SECOND SCOPING WORKSHOP ON NEXT GENERATION OF MIXED FISHERIES ADVICE (WKMIXFISH2)

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SECOND SCOPING WORKSHOP ON NEXT GENERATION OF MIXED FISHERIES ADVICE (WKMIXFISH2)

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ICES International Council for the Exploration of the Sea
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i Executive summary

The objective of the Second Scoping workshop on the next generation of mixed fisheries advice (WKMIXFISH2) was to continue a dialogue with advice recipients, stakeholders, and scientists on developing mixed fisheries science and advice to meet management needs. The meeting aimed at establishing the current use and utility of mixed fisheries considerations and identifying priority areas for future development.

There was overall support for scenario-based advice on the consequences of mixed fisheries interactions given incompatibilities among single stock advice catch limits. Mixed fisheries considerations are currently used as supplementary information to single stock advice, providing managers with a directional tool when considering catch limits that protect vulnerable stocks. This focus on general trends, rather than specific values in the mixed fisheries scenario forecasts, is due in some cases to a combination of uncertainties associated with mixed fisheries interactions among fleets and metiers, considerations of economic trade-offs, as well as the potential behavioural response to changing catch opportunities. A clearer presentation of model assumptions was seen as important for framing the interpretation of mixed fisheries considerations and these factors. For example, mixed fisheries forecasts highlight incompatibilities in single stock advice under the assumption that future fishing will resemble recent historic patterns. In addition to influencing catch limits, it was recognised that the scenario forecasts could be used in conjunction with other data and advice products to aid in the development of adaptive strategies to changing fishing opportunities.

Discussions on potential improvements focussed on model and scenario assumptions that can influence technical interactions among fleet and metiers. These included fleet and metier definitions, quotas share distributions among fleets, effort shares among metiers in each fleet and the development of alternate scenarios. In addition to the ongoing review of these aspects, it was suggested that further transparency and feedback from stakeholders would be beneficial, especially in the definition of fleets and metiers that best capture technical interactions. Other areas of development included the potential of mixed fisheries models to provide further information on impacts to bycatch stocks and additional scenarios for assessing stock rebuilding strategies, and the incorporation of routines to understand uncertainty in the model forecasts to input data and conditioning.

There was a clear call for the availability of more detailed information on spatial dynamics in mixed fisheries and on supplemental advice products that can help inform mitigation strategies to overcome imbalances in TACs.

The workshop identified several areas where developments can be made to the current advice product, as well as additional advice products that could support management decisions. There is now planned technical work to develop these ideas before the subsequent workshop (WKMIXFISH3) in March 2024.

ii Expert group information

Expert group name	Second Scoping workshop on next generation of mixed fisheries advice (WKMIXFISH2)
Expert group cycle	Annual
Year cycle started	2022
Reporting year in cycle	1/1
Chairs	Paul Dolder, UK
	Marc Taylor, Germany
Meeting venue and dates	1–2 March 2023, Copenhagen, Denmark, (35 participants)

1 Introduction

The Second Scoping workshop on the next generation of mixed fisheries advice (WKMIXFISH2) chaired by Paul Dolder, UK, and Marc Taylor, Germany, met at ICES HQ, Copenhagen, 1-2 March 2023, to continue a dialogue with advice recipients, stakeholders, and scientists on developing mixed fisheries science and advice to meet management needs. The overall goal of the second workshop was to establish use and utility of the current advisory product, mixed fisheries considerations (MFC), to improve understanding of the mixed fisheries science and the assumptions that go into MFC, and to identify priority areas for development. The main outcome was a roadmap with a list of prioritised topics for improving methods and communication of mixed fisheries advice produced by ICES.

The workshop was attended by 35 participants (16 industry, 4 advice recipients/managers, 2 non-governmental organisations, 13 scientists working in research organisations) and this report represents the chairs' summary of proceedings and the views expressed.

WKMIXFISH2 participants at ICES Secretariat, Copenhagen, Denmark

2 Meeting structure

The meeting was organized into two breakout sessions on the first day, followed by a second half day of general discussion and definition of goals and actions for WGMIXFISH. The goal was to use the breakouts and plenary discussions to establish a common understanding of the current advisory product, to establish how the advice is currently used and identify where different methodological approaches or ways of communicating the core messages from the advice could be developed and tested. The intention is for some of those ideas to be developed over the next 12 months and brought back to a subsequent workshop in March 2024 (WKMIXFISH3), while others will take longer to develop due to resource, model, or data limitations.

Breakout 1 focused on understanding how current advice is used, while Breakout 2 focused on shortcomings and potential improvements to the advice. Before each breakout, several short introductory presentations were made by WGMIXFISH members to help frame the discussions and provide context to the current approaches used by WGMIXFISH. The composition of Breakout groups was designed to ensure a mix of participants in terms of expertise and experience (industry, non-governmental organisations, advice recipients/managers, scientists) so that a range of views could be presented and challenged in each group discussion. Breakout groups reported back to the plenary for a more general discussion, summary and identification of areas to develop.

2.1 Breakout 1: How do you use mixed fisheries advice?

The first breakout aimed at better understanding how mixed fisheries advice is currently used by advice recipients and stakeholders. Two presentations were first given in order to generally frame the workshop and the first breakout.

The first presentation, *Development of mixed fisheries advice in ICES: MIXMAN to WGMIXFISH* (by Paul Dolder and Dorleta García, both current members of WGMIXFISH), provided context to the development of the methods and approaches employed by WGMIXFISH, including some of the key milestones in development of the methodology and management considerations that have influenced the advice product over time. The issue of modelling technical interactions in mixed fisheries was first discussed in ICES by Laurec *et al.* (1991) before more structure modelling frameworks were developed and reviewed (ICES, 2006). The first candidate modelling approach identified for advice provision was MTAC (Vinther *et al.*, 2004), but this was rejected by the ICES Advisory Committee for Fisheries Management (ACFM) for several reasons, including the sensitivity of results to fishery definitions and policy weightings, and the mismatch between fleet efforts identified by MTAC and the overall fixed allocation of quotas under relative stability (see Kraak, 2004 for a full review). Ultimately the fleet and fishery forecast model (FCube) was adopted for advice (Ulrich *et al*., 2011) by ICES, first applied in the North Sea for advice provision in 2012. The approach has subsequently been expanded to multiple regions using both FCube and FLBEIA (Garcia *et al.*, 2017). The modelling approach has been developed partly in parallel with policy changes aimed at better aligning fishing effort to stocks caught as part of mixed fisheries (Figure 2.1).

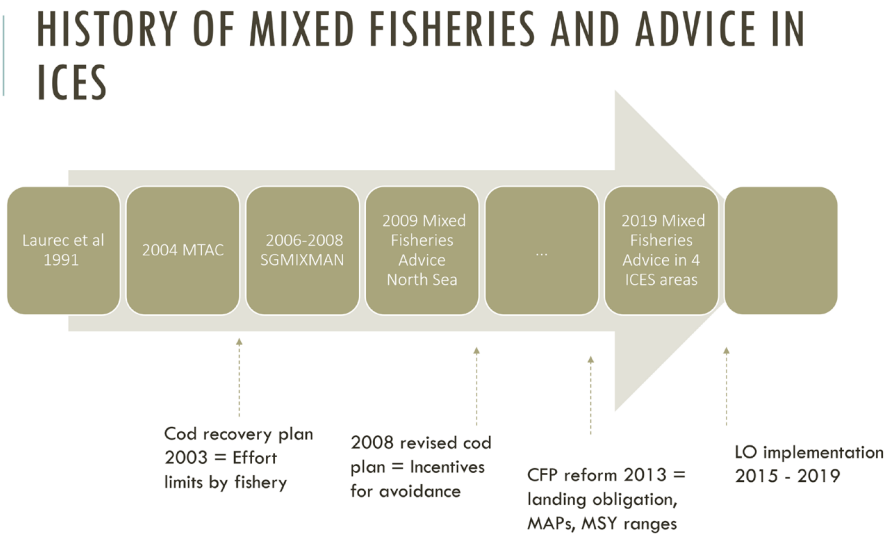

Figure 2.1. Timeline of the development of mixed fisheries considerations by ICES.

The second presentation, *Introduction to the current advice structure* (Marc Taylor and Harriet Cole, current WGMIXFISH chairs), provided an overview of the annual schedule of WGMIXFISH, including the group's two regular meetings, WGMIXFISH-METHODS and WGMIXFISH-ADVICE, and how these are organized around relevant assessment groups throughout the year (Figure 2.2). Further information included how different data sources are used and integrated, which modelling frameworks are employed, and the growth of the group over time in terms of regions covered. Finally, a brief review of the current advice structure was provided (Figure 2.3).

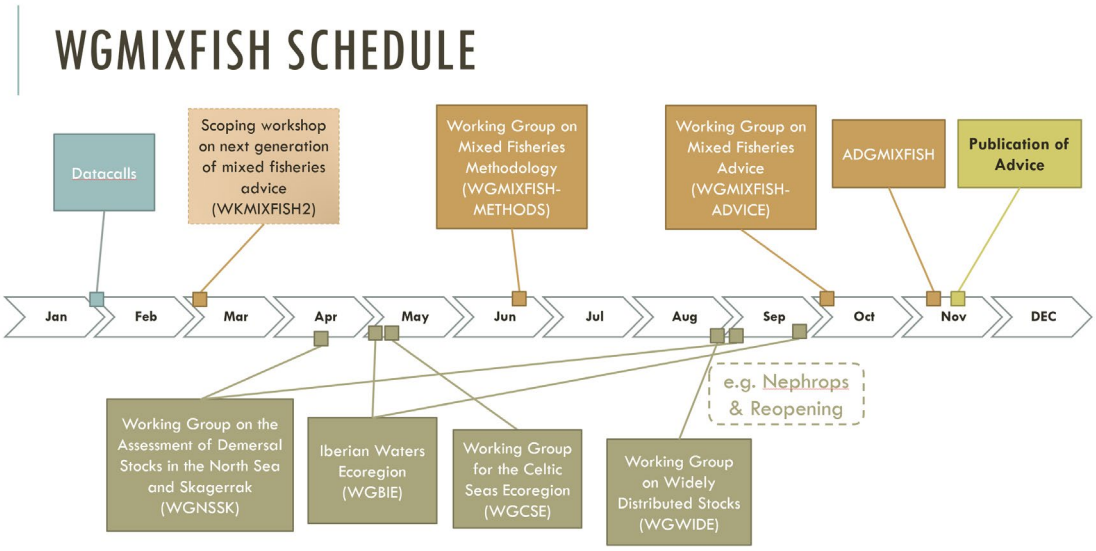

Figure 2.2. Overview of the annually-scheduled working groups related to WGMIXFISH outputs. Assessment groups (in brown) occur in both spring and early fall, depending on the stocks covered, and re-openings or revisions to advice. WGMIXFISH working groups (in orange) consist of a methods-focused meeting in early summer (WGMIXFISH-METHODS) and an advice meeting in fall (WGMIXFISH-ADVICE), followed by a finalising advice drafting committee meeting (ADGMIXFISH) before publication in November.

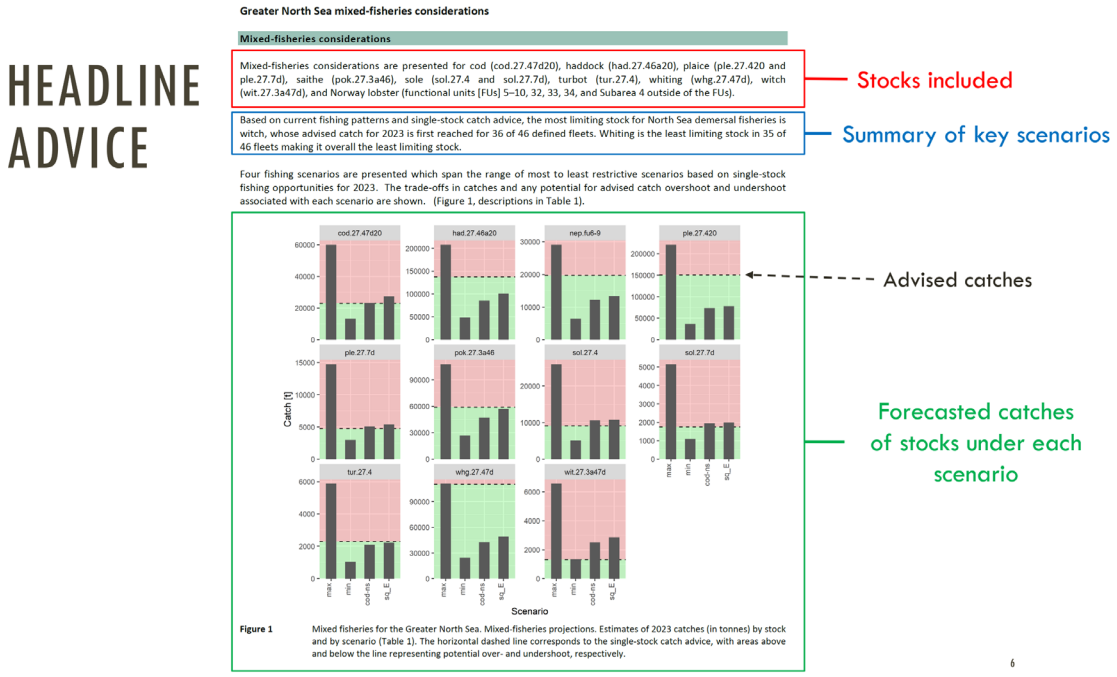

Figure 2.3. Example of headline advice structure from the Greater North Sea mixed fisheries considerations document from 2022.

Participants were then split into several groups to discuss the first breakout discussion topic, with guiding questions provided (see Box 1).

Box 1. Breakout 1 guiding questions

Breakout 1: *How do you use mixed fisheries advice?*

1. How is mixed fisheries advice used by your group?
2. How is mixed fisheries advice influencing your activities?
3. What is your main take home from reading the mixed fisheries advice sheets?

In this breakout we would like to better understand how mixed fisheries advice is currently used by clients and stakeholders. Please discuss what elements you focus on, such as the current stock status, incompatibilities in catch advice among stock, fleet-specific limitations, etc. How does the advice help inform subsequent actions by your group? Is mixed fisheries advice used in conjunction with other advice reports?

2.2 Breakout 2: How can mixed fisheries advice be more useful?

The second breakout was focused on potential improvements to mixed fisheries advice. Participants were encouraged to discuss difficulties that exist in using the advice; for example, in terms of the its clarity and utility, or other reservations related to its assumptions.

An introductory presentation summarized topics that have been addressed in recent meetings - *Recent topics covered by WGMIXFISH-METHODS* (Marc Taylor). A subset of topics included operating model comparisons, intermediate year assumption performance vs. single stock advice, *Fmsy range* scenario development and communication, incorporation of uncertainty, assumptions of effort share among metiers and quota shares among fleets.

Following the presentation, participants were again split into several groups, with guiding questions provided (see Box 2).

Box 2. Breakout 2 guiding questions

Breakout 2: *How can mixed fisheries advice be more useful?*

1. What are the specific challenges for using mixed fisheries considerations for your region?
2. What scenarios would help in exploring the trade-offs of different solutions?
3. What are the most important assumptions for forecasting fishing behaviour in your region?
4. What are the barriers for transitioning from mixed fisheries "considerations" to "advice"?

In this breakout we would like participants' feedback on possible improvements to the mixed fisheries advice. Please discuss the current mixed fisheries challenges for using the advice in your region. Given your knowledge of your fishery / region, are the current model assumptions and scenarios sufficient to describe mixed fisheries interactions and aid decision making?

2.3 Concluding plenary and definition of goals and actions

The second day was used to summarize the main topics raised during the breakout discussions and to try and define a list of goals and actions to guide future development in WGMIXFISH. The intent was for the development of a roadmap; some of the issues can be developed and presented back to a subsequent workshop (WKMIXFISH3, planned March 2024) while others will be on a longer timeframe either due to resource, model or data constraints. Development topic were characterised in terms of the potential time required for implementation, while also prioritising topics with clearest benefits in the short term.

3 Current use of mixed fisheries considerations (ToR a)

In general, mixed fisheries considerations (MFC) are seen as supplementary information to the more familiar single stock advice (SSA). Members of industry use MFC to help identify potential choking situations, and in the subsequent development of mitigation strategies, where economic viability is of importance. Managers use MFC more as a directional tool alongside SSA when considering catch limits that can help protect vulnerable stocks. Relatedly, non-governmental organization (NGO) members mentioned their use of MFC to better understand potential barriers to the rebuilding of vulnerable stocks.

The publishing of MFC relatively late in the calendar year was seen as somewhat limiting to its use in negotiations setting catch limits, although there was recognition that this is likely unavoidable given the reliance of WGMIXFISH on the SSA produced by several assessment working groups. MFC influences quota negotiations to some degree, both as guide to potential incompatibilities in SSA and in the setting of quotas that may minimize the risk of overfishing. MFC was seen by some to aid in the acceptance of quotas below those proposed by SSA in cases of least-limiting stocks, for which full quota uptake can be demonstrated as unlikely due to advised increases for those stocks and given the technical interactions with vulnerable stocks (for example, in setting the North Sea haddock and whiting catch limits below the SSA, in recognition of interactions with North Sea cod). However, it was expressed that there is a risk that the use of MFC to inform catch limits can lead to entrenched positions because of differences in the SSA and the significantly lower catches in for target stocks in MFC scenarios (e.g. under the 'min' scenario) required to achieve SSA. In particular, there may be disagreements on the degree to which fishers can adapt to quotas by changing behaviour. For example, industry members may prefer the more direct adoption of SSA-derived catch levels and be allowed the freedom to define for themselves how to best adapt fishing operations to the quota imbalances.

MFC is published as an advisory product but categorised as "considerations", and this distinction was confusing for some end users and stakeholders. It was clarified that no single scenario was "advice" on catch limits and that ICES advice stems from defined policy objectives in relation to maximum sustainable yield (MSY) on a single stock basis. That may be partly the source of confusion as equivalent objectives do not exist for mixed fisheries. The treatment of MFC as "advice" likely stems from several issues relating to the presentation of the scenario assumptions, which should be remedied in future MFC releases. Overall, MFC is seen as a valuable component to management and the development of mitigation strategies, although it is used mainly as a tool for more general, directional guidance.

There was expressed a lower confidence in the realism of model assumptions when compared to SSA. The ongoing development within WGMIXFISH Methods regarding model components including the fleet and métier definitions and forecast assumptions were highlighted. Some of the differences in perception between SSA and mixed fisheries model assumptions stem from the unavoidable complexity of forecasting fishing behaviour, which requires better communication in how the MFC should be interpreted, while other more technically-based critiques on modelling assumptions can hopefully be addressed more immediately. These issues are further elaborated in the following section, along with possible solutions.

4 Potential improvements to mixed fisheries considerations (ToR b)

As mentioned above, critiques of MFC could be broadly categorized as either issues of clarity or issues of realism. Clarity issues stemmed from how the MFC are framed, with model assumptions presented as technical details rather than, more appropriately, essential aspects for interpretation. These issues of clarity are most likely to be solved by a more forward-facing introduction of model assumptions and their rationale. Furthermore, it was clear that MFC is used in conjunction with other advice or data products, such as the SSAs, spatial catch composition data, and economic considerations. It was considered that TACs were not the only tool to address mixed fisheries problems, and that other information would help identify if a technical solution could be available. It is unrealistic to assume that all of these aspects may be combined into a single advice product; nevertheless, the availability of accompanying information and tools could increase the utility of MFC, and the identification of the most appropriate solution, in the future.

Critiques on the realism of MFC typically may require technological changes in the form of data considered, model structure and model assumptions. While some changes will require additional data sources and investigation into their integration, others, which may stem from incorrect model specification identified by stakeholders, can hopefully be more immediately remedied. Providing avenues for stakeholder feedback, including, but not restricted to, workshops such as this one, will further improve the turn-around time for improvements to the MFC approach.

4.1 Communication and interpretation (ToR d)

One of the clearest issues identified, was the lack of concise, clearly-worded assumptions and guidance to MFC interpretation. This aspect was further revealed in breakout discussions regarding the distinction within ICES between "considerations" versus "advice", and further discussions on whether there was the potential for moving towards a more traditional advice product with a headline "mixed fisheries advice". Several participants indicated that MFC was being used as something in between the two options, and that this was creating some confusion.

ICES releases mixed fisheries considerations as an advisory product but does not provide specific mixed fisheries advice and has previously stated in the advice sheets that "*In the absence of specific mixed-fisheries management objectives, ICES does not advise on specific mixed-fisheries catch opportunities for the individual stocks*" (ICES, 2020). Instead, mixed fisheries considerations "*provide information on the consequences and risks of management options, even when the management objectives are not defined (e.g. mixed fisheries)*" (ICES, 2023).

There was some degree of consensus around the continued use of the term "considerations" for MFC given the lack of defined objectives for mixed fisheries which prioritise trade-offs among single stock objectives. There were also questions raised about the fleet behavioural assumptions in the model in the context of restricting catch limits for target stocks. In particular, a simple assumption of fixed fishing behaviour is used, based on recent historical fishing activities (i.e. effort share of metiers for a given fleet). Although fleets are in reality more flexible and adaptive to shifts in fishing opportunities through time, the assumption is, nevertheless, accepted to be easily understood. It was also noted that predicting fishing responses to changing quotas was extremely challenging given the number of potential drivers, and there is a lack of available models at the scale needed for incorporation in mixed fisheries scenarios in a realistic way.

Choking behaviour exhibited by fleets in the model may thus be interpreted as elucidating potential limitations to fishing opportunities *if* behaviour remains similar to the recent past. Therefore, MFC could potentially include additional clarification as to its interpretation within the headline summary (e.g. Box 3):

Box 3. Potential aspects for framing the interpretation of mixed fisheries considerations:

- Elucidates incompatibilities in single stock advice
- Uses information on how recent catches break down among main fleet and metier divisions to show potential choke situations *if fishing behaviour remains static*
- Recognises that fishing behaviour is not static, but attempting to predict fishing behaviour requires additional complex assumptions
- Thus, mixed fisheries considerations should not be treated as direct advice, but should be used in conjunction with other tools to guide management towards more efficient quota uptake.

Other aspects of the current MFC structure were not specifically highlighted as being unclear, but some additions were discussed. In addition to the graphical presentation of effort limitation by fleet and stock, a similar figure showing catches by fleet was suggested (e.g. comparing catches from "status quo" and "min" scenarios). In cases of stock rebuilding, e.g. when a stock is below a given reference point of good status, or the more extreme case of zero-catch advice, additional scenarios of catch options would be beneficial, such as sequential catch advice levels. These would ideally be consistent with those provided in SSA catch option tables. Additional scenarios could potentially be suggested by managers prior to WGMIXFISH-ADVICE meeting for inclusion in the MFC or accompanying report, in the gap between SSA being released and MFC being developed.

There was generally support for the current limited set of scenarios which most clearly illustrate the incompatibilities among different stocks caught together. It was considered this would most clearly allow communication of the key consequences of the SSA, though in some circumstances also recognised there was value in region specific scenarios in response to particular management challenges. There was also interest in other types of scenarios that could attempt to smooth out tensions among incompatible catch advice levels. The previously provided "range" scenario is particularly relevant in this regard, as it explored the possibility of using the upper range of Fmsy reference points to reduce choking, along the lines of a "pretty good yield" management strategy (Rindorf *et al.*, 2016). The scenario is currently being revised, and is likely to be reinstated as part of MFC in the near future. The inclusion of scenarios that result in incremental increases in stock biomass for depleted stocks were also mentioned as potentially useful in informing incompatibilities among objectives, but to avoid distracting from the main messages, it may be that these are included either in the report or only in the tables in a similar way to *catch options* in the single stock advice.

4.2 Model structure, assumptions and scenarios (ToR c)

The group discussed several modelling aspects, both structural- and assumption-based, including where data aggregation could lead to what were termed "false technical interactions". These are situations where fleets in the model are limited by incompatibilities in SSA that do not exist due to spatial or temporal decoupling of catches of the stocks, or where it was considered unrealistic for a fleet to be choked by a stock making up a relatively small component of their catches. The main points of discussion concerned the following aspects: 1) Fleet and metier definitions,

2) Quota share distributions among fleets, 3) Effort shares among metiers in a given fleet, 4) scenario formulation.

Fleet and métier definitions

Fleets are typically defined by country, vessel length category, and main gear employed. For example, in the North Sea case study, the "NL_Beam_24-40" fleet contains Dutch beam trawlers between 24-40 m. Within a fleet, several metiers may exist, which define groups of fishing operations targeting similar species using similar gears in a similar area; e.g. "BT2.4" is small mesh beam trawling in ICES area 4. A fleet's effort is thus distributed among its metiers (i.e. "effort share") proportionally to the recent past, and WGMIXFISH assumes these effort shares to be constant. Furthermore, a fleet's fishing effort could potentially be limited by catches of a limiting stock within a single metier. False technical interactions may thus result when fishing operations, which in reality are quite independent activities, become grouped within a fleet. The alternative approach would be to completely separate out these activities, and using more fishery-based fleet definitions. The realism of treating these activities as fully independent is also questionable, however, and this full flexibility was recognised as unrealistic in previous mixed fisheries modelling approaches (e.g. MTAC: Vinther *et al.*, 2004; ICES, 2006). So, there are pros and cons to both definitions, and it is likely that increased communication with stakeholders could help to identify poorly-defined fleets. One suggestion was for WGMIXFISH to be more transparent in the metier aggregations used in defining fleets, or stakeholder input to defining this structure. This could take the form of an extended table, made available to stakeholders for review and feedback. The topic is recognised as being one of the top priorities to be addressed by WGMIXFISH-METHODS in 2023.

Quota share distributions among fleets

Quota shares among fleets are currently based on each fleet's historical catch or landings shares (proportion of the overall landings, by stock). This obviously deviates from the reality of initial national quotas being based on legally-agreed upon shares (e.g. "relative stability"). However, countries will typically swap quotas according to their specific economic interests, and these swaps tend to be fairly constant over time. Defining quota shares based on catch or landings shares attempts to reconcile these dynamics, but inconsistencies can result, such as the creation of unrealistic choking situations if a given fleet had unrealised quota in the previous historical years. WGMIXFISH-METHODS 2022 (ICES, 2022a) looked into using information from the Fisheries Data Exchange System (FIDES) as the basis for alternate quota shares based on pre- and post- TAC swaps among countries. The results showed clear promise, especially post- TAC swap proportions, yet questions remain as to the future availability of the FIDES data to the group and the fact that the database may only cover EU member states. The group appreciated the potential of the approach and suggested that further investigation should be conducted into its continued availability and use.

Effort shares among métiers in a given fleet

As mentioned in the previous section "Communication and interpretation", the assumption of constant effort shares by metiers is easily understood, and may help to frame the MFC in terms of potential SSA incompatibilities in the absence of fishing behaviour changes. Furthermore, it was generally agreed that past fishing behaviour is often the best proxy for the future, especially in the short-term. Nevertheless, WGMIXFISH-METHODS 2023 is planning to investigate whether effort share by métiers could potentially be allowed to vary to some degree in order to represent a more optimal quota uptake behaviour by fleets. This could potentially result in more

realistic behaviour, but possibly at the expense of additional assumptions about the complexities of fishing behaviour and reduced clarity of the MFC. Even if constant effort shares are maintained going forward, the issue is intimately linked with fleet/métier definitions, which would again benefit from periodic revision by stakeholders.

Treatment of uncertainty

There is also recognition that within a métier there is variability in catch rates (terms "catchability") for different stocks over years, which likely reflects changes in targeting behaviour within a métier among years. The influence of this catchability variability on catch projections is directly linked to the fleet and métier definitions and effort shares among métiers, and one suggestion was better treatment of uncertainty about parameterisation of these in the models. Uncertainty in future catches, conditioned based on past variability, could give greater confidence in the catch predictions, and identify the parameter assumptions to which the forecast catches are most sensitive. WGMIXFISH-METHODS 2022 (ICES, 2022a) began looking at this issue, and there is planned work to continue to develop routines that can be incorporated in the workflow of mixed fisheries considerations to increase confidence in the catch forecasts. How these uncertainties can be clearly communicated and presented is still something to be discussed.

Scenarios to inform decision making

Scenarios provided by WGMIXFISH were discussed, and it was generally considered that in the absence of defined management objectives for mixed fisheries the current simple scenarios are most useful to address the question of "what are the incompatibilities among stocks". Were there to be a desire to consider more directly implementable scenarios, the need for clear, unambiguous definitions on the priorities among stocks was identified as something that WGMIXFISH would need to be provided by managers. For example, while there was general recognition that zero catch advice is not being or likely to be implemented, it's not clear what catch options (and undershoots of other target stock quota) would be acceptable to provide an informative mixed fisheries scenario.

It was also suggested that current scenarios were "blunt tools" since they do not take account of the strength of technical interactions among stocks. This resulted in too steep an economic impact through loss of target stock fishing opportunities for some fleets compared to the benefits in reduction in catches for the depleted stocks by those fleets. It was mentioned that it's unlikely that target stocks that have only weak interactions with depleted stocks would have their TACs limited, and that this was a reason why the current scenarios could not be implemented directly in some circumstances. This in part has more to do with constraints of the management system limiting the types of scenarios that can be explored than the modelling of the interactions and was a reason why MTAC was previously rejected due to the explicit need for introducing policy weightings which affected fleets differently. It was highlighted that WGMIXFISH can provide scenarios that do not restrict fleets with relatively weak interactions (for example, restricting choking effects based on a minimum share of catch of a stock), but these trade-offs would need to be clearly defined by managers *a priori*. It was also noted that i) these would result in violation of single stock objectives and catch advice for the depleted stocks so there would need to be some consideration of redefined objectives in terms of rebuilding for these stocks, ii) it would also result in the same mismatches as MTAC in terms of the model assumptions of fleet catches and the fixed quota allocations to fleets, so it would be necessary to allocate quotas to fleets in accordance with the model outputs to achieve the intended outcome.

Due to the complexity of the various issues discussed, a technical guidance document was prepared ahead of the workshop and has been included here as Annex 3.

4.3 Further development

Several topics were discussed that may either be categorized as long-term developments or more applicable to mixed fisheries explorations outside of the short-term forecast context of MFC.

First, there is interest in looking at mixed fisheries implications for stocks not included in multi-annual plans or those stocks currently not managed by catch limits (i.e. non-quota stocks, as well as e.g. cetaceans), in order to better assess the potential risks to bycatch stocks or other sensitive species. Their incorporation in current mixed fisheries frameworks should be feasible, even for stocks lacking quantitative assessments and for which only biomass-based dynamics or catch thresholds are defined.

Long-term scenarios were also discussed, such as the performance evaluation of specific management measures; i.e. "management strategy evaluation" (MSE). For example, mixed fisheries MSEs have been used in several side projects in evaluating the long-term sustainability of fish stocks and economic viability under climate change (PANDORA project, https://doi.org/10.3030/773713), as part of the implementation of ecosystem-based fishery management (SEAwise project, https://doi.org/10.3030/101000318), and in the protection of bycatch stocks (ProByFish project, EASME, 2021). Other long-term scenarios of interest were to address stock rebuilding strategies. While not specifically focused on stock rebuilding, mixed fisheries models developed in WGMIXFISH have been used to evaluate whether fisheries management strategies are able to promote stock resilience to shocks and changes in climate (Bastardie et al., 2022).

Socio-economic considerations are also of interest, although some issues of technical feasibility currently hinder such efforts. The WGMIXFISH data call includes information of fishing effort and fish price (used in calculating revenue) by fleets/metiers, yet information on fixed and variable costs are not currently requested. The difficulty in collecting this information stems from privacy issues and discrepancies between model domain definitions (e.g. ICES areas) and stocks covered. Similar discrepancies make unification with STECF (Scientific, Technical and Economic Committee for Fisheries) FDI (Fisheries Dependent Information) economic data difficult, as data are aggregated over all larger areas. Nevertheless, revenue information has been used to develop alternate scenarios in past MFC ("value" scenario) that make other assumptions about fleet fishing effort based on most valuable stocks. Further consultation with stakeholders may be needed in order to evaluate if revenue information, or other economic variables, could assist in management decisions.

Stakeholders mentioned that model sensitivity and uncertainty could be better communicated. Some exploration has already been conducted within WGMIXFISH-METHODS on aspects associated with catchability, effort share, and quota share (ICES, 2022a). Further development of the routines needs to be conducted, as it is unclear whether such information can be both clearly communicated and incorporated routinely.

Finally, MFC could be better combined with other advice tools to help aid in management decisions and in the guiding of fishing strategies to deal with potential TAC incompatibilities. One idea was to investigate whether spatial landings data by metier, e.g. STECF FDI (https://stecf.jrc.ec.europa.eu/dd/fdi/spatial-land-map), could be made more readily available. The Celtic Sea Fisheries Overview (ICES, 2022b) presents a subset of maps, aggregated across metiers. More interactive online interfaces could be helpful in this respect. Generally, there was a desire for a better overview about the availability of publicly-available data, some of which stakeholders submit to.

5 Recommendations and work plan (ToR e)

The following actions were identified by the group to develop a workplan for proposed changes to MIXFISH advice. Some of these steps can be taken in the next months in order to be presented and reviewed at a subsequent workshop (WKMIXFISH3) in March 2024. Some others will take longer, but the expectation is that they can be scoped for discussion at the workshop to identify when and how they can be implemented. Specific recommendations for other ICES working groups are presented at Annex 4.

Short-term goals:

Objective	Timeframe	Comments
Develop a feedback mechanism and communications guidelines to engage with stakeholders on an annual basis	< 1 year	
Develop ways of presenting the trade-offs for over/undershoot of quotas at the fleet level which are currently not clear	< 1 year	To be developed by WGMIXFISH
Include more descriptive information on strength of technical interactions among stocks	1-2 years	Ongoing work as part of WGMIXFISH. Should be included in the fisheries overview.
Provide clear, consistent wording on assumptions in the advice sheet including rationale for the assumptions, including on why certain stocks are/aren't included	< 1 year	Review consistency with assumptions for single stock catch advice
Review of scenarios for each ecoregion including identification of any additional scenarios that could be helpful (and understanding this didn't need to be each year, as many of the challenges were the same each year)	< 1 year	Consider how best to incorporate. In "main" scenarios, or as supplementary?
Continued development of validation of models, hindcasting methods and uncertainty/sensitivity analysis (as currently planned by the group which will also help address the UK/EU Specialised committee on Fisheries questions)	1-2 years	Initial work should be available by WGMIXFISH Methods in June. Likely to be ongoing task.

Short/medium-term goals:

Objective	Timeframe	Comments
More descriptive information including working with ICES WGSFD to make available supplemental data on catch composition at high spatial resolution	2-3 years	Potential data and confidentiality limitations. Lower resolution data (i.e. by ICES rectangle) is more immediately available through STECF** for EU countries and the UK to 2020. RDBES* may be able to support this going forwards for all countries.
More information on fleets and métier contributing most to fishing mortality of the stocks, and their spatial patterns	1-2 years	Make use of developing RDBES* database

Objective	Timeframe	Comments
Reviewing the fleet and métier structure for each ecoregion to ensure credibility to stakeholders (and considering what role stakeholder could have in this process)	1-2 years	Consider how to review and make information available to stakeholders.
Communication of uncertainty	2-3 years	Consider how best to integrate with current advisory products
Provide tools to present the data (at a suitably aggregated level) so its accessible to stakeholders, e.g. through an app	2-3 years	As part of ICES web tools development.
Continued links with WGECON to improve economic considerations	2-3 years	

Notes: * RDBES = Regional Database & Estimation System; ** STECF = Scientific, Technical and Economic Committee for Fisheries

Medium/long-term goals:

Objective	Timeframe	Comments
Development of approaches that can identify long-term trade-offs and consider rebuilding of depleted stocks from a mixed fisheries perspective	3-5 years	Consider what processes necessary to define and evaluate objectives.

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Annex 1: Terms of Reference

WKMIXFISH2 – Scoping workshop on next generation of mixed fisheries advice 2.

2022/WK/FRSG43 The second **Scoping workshop on next generation of mixed fisheries advice (WKMIXFISH2),** chaired by Paul Dolder*, UK, and Marc Taylor*, Germany, will meet on 1–2 March 2023 in ICES HQ, Copenhagen to:

a) Review the current scenario-based approach for communicating mixed fisheries considerations to establish its utility and usability for informing management decisions.
b) Identify alternative approaches, including the steps necessary to transition to advice, establishing the questions to be answered from managers, including potential operational priorities and objectives to manage mixed fisheries.
c) Review current assumptions on plausible fleet dynamics and behaviour (e.g. quota share, effort distribution, catchability…) and identify ways to improve them given available data and models.
d) Identify key fleet-based information of interest to managers and stakeholders as well as how best to communicate this information clearly and transparently.
e) Develop a workplan for proposed changes to MIXFISH advice to be presented and reviewed at a second workshop (WKMIXFISH3) in March 2024.

WKMIXFISH2 will report by 31 March 2023 to the attention of the ACOM Committee.
The plan is for a two-part workshop, with WKMIXFISH3 to take place in March 2024 to present proposals for changes to MIXFISH advice developed between the two meetings.

Supporting Information

Priority	Mixed fisheries considerations are requested by several ICES clients. While they were first delivered in 2009 for the North Sea, there are still basic gaps on how mixed fisheries considerations are used, what is needed that is not yet provided, validity of assumptions made, and how to communicate them. The activity of this working group will enable ICES to close the existing knowledge gaps and to reshape the advice to fulfil clients' needs and make it more informative. Consequently, these activities are considered to have a high priority.
Scientific justification	ToR [a] There is a lack of knowledge on how mixed fisheries considerations are used by clients to shape fisheries management. An enhanced knowledge of how they are used could facilitate the further development of the approach and the improvement of the communication. ToR [b] Currently the output of mixed fisheries analyses is not an advice per se but a battery of scenarios about consequences of single stock advice. A better understanding of the objectives and priorities in the management of mixed fisheries would facilitate the transition to provision of advice. ToR [c] will allow to advance in the validation of mixed fisheries models implementation and building trust in the output of the modelling approaches used. ToR [d] Mixed fisheries considerations are based in complex model implementations with multiple dimensions. Presenting the output of those models is a challenge and it requires finding the right balance between clarity and utility. In fact, some currently-provided plots have been criticized for being difficult to understand. Identifying the outputs and the format that is useful and informative for the end users will allow the group to present the output adequately and tailored to the user's needs.
Resource requirements	Some support will be required from the ICES Secretariat
Participants	The Group is normally attended by some 15–20 members and guests

Secretariat facilities	SharePoint site provision and Atlantic room; an extra room for breakout groups would be beneficial
Financial	No financial implications.
Linkages to advisory committees	ACOM
Linkages to other committees or groups	WGMIXFISH-Methods and WGMIXFISH-advice
Linkages to other organizations	STECF – Fisheries Dependent Information expert group.

Annex 2: List of participants

Name	Country	Affiliation
Chloe North	UK	Western Fish Producers' Organisation
Chloe Rogers	UK	The Fish Producers' Organisation
Claire Moore	Ireland	Marine Institute
Dale Rodmell	UK	Eastern England Fish Producers Organisation Ltd
Dorleta Garcia	ICES	ICES
Edward Farrell	Ireland	Killybegs Fishermen's Organisation Ltd.
Elena Balestri	UK	Scottish Fishermen's Federation
Elizabeth Bourke	UK	National Federation of Fishermen's Organisations
Ellen Colebrook	UK	DEFRA
Erik Sulanke	Germany	Thünen Institute
Ewen Bell	UK	CEFAS
Geert Meun	Netherlands	VisNed
Georgina Evans	UK	DEFRA
Harriet Cole	UK	Marine Scotland Science
Irene Prieto	Spain	Cooperativa de Armadores de Pesca del Puerto de Vigo
Jane Sandel	UK	The Fish Producers' Organisation
Jasper Bleijenberg	Netherlands	WUR
Javier Lopez	Spain	Oceana
Jenni Grossmann	UK	ClientEarth
Johan Lövgren	Sweden	SLU Department of Aquatic Resources
Joshua Nyarko Boampong	Norway	IMR
Kenny Coull	UK	Scottish White Fish Producers Association Limited
Kyle Payton	UK	Clydefish
Luca Lamoni	ICES	ICES
Luis Francisco Marín	Spain	Organización de Productores de Pesca de Altura de Ondárroa
Marc Taylor	Germany	Thünen Institute
Matthew Pace	UK	CEFAS

Name	Country	Affiliation
Michael Wall Andersen	Denmark	Danish Fishermen
Mike Park	UK	Scottish White Fish Producers Association Limited
Mikel Ortiz	Spain	Organización de Productores de Pesca de Altura de Ondárroa
Mogens Schou	DK	AquaMind
Norman Graham	EC	DGMARE
Paul Dolder	UK	CEFAS
Robert Cook	UK	DEFRA
Robyn Forrest	Canada	DFO
Ruth Kelly	UK	AFBI
Sarah Millar	ICES	ICES
Youen Vermard	France	IFREMER

Annex 3: Mixed fisheries forecast modelling approaches

This document sets out a range of assumptions and model choices that need to be made to produce short-term forecasts when advising on the impact of technical interactions on catches in mixed fisheries.

It is not an exhaustive list but intended to give an understanding of the types of modelling approaches that can be pursued, the assumptions behind each of them and the strength and limitations these confer. There may also be interdependencies so that the choice in one table may alleviate problems associated with a different model aspect found in another table.

Definitions of 'fleets' and 'metiers'

Two basic concepts are of primary importance when dealing with mixed-fisheries, the Fleet (or fleet segment), and the Métier. Their definition has evolved with time, but the most recent official definitions are those from the CEC's Data Collection Framework (DCF, Reg. (EC) No949/2008), which we adopt here:

- A Fleet segment is a group of vessels with the same length class and predominant fishing gear during the year. Vessels may have different fishing activities during the reference period, but might be classified in only one fleet segment.
- A Métier is a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterized by a similar exploitation pattern.

In practice, the starting point for assigning definitions is country, gear group, vessel length for fleets and gear, target assemblage and, area for metiers. Such that, for a simplified example a fleet could consist of 'all Irish boats using otter trawls between 10-24m in length', and the metiers associated with this fleet might be otter trawling with a given mesh size targeting *Nephrops* (e.g. OTB_CRU_70-99) and otter trawling with a given mesh size targeting whitefish (e.g. OTB_CRU_100-119). Boats within a fleet may use multiple different metiers. In some models, boats can be part of multiple fleets (see Fleet, fishery, and métier structure table below).

Table 1. Fleet, fishery, and métiers as a model basis:

Options	Fleet-based	Fishery-based	Fleet and métier based
Description	The operational unit in the model is a "fleet", that is a physical group of vessels with a predominant activity (e.g., Dutch beam trawlers of 24-40m). A vessel belongs to only one fleet.	The operational unit in the model is a "fishery", that is a group of vessels doing a particular activity (e.g., Scottish otter trawlers of 24-40m targeting whitefish in the North Sea). A vessel may take part in several fisheries.	The operational unit is a hierarchy of fleet and fishery so to distinguish between the fleet and its activity in one or more fisheries (métier),
Strengths	Linked to economics of vessels, May directly align with licencing and management systems.	Provides full flexibility for effort in fisheries to adjust to species quotas. Catch compositions linked to definitions of fishery,	Explicit link between physical vessels (fleets) and activity (métier). Allows for modelling effort allocation to different fisheries (currently based on past shares), Inclusion of fleet level allows for economic considerations.
Limitations	No description of the fisheries themselves, Limited to fleet level catches (no fleet behaviour possible), Merges activity in different fisheries, Polyvalent activity is impossible to identity,	No link to the economic unit, No constraints on effort as link to physical vessels not included (unrealistic effort), Definitions of fisheries do not capture all variation in fishing activity (compromise between data availability and classifying fishing activity), Limited data availability (space, time) to define fisheries, Polyvalent activity is impossible to identity, Catches may not match current relative stability shares,	If métier dynamics are not modelled the choke effect is at the fleet level (see Table 3), Definitions of fisheries do not capture all variation in fishing activity (compromise between data availability and classifying fishing activity), Limited data availability (space, time) to define fishing métier,
Examples		Previous model MTAC (rejected by ICES as advisory tool for reasons outlined in ICES, 2006).	Current approaches FCube and FLBEIA

Table 2. Stocks included in the models:

Options	(a) Only those stocks with full age-based assessments and forecast methods or an absolute abundance estimate	(b) Also includes stocks with biomass-dynamics methods	(c) Include TAC stocks, even where no analytical population model available.	(d) Include all stocks, even non-quota.
Description	Only those stocks that have a full category 1 assessment with age-based or size-based population dynamics or an absolute abundance estimate (e.g., Nephrops) are included.	Includes stocks that have biomass-dynamic models for future population dynamics.	Includes TAC stocks with no population model are included on a "constant CPUE" basis.	Includes all stocks caught by the fleets and fisheries are explicitly included on a "constant CPUE basis".
Strengths	Technical interactions modelled reflect changing stock abundance, The conditioning of the model is based on well stabilised robust quantitative stock assessments. Differences in selectivity by fleet/metier can be introduced and evaluations of changes in selectivity can be evaluated.	Same as (a), technical interactions reflect abundance changes, It could improve the description/modelling of fishing activity or fleet dynamics	Encompasses a greater number of potential choke stocks, It could improve the description/modelling of fishing activity or fleet dynamics	Encompasses all the target stocks so may better reflect fishing effort expected, revenue can be modelled better. Can be used to forecast bycatch of sensitive species that are not in the TAC and quota system but are relevant to other management frameworks/directives. It could improve the description/modelling of fishing activity or fleet dynamics.
Limitations	Does not include all stocks caught by fishery, and possibly not all target stocks, May not include the choke stock, the definition of métiers could be wrong because other relevant species are not considered.	Does not include all stocks, May not have a way of projecting future stock size,	Choke effects may be unrealistic due to increases or decreases in abundance, Assumption of constant biomass may only be reasonable for short term projections.	Non-quota stocks cannot choke fisheries, Difficult to communicate, May involve too many stocks to accurately evaluate, Potential missing data on stocks, Assumption of constant biomass may only be reasonable for short term projections.
Examples	Current FCube model for the Celtic Sea,	Long-term scenarios of the North Sea FLBEIA model in external projects (Probyfish, Pandora). Current FLBEIA model for the Iberian Waters (one cat.2 stock ank.27.8c9a)	Current FLBEIA model for the Bay of Biscay, and Nephrops stocks in other regions.	Long-term scenarios of the North Sea and Bay of Biscay FLBEIA models in external projects (Probyfish, Pandora) included some bycatch stock.

Table 3. Modelling fishing patterns and resultant fleet catch compositions:

The options proposed only reflect changes in effort allocations between métiers and their effect on catch composition at fleet level. However, métier definitions are coarse and based on existing data availability (aggregations in space and time). A lot of the possible changes in fishing patterns may occur inside a métier, and this will be evident in variability in past catchability.

Options	(a) Based on past observations	(b) Based on past observations, include uncertainty	(c) Based on fleet dynamic model fitted to past observations	(d) Based on optimisation, but limited to range of past observations	(e) Based on optimisation model (unconstrained)
Description	No adaptation of fleets to quotas,	Provide uncertainty estimates based on (recent) past fishing patterns	Use model to predict how fleets will adapt effort to quotas	Optimisation of effort in métier to maximise catch or revenue given quota constraints constrained to past observed shares of effort.	Optimisation of effort in métier to maximise catch or revenue given quota constraints unconstrained.
Strengths	Identifies choke stocks "if all else the same", Simple and easier to understand,	Reflect historic adaptability in fishing patterns, Can include uncertainty given variability within a métier, Provides upper and lower bounds of expected catch,	Allows for fleet adaptation to be considered in choke effects,	Adaptation to quotas within historic observations, Provides flexibility to maximise uptake of quota given differences among métier	Maximum flexibility,
Limitations	May over or underestimate choke effects based on changing fishing behaviour, Simple process model of 1:1 relationship between effort and F/catch,	More difficult to communicate outputs, May not capture full flexibility of fleets if change outside of past observations,	Lack of available models may require simple assumptions, More complexity in model, Do not have data on all drivers of effort.	Definition of métier can affect outcome, May not capture full flexibility of fleets if change outside of past observations,	May result in unrealistic effort allocations (e.g., all to single fishery) but can be constrained, Definition of métier can define outcome, Remains variability in catchability within métier (how to account for it),
Examples	Current FCube and FLBEIA applications	Presented at WGMIXFISH Methods, 2022.	Simple models could be e.g., effort driven by revenue and historic patterns as in Marchal et al. (2013)	E.g., MaxProfit routine in FLBEIA	E.g., MaxProfit routine in FLBEIA

Table 4. Modelling gear catch-at-age selectivity*:

This refers to gear changes that affect the size or age at capture of the fishing gear, where catches of different species may or may not be differentially affected.

Options	(a) Based on past observations	(b) Based on past observations, include uncertainty in recent past	(c) Based on proposed gear modifications and potential impact
Description	Fixed selectivity for each fleet and métier based on recent past observation,	Fixed selectivity for each fleet and métier based on recent past observation but capturing historic variability,	Gear selectivity for given fleet or métier adjusted based on anticipated changes for a defined gear being introduced,
Strengths	Based on observation as with single stock advice, No evidence or data to deviate from current selection,	Based on observation but captures uncertainty, Allows for greater understanding of impact of variability on predicted catches,	May capture intended benefits of gear change, Ability to evaluate overall effect of gear, Opportunity for different scenarios to be developed,
Limitations	Does not capture potential solutions to choke effects, Data not always available in logbooks (i.e., selectivity device) to define métier level selectivity, so assumptions made at national level	Harder to communicate, Computationally intensive requiring multiple runs, Data not always available in logbooks (i.e., selectivity device) to define métier level selectivity, so assumptions made at national level, Not clear how uncertainty around outputs could be used in ICES advice	Intended benefit of gear changes not always realised (unrealistic?): gear studies do not account for fisher behaviour, a net can be fished very differently from the design, Gear studies are limited in space/time/species they are looking at. Hard to transpose to other areas and all species, Less practical for short-term forecasts, Implications for stock reference points relating to MSY in the long-term, Likely to have limited impact in the short term,
Examples	North Sea FLBEIA model.		Long-term scenarios of the North Sea FLBEIA model in external projects (Probyfish, ECOMAN) and the Celtic Sea (BIM BIOECON project)

* These options are only available to mixed fisheries models that define differing selection patterns by metier, which is currently only the case for the North Sea model. All other case study models have a common selection pattern across all fleets and métiers.

Table 5. Modelling quota-allocations:

Options	(a) Based on recently observed landings share	(b) Based on country specific relative stability shares (pre-swaps)	(c) Based on post-swap shares from historical data	(d) Based on optimising within country allocations
Description	The share of each fleets quota is based on its (recent) past observed catch/landings share.	The share of each fleet's quota is based first on the country relative stability share, then on historic shares within country.	The share of each fleet's quota is based first on the country relative stability share adjusted for observed quota swaps, then on historic shares within country.	The share of each fleet's quota is optimised to maximise quota uptake within country.
Strengths	A proxy for the relative stability shares, recent quota exchanges and recent quota consumption rates	Reflect the real fishing opportunities of the fleets (will likely avoid situations where a country can get choked by a stock even though they have historically underused their fishing opportunities).	Will accurately reflect the recent practices in quota exchange by the various countries to avoid choking effects	Reflect what could be achieved,
Limitations	May not be suitable in case of strong changes in TAC, as countries may decide to change their quota exchange (e.g. to keep quota available if a stock becomes choke), and adjust their quota consumption rate, Do not reflect the under-consumption	Will exaggerate choke effects for countries that are generally able to get extra quota for their potential choke stocks.	Will not be accurate if TAC changes strongly and countries decide to no longer swap quotas for the stocks with concerns, Limited data availability, no access to complete international quota swaps and national distributions.	Probably multiple solutions and trade-offs, Does not reflect current management,
Examples	Current case study implementations	Trial runs using FIDES at WGMIXFISH method 2022	Trial runs using FIDES at WGMIXFISH-METHODS 2022	

Table 6. Scenario assumptions

Options	(a) Based on simple rules for all fleets	(b) Based on bespoke rules for fleets	(c) Based on some weighting for each fleet
Description	All fleets stop fishing when they reach any quota* (min scenario), all quotas* (max scenario) or a defined stock quota*	Fleets stop fishing when they reach their quota for a selected set of stocks for that fleet (min) scenario, or all quotas of those stocks (max scenario),	Fleets fishing effort weighted towards some target (e.g., weighted to value or share of catch of a stock)
Strengths	Easier to explain scenarios, Reflects the landing obligation policy.	May be more realistic, Reduces severe reduction in catches under the 'min' scenario for some fleets, Could be defined with stakeholder input.	Impacts on fleets reduced for fleets that have small catches of limiting stocks,
Limitations	Can result in significant under-quota catches of target stocks for small reductions in non-target catches for fleets where catches are low to start with, 'Min' and 'Max' scenarios do not reflect realistic fishery or management behaviour.	Does not reflect landing obligation policy, Likely to result in catches above the single stock advice for by-catch stocks in the 'min' scenario.	Quotas would need to be managed by fleet else intended outcome not realised, Weighting process would need to be decided by managers,
Examples	Current WGMIXFISH approach		"Value" approach in WGMIXFISH (value weighting) and MTAC approach (share of catch approach)

*Here, 'quota' refers to a fleet's share of the advised catches in the forecast year