WORKSHOP ON RESEARCH NEEDS AND A ROADMAP FOR FURTHER RESEARCH ON COD IN THE NORTHERN SHELF SEAS (INCLUDING COD IN THE CELTIC SEAS) (WKRRCOD)

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i Executive summary

The Workshop on research needs and a roadmap for further research on cod in the northern shelf seas (including cod in the Celtic Seas) (WKRRCOD) met in Edinburgh, United Kingdom, 1–2 November 2022 to identify evidence needs necessary to achieve management objectives of cod fisheries, share plans for assessments and consider ways to incorporate further knowledge in the advisory process. A total of 35 participants discussed the terms of reference in breakout groups an identified the objectives as a need for good fisheries governance and management that balances social, ecological, economic considerations in management based on agreed perceptions of stock status. The challenges were identified as the Landing Obligation, the use of advice by managers, lack of agreement on stock status, unclear consideration of the effects of changes in cod distribution and inclusion of information from the fishery among other issues. The workshop concluded with six recommendations to address these challenges relating to how industry data can be quality assured and incorporated in the benchmark and assessment process, how the benchmark process can become more transparent to end users, how knowledge from industry can be used to improve assessments through pre-assessment meetings, how managers can become more involved in the advice process and finally how the experience from WKRRCOD can be used for other species.

ii Expert group information

Expert group name	Workshop on research needs and a roadmap for further research on cod in the northern shelf seas (including cod in the Celtic Seas) (WKRRCOD))
Expert group cycle	Annual
Year cycle started	2022
Reporting year in cycle	1/1
Chairs	Anna Rindorf, Denmark
	Carl O'Brien, UK
Meeting venue and dates	1-2 November 2022, Edinburgh, UK, 35 participants

1 Terms of Reference

Workshops on research needs and a roadmap for further research on cod in the northern shelf seas (including cod in the Celtic Seas) (WKRRCOD)

Two workshops to supplement the Greater North Sea cod benchmark, and add research needs including on cod in the Celtic Seas, leading to a roadmap for further research on cod in the northern shelf seas will be established.

Workshops on research needs and a roadmap for further research on cod in the northern shelf seas (including cod in the Celtic Seas) (WKRRCOD), chaired by Anna Rindorf, Denmark, and Carl O'Brien, United Kingdom, will meet in Edinburgh, United Kingdom, 1–2 November 2022 to:

a) With stakeholders and managers, identify evidence needs necessary to achieve management objectives of cod fisheries.
b) Share plans for the assessment and advice for North Sea and Celtic Seas cod (include upcoming benchmark on North Sea cod and West of Scotland cod).
c) Consider knowledge and data sources, potential methods and timetables by which further evidence can be incorporated into the scientific advisory process and identify where industry can provide evidence to underpin modelling and advice.

The first meeting of WKRRCOD will report by 21 November 2022 for the attention of the Fisheries Resources Steering Group and the Advisory Committee.

The second meeting will take place in Edinburgh, United Kingdom (or online, *tbd*) for 2 days in the second quarter of 2023 (dates tbd) to:

a) List issues from stakeholders and fisheries managers which they perceive as suffering from further knowledge deficits and prioritise recommendations for research to improve scientific advice for cod.
b) Produce a roadmap for the delivery of future research needs for the management of fisheries on cod and mixed demersal fisheries in southern shelf seas.

The second meeting of WKRRCOD will report by (TBD) 2023 for the attention of the Fisheries Resources Steering Group and the Advisory Committee.

2 Workshop approach

The meeting commenced with a brief introduction by Mike Park on the motivation for the workshop and proceeded with a round of introduction of all participants. The workshop agenda (Annex 2) was briefly described and agreed upon. An introduction to group work addressing term of reference a (With stakeholders and managers, identify evidence needs necessary to achieve management objectives of cod fisheries) was given. The difference between management, advice and assessment issues was presented in an example listing possible objectives for each of these as well as the forum in which these issues can be brought up, addressed, and decided upon (fig. 2.1). Due to the overlapping timing of international quota negotiations, managers were not well represented at the meeting. This can hopefully be remedied at the second planned workshop.

The participants in the workshop were divided into 3 groups, and the groups were tasked with identifying management, advice and assessment objectives related to cod, challenges in meeting these objectives and suggestions for what can possibly be done about these challenges. The key points mentioned in the groups were then reported back in a plenary session. Subsequently, the stock assessments of cod in Celtic Seas, west of Scotland and North Sea were presented followed by a presentation and discussion of the plans for the 2023 benchmark for cod in the North Sea, Channel, Skagerrak and West of Scotland (tor b: hare plans for the assessment and advice for North Sea and Celtic Seas cod (include upcoming benchmark on North Sea cod and West of Scotland cod). On day two, some key issues raised on day one were addressed in plenary followed by group discussions to suggest additional knowledge, data sources and methods that can potentially be used in the scientific advisory process and cases where industry can provide evidence to underpin modelling and advice (tor c: Consider knowledge and data sources, potential methods and timetables by which further evidence can be incorporated into the scientific advisory process and identify where industry can provide evidence to underpin modelling and advice). The workshop concluded by summing up results, identifying first steps in the roadmap and providing recommendations for similar processes for other stocks or areas.

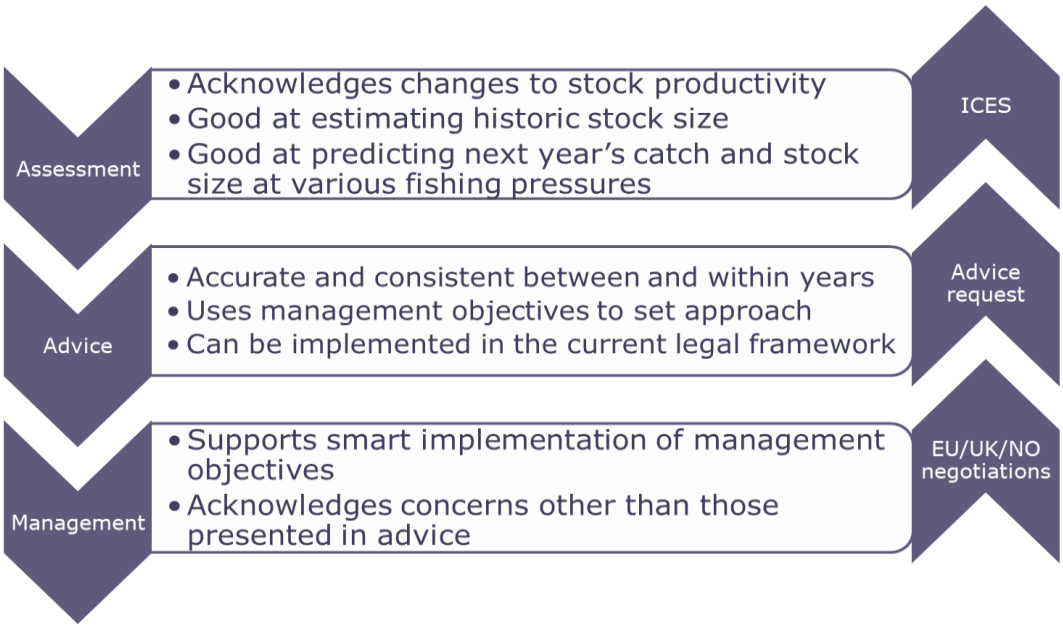

Fig. 2.1. Distinction between assessment, advice and management, possible objectives for each of these and forum in which decisions are made on these objectives.

3 ToR a: With stakeholders and managers, identify evidence needs necessary to achieve management objectives of cod fisheries

The participants were divided into three groups and asked to identify management objectives and challenges in achieving these, considering whether the challenges were most appropriately addressed in assessment, advice or management. The three groups reported back to plenary and the main points made by each group are summarised below.

3.1 Group 1

Objectives for cod management: Group 1 identified the need for a better agreement between industry and ICES on the perception of stock status and for improved working relationships between industry and science participants. The group further suggested that there must be flexibility in the process of setting advice and quotas so these can change when stock conditions are changing but not flexibility to the extent where everything changes all the time. The necessity to consider the balance or trade-offs between social, ecological, economic considerations was also mentioned, along with the re-evaluation of MSY as an economic concept. There were discussions on how well scientific surveys reflect the industry perception of the stock, and why there may be misalignment, such as in the gear selection and the targeted areas. Additional identified objectives were improved sampling to ensure that reference points reflect changes over time in recruitment and distribution and the incorporation of industry data/surveys to ensure that all relevant knowledge is included in the assessment. The lack of use and eventual discontinuation of the North Sea stocks survey by industry was mentioned.

Challenges: Communication between stakeholders and science can be slow and sometimes difficult. Though changes are made in the assessment and advice in response to changes in productivity and distribution, these are not always well communicated well or if communicated do not lead to the expected results. The Landing Obligation and its implementation is not aligned with the socioeconomic objectives of the fisheries, and as there is substantial incentive to continue discarding and misreport this, the Landing Obligation may lead to changes that are directly in opposition to objectives. Fisheries are placed in a societal setting where the public perception of advice differs from that of fishers and may also differ depending on whether advice is increased and decreased. The observed changes in stock distribution and structure are not perceived to be well addressed in the assessment and there were questions about how appropriate the surveys used are for juvenile cod. In general, the quality of the data included was discussed at length and issues of misreporting and the possible effects on the stock assessment mentioned. It was acknowledged that local densities and thereby local fisher perceptions of stock abundance can differ from regional advice due to local variation. However, there are also cases where inconsistencies between advice and perceived stock size differs consistently across large areas.

Other pressures on the marine environment and on fisheries were also discussed, particularly offshore wind farms and Marine Protected Areas and the challenge these would pose to industry going forward.

Suggestions for changes to address challenges: A new approach to incorporation industry information into ICES groups could be constructed. This could be conducted before or at benchmarks or annually in advance of the annual stock assessment, where a short meeting was held between the WG experts and some industry representatives, in a similar way to the current process with

WG members talking to the survey groups before WGs. Industry were also interested to know where they could best help the process, for instance by increasing discard trips, paying for more observers, or self-sampling. The cost of these initiatives and the limited amount available from grants was acknowledged. The challenge of cod being part of a mixed fishery where it was the limiting TAC and where it was a small (financial) part of the collective fishery were discussed.

3.2 Group 2

Objectives for cod management: The need to consider economic considerations was discussed and Maximum Economic Yield was mentioned as a more appropriate target than the current single stock MSY in combination with the Landing Obligation. It was mentioned that quota should match the available biomass and that this biomass should ideally be agreed between industry and science. Further, all appropriate data should contribute to the assessment, also data derived from fisheries.

Challenges: There is a perceived reluctance from managers to open to more pragmatic approaches and the way the managers use ICES as gospel makes it difficult to account for social and economic considerations. In general, there is a perceived lack of resources in stock assessment, and often the scientists available do not have time to explore the assessments and data fully.

Suggestions for changes to address challenges: There is a need for management actions to address the issues with MSY/Landing Obligation management. Workshops with industry, managers and scientists should be conducted on a regular basis, possibly organised by someone other than ICES. The possibility to derive data from industry sampling should be utilised.

3.3 Group 3

Objectives for cod management: Group 3 identified the objectives as "science that reflects reality – harvesting a sustainable stock – manage to remove need to discard". Science should reflect the actual status of the stocks. This will allow the fishery the ability to harvest the sustainable stock. It is also necessary to remove the necessity for discarding in order to have an economically viable fishery.

Challenges: There is a lack of clarity on how observations enter the data stream and therefore also on where fishers can potentially contribute with additional data and knowledge. The implementation of the Landing Obligation has had profound effects on the reporting of discards. It is unclear if this effect means that the quality of assessments before and after the Landing Obligation implementation is the same or has deteriorated. There is a lack of crosschecks of reported data with industry, removing the opportunity to point to errors or issues that may be clear to fishers but not at the assessment level. The changing distribution of cod is a challenge, both at a north-south scale and on a more local scale where hot spots occur. The effects of both distributional change and hot spots on the assessments are unclear, for example, what happens if a fisher in a hotspot catches the annual quota in a few weeks. There are substantial challenges in the interface between policy, compliance and science (e.g. the Landing Obligation). The time lag between assessment data, advice and quota is problematic as this means that the stock status can have changed considerably in the year where the quota is taken.

Suggestions for changes to address challenges: If assessments and advice can be updated with near-to-real time data, this can alleviate the problem of the stock developing in a different direction than expected at the assessment in the year that it takes to implement the new quota. The North Sea cod stocks should be split in several regional assessments, using genetic, tagging and other data to ensure that areas are appropriate. Currently, several industry scientists provide

science syntheses to the industry, but they could also work in the opposite direction, providing syntheses of fisher observations to science.

3.4 Synthesis

The objectives, challenges and suggestions mentioned in the three groups were quite similar and discussed in plenary. The objectives focused on the topics fisheries governance and management, the need for agreed perceptions of stock status, improved data and inclusion of industry knowledge and improved industry-science relationships.

3.4.1 Fisheries governance and management

All groups recognized the need to balance or trade-off social, ecological, economic considerations in management. An example is using Maximum Economic Yield rather than single stock MSY in combination with the Landing Obligation and the removal of incentive to discard to maintain an economically viable fishery. These objectives were faced with a range of challenges in the management system including the implementation of the Landing Obligation, the use of advice by managers and the relationship between fisheries and the surrounding society. Managers were perceived as being reluctant to open to more pragmatic approaches and to use ICES advice in ways that make it difficult to account sufficiently for social and economic considerations. The Landing Obligation and its implementation is not aligned with the socioeconomic objectives of the fisheries. As there is substantial incentive to continue discarding and misreport this, the Landing Obligation may lead to changes that are directly in opposition to objectives (discarding, poorer data quality for assessments). There is a trade off in the need for a flexible process of setting advice and quotas so these can change with stock status but not make this process flexible to the extent where everything changes all the time. Finally, fisheries are placed in a societal setting where the public perception of advice differs from that of fishers and may also differ depending on whether advice is increased and decreased. Other sectors may have a greater impact than fisheries on stock status, but this is often ignored in advice and management (e.g. offshore wind farms).

3.4.2 Agreed perceptions of stock status

There was a broad desire to improved agreement between industry and ICES on the perception of stock status. This would allow advice and quota to match the actual biomass better thereby allowing the fishery the ability to harvest the stock sustainably.

On the management side, challenges identified were lack of resources for stock assessment not allowing sufficient time to explore the assessments and data fully and the need to decide on what the management objective should be in the case where a stock due to e.g. climate change has so low productivity that it is likely to disappear from the area or where there are substantial conflicts between fisheries objectives and the stock size of protected predators such as seals.

On the assessment and advice side, effects of changes in cod distribution, the quality of the data included and the need for inclusion of real time knowledge was discussed at length. The changing distribution of cod is a challenge, both at a north-south, scale and on a more local scale where hot spots occur. The effects of distributional change and hot spots on the assessments are unclear. Some participants felt that the North Sea cod stocks should be split in several regional assessments, using genetic, tagging and other data to ensure that areas are appropriate. The issues of misreporting caused by the Landing Obligation and the possible effects on the stock assessment was also discussed as well as the recent problems with sampling under Covid. It was

acknowledged that local densities and thereby local fisher perceptions of stock abundance can differ from regional advice due to local variation. However, there are also cases where inconsistencies between advice and perceived stock size differs consistently across large areas. The lack of crosschecks of reported data with industry removes the opportunity to point to errors or issues that are clear to fishers but not at the assessment level. Currently, several industry scientists provide science syntheses to the industry, but they could also work in the opposite direction for cod, providing syntheses of fisher observations to science. There is a need for flexibility in the process of setting advice and quotas so these can change when stock conditions are changing without ending in a situation where everything changes all the time.

3.4.3 Improved data and inclusion of industry knowledge

The discussion of improved data and knowledge focused on the possibility to incorporate industry data and surveys in the stock assessment (historical changes), the need to improve the knowledge of the processes in the intermediate year to account for situations where stock status changes considerably in the year where the quota is taken and advice therefore should be updated and finally the setting of appropriate reference points.

Industry data and sampling can provide substantial knowledge about stock status and distribution, a knowledge that is presently not utilised in the assessment beyond the inclusion of total catches. There is a need for greater clarity on where data can be particularly useful, how observations enter the data stream and therefore where and how fishers can potentially contribute with additional data and knowledge. If assessments and advice can be updated with real time data from fisheries, this can alleviate the problem of the stock developing in a different direction than expected at the assessment in the year that it takes to implement the new quota. The was a general concern that the observed changes in stock distribution and structure were not appropriately addressed in the current assessment and reference points.

3.4.4 Improved industry-science relationships

Communication between stakeholders and science can be difficult and the background for changes made in the assessment and advice are not always well communicated well and does not always lead to the expected results. Workshops with industry, managers and scientists should be conducted on a regular basis to improve the communication.

4 ToR b: Share plans for the assessment and advice for North Sea and Celtic Seas cod (include upcoming benchmark on North Sea cod and West of Scotland cod)

4.1 Assessment and advice for Celtic Seas cod

Besides the West of Scotland, Division 6.a cod stock (cod.27.6.a) there are further stocks in the "northern shelf seas": Irish sea cod (cod.27.7a), Celtic sea cod (cod.7.7e-k) and Rockall cod (cod.27.6b), which strictly speaking while not on the northern shelf, is worth mention.

Irish sea cod (cod.27.7a) and Celtic sea cod (cod.7.7e-k) are assessed by ICES as "Category 1", fully analytical assessments, meaning that data are available and used to assess the annual age structure of the stock. The Rockall cod stock (cod.27.6b) is assessed as a Category 6 "landings only" stock, meaning data of the fisheries landings are used to monitor the stock, with scientific survey biomass estimates and landings per unit effort used in support of the assessment. All three stocks have shown declines in catches, recruitment and Spawning Stock Biomass (SSB).

In the latest Irish sea cod (cod.27.7a) advice released in June 2022, ICES advised that when the MSY approach and precautionary considerations are applied, there should be zero catch in 2023. Fishing pressure has been below the F_{MSY} reference point since 2012 while SSB has been below MSY $B_{trigger}$ since 1995 and below B_{lim} since 2019. Recruitment has generally declined over the time series, generally at the lowest levels since 1999 (Figure 4.1).

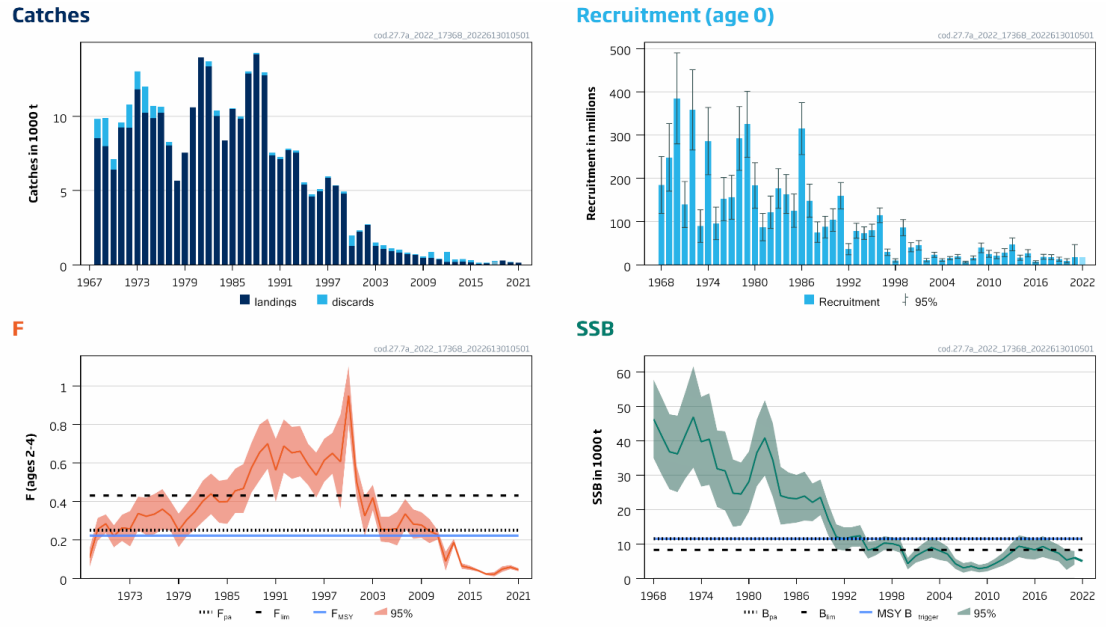

Figure 4.1. Cod in Division 7.a. Summary of the stock. The assumed recruitment value for 2022 is shaded in a lighter colour. The SSB in 2022 is forecasted.

The Irish sea assessment has also introduced the concept of an ecosystem based reference point, where F_{eco} designates the level of fishing pressure expected to be analogous to stock sustainability linked with environmental change in the form of sea-surface temperature (Figure 4.2).

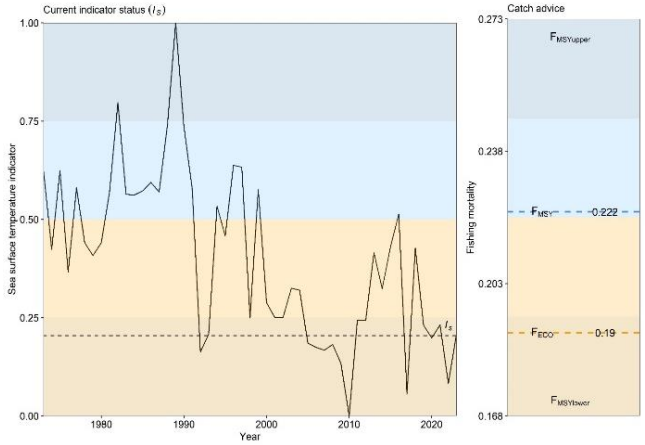

Figure 4.2. Derivation of F_{eco} for Irish Sea cod. Left: time-series of inverted SST (three-year lag) *I* rescaled between zero and one which informs the status of the indicator (I_s) in 2023 compared with previous years. Right: the status of the indicator determines the placement of the F_{eco} reference point within F_{MSY} ranges (ICES, 2019, 2020).

For Celtic sea cod (cod.7.7e-k), ICES advised in June 2022 that there should be zero catch in 2023. F has been above F_{MSY} and F_{pa} since 1981. SSB has been below MSY $B_{trigger}$ and B_{pa} since 2016 and below B_{lim} since 2017. Recruitment has been low since 2002 with a few high recruitment events (2010, 2011 and 2014; Figure 4.3).

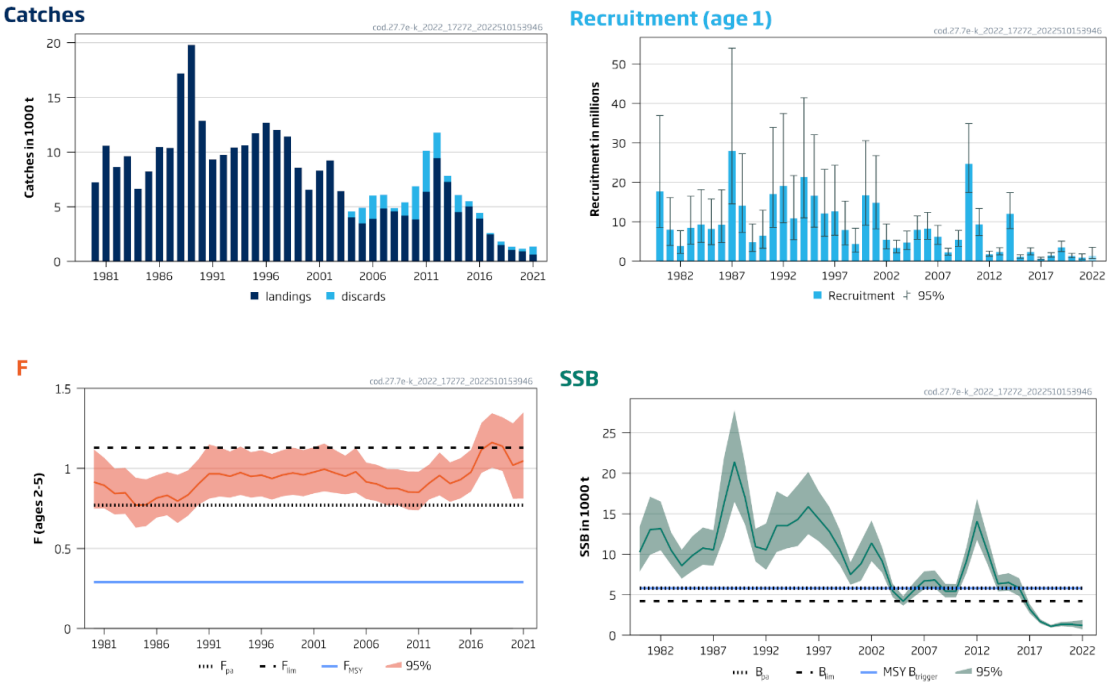

Figure 4.3. Cod in divisions 7.e–k. Summary of the stock assessment. Discard estimates are available from 2004. The assumed recruitment value for 2022 is shaded in a lighter colour.

Research pertaining to cod stock definitions and migrations

There have been several studies in recent history around the Celtic Seas that can offer information of cod distributions and their migration through the Irish Sea and adjoining areas.

Tagging studies pre-2011 (Bedford 1966, Bendell and Randall 2011, Bendell et al., 2009, Neat *et al.*, 2014) and in 2016 to 2017 (Figure 4.4; Lundy *et al.*, 2022) provide much of the current understanding. Data from the 2016-2017 tagging campaign are available online https://shiny.marine.ie/tagging/

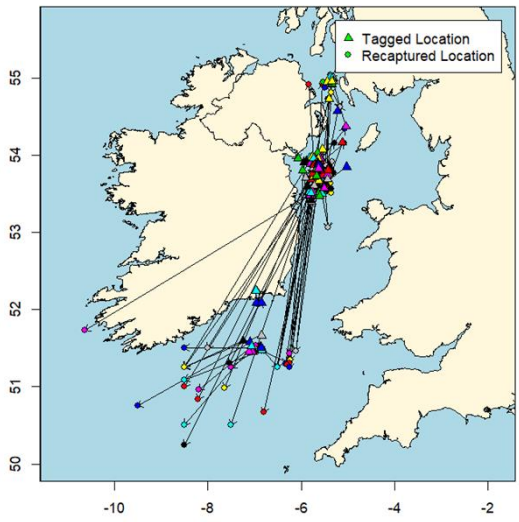

Figure 4.4. Release and recapture locations of cod tagged as part of the Tagging study to determine mortality sources on cod in the Irish Sea (Lundy *et al.*, 2022).

Developing and on-going work includes:

- Data storage and satellite tagging programmes,
- Seafloor mounted listening arrays to monitor for acoustic transmitting tagged fish migrations
- Stable isotope studies which can relate tissues samples from cod to areas of origin through chemical composition, usually of carbon, nitrogen and sulphur
- Gathering of tissue samples for genetic studies.

Most of this current work being undertaken is in its infancy and focused on the Irish sea. These developments along with past work need to be reviewed in detail to determine their potential contribution to discerning cod stock definitions and migrations. Further work is likely necessary to gain a robust insight of the present status of cod stocks in the northern shelf seas and Celtic seas, encompassing all stocks.

4.2 Assessment and advice for North Sea/Channel/Skagerrak cod

The North Sea cod stock was last benchmarked early in 2021. This benchmark process began with a four-day workshop on Stock Identification of North Sea Cod (WKNSCodID) held in August 2020 to review information on the population structure of cod in the North Sea and adjacent waters. The workshop concluded that the North Sea includes reproductively isolated populations of Viking and Dogger cod, and that the Dogger cod population has some phenotypic structure and extends to the West of Scotland (6.a.N). Data were requested at a finer resolution (divisions 4.b-c and 7.d and subdivisions 4.aE, 4.aW and 3.a.20) to facilitate development of spatial approaches to stock assessment; however, the data compilation workshop, held November 2020, found unexplained discrepancies between the spatially disaggregated data and the data as used in the current assessment. Furthermore, given that the West of Scotland cod stock had recently undergone a benchmark and, at the time, hadn't received the same attention with regards to stock ID, connectivity between the two stocks was predetermined outside the scope of the 2021 benchmark. The data compilation workshop therefore concluded that development of spatial approaches would not be possible in time for a benchmark in 2021.

Nevertheless, it was decided to continue with the benchmark given that the assessment (modelling a unit stock of cod in the North Sea, Channel and Skagerrak) could be improved by improving the survey indices, biological data, and SAM assessment model configuration, thus lessening the data and assessment issues that had triggered the benchmark process (conflicting signals in the underlying data and a developing retrospective bias in the assessment).

One of the main changes to the assessment was to introduce an *ad hoc* adjustment on the natural mortality of ages 3+ from 2011 to account for migration to the West of Scotland area, which could not be included in the assessment area. This adjustment represents a pragmatic solution that was within the scope of the 2021 benchmark and addresses the issue of not dealing with a closed population, as assumed by the SAM assessment model. Essentially, the adjustment removes the fish we believe have migrated away from the North Sea from the modelled population in the North Sea and was shown to result in better model diagnostics. This is seen as an interim solution while spatial approaches are being developed and, in the meantime, sub-stock trends continue to be monitored and presented in the ICES advice.

4.3 Assessment and advice for West of Scotland cod

Advice for the West of Scotland cod stock has been for zero catches for almost the last 20 years. Until the full implementation of the LO in this area, there was a zero TAC for this stock with a small bycatch allowance, but since 2019 a bycatch TAC has been available. The advice is based on an assessment that estimates recruitment to be very low and SSB to be well below B_{lim}. The estimated fishing mortality has declined since the 2000s, but still remains high and has been around F_{lim} since 2012. The stock assessment was last benchmarked in 2020 at WKDEM (ICES, 2020) and while the meeting addressed a variety of issues which improved the stock assessment and basis for advice, it was acknowledged that a number of issues remained:

- Stock structure is complex and a number of different subpopulations are known to occur within this area (WK6aCodID; ICES, 2022). The stock assessment therefore represents an assessment of multiple sub-stocks with the northern component (which is linked to the N Sea) accounting for most of the landings since the mid-2000s.
- Since the early 1990s the most significant problem with the assessment of West of Scotland cod is with commercial catch data. Incorrect reporting of landings, species, quantity

and management area, is known to have occurred. In an attempt to reduce bias in the assessment, a combination of externally estimated misreported landings data and model estimated catches are used. In addition, discards have been extremely high and these are typically poorly sampled for age compositions (due to low observer coverage). All these issues contribute to making the catch data highly uncertain for this stock.

- There are multiple scientific research surveys covering this stock, but the change in survey design and ground gear of the Scottish surveys in 2011 means that there are currently no continuous indices over the whole assessment time period. Additionally, catch rates from the recent surveys are characterised by high numbers of zeros and occasional large catches, resulting in highly uncertain survey indices.
- There has long been debate about the impact of seal predation on West of Scotland cod. Hammond and Wilson (2016) estimated cod consumption by seals to be of a similar order of magnitude to the estimated stock size and it has been suggested that seals may be impairing the recovery of this stock. However, there is uncertainty as to whether the seals are actually exploiting the same population as the fishery with limited overlap between seal foraging and the fishery (Russel *et al.*, 2017). Natural mortality clearly remains a major source of uncertainty in this assessment and incorrect assumptions regarding its trend and magnitude can have a significant impact on estimates of stock status.
- The input data for this cod assessment are particularly uncertain (both survey indices and commercial data) and as a result, the data can be interpreted in different ways by different assessment methods which make very similar assumptions. Cook (2019) and a number of exploratory assessments presented at WKDEM show a stock which by 2016 had recovered to levels consistent with those of the 1990s in contrast to the agreed SAM assessment. Given these model uncertainties, the benchmark considered that estimates of uncertainty from the final SAM assessment are therefore unlikely to adequately reflect the true uncertainty in the estimates of stock biomass and fishing mortality for this stock.

4.4 Plans for the joint North Sea/Channel/Skagerrak/West of Scotland cod benchmark

A benchmark workshop for northern shelf cod stocks will meet in November 2022 for a data compilation workshop and in February 2023 for a 5-day benchmark meeting. Given the conclusions of the two stock ID workshops (WKNSCodID, 2020 and WK6aCodID, 2022) the main objectives of this benchmark are to (1) assess North Sea and West of Scotland cod in a single assessment framework; and (2) explicitly model sub-stock dynamics. The approach being developed is an extension of the SAM model for North Sea cod that is implemented in the multiStockassessment R package. It models three or four sub-stocks of cod (fig. 4.5), splitting observations where there is good rationale to do so (based on knowledge about biology, distribution, and movements of sub-stocks) and using shared observations when mixing of sub-stocks is believed to occur. This approach acknowledges mixing between sub-stocks but does not explicitly model movement, for which the available data are likely insufficient.

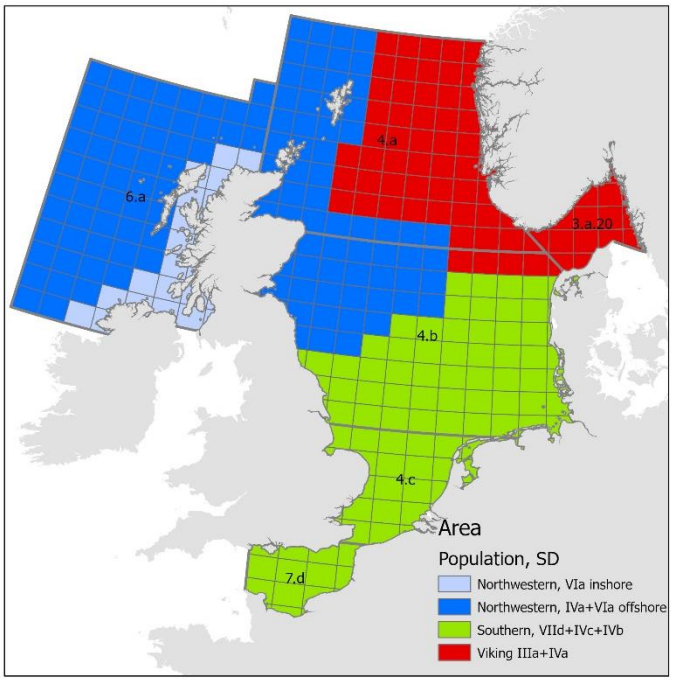

Fig. 4.5. Proposed sub-stock structure to be considered in the upcoming benchmark of northern shelf cod stocks. Under a three sub-stock hypothesis the two blue areas are considered a single northwestern sub-stock. Under a four sub-stock hypothesis, 6.a is split into inshore (light blue) and offshore (dark blue) components.

Challenges relating to compiling the required data were described: (1) combining data for two stocks that currently use different methodologies, age ranges and have varying time-series lengths; and (2) splitting data to the biologically based sub-stock definitions (fig. 4.5), particularly when data were not collected with these definitions in mind.

Preliminary runs from a limited version of the new SAM assessment model were presented. These runs were based on the benchmark assessment of North Sea cod (WKNSEA, 2021) and therefore do not currently include 6.a cod. Furthermore, all input data aside from the Q1 survey indices are currently shared between sub-stocks. Nevertheless, these runs demonstrate that SSB and fishing pressure for the total stock can be estimated for the entire period and that sub-stock compositions can be estimated for the period with survey data. Current challenges are that the Q1 survey data do not contain enough information to estimate individual commercial selectivities for sub-stocks and it is difficult to identify sub-stocks in the period before surveys. The upcoming data compilation workshop will explore the use of landings data submitted by year, quarter, cod area and ICES rectangle and options for collating biological data by sub-stock (including maturities, stock weights and natural mortality), while some modelling approaches are being considered to address the issues around commercial selectivity.

4.5 Clarification of how advice has developed for North Sea cod and biomass reference points are determined

At the end of day 1, the question of how advice could decrease and increase so much between years in the last 5 years and whether this was related to poor knowledge of the stock status. Further, the process of defining reference points was question, in particular whether data from the gadoid outburst in the 1980s are used in the definition of biomass and fisheries mortality reference points, thereby effectively introducing a requirement for the stock to return to the productivity is used to have when the distribution covered all of the North Sea.

The development in stock size estimated by ICES in the last 5 years is shown in fig. 4.6. In the years from 2016 to 2020, the assessment consistently observed less large cod in a year than expected from the number of one year younger fish estimated in the previous year. This can be caused by, for example, increased fishing mortality (unreported catches), increased natural mortality or increased migration out of the assessment area of older cod. Cod this large did not appear to be likely targets for discarding or for natural predators such as seals, but there is evidence of migration between the North Sea and West of Scotland cod stocks, and therefore it was assumed that the lack of older cod is caused by migration out of the North Sea. This change was implemented in the 2021 assessment and subsequently, the 2022 assessment showed results that were consistent with the previous year.

The continued overestimation of stock size because the cod disappearing from the stock were not accounted for has led to a historic advice that was above what would have been given with the current knowledge of the stock. After the 2021 benchmark, the advice has been fluctuation close to 30% of the spawning stock biomass. There are now signs of stock rebuilding, though the 2023 value is still uncertain as it depends to a large degree on fisheries in 2022 which are not yet fully known. In total, the large decrease in advice was caused by an overestimation of stock biomass in 2018 to 2020. The recent increase in advice is caused by a predicted increase in stock size.

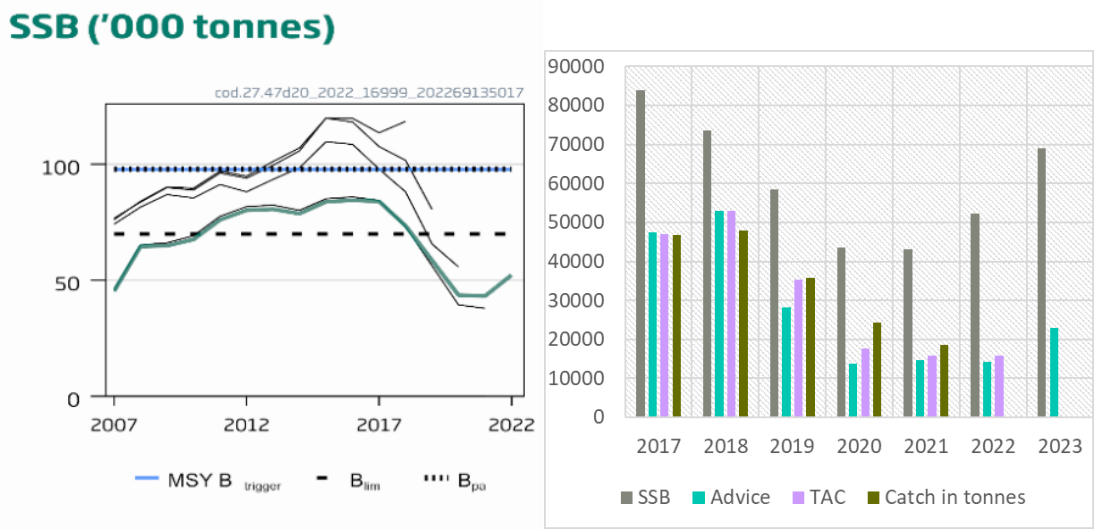

Fig. 4.6. Left: Development in spawning stock biomass estimated by ICES in the past five assessments. Right: Development in spawning stock biomass (SSB), advised catch, TAC and total catch in tonnes as estimated by ICES. Note that the 2023 SSB is a prediction based on specific assumptions about the fisheries in 2022 and hence has greater uncertainty than the previous values.

Defining reference points for ICES stocks with age-based assessments depend heavily on the observed relationship between spawning stock size and recruitment. The aim is to identified the spawning stock biomass below which recruitment is expected to be impaired. This is difficult for many stock due to the large variation in recruitment between years. For cod, there is also a severe decrease in the amount of recruits produced by a ton of spawning stock biomass from the gadoid outburst in the 1980s, where the stock was abundant throughout the North Sea, to today, where most of the cod stock resides in the northern North Sea and where individual spawning fish are smaller. To address this, the 2021 benchmark participants decided to use only data corresponding to recruitments from 1998 onwards in the estimation of both biomass and fisheries mortality reference points. There is no clear relationship between recruitment and spawning stock biomass but a tendency for low recruitments in the period from 1998 to 2020 (fig. 4.7). This leaves two options within the guidelines: If the stock has been fished at a low fishing mortality throughout

the period, the lowest biomass observed in the period can be used as an indicator of B_{lim}. Alternatively, if the stock has been fished at a high fishing mortality throughout the period, the highest biomass observed in the period can be taken as an indicator of B_{pa} (and MSY $B_{trigger}$ at present). As the cod stock has experienced high fishing mortalities in at least some of the period, the latter method was chosen. The resulting B_{pa} is 97 777 tonnes and the corresponding fishing mortality resulting in MSY, F_{MSY}, is 0.28. The average biomass if fishing at this fishing mortality and experiencing recruitment similar to that seen in the period from 1998 to 2020 is 163 738 tonnes.

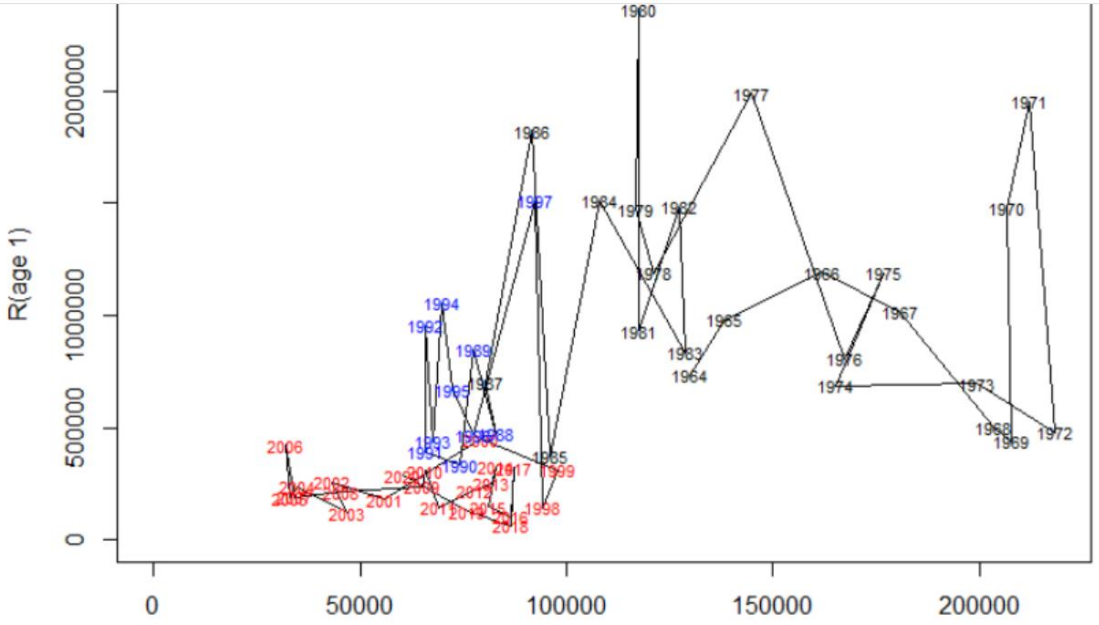

Fig. 4.7. Relationship between spawning stock biomass and recruitment in North Sea cod. Colours indicate different regimes, with red indicating the recent period.

5 Individual observations day 1

Both days of the workshop included a round of personal comments at the end of the meeting day to ensure that all participants had an opportunity to express their views. The views are summarized below.

Many participants commented that it had been a good experience to have open talks among industry and scientists and that the similarity between the comments of the three groups provided confidence that the conclusions were indeed relevant also beyond the participants in the meeting. There were constructive discussions of differences and a feeling of all wanting to make a change together. The joining of cod in the North Sea and west of Scotland were mentioned as the first step in the right direction. Regular meetings in advance of stock assessments was identified as a key recommendation, providing opportunities for industry and science working together.

Among challenges lying ahead, it was recognized that many of the problems faced by fishers have to do with the use of advice and the fact that the policy drive may not be to the benefit fishers. Fishing is at uncomfortable crossroads of many policy currents and this makes the industry vulnerable. In many cases, the challenge is how the advice is used more than the quality of science. However, it would also be useful to have a clear specification of situations where advice is more uncertain than in other cases.

On the use of data, possibilities to include more real time advice from fishers in practice and increasing the understanding of the management process among scientists were see as promising. The need to include spatial aspects in assessments to allow spatial management advice was brought up, and it was recognised that industry and scientists may have different perceptions of reality, particularly if they do not consider the same area (local vs regional). Having spatial assessments will however also produce challenges in how the pooling of substocks is taken into advice. The possibilities to include real time data were mentioned as a way to diminish the gap between experienced change and change in advice. Science has a role to help industry get to the point where they are producing quality assessment input for the benefit of all, with particular focus on identifying places where data or knowledge can really help and where fisher knowledge to the assessment.

It was commented that the use of loaded words such as bad science or damaging fishers are not helpful in the debate.

The final challenge will be to do something with the results of the workshop.

6 ToR c: Consider knowledge and data sources, potential methods and timetables by which further evidence can be incorporated into the scientific advisory process and identify where industry can provide evidence to underpin modelling and advice

The participants were divided into the same groups as on the previous day and discussed potential additional knowledge, data sources and methods for use in the scientific advisory process and to identify where industry can provide evidence to underpin modelling and advice. The summaries of the reporting from each group is given below.

6.1 Group 3

Group 3 discussed a variety of ways whereby catch data for stock assessment and real time input can be improved.

Catch data for stock assessment

The implementation of the Landing Obligation and the low (and lately decreasing due to Covid) observer coverage has raised concerns about the quality of discard data while landings data were still considered reliable. Incomplete data leads to poorer quality in the assessments and hence actions need to be taken to improve discard data without raising legal issues for fishers. A cost-efficient way to complement observer data is to use of self-sampling to document discards as in Ireland where a process was initiated under covid where boxes of catch and landings randomly selected from the trips are bought from fishers and quality assured by comparing with observer data. Another option is electronic monitoring, but this may have privacy issues in addition to possibly being used in a legal setting. Logbook/sales slips can also potentially be used in assessments, though the examples from Canada where hot spots retained high catch rates means that care has to be taken when including these.

There seems to be some lack of capacity in national labs to respond to fishers and fisher samples. Topics such as the amount of cod eaten by seals and other natural predators are also important an require more effort and hence more funding than at present to allow a more accurate estimation of natural mortality.

Survey method and allocation of haul sites were also discussed as a possible area where fishers may aid in identifying ways to ensure the fishing gear is efficient and that locations are relevant. However, as surveys are used for multiple species, allocating specific stations for cod is likely to be problematic unless the focus of the surveys is change to cod.

Data that can be used in real time

A Bycatch avoidance scheme with mapping developed between Scottish industry and the University of Aberdeen ("BATmap") provides information that allows other fishers to avoid areas with high densities of cod, this could provide CPUE data. The alternative of sending in photos of large catches was considered less useful as small catches are not photographed and therefore it is not possible to say whether the photo is derived from a single hot spot.

Industry input to the advisory process, both subjective/objective, could be organized in international/national meeting ahead of assessments. This could aid in making better intermediate year assumptions.

6.2 Group 2

Group 2 discussed possible routes and barriers to introduce fisher data and knowledge in advice. Fishing vessels could be used to deliver both cod related and other (e.g. sea temperature) data. If the data that can be used is limited to that which can be used in existing assessments, that may act as a barrier for including industry knowledge and data. This problem can be addressed by providing input to the ICES process before benchmarks and annual assessments. The knowledge for this could also be collated through national organisations. Due to the Landing Obligation stating that discards are not allowed, fishers may not be comfortable delivering true catch data to ICES, though some may be comfortable providing data to national scientists. The Fisher North Sea survey was discussed but it was considered that taking this up again would require some kind of guarantee that the results are used. It was suggested that an ICES group could be designated as having contact with the fishers. Possibly, this group could be a way to discuss if industry surveys could trigger a reopening of advice.

6.3 Group 1

Group 1 discussed the problems that the Landing Obligation causes for the use of fisheries data. The Landing Obligation provides a strong economic incentive to discard but at the same time, this cannot be reported without risk of prosecution. Further, as the fishers are not allowed to land the cod, they may have to focus on species that occur together with cod, leading to greater discard. Possible approaches to allow fishers to provide unbiased information included:

- Data on fish above minimum conservation reference size can be measured and information on location/size distribution/catch rates reported on a haul by haul basis providing detailed information on the spatial distribution of larger fish that are often not well represented in the survey.
- Various kinds of amnesty can be explored for vessels with observers or for vessels providing data for science.
- Undersized fish can count against scientific quota on selected vessels, but as scientific quota can be in high demand/difficult to get this may be difficult in practice.

In general, it was felt that observer coverage was insufficient to document the extent of discards and an increase in the long-term funding for observers would be necessary to allow better coverage. All of these issues need to be addressed together with managers. However, there was a general feeling that finding policy support can be difficult when other actors (e.g. greens, energy sector) are more important in the political environment.

Real time information could include reporting of areas of large unwanted catches by fishers to fishers.

6.4 Synthesis

The issue of how data can be improved while the Landing Obligation is in force was discussed in all three groups and there was agreement that this issue needs to be addressed together with managers and that these issues are hindering the full use of industry derived data. It was discussed that perhaps a selection of the fleet would be sufficient to provide additional data rather than trying to convince fishers that think participation is too risky or troublesome. There were

also various suggestions for pilot initiatives that could be initiated while waiting for a more thorough revision of the management system. Various approaches to deriving accurate catch data are possible, including TV based systems. Logbook/sales slips can also potentially be used in assessments, though care has to be taken when including these as they may not respond to low densities. Observer coverage was perceived as insufficient to document the extent of discards and an increase in the long-term funding for observers would be necessary to allow better coverage. Further, funding should be made available to address the lack of capacity in national labs to respond to fishers and fisher sampling and to investigate effects of natural predators.

Fishing vessels could be used to deliver both cod related and other (e.g. sea temperature) data for assessments to the ICES process before benchmarks and annual assessments. This requires collaboration between fishers and scientists to identify the type of information that would be most needed and how this should be delivered. Such a collaboration could be organized through a dedicated ICES group. Industry sampling has the potential to provide better descriptions in space and time of distribution of fish and better catch data, but are often hampered by limited international coordination. ICES should play a role in coordination between countries (WKEVUT/WKEnsure), defining data needed and protocols. Commercial catch rates can potentially also be used in assessments but this will require funds to analyse data, presentation at a WG and possibly an interbenchmark/benchmark. Industry data can also aid in identification of high-density cod areas for possible closures during spawning. These closures could possibly be combined with higher TAC in open areas. Perception based input pre-assessment based on fisher observations can be used by stock assessor as a guide in what to investigate further in the assessment that year. Meetings to communicate these observations could be regional, held with all surveys together with all fishers.

Real time information could include reporting of areas of large unwanted catches by fishers to fishers. Industry input to the advisory process, both subjective/objective, could be organized in international/national meeting ahead of assessments. This could aid in making better intermediate year assumptions.

7 Individual observations day 2

Both days of the workshop included a round of personal comments at the end of the meeting day to ensure that all participants had an opportunity to express their views. The views are summarized below.

There was general agreement that working together is the right way to break the current lock down. With a will on both sides to get something done and science willing to listen to industry, we just need to find out how to organize the work. Concrete follow ups are important as is the recognition that organising follow up meetings can take time and that having productive meetings with managers requires knowing what we want from them. There was a general feeling that it is necessary to think about the consequences of the Landing Obligation.

It was generally thought to be an excellent idea to have pre-assessment meetings. It should be possible with a dedicated effort to organise the pre-assessment meeting before the assessment meeting next year. The next WKRRCod meeting can then evaluate how the pre-assessment meeting and subsequent follow up went. The interim year is a place where the pre-assessment meeting can provide valuable information.

There is a need to provide greater clarity in explaining assessment models, the data that go in and the results. Easy to read wrap up on guidelines for e.g. reference points would also be useful. Specific requirement for data input from industry to the assessment process need to be clear from the onset (protocols, is it useful, for what) to avoid providing long time series that are then not used. Transparency, quality and communication of the data that we use and evaluation of quality of data is important, also where data or quality is lacking.

It was mentioned that with the huge amount of passion and drive for change, the momentum should be used and acted on quick, also in scaling up the observer program and getting improved data into the assessments and in push for policy change. It was good that ICES has organised the meeting and shows openness to getting input from industry and the conclusion can be considered stepping stones to improve relation between science and industry. Hopefully the meeting is a start of a common agenda in making advice and managing advice by closing the gap between observations on fishing grounds and assessments. Recruitment estimates are still a problem as advice is perceived as lacking behind large recruitment events.

It was positive that there is agreement among North Sea fishers in supporting data collection and data quality and good to coordinate how to collect and use data. Input from fishers on when there are many and when there are few fish may help in the future advice. The data from fishers include soft information/qualitative information that could help inform the assessment process, result and advice.

8 Synthesis and recommendations

The backbone of high-quality assessments is high-quality data and knowledge, including survey, landings and discards data. The workshop presented an opportunity for industry and scientist work together to increase the quality of data and knowledge in the assessments. The large influence of the Landing Obligation on the fisheries meant that this issue was repeatedly discussed, but the lack of widespread management attendance meant that it was not possible to produce concrete actions to address these challenges. This should be a key topic for the next workshop.

The conclusions of the workshop were distilled into the following six recommendations:

1. Guidance from ICES on what kind of data should be collected and how should be discussed in WKEnsure and these data should be considered for use in benchmarks and assessments.
2. Cod benchmark participants are recommended to produce a plain-spoken summary of the main changes in the assessment and forecast decided at the benchmark. Areas where additional knowledge would particularly benefit the assessment are also to be identified. The summary should be delivered to WKRRCOD participants in advance of the pre-assessment meeting
3. A pre-assessment meeting should be organised to discuss new knowledge in support of the annual assessment including intermediate year assumptions. This meeting should take place together with an overview of survey results and be repeated annually. The meeting should be at least two weeks in advance of the benchmark to allow the stock assessors to consider the discussion points.
4. In the assessment report, a short text should be added stating the main input from the industry in the pre-assessment meeting as well as how this was investigated or incorporated in the further work.
5. The next meeting of WKRRCOD should include managers. The meeting should address policy and the landing obligation and evaluate the pre-assessment process. Timing of this meeting should be end-May/mid-June.
6. Similar processes as WKRRCOD can be organized by region, focusing on major challenges in assessment and advice as perceived by the industry. Demersal and pelagic fish should be addressed separately. Likely topics for 2023 onwards are monkfish, ling and mixed fishery issues. Multispecies/ecosystem expansions could be possible topics in the future.

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Annex 1: List of participants

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Annex 2: Agenda

Time	Issue	Responsible
Tuesday November 1st		
10.00-10.30	Welcome, round of presentation, discussion of scope and terms of reference and adoption of agenda	Anna
10.30-10.45	Presentation of group work/depending on participant number	
10.45-11.45	Identify objectives for management of cod stocks and challenges in the current assessment and advice (groups)	
11.45-12.00	Coffee break	
12.00-12.30	Identify evidence needs to achieve advice supporting identified management objectives (groups)	
12.30-13.00	Reporting back from groups to plenary	
13.00-14.00	Lunch break	
14.00-15.30	Plans for the assessment and advice for North Sea cod identify objectives and challenges met by the plans	
15.30-15.45	Coffee break	
15.45-17.00	Approach for the assessment and advice for West of Scotland Sea cod and identify objectives and challenges met by the approach.	
17.00-17.30	Wrap up of the day in plenary	
Wednesday November 2nd		
9.00-9.30	Summarise objectives and challenges met/not met by the current plans and approaches for North Sea and West of Scotland approaches (plenary)	
9.30-10.30	Consider additional knowledge, data sources and methods that can potentially be used in the scientific advisory process (groups)	
10.30-11.15	Identify where industry can provide evidence to underpin modelling and advice (groups)	
11.15-11.30	Coffee	
11.30-12.30	Review group results and make a plan for what evidence should be introduced into the advisory process and when (plenary)	
12.30-13.00	Where this plan includes substantial work, identify possible solutions for organisation and funding (plenary)	
13.00-14.00	Way forward and concluding remarks	
14.00	End of meeting	