

WGMIXFISH best practices

Contents

1	Introduction	1
2	Input Data	1
2.1	Stocks	1
2.2	Catch and effort by metier	2
2.3	Quality checks and diagnostics	2
3	Model conditioning and assumptions	2
3.1	Stocks – forecast settings	3
3.2	Defining fleets and metiers	3
3.2.1	Definition	3
3.2.2	Consistency of total fleet catches with stock assessment	6
3.3	Fleet behaviour	7
3.4	Quality checks and diagnostics	8
4	Scenarios	8
4.1	Baseline scenario (Reproduce the advice)	8
4.2	Mixed fisheries scenarios	8
4.3	Quality checks and diagnostics	9
5	References	10
6	Annex 1	11

1 Introduction

This document provides a methodological framework showing decision-making processes and “best practice” recommendations for the implementation of models for mixed fisheries advice. The particular details relating to an ecoregion are specified in the ecoregion’s Stock Annex.

2 Input Data

2.1 Stocks

The following points are considered for deciding which stocks to include in the models:

- Priority should be given to stocks of commercial importance (i.e. target stocks, managed by TAC). However, bycatch of non-target stocks may also be of interest in a mixed fisheries context.
- Stocks which are not thought to have a high degree of mixed fisheries interactions due to their ecology or fisheries can be excluded (e.g. pelagic stocks).
- Specific pelagic stocks should be considered if they account for a significant proportion of the demersal fleet catches (for example, 50% of demersal fleet catch consists of pelagic species in the Iberian Waters model).
- The number of stocks included in the model also needs to be manageable both computationally and due to the time involved in data processing and model conditioning.

Stock assessment results and the forecast settings used to produce the single stock advice are obtained directly from the stock assessor, advice sheet or WG report. Where relevant, information on the raising procedures for discards and the allocation of age compositions should also be collected. This ensures that the starting point of the mixed fisheries scenarios is the same as for the single stock advice.

Development steps for best practice:

- *STARMIXFISH task 8: A framework for adding stocks identified as having important technical interactions*
- *See Table A1 in Annex 1 for a summary of different options that could be taken.*

2.2 Catch and effort by metier

Data on landings and effort (“fleet data”) by year, country, area, metier, vessel length and in the case of landings, species, are requested through the ICES annual fisheries data call. The fleet data received by WGMIXFISH from the ICES annual fisheries data call is run through a QC procedure to identify and resolve data issue with national data submitters. The consistency between the reporting of metiers between the fleet landings and effort data and the landings data available in InterCatch for each stock is assessed and steps are taken to increase consistency where appropriate. The accessions data is merged with the InterCatch data by transferring the discard rates and age structure from InterCatch to the fleet data on a country-metier-area-quarter basis for each stock. However, in some cases, an exact match to an InterCatch record will not be possible. In these cases an alternative match can be made based on a hierarchy of assumptions (example: drop quarter > mesh > target > gear > area > country > everything (i.e. stock level distributions)). The procedure for merging the fleet and InterCatch data is detailed below. This can be done on an age-aggregated or age-disaggregated basis.

- For each stock:
 - a) Match accessions records to InterCatch metier-level records by: country, metier (gear*target*mesh size), area and quarter.
 - b) If a direct match is not found then assume an average discard rate and/or age structure from InterCatch records matched by: country, metier (gear*target*mesh size), area (i.e. drop quarter).
 - c) Continue matching process using a hierarchy of assumptions (drop mesh > target > gear > area > country).
 - d) Use the stock level discard rate and/or age structure where the hierarchy of assumptions fails to make a match.

Development steps for best practice:

- *Refine and apply fleet data-InterCatch matching procedure across all ecoregions.*

2.3 Quality checks and diagnostics

- Stock assessment results received from the stock assessor are checked against the ICES Standard Assessment Graphs (SAG) or tables from the WG report.
- Each landings record in the fleet data should have corresponding effort record. Instances where this criterion is not met are investigated.
- The merged fleet data are compared to the stock level data received from the stock assessor for: total tonnage, numbers-at-age and sum-of products (SOP, numbers*mean weight-at-age) for landings, discards and total catch.

3 Model conditioning and assumptions

Two models are available for use: Fcube and FLBEIA. The use of FLBEIA allows for an age-disaggregated version as an alternative to using age-aggregated data. Using age-disaggregated catch information at the fleet and métier level allows for differences in selectivity among fleets/métiers. Additionally, FLBEIA offers more flexibility for future changes to methodology. However, in certain circumstances Fcube may be the

more appropriate model to use, for example, when the provided age-disaggregated data are questionable or where the dynamics are driven primarily by discarding (due to the way discards are projected in FLBEIA). Additionally, the Cobb-Douglas catch production model used within FLBEIA is not considered suitable in extreme fishing situations (e.g. 0 TAC advice) (ICES (2021)).

3.1 Stocks – forecast settings

The settings used in the forecasts that produce the single stock advice are replicated for each fish stock in the mixed fisheries models. These settings relate to mean weight-at-age, selectivity, and recruitment, as well as assumptions on the catch in the intermediate year and basis for advice (MSY approach/Management plan etc). This provides the target catches and forecast stock dynamics under which each mixed fisheries scenario will operate. Single stock “reproduce the advice” forecasting (see “Baseline scenario” section) may be done to ensure consistent translation of these settings to the mixed fishery framework. Future recruitment is conditioned in the models by using fixed value inputs set to match those used to produce the single stock advice. Where single stock advice is produced from stochastic forecasting methods (e.g. using the SAM assessment models for cod, haddock, whiting and sole), the median value from the stochastic projections is used for the fixed recruitment value, as reported in the single stock advice sheets. This however can sometimes lead to small differences as the median of the stochastic projections does not exactly match the deterministic forecast from the median of the assessment outputs. Generally, these are within a few percent. Nephrops functional units are conditioned using a fixed dynamics approach meaning that there is no feedback mechanism between the catches taken and the population abundance (i.e. catches in the advice year are not influenced by population changes arising from catches in the intermediate year). Only functional units with an annual abundance estimate derived from UWTV surveys are subject to the fleet effort restriction rules set in the mixed fisheries scenarios.

Development for best practice:

- *Develop methods for category 3/trend-based stocks.*
- *Aim to move to a, preferably age-based, FLBEIA model in all ecoregions.*

3.2 Defining fleets and metiers

3.2.1 Definition

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.

Table A2 in Annex 1 summarises the different options that could be taken to use define the model basis for fisheries, fleets and metiers in the mixed fisheries models. The current approach used in all the mixed fisheries models is the fleet and metier-based approach. Initially, fleets are defined using country, gear group and vessel length. Metiers are defined using combinations of gear, target assemblage, mesh size and area. Currently, there is not a standardized way to define the fleets and metiers and so each ecoregion has developed its own approach by considering the following:

- Matching DCF métiers with definitions used in the cod long-term management plan (e.g. North Sea).
- Consider if separation of fleets over vessel length is necessary.
- Consider combining across gear groupings which have similar catch profiles.
- Consider combining countries which only account for a small proportion of the catch (e.g. Bay of Biscay - countries other than Spain and France are grouped together).

- Combine métiers across ICES divisions which are often combined for sampling, management and advice purposes (e.g. Celtic Sea).
- Consider conducting a clustering analysis (or similar) to characterise the fishery and ascertain if fleets/métiers with similar data/interactions can be merged.
- Consider compatibility with other datasets (e.g. STECF for economic data) or with regulations/technical measures.
- Opinion of fisheries experts for the ecoregion.

The initial fleet definitions often result in a large number of fleets and métiers, many of which will likely only represent very small amounts of the total catch for each stock. Therefore, to reduce the complexity of the model a threshold is defined to combine smaller fleets/métiers into an “other” category (Table 1). It is recommended that a sensitivity analysis is conducted when deciding on a threshold value. As such, different threshold values are used across the ecoregions.

The initial fleet definitions often result in a large number of fleets and métiers, many of which will likely only represent very small amounts of the total catch for each stock. Therefore, to reduce the complexity of the model a threshold is defined to combine smaller fleets/métiers into an “other” category (Table 1). It is recommended that a sensitivity analysis is conducted when deciding on a threshold value. As such, different threshold values are used across the ecoregions.

Table 1: Fleet and métier definitions by ecoregion.

	"OTH" métier/"MIS" métier	"OTH_OTH" fleet/"MIS" fleet
North Sea	Métiers that fail to catch at least 1% of the total landings of any stock, in the data year	Fleets that contain only the "OTH" métier.
Bay of Biscay	Métiers within a fleet that contribute less than 2% to a stock's landings for that fleet, in the last 3 years. ("MIS" métier)	Fleets catching less than 1% of the total catch of all stocks considered, in the last 3 years (country specific "MIS" fleet).
Iberian Waters	Metiers associated with the small, artisanal, multigear are combined under one métier ("MIS"). Métiers within a fleet that contribute less than 2% to a stock's landings for that fleet, in the last 3 years ("MIS" métier).	Fleets catching less than 1% of the total catch of all stocks considered, in the last 3 years (country specific "MIS" fleet).
Irish Sea	Metiers that fail to catch at least 1% of the total landings for any stock ("OTHER").	"OTH_OTH" fleet combines all small fleets and métier with landings < 1% for any stock in the model.

Table 2 summarises all the approaches used to define the fleets for each ecoregion.

Table 2: Fleet and métier definitions by ecoregion.

	Fleets	Metiers	Additional comments
North Sea	<p>Defined by country, gear group and vessel length. Gear groups are static (pots, nets, longlines), otter trawls, demersal seines, beam trawlers, pelagic (purse seine, mid water trawls) and miscellaneous (any other gear types). Following the initial allocation some vessel length categories within a country and gear group are combined together.</p> <p>Where appropriate, some specific gear types are separated out from the initial allocation (e.g. gillnets separated from static).</p> <p>Within a country, smaller fleets are added to the miscellaneous gear grouping based on expert opinion.</p>	<p>Defined using the DCF métiers definitions used in the cod long-term management plan which are based on mesh size (e.g. TR1, TR2).</p> <p>The metiers are also defined by the area the metier is operating in (i.e. 3.a.20, 4, 6.a, 7.d).</p>	<p>Only fleets and metiers operating in the latest data year are considered in the full time series.</p> <p>Metiers with catch but no effort are removed.</p>
Celtic Sea	<p>Defined by country, gear group and vessel length. Gear groups are static (pots, nets, longlines), otter trawls and demersal seines, beam trawlers, pelagic (any gear where the target assemblage is pelagic fish) and miscellaneous (any other gear types).</p> <p>Out of area catches for each stock are put into a stock-specific “OTH” fleet.</p>	<p>Defined by gear type and target assemblage (i.e. DCF metier level 4).</p> <p>Metiers are combined across ICES divisions (7.bc, 7.fg, 7.hjk) since these are often combined for sampling, management and advice purposes.</p>	<p>Métiers with effort and no catch are aggregated to the “OTH” fleet.</p>
Bay of Biscay	<p>Defined by country, gear group and vessel length. Countries other than Spain and France are grouped together. Gear groups are gillnets, trammelnets, otter trawls, longlines, seines, midwater trawls and miscellaneous (any other gear types).</p> <p>Following the initial allocation some vessel length categories within a country and gear group are combined together. Additionally, some gear groups within a country are also combined together.</p> <p>Within a country, smaller fleets are added to the miscellaneous gear grouping (country specific MIS fleet).</p> <p>Out of area catches for each stock are put into a stock-specific “OTH” fleet.</p>	<p>Initially defined by gear type, target assemblage and mesh size.</p> <p>Some metiers with similar catch profiles are combined together.</p> <p>Smaller metiers with low shares of the catches are combined under one metier in the country-specific MIS fleet. Metiers are combined across ICES divisions 8.abd.</p>	<p>Métiers with catch but no effort are added to the country-specific MIS fleet.</p> <p>Métiers with effort and no catch are removed.</p> <p>Specific purse seine and artisanal fleets are removed from the analysis.</p>

Table 2: Fleet and métier definitions by ecoregion. (*continued*)

	Fleets	Metiers	Additional comments
Iberian Waters	<p>Defined mostly by country and gear group with occasional use of vessel length. Countries other than Spain and Portugal are grouped together. Gear groups are gillnets, trammelnets, otter trawls, longlines, pair trawls and miscellaneous (any other gear types).</p> <p>Within a country, smaller fleets are added to the miscellaneous gear grouping (country specific MIS fleet).</p> <p>Out of area catches for each stock are put into a stock-specific “OTH” fleet.</p>	<p>Initially defined by target assemblage and mesh size. Some metiers within a fleet (same country and gear) are combined across mesh sizes.</p> <p>Metiers associated with the small, artisanal, multigear are combined under one metier (“MIS”).</p> <p>A mixed category of catches without corresponding effort (including French fleets with catches < 1%) are combined into one metier (“OTH”).</p>	
Irish Sea	<p>Defined mostly by country and gear group. All vessel length categories are grouped together. Gear groups are otter trawls, demersal seines, beam trawlers, pelagic (midwater trawls targeting pelagic fish) and miscellaneous (any other gear types). Otter trawls fleets are further separated by target assemblage.</p>	<p>Defined by gear type and target assemblage (i.e. DCF metier level 4).</p> <p>Some similar gear types with the same target assemblage are combined together (e.g. OTB/OTM_DEF and PTM/OTM_SPF).</p>	

Development for best practice:

- *Each ecoregion should aim to produce a list of final fleet definitions which provides enough relevant detail within the smallest number of fleets (annually reported in WGMIXFISH-ADVICE report).*
- *Consider implementing a consistent approach for catch-no-effort and effort-no-catch records in the fleet data.*
- *Implement a consistent approach for small fleets and metiers across all ecoregions including naming convention. Consider conducting a sensitivity analysis for defining the threshold.*
- *More long term, develop a procedure for finding the optimal level aggregation of fleet/metier definitions (see Moore et al. (2019)).*

3.2.2 Consistency of total fleet catches with stock assessment

Often there are “missing” catches within an ecoregion which need to be accounted for to ensure that the total removals used as input to the mixed fisheries model is the same as the single stock assessments. Sometimes, these “missing” catches result either where fleet data that has not been submitted or is incomplete (e.g. missing specific fleet segments). Other times these “missing” catches become evident when a stock is widely distributed and a significant portion of a stock’s catch occurs outside of the ecoregion (e.g. hake in Bay of Biscay). The magnitude of the missing catches per stock is obtained by comparing the total catches from the fleet data

to the total catches from the stock assessment. The approach taken to account for differences in the total catches is to allocate these catches to a pseudo fleet (details given in Table 3).

Table 3: Accounting for missing catches in the fleet data.

	Missing fleet data	Out of area catches
North Sea	Specific fleet segments (<15 m) not submitted by Norway. Added to OTH_OTH fleet.	
Celtic Sea		Put in a stock-specific “OTH” fleet (pseudo fleet).
Bay of Biscay	Pelagic fleet data not available. Missing pelagic catches are added to a stock-specific “OTH” fleet (pseudo fleet).	Put in a stock-specific “OTH” fleet (pseudo fleet).
Iberian Waters		Put in a stock-specific “OTH” fleet (pseudo fleet).
Irish Sea		

Development for best practice:

- Implement consistent approach for “missing” catches (e.g. out of area catches) across all ecoregions.
- Scaling down procedure (implement use of estimated values in stock objects and develop a (scaling) procedure to unifying estimated values with observed values (e.g. Intercatch/Accessions data) used in conditioning fleets.)

3.3 Fleet behaviour

Fleet behaviour in the mixed fisheries model is assumed to be similar to the recent past (last 3 years except for North Sea which is the last data year) as observed in the fleet data.

Fleet behaviour encompasses:

- Effort allocation per metier within a fleet.
- Catchability (catch efficiency) per metier and species.
- Gear selectivity per metier and species (age-based models only)
- Quota share per fleet (typically based on historic landings share)

Different modelling approaches for each of these parameters are described in Tables A3-A5 in Annex 1 which could be explored in future.

The TAC used for the intermediate year and advice year are taken from the last single species advice issued for each stock. The TACs are shared between the fleets using the assumption made on the quota share per fleet. TACs for *Nephrops norvegicus* sometimes need to be split between ecoregions (e.g. Celtic and Irish Sea ecoregion, using average proportions of landings since 2000) and between Functional Units (using the most recent data year’s proportions of landings).

Development for best practice:

- Implement consistency in the time period used to calculate average fleet behaviour parameters. Consider using a shorter time period when strong trends exist in the historic data and develop procedure if necessary.
- Explore different options for quota share per fleet (e.g. use of post quota swaps instead of landings shares).

- Define maximum fleet effort (e.g. multiple of status quo) as an upper limit in scenarios.
- Explore quota share grouping setting in FLBEIA for Nephrops FU.
- Assess sensitivity of projections to fleet and metier definitions (STARMIXFISH)
- Assess sensitivity of projections to uncertainties in input parameters (catchability, effort share among a fleet’s metiers, quota share among fleets, selectivity) (STARMIXFISH)
- Develop hindcasting methods to assess predictive capacity and uncertainty/sensitivity analysis
- Consider adding runs of many stock-specific scenarios as a diagnostic to help reveal issues (through unrealistic results) in the model setup.

3.4 Quality checks and diagnostics

- Compare total catches/catches-at-age for each stock from the fleets to the stock assessment.
- Compare total F-at-age for each stock from the fleets to the stock assessment.
- Check that the “OTH”/”MIS” fleets account for a small percentage of total catches.
- Plot trends in catches by stock for each fleet/metier.
- Check for strong trends in catchability/catchability-at-age and effort (total and effort share).
- Plot fleet-level forecast values used in the context of the data time series.
- Compare stock-level forecast values against single stock advice values.

4 Scenarios

4.1 Baseline scenario (Reproduce the advice)

The baseline scenario reproduces the single stock advice within the mixed fisheries models. This acts as a quality check on the model conditioning in addition to providing a reference baseline for the mixed fisheries scenarios. This scenario is conducted in two ways. The first is designed to quantify the differences in catch advice arising from using a different forecasting method to that used to produce the single stock advice. These differences are expected to be larger when dealing with stocks that have sex- or season-separated and/or multi-fleet assessments and forecasts. Furthermore, reproduce the advice forecasts are currently deterministic, which will differ from stochastic assessment model forecasts. The second type of reproduce the advice tests the ability of the mixed fisheries (i.e. fleet based) model framework to reproduce the advice.

Development for best practice:

- Implement the second method (RTA in mixed fisheries model) in all ecoregions (done by BoB, IW, and NS).

4.2 Mixed fisheries scenarios

The mixed fisheries scenarios start with projecting the intermediate year. The same intermediate assumption of status quo effort (average effort per fleet for the last 3 years, except for North Sea where it is equal to effort in the last data year) is used in all the mixed fisheries scenarios. However, for pseudo fleets catching only pelagic stocks, it may be more appropriate to follow the intermediate year assumptions made by the relevant assessment working group.

For the advice year, each mixed fisheries scenario applies a different rule on when a fleet ceases all fishing activity (see Table 4). This restriction is dependent on each fleet’s share of the fishing opportunities for each stock (“stock share”). The rules applied in each scenario are described in the table below. The scenario rules are not applied to any pseudo fleets (pseudo fleets are included in the model to account for either pelagic fleet catches or catches taken outside of the ecoregion area). It is assumed that the pseudo fleets fill their quota share regardless of the scenario rule applied to the true fleets. Possible alternative scenario modelling approaches are detailed in Table A6 in Annex 1.

Table 4: Scenario descriptions

Scenario	Description	Aim
Maximum (“max”)	For each fleet, fishing in the advice year stops when all stock shares of that fleet have been caught.	This scenario highlights the least restrictive stocks and results in overshoot of the advised catch for most stocks.
Minimum (“min”)	For each fleet, fishing in the advice year stops when the first stock share of that fleet has been caught.	This scenario is the most precautionary option and can highlight some potential “choke species” issues. This option results in the underutilization of the single-stock advice possibilities of most stocks.
Status quo effort (“Sq_E”)	The effort of each fleet in the advice year is set equal to the effort in the most recent historical period (average of last 3 years) for which landings and discard data are available.	This scenario indicates the likely level of catch if there is no change to the fishing effort exerted by each fleet.
Single stock (“stock”)	The effort of each fleet in the advice year corresponds to the effort needed to take their stock share of the specified “stock”, regardless of other catches. If a fleet does not have any fishing opportunities for the specified stock then status quo effort is used.	This scenario indicates the likely level of catch for other stocks if the single stock advice for the stock of interest is fully taken.
Pretty good yield (“pgy”)	The scenario is similar to that of the “min”, but uses the Fmsyupper associated advice. Fmsyupper is not defined for all stocks, and is only presented as a catch option when the stock is shown to be in good status; i.e. when $SSB > B_{trigger}$.	The higher catch advice associated with the upper range of Fmsy reference points may reduce choking behaviour in mixed fisheries and increase overall quota uptake.

Development for best practice:

- *Refine and implement a Range/Min scenario across all ecoregions.*
- *Implement a consistent approach to the effort assumption for fleets that do not have any fishing opportunities for the stock specified in the single stock focussed scenario.*
- *Define a best practice approach for deciding on which single-stock-focussed scenarios should be included in the advice sheet.*
- *Define a process for running other scenarios of interest (e.g. Feco, intermediate scenarios for zero-advice/vulnerable stocks)*

4.3 Quality checks and diagnostics

- Baseline scenario: compare intermediate and advice year results: SSB, F, catch, landings, discards. Investigate discrepancies. Target tolerance is 5%, but within 10% is acceptable if there is a clear explanation for the discrepancy.
- Mixed fisheries scenarios: compare intermediate year results: SSB, F, catch, landings, discards to single stock advice values.
- Mixed fisheries scenarios: compare intermediate year assumed catches to actual catches (retrospective comparison).

5 References

- ICES. 2021. “Inter-Benchmark Process to Evaluate a Change in Operating Model for Mixed Fishery Considerations in the Celtic Sea and North Sea (IBPMIXFISH).” *ICES Scientific Reports* 3 (101). <https://doi.org/10.17895/ICES.PUB.5957>.
- Moore, Claire, Sarah Davie, Marianne Robert, Lionel Pawlowski, Paul Dolder, and Colm Lordan. 2019. “Defining Métier for the Celtic Sea Mixed Fisheries: A Multiannual International Study of Typology.” *Fisheries Research* 219 (November): 105310. <https://doi.org/10.1016/j.fishres.2019.105310>.

6 Annex 1

Table A1: 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.

Table A1: Stocks included in the models: *(continued)*

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.
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 A2: 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 A3: Modelling fishing patterns (effort allocation per metier, catchability per metier and species) and resultant fleet catch compositions:

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,	Provides upper and lower bounds of expected catch, Allows for fleet adaptation to be considered in choke effects,	Adaptation to quotas within historic observations,	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,	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 define outcome, Remains variability in catchability within métier, May not capture full flexibility of fleets,	May result in unrealistic effort allocations (e.g., all to single fishery), Definition of métier can define outcome, Remains variability in catchability within métier (how to account for it),
Examples	Current FCube and FLBEIA applications for all ecoregions		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 A4: Modelling gear selectivity: only available in age disaggregated

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), so assumptions made at national level	Greater data requirements, Harder to communicate, Computationally intensive requiring multiple runs, Data not always available in logbooks (i.e. selectivity device), so assumptions made at national level Only informs uncertainty around outputs that is not use in ICES advice	Intended benefit of gear changes not always realised (unrealistic?), Less practical for short-term forecasts, Implications for stock reference points relating to MSY in the long-term, Gear studies do not account for fisher behaviour, a net can be fished very differently from the design Modelled via changes in metier catchability but catchability accounts for gear selectivity and availability of the stocks so the changes might not capture what's happening in reality.
Examples	North Sea FLBEIA model.		Long-term scenarios of the North Sea FLBEIA model in external projects (Probyfish, ECOMAN)

Table A5: Modelling quota-allocations:

Options	(a) Based on recently observed landings share	(b) Based on country specific relative stability shares	(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 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	Reflects at the same time the relative stability shares, the recent quota exchanges and the 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,	Will exaggerate choke effects for countries that are generally able to get extra quota for their potential choke stocks. Would require a lot of assumptions	Will not be accurate if TAC changes strongly and countries decide to no longer swap quotas for the stocks with concerns, Data availability, no access to complete international quota swaps and national distributions.	Probably multiple solutions and trade-offs, Does not reflect current management, No available data source
Examples	Current FLBEIA and FCube implementations for all ecoregions	Trial runs using FIDES at WGMIXFISH-METHODS 2022	Trial runs using FIDES at WGMIXFISH-METHODS 2022	

Table A6: 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
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),	All fleets stop fishing when they reach any quota (min scenario), all quotas (max scenario) or a defined stock quota,
Strengths	Simple to understand scenarios, Reflects the landing obligation policy,	May be more realistic, Reduces severe reduction in catches under the ‘min’ scenario for some fleets with small catches, 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,	Does not reflect landing obligation policy, Results in catches above the single stock advice,	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		MTAC approach