-class abundance rise and reduction were determined.

## Results

According to Drinkwater *et al.* (MS 2001) the data registered at Station 27 located not far from the Newfoundland coast, sufficiently clear characterize interannual changes of hydrological conditions on the southern Labrador Shelf and Grand Bank. The information based on the specified data (Fig. 24 from Drinkwater *et al.* (MS 2001) was used for allocation of the most pronounced periods of warming and cooling (Table 1).

Now let us consider briefly the recruitment dynamics of five commercial fish populations distributed in Subareas 2 and 3 and try to allocate the basic periods of their abundance increase and reduction. The curves describing fluctuations of respective year-class size are shown in Fig. 1-5. Beginning with Div. 2J+3KL cod (Fig. 1). It is evident that the sharp abundance decrease occurred in 1982-85 and 1988-92 with subsequent stabilization at a very low level (1992-95).

Sharp growth of Div. 3NO cod recruitment abundance (Fig. 2) was observed in 1980-82 followed with not less sharp reduction in 1983-84. Subsequent fluctuations in 1985-88 were at the level below the average. In 1989 the year-class slightly exceeding the average level appeared, and further there was a collapse up to extremely low level (1990-92).

During rather long period (1978-91), the abundance of Div. 2J+3LKMNO Greenland halibut year-class did not reach the average level (Fig. 3). The appreciable rise appeared only in 1992 with the subsequent occurrence of the year-class, considerably exceeding the average level (1993-95).

The similar picture was observed in Div. 3LNO yellowtail flounder (Fig. 4), with some trend to recruitment abundance increase observed in 1982-86 followed by reduction to a very low level (1987-92). However, in 1993-95, there were in succession three rather strong year-classes.

The rather monotonous picture of almost continuous abundance decrease is represented by dynamics of Div. 3LNO American plaice recruitment for the considered period (Fig. 5). The curve is actually divided with a horizontal line into two almost equal sectors: the left one (1978-85) is above the average long-term level, and the right one is below the latter approaching a very low level in the end (1986-93).

The summary of abundance dynamics of considered populations is submitted in Table 2. The comparison of data presented in Tables 1 and 2 show, that the cooling periods mainly coincided with the years of sharp recruitment reduction of Div. 2J+3KL, Div. 3NO cod and Div. 3LNO American plaice. At the same time strong year-classes of Div. 2J+3KLMNO Greenland halibut and Div. 3LNO yellowtail flounder appeared as a rule in cold years. Therefore it is possible to assume, that strong and long-term cooling negatively affects the year-class abundance of considered stock units, however, promotes a good survival of juvenile Greenland halibut and yellowtail flounder. It is more difficult to specify definitely the effect of warming (the latest period of which occurred in 1996-2000) in view of the absence of any reliable information on year-class abundance in the specified years. It is possible only to assume, that strong and sufficiently long increase of water temperature has the effect opposite to that mentioned above. Certainly, the mechanism of warming and cooling impact on formation of fish population abundance seems rather complex, specific in each case and requires individual research.

To characterize the dynamics of water temperature on the Scotian Shelf, the information from Fig. 43, 51 and 52 of Drinkwater *et al.* (MS 2001) was used (Table 3). From 1980 to 2000 inclusive, two rather long warming periods intermitted with not less long periods of low water temperature were observed.

The curves describing the recruitment of dynamics of four populations distributed on the Scotian Shelf with partial distribution area of two of them in the adjacent waters are shown on Fig. 6-9. Similar to the previous case, we shall very shortly comment on the most significant events in the dynamics of considered populations.

Abundance of all Div. 4TVW haddock year-classes in 1978-83 exceeded (sometimes significantly) the average level (Fig. 6). Sharp reduction occurred in 1984-86 with subsequent short-term increase in 1988 followed with another decrease to a very low level (1989-91). In 1992-93 the trend to recruitment abundance appeared.

Size of Div. 4VsW cod year-classes in 1978-87 as a whole appreciably exceeded the average level (Fig. 7). A short-term reduction was observed only in 1983. Sharp decrease of abundance occurred in 1988-91, followed with subsequent stabilization at a very low level (1992-95).

Any certain trend in abundance dynamics of Div. 4VWX+5Zc pollock recruitment in 1980-89 is hardly evident (Fig. 8). The abundance of year-classes appeared in these years varied mainly at the level slightly above the average one. In the period from 1990 to 1995, fluctuations also were observed with the obvious trend to reduction.

The abundance of Div. 4VWX silver hake year-classes in 1981-85 fluctuated sharply, but nevertheless, frequently significantly exceeded the average level (Fig. 9). The sharp decrease occurred in 1986 followed with fluctuations at the level below the average one (1987-93). Sufficiently strong year-classes appeared in 1994-95.

The summary of four population abundance dynamics is presented in Table 4. The comparison of data from Tables 3 and 4 allows to state that the common event for Div. 4TVW haddock, Div. 4VsW cod, Subareas 4+5 pollock and Div. 4VWX silver hake is the occurrence of several weak year-classes in years the most significant cooling (1989-92, 1988-91, 1990-93 and 1989-93, respectively). In the other time any relationship between water temperature fluctuations and recruitment abundance of the above stock units except silver hake is hardly traced. In this case a total coincidence of the trends of water thermal regime on the Scotian Shelf and recruitment abundance was observed. We shall consider in more details the last warming period (1994-2000). Despite the lack of reliable retrospective estimates of hake year-classes abundance after 1995, the available information allows to estimate 1996-2000 year-classes on the qualitative basis. So, according to the data of Canadian groundfish surveys carried out annually in July, 1996 year-class is rather strong and 1997 year-class is weak (Showell and Fanning, MS 1999). However, there are the doubts concerning the latter, since the abundance index of 0-group of this year-class, determined on the data of Canadian-Russian juvenile hake surveys, appeared extremely high (second in the observation series since 1981). Besides judging on the length structure of Canadian landings in 1998 and 1999 (Showell and Fanning, MS 1999), the essential part of their catches in 1998 and 1999 is represented by fish in the age of 1 and 2 years, respectively (1997 year-class). According to the information kindly provided to us by M/ Showell (pers. comm.), 1998 and 1999 year-classes are strong and year-class 2000 is the weak based on the July surveys data.

Thus, in 1996-2000 the abundance of at least three year-classes appreciably exceeded the average level. This is actually similar to warming period in 1981-85. The facts mentioned are in good agreement with the results of the previous researches evidencing the availability of statistically significant positive correlation between hake recruitment and average annual SST (Sigaev and Rikhter, 1996).

## Discussion

The results of researches evidence that the recruitment abundance of seven populations out of considered ones decreased during long-term and strong cooling while that of the other two increased. The most distinctly this process was observed in Subareas 2 and 3. On the other hand, it is reasonable to expect that the reaction to warming of populations with reliable relationship between recruitment dynamics was mainly the opposite one. The correlation coefficients are shown in Table 5, being the reduced version of the Table from Rikhter *et al*. (2001). The data shows evidence the positive relationship between recruitment of all stock units cod, pollock, haddock and American place and the negative one between these species and Greenland halibut and yellowtail flounder.

Now to estimate the impact of the last water warming period (1996-2000) upon recruitment of populations listed in Table 5, we shall try to find among them the object able to become a biological reference point to other species. It seems probable to use for this purpose Div. 4TVW haddock with year-class abundance fluctuations from average up to very high during the period considered (DFO, 2000). Thus, it is possible to assume that strong year-classes in the specified years occurred also in populations with positive correlation between recruitment values. The negative relationship between recruitment of Greenland halibut, yellowtail flounder and other species, in turn, allows to assume that in the years of high positive anomalies of water temperature weak year-classes are forming in two first species.

**Outlook**

It is time to proceed to a final part of the paper, where actually we shall discuss the expected trends in biomass dynamics of the respective stock units during the first decade of the new century. If in 1996-2000, several numerous year-classes of cod and American plaice appeared, by about 2005, taking into account the maturation period (Morgan *et al*., 1999; Morgan and Brattey, 1997), the appreciable increase of fishing, and in subsequent 2-3 years also spawning biomass should be expected.

Biomass of yellowtail flounder in the first half of the decade is likely to remain at the high level of 2001 (NAFO, 2002), and after 2005, taking into account probability of weak year-classes occurrence during the latest cooling and maturation period (Walsh and Morgan, 1999), the decrease may begin.

Biomass increase of Greenland halibut being the most long-living and late-ripening species (Morgan and Bowering, 2000) seems to continue for a long period, probably, only in the second half of the decade the stabilization will occur with subsequent decrease of biomass for the same reason, as in the case for yellowtail flounder.

As to such relatively short-cycle species as silver hake and pollock, the prediction of their stock dynamics even at the trends level for 10 years ahead seems not possible yet. As regards hake more than 90% of which at the age of three years is represented by mature fish (Rikhter *et al*., 2001), it is possible only to assume by analogy to the previous observations (Rikhter *et al*., 2001), that the period of high recruitment abundance starting approximately from 1995 is approaching the end (or already finished in 2001) and, beginning from about 2003 the fishing and spawning biomass of the latter will decrease.

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TABLE 1. Dynamics of water temperature on the shelf of Southern Labrador and Grand Bank (Div. 2J+3KLMNO) in 1977-2000 (from Drinkwater *et al*., MS 2000).

| Period, years | 1977-82 | 1983-85 | 1986-89 | 1990-95 | 1996-2000 |
|---|---|---|---|---|---|
| Vertically averaged (0-176 m) temperature anomalies | Warming, strong negative anomalies | Cooling, strong negative anomalies | Slight warming, weak negative anomalies | Cooling, strong negative anomalies | Warming predominance of strong positive anomalies |

TABLE 2. Abundance dynamics and recruitment of some commercial fish populations (stock units) in NAFO Subareas 2 and 3.

| Period, year-classes | 2J+3KL Cod | Period, year-classes | 3NO Cod | Period, year-classes | 2J+3KLMNO Greenland halibut | Period, year-classes | 3LNO Yellowtail flounder | Period, year-classes | 3LNO American plaice |
|---|---|---|---|---|---|---|---|---|---|
| 1982-85 | Abundance reduction to the level below the average | 1978-82 | Fluctuations at the level higher than the average | 1978-85 | Trend towards increase at the level below the average | 1981-86 | Fluctuations with a trend towards increase | 1979-84 | Sustainable decrease to the average level |
| 1986-87 | Increase above the average level | 1983-88 | Reduction and fluctuations at the level below the average | 1986-90 | Trend towards reduction at the level below the average | 1987-92 | Decrease to a very low level | 1985 | The year-class level slightly higher than the average |
| 1988-92 | Decrease to a very low level | 1989 | Relatively strong year-class | 1991-95 | Sustainable increase to the high level | 1993-95 | Increase to the high level | 1986-92 | Sustainable decrease to a very low level |
| 1993-95 | Sustainable and very poor recruitment | 1990-92 | Decrease to a very low level | | | | | | |
| | | 1993-95 | Sustainable and very poor recruitment | | | | | | |

TABLE 3. Dynamics of water temperature on Scotian Shelf (Div. 4VWX) in 1980-2000 (from Drinkwater *et al*., MS 2001).

| Period, years | 1980-85 | 1986-93 | 1994-2000 |
|---|---|---|---|
| SST anomalies & temperature anomalies at the depth of 100 m | Warming, strong positive anomalies | Cooling, strong negative anomalies | Warming, strong positive anomalies |

TABLE 4. Dynamics of abundance and recruitment of some commercial fish populations (stock units) in NAFO Subareas 4.

| Period, year-classes | 4TVW Haddock | Period, year-classes | 4VsW Cod | Period, year-classes | 4+5 Pollock | Period, year-classes | 4VWX Silver hake |
|---|---|---|---|---|---|---|---|
| 1978-83 | Increase to the level considerably higher than the average | 1978-82 | Abundance level considerably higher than the average | 1980-86 | Fluctuations with reduction to the average level | 1978-80 | Abundance level slightly lower than the average |
| 1984-86 | Decrease to a very low level | 1983 | The year-class at the average level | 1987-89 | Increase to the level higher than the average | 1981-85 | Fluctuations with 3 strong year-classes appearance |
| 1987-88 | Increase to the level higher than the average | 1984-87 | Increase to the level significantly higher than the average | 1990-95 | Reduction to the level significantly lower than the average | 1986-93 | Fluctuations with reduction to a level below the average |
| 1989-91 | Decrease to a very low level | 1988-91 | Decrease to a very low level | | | 1994-95 | Increase to the level higher than the average |
| 1992-93 | Trend towards increase | 1992-95 | Sustainable and very poor recruitment | | | | |

TABLE 5. Matrix of correlation coefficients between recruitment of 8 fish populations in NAFO Subareas 2-4 (+ and ++ below a coefficient value means that this relation is reliable at 95 and 99% probability, respectively).

| Stock Unit | 2J+3KL Cod | 3NO Cod | 3LNO American plaice | 3LNO Yellowtail flounder | 2+3KLMNO Greenland halibut | SA 4+5 Pollock | 4VsW Cod | 4TVW Haddock |
|---|---|---|---|---|---|---|---|---|
| 2J+3KL Cod | 1.000 | 0.679++ | 0.440 | -0.255 | -0.433 | 0.558+ | 0.704++ | 0.641++ |
| 3NO Cod | 0.679++ | 1.000 | 0.703++ | -0.273 | -0.499+ | 0.683++ | 0.629++ | 0.762++ |
| 3LNO American plaice | 0.440 | 0.703++ | 1.000 | 0.095 | -0.417 | 0.580+ | 0.562+ | 0.599+ |
| 3LNO Yellowtail flounder | -0.255 | -0.273 | 0.095 | 1.000 | 0.652++ | -0.360 | -0.191 | -0.084 |
| 2+3KLMNO Greenland halibut | -0.433 | -0.499+ | -0.417 | 0.652++ | 1.000 | -0.580+ | -0.495+ | -0.232 |
| 4+5 Pollock | 0.558 | 0.683+ | 0.580+ | -0.360 | -0.580+ | 1.000 | 0.618+ | 0.656+ |
| 4VsW Cod | 0.704++ | 0.629++ | 0.562+ | -0.191 | -0.495+ | 0.618+ | 1.000 | 0.437 |
| 4TVW Haddock | 0.641++ | 0.762++ | 0.599+ | -0.084 | -0.232 | 0.656+ | 0.437 | 1.000 |

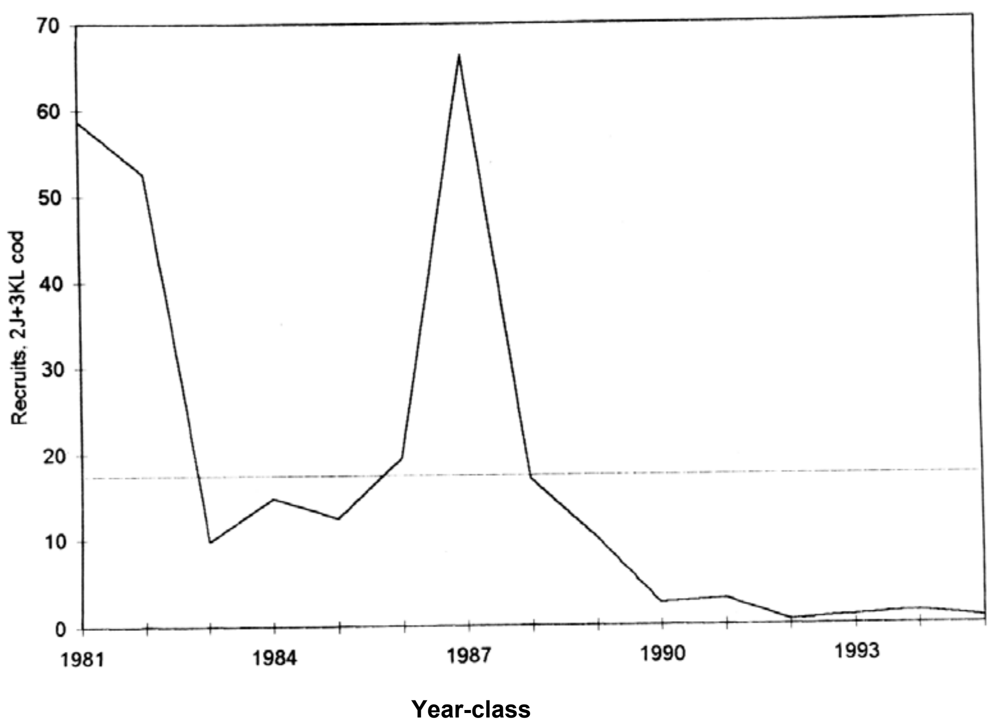


Fig. 1. Recruitment dynamics of 2J+3KL cod (1981-95 year-classes). Horizontal lines in all figures represent the long-term means of year-classes indicated in brackets.

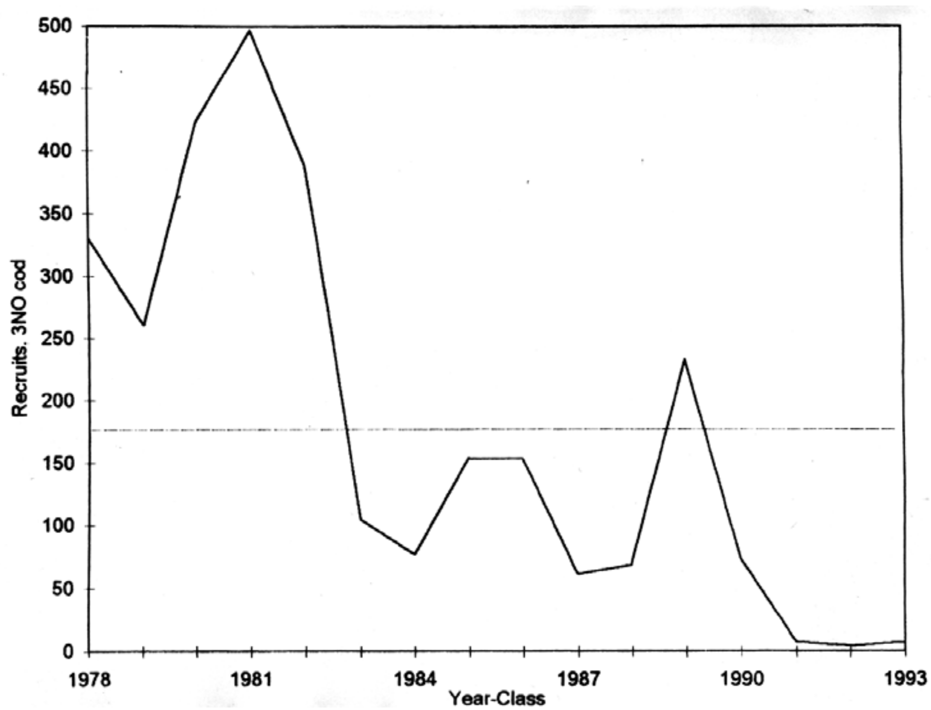


Fig. 2. Recruitment dynamics of 3NO cod (1978-93 year-classes).

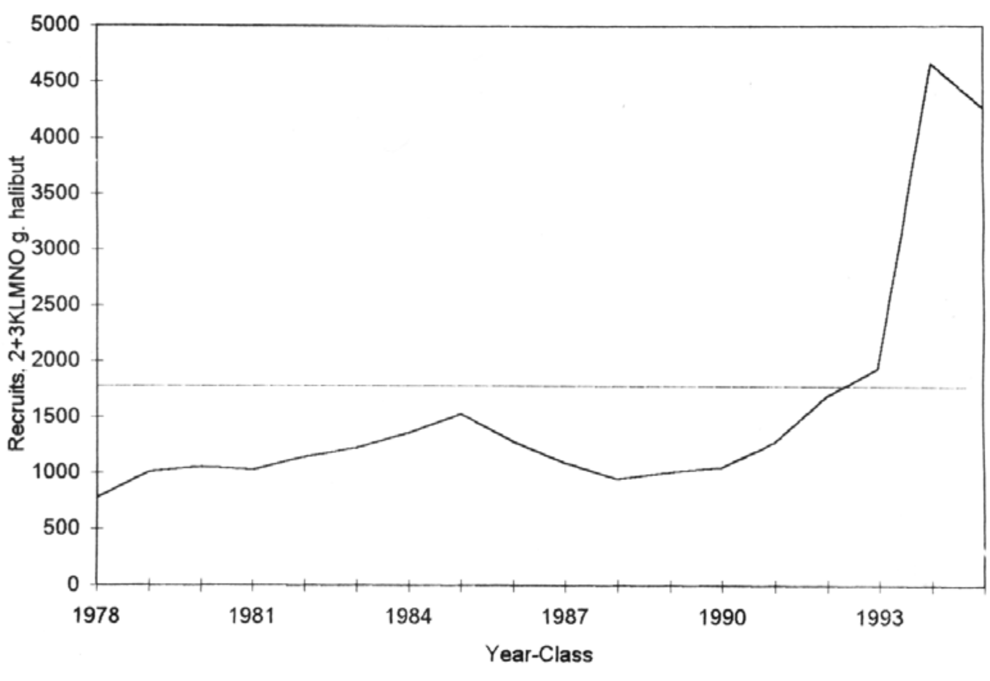


Fig. 3. Recruitment dynamics of 2J+3KLMNO Greenland halibut (1978-95 year-classes).

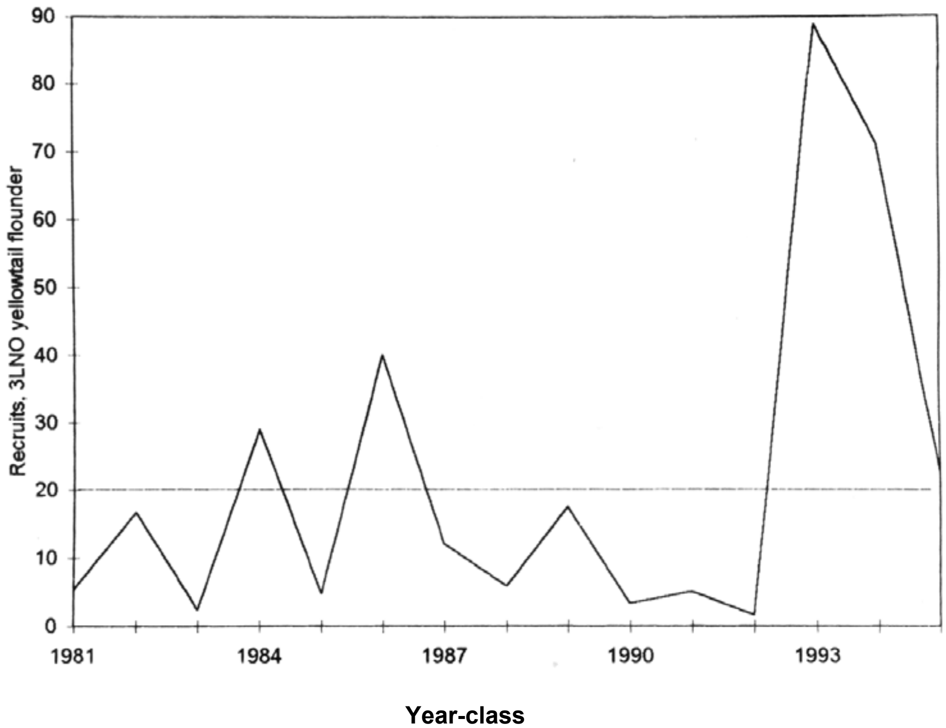


Fig. 4. Recruitment dynamics of 3LNO yellowtail flounder (1981-95 year-classes).

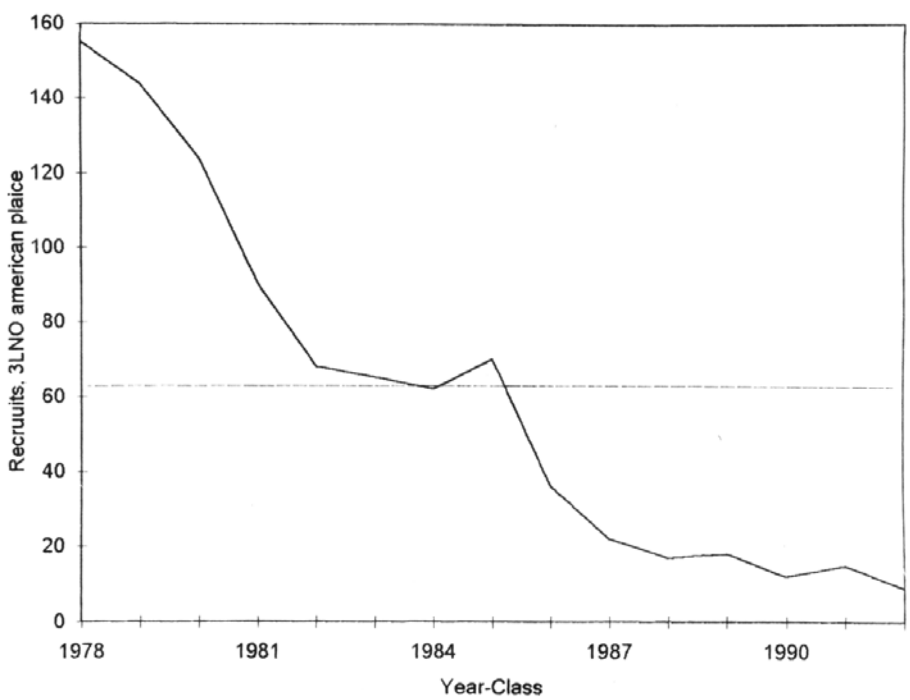


Fig. 5. Recruitment dynamics of 3LNO American plaice (1978-92 year-classes).

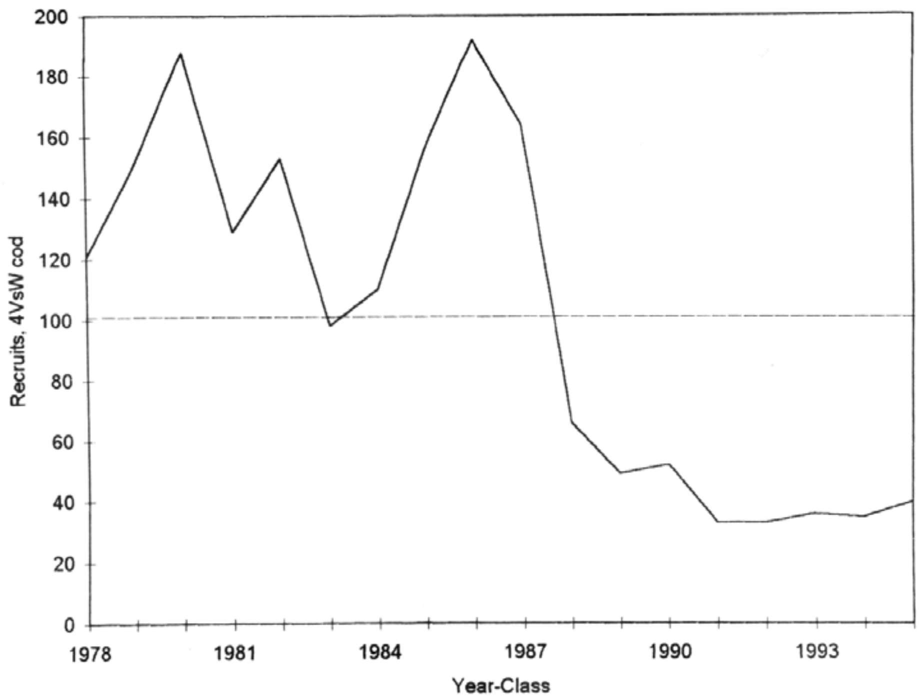


Fig. 6. Recruitment dynamics of 4VsW cod (1978-95 year-classes).

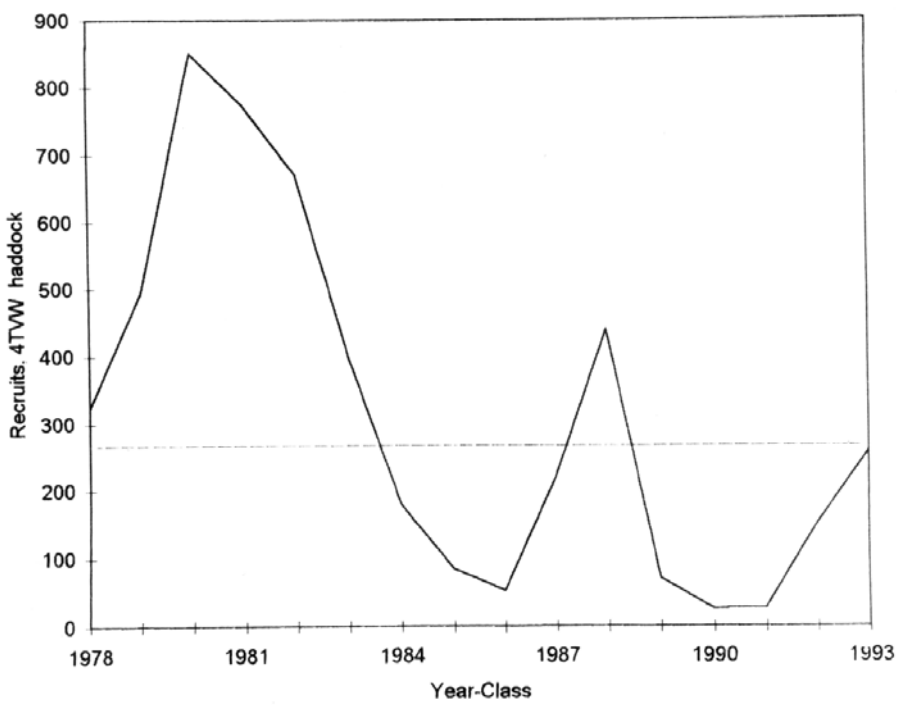


Fig. 7. Recruitment dynamics of 4TVW haddock (1978-93 year-classes).

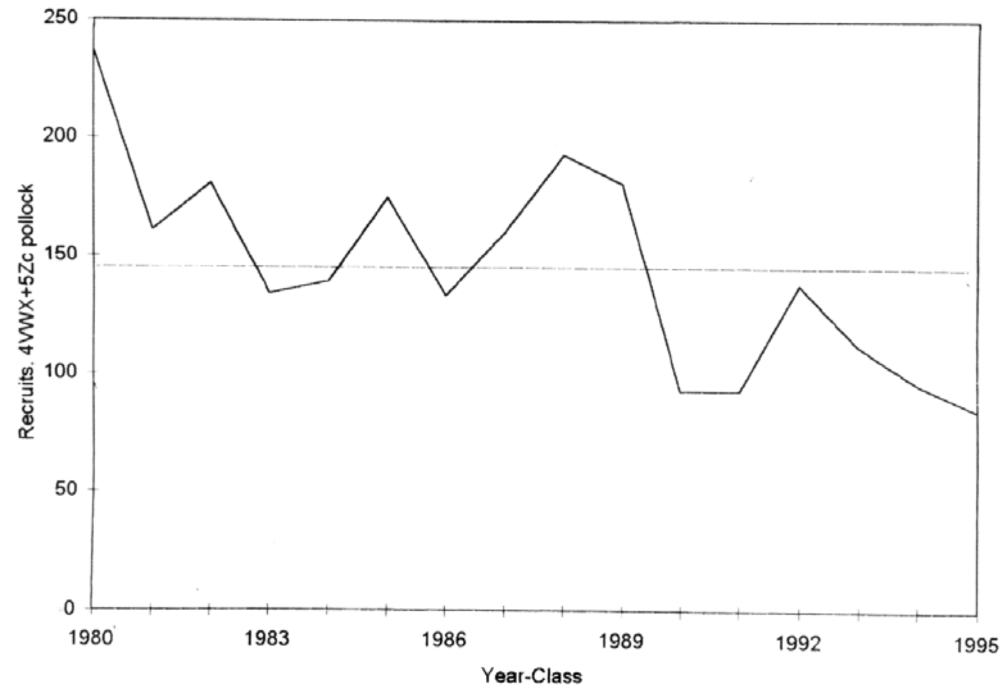


Fig. 8. Recruitment dynamics of 4VWX+5Zc pollock (1980-95 year-classes).

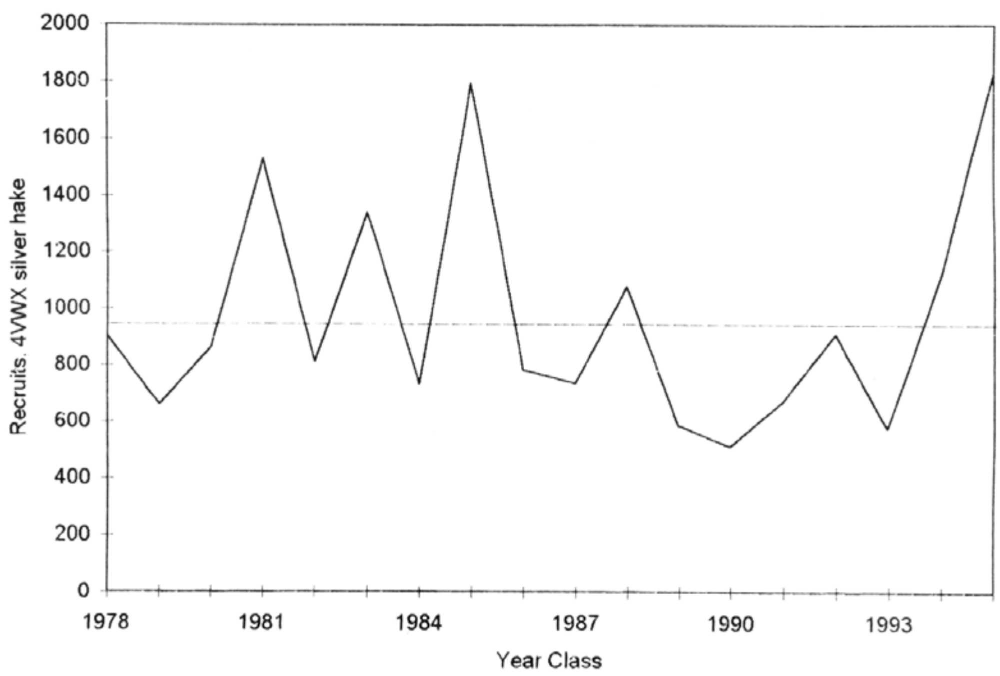


Fig. 9. Recruitment dynamics of 4VWX silver hake (1978-95 year-classes).