THE PRESENT STATUS OF COD STOCKS IN THE BARENTS SEA AND TAC FORECAST IN 2008

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INTRODUCTION

The northeast Arctic cod is one of the most important fishing species in the Norwegian and Barents Seas. According to the ICES data (www.ices.dk) the catches of cod during the last 30 years had two notable peaks: 905,000 tons in the mid-1970s and 771,000 tons in the mid-1990s. Later on catches declined (415,000 tons in 2000), while some upward trend was recorded in the recent years.

The cod fishery is being managed with the aid of advice given annually by ICES WG on Arctic Fisheries. The fishing stock is estimated using XSA method which is based on fishery statistics data. This technique is the only one applied both to the assessment of the fishable biomass of cod during the surveyed period, and to projecting the stock and total allowable catch (TAC) for one to two years.

As is known, however, using one stock assessment method only is fraught with the risk of an error which would inevitably occur because of the assumptions used for calculations repeatedly throughout a number of years; such an error may be offset in a comparative analysis of data thus not affecting the quality aspect. In order to evaluate how adequately a concrete method ensures fishable stock assessment in quantity terms one should compare its results with the data ensuing from the application of other techniques. That is why it is common in the present scientific research practice to compare the results of stock assessment obtained from using a variety of methods.

The authors of this report used fishery statistics to assess the fishable stock biomass of cod by the GIS method developed at VNIRO (Bulatov et al., 2007), which showed 1.6 times greater volumes of fishable stock biomass as opposed to the XSA method. The representativeness of fishery reports in recent years is certainly not marked by great accuracy. However, this source of information is being used by

scientists from many nations for the assessment of stocks of various fish species. Moreover, most analytical approaches are based on the fishery statistics data.

The authors of this paper aimed at collating the results of cod stock assessment made in 2000-2007 through the use of various techniques, and at evaluating tentatively the prospects for the cod fishery in 2008.

MATERIAL AND METHODS

They used the daily vessel reports (VDRs) to appraise the cod stock variability in the area of study. The following parameters of those reports reflecting the fishing activity of a vessel were taken into account: the reported date, latitude, longitude, fishing species and its catch, fishing gear, and time spent for the fishing operations. The whole area was subdivided into test sites of 0.5° latitude and 2° longitude.

A variety of trawl designs were applied in the cod fishery during the surveyed period. Trawling effectiveness analysis indicated that out of 35 fishing gears used six types of bottom trawls had provided for 39% - 62% of the total number of fishing reports. In total, 196,715 daily fishing reports for 2000-2007 were analyzed; half of them were utilized for cod stock assessment in this area (Table 1).

The analysis of fishery reports showed that vessels of 17 types had taken part in the cod fishery. The authors chose 6 types of mid-sized vessels that had taken the largest share of the annual catch. The most significant share of reports was sent from SRTM "Vasiliy Yakovenko" type vessels (Figure 1). The review of significance of the vessel type depending on the catch showed that " Vasiliy Yakovenko", "Orlyonok" and "Barentsevo More" vessel types yielded the largest catches in 2000-2006 (Table 2).

Table 1

Number of daily reports submitted for the surveyed area, 2000-2007

Year	Total number of reports	Number of reports with the known type of trawl	Share of reports with the known type of trawl of the total number of reports
2000	36797	14458	0.393
2001	31118	13220	0.425
2002	23716	11236	0.474
2003	20095	11052	0.550
2004	22111	13712	0.621
2005	21746	10969	0.505
2006	25485	14381	0.565
2007 (April-August)	15647	10766	0.688
Totally	196715	99794	0.507

Table 2

The share of relative catch depending on vessel types, %%

Vessel type	2000	2001	2002	2003	2004	2005	2006
"Vasiliy Yakovenko"	40.3	40.1	35.8	28.9	28.6	27.1	33.0
"Orlyonok"	15.7	14.4	12.7	17.4	15.2	18.6	18.4
"Barentsevo More"	14.2	16.4	22.0	9.9	18.3	15.3	16.6
Others	29.8	29.1	29.5	43.8	37.9	39.0	32.0
Total	100	100	100	100	100	100	100

Since the known types of trawls did not cover the entire fishing area or the whole range of cod the data obtained in relation to the distribution and biomass of cod are definitely underestimated. The data on the duration of trawling and the weight of cod catch obtained from the daily messages were used to find out

the catch per one hour haul. Using the characteristics of the specific trawls and catchability coefficient they calculated the density (t/km^2). The catches exceeding 2 t/h of trawling were considered erroneous and were disregarded. The catch frequency distribution made it possible to apply the log-normal distribution assumption.

The biomass of cod in each square was determined according to the method of Aksyutina (1968).

$$P = \sum_{i=1}^{n} \left(\frac{Q_i \times x_i}{q \times k}\right);$$

where P is the biomass (tons);

Q_i is the area of each square (i), (km^2);

x_i is the mean actual catch in square (i), (t/h of trawling);

q is the area of trawling (determined through multiplication of the trawl horizontal opening by the distance covered), (km^2);

k is the catchability coefficient taken as 0.3 (Serebrov, 1988).

The mean catch per one hour haul for the 15-day period was calculated for each square (0.5 degree of latitude x 2 degree of longitude). Given the square area and catchability coefficient of the trawl, they calculated the densities and biomass value for each square. The estimated biomass for the entire area was taken as a sum of the biomass estimates within the area.

The average monthly biomass value was found as the mean value of the biomass for two 15-day periods. Since fishing in January-March was not active (Figure 2), the average annual values of biomass were taken as the mean arithmetical values of the average monthly biomass for April-December (for April-August in 2007). The squares were computed using the GIS software ArcView 3.2 (ESRI). The extrapolation technique was not resorted to; the actual catches were taken into account.

The data of bioanalysis of cod collected by VNIRO observers on fishing vessels in the Barents Sea in summer 2007 were used for the calculations. The

age of cod was determined by otoliths at the Fish Ecology Laboratory of VNIRO; a total of 476 was examined.

Results and discussion

The fishing biomass in the surveyed area was assessed repeatedly. Altogether, in 2000-2006 we received 126 fishable biomass values. Besides, in April-August 2007 we received 10 more values. The results showed that in 2006-2007 there were two seasonal peaks of cod stocks: summer and autumn-winter. The exceptions were 2000 and 2001 when the autumn maximum was not pronounced enough. The averaged values of monthly biomass showed that in April-June the biomass was 86-91% of the seasonal maximum observed in July when cod feeds actively and migrations are not intensive. In September-October, when the migration was reverse, the recorded biomass went down to 75% of the seasonal maximum; later on the figure increased in November-December up to 81-91% (Table 3).

Table 3

Dynamics of fishable biomass of cod in April-December, '000 t

Month	2000	2001	2002	2003	2004	2005	2006	Average	%
April	2323	2045	**2878**	**2273**	2404	2056	1845	2260	88.0
May	2358	2302	2248	1286	2167	2271	2785	2202	85.8
June	2136	**2799**	2702	1922	2298	2276	2262	2342	91.2
July	2439	2640	2502	1322	**3369**	**2432**	3264	**2567**	**100.0**
August	**2902**	2180	2323	1493	2899	1713	**3738**	2464	96.0
September	1485	1558	2206	1499	2242	1734	2705	1918	74.7
October	1585	1840	1674	2178	2972	1881	2394	2075	80.8
November	1748	1384	**2991**	**2427**	2954	**2020**	**2883**	**2344**	**91.3**
December	1736	1466	2342	2360	**3596**	1950	1976	2204	85.8

The development of fishing stocks of cod has a long history. According to ICES data (ICES AFWG Rep., 2007) the biomass of cod reached a high level three times throughout the past 30 years: in the mid 1970s, mid-1990s and in 2003 (Figure 3). The maximum catch exceeding 700,000 t was observed twice

during this period: in 1977-1978 and in 1993-1997 (Fig.2). It is notable that there was an extremely high level of stock exploitation which existed mostly when fishable biomass was low. In that period the level of harvesting used to approach about 50% for three times.

Despite that, the stocks did not collapse. It is known however that the age structure of the fishable stock of cod is rather complex. The range is 2-15 years. Such a situation is hypothetically possible only in the event that the fishery is based on the species having a short life cycle: arctic cod, pacific saury, smelts, etc. Despite the excessive exploitation level the stocks began to rise constantly after 2-3 years. Such a "paradox" becomes possible only when the cod stocks are significantly underestimated while XSA method is used.

The average monthly values of fishable biomass of cod in April-August 2000-2007 were used to obtain average yearly values. The comparison of our GIS-based data with those obtained by the ICES WG on Arctic Fisheries showed that they are considerably different (Figure 4).

On the average the fishable biomass of cod according to GIS method was 2.4 million tons while it was nearly twice as smaller in the case of XSA (1.3 million tons). Another notable feature is the biomass variability trend. Our data indicate that during 2005-2007 there was a rise in biomass from 2.15 to 2.97 million tons (+38%), whereas the ICES WG on Arctic Fisheries data is that in 2004-2006 the stocks declined from 1353 to 1297 thousand tons (-4%). Hence, the application of XSA method to the period compared brought about an important underestimation of the fishable biomass.

TAC was calculated retrospectively on the basis of the Barents Sea fishable stock values obtained by the authors and the actual magnitudes of exploitation level recorded in 2000-2006. As we assessed it the average catch could be 700,000 tons; yet, according to the advice of the Joint Russian-Norwegian Commission, the actual TAC was a little over 400,000 tons (Figure 5).

Consequently, the fishable biomass as underestimated by the WG on Arctic Fisheries was taken as foundation for the respective recommendation of the Joint Russian-Norwegian Commission, and entailed a significant lowering of TAC to the detriment of Russia's national interests.

In order to be able to compute the projected fishable biomass of cod one has to know what recruitment to the fishing stock will be (fish aged 3). In its forecasting the recruitment the WG on Arctic Fisheries is supported by the "parents-progeny" relationship. To test how dependable this relationship is we made a correlation analysis of the last 40 years' data. The resulting correlation coefficient for that period was found to be 0.27 which allows us to assume the absence of a statictically correct correlation between these phenomena (Figure 6).

In addition the authors analyzed the dependence of the age 3 recruitment on the mean annual water temperature within 0-200 m. It was found that coefficient for the 26 year period was rather high (r=0.68). So, this correlation coefficient value obtained points to the existing close relationship here. Then we calculated the formula which may be used as forecasting model already at present. The curve shown in Figure 7 shows a linear dependence, and can be described as

$$N = 328{,}69\,T - 807{,}93$$

where N – is the recruitment of cod aged 3 (million ind.);

T – is the average water temperature at the Kola section within 0-200 m.

As is known (ICES AFWG Rep., 2007), the average recruitment of cod for 1977-2002 was 485 million fish. Our formula then makes it possible to find the temperature value at which, as a rule, medium and strong year-classes emerge. After a respective quantification this temperature value is 3.9 C. Since the average water temperature between 2003 and 2006 was 3.4-5.1 C, we can

assume with a large measure of certainty that the reproduction conditions were favorable. It is expected therefore that the fishing biomass of cod will go up in 2008-2011 versus 2000-2005. Consequently, the status of stocks of this fishing species does not cause concern, and the forecast for the upcoming four years is optimistic.

In order to introduce the expected recruitment parameters for the age 3 fish to the estimates of the projected fishable biomass for 2008 let us fix 5.1 C as an estimated value of the mean temperature of water in the Kola section within 0-200 m for 2005. As we computed it, the expected recruitment will be 868 million fish which is 87% above the average level.

The most recent data obtained by Norwegian hydrologists also showed a statistically valid correlation between the recruitment numbers and factors of habitat (Svendsen, 2007). This author points out that 70% of this abundance is formed in the fourth quarter of the year preceding the spawning and making up of the primary production in April (postspawning period) depending on water temperature. As E.Svendsen calculated, the expected recruitment of fish aged 3 for 2008 will be at least 700 million individuals.

Thus, quite close values obtained independently of the existing definite relationship not with the initial biomass of the parent stock, but with the environmental conditions in the pre spawning and post spawning periods.

As was pointed out above, the GIS-recorded fishable biomass of the population in 2007 was 2971 thousand tons. The bioanalysis data indicate that the mean weight of the individual on the fishing grounds was 1.957 kg. The ensuing abundance of the fishing stock of cod in the Barents Sea in 2007 was 1518 million fish. The VNIRO Ecology Laboratory data show that the age structure of the fishable stock of cod in 2007 was marked by the dominance of fish aged 5 in catches. Using these data and the survival data (Borisov, 1976; Barents Sea cod..., 2003) for each year-class of cod the authors calculated the projected fishable biomass of cod in 2008 (Table 4).

Table 4

Tentative forecast of the fishable stock of the Barents Sea cod for 2008.

	2	3	4	5	6	7	8	9	10	>11 and more
Year of birth in 2007	2005	2004	2003	2002	2001	2000	1999	1998	1997	>1996
Age composition in 2007 (%%)	1,4	5,4	22,4	28,7	21,1	9,3	5,6	4,3	1,0	0,8
Fishable stock abundance (million ind.)	21,2	82,0	340,0	435,7	320,3	141,2	85,0	65,3	15,2	12,1
Year of birth in 2008	2006	2005	2004	2003	2002	2001	2000	1999	1998	>1997
Survival	-	-	0,70	0,79	0,80	0,80	0,80	0,78	0,76	0,72
Forecasted fishable stock abundance (million ind.)	-	(700*)	238,0	344,2	256,2	113,0	68,0	50,9	11,6	8,7
Average weight (kg)	0,31	0,55	0,83	1,22	1,74	2,44	2,96	6,62	9,12	10,50
Forecasted fishable biomass (thousand tons)	-	(385,0)	197,5	419,9	445,8	275,7	201,3	337,0	105,8	91,4

* - according to Svendsen data

The above calculations show that the forecasted fishable biomass of the Barents Sea cod in 2008, with the added 2005 recruitment, will be 2,459 thousand tons which corresponds to the average miltiannual level for 2000-2006. Assuming the fishery in the second half of 2007 will utilize half of TAC for 2007 (212 thousand tons), the fishable biomass by the onset of 2008 should be at least: 2459 – 212 = 2247 thousand tons.

Without the recruitment (2005 year-class), the forecasted fishable biomass in 2008 will be: 2459 – 385 = 2074 thousand tons. Accounting for the fishing mortality we would get it that the forecasted fishable biomass of cod in 2008 will be: 2074 – 212 = 1862 million tons.

As is known, it appears impossible calculate TAC without a figure for the harvest level. Let us analyze the exploitation rate using ICES AFWG data which include the illegal catch. During the past 10 years this indicator ranged between 34 and 50% (Table 5).

Table 5.

Dynamics of catch, fishing biomass, and actual exploitation rates of cod in 1997-2006

Year	Catch, including illegal (AFWG Rep., 2007), '000 tons	Fishable biomass (AFWG Rep., 2007) '000 tons	Actual exploitation rate (%%)
1997	762	1530	49.8
1998	592	1221	48.5
1999	484	1076	45.0
2000	415	1045	39.7
2001	426	1253	34.0
2002	535	1341	39.9
2003	552	1382	39.9
2004	606	1354	44.8
2005	641	1336	48.0
2006	596	1298	45.9
Средняя	561	1284	43.6

The rates obtained appear to be overestimated, and not realistic for such a species as cod. More realistic values could be found using the actual exploitation rate figures without the illegal fishery. Hence, in 2004-2006 the average exploitation rate was 33.8%, that is very close to *F=0.4*. Consequently, the **TAC for 2008** without the recruitment of the age 3 fish would be: 1862 x 0.338 = **629 thousand tons**. As is known, the TAC in 2008 recommended by the ICES AFWG was 409 thousand tons which is 54% below our estimate.

Conclusions

1. Dynamics of the fishable biomass of the Barents Sea cod in 2000-2007 were stable, with an upward trend in recent years (2005-2007).
2. The result of a correlation analysis made is that the "parents-progeny" relationship is not provided with a significant level, whereas the recruitment of cod aged 3 is directly related to the mean water temperature within 0-200 m, and correlation coefficient was 0.68.

3. The analysis of the dependence of recruitment on water temperature was made formal which enabled us to generate a prognostic model, and evaluate the size of recruitment at age 3.
4. The estimated fishable biomass forecast and TAC for cod of the Barents Sea based on GIS method showed that a possible yield in 2008 will be 629 thousand tons which is 1.5 times greater than it had been suggested by the AFWG.
5. The procedure to assess the fishable biomass and forecasted TAC, as suggested by the authors, has by far fewer sources of uncertainty, and is much simpler to apply, as compared to the XSA procedure used in recent years by the ICES WG on Arctic Fisheries.

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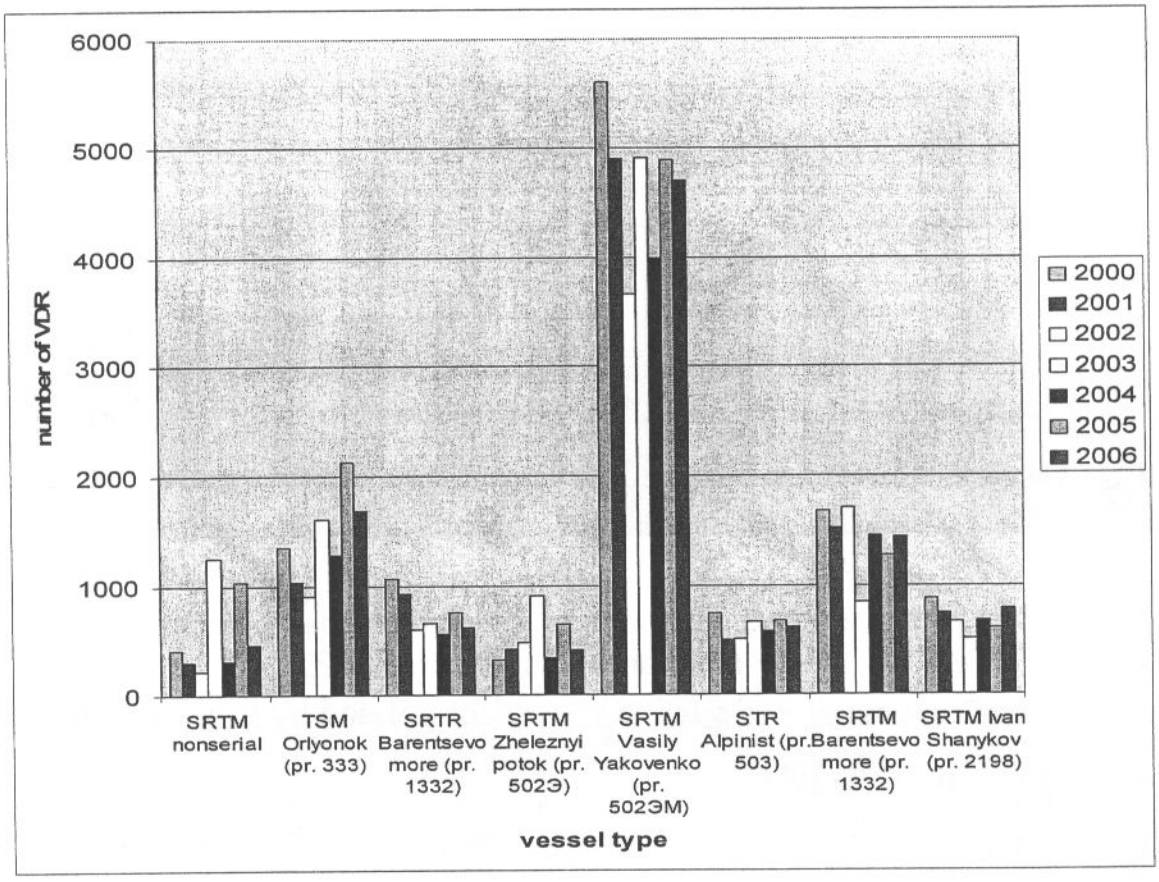

Fig.1. Number of daily vessel reports depending on the type of vessel

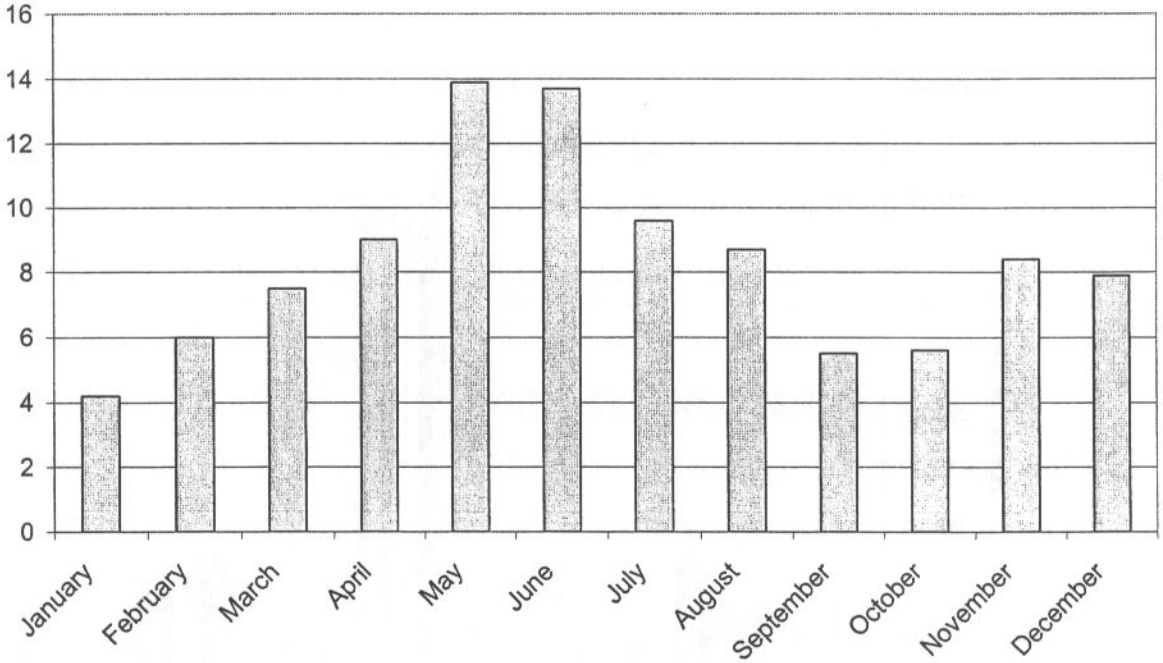

Fig. 2. Dynamics of relative (%) catches of cod by Russian vessels in the Barents Sea in 2000-2006

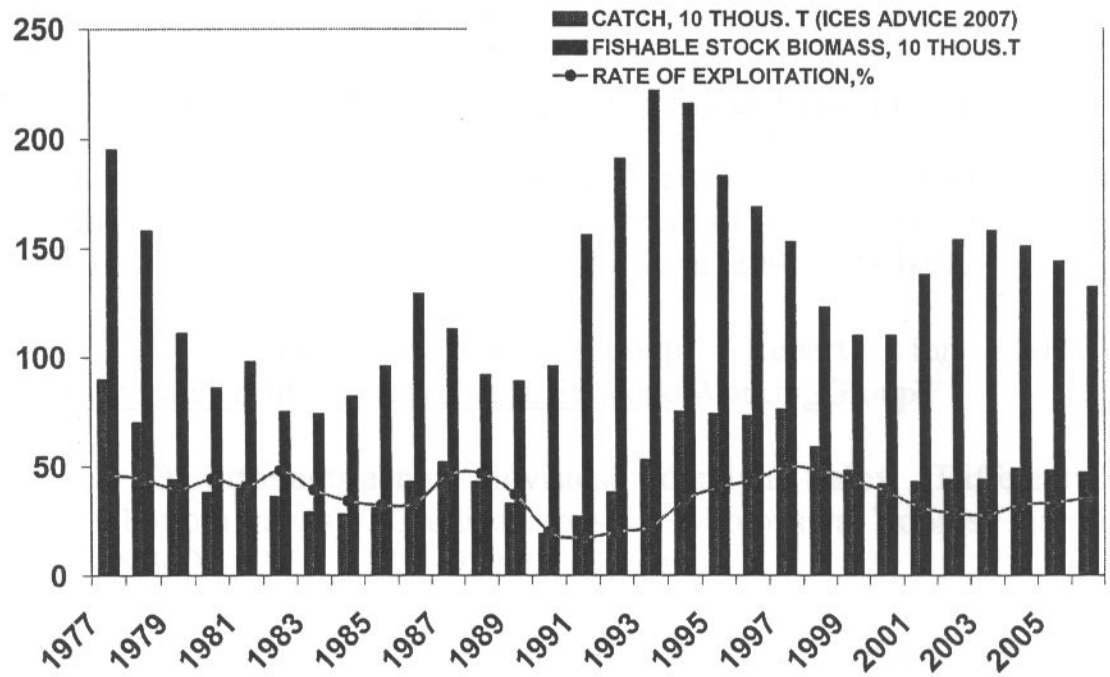

Fig. 3. Dynamics of the fishable biomass and catches of cod (ICES AFWG Rep., 2007) and exploitation rate

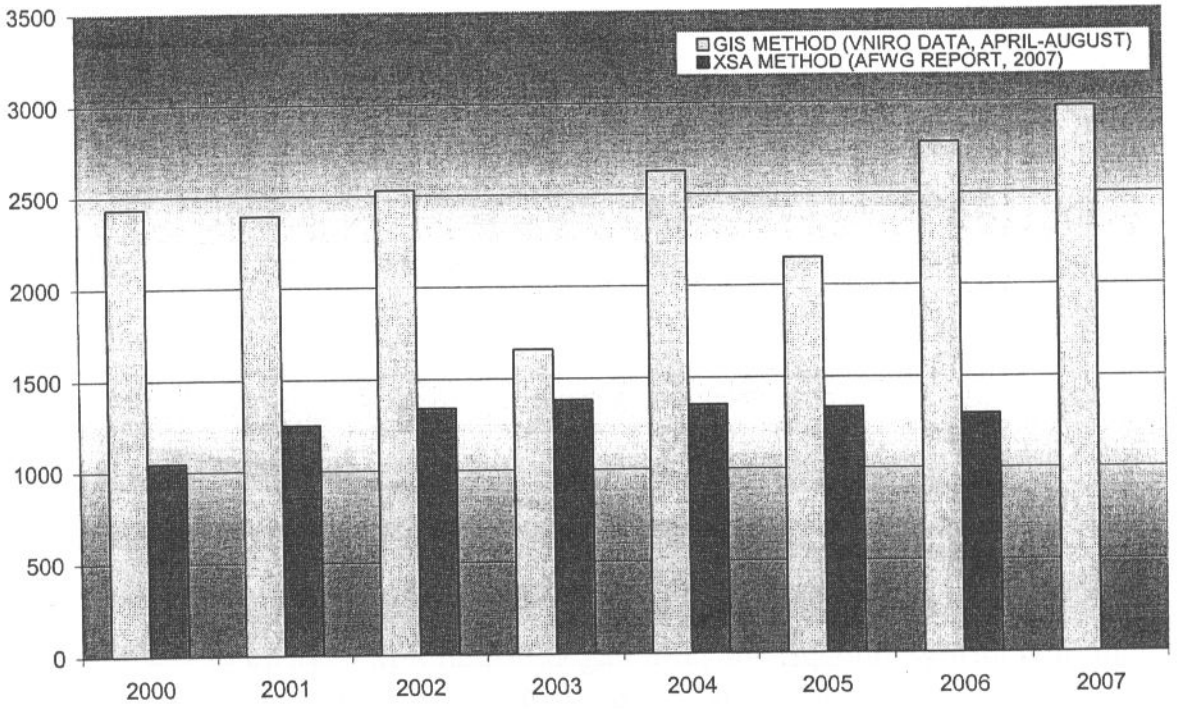

Fig. 4 Estimated fishable biomass of cod in the Barents Sea by GIS and XSA methods (thousand tons)

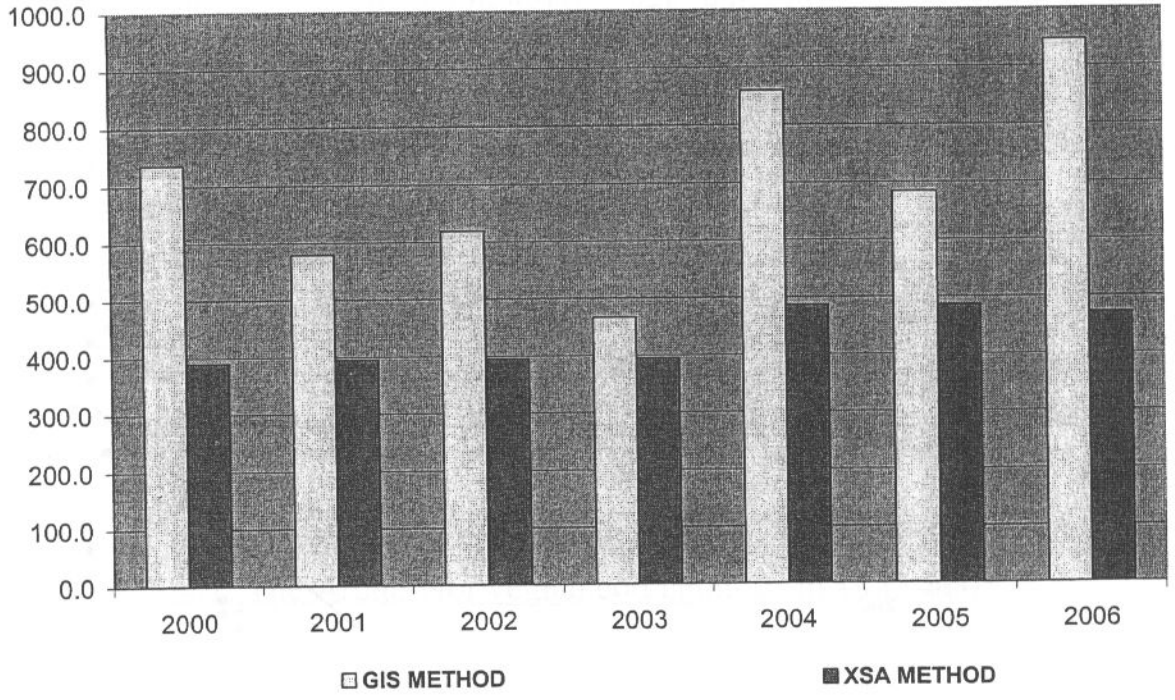

Fig. 5 TAC for the Barents Sea cod based on GIS and XSA methods (thousand tons)

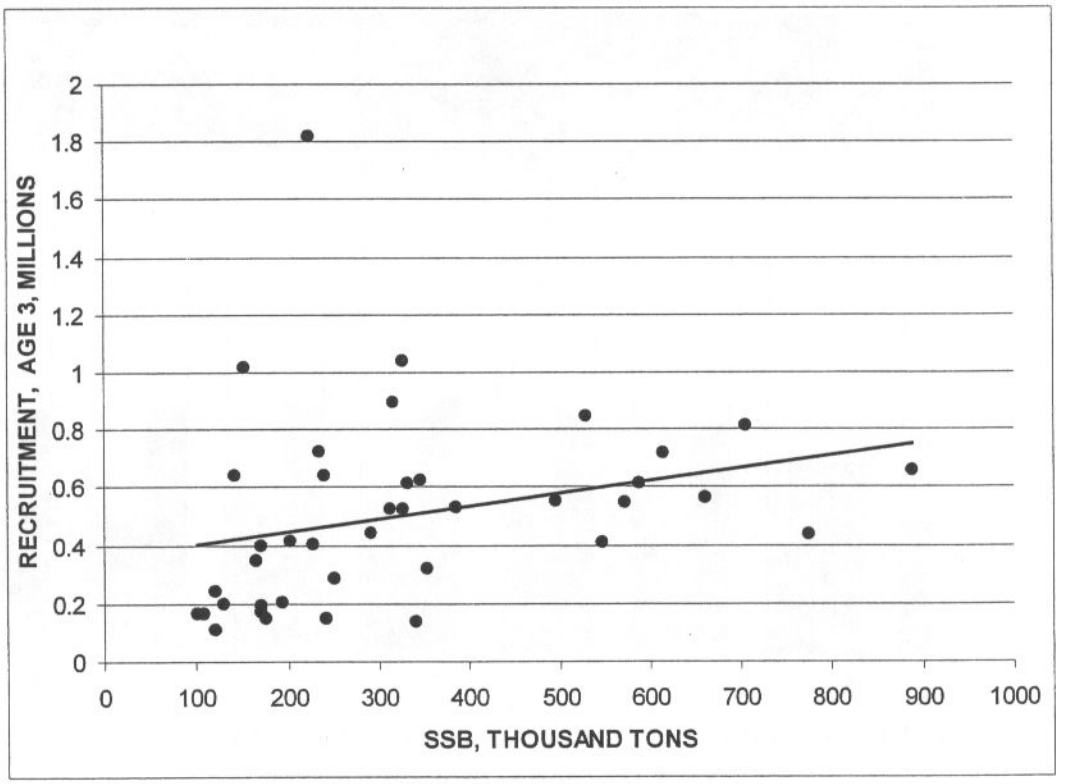

Fig. 6 Recruitment at age 3 in relation to spawning stock biomass of cod in 1965-2004 (data from ICES AFWG Rep., 2007)

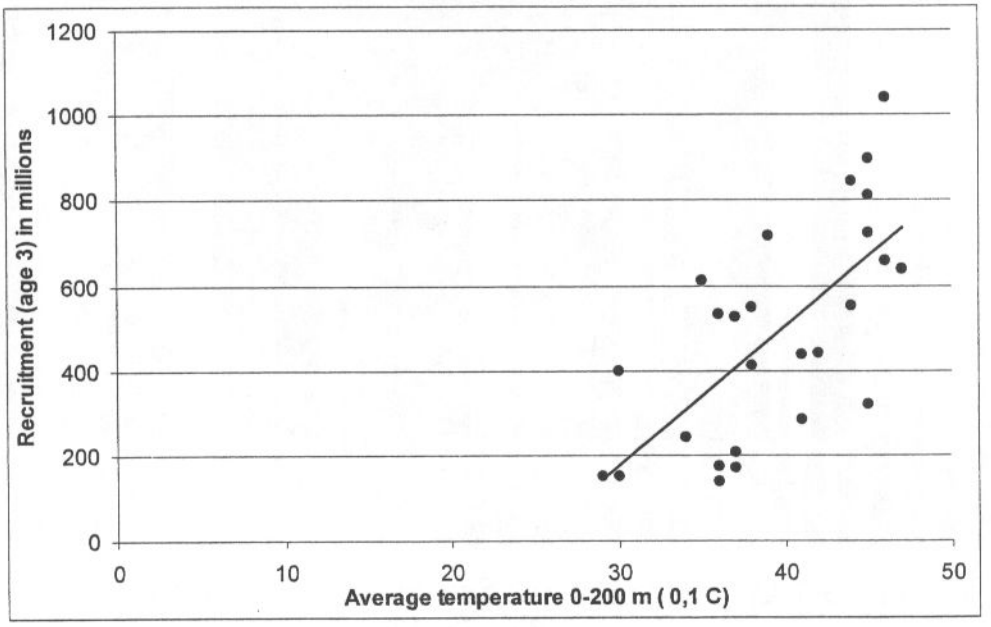

Fig. 7 Recruitment of age 3 cod in relation to average temperature within 0-200 m at Kola section in 1977-2002 (PINRO data)