SESSION 2: Demersal fish

Cod

A. Aglen[1], K. Drevetnyak[2] and K. Sokolov[2]: Cod in the Barents Sea (Northeast Arctic cod) - a review of the biology and history of the fishery and its management

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Abstract

This paper briefly reviews our knowledge of the spatial distribution, ecology, stocks dynamics and fishery for Northeast Arctic cod. The history of stock assessments and scientific advice, and of fisheries regulations and management strategies, are described and discussed.

Key words: Northeast Arctic cod, stock, fishery, scientific advice, management strategy.

Stock characteristics

Stock distribution

Northeast Arctic cod (*Gadus morhua L.*) has the most northerly area of distribution of all North Atlantic cod populations, including the Barents Sea and adjacent waters of the Norwegian and Greenland Seas. According to ICES divisioning it comprises ICES area I and subareas IIa and IIb.

The northern border of cod distribution is usually is the polar front zone (a zone where warm Atlantic waters mix with cold waters of the Arctic and the Barents Sea origin) with steep gradients in its physical and chemical parameters. From the east, the distribution of cod is limited by the edge of summer ice. The western border is the shelf edge of the Norwegian Sea.

The Barents Sea is influenced by warm Atlantic water flowing in from the southwest and cold Arctic water coming from the north (Midttun, 1969; Blindheim and Loeng, 1981). There are major spatial, seasonal and interannual fluctuations in the temperature of the water masses (Bochkov, Tereshchenko, 1992; Tereshchenko, 1996).

The main feeding areas for cod are the central and eastern parts of the Barents Sea and the waters near the Spitsbergen Archipelago. However the area whose waters are favourable for cod decreases in cold years and increases in warm years.

The main cod spawning areas are nearshore banks and open fjords along the Norwegian coast from 62º N to 71º N. The larvae drift northwards, north-eastwards and eastwards. The spatial distribution of cod larvae and fry in shallow waters around Bear Island, the Spitsbergen area and in the southern part of the Barents Sea varies, mainly due to fluctuations in the distribution of the various water masses.

The period of regular spawning/postspawning migrations of mature fish as well as feeding/wintering migrations of young immature fish is highly influenced by water temperature conditions in the Barents Sea. The hydrologic regime of the Northeast Arctic cod distribution area has an important impact on reproduction and abundance dynamics. Thus, stronger than average year classes tend to appear when temperature anomaly cycles change from cold to warm (Sætersdal and Loeng, 1987; Nilssen *et al*., 1993), while poor year classes tend to appear in cold years (Tretyak *et al*., 1995).

Stock separation and management units

From a management point of view the cod in the Barents Sea and adjacent waters are treated as two units: Northeast Arctic cod and coastal cod. From a biological point of view, cod in the Barents Sea, the Norwegian Sea and in the coastal areas living under variable environmental conditions form groups with some peculiarities in geographical distribution, pattern of migration, growth, maturation rates, genetic features, etc. (Rollefsen, 1933: Møller, 1968; Jørstad, 1984).

The degree of intermingling of different groups is uncertain. However, taking into account some biological characteristics of cod in the coastal zone and the specifics of the coastal fishery, the ICES Arctic Fisheries Working Group (AFWG) assess the Norwegian coastal cod stock separately from North-East Arctic cod.

It should be noted that some research has considered this division of the cod stock as theoretical, which has not yet been finally proved (Artemieva, 1988).

Stock size and history

The Northeast Arctic cod stock is one of the most important cod stocks in the North Atlantic. Figure 1 shows the dynamics of total biomass (age three and older, labelled "commercial" in the Figure) and spawning stock biomass estimated by the virtual population analyses (VPA) from 1946 to 2002. During these years the stock has displayed wide fluctuations, and a gradual decrease in the stock was observed from the 1950s to the 1980s.

In the 1980s two minima in the cod stock were registered. The total stock fell to a minimum in 1982-1983 and again in 1988-1989, when its size was about 0.8 million tonnes. The spawning stock had its first minimum in 1980-1981 and its second in 1986-1989, when its size was estimated as 140-160 000 tonnes. In the early 1990s the stock increased, mainly as a result of strong regulations that reduced the fishing pressure, and the average spawning stock in the 1990s was high in comparison the previous period. In 2002, according to Arctic Fishery Working Group (AFWG) estimates, the total stock was 1.6 million tonnes and the spawning stock was about 500 000 tonnes (Anon., 2003). Such large fluctuations in stocks are caused mainly by variations in recruitment abundance (cod year-classes at age three).

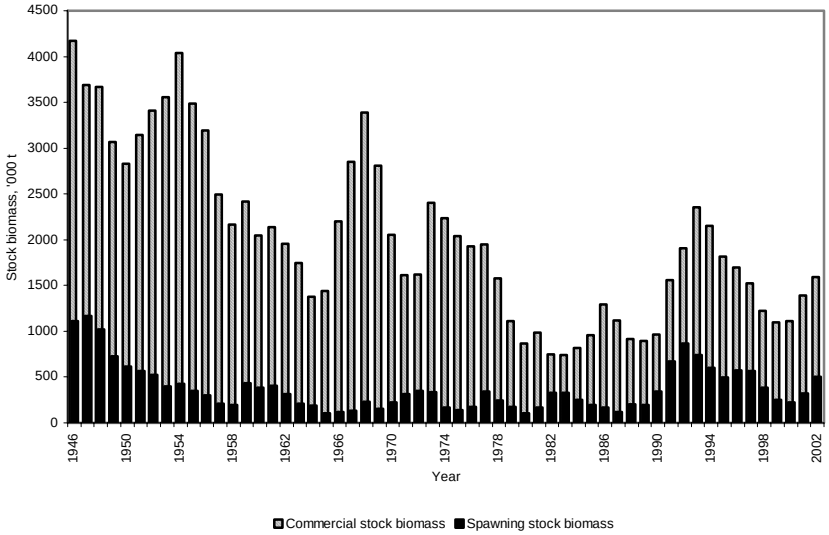

Figure 1. Commercial stock biomass and spawning stock biomass of Northeast Arctic cod in 1946-2002, in thousand tonnes.

Figure 2 shows the abundance dynamics of cod year-classes at age three. As we can see, the rich year-classes are more than ten times as abundant as the poor ones. The appearance of several successive poor cod year-classes is greatly unfavourable. The stock minima mentioned above were caused by five successive poor year-classes recruited to the stock in 1979-1983.

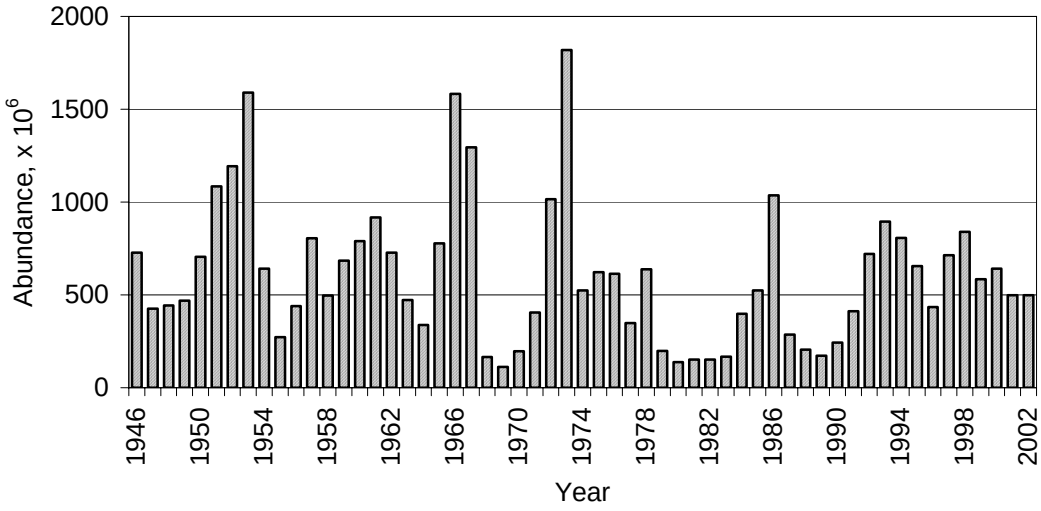

Figure 2. Year-class abundance of Northeast Arctic cod at age 3.

Position in the food web

The Northeast Arctic cod can be characterized as an active predator. Key objects in its diet are fish and crustaceans. The food habits of cod vary with its size. *Calanus* at various stages is the most important food item for cod larvae at all stages (Wiborg, 1948; Sysoeva, 1971; Tilseth and Ellertsen, 1984). When fish reach a length of 30-50 cm (at an age of three or four years) the importance of ephausiids, amphipods and shrimp in the diet increases. Fish prey (capelin, herring, polar cod, sand eel, young gadoids, etc.) make up to 70% of the total food consumption for cod between 30 and 80 cm (Zatsepin and Petrova, 1939; Mehl, 1986). Cod individuals more than 80 cm in length consume almost only fish. Annual cod consumption of different prey species in the Barents Sea and adjacent waters comes to between 1.4 and 6.0 million tonnes (Anon., 2003a). About one third of this amount is capelin.

In the years when consumption of capelin decreases the proportion of other prey species in the cod diet increases.

One of the important components of the cod's diet is its own juveniles. Cannibalism increases when there is a lack of other prey. For example, it was relatively high in 1986-1988 when stocks of capelin and young herring were small. Cannibalism increased especially in 1995-1996, when the biomass of young fish of their own species consumed by cod reached 400-500 000 tonnes (25×10^9 - 33×10^9 spec.) compared to 10-100 thousand tonnes ($0{,}4 \times 10^9$ – $1{,}0 \times 10^9$ spec.) in the 1980s (Korzhev, Tretyak, 1989; Bogstad *et al*., 1994; Anon., 2003).

The main predators for cod is harp seal (*Phoca groenlandica*) and minke whale (*Balaenoptera acutorostrata*). The total annual consumption of cod by these species was estimated to be 350-550 thousand tonnes (Nilssen *et al*., 2000; Folkow *et al*,. 2000).

History of the fishery

The Northeast Arctic cod is a traditional fishing object in the Barents Sea and adjacent waters. First references to cod fishery in the Barents Sea are found in historic documents of the 16th century (Dyrvik *et al*., 1979; Øiestad, 1994).

Statistics of the Norwegian cod fishery in spawning grounds near Lofoten islands have existed since 1866 and first Russian fishery statistical data near Murmansk are dated 1880 (Sætersdal and Hylen, 1964; Glebov, 1963). Annual catches of cod in this period were about 200-300 000 tonnes. The major part of these landings (75-85%) has been fished on the spawning grounds near the north-western coast of Norway.

The rapid development of the cod fishery started in first decades of the 20th century with the introduction of bottom trawls. Cod landings in this period depended generally on fishing effort and grew up to the 1950s.

The landings of Northeast Arctic cod in 1946-2002 varied considerably from the mean long-term level, which is around 700 thousand tonnes. In the 1950s the mean catch was about 850 000 tonnes and in the 1960s and70s it came to about 750 000 tonnes (Fig. 3). A fall in cod landings occurred in the 80s, when annual catches fell to 350 000 tonnes, which was preceded by high fishing mortality during a number of previous years.

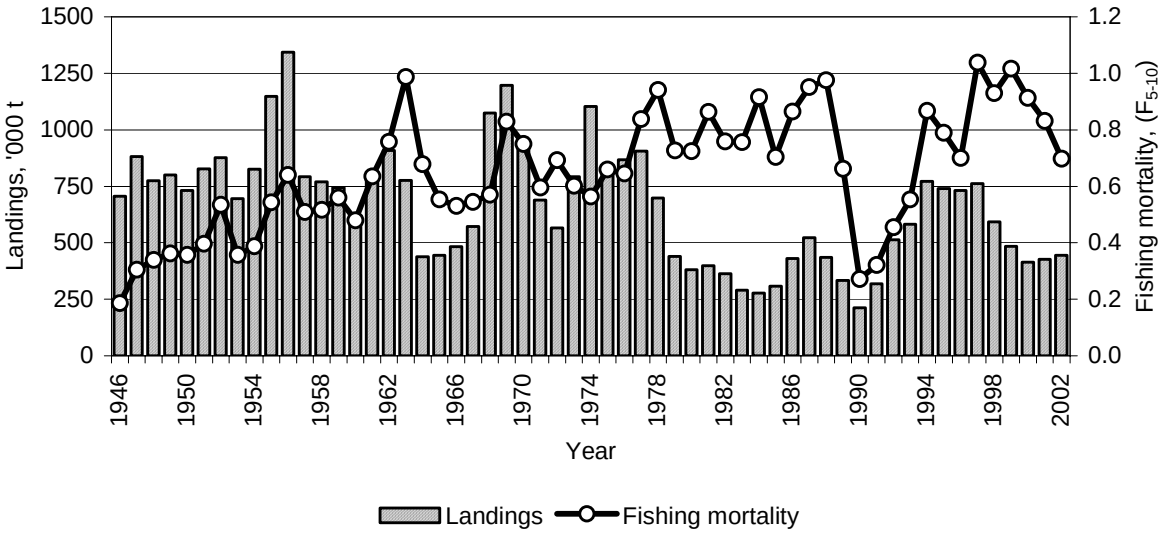

Figure 3. Landings of Northeast Arctic cod and fishing mortality (F_{5-10}) in 1946-2002.

The modern conventional cod fishery is conducted by both international trawl fleets and coastal vessels using active (bottom trawl, Danish seine) and passive (long-line, hooks) fishing gears.

Fishermen of Russia (former USSR), Norway, the United Kingdom, Germany, Poland, Iceland, Spain and other countries fish cod. Historically the main cod fishing counties were Norway, the USSR, UK and Germany, but their role in fisheries has been changing.

Cod are fished throughout the whole of the Barents Sea. The main fishing grounds are off the northeast coast of Norway (subarea IIa), waters near the Spitsbergen archipelago and Bear Island (subarea IIb) and the southern part of the Barents Sea (area I). Mature and large immature fish ("loddetorsk") is mainly caught near the Norwegian coast. A significant proportion of the cod catches taken in the southern part of the sea and in the Spitsbergen-Bear Island area consists of immature fish eight years of age and younger.

During 1946-2002 about 60% of the total catch was taken in feeding areas 45% of which were in the southern part of the Barents Sea and 15% in the Spitsbergen-Bear Island area. However, the importance of the various sea areas was subject to great fluctuations estimated by years and decades.

The significance of the Spitsbergen-Bear Island area for the cod fishery is less than two other areas mentioned above. However, its contribution to the total cod catch in some years can be quite considerable (1946, 1957-1959, 1961-1962, 1974). It is probably caused by the distribution of feeding cod in the north-western parts of the sea due to migrations determined by the stock size and length at age composition of the stock, as well as specific features of oceanographic processes and abundance of prey species.

Since the end of the 1940's until now the fishery has been a robust factor, which generally impacts all commercial fish stocks, and cod stock dynamics in particular.

Thus, unlike changes in natural factors that influence the dynamics of cod stocks, the extremely high fishing mortality, which has been growing for more than 50 years while fish stocks have been decreasing, can be regarded as a factor with a major impact on cod stocks.

The Management System

Stock assessment and advice

The first meeting of the ICES Working Group on Arctic Fisheries was in 1959 and, with the exception of 1961, the working group has met at least once a year ever since (Hylen, 2002). In its first years, AFWG reported the status of research and described recent trends in catches and stock condition. The first "Virtual Population Analysis" of Barents Sea cod was made in 1965 (Gulland, 1965), and this led to recommendations for measures to improve catch selectivity and limit fishing mortality.

Quantified advice on the following year's catch has been provided by ICES since 1975 (Anon, 1975). Table 3.1 shows the total allowable catch (TAC) advice since 1978. Over the years the internal ICES rules regarding the Form of the Advice have become more detailed and specific in order to ensure consistency between stocks and management areas and to meet new management objectives.

Fishing mortality (F) reference points based on theoretical yield-F relationships were often used to provide advice for F-levels capable of maximising long-term yield (and thereby avoiding growth overfishing). It was also recognised that several stocks could be in danger of recruitment overfishing, and rebuilding of the spawning stock biomass (SSB) was recommended when the SSB was observed to approach historic low levels.

In the late 80s the SSB of Barents Sea cod was estimated to have declined to very low levels and severe reductions in catches were recommended with the aim of rebuilding the stock.

In 1991 ICES introduced the term "minimum biological acceptable level" (MBAL) (Anon, 1992). This was defined as the spawning stock biomass below which recruitment decreases. MBAL was quantified for stocks for which there were sufficient data to indicate a biomass level where recruitment was impaired, but not defined when there was lack of clear evidence. For stocks assessed as being below MBAL the advice from ICES was to restrict the fishery in order to allow them to rebuild above MBAL. In other cases no specific advice was given, but (for stocks with an analytical assessment) a range of options showing the short-term consequences of various TACs would be presented.

Table 3.1 Advised, agreed and actual catches of North-East Arctic cod ('000 tonnes) since 1978. Actual catch is as estimated by AFWG. (Partly from Nakken, 1998)

Year	Advised catch	Agreed catch	Actual catch
1978	850	850	699
1979	600	700	441
1980	390	390	382
1981	-	300	399
1982	<432	300	365
1983	<380	300	290
1984	150	220	278
1985	170	220	308
1986	<446	400	430
1987	<645	560	518
1988	530*	590	459
1989	335	300	351
1990	172	160	212
1991	215	215	319
1992	250	356	513
1993	256	500	582
1994	649	700	771
1995	681	700	740
1996	746	700	732
1997	<993	850	762
1998	514	654	593
1999	360	480	485
2000	110	390	415
2001	263	395	426
2002	181	395	445
2003	305	395	
2004	398		

*revised advice May 1988: 320-360 000 tonnes

The 1991 Form of Advice can be summarised as:
SSB>MBAL: No specific advice
SSB<MBAL: Sufficient reduction in fishing to allow for rebuilding of SSB
This Form of Advice was applied for the first time to the advice regarding catches in 1992. At this time the Barents Sea cod had just recovered to above MBAL, which had been set at 500 000 tonnes. For this stock, therefore, no specific advice was given for the whole period 1992-1996. (In 1994-1996 the advice was; "No long-term gains in increased F"). For 1997 and 1998 a specific advice (F below F_{med}) was offered, even though the SSB was still estimated to be above MBAL. The reason for this type of advice in 1997 and 1998 was that the uncertainty of the assessment was regarded as quite high. (The following meeting of the Russian Norwegian Fishery Commission agreed to aim to reduce F to below the recommended F_{med}, but at the same time set a quota for 1998 corresponding to a higher F). Subsequent history has shown that the assessments for those years considerably overestimated the stock.

When the precautionary approach was agreed on by a number of nations, this was considered as a set of additional specifications to the management objectives. There was thus a need to modify the ICES Form of Advice in such a way as to ensure that it would meet precautionary criteria. In particular there was a need to account for the uncertainty in the stock assessment/prediction. The new precautionary framework was put in operation in 1998 when the advice for 1999 was being formulated (Anon, 1999). The main criteria were that the advice should ensure a high probability both that the true spawning biomass was kept above a

minimum limit (B_{lim}) and that the true fishing mortality should be kept below a maximum limit (F_{lim}). In order to take uncertainty into account, the precautionary limits for biomass (B_{pa}) and fishing mortality (F_{pa}) were defined. These precautionary limits were intended to ensure a high probability that the true stock would remain on the safe side of B_{lim} and F_{lim} when the TAC was set according to B_{pa} and F_{pa} applied to the predicted stock.

The main conceptual change in the 1998 Form of Advice is that uncertainty is taken into account. A limitation on fishing mortality is also now advised, regardless of the stock condition. This means that ICES now attempts to offer specific advice in all cases. Even in data-poor cases where stock size and fishing mortality are not estimated, advice is usually given, partly based on trends in catches and size composition and partly on knowledge of the life history of the species.
The 1998 Form of Advice can be summarised as:
SSB>B_{pa}: Restrict TAC so that F<F_{pa}
SSB<B_{pa}: Sufficient reduction in fishing to allow for rebuilding of SSB
The 1998 assessment of the Barents Sea cod represented a considerable downward revision of the stock size. The new F_{pa} was applied, resulting in a TAC advice of 360 000 tonnes for 1999, compared to an agreed TAC of 654 000 tonnes for 1998. In the subsequent three years the stock was estimated to be below B_{pa}. The advice for 2000 and 2002 was aimed at rebuilding after one year, while the advice for 2001 was aiming at rebuilding over a two-year period. For this reason, the advices for these three years varied more than the assessed status of the stock. The two most recent assessments have predicted an SSB>B_{pa} when fishing at F_{pa}, and the advice for 2003 and 2004 has been to reduce F to below F_{pa}.

The conceptual definition of B_{lim} is the same as that of the former MBAL. They both refer to a spawning stock level at which recruitment is decreased or impaired. However, neither in 1991 nor in 1998 was "impaired recruitment" clearly defined, and it is worth noticing that in most cases B_{lim} was set differently from MBAL. In some cases (such as the Barents Sea cod) B_{pa} was in fact set equal to MBAL. In 1998 the safety margin between "lim" and "pa" values was based on some rough rules of thumb and did not take the particular uncertainty of each stock sufficiently into account. Experience over the six years when these reference points have been used is that at least some of them need to be improved. An ICES study group (Anon, 2003c) has suggested some new guidelines for calculating reference points, and ICES is now trying to apply these to most stocks. Two important achievements have been incorporated into the new guidelines; a more objective way of defining "the biomass below which recruitment is impaired" and a procedure to quantify the uncertainty in assessment and prediction.

For the Barents Sea cod the need for revision of reference points became obvious when the historic time series of SSB was revised in 2001. Here new reference points were calculated in 2003 on the basis of these new guidelines (Anon, 2003b). Table 3.2. summarises the most important reference points.

Table 3.2. The most important reference points used for the ICES advice on North-East Arctic cod

Advice for catch in:	Main reference points for advice	Additional reference points used
1978-1991	F_{low}=0.32 (for rebuilding)	F_{max}(~0.25),$F_{0.1}$(~0.15)
1992-1998	MBAL=500,000 tonnes	F_{med}=0.46
1999-2003	F_{pa}=0.42 B_{pa}=500,000 tonnes	F_{lim}=0.70 B_{lim}=112,000 tonnes
2004-	F_{pa}=0.40 B_{pa}=460,000 tonnes	F_{lim}=0.74 B_{lim}=220,000 tonnes

Data used for assessment

Landings in tonnes have been available at least since 1900. Since 1946 all the most important nations fishing in the Barents Sea have sampled their cod landings, either at sea or in landing ports. This sampling forms the basis for calculating annual catch at age. A reasonable Norwegian sampling coverage also exists for the period 1932-1945, and some more sporadic and less consistent sampling data exist for 1900-1931. Most meetings in AFWG have used catch at age data starting in 1946 to describe the history of the stock. Hylen (2002) has combined the available sampling information and presented a catch at age analysis (VPA) extending back to 1900.

The marine research institutes in Russia, Norway, Spain and Germany currently report landing statistics and sampling data to AFWG. Both sales-note statistics and logbooks are available to the institutes. The fisheries are sampled both by observers onboard vessels and by sampling at landing ports. Sampling information is also obtained by direct contact with fishing vessels and through reports from the coastguards. Landings by nations not reporting any sampling are usually distributed by age group, by using the distributions observed in the sampled fisheries.

The models used for the cod assessment are catch-at-age analyses belonging to the "VPA family". In principle, these models are bookkeeping of catches which, combined with an assumed (or externally estimated) value of natural mortality gives a historic estimate of the year-classes, when they are fully fished out. The models estimate the historic stock numbers needed to explain the observed catches. Therefore, some additional stock indicators are needed in order to provide information on the most recent development of the stock. Such indicators are used to "tune" the VPA, which means that the indicator is scaled to the historic VPA so that the recent values of the indicator become estimates of recent stock size.

In the 60s and 70s catch per unit effort (CPUE) for various fishing fleets was the main stock indicator used for tuning. The use of CPUE by the fishing fleet, however, has proven to be problematic due to changes in the fleet (technological development and learning). Each unit of effort is fishing more efficiently every year. For this reason, standardised surveys were initiated in order to provide tuning series independent of the development in the fleet. In the early 80s the USSR had an annual survey in late autumn (October-December) and Norway started an annual winter survey (February) and later an autumn survey (September) as well in the Bear Island-Spitsbergen area. In the main spawning areas there was an annual monitoring survey (March), which was subsequently also used in stock assessment. Since the late 80s, these survey results have been the main input for the stock assessment, and gradually less information based on CPUE has been used.

In the two most recent assessments (2002 and 2003) the bottom trawl results from the October-December survey and both bottom trawl and acoustic results from the February survey were used. The acoustic results of the February survey (which since 2000 has been a joint Russian-Norwegian survey) are added to the acoustic results of the spawning survey before it is used in the tuning. Since these surveys do not fully cover the oldest fish, CPUE information for age groups 9-12 in the Russian trawl fleet is still used. The CPUE from the Norwegian trawl fleet has been disregarded since this fleet started to use double trawls. The Bear Island-Spitsbergen survey has also been disregarded, because it covers a rather small but variable part of the sock. The acoustic estimates from the October-December survey was also left out some years ago due to some methodological changes.

Shortcomings and improvements of the assessment

A crucial point in stock assessment is quantification of the sources of mortality. In particular, when giving advice on fisheries it is important to properly quantify the mortality caused by the fishery. In the period when cod trawlers in the Barents Sea used rather small-meshed trawls, discards of small cod were quite significant. Large discards of small cod have also occurred in the shrimp fishery, before area closures and sorting grids came into operation. Some discarding of cod may still take place in all cod fleets. Cases of underreporting and black landings have also been raised and this was paid a great deal of attention in the Norwegian press in 2000-2001. The cod assessment is based on the official landing statistics (except for 1990-1994, when some additional catch was estimated). The errors caused by incomplete information on real catch are still unknown. AFWG is working on available information on discards in the trawl fisheries for cod and shrimp. When a time series of realistic discard estimates becomes available, the assessment will improve.

Predation is the other main cause of mortality. Predation by large cod on smaller cod has been quantified and used in the assessment. Some data on predation by marine mammals is also available, but are not yet used in the assessment. More data and some realistic modelling are still required in this field of research.

Ongoing research on improved survey methodology is expected to improve assessments in the future. A new assessment model (Fleksibest), (Frøysa et al., 2002) has been developed and applied on the Barents Sea cod data. This model makes better use of the available information on fish length and allows for uncertainty in the catch data. The three latest AFWG meetings have run this model in parallel with the standard assessment and obtained satisfactory agreements in the results obtained.

TAC settings and Management Strategies

Nakken (1998) states that "the first TAC for cod which was introduced in 1975 was far too high and it seems fair to conclude that no effective management measures had been in operation for demersal fish in the area prior to the establishment of the national economic zones (NEZ) in 1977". For 1975 and 1976, a TAC was set by the North-East Atlantic Fisheries Commission (NEAFC). At that time, the Mixed Soviet-Norwegian Commission had already been established (Zilanov, 1984), and after the introduction of the 200 nautical mile Economic Zones in 1977, this Commission decided the TAC for cod. Table 1 shows the advice and recommended quotas and observed catch for the years after 1978. This is an updated version of the table in Nakken (1998).

Since about 1980 the quota shareout has been as follows: First a total TAC of North-East Arctic cod is agreed. Then approximately 10% is set aside for third countries, and 40 thousand tonnes of Murmansk cod are set aside for Russia. The remaining quota is shared half and half between Russia and Norway. The TAC for Norway is then increased by 40 thousand tonnes of Norwegian coastal cod. It should be noticed that in the ICES advice the North-East Arctic cod stock covers both the "oceanic" Barents Sea cod and the Murmansk cod, while Norwegian coastal cod are not included. In some years, various transfers of quotas have been agreed between the parties, which means that the actual shares have varied slightly from one year to another. The quota set aside for third countries has also varied somewhat. Over the period 1986-2003, their quota has been between 7% and 13% of the total cod quota (North-East Arctic cod plus Norwegian coastal cod).

The agreements of the Fishery Commission since the early 80s focus on protecting young fish. Although this is not stated explicitly, the underlying objective has obviously been to better utilise the growth potential of the fish, thereby increasing the long-term yield in the

fishery. A number of important regulations have been agreed on and put into effect (see section 3.5).

The agreements for 1985-1996 use the phrase "improve long-term regulations". In 1997-2001, this was changed to "further develop agreed long-term strategies". In 1997 it was added that until this has been achieved it is agreed to keep SSB>500,000 tonnes and F<0.46 (but the same meeting set a TAC for 1998 corresponding to a higher F). This was repeated in 1998, with the modification that F should be brought below 0.46 before 2001. In 1999 it was agreed to quickly rebuild SSB to 500,000 tonnes and bring F below F_{pa}=0.42. In 2000 this was repeated and it was agreed to fix the total quota for three years, unless later stock assessments showed dramatic changes. In addition, ICES was asked to re-evaluate B_{pa}.

At the 2002 meeting of the Joint Norwegian-Russian Fishery Commission the Parties agreed that a new harvesting strategy for Northeast Arctic cod and haddock should incorporate the following considerations:

- to prepare the basis for long-term high yield of the stocks
- the desirability of obtaining a high annual degree of stability in the TAC
- full utilization of the most recent information available on stock development

On this basis, the Parties agreed on the following decision rule for setting the annual fishing quota (or TAC) for Northeast Arctic cod from 2004 onwards:

- estimate the average TAC level for the coming 3 years based on F_{pa}. TAC for next year will be set to this level as a starting value for the 3 years period
- the year after, the TAC calculation for the next 3 years is repeated based on updated information about the stock development, though such that the TAC should not be changed by more than +/- 10% compared with the previous year's TAC
- if the spawning stock falls below B_{pa}, the Parties should consider a lower TAC than according to the decision rule above

ICES has made the following comments on the above decision rule: "The 2004 catches calculated by applying the harvest rule imply a fishing mortality above F_{pa}. However, the Precautionary Reference Points as currently used by ICES are defined in the context of advising on an annual TAC based on a predicted catch based on a maximum F. The objective of this harvest control law is to have a low risk of SSB dropping below a B_{lim} point. The proposed harvest control rule or modifications of it may actually secure a low probability of SSB dropping below a B_{lim} point and hence be in accordance with the Precautionary Approach because the decision rule is different from that implied in calculating F_{pa}. Simulation studies are needed to reveal if this is the case. ICES is prepared to review and evaluate results of such studies."

The above description shows that the management objectives have progressively been formulated in a more detailed and specific manner: starting with some general statements on improved regulations, which in the 80s led to a number of important regulations protecting young fish, later specifying reference points for TAC settings, and finally developing the decision rule agreed for setting the TAC for 2004. The comments to this rule made by ICES may lead to some further specifications or modifications in order to ensure that the rule agrees with the Precautionary Approach.

Other regulations and enforcement

Along the Norwegian coast a wide range of regulations has been in effect for more than 100 years. The purpose of those early regulations was to coordinate the activity on space-limited fishing grounds. Conflicts between fishermen using different fishing gears are an important reason for many of these regulations, and some of them are still in operation in the spawning-season fishery in Lofoten and Vesterålen.

Mesh size regulations in the international trawl fishery were introduced as a result of the "Convention for the regulation of the meshes of fishing nets and the size limits of fish" signed in London in 1946 and which came into force in 1953. The minimum allowable mesh size was increased several times (Table 3.3). The minimum landing size of cod was initially implemented in 1967 and set at 34 cm. This was raised in 1981 to 39 cm, in 1982 to 42 cm, and to 47 cm in the Norwegian economic zone on January 1, 1990. Fifteen percent of undersized fish are permitted in the catches. Discarding cod has been prohibited since 1977 following the implementation of the complex system of fishery regulations in the Barents Sea. In 1997 sorting grids (min 55 mm spacing between bars) were made mandatory in the trawl fisheries for cod and haddock. In the shrimp trawl fishery the use of sorting grids to reduce the bycatch of fish has been mandatory since 1992.

Table 3.3. Minimum mesh size* in the trawl fishery for cod in the Barents Sea by Norwegian and Russian (Soviet) trawlers (partly from Dingsør, 2001 and Ponomarenko et al., 1978).

Year of coming into force	Minimum mesh size (mm)	
	Norwegian trawlers	Russian (Soviet) trawlers
1946	80	90
1954	110	
1961		110
1963	130	120
1967		120
1981		125
1982	135**	
1997	135 plus sorting grid, 55 mm bar spacing**	
1998		125 plus sorting grid, 55 mm bar spacing

* mesh sizes applied to manila nets before 1966 and to nylon since 1967

** applied to all vessels in Norwegian economic zone

In order to further protect young cod and haddock (and later also young redfish) a closed area system was introduced in the trawl fisheries for cod, haddock and shrimp in the early 1980s. Areas are closed and reopened according to the percentage of small fish in the catches taken in monitoring surveys. The area within 20 nautical miles of Bear Island is permanently closed for fishing. In the REZ some areas are also closed for fishing, either permanently or during certain seasons.

Mesh-size regulations are also in effect for Danish seine and gill net. For gill net there are also limitations on the number of nets per vessel. By licensing vessels, participation in the cod fishery has been limited since 1972. Control and enforcement is exercised at sea by the Norwegian Coast-Guard and Russian fishery inspectors and by observers, and on landing by government officers.

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