3 Northeast Arctic cod[1]

On 30 March 2022, all Russian participation in ICES was suspended. As a result of this decision, it is not possible to run ICES stock assessments or provide ICES advice for the Barents Sea stocks of NEA cod, NEA haddock, *Sebastes mentella* or Greenland Halibut, as management and data collection for these stocks are shared between Norway and Russia. There is therefore no stock assessment for NEA cod this year, but input data to the assessment are updated as far as possible.

The tables and figures updated are the following: Tables 3.1–3.5, 3.7, 3.13, Tables A1–A8, A13–A15 and Figure 3.6b. The numbering of tables and figures is unchanged from AFWG 2021 so there are some 'holes' in the numbering.

Figures and tables can be found in the Data/NEA cod folder. Tables A9–A12 are not updated and will not be included in the report, but for completeness, they are also uploaded in the AFWG SharePoint folder.

3.1 Status of the fisheries

3.1.1 Historical development of the fisheries (Table 3.1)

From a level of about 900 000 t in the mid-1970s, the total catch declined steadily to around 300 000 t in 1983–1985 (Table 3.1). Catches increased to above 500 000 t in 1987 before dropping to 212 000 t in 1990, the lowest level recorded in the post-war period. The catches increased rapidly from 1991 onwards, stabilized around 750 000 t in 1994–1997 but decreased to about 414 000 t in 2000. From 2000–2009, the reported catches were between 400 000 and 520 000 t, in addition, there were unreported catches (see below). Catches have been above the long-term average since 2011 and have decreased from a peak of 986 449 tonnes in 2014 to 693 000 tonnes in 2019–2020 before increasing to 758 000 tonnes in 2021. The fishery is conducted both with an international trawler fleet and with coastal vessels using traditional fishing gears. Quotas were introduced in 1978 for the trawler fleets and in 1989 for the coastal fleets. In addition to quotas, the fishery is regulated by a minimum catch size, a minimum mesh size in trawls and Danish seines, a maximum bycatch of undersized fish, closure of areas having high densities of juveniles and seasonal and area restrictions.

3.1.2 Reported catches prior to 2021 (Tables 3.1–3.4, Figure 3.1)

The provisional catch of cod in Subarea 1 and divisions 2.a and 2.b for 2021 reported to the working group is 800 427 t (including both NEA cod and NCC catches).

Reported catch figures used for the assessment of Northeast Arctic cod:

The historical practice (considering catches between 62°N and 67°N for the whole year and catches between 67°N and 69°N for the second half of the year to be Norwegian coastal cod) has been used for estimating the Norwegian landings of Northeast Arctic cod up to and including 2011 (Table 3.2). The catches of coastal cod subtracted from total cod catches in Subarea 1 and divisions 2.a and 2.b for the period 1960–2021 are given in Table 3.2. For 2012–2021 the

[1] Cod (*Gadus morhua*) in subareas 1 and 2 (Northeast Arctic); cod.27.1-2.

Norwegian catches have been analysed by an ECA-version designed for simultaneously providing estimates of catch numbers-at-age for each of the two stocks.

Coastal cod catches in 2021 for the southern and northern areas combined were 42 044 tonnes using the current conversion factors between round and gutted weight, and this amount was as in previous years subtracted from the total cod catch north of 62° N to get the figure for NEA cod used in that assessment (Table 3.1 and 3.2). The figure for the total coastal cod catch in 2021 using the revised conversion factors, as decided at WKBARFAR 2021 and used in the coastal cod assessment was 32 043 tonnes (Table 2.1a), which is 3.9% above the value using the current conversion factors.

These values for coastal cod are now inconsistent with the coastal cod catches presented in Chapter 2, as the coastal cod catch time-series were revised at WKBARFAR, but not the NEA cod time-series. At WKBARFAR, the proposal for revision of NEA cod catch dataseries was rejected, as Norwegian data for many years and age groups (especially ages 12+ in years prior to 2013) were changed considerably and the reason for this was not sufficiently explained. WKBARFAR recommended that when the revision of the historical Norwegian catch data are ready it should be submitted to ICES for review, ideally by a review attached to the AFWG.

The catch by area is shown in Table 3.1, and further split into trawl and other gears in Table 3.3. The distribution of catches by areas and gears in 2021 was similar to 2020. The nominal landings by country are given in Table 3.4.

There is information on cod discards (see section 0.4) but it was not included in the assessment because these data are fragmented and different estimates are in contradiction with each other. Moreover, the level of discards is relatively small in the recent period and the inclusion of these estimates in the assessment should not change our perception on NEA cod stock size.

In summer/autumn 2018, a Norwegian vessel caught 441 t of cod in the Jan Mayen EEZ, which is a part of ICES area 2a, mostly by longline. Cod is known to occasionally occur in this area, but rarely in densities which are suitable for commercial fisheries. The cod caught in this area in 2018 was large (65–110 cm), and otolith readings and genetics both showed this cod to be a mix of Northeast Arctic and Icelandic cod. Norway did in 2019–2020 carry out an experimental longline fishery during four different periods each year in order to investigate further the occurrence of cod in this area in space and time as well as stock identity. The size distribution and genetic composition of the cod caught in this area in 2019–2021 were similar to that in 2018, although there was somewhat smaller cod (< 65 cm) in 2020–2021 than in 2019. Most of the cod caught in April-May 2019 was spawning or spent, while most cod caught in March 2020 had not started spawning. Cod spawning in this area has not been observed prior to 2019. Total catches in 2019 amounted to 628 t, in 2020 to 522 t and in 2021 to 146 t. The 2018 catches in this area were partly counted against the Norwegian TAC for cod north of 62° N, while the 2019 and 2020 TAC for this area comes in addition to the Norwegian TAC for cod as agreed by JNRFC. There have been varying practice considering including those catches in the assessment, they were included in 2020 but the plan is to exclude them for all years in future assessments. Regulations for the fishery in this area for 2022 have not yet been decided upon.

3.1.3 Unreported catches of Northeast Arctic cod (Table 3.1)

In the years 2002–2008, certain quantities of unreported catches (IUU catches) have been added to the reported landings. More details on this issue are given in the Working group reports for that period.

There are no reliable data on the level of IUU catches outside the periods 1990–1994 and 2002–2008, but it is believed that their level was not substantial enough to influence historical stock assessment.

According to reports from the Norwegian-Russian analysis group on estimation of total catches the total catches of cod since 2009 were very close to officially reported landings.

3.1.4 TACs and advised catches for 2021 and 2022

The Joint Norwegian-Russian Fisheries Commission (JNRFC) agreed on a cod TAC of 885 600 t for 2020 and in addition 21 000 t Norwegian coastal cod. The total reported catch of 800 427 t in 2021 was 106 173 t below the agreed TAC. Since 2015 JNRFC has decided that Norway and Russia can transfer to next year or borrow from last year 10% of the cod country's quota. That may lead to some deviation between agreed TAC and reported catch. As an extraordinary measure due to expected underfishing of the TAC in 2021, JNRFC decided that it should be possible to transfer 15% of the TAC between 2021 and 2022.

The advice for 2022 given by ACOM in 2021 was 708 480 t based on the agreed harvest control rule. The quota established by JNRFC for 2022 was set equal to the advice. In addition, the TAC for Norwegian Coastal Cod was set to the same value for 2022 as for 2021: 21 000 t.

ICES will not give advice for this stock for 2023.

3.2 Status of research

3.2.1 Fishing effort and CPUE (Table A1, Figure 3.6a-c)

CPUE series of the Norwegian and Russian trawl fisheries are given in Table A1. Russian CPUE data for 2021 were not available. The data reflect the total trawl effort (Figure 3.6a), both for Norway and Russia. The Norwegian series is given as a total for all areas. Norwegian data for 2011–2021 are not necessarily compatible with data for 2007 and previous years. Norwegian CPUE declined from 2020 to 2021 and reached the lowest level in the 2011–2021 time-series (Figure 3.6b).

3.2.2 Survey results - abundance and size at age (Tables 3.5, A2–A14)

Some survey results for 2021 were revised since AFWG 2021, for a summary of this, see section 3.2.3.

3.2.2.1 Joint Barents Sea winter survey (bottom trawl and acoustics) Acronyms: BS-NoRu-Q1 (BTr) and BS-NoRu-Q1 (Aco)

Results from this survey were not available as Russian data have not been exchanged, but the survey was carried out as planned with good spatial coverage.

Before 2000 this survey was made without participation from Russian vessels, while in 2001–2005, 2008–2016 and 2018–2022 Russian vessels have covered important parts of the Russian zone. In 2006–2007 the survey was carried out only by Norwegian vessels. In 2007, 2016, 2021 and 2022 the Norwegian vessels were not allowed to cover the Russian EEZ. The method for adjustment for incomplete area coverage in 2007 is described in the 2007 report. The same method was used to adjust the 1997–1998 survey indices in the 2016 revision (Mehl *et al*. 2016). Table 3.5 shows areas covered in the time-series and the additional areas implied in the method used to adjust for missing coverage in the Russian Economic Zone. In 5 of the 8 adjusted years

(including 2021) the adjustments were not based on area ratios, but the "index ratio by age" was used. This means that the index by age for the covered area was scaled by the observed ratio between total index and the index for the same area observed in the years prior to the survey. The adjustments for 2017 were based on average index rations by age for 2014–2016. Adjustments were also made in 2020–2021 using the average index ratios by age for 2018–2019 and 2019–2020, respectively.

Regarding the older part of this time-series it should be noted that the survey prior to 1993 covered a smaller area (Jakobsen *et al*. 1997), and the number of young cod (particularly 1- and 2-year old fish) was probably underestimated. Other changes in the survey methodology through time are described by Jakobsen *et al.* (1997), while the surveys for the years 2007–2012 and 2013–2018 are reported in Mehl *et al.* (2013, 2014, 2015, 2016, 2017a). Note that the change from 35 to 22 mm mesh size in the codend in 1994 is not corrected for in the time-series. This mainly affects the age 1 indices.

With the recent expansion of the cod distribution it is likely that in recent years the coverage in the February survey (BS-NoRu-Q1 (BTr) and BS-NoRu-Q1 (Aco)) has been incomplete, in particular for the younger ages. This could cause a bias in the assessment, but the magnitude is unknown. The 2014–2021 surveys covered considerably larger areas than earlier winter surveys, and showed that most age groups of cod (particularly ages 1 and 2) were distributed far outside the standard survey area. The bottom trawl survey estimates including the extended area for 2014–2021 were used in the tuning data separately from the same index before 2014, as decided at WKBARFAR 2021.

3.2.2.2 Lofoten acoustic survey on spawners Acronym: Lof-Aco-Q1

The estimated abundance indices from the Norwegian acoustic survey off Lofoten and Vesterålen (the main spawning area for this stock) in March/April are given in Table A4. A description of the survey, sampling effort and details of the estimation procedure can be found in Korsbrekke (1997). The 2022 survey results in biomass terms was 182 thousand tonnes, this is 21 % below the 2021 level and the lowest since 2006.

3.2.2.3 Russian autumn survey Acronym: RU-BTr-Q4

Abundance estimates from the Russian autumn survey (November-December) are given in Table A9 (acoustic estimates) and Table A10 (bottom trawl estimates). The entire bottom trawl time-series was in 2007 revised backwards to 1982 (Golovanov *et al.*, 2007, WD3), using the same method as in the revision presented in 2006, which went back to 1994. The new swept-area indices reflect Northeast Arctic cod stock dynamics more precisely compared to the previous one - catch per hour trawling. The Russian autumn survey in 2006 was carried out with reduced area coverage. Divisions 2a and 2b were adequately investigated in the survey in contrast to Subarea 1, where the survey covered approximately 40% of the long-term average area coverage. The Subarea 1 survey indices were calculated based on actual covered area (40 541 sq. miles). The 2007 AFWG decided to use the "final" year-class indices without any correction because of satisfactory internal correspondence between year-class abundances at age 2–9 years according to the 2006 survey and ones due to the previous surveys.

This survey was not conducted in 2016, but was carried out in 2017, when 79% of the standard survey area was covered (Sokolov *et al* 2018, WD 11). The index shows a reliable internal consistence and it was decided to use it in the assessment. This survey was not carried out in 2018–2021 and will likely be discontinued.

3.2.2.4 Joint Ecosystem survey Acronym: Eco-NoRu-Q3 (Btr)

Swept-area bottom trawl estimates from the joint Norwegian-Russian ecosystem survey in August-September for the period 2004–2021 are given in Table A14. This survey normally covers the entire distribution area of cod at that time of the year.

In 2014 this survey had an essential problem with area coverage in the northwest region because of difficult ice conditions. In the area covered by ice in 2014 a substantial part of population was distributed during 2013 survey. So, based on those observations AFWG decided in 2015 to exclude 2014 year from that tuning series in current assessment. In 2016 there was incomplete coverage in the international waters and close to the Murmansk coast. An adjustment for this incomplete coverage was made based on interpolation from adjacent areas (Kovalev *et al* 2017, WD 12). At this time of the year, usually a relatively small part of the cod stock is found in the area which was not covered in 2016. In 2017 and 2019 the coverage was close to complete, although the far northeastern part of the survey area (west of the north island of Novaya Zemlya) was not covered due to military restrictions. In 2018, a large area in the eastern part of the Barents Sea was not covered Thus it was decided not to include 2018 data from this survey in the assessment.

The coverage in 2020 was less synoptic than usual, as explained in Section 0.6. As the survey indices from the BESS 2020 showed an unexplainable large decline compared to the 2019 indices, it was considered to exclude 2020 indices from this survey, but it was decided to keep them in and re-evaluate next year whether they should still be included in the assessment. The 2021 coverage was good, although as in several previous years, most of the international waters in the Barents Sea was not covered. The mentioned re-evaluation has not been carried out.

The survey indices are calculated both the BioFox and StoX calculation methods, and as in earlier years, the Biofox series was used in the tuning. A research recommendation from WKBARFAR was to unify these two methods for estimating indices from ecosystem survey. However, the benchmark decided to use weight at age from the StoX in calculations of weight at age used in the assessment.

3.2.2.5 Survey results - length and weight-at-age (Tables A5–A8, A11–A12, A15)

Length-at-age is shown in Table A5 for the Norwegian survey in the Barents Sea in winter, in Table A7 for the Lofoten survey and in Table A11 for the Russian survey in October-December. Weight-at-age is shown in Table A6 for the Norwegian survey in the Barents Sea in winter, in Table A8 for the Lofoten survey, Table A12 for the Russian survey in October-December and Table A15 for the BESS survey (calculated using StoX).

Length and weight at age in the Lofoten survey increased from 2021 to 2022 for age groups 5–6 and 8–11. The size at age in the BESS survey was about the same in 2021 as in 2020.

3.2.3 Revision of 2021 survey results

Some errors in StoX software were found in summer 2021, affecting the 2021 winter survey results (bottom trawl and acoustic) for cod and haddock and thus a revised assessment was carried out in September 2021 for both stocks (as described in the AFWG 2021 report executive summary). Also an error in calculating the 12+ group for the bottom trawl survey for use in the tuning was corrected. After that some additional errors in StoX software have been found and corrected, final estimates for 2021 are in the survey report which is now published (Fall et al. 2022). In addition, the 2020 ecosystem survey indices and weight at age as well as the 2021 Lofoten survey indices and weight at age have been revised.

3.2.4 Age reading

The joint Norwegian-Russian work on cod otolith reading has continued, with regular exchanges of otoliths and age readers (see chapter 0.7). The results of fifteen years of annual comparative age readings are described in Yaragina *et al.* (2009). Zuykova *et al.* (2009) re-read old otoliths and found no significant difference in contemporary and historical age determination and subsequent length-at-age. However, age at first maturation in the historical material as determined by contemporary readers is younger than that determined by historical readers. Taking this difference into account would thus have effect on the spawning stock–recruitment relationship and thus on the biological reference points. The overall percentage agreement for the 2017–2018 exchange was 87.7% (WD 8, AFWG 2020). The main reason for cod ageing discrepancies between Russian and Norwegian specialists remains the same, representing the latest summer growth zone, and different interpretations of the false zones. The general trend is that the Russian readers assign slightly lower ages than the Norwegian readers compared to the modal age for all age groups. This is opposite of what we have seen in previous readings, where the Russian readers has tended to be slightly overestimating the age compared to the Norwegian readers. More details can be found in section 0.7.

The trend with bias in NEA cod age determination registered for some years of the period 1992–2018 between experts of both countries is a solid argument to continue comparative cod age reading between PINRO and IMR to monitor the situation. The German participant has expressed an intention to join the age reading cooperation in future.

3.3 Data available for use in assessment

Data for the period 1946–1983 are taken from the AFWG 2001 report (ICES CM 2001/ACFM:19) and were not revised at the WKBARFAR benchmark in 2021.

3.3.1 Catch-at-age (Table 3.6)

For 2021, age compositions from all areas were available from Norway, Spain and Germany. Russian data were not available and thus total catch-at-age was not calculated.

There is still a concern about the biological sampling from parts of the Norwegian fishery that may be too low. Also the split between NEA cod and coastal cod may be affected by the sampling coverage.

3.3.2 Survey indices available for use in assessment (Table 3.13, A13)

The following survey dataseries were available:

Fleet code	Name	Place	Season	Age	Years
Fleet 15*	Joint bottom trawl survey	Barents Sea	Feb-Mar	3–12+	1981–2013, 2014–2021
Fleet 16	Joint acoustic survey	Barents Sea+Lofoten	Feb-Mar	3–12+	1985–2021
Fleet 18	Russian bottom trawl surv.	Total area	Oct-Dec	3–12+	1982–2017
Fleet 007	Ecosystem surv.	Total area	Aug-Sep	3–12+	2004–2021

***Survey indices for Fleet 15 were divided by two series (before and after 2014) in model tuning as decided at WKBARFAR 2021.**

The tuning fleet file is shown in Table 3.13. Note that the joint acoustic survey (sum of Barents Sea and Lofoten acoustic survey indices) is given in Table A13.

Survey indices for Fleet 15 have been multiplied by a factor 100, while survey indices for Fleets 007, 16 and 18 have been multiplied by a factor 10. This is done to keep the dynamics of the surveys even for very low indices, because some models (e.g. XSA) adds 1.0 to the indices before the logarithm is taken.

3.3.3 Weight-at-age (Tables 3.7–3.9, A2, A4, A6, A8, A12).

3.3.3.1 Catch weights

For 2021, weight-at-age in the catch for areas 1, 2a and 2b was provided by Norway, Spain and Germany (Table 3.7). Russian data were not available and thus total weight at age was not calculated. For ages up to and including 11, observations are used. Following the WKBARFAR 2021 decision, weight at age in catch for the years 1983–present for ages 12–15+ are calculated by a cohort-based von Bertalanffy approach used to replace previous fixed values.

3.3.3.2 Stock weights

Weight at age in the stock for 2022 were not calculated as winter survey data were not available.

For ages 1–11 stock weights-at-age at the start of year y ($W_{a,y}$) for 1983–2021 are calculated combining, when available, weight at age from the Winter, Lofoten, Russian autumn and ecosystem surveys. The details are given in the stock annex. For ages 12–15+ a similar approach as for weight at age in the catch was used.

3.3.4 Natural mortality including cannibalism (Table 3.12, Table 3.17)

A natural mortality (M) of 0.2 + cannibalism was used. Cannibalism is assumed to only affect natural mortality of ages 3–6.

2021 data are available and 2020 data have been updated, but tables with results based on these data are not included (Tables 3.12 and 3.17 in the 2021 AFWG report) as no assessment was done.

The method used for calculation of the prey consumption by cod described by Bogstad and Mehl (1997) is used to calculate the consumption of cod by cod for use in cod stock assessment. The consumption is calculated based on cod stomach content data taken from the joint PINRO-IMR stomach content database (methods described in Mehl and Yaragina 1992). On average about 9000 cod stomachs from the Barents Sea have been analysed annually in the period 1984–2021.

These data are used to calculate the per capita consumption of cod by cod for each half-year (by prey age groups 0–6 and predator age groups 1–11+). It was assumed that the mature part of the cod stock is found outside the Barents Sea for three months during the first half of the year. Thus, consumption by cod in the spawning period was omitted from the calculations.

An iterative procedure was applied to include the per capita consumption data in the SAM run. It is described in detail in Stock Annex.

For the cod assessment data from annual sampling of cod stomachs has been used for estimating cannibalism, since the 1995 assessment. The argument has been raised that the uncertainty in such calculations are so large that they introduce too much noise in the assessment. A rather comprehensive analysis of the usefulness of this was presented in Appendix 1 in the 2004 AFWG report. The conclusion was that it improves the assessment.

The data on cod cannibalism for the historical period (1946–1983) was included in assessment during the benchmark to make the time-series consistent (ICES 2015, WKARCT 2015). These estimates were based on hindcasted values of NEA cod natural mortality-at-ages 3–5 using PINRO database on food composition from cod stomach for the historical period (Yaragina *et al*. 2018).

3.3.5 Maturity-at-age (Tables 3.10–3.11, Tables 3.10–3.11)

Since data from the winter survey 2022 were not available, ogives for 2022 could not be calculated.

Historical (pre–1982) Norwegian and Russian time-series on maturity ogives were reconstructed by the 2001 AFWG meeting (ICES CM 2001/ACFM:19). The Norwegian maturity ogives were constructed using the Gulland method for individual cohorts, based on information on age at first spawning from otoliths. For the period 1946–1958 only the Norwegian data were available. The Russian proportions mature-at-age, based on visual examinations of gonads, were available from 1959.

Since 1982 Russian and Norwegian survey data have been used (Table 3.10). For the years 1985–2021, Norwegian maturity-at-age ogives have been obtained by combining the Barents Sea winter survey and the Lofoten survey. Russian maturity ogives from the autumn survey as well as from commercial fishery for November-February are available from 1984 until present. The Norwegian maturity ogives tend to give a higher percent mature-at-age compared to the Russian ogives, which is consistent with the generally higher growth rates observed in cod sampled by the Norwegian surveys. The percent mature-at-age for the Russian and Norwegian surveys have been arithmetically averaged for all years, except 1982–1983 when only Norwegian observations were used and 1984 when only Russian observations were used.

Russian data for the autumn survey for 2018 and later years were not available as the survey was not conducted. In WD15, 2019, updated correction factors to allow for this when calculating the combined maturity-at-age in 2019 were calculated, based on historical differences between Norwegian and Russian data. These correction factors were then applied to the Norwegian data for 2020–2021.

The approach used for calculating maturity-at-age is the same as previously used and consistent with the approach used to estimate the weight-at-age in the stock, except that no data from the BESS survey are used. However, since survey data, both abundance indices and proportion mature, have been revised, the entire time-series of ogives back to 1994 was revised at the benchmark. The proportions of mature cod for age 13–15 are set to 1 for the period 1984–present.

Maturity-at-age for cod has been variable the last five years, particularly for ages 6–9. According to the combined data, maturity-at-age decreased in 2015–2016, then increased, but decreased again from 2019 to 2021 (Table 3.11).

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