WORKING GROUP ON MIXED FISHERIES ADVICE METHODOLOGY (WGMIXFISH-METHODS)

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i Executive summary

The ICES Working Group on Mixed Fisheries Methodology (WGMIXFISH-METHODS) met to progress work on the improvement and development of the mixed fisheries considerations.

The work addressed in 2024 included improving workflows for the advice process, presenting methodological advances, developing new ecoregions and responding to issues encountered during WGMIXFISH-ADVICE 2023. The group reviewed the annual data call and processing procedures and continued the development of the WGMIXFISH Methodological Framework document to better define best practices to be used across case studies.

In 2024, WGMIXFISH members contributed to several workshops and projects relating to methodological developments, which included the Third scoping workshop on next generation of mixed fisheries advice (WKMIXFISH3), the Workshop on mixed fisheries fleets (WKMIXFLEET), and a Special Request (EU/UK joint request regarding mixed fisheries science). The outcomes of these meetings were summarised and further discussed in terms of potential methodological changes that may be adopted over various time frames. Furthermore, the group discussed strategies for improving communication of mixed fishery advice (e.g. via online interactive app, increased integration in Fisheries Overviews) and integration with other working groups (WGECON) through common criteria for fleet definitions as facilitated by new data sources (e.g. RDBES).

Several mixed fishery applications were presented from other work and projects, with potential applications for WGMIXFISH discussed. These included work on bioeconomic modelling, use of continuous-time catch production, sensitivity of mixed fishery forecasts to residual fleet definitions and settings, and potential strategies for reducing fleet choking behaviour by "weak", or less significant, stock interactions. A summary of a recent workshop on methods to incorporate environmental factors in management strategy evaluations (WKECOMSE) provided guidance for longer-term forecast scenarios.

Finally, each case study addressed outcomes and issues encountered during the previous year in preparation for WGMIXFISH-ADVICE 2024.

Keywords: mixed fisheries, fishing fleets, fleet definition, harvest control rule

ii Expert group information

Expert group name	Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS)
Expert group cycle	Annual
Year cycle started	2024
Reporting year in cycle	1/1
Chairs	Harriet Cole, UK
	Marc Taylor, Germany
Meeting venue(s) and dates	17–21 June 2024, Edinburgh, UK (26, hybrid)

1 Introduction

WGMIXFISH-METHODS - Working Group on Mixed Fisheries Advice Methodology

2023/AT/FRSG17 The **Working Group on Mixed Fisheries Advice Methodology** (WGMIXFISH-METHODS), chaired by Marc Taylor, Germany, and Harriet Cole, UK, will meet in Edinburgh, UK, 17–21 June 2024 to:

a) Continue the improvement of WGMIXFISH-ADVICE data call, data processing, methodological framework, workflow, auditing, updating associated documentation and increasing transparency;
b) Respond to the outcomes of the Mixed Fisheries Scoping Meeting;
c) Exploration of developments in methodology and advice;
d) Respond to the outcomes and issues encountered during WGMIXFISH-ADVICE;
e) Develop mixed fisheries models for sea regions not currently covered in the mixed fisheries advice.

WGMIXFISH-METHODS will report by 29 July 2024 for the attention of ACOM.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group.

Supporting information

Priority:	The work is essential to ICES to progress in the development of its capacity to provide advice on multispecies fisheries. Such advice is necessary to fulfil the requirements stipulated in the MoUs between ICES and its client commissions.
Scientific justification and relation to action plan:	The issue of providing advice for mixed fisheries remains an important one for ICES. The Aframe project, which started on 1 April 2007 and finished on 31 March 2009 developed further methodologies for mixed fisheries forecasts. The work under this project included the development and testing of the FCube approach to modelling and forecasts. In 2008, SGMIXMAN produced an outline of a possible advisory format that included mixed fisheries forecasts. Subsequently, WKMIXFISH was tasked with investigating the application of this to North Sea advice for 2010. AGMIXNS further developed the approach when it met in November 2009 and produced a draft template for mixed fisheries advice. WGMIXFISH has continued this work since 2010.
Resource requirements:	No specific resource requirements, beyond the need for members to prepare for and participate in the meeting.
Participants:	Experts with qualifications regarding mixed fisheries aspects, fisheries management and modelling based on limited and uncertain data.

Secretariat facilities:	Meeting facilities, production of report.
Financial:	None
Linkages to advisory committee:	ACOM
Linkages to other committees or groups:	SCICOM through the WGMG. Strong link to STECF.
Linkages to other organizations:	This work serves as a mechanism in fulfilment of the MoU with EC and fisheries commissions. It is also linked with STECF work on mixed fisheries.

2 ToR A: Continue the improvement of WGMIXFISH-ADVICE data call, data processing, methodological framework, workflow, auditing, updating associated documentation and increasing transparency

2.1 Data call update/QC reports

Landing and effort data were submitted through the 2024 data call for WGMIXFISH for the North Sea, Bay of Biscay, Iberian Waters, Celtic Sea and Irish Sea. Data were received from nearly all countries expected except for Spain. A submission from Spain will potentially be received before the Advice meeting in October. Several new métiers appeared for the first time in the data for 2023. In particular, Portugal provided more métiers due to a further disaggregation of mesh sizes.

Table 2.1: Number of new métiers appearing in the 2024 data call by country.

Country	2022	2023
DE		1
DK	1	2
IE		2
NL		5
NO		5
PT		1

The submissions received were processed within the 2024_wgmixfish_accessions repository on GitHub. Here, simple fixes such as formatting column names, standardizing area codes, or fixing quarter entries, were made to the raw data across the whole time series. Ireland, Denmark and Norway resubmitted data for the whole time series, while England resubmitted data from 2020 onwards. Finally, quality checks were performed using two different QC reports (by country and ecoregion). Nevertheless, as some of the InterCatch data was still missing at the time of the METHODS meeting, a thorough check could not be performed.

2.2 Methodological framework for best practice

For the past three years WGMIXFISH has been working to produce a methodological framework outlining the key decision-making steps, methodological choices and development requirements for best practice for the models used to produce mixed fisheries advice. At this year's meeting this document was finalised for publication. The document covers the choice of stocks, data processing steps, model conditioning and assumptions, fleet and metier definitions by case study region, scenario descriptions and a list of key quality control checks and diagnostics. In addition, a framework for developing mixed fisheries models in new regions is detailed along with a list of useful tools that have been developed to aid model testing.

2.3 WKECOMSE & SEAwise update

The talk outlined recent methodological extensions to the North Sea FLBEIA model to consider climate change effects on recruitment and growth as well as biotic interactions between the main gadoid stocks. This work was undertaken under the EU-Horizon 2020 project "SEAwise" and set into the context of MSE-simulations in the recently held workshop WKecoMSE. The goal was to show the context in which the demersal mixed-fisheries model of the North Sea is used besides the WGMIXFISH working group with the focus on long-term simulations, productivity changes due to climate change and methodological extensions needed in order to meet those requirements.

Environmentally-mediated stock recruitment relationships (EMSRRs)

Building on work already presented during the WGMIXFISH-METHODS meeting 2022 (ICES, 2022), we updated the implementation (EMSRRs) to automatically build a generic predict function for the use in FLBEIA, that takes into account the name of the fitted env. covariates, the specific EMSRR-model structure & covariate object to allow for easier integration of EMSRRs for multiple stocks at once.

(Environmentally-driven) growth for age-based stocks

So far, growth is not considered in the age-based stock dynamics of FLBEIA, but weight-at-age is assumed to stay constant over the simulation period or resampled from the historical records. To consider changes in weight at age due to growth, we fitted various types of growth models (Length-at-age or generalised linear-mixed models (glmms)) to the weight-at-age data of the stock objects. North Sea haddock (had.27.46a.20) was presented as an example as the fitted growth relationship was both density- and temperature-dependent. For inclusion of a given growth-model into FLBEIA, on needs to build a predict-function to generate weight at age of the current year, given last year's weights and additional covariates (e.g. SSB and/or temperature). Then the predict-function needs to be integrated into the age-structured-population-growth (ASPG) function of FLBEIA. Since changes in weight-at-age likely affect natural mortality (m) and catchability of the fleets, we considered updating those as well via linear/smooth-spline interpolation of the historical records at age (last 5 historical years). The updating of m can also be considered in the ASPG-function, whereas the update of catchabilities needs to be done in the Fleets Operating Model (Fleets-OM), specifically in the SMFB-function, which simulates the simple-mixed fisheries behaviour in FLBEIA. Landings and discard weights for each fleet are updated based on the changed stock weights via a multiplier, reflecting the change in weight from one year to the other (ratio of this year's weight over last year's weight). Additional covariates (e.g. a temperature influence on growth) needed for the growth-model can be included in the respective covars-object passed to the FLBEIA function.

Species-interactions and dynamic natural mortality

FLBEIA is a framework with the focus on simulating mixed-fisheries with the focus on technical interactions, rather than species-interactions. Therefore, we extended the model to consider dynamic changes in natural mortality utilising the output of a multi-species model for the North Sea (SMS), where species-interactions are explicitly integrated. A way to do this is by creating a mapping of predator and prey numbers to the predation-related natural mortality (partial m2) originating from SMS effectively representing an integration of a specific feeding response-type in FLBEIA. The technical integration was done again in the age-structured-population-growth (ASPG) function within FLBEIA. Several different functional forms were tested (a simplified log-log mapping of predator-prey-numbers to partial m2, Holling-type II, Holling-type III) in a simplified 4-stock-1-fleet model to see effects on stability/model behaviour with implications on stock equilibria and choking effects.

Changes in reference points due to climate change

When simulating long-term scenarios under climate change, changes in stock-productivity might occur, which eventually lead to changes in reference points for sustainable harvesting. A way to consider those aspects would be to run single-species MSEs for stocks with an explicit climate influence and recalculate reference points for different time-horizons in the future, which are then passed to the respective multi-fleet, multi-stock simulation. The way we envisioned this, was to take the average level of the environmental covariate at different time windows (e.g. 2030s, 2040s, 2050s) and shift the detrended environmental covariate to this level for simulating the stock-response under different fishing mortalities in equilibrium. As this is still work in progress, only some examples on how reference points might change for some stocks in the future were given with the focus on highlighting their potential to inform the multi-stock, multi-fleet simulations.

2.4 Advice plan

As per last year, an advice plan was drafted during WGMIXFISH-METHODS. This plan sets out the stocks to be included, support materials and accounts for all information learned from the single species advice production process such as the availability of stock information and benchmarking processes. The key responsibilities per advice region have been identified and allocated members of the group. This has been revised compared to last year due to a change in the request for advice received by ICES.

An online meeting has been scheduled (early September 2024) ahead of the WGMIXFISH-ADVICE 2024 meeting to provide an opportunity to discuss any data and model conditioning issues encountered and share developments on any intersessional work relevant to the outputs of the Advice meeting.

This year, the Advice meeting will be held in two parts. The first part (30 Sept – 4 Oct 2024) will be a hybrid meeting and form the bulk of the work needed to produce the advice. The second part (14–15 Oct 2024) will be held online and will be used to address any outstanding issues from the Advice meeting such as changes to the *Nephrops* advice following ADGNEPH (7–11 October 2024) and corrections to any single stock assessment errors found by WGMIXFISH.

Baltic Sea

Advice 2024	No	Summary plots for Fisheries Overview to be provided
TAF repo	Yes	https://github.com/ices-taf/2024_BS_MixedFisheriesAdvice
Stock Annex	No	In development
Subgroup leader	Kristiina Hommik, kristiina.hommik@ut.ee	
Advice Meeting Participants	Kristiina Hommik, kristiina.hommik@ut.ee	

Bay of Biscay

Advice 2024	**Yes**	**ank.27.78abd, bss.27.8ab, hke.27.3a46-8abd, hom.27.2a4a5b6a7a-ce-k8, mac.27.nea, meg.27.7b-k8abd, mon.27.78abd, nep.fu.2324, pol.27.89a, sdv.27.nea, sol.27.8ab, whb.27.1-91214, whg.27.89a**
TAF repo	Yes	https://github.com/ices-taf/2024_BoB_MixedFisheriesAdvice
Stock Annex	Yes	Stock Annex: Bay of Biscay Mixed Fisheries Annex (figshare.com)
Subgroup leader	Sonia Sanchez, ssanchez@azti.es	
Advice Meeting Participants	Sonia Sanchez, ssanchez@azti.es Dorleta García, dgarcia@azti.es Youen Vermard, youen.vermard@ifremer.fr Miren Alturna, maltuna@azti.es	

Celtic Sea

Advice 2024	**Yes**	**ank.27.78abd, cod.27.7e-k, had.27.b-k, whg.27.7b-ce-k, sol.27.7e, sol.27.7fg, nep.FU.16, nep.FU.17, nep.FU.19, nep.FU.20-21, nep.FU.22, nep.FU.27.7 outside FUs, hke.27.3a46-8abd, meg.27.7b-k8abd ,mon.27.78abd,**
TAF repo	Yes	https://github.com/ices-taf/2024_CS_MixedFisheriesAdvice
Stock Annex	Yes	mix.cs_SA.pdf (ices.dk)
Subgroup leader	Paul Dolder, paul.dolder@cefas.gov.uk	
Advice Meeting Participants	Claire Moore, claire.moore@marine.ie Lionel Pawlowski, Lionel.Pawlowski@ifremer.fr Paul Dolder, paul.dolder@cefas.gov.uk Johnathan Ball, johnathan.ball@cefas.gov.uk	

	Matthew Pace, matthew.pace@cefas.gov.uk Marta Ferraro, Marta.Ferraro@Marine.ie

Iberian Waters

Advice 2024	**Yes**	**ank.27.8c9a, mon.27.8c9a, ldb.27.8c9a, meg.27.8c9a, hke.27.8c9a**
TAF repo	Yes	https://github.com/ices-taf/2024_IW_MixedFisheriesAdvice
Stock Annex	Yes	Stock Annex: Iberian Waters Mixed Fisheries Annex (figshare.com)
Subgroup leader	Hugo Mendes hmendes@ipma.pt	
Advice Meeting Participants	Hugo Mendes, hmendes@ipma.pt Margarita Rincón Hidalgo, margarita.rincon@csic.es Santiago Cervino, santiago.cervino@ieo.csic.es	

Irish Sea

Advice 2024	**Yes**	**cod.27.7.a, had.27.7.a, whg.27.7.a, ple.27.7a, sol.27.7a, NEP.FU.15, NEP.FU.14**
TAF repo	Yes	https://github.com/ices-taf/2024_IrS_MixedFisheriesAdvice
Stock Annex	Yes	Irish Sea Mixed Fisheries Annex (figshare.com)
Subgroup leader	Ruth Kelly, ruth.kelly@afbini.gov.uk	
Advice Meeting Participants	Ruth Kelly ruth.kelly@afbini.gov.uk Gianfranco Anastasi gianfranco.anastasi@cefas.gov.uk	

North Sea

Advice 2024	**Yes**	**bll.27.3a47de, cod.27.46a7d20, had.27.46a20, ple.27.7d, ple.27.4, pok.27.3a46, sol.27.4, sol.27.7d, tur.27.4, whg.47d, wit.27.3a47d, NEP.FU. 5, NEP.FU. 6, NEP.FU. 7, NEP.FU. 8, NEP.FU. 9, NEP.FU. 10, NEP.FU. 32, NEP.FU. 33, NEP.FU. 34, NEP.FU. 4, outside FUs**
TAF repo	Yes	https://github.com/ices-taf/2024_NrS_MixedFisheriesAdvice
Stock Annex	Yes	North Sea Mixed Fisheries Annex (ices.dk)
Subgroup leader	Thomas Brunel, thomas.brunel@wur.nl	
Advice Meeting Participants	Alessandro Orio, alessandro.orio@slu.se Harriet Cole, harriet.cole@gov.scot Klaas Sys, klaas.sys@ilvo.vlaanderen.be Marc Taylor, marc.taylor@thuenen.de Thomas Brunel, thomas.brunel@wur.nl	

Marieke Desender, marieke.desender@cefas.gov.uk

Jasper Bleijenberg, jasper.bleijenberg@wur.nl

2.5 Reference list

ICES. 2022. Working Group on Mixed Fisheries Methodology (WGMIXFISH-METHODS). ICES Scientific Reports. Report. https://doi.org/10.17895/ices.pub.20401389.v1

3 ToR B: Respond to the outcomes of the Mixed Fisheries Scoping Meeting;

3.1 WKMIXFISH3 summary

A third scoping workshop on the next generation of mixed fisheries advice (WKMIXFISH3) was held in Copenhagen on 14 March 2024 (ICES, 2024c). The workshop was primarily an opportunity to discuss - alongside managers and stakeholders - the outcomes from the analyses undertaken in the past year to address an EU/UK request on mixed fisheries science. There was also a discussion on the workshop that took place in the preceding two days on fleet definitions in mixed fisheries models (WKMIXFLEET; ICES, 2024d).

Feedback to working group members on the outcomes of WKMIXFISH3 highlighted the clear support from managers and stakeholders on the work of the group. In particular, stakeholders valued that their input had led to improvements in clarity of the advice, the opportunity to contribute to definition of fleets and métiers in mixed fisheries models and the design and advancement of visualisation tools which are able to provide an interactive way to interrogate data and model outputs at a scale relevant to different end users.

There was discussion of the evolution of the types of mixed fisheries advice requests by managers (from catch based options, to more descriptive analyses) and that the group was entering a period where there was an opportunity to develop new approaches and ideas. With that in mind, two proposals were discussed, i) to have a dedicated session to discuss future ideas to progress (summarised in Section 3.2), ii) to develop a manuscript summarising all the developments in the field and identifying features that need to be developed for the next generation of advice. These proposals would be developed in the coming months

3.2 Incorporation of developmental work into mixed fisheries methodology and advice

Over the last few years, a large volume of method development has been undertaken by WGMIXFISH members. This work has primarily been conducted through the CINEA STARMIXFISH project (EU, 2024), the ICES technical service on Mixed Fisheries Science (ICES 2024a, b and the WKMIXFISH series running from 2020 to 2023 (ICES 2021, 2023b, 2024c) and the related WKMIXFLEET workshop (ICES 2024d). During WGMIXFISH-METHODS 2024 a discussion was held to identify ways to integrate these developments and findings into the current workflow and to indicate the timescales involved.

Sensitivity to fleet and metier definitions

The sensitivity of scenario results to fleet and metier definitions was raised as a concern at WKMIXFISH from stakeholders and advice requestors. As a result, it was a specific term of reference for the STARMIXFISH project and the ICES technical service where the sensitivity of scenario outcomes to fleet and metier definitions was assessed. The summary of these analyses was that scenario results are fairly insensitive to alternative fleet and metier definitions given the current source of fleet and metier data. This finding could be added as a sentence to the advice sheets to provide this information to advice requestors.

However, given the availability of new data sources, such as the recently launched RDBES, this finding could change. The RDBES data on effort and landings provides additional variables opening up new avenues for defining fleets as explored at WKMIXFLEET (ICES 2024d, see section 3.5). This developmental work will continue over the next few years with the aim of following a participatory modelling approach with stakeholders and advice requestors to raise stakeholder confidence in mixed fisheries science.

Uncertainty in, and sensitivity to input parameters

Both the STARMIXFISH and ICES technical service investigated the effect of parameter uncertainty on model scenario results as well as the sensitivity of the scenario results to input parameters (e.g. catchability, quota share, metier effort share). The results of this assessment would be too voluminous to show succinctly in an advice sheet. Instead, these analyses would be of greater use as diagnostic tools during model development and benchmark processes.

However, uncertainty could be captured in the advice sheet headline plot through displaying error bars or showing median results from a stochastic approach rather than the current deterministic result. Additionally, a stochastic approach would enable WGMIXFISH to report the likelihood of each stock being the choke stock giving advice requestors and stakeholders a more comprehensive and nuanced mixed fisheries narrative.

Sensitivity analyses would also be a useful diagnostic tool for identifying highly influential parameters. This would help indicate where advances in data provision are needed and where more consideration to model conditioning is required.

Retrospective analysis of intermediate year assumptions

The ICES technical service also explored the validity of the assumption used for intermediate year values of catchability, quota share and metier effort share in the North Sea case study. In this analysis the current assumption –that intermediate year values are equal to the last data year values – was seen to give the best performance. It would be prudent to repeat this analysis in the other case studies to assess the appropriateness of their current intermediate year assumptions. Moreover, this methodology provides another useful tool for model development and validation.

More broadly, model validation and hindcasting methods should be further developed to enable the evaluation of the prediction skill of the mixed fisheries models. These methods are useful model development tools for spotting issues in the fleet-metier definitions and model conditioning through poor prediction skill. Additionally, they enable WGMIXFISH to improve confidence in model results by being able to demonstrate model prediction skill in a quantifiable way.

Stock interaction plots

During the STARMIXFISH project, ICES technical service and WKMIXFISH series many new visualisations of stock interactions were produced. These plots provide a qualitative way to provide information on the strength of technical interactions. Existing versions are currently included in the Fisheries Overviews for each ecoregion.

To take the methods for these visualisations further a more appropriate data source would be needed such as the RDBES. Furthermore, a review would be needed to decide which visualisations are of most use for providing advice through the Fisheries Overviews. Finally, interactive versions of these plots should be added to the upcoming fisheriesXplorer app.

Improving communication

Two specific examples were highlighted as needing development to improve understanding through better communication. The first was providing a way to trace the aggregation of data from the raw data source submitted to WGMIXFISH to the fleets and metiers used in the models in an understandable way. Two methods were developed for this: a table detailing the raw data metiers which were aggregated under each model metier and fleet and a Sankey diagram that presented the same information in a graphical way. Code for producing the Sankey plot has been added to the mixfishtools R package and so is available for immediate use, most suitably through the fisheriesXplorer app since Sankey plots are easily made interactive. Static versions could also be added to WGMIXFISH-ADVICE reports.

The second was to reconsider providing fleet-based scenario results in terms of fishing effort. It is understood that fishing effort does not translate easily to real world experiences for most stakeholders and so not be the most suitable variable to use for displaying fleet information. Therefore, it was suggested that the fleet-based effort plot (Figure 2 in the advice sheet) in the advice sheets should be reconfigured to show relative changes in catch rather than effort. Code for this new plot has been added to the mixfishtools R package and so this plot could be used as a replacement in the advice sheet or added as an additional plot in the WGMIXFISH-ADVICE report.

More descriptive information on fleet and métier activity in Fisheries Overviews

Currently, plots to show the landings compositions by fleet or metier are include for each ecoregion in the Fisheries Overviews. However, the way these data are displayed is not consistent across the mixed fisheries case study regions. Therefore, a consistent approach needs developing with consideration being taken to the likely change in data source for these plots as RDBES data become more widely available. Additionally, these plots would be a perfect addition to the fisheriesXplorer app to allow users to filter, select and aggregate across variables of their choice. Code has been added to the mixfishtools R package to produce such plots.

Framework for vulnerable stocks, technical measures, long term stock recovery

Frameworks for adding vulnerable stocks, scenarios based on technical measures and long-term stock recovery plans were considered by the STARMIXFISH project and the ICES special request. This work is likely to happen on a long-term basis as it will require engagement with advice requestors, input from experts in other ICES Working Groups to design new scenarios and new data sources.

3.3 Online app and standard outputs discussion

WGMIXFISH outputs are expected to be included in the fisheriesXplorer app that is set to be available from autumn 2024. Initially, this will include the main figures included in the Mixed Fisheries Consideration advice sheets.

Some discussions took place to detail what will be needed to ensure a smooth transition of outputs from advice sheet to online app:

- Instead of adding the app functionality to the mixfishtools package it is likely to be more computationally efficient to place that code in the app itself.
- Mixfishtools R package code needs to be clean and well documented.
- Figure captions need to be generic between case study advice sheets.
- Generic sentences to explain each plot need to be written.
- Common file names and data formats should be used across the case studies (see Table 3.1 for details).
- Each ecoregion TAF repo needs to add a folder to contain outputs needed to make the advice sheet plots - “output/fisheriesXplorer”

Table 3.1: Summary of advice plots for inclusion in the fisheriesXplorer app detailing priority, input file names and required data format.

Priority	Plot name	Input file name	Data format/column names	Code status/function name
Required for 2024	N/A	refTable.csv	stock, order, col, stock_short where, stock is the ICES stock code; order is the numerical order the stock should be plotted in; col is a palette colour for plotting. stock_short is the model stock code.	Provided by each ecoregion. North Sea example is available in mixfishtools.
Required for 2024	Figure 1 - headline plot	Figure1_HeadlinePlot_data.csv	scenario, stock, catch, catch_ofwhich	Plot function exists in mixfishtools: plot_catchScenStk()
		Figure1_HeadlinePlot_advice.csv	Stock, advice, lower, upper, advice_ofwhich	
Required for 2024	Figure 2 – effort by fleet	Figure2_EffortByFleet_data.csv	fleet, stock, quotaEffort, sqEffort, Limitation where, fleet is the ecoregion specific fleet names; stock is the ICES stock code; quotaEffort is the effort, by fleet, required to take up the quota share of each stock; sqEffort is the status quo effort corresponding to most recent data year before forecast; Limitation is “most”, “least”, or “NA” and are set by fleet.	Plot function exists in mixfishtools: plot_effortFltStk()
Required for 2024	Figure 3 – landings by metier	Figure3_MetierLandings.csv	stock, metier, value Where, Stock is the ICES stock codes; Value is the landings/catch in tonnes.	Plot function exists in mixfishtools: plot_landByMetStock()
Required for 2024	Figure 4 – landings by stock	Figure4_StockLandings.csv	stock, value Where, Stock is the ICES stock codes;	Plot function exists in mixfishtools: plot_landByStock()

Priority	Plot name	Input file name	Data format/column names	Code status/function name
			Value is the landings/catch in tonnes.	
2025 or later	Sankey - Met-MetFleet	FigureX_Sankey_Met-MetData.csv	Original_Metier, Metier, Landings	Plot function exists in mixfishtools: plot_Met-MetFleet()
		FigureX_Sankey_Met-FleetData.csv	Metier, Fleet, Landings	
2025 or later	Build you own catch composition	FO_CatchComp_Data.csv	Time series of historic fleet data - year, fleet, metier, stock, landings, discards, catch, area, country	Plot function exists in mixfishtools: plot_catch-Comp()

3.4 FLBEIA interactive outputs

FLBEIAshiny is an R library (https://www.r-project.org/) that facilitates the generation of an interactive interface using Shiny (https://shiny.posit.co/). The package source code is available at https://github.com/flr/FLBEIAshiny. FLBEIA Shiny application interface can be used to analyse the biological, economic and social indicators obtained through FLBEIA simulation model (Garcia *et al.*, 2017; https://github.com/flr/FLBEIA). It provides lots of graphics at scenario, stock, fleet and metier level (Table 3.2) for different indicators (Table 3.3) to facilitate the analysis of the results and the comparison among scenarios. All the generated figures can be tuned (e.g. by including confidence intervals, reference points levels or defining the number of columns in the facets or setting the line width and dot size) and downloaded with the desired file name and properties (e.g. width, heigh and scale).

The package FLBEIAshiny has been primarily employed to quickly analyse the results of the simulations when using the FLBEIA framework without the need to writing specific code. However, it can be used to download figures to be included in technical reports or to show the results to stakeholders. Furthermore, the case-specific developed FLBEIAshiny Apps can be published in external servers to externally share them. FLBEIAshiny package is independent of FLBEIA and can be used with both FLBEIA output objects directly or with R data frames. If results obtained with a different model are stored in data frames with the same columns as the summary data frames used to summarise FLBEIA results, the Shiny app can be employed also directly. FLBEIA has several summary data frames to store the results at different levels and although one of the data frames is missing FLBEIAshiny can still be used, but the corresponding indicators will not be shown in the app.

Table 3.2: Plots currently available in the FLBEIA Shiny App.

Plot name	Plot description	Aggregation levels
Time series	Shows the evolution of indicators over time (different colours are used for each scenario). Confidence intervals can also be added. Several indicators and stock, fleets or métiers (depending on the case) can be selected simultaneously, and they are plotted in different facets.	- Stocks (status, exploitation level and advice): - Fleets - Fleets and stocks - Fleets and

Plot name	Plot description	Aggregation levels
		métiers - Fleets, métiers and stocks.
Area plot	Shows the median of an specific indicator over time. Each coloured area corresponds with one stock, fleet or métier. When several indicators are selected simultaneously, they are plotted in different facets.	- Stocks - Fleets and stocks - Fleets and métiers - Fleets and métiers and stocks.
Kobe plot	Provides the trajectory of SSB and F pairs (median values) over time. Plot is divided in different quadrants defined by the ratio between SSB and F and their corresponding MSY values. The green quadrant represents the area where the stock is sustainably exploited (SSB>B_{MSY} and F<F_{MSY}), and the red the area where the stock is over-exploited and over-fished (SSB<B_{MSY} and F>F_{MSY}).	- Stocks
Spider	Compares the (median) value of an indicator along a big set of scenarios for a certain year. The scenarios correspond with the edges of the web. The value is standardised comparing the value in one year with a base year (year option) or with a base scenario (scenario option). Thus, the dashed black line corresponds with the unit circle, so lines outside the circle represent values higher than in the base year/scenario and those inside the circle represent lower values. The variables used to draw lines and facets can be exchanged, so lines can correspond with stock/fleets and facets with indicators (or the other way around).	- Stocks - Fleets - Fleets and stocks
Summary	Summarises, for a specific scenario, the biological and economic results in a single plot. Each quadrant represents one indicator F (top-left), SSB (top-right), gross Surplus (bottom-left) and capacity (bottom-right). The values of those indicators in a certain year (or the mean over a range of years) are compared with the values in a reference year. The black circle corresponds with the unit circle, so areas outside the circle correspond with indicator values higher than in the reference year and those inside the circle represent lower values. Stocks and fleets are represented with different colours.	- Fleets and stocks

Table 3.3: Indicators provided by FLBEIA summary functions.

Aggregation level	Indicators
Stocks (status, exploitation level)	biomass, recruitment (rec), spawning stock biomass - SSB (ssb), ratio between SSB and Btarget (ssb2Btarget), probability of SSB being below B_{lim} (pBlim), , probability of SSB being below B_{pa} (pBpa), , probability of SSB being below B_{target} (pBtarget), fishing mortality (f), ratio between exerted fishing mortality and target one (f2Ftarget), probability of F being above F_{lim} (pFlim) , probability of F being above F_{pa} (pFpa) , probability of F being above F_{target} (pFtarget), catch, interannual variation of catch (catch.iyv), landings, interannual variation of landings (land.iyv), discards, interannual variation of discards (disc.iyv)
Fleets	effort, capacity, number of vessels (nVessels), catch, landings, discards, discard rate (discRat), quota uptake (quotaUpt), price, costs, fixed costs (fcosts), variable costs (vcosts), full equity profit (fep), gross surplus (grossSurplus), gross value (grossValue), gross value added (gva), net profits (netProfit), profitability, salaries
Fleets and stocks	catch, landings, discards, discard rate (discRat), quota, quota uptake (quotaUpt), price, TAC share (tacshare), choke species (choke)

Aggregation level	Indicators
Fleets and métiers	effort, effort share (effshare), gross value (grossValue), variable costs (vcost)
Fleets, métiers and stocks	catch, landings, discards, discard rate (discRat), price, revenues per stock (revst)
Stocks (advice)	catch, landings, discards, discard rate (discRat), TAC (tac) , quota uptake (quotaUpt).

3.5 WKMIXFLEET summary

A summary of the work undertaken at the recent Workshop on Mixed Fisheries Fleets (WKMIXFLEET; ICES, 2024d) was presented. The need for this workshop arose out of concerns raised by attendees of WKMIXFISH2 about the suitability of fleet definitions. Particular concerns included the lack of transparency around the data processing, lack of use of spatial data and the lack of consistency in effort calculation methods used between countries. Another particular concern was the lack of compatibility with other fleet-based databases, especially, economic data for performing economic impact assessments on WGMIXFISH scenario results.

WKMIXFLEET brought together mixed fishery scientists and fisheries economists to improve the linkages between mixed fisheries data and economic data from the Annual Economic Report (STECF, 2023). The workshop also took advantage of the RDBES as a new data source for effort and landings data as it not only includes key economic variables (DCF fishing technique, vessel length category) but is also disaggregated to statistical rectangle level and contains encrypted vessel IDs.

The key outcome of WKMIXFLEET include a framework detailing important variables for use in fleet segmentation. Parts of this framework were explored further at WGMIXFISH-METHODS. The first part of this was to explore allocating a vessel to an ecoregion. Most vessels were seen to spend 100% of their effort in a single ecoregion with a smaller proportion of vessels operating in more than one ecoregion (Figure 3.1 and 3.2). The next step involved assigning individual vessels to an ecoregion using an arbitrary threshold of 50% of effort – i.e. a vessel gets assigned to an ecoregion if it spends at least 50% of its effort there. If this threshold was not met, then a vessel was designated as "polyregional". A sensitivity analysis was conducted on the 50% threshold and was not seen to substantially influence the results. These ecoregion designations provide a key identifier for use in further analysis to see if polyregional vessels have different catch compositions to similar vessels operating predominantly within the same ecoregion. It also assists in storytelling by separating out vessels such as the Belgian beam trawlers who operate in the English Channel but also in the Irish Sea when sole quota is available there. This fleet specific behaviour was seen to be significant for the design of ecoregion specific scenarios in the Irish Sea case study last year (ICES, 2023a).

Other aspects explored were the exclusivity of gear choice and species targeting. Again, this segmentation was made to aid assessment by national experts and stakeholders to make suitable fleet definitions. We found that exclusive gear choice was quote common for some countries (e.g. Scotland) but that this could vary across countries and ecoregions. Exclusivity in the species landed was less common and heavily dominated by vessels targeting crustaceans, most of which are not currently species/stocks considered by the WGMIXFISH models. However, there were some specific examples where this segmentation may be important for the models such as separating out the 200 Scottish vessels in the North Sea exclusively targeting *Nephrops*. Alternatively, this segmentation may be useful for visualisation of fleet-based data as a tool for mixed fisheries storytelling in the fisheriesXplorer online app.

Examining gear exclusivity also allows polyvalency to be visualised. Following discussion at WKMIXFLEET and WGMIXFISH-METHODS we investigated polyvalency in the UK fishing fleets. A simple method of fishing days with a specific gear was used to define subgroups of vessels showing polyvalency and outline where a primary gear is used in conjunction with other gears throughout the year. The threshold for assigning the primary gear was set at a 50% of the total days spent fishing by the vessel. Figure 3.3 shows that for FPO gears, polyvalency was commonly associated with Gill nets and Long lines. Conversely, Otter trawls showed a high level of monovalency, with some mixed gear usage, but no clear pattern to alternate gear use (Figure 3.4).

Surprisingly, beam trawlers showed mixed gear usage with miscellaneous gears (Figure 3.5). In the case of the UK, the MIS category is predominantly dredge gears and the result could be explained in the context of trawl capable vessels also having the horsepower to tow a dredge.

While the bulk of vessels showed some level of gear preference mixed with varying levels of polyvalency, a subset of vessels had a fully mixed gear portfolio with no predominant gear (Figure 3.6). The results point towards a small fully polyvalent fleet and multiple gear-polyvalent fleets predominantly centring on the fixed and static gears used by the UK (Pots, Gill nets and Long lines). For mixed fisheries this indicates that the UK static fleet could be broken down to better describe the fleet. Breaking these fleets out from the current "Static" fleets will not change the overall outcome of the model but may become more relevant as additional species, specifically pelagics, targeted by these gears are included, as hooked gear can have high species-specific selectivity. Similar analysis could be done for other countries to justify disaggregation of the static fleets withing the models and might have a greater impact on the fine scale for countries with different fishing practices and target preferences.

While these graphs do not indicate any evidence for breaking down the major gear groups any further, they only show days spent fishing with a gear and do not take in to account any nuances that may relate to area fished or catch composition that might further describe fishing activity.

The next steps following the WKMIXFLEET work are to develop methods for fleet segmentation using the spatial information before conducting a participatory modelling approach to make final fleet designations for use in the mixed fisheries models. Additionally, the fleet data would be available for visualisation in an online tool which would be a simple way to display the links between the raw RDBES data and the fleets used in the mixed fisheries models as well as the processing steps and decisions taken to define the fleets.

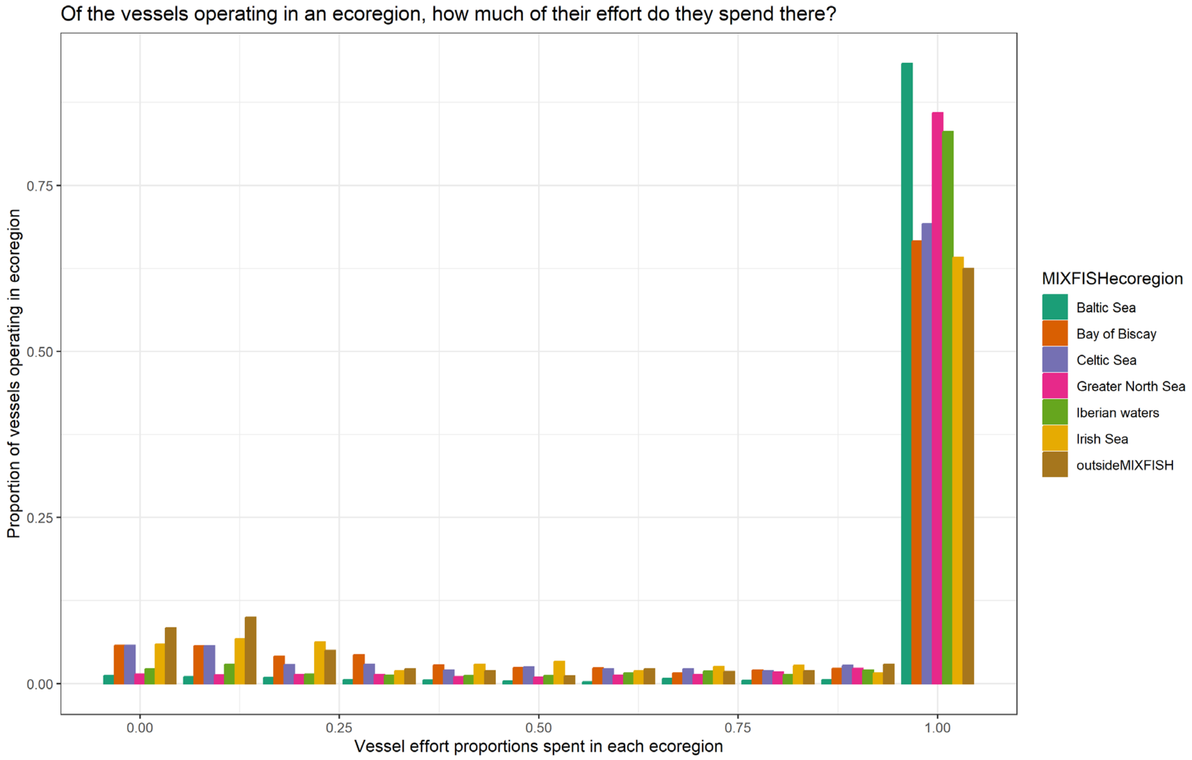

Figure 3.1: The proportion of vessels expending effort by WGMIXFISH ecoregion, binned by effort proportion spent.

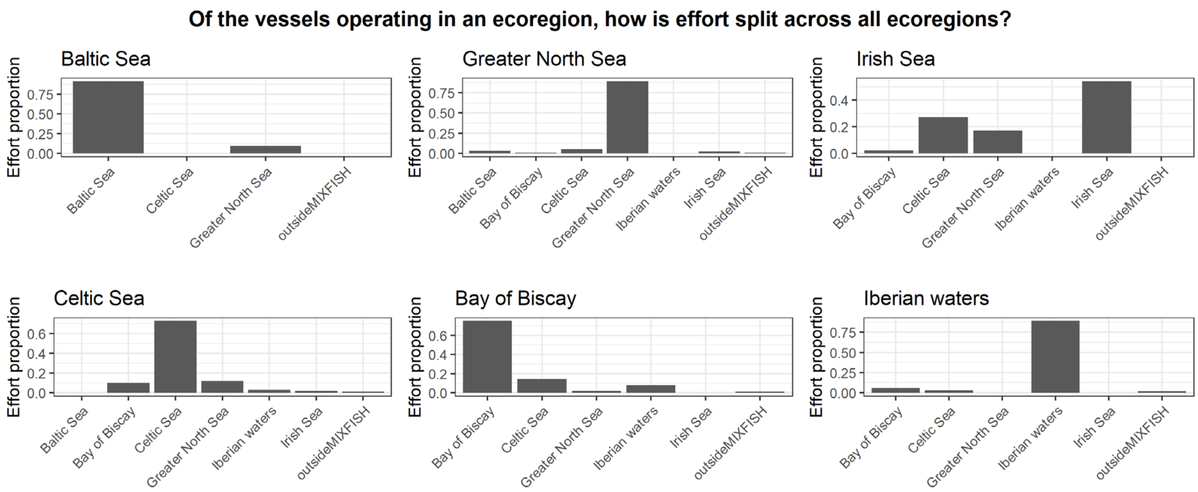

Figure 3.2: Effort proportion expended per WGMIXFISH ecoregion by all vessels expending some effort in a WGMIXFISH ecoregion.

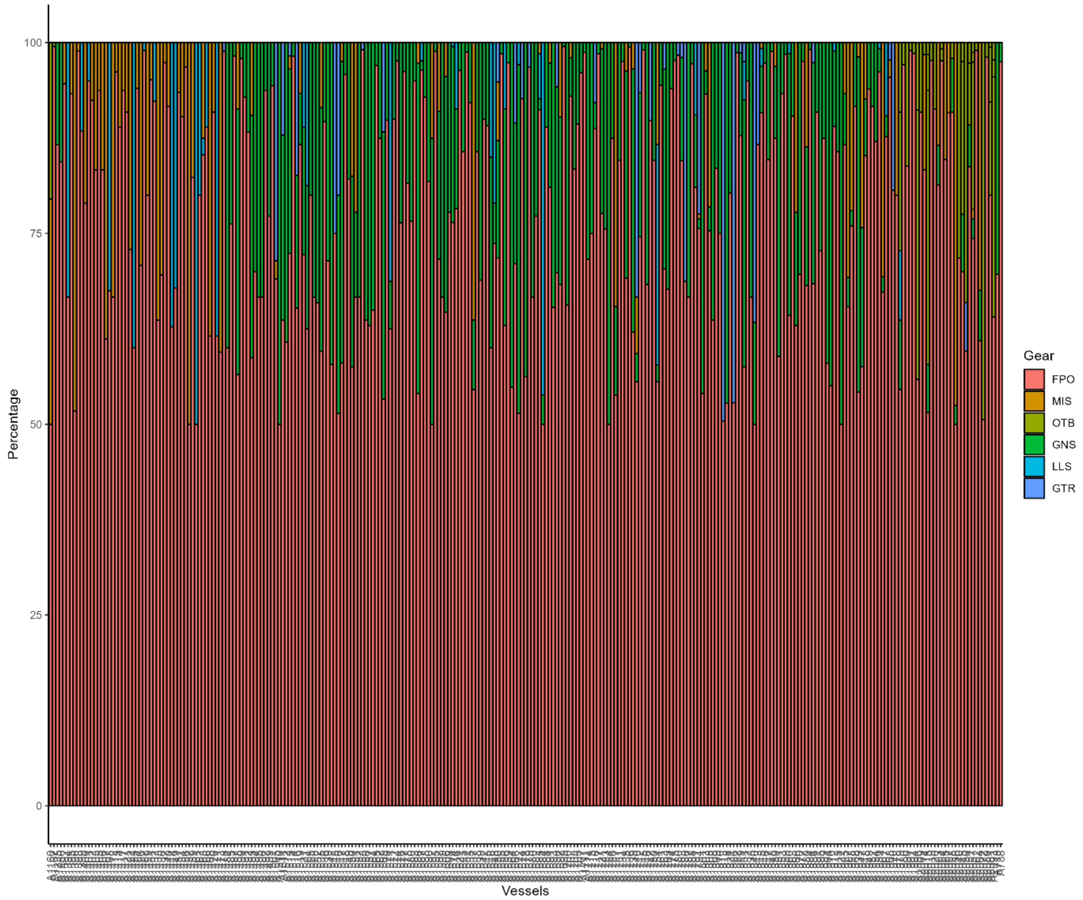

Figure 3.3: Proportion of fishing days with gear against anonymised vessel ID in UK vessels predominantly using FPO gear, showing widespread use of GNS and LLS amongst the polyvalent vessels.

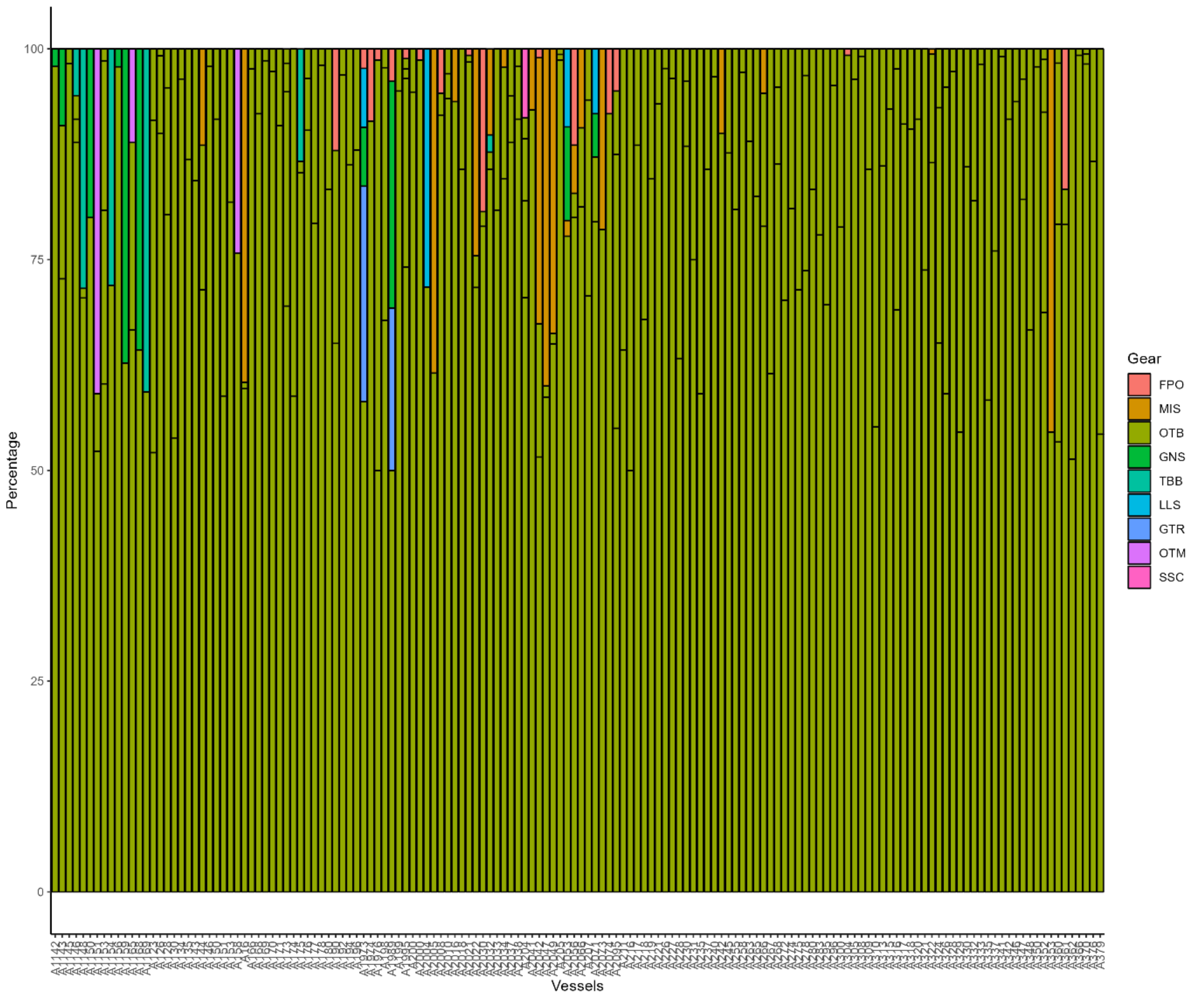

Figure 3.4: Proportion of fishing days with gear against anonymised vessel ID in UK vessels predominantly using otter trawl gears. A small number of vessels display mixed gear usage with the bulk of the otter trawl fleet displaying very little polyvalency.

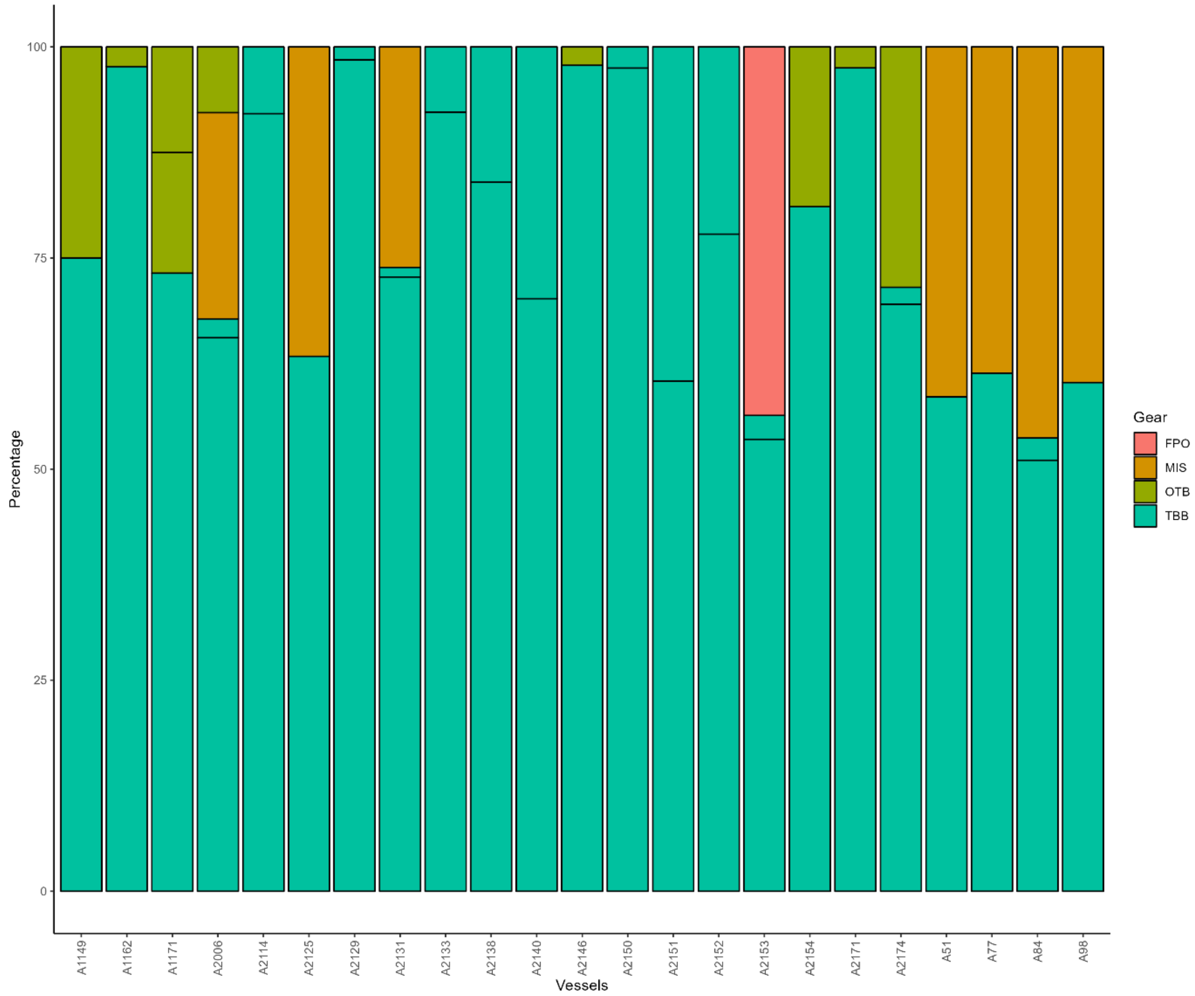

Figure 3.5: Proportion of fishing days with gear against anonymised vessel ID in the UK vessels predominantly using beam trawl gears. The MIS gear category is a mix of dredge gears.

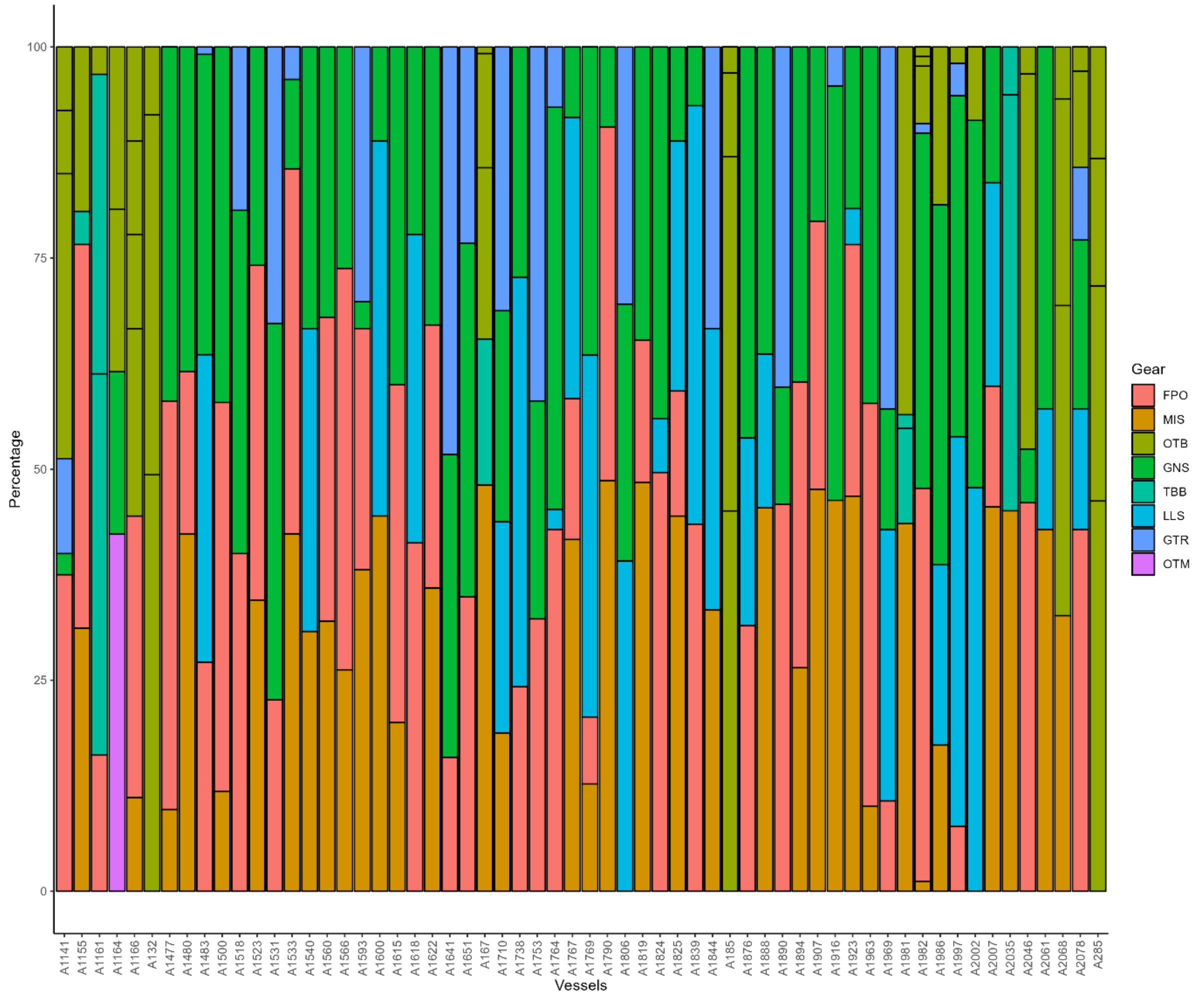

Figure 3.6: Proportion of fishing days with gear against anonymised vessel ID in the UK fleet with no predominant gear type.

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4 Tor C: Exploration of developments in methodology and advice

4.1 Bioeconomic mixfish application in IAM

While there are existing bio-economic models used in different contexts (Nielsen et al, 2018), their use in ICES context has remained scarce despite the potential interest for advice of assessing biological and socio-economic impacts of scenarios in particular regarding mixed fisheries issues. A bio-economic application of the MIXFISH framework has been initiated in this context with the IAM model and applied to the Bay of Biscay. This application is being developed within WGMIXFISH-METHODS work since beginning 2024 with a medium term perspective of delivering results for use to WGMIXFISH-ADVICE. It is developed in line with WKMIXFLEET, WKMIXFISH, WKMIXFISH2 and WGECON (ICES, 2021, 2023, 2024a, 2024), which emphasised the need to foster a broader use of bio-economic modelling frameworks for advice.

The modelling framework aims at complementing the existing advice with an integrated bio-economic assessment, linking biology and economics, accounting for socio-economic issues in mixed fisheries advice, accounting for short- and longer-term perspectives and distributional effects of mixed fisheries scenarios. One of the potential contributions also concerns the refining of the fleet/vessel approach and the exploration of impacts and chokes on an individual vessel basis, taking into account detailed data available and stakeholders knowledge to model the salient dimensions at the appropriated level of aggregation. The application also aims at better understanding flexibility in joint production- choke effects and behaviours and developing capacity/methods to update annually this kind of integrated models

Within the WGMIXFISH METHOD 2024, an application of IAM has thus been developed on the Bay of Biscay.

IAM is a Bio-economic Model developed by Ifremer since 2009 - under a participatory modelling approach with stakeholders, within the last CFP reform context and an EBFM approach to perform multi-criteria impact assessment of scenarios (including TAC and quotas scenarios, MAP, selectivity, MSY, MEY objectives). It enables to highlight trade-offs – socio-economic impacts/distributional effects and the exploration of co-viability conditions in fisheries. It has been applied in a number of case studies and contexts (see https://ifremer-iam.github.io/IAM/). It is an integrated model coupling the biological dynamics of fish stocks with the economic dynamics and governance developed based on existing data/knowledge and connected to existing databases. It relies on either Baranov or global model or constant CPUE production function and has alternative possible behaviours implemented.

The Bay of Biscay MIXFISH IAM application developed in 2024 models explicitly 945 (French) vessels operating mainly in the Bay of Biscay[1] * 23 metiers* 24 species of which 9 species have a biological dynamic (sole, sea bass, hake, anglerfish, monkfish, megrims, mackerel, horse mackerel, blue whiting) while other species have constant Catches per Unit of Effort. Each vessel is allocated to a fleet according to an *ad hoc* typology derived from the DCF segmentation and identifying main emblematic fleets based on stakeholder knowledge (Demaneche et al, 2022).

The provisional application developed for the proof of concept is parameterized with 2023 effort and landings data from the Fisheries Information system from Ifremer (which are the base for

[1] 25% of time in the Bay of Biscay –ecoregional approach

RDBES data call) and 2022 economic cost-structure from the 2022 data from STECF Annual Economic Report raised by vessel according to Value of landings and Effort 2023. Stocks were parameterized provisionally for the group of June with FLSTOCK 2022. First examples of results of simulation of a 'min' scenario are provided in appendix 4.

Future steps of development of the Bay of Biscay application are the following:

- Parameterization/calibration:
  - Stocks - update with 2023 data – adapt assumptions for intermediary year
  - Parameterize with real TAC values
  - Include Spanish vessels
  - Check access and possible use of catch number at age by metier to calculate partial F accounting for different selection pattern
  - Check access and possible use of data of age composition of commercial grades to account for different prices per grade/age
- Validate simulations and results
- Implement other WGMIXFISH scenarios and scripts of visualization of results
- Results analysis, sensitivity analysis, comparison of results between individual/fleet approach

Future methodological steps to be developed in the medium term are the following:

- Develop scripts for parameterizing effort, costs and catches by vessel with RDBES and AER
- Develop methods and script for Ad Hoc Bay of Biscay typology for results visualization
- Explore the opportunity to develop a participatory process with a core group of stakeholders to refine scenarios, assumptions, outputs
- Further strengthen links between WGECON and WGMIXFISH
- Find/Save/increase resources and capacity for annual bio-economic parameterization, simulation and reporting.

4.2 Future mixed fisheries science discussion summary

An afternoon discussion was dedicated to identifying developments and advancements needed to progress mixed fisheries science. The goal is to summarise these as a manuscript that can set out the group's collective expertise and views on the future direction of travel, and what is needed to develop the "next generation of mixed fisheries models and science".

The discussion was lively, and several topic areas were identified:

- The need to reframe and refocus the mission statement of the group to emphasise that mixed-fisheries do not operate in isolation but as part of an Ecosystem-Based Fisheries Management,
- To delineate different types of potential mixed fisheries science:
  - Advice,
  - Scenario considerations,
  - Information only,
- Evaluate what would be needed to move away from scenarios based on effort assumptions towards different catch-options,

    - Validation of fleet-specific effort models (assumptions on effort drivers, behaviour), which may be learnt about from past dynamics,
    - Treatment of uncertainties,
    - Manager and stakeholder buy-in / support
- Development of long-term approaches:
    - Integration of Management Strategy Evaluation (MSE) concepts and philosophy to address questions around what mixed-fisheries consequences are in the long-term for risk to stocks and yield,
    - Mixed-fishery specific harvest control rules,
    - Exploration of choke risk given uncertainty, noting that often unrealistic choke dynamics are often clearer in long-term simulations than short-term simulations,
- Addressing the spectre of false or 'weak' interactions:
    - Identifying where fleet technical interactions can be decoupled by better use of spatial data. It was noted that in some cases choke situations were unrealistic as they related to stocks that were geographically delineated (e.g. two sole stocks in different locations), and that there may be a need for more spatially explicit dynamics and/or flexibility to be introduced to improve realism,
    - Elucidating the consequences of removing 'weak' technical interactions from choking behaviour. As explored elsewhere (Section 4.5), some significant choking of target fisheries can occur with only minor bycatch of the choke stocks – these could, for example, be removed with some criteria for minimum proportion of a stocks catch by a fleet.
    - It was noted that the consequences of the types of changes to address 'false' and 'weak' interactions would need to be made clear, e.g. moving to a fishery-based approach would potentially remove links to fleet economics, make the implicit assumption of complete freedom to reallocate effort among fisheries (though this could be done explicitly with a fleet-dynamics model), and need to be implemented on a fleet-by-fleet basis to be consistent with the modelling assumptions, resulting in catches by country that are inconsistent with relative stability. A full exploration of these consequences and alternatives could be explored.
- Incorporating socioeconomics: it was noted that policies were increasingly giving socio-economic stronger weight with a requirement for explicit evidence to support decision making alongside MSY type objectives:
    - WGECON were working towards improving socio-economic methods and data, and there were continued opportunities for WGECON and WGMIXFISH to collaborate,
- Improving fleet dynamics:
    - There was noted potential for the use of new datasets such as RBDES to evaluate hypotheses related to fleet dynamics, including whether vessels change behaviour in response to changing fishing opportunities – such insights could help develop simpler fleet dynamics models or relationships that could be implemented in advisory models,
    - Moving towards increased flexibility for fleets in effort allocation was highlighted as an avenue to improve forecast realism and/or to reflect that quota-

uptakes could increase where fleets adapt behaviour to changing fishing opportunities,
  - In addition, vessel flexibility may exist across models (e.g. Bay of Biscay and Iberian waters where some vessels fish in both regions) and that this may require combining or linking models to account for these flexibilities,
- Methods to improve evaluation of technical measures and ecosystem-level impacts:
  - Increasingly there was a desire to develop scenarios and evaluations of the impact of new technical measures (gears, spatial measures) on stocks and fisheries: WGMIXFISH was well placed to lead this charge, with models and methods available already,
  - Incorporation of age-based indicators alongside MSY were also highlighted as a potential area of development, with some readily available and suitable (e.g. Vasilakopoulos et al., 2020; Griffiths et al., 2024) as well as Marine Strategy Framework Directive (MFSD) indicators. However, it was noted that some may require the development or implementation of growth models,

The objective is for a think piece manuscript to be developed, which both summarises the 'state of play' in mixed fisheries science, recent developments, and a vision for the future. More specifically, more analytical work was also highlighted. For example, repetition of previous analysis of métier definitions (e.g. Moore et al., 2019) with higher spatial resolution datasets may provide further insights to fleet behaviour. These would be in the form individual papers that could contribute to a future special journal.

4.3 Continuous catch production function R package

MixME is an R package for the simulation of quota-based management in mixed fisheries (https://github.com/CefasRepRes/MixME). The key innovation is the use of numerical optimisation to identify the fleet effort required to catch quota targets in continuous time. This approach is more consistent with single-stock population models than existing tools, allowing for direct comparison with single-stock forecasts, and ensures that fleet interactions inform the catches achieved for a given fishing mortality. Efficient and robust optimisation is achieved using the TMB R package (Kristensen et al. 2016) to define objective and gradient functions and is a development of work presented at WGMIXFISH-METHODS in 2022 and 2023.

MixME is geared towards full-feedback Management Strategy Evaluation (Punt et al. 2016). The Operating Model (OM) contains the true stock and fleet dynamics. Imperfect observations are generated by the Observation Error Model (OEM) and passed to the management procedure modules (Estimation, Harvest Control Rule and Advice Implementation) which represent the advice generation and implementation processes. Simple short-term forecasts, with perfect stock and fishery observations, can also be carried out for the evaluation of harvest control rule performance.

MixME can carry out most of the simulations that are of interest to ICES WGMIXFISH. The package allows for a flexible specification of fleet effort dynamics, including constraining effort by the most or least limiting stock, *status quo* effort, and fleet-specific stock exemptions. MixME uses FLR libraries (Kell et al. 2007) and takes age-resolved stock inputs as FLBiols and fleet inputs as FLFisheries. Fleet data are not resolved at the metier-level in the current version of MixME. However, equivalent results are expected if the effort distribution across metiers is fixed. Metier structuring and accommodation of fixed populations will be included in a future version of the package. Hence, MixME is a potential candidate for the delivery of Celtic Sea mixed fisheries advice.

An application of MixME was demonstrated to the ICES WGMixfish group using the 2023 Fcube advice model inputs to condition a model for the Celtic Sea. Fleet catchability and age selectivity for each stock was estimated by partitioning single-stock assessment fishing mortality by the proportional catch-at-age. There were some notable differences in conditioning between the Fcube and MixME models. In MixME, top-ups to account for the discrepancy between fleet accessions data and assessed stock catches were referenced to the overall catch numbers whereas the Fcube model topped-up landings and discards independently. Simulations carried out for a range of effort assumptions: *status quo* effort (*sqE*) or fleet effort constrained by most-limiting stock (*min*), least-limiting stock (*max*), cod (*cod*), haddock (*had*) or whiting (*whg*) quota.

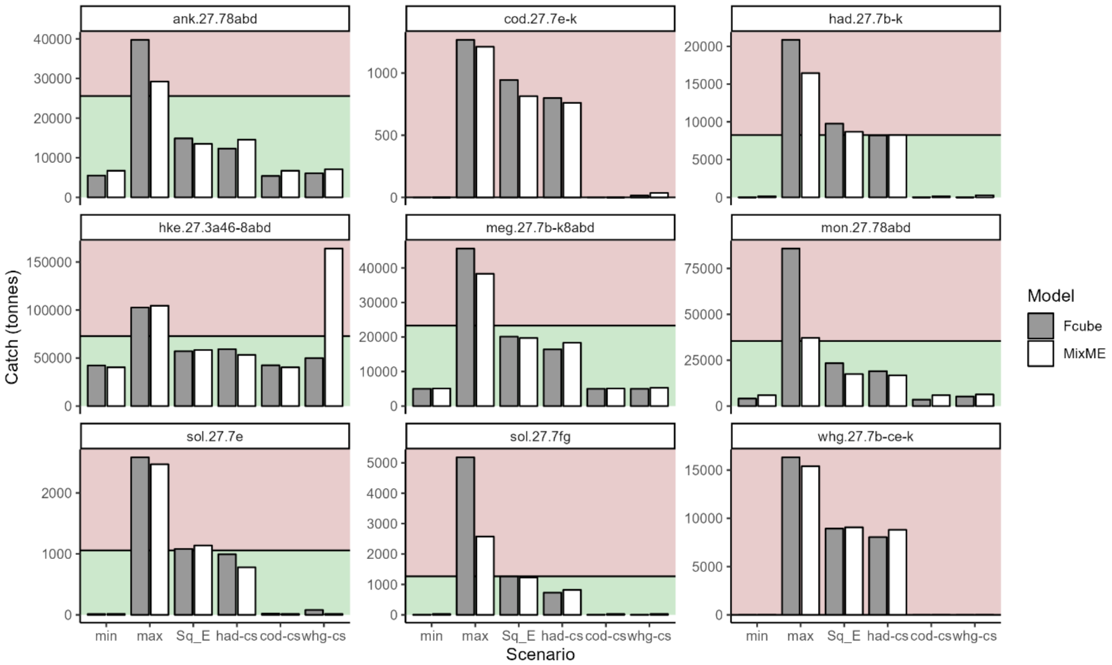

Figure 4.1: Celtic Sea mixed fisheries forecast for Fcube (dark bars) and MixME (white bars). Estimated catches (in tonnes) by stock and scenario. Horizonal lines correspond to the single-stock catch advice, and areas above and below the line represent over- and under-quota catches, respectively.

Results showed similar catches for many stocks and scenarios (Figure 4.1). However, large differences were noted for white anglerfish (mon.27.78abd) and sole (sol.27.7fg). This is mainly due to differences in the calculation of top-ups, resulting in differences in distribution of partial fishing mortality and hence impacting fleet catchabilities and quota-shares. Future work will focus on refining the implementation of MixME for the Celtic Sea, building package functionality meet the requirements of WGMIXFISH and generating tutorials and package documentation to aid user uptake.

4.4 Discussion on residual fleets

'Out-of-area' catches occur when the mixed fisheries model domain does not match the management areas of one or more stocks. This affects several case-study areas, including Celtic Sea, North Sea and Bay of Biscay, and results a discrepancy between fleet accessions and stock assessment catches. This discrepancy is often resolved by calculating 'out-of-area' catches as a 'top-up' to match stock assessment catches and these are allocated to one or more residual 'out-of-area' fleets. However, parameterisation of residual fleets is often arbitrary, and approaches vary between case-study areas.

This matters because residual fleets contribute to overall projected stock catches in mixed fisheries forecasts, but interpretation of the resulting effort dynamics and stock catches can be challenging. For instance, a sensitivity analysis of the 2022 Celtic Sea Fcube model showed that landings for many stocks were sensitive to the corresponding residual fleet quota-share when fleet effort was constrained by the most limiting stock quota ('min' scenario). This is because fleets were overwhelmingly limited by the availability of cod quota, and changes in quota allocation to unchoked residual fleets strongly impacted overall stock landings. Moreover, catchability and quota-share parameters are strongly influenced by catch 'top-up' calculations, and mis-specified catches also may impact the partial fishing mortalities and quota-shares of detailed fleets in the model. Differences in parameterisation of residual fleets may therefore impact the dynamics and catches of both residual and detailed fleets in mixed fisheries forecasts.

WGMIXFISH discussed strategies to:

- improve the parameterisation of out-of-area fleets
- reduce the influence of out-of-area fleets on mixed fisheries forecasts
- better communicate the contribution of out-of-area catches in mixed fisheries forecasts to end-users

Residual fleet parameterisation could be improved by using available historical effort data from fleet accessions, rather than arbitrary effort values. In doing so, derived stock catchabilities might be expected to show more consistent time-series trends that are more readily interpretable and can inform deterministic or stochastic parameter projections. The quota-share for 'out-of-area' fleets could be fixed using the split of Total Allowable Catch (TAC) between areas. This depends on the historical splitting of TAC between areas according to relative stability to inform the predicted split of quota between 'out-of-area' fleets and detailed fleets within the mixed fisheries model domain.

The influence of residual fleets on mixed fisheries forecasts could be reduced by ensuring that 'out-of-area' fleets harvesting a single stock fully consume their quota. This mitigates the impact of mis-specified catchability parameters and ensures that residual fleets do not contribute to over- or under-quota utilisation in any effort scenario. However, quota-share parameters remain influential under this approach, underscoring the importance of careful parameterisation of these fleets.

The contributions of 'out-of-area' fleets to catches should be highlighted in figures presented by the working group to allow distinction between detailed fleet catches and 'out-of-area' catches. Additionally, 'out-of-area' fleets should be distinguished from 'top-ups' to other fleets, where catch discrepancies between accessions and stock assessment data are not linked to 'out-of-area' catches, but rather to the addition of uncertainty included in catches estimated by the assessment model. Finally, the methods used by each case-study to parameterise 'out-of-area' fleets should be fully documented.

Additional work is needed to better understand the impact of different 'out-of-area' fleet conditioning approaches on model behaviour. Systematic investigation of the different approaches may yield general recommendations for the treatment of 'out-of-area' catches in mixed fisheries models that could be more broadly applied across case-studies.

4.5 Exploring the impact of ‘weak’ interactions on model forecasts

In previous discussions managers have highlighted that ‘weak' interactions limiting opportunities for target stocks, as sometimes highlighted by mixed fisheries scenarios, was unlikely to be politically acceptable. A simple analysis was presented as an experiment to evaluate the consequence of removing ‘weak’ interactions from choking fleets in the Celtic Sea mixed fishery model.

No definition of ‘weak’ exists, and it is not a scientific question to define. As such, three alternatives were presented: based on where a fleets landings of a stock are <1%, <2% and <5% of the total landings for that stock. This highlights that in many cases a few fleets dominate landings of most stocks, and many fleet-stock combinations fall below even a 1% threshold (Figure 4.2).

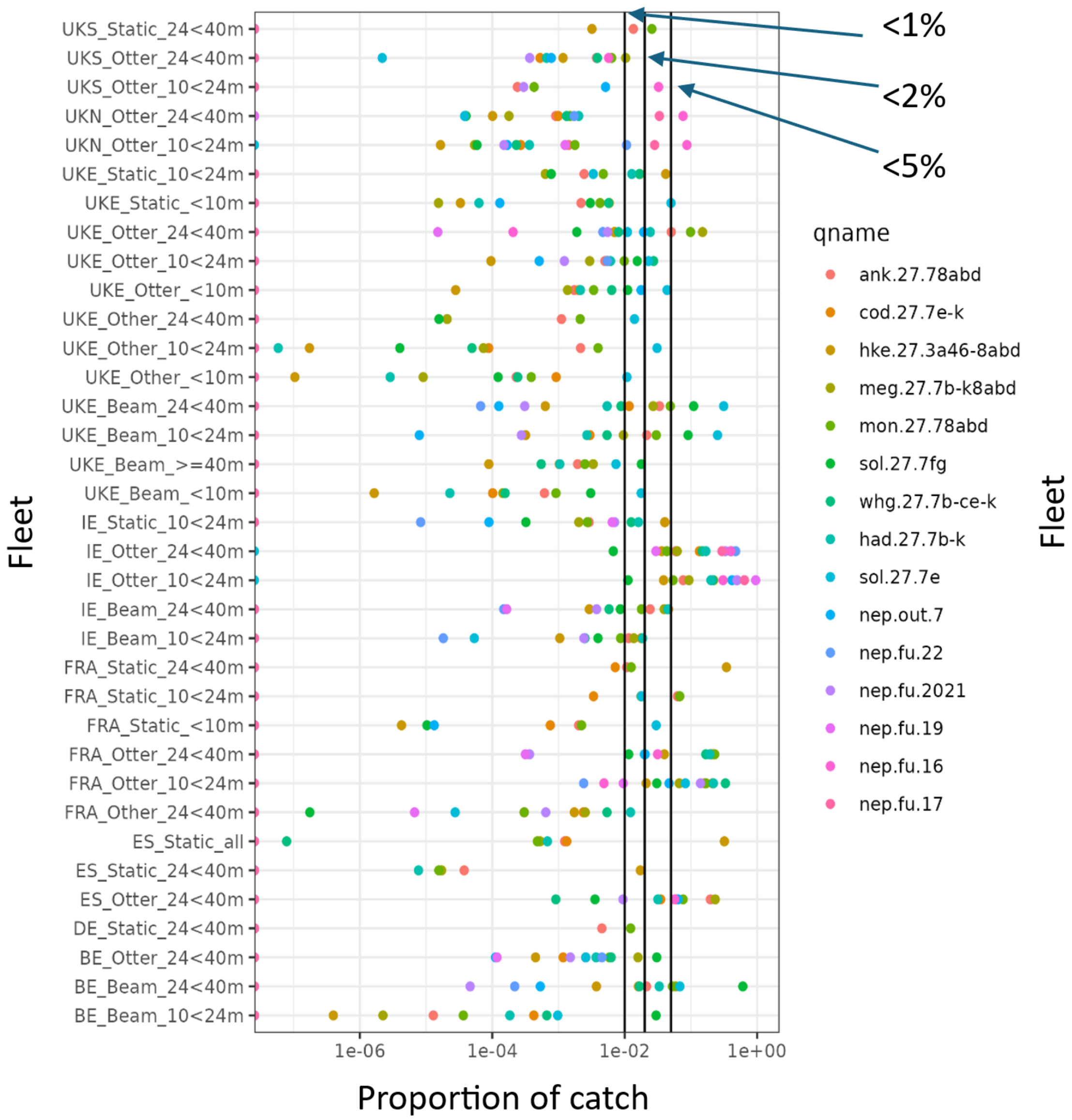

Figure 4.2: The proportion of each stock landings for each fleet in the Celtic Sea mixed fisheries model (average share 2020–2022, as conditioned for forecasts in the 2023 advisory model). The 1%, 2% and 5% threshold lines are indicated, with the x-axis on a log-scale.

Following this approach, a revised model was implemented where fleet-stock combinations were only considered a 'choke' if it fell above each of these thresholds. A 'min' scenario then simulated based on these changes and compared against the standard 'min' scenario used in the 2023 advisory model. The results (Figure 4.3) highlight that in some cases removing weak interactions based on a 1% threshold can allow for considerably higher catches of some target stocks to be realised (e.g. hake, >20,000 tonnes additional catches) for only a limited additional catch of the choke stocks (cod and whiting). In other cases, a 2% threshold can allow almost full uptake of the sole stocks (7e and 7fg), with relatively limited catches of cod (140 tonnes) and moderate catches of whiting (1003 tonnes).

Figure 4.3: The resultant catches of the 'min' scenario from the Celtic Sea mixed fisheries model where fleets are not choked by stocks where they have <1%, 2% and 5% of the share of landings, as compared the standard 'min' scenario. The red line is the single stock catch advice for each stock.

The implications of excluding certain fleet-stock combinations from choke stocks was discussed. The following consequences were highlighted:

- The resultant catch for the choke stocks exceeds the single stock advice (e.g. for cod and whiting in Figure 4.3. above). This cuts across the general purpose of mixed-fisheries scenarios to highlight choke stock implications,
- This implicitly results in a break from the quota-share assumption in the model, where some fleets can realise catches for some stocks while others are not. While emergent, this does imply that to achieve the catches forecast by the model quotas would need to be allocated at the fleet-level, consistent with the catch projections,

- The definition of 'weak' interactions is somewhat arbitrary and not a science question. This implies it needs policy/managers to input as to what is acceptable. It was also highlighted that defining it based on the share of the landings of a stock may not make much sense from a fishery-perspective and basing it on the share of the fleet's catches may make more sense, depending on whether you take a stock or fishery perspective to the question.
- The application of the threshold and the level of the threshold will be sensitive to the definition and number of the fleets – so the two issues cannot be separated,
- There will remain 'weak' interactions at the métier level, and without either fleet dynamics to allow more effort within these métiers or a radically different approach based on fisheries or métier these will remain and may be a further barrier to uptake of mixed fisheries-based advice.

4.6 Interactions among spatially independent stocks

In the Celtic Sea model both Sole 7e and Sole 7fg are included, and some fleets (25 of the 35 fleets in the model) catch both stocks in different métier (e.g. beam trawlers in TBB_DEF_7e catch sole 7e and TBB_DEF_7fg catch sole 7fg). With the current assumption in forecasts of fishing patterns being assumed to be the same as in recent years, it is possible for one sole stock to choke the catches of the other sole stock, even though this is not possible, and in reality, vessels would have flexibility to change location fishing if one of the quotas were exhausted.

There was a discussion on how to address this false interaction. It may be possible to allow flexibility were one of these stocks to be the choke stock each year. An alternative approach would be to define area-specific fleets, but this was not the preference.

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5 ToR D: Respond to the outcomes and issues encountered during WGMIXFISH-Advice;

5.1 Bay of Biscay

The following issues were identified at WGMIXFISH-ADVICE 2023, with progress highlighted:

Issue	Progress
Analyse stability of main model parameters, i.e. catchability, total effort, effort share and quota share. Based on the analysis consider the best way of conditioning the model at fleet/métier level, recent years average or last year value.	Ongoing work. Work carried out under several projects (see Section 2.2). The uncertainty analysis and global sensitivity analysis carried out on some input parameters (catchability, effort share and quota allocation) could aid to condition the uncertainty in the mixed fisheries advice. Nevertheless, the mixed fisheries advice is still provided with a deterministic approach.
Develop criteria for choosing relevant scenarios to run. In case of zero-catch advice, exzero may be considered as a standard scenario for estimating bycatch. Analyse the relevance of existing scenarios and identify new relevant ones.	Currently existing scenarios are considered relevant for the case study and consequently will be maintained for the 2024 advice meeting. The exzero scenario was already incorporated last year (due to the zero TAC advice for horse mackerel). Additionally, alternative scenarios for pollack TAC were tested due to its very low TAC in the latest years, which turns this stock as the main choking species for most of the fleets (see Annex 2. Impact assessment of pollack TAC values on overall landings and fleets choked).
Develop criteria for stock inclusion in the mixed fisheries models. Where possibly, advice summary tables should include all stocks for which the variable can be estimated (e.g. F for Category 1 Nephrops).	
Define maximum fleet effort (e.g. multiple of status quo) as upper limit in scenarios.	Will be implemented when agreed which should be the appropriate limit to be used. Maximum observed effort (or a multiplier) could be a potential threshold.
Assess possible use of grouped TAC constraints to better reflect management.	The impact of combined TACs for anglerfishes (Lophius spp.) was tested in the past (ICES, 2021), with minor impact expected under assumed conditions. Consequently, at the moment the single stock advice is considered as the reference and accordingly the single stock TAC approach is maintained as reference for mixed fisheries advice. Analysis should be repeated every several years to check this is still the case.
Continued implementation of the code, tables and figures in the ICES-taf repository (https://github.com/ices-taf) and automate the preparation of the different reports.	Ongoing work. Code has been developed to automatically generate all report and advice sheet tables and figures. Work will continue to incorporate new figures that could aid communication with stakeholders (as developed under STARMIXFISH project, ICES technical service and WKMIXFISH workshops) and to allow the

Issue	Progress
	consistency among case studies (e.g. in the fisheries overviews plots). Input data necessary for the fisheriesXplorer app will automatically be generated for the 2024 advice meeting. And new plots/tables will be provided if necessary. For example, new figure for detailing how the raw data métiers have been aggregated in the case study area (by using Sankey plot available at the mixfishtools R package). Additional developments yet to be implemented in future years are: - Incorporation of RDBES information. - Retrospective analysis of intermediate year assumptions (on catchability, quota share and metier effort share). Currently it is assumed that intermediate year values are the mean of the three latest data years.
Investigate the differences obtained in the short-term forecast between that carried out for mixed fisheries advice and that of the assessment working groups, specifically for hake, white anglerfish and blue whiting.	Reproducing short-term forecast for hake still presents issues to replicate the estimated discards. Problems are experienced to extract the information necessary to condition de biological model given the Stock Synthesis outputs (as, for example, currently it is not possible to correctly estimate the discards mean weights at age). Further work will be carried out for next year methods meeting.
Improve fleet structure based on this year's fleet configuration, if considered necessary. Revise the assumptions for the pelagic fleets with very low or null bycatch of demersal stocks (currently all removed from the analysis but should be reconsidered how to deal with fleets with minor bycatch, e.g. French purse seiners). Revise the assumptions for out of area catches for harmonisation with other case studies. Documentation and justification of the procedure.	Fleet structure has not been changed from last year. However, RDBES data has been analysed and could be used to improve the fleet-métier definition in the future based also on WKMIXFLEET highlights. Use of the main fishing technique*vessel length categorisation from RDBES will improve the approach by grouping vessels with more homogeneous characteristics, strategies, fishing possibilities and behaviours. It will also enable to connect to economic data available at this level of aggregation and thus enable more integrated bio-economic approaches to Mixed fisheries issues. However, changes are not planned for current year advice.
Analyse reported data for rays and decide on how to make assignments to the different species, given official catch data and information from surveys. Documentation and justification of the assumptions made.	This analysis is yet to be carried out, but the data reporters declare high confidence on reported information on these stocks.
Analyse the option of including fleet-dependent age structure in the conditioning of the model for some stocks.	This change is yet to be implemented and consequently it is not planned to be used for the 2024 advice meeting. However, the inclusion of different selectivity-at-age by métier for hake will be explored before next year methods meeting.

5.2 Celtic Sea

The following issues were identified at WGMIXFISH-ADVICE 2023, with progress highlighted:

Issue	Progress
Continue work on the implementation of an age-based model.	The age-disaggregated 'MixME' approach that implements a fleet-based Baranov catch equation continues to be tested and compared against the current FCube model (see Section 4.3 for further details). This method is designed to address some of the issues identified at the Interbenchmark meeting (ICES, 2021) in implementing a Cobb-Douglas catch equation in the FLBEIA model, where there are inconsistencies in catches with single stock forecast methods under high fishing mortality rates (as is the case for some stocks in the Celtic Sea). Full functionality will continue to be developed for 'MixME', with a view to its future use, following a review process. The manuscript detailing the MixME method is also currently under review (Pace *et al.*, in review).
Consider handling of the 'out of area' catches; the fleet should have explicit quota shares based on TAC splits (as indicated by the sensitivity analysis, this fleet quota share assumption can have a large influence on overall projections for these stocks),	This change is yet to be implemented but intended to be used for the 2024 advice meeting.
Consider outcomes of fleet and métier sensitivity analyses, and uncertainty and sensitivity analyses and any changes that should be implemented to the model as a result,	Ongoing.
Investigate raising procedure and "top-up" fleets: currently operating on landings and discards independently, but need to consider total catch,	A new method was testing to provide more consistency. This will be used for the 2024 advisory meeting.
Consider whether to split the Static fleet into separate Longline and gillnet fleets to better represent differences,	The polyvalency of vessels was evaluated for the UK and confirmed that there were vessels that predominantly used longlines, those that predominantly used nets and those that used a mix (see Section 3.5). Current accessions data does not provide for splitting these into separate fleets, but it is something that could be done should a future data call request fleet definitions *a priori*. This would look to be implemented soon.
Streamline code, repository and results tables and figures in TAF	Further development on automating the report was progressed, with some of the previous issues resolved. Work will continue to improve automatic table and figure numbering.
Evaluate alternative effort scenarios based on changes implemented to allow fleet specific vectors of choking stocks,	Analysis on the consequences of removing 'weak' technical interactions was undertaken and shows the significant changes in catches projected some stocks with limited impact on catches of the choke stocks (see Section 4.5). This occurs particularly for stocks whether the main fisheries have a weak interaction with the choking stocks, such as hake with cod and whiting. Further scenarios could be tested and included as part of the report this year, though it was noted that there are significant consequences for interpretation and implementation of such scenarios (see Section 4.5).
Develop methods for longer term projections based on rebuilding of depleted stocks	This work is ongoing.

Issue	Progress
Two additional issues were identified during the meeting and added to the work programme:	
Comparison of RDBES data submissions with accessions	Consistency of RDBES data with accession data was evaluated for the French data submission. Differences in some years was identified and needed further investigation in conjunction with the RDBES data submitter.
Analysis of the conditioning of catchability, quota share and effort share for the North Sea identified that using a one-year average instead of a three-year average of historic values resulted in the best predictions of future catch, on average (European Commission, 2024). This analysis has not been undertaken for the Celtic Sea model (which uses a three-year average) and it was considered this should be done in future.	To progress.

5.3 Irish Sea

Issue	Progress
Investigate further scenarios based on alternative advice options for zero-catch stocks (e.g. cod and whiting).	To progress when human resources allow.
Implement historic model validation techniques in annual workflow	To progress when human resources allow.
Further streamlining code, repository and results tables and figures.	To progress when human resources allow.
Investigate the potential for implementation of an age-based model (e.g. FLBEIA/ age-based FCube model) and compare with current FCube approach	To progress when human resources allow.
Investigate differences in catch compositions of fish-stocks between Nephrops FU's if data sources allow	To progress when human resources allow.

5.4 Iberian waters

Issue	Progress
Analyse stability of main model parameters, i.e. catchability, total effort, effort share and quota share. Based on the analysis consider the best way of conditioning the model at fleet/metier level, recent years average or last year value.	To progress.

Issue	Progress
Develop criteria for choosing relevant scenarios to run. In case of zero-catch advice, exzero may be considered as a standard scenario for estimating bycatch	Current advice scenarios are considered relevant for the case study and the number of species included in the mixed fisheries models Changes to existing scenarios will be discussed at next Advice meeting as full advice was not requested for the case study region advice.
Develop criteria for stock inclusion in the mixed fisheries models. Where possibly, advice summary tables should include all stocks for which the variable can be estimated (e.g. F for category 1 Nephrops).	No criteria were developed, however several stocks are candidate for inclusion in the mixed fisheries model based on catch volume. Scomber scombrus (mac.27.nea) and Micromesistius poutassou(whb.27.1-91214) despite having seasonal, minor catches (when compared to the rest of the wide stock) are relevant to demersal métiers operating in the area.
Define maximum fleet effort (e.g. multiple of status quo) as upper limit in scenarios.	To be analysed if relevant for case study at next Advice meeting
Implement the "range" scenario following further development to be conducted for the North Sea and Celtic Sea.	Implemented
Continued implementation of the code, tables and figures in the ICES-taf repository (https://github.com/ices-taf) and automate the preparation of the different reports.	Ongoing work focused on enhancing automation procedures in input data processing and report generation
Improve mixed fisheries fleets' structure	Although some preliminary analysis was made in the past, no changes are planned for this year advice. RDBES data has the potential to enhance this work

5.5 North Sea

The following issues were identified at WGMIXFISH-ADVICE 2023, with progress highlighted:

Issue	Progress
TAF: Modify model_01 to read the BRPs (reference points) csv automatically. Better handle dataPrep scripts so they are run before running data.R. data.R and model_00 have similar code (e.g. stock names), make consistent and delete repetitions. Delete any reference to years in the script names so they do not need to be updated every year. Check if the projection is needed in output.R script or if the results from model_04 can be used instead.	These coding edits will be made while preparing for WGMIXFISH-ADVICE 2024.
The function spfunction() in the file "bootstrap/initial/software/functions/FunctionDefineFleetCategories.R" needs to be checked for correct fleet naming convention. For instance, "SC_Otter10-24" and "SC_DSeine10-24" are aggregated under "SC_Otter	The function that assigns fleet names was reviewed to ensure that the length categories indicated in the name were an accurate reflection of the data aggregations made to form the fleets. Discrepancies were noted and the function was edited to revise the fleet names accordingly (see Annex 4).

Issue	Progress
Fleets for Norway are much more disaggregated than similar fleets and metiers from other countries. Fleet data for Norway should be examined to determine if these fleets need aggregating.	To be investigated ahead of WGMIXFISH-ADVICE 2024.
The discards are not raised as they should if landings are 0. Data_02a and 02b scripts need to be modified to allow the raising.	To enable discards at ages without landings to be estimated, we have changed to raising procedure to use a ratio of discards-at-age to the age aggregated landings for each year-country-area-metier-stock combination (see Annex 4).
Consider adding Nephrops in FU 3 (and eventually in FU 4 if Kattegat also added) to the model.	Data availability in accessions has been reviewed. The impact on existing fleet dynamics was also examined (See Annex 4). Adding these FUs would result in new fleet or métiers being added to the model for Sweden and Denmark. In the case of Norway, catches from FUs 3-4 would be added to existing fleets and métiers.
Use the results of STAFMixFish project to update the methodology where relevant.	To progress
Further maintenance of report section and stock annex	To progress
Improvement of the RMarkdown report script, i.e. delete all old range code, add the Nephrops stocks to Table 4 and 5 of advice sheet, add ICES rounding rule to the outputs (notably advice sheet tables) using icesAdvice::icesRound().	To progress

5.6 Fisheries Overviews

Issue	Progress
Stock interaction plots need updating and adding to the Fishery Overviews for all case study regions.	New formats of the stock interaction plot have been developed. A discussion is needed to decide which format(s) would be best to replace the current one.
The catch composition plots are not presented in a standard way across the case study regions – some show métiers, some show fleets. What story are we trying to tell here?	A generic function has been written to produce a variety of catch composition plots. This is expected to be added to the fisheriesXplorer app so end users can decide themselves how to filter and aggregate the data. A discussion is needed to decide which format is best for the Fisheries Overviews, the data source to be used, and the level of data aggregation.

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6 ToR E: Develop mixed fisheries models for sea regions not currently covered in the mixed fisheries advice

6.1 Baltic Sea

In previous WGMIXFISH-METHODS (ICES, 2023a) and WGMIXFISH-ADVICE (ICES, 2023b) meetings it has been agreed upon that RDBES data is used to investigate and describe current technical interactions and to provide landings composition plots for the Baltic Sea Fisheries Overview. It is acknowledged that the RDBES is still under development and some discrepancies in RDBES data compared to InterCatch data are present. However, comparisons between the two data sources are made to identify the discrepancies and understand the exact causes and report back to countries. The latest comparisons were made in WGBFAS (ICES, 2024). The main problems were summarized as following:

1) Rounding issues: Data are uploaded in tonnes to InterCatch and kg in RDBES. Furthermore, numbers should only be rounded at the very end of the script to avoid transporting rounding issues in the analysis.
2) As the RDBES has a higher resolution (rectangle level), landings were in a few cases assigned to the wrong subdivision when fishing was conducted very close to the border.
3) In 2022, when data were resubmitted to the RDBES database, values were not overwritten but added causing double as high landing data. These have been communicated to the ICES data centre and were corrected subsequently.
4) In some cases, the data in RDBES differ from the uploaded data. This has also been communicated to the ICES data centre.
5) In some cases (DK) adjustments to the landed amounts (box weights) are made while creating InterCatch data, but the same procedures are not possible (yet) for RDBES data.
6) For the Central Baltic herring and the Gulf of Riga herring, differences in landings in SD 28.1 and SD 28.2 between the two investigated databases occur in Latvia and Estonia. This is caused by the allocations of herring catches in SD 28.1 and 28.2 into particular stocks.
7) Unlike InterCatch, the RDBES data is updated every year. Because the data uploaded to the InterCatch are preliminary, there can be differences between those two databases in the previous years.
8) Effort data in InterCatch (demersal species), are often reported by fleet segments, and often only for the fleets with the potential to catch the given species, so direct comparison is difficult, without first aligning the fleets, to which no comprehensive code list could be found.
9) Effort days at sea, can be calculated in different ways, and data providers need to ensure that the input for the two databases is calculated similarly.

It is advised that continuous comparisons between the two data sources are made each year to help the transition from one data base to another. It should be noted that the development of the mixed fisheries model(s) for Baltic Sea is dependent on the developments of RDBES and the transition from one data base to another. Currently the main effort is to better define fleets and metiers to describe the technical interactions.

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Annex 2: Resolutions

2023/AT/FRSG17 The **Working Group on Mixed Fisheries Advice Methodology** (WGMIXFISH-METHODS), chaired by Marc Taylor, Germany, and Harriet Cole, UK, will meet in Edinburgh, UK, 17–21 June 2024 to:

f) Continue the improvement of WGMIXFISH-ADVICE data call, data processing, methodological framework, workflow, auditing, updating associated documentation and increasing transparency;
g) Respond to the outcomes of the Mixed Fisheries Scoping Meeting;
h) Exploration of developments in methodology and advice;
i) Respond to the outcomes and issues encountered during WGMIXFISH-ADVICE;
j) Develop mixed fisheries models for sea regions not currently covered in the mixed fisheries advice.

WGMIXFISH-METHODS will report by 29 July 2024 for the attention of ACOM.

Supporting Information

Priority:	The work is essential to ICES to progress in the development of its capacity to provide advice on multispecies fisheries. Such advice is necessary to fulfil the requirements stipulated in the MoUs between ICES and its client commissions.
Scientific justification and relation to action plan:	The issue of providing advice for mixed fisheries remains an important one for ICES. Following the Aframe project (2007-2009), SGMIXMAN (2008) and AGMIXNS (2009) where methods were developed and applied, WGMIXFISH has continued this work, combining outputs of single-stock-assessments and métier-effort data to provide forecast of effort and multi-species catch at fleet level based on annual single stock catch advice. WGMIXFISH –METHODS will meet to continue this development, ensuring outputs are informative and fit for purpose.
Resource requirements:	No specific resource requirements, beyond the need for members to prepare for and participate in the meeting.
Participants:	Experts with qualifications regarding mixed fisheries aspects, fisheries management and modelling based on limited and uncertain data.
Secretariat facilities:	Meeting facilities, production of report.
Financial:	None
Linkages to advisory committee:	ACOM
Linkages to other committees or groups:	SCICOM through the WGMG. Strong link to STECF.
Linkages to other organizations:	This work serves as a mechanism in fulfilment of the MoU with EC and fisheries commissions. It is also linked with STECF work on mixed fisheries.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group

Annex 3: Impact assessment of pollack TAC values on overall landings and fleets choked

Introduction

In 2023 mixed fisheries considerations, after horse mackerel, pollack was the most limiting stock in the Bay of Biscay Case Study. During the 2023 council of minister, the TAC for pollack was not set but a provisional TAC was agreed running for only six month and the European Commission asked for more information about the level of choke induced by Pollack TAC depending on its level.

Some analyses using FLBEIA model developed for the BoB CS were run, testing the impact of several TAC levels.

Results show that if TAC is set with a reduction greater than 20%, pollack is still the most limiting stock for 5 of the 9 fleets catching pollack. With a TAC set between 20% reduction and a rolle-over compared to 2023 situation, withing starts to also be limiting and this impacts pollack landings.

Material and method

The analyses were carried out using the model developed by the ICES WGMIXFISH-METHODE and WGMIXFISH-ADVICE working groups. The parameterisation is strictly identical to that used to produce the mixed fisheries advice as produced on 14 November 2023 (https://ices-library.figshare.com/articles/report/Bay_of_Biscay_mixed_fisheries_considerations/24212037).

The only changes made to the parameters are to the level of advice for pollack in area 89a.

As a reminder, the stocks included in the FLBEIA model for the Bay of Biscay and used by the WGMIXFISH group are:

black-bellied anglerfish (ank.27.78abd), sea bass (bss.27.8ab), hake (hke.27.3a46-8abd), horse mackerel (hom.27.2a4a5b6a7a-ce-k8), mackerel (mac.27.nea), megrim (meg.27.7b-k8abd), white anglerfish (mon.27 .78abd), Norway lobster (functional units [FUs] 23 and 24; nep.fu.2324), pollack (pol.27.89a), smooth-hound (sdv.27.nea), sole (sol.27.8ab), blue whiting (whb.27.1-91214), and whiting (whg.27.89a).

Horse mackerel (hom.27.2a4a5b6a7a-ce-k8) is a limiting stock for most fleets (TAC 0 advice for this stock) but is caught as a by-catch or even as a collateral by-catch by most fleets. This by-catch, combined with the fact that the fleets modelled as part of this exercise (demersal fleets) do not have a significant impact on horse mackerel dynamics, led to the removal of horse mackerel from the ‘min’ scenario, as was the case for the mixed fisheries advice. The results presented below therefore correspond to the ‘min_exzero’ scenario presented in the ICES advice sheet.

This scenario corresponds to a dynamic as described here:

For each fleet, fishing in 2024 stops when the catch for any one of the stocks (excluding zero-catch advice) meets its stock share. Horse mackerel is a potential choke species for most of the fleets included in the analysis (due to the zero-TAC advice for 2024). However, over 2020-2022 the demersal fleets considered here account for less than 1% of stock landings.

As a reminder, pollack and whiting stocks are not subject to analytical assessment. In the model, the projected effort required to catch quotas by fleet is therefore derived from a catch-per-unit-effort relationship based on the past, with no relation to the biological dynamics of these two stocks. It is therefore impossible to assess the impact on the biomass of these stocks as a function of the levels of fishing carried out.

The model fleets and the stocks they catch are shown in the figure below, taken from the ICES advice sheet.

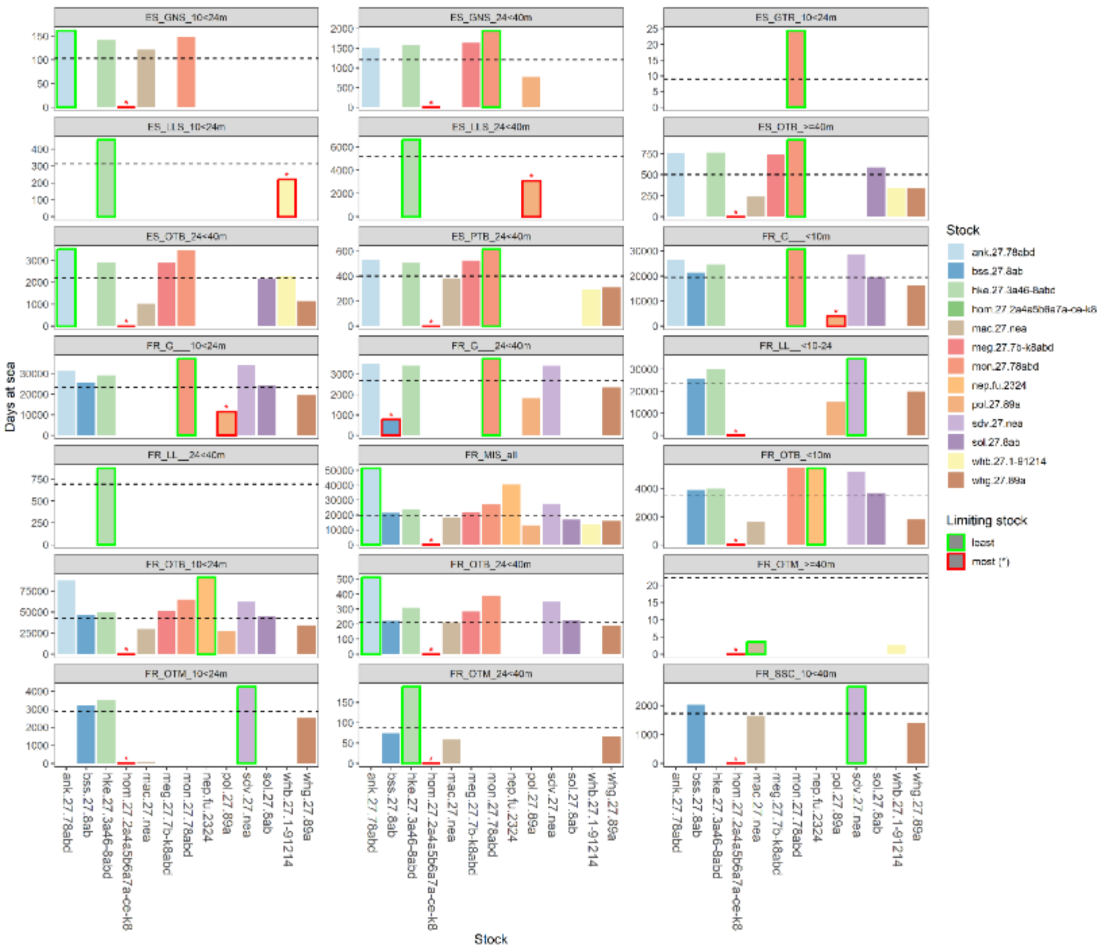

Figure 1: Mixed fisheries for the Bay of Biscay. Estimates of effort by fleet needed to reach each single-stock catch advice. Stocks are coded by colour, with the bars for the most limiting stock ("choke species") for each fleet in 2024 highlighted with a red border and asterisk and the bars for the least limiting species highlighted with a green border. Fleet names are given by country (FR = France, ES = Spain), main gear, and vessel size (m). The status quo effort for each fleet (average 2020–2022) is shown as a dashed line for reference.

These fleets each practice a set of métiers that jointly catch a certain number of species.

The technical interactions described by the model are those estimated using the data available to parameterise the model (i.e. InterCatch data used to assess stocks). These data are available at DCF level 6, quarterly, sub-division or ICES division level. Because of this level of aggregation, these technical interactions may be overestimated.

Simulated scenarios

Based on the parameterisation used by the working group, 3 new scenarios were simulated. Each corresponds to a different level of pollack TAC, as detailed in the table below

Description	abbreviation	TAC Value (tonnes)
Ref = ICES advice = -53% compared to 2023 TAC	pol_53	872
-35% compared to 2023 TAC in 8ABDE	pol_35	963
-20% compared to 2023 TAC in 8ABDE	pol_20	1185
TAC 2024 = TAC 2023 (roll over)	pol_2023	1482

Pollack TAC impact on fleets and other stock landings

During its assessment in November 2023, ICES showed that after horse mackerel, pollack was the second most limiting stock. The sharp reduction in the advice in 2024 will limit catches of other species that can be caught together.

The impact of the increase in the pollack quota on the modelled fleets and catches of other stocks is assessed using several metrics:

- the number of fleets limited by stock (among the fleets catching this stock)
- changes in landings under the various scenarios

Impact on landings

Figures 2 and 3 show that, with the exception of anglerfish and megrim stocks, landings from all stocks are affected by an increase in the pollack TAC. Showing technical interactions at different levels within the fleets as modelled in the case study.

Figure 2 shows that in the 'pol_53' scenario almost all (8/9) of the fleets catching pollack (POL) are constrained by the TAC level. This number decreases as the TAC increases in the various scenarios. Up to the pol_20 scenario, pollack catches are very close to the TAC set by the scenario (points and horizontal lines are almost equal), which shows that pollack remains the most limiting species in the simulation. The pol_2023 scenario is different in that there is a decoupling between the TAC level and the catches made. This is explained by a whiting TAC level (WHG) that becomes more restrictive than the pollack TAC level, and pollack catches are then limited by the catch possibilities associated with whiting (4 out of 14 fleets are limited by whiting in the pol_2023 scenario).

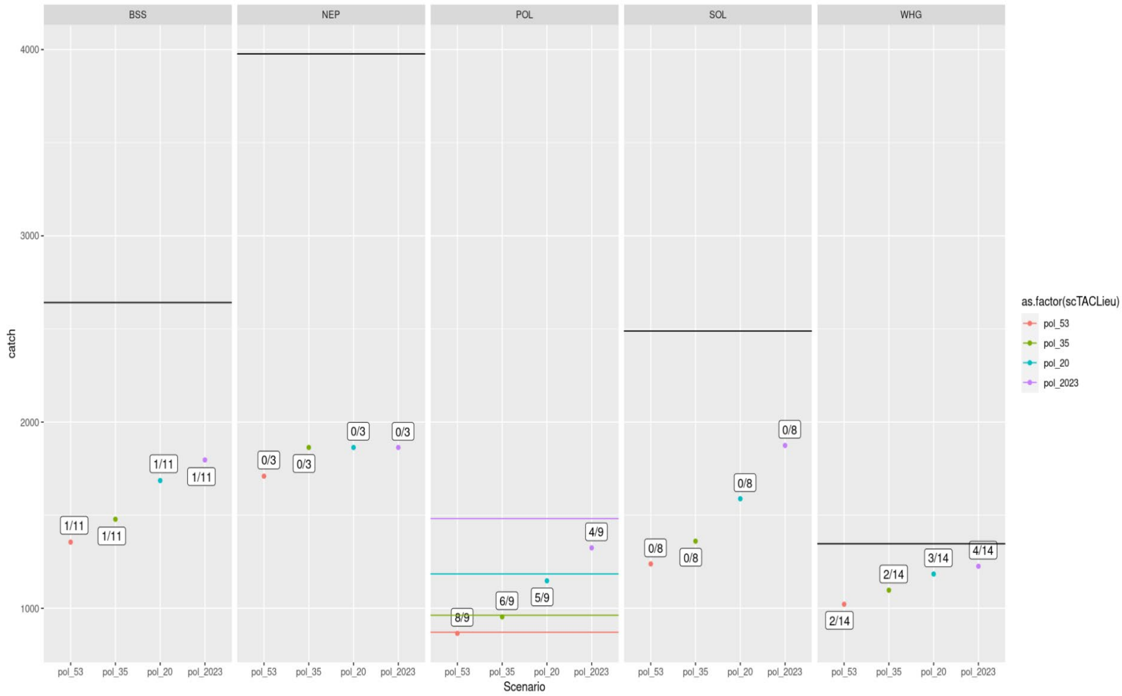

Figure 2: Landings for the different stocks following pollack TAC hypotheses and under mixfish min_exHOM scenario. Horizontal lines are monospecific TAC, Colored horizontal lines are different pollack TAC scenarios. Number are fleets limited by the given stock / total number of fleet catching this stock

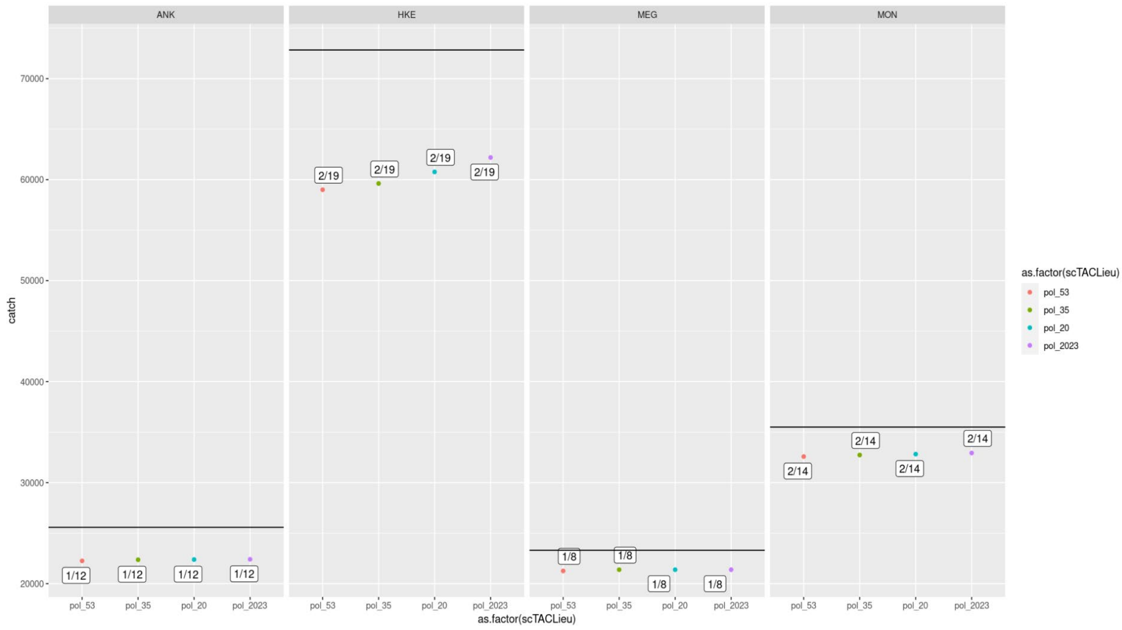

Figure 3: Landings for the different stocks following pollack TAC hypotheses and under mixfish min_exHOM scenario. Horizontal lines are monospecific TAC, Colored horizontal lines are different pollack TAC scenarios. Number are fleets limited by the given stock / totla number of fleet catching this stock

Table 1. Aggregated results by scenario.

Scenario	stock	catch	quota	Number of fleets limited by the stock	Number of fleets that capture the stock	Quota uptake
pol_53	ANK	22257	25579	1	12	0.87
pol_53	BSS	1356	2642	1	11	0.51
pol_53	HKE	59003	72839	2	19	0.81
pol_53	HOM	773	0	0	15	Inf
pol_53	MAC	739122	739386	7	13	1.00
pol_53	MEG	21258	23303	1	8	0.91
pol_53	MON	32584	35502	2	14	0.92
pol_53	NEP	1710	3977	0	3	0.43
pol_53	POL	866	872	8	9	0.99
pol_53	SDV	2174	5329	0	10	0.41
pol_53	SOL	1239	2489	0	8	0.50
pol_53	WHB	1529749	1529754	4	7	1.00

Scenario	stock	catch	quota	Number of fleets limited by the stock	Number of fleets that capture the stock	Quota uptake
pol_53	WHG	1022	1347	2	14	0.76
pol_35	ANK	22367	25579	1	12	0.87
pol_35	BSS	1478	2642	1	11	0.56
pol_35	HKE	59620	72839	2	19	0.82
pol_35	HOM	811	0	0	15	Inf
pol_35	MAC	739183	739386	8	13	1.00
pol_35	MEG	21384	23303	1	8	0.92
pol_35	MON	32738	35502	2	14	0.92
pol_35	NEP	1864	3977	0	3	0.47
pol_35	POL	954	963	6	9	0.99
pol_35	SDV	2357	5329	0	10	0.44
pol_35	SOL	1361	2489	0	8	0.55
pol_35	WHB	1529749	1529754	5	7	1.00
pol_35	WHG	1097	1347	2	14	0.81
pol_20	ANK	22387	25579	1	12	0.88
pol_20	BSS	1686	2642	1	11	0.64
pol_20	HKE	60770	72839	2	19	0.83
pol_20	HOM	812	0	0	15	Inf
pol_20	MAC	739183	739386	8	13	1.00
pol_20	MEG	21385	23303	1	8	0.92
pol_20	MON	32827	35502	2	14	0.92
pol_20	NEP	1864	3977	0	3	0.47
pol_20	POL	1148	1185	5	9	0.97
pol_20	SDV	2447	5329	0	10	0.46
pol_20	SOL	1588	2489	0	8	0.64
pol_20	WHB	1529749	1529754	5	7	1.00
pol_20	WHG	1184	1347	3	14	0.88
pol_2023	ANK	22412	25579	1	12	0.88

Scenario	stock	catch	quota	Number of fleets limited by the stock	Number of fleets that capture the stock	Quota uptake
pol_2023	BSS	1797	2642	1	11	0.68
pol_2023	HKE	62197	72839	2	19	0.85
pol_2023	HOM	812	0	0	15	Inf
pol_2023	MAC	739183	739386	8	13	1.00
pol_2023	MEG	21387	23303	1	8	0.92
pol_2023	MON	32938	35502	2	14	0.93
pol_2023	NEP	1864	3977	0	3	0.47
pol_2023	POL	1325	1482	4	9	0.89
pol_2023	SDV	2553	5329	0	10	0.48
pol_2023	SOL	1875	2489	0	8	0.75
pol_2023	WHB	1529749	1529754	5	7	1.00
pol_2023	WHG	1226	1347	4	14	0.91

Annex 4: North Sea issues addressed at WGMIXFISH-METHODS

Fleet naming convention

After WGMIXFISH-ADVICE 2023 it was noted that some of the fleet names were contradictory in that the vessel length categories indicated in the fleet names overlapped between fleets (e.g. SC_Otter<10 and SC_Otter<24). This made it unclear as to whether fleets were being partially replicated.

The function that assigns fleet names was reviewed to ensure that the length categories indicated in the name were an accurate reflection of the data aggregations made to form the fleets. Discrepancies were noted and the function was edited to revise the fleet names accordingly (see Table A3.1).

It was also noted that the fleets for Norway are much more disaggregated than similar fleets and metiers from other countries. For example, the "Otter" fleets often combine demersal seine metiers (DSeine) for many countries. Therefore, it is suggested that the fleet data for the Otter and DSeine fleets from Norway be examined to determine if these fleets should stay separated.

Table A4.1: List of current fleet names, the vessel length categories included in each fleet and the suggested new fleet name.

Fleet name	Vessel length categories	Suggested new fleet name
BE_Beam<24	10 to 24	BE_Beam10-24
BE_Beam=>24	24 to 40+	
BE_Otter	all lengths	
DK_OTH	all lengths	
DK_Otter<24	10 to 24	DK_otter10-24
DK_Otter=>24	24 to 40+	
DK_Pelagic	all lengths	
DK_Seine	all lengths	
DK_Static	all lengths	
EN<10	under 10	
EN_Beam	over 10	EN_Beam>10
EN_Otter<24	10 to 24	EN_Otter10-24
EN_Otter>=40	over 40	
EN_Otter24-40	24 to 40	

Fleet name	Vessel length categories	Suggested new fleet name
FR_<10	under 10	
FR_Nets	over 10	FR_Nets>10
FR_OTH	all lengths	
FR_Otter>=40	over 40	
FR_Otter10-40	10 to 40	
GE_Beam>=24	24 to 40+	
GE_Otter<24	10 to 24	GE_Otter10-24
GE_Otter24-40	24 to 40	
NL_Beam<24	under 24	
NL_Beam>=40	over 40	
NL_Beam24-40	24 to 40	
NL_OTH	all lengths	
NL_Otter	all lengths	
NL_Pelagic	all lengths	
NO_<15	<15 (Based on data not submitted)	
NO_DSeine24-40	24 to 40	
NO_OTH	all lengths	
NO_Otter	all lengths	
NO_Otter10-24	10 to 24	
NO_Otter24-40	24 to 40	
NO_Pelagicall	all lengths	NO_Pelagic
NO_Static	all lengths	
SC_Otter<10	under 10	
SC_Otter<24	10 to 24	SC_Otter10-24
SC_Otter>=24	24 to 40+	
SC_Static<10	under 10	
SW_Otter	all lengths	

Raising discards at age 0

At WGMIXFISH-ADVICE 2023 it was noted that there was a substantial discrepancy in the discards of North Sea Plaice at age 0 between InterCatch and the fleet data (Figure A4.1). The current discard raising procedure derives a proportion at age for landings and a discard:landing ratio-at-age from InterCatch data. These are then applied to the landings' weights in the WGMIXFISH fleet data for matching combinations of year, country, area, metier and stock to generate the discards-at-age. However, if the landings-at-age are 0 then the raised discards will also be 0 from this method, even though in InterCatch we can often see that all catch at age 0 is discards. Therefore, to enable discards at ages without landings to be estimated, we have changed to raising procedure to use a ratio of discards-at-age to the age aggregated landings for each year-country-area-metier-stock combination. The resulting discards-at-age are compared to the single stock assessment estimates in Figure A3.2 and show improvements in the "FLEBEIA" estimates of discards at age 0 as well as older ages for some stocks.

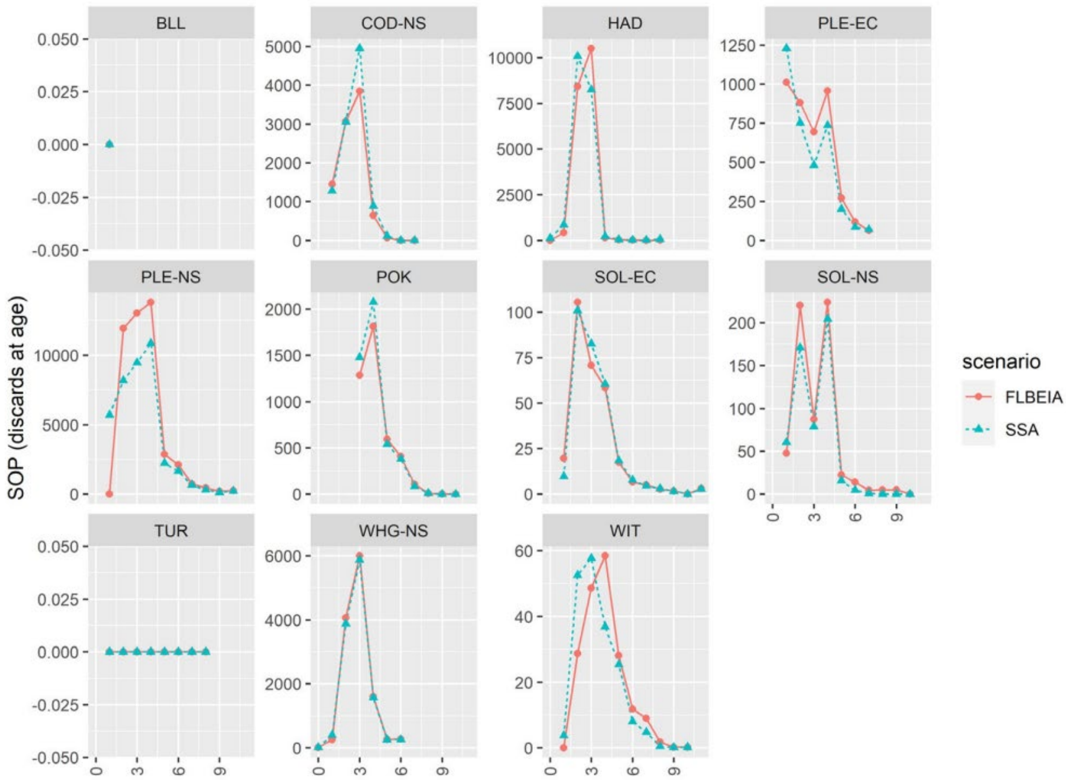

Figure A4.1: Figure 6.6 from the WGMIXFISH-ADVICE 2023 report (ICES, 2023). Sum of product (numbers*weight) discards in the last assessment (2022) (SSA) compared to WGMIXFISH fleet data (FLBEIA).

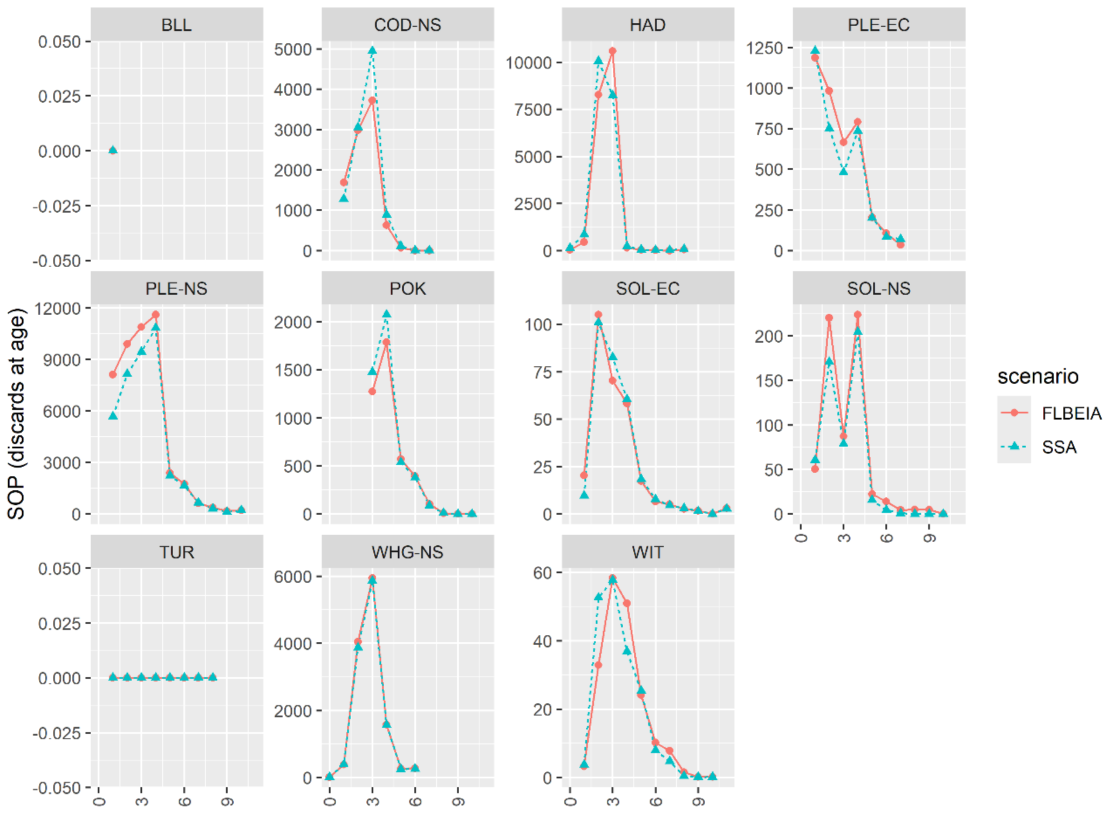

Figure A4.2: Sum of product (numbers*weight) discards in the last assessment (2022) (SSA) compared to WGMIXFISH fleet data (FLBEIA) following correction to discard raising procedure.

Including Nephrops Functional Units 3–4 into the North Sea model

It has been previously mentioned that we should look at including *Nephrops* Function Units 3 and 4 into the North Sea model.

FU 3–4 is a category 1 stock as a underwater TV survey is carried out each year. However, the time series is relatively short and so MSY $B_{trigger}$ values cannot be determined. Stock abundance has been decreasing since 2017 and the harvest rate has been increased, although the harvest rate is estimated as being below F_{MSY}. This stock is assessed through WGNSSK.

Data availability and quality

From the fleet (accessions) data, the main countries exploiting FU 3–4 are Denmark, Sweden and to a lesser extent, Norway (Figure A3.3). However, historically, there are isolated, low-level landings reported for NEP.FU.3–4 from Belgium, Germany and Netherlands. Landings are reported under 3 codes: "NEP.FU.3, NEP.FU.4, NEP.FU3–4".

Before 2021, Sweden mislabelled FU 3–4 landings in subdivisions 20 and 21 as "FU 34". Additionally, landings of FU 4 are reported in 27.3.b.23, 27.3.c.22 and landings of FU 3 are reported in 27.4.a, 27.4.b. These reported landings appear to be outside of the FU area (Figure A4.4).

No data for FU 3–4 exists within the current InterCatch extraction. However, this could be because we do not explicitly request it.

Figure A4.3: Landings of FU 3 and 4 by area for each country.

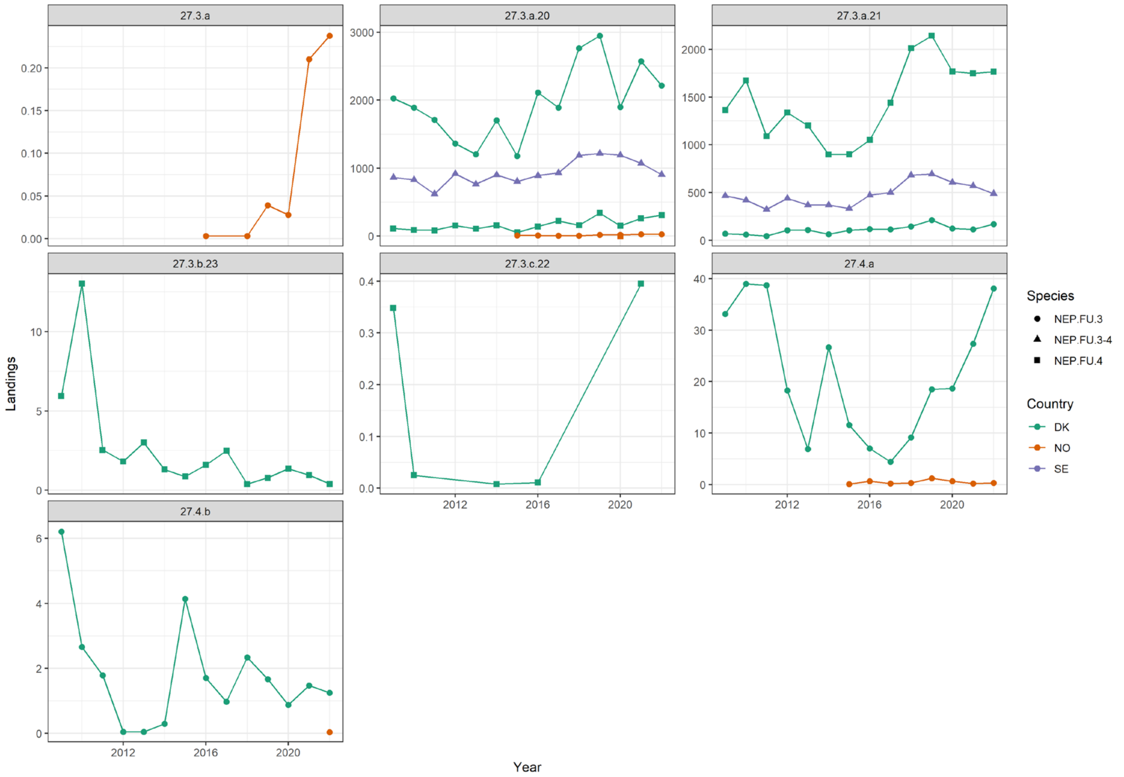

Figure A4.4: Landings of FU 3 and 4 by country for each area.

Fleet dynamics

The fleet and metier landings compositions from WGMIXFISH-ADVICE 2023 were compared to the landings compositions where landings of FU 3–4 and catches of existing NS model stocks in subdivision 21 were included. This comparison was done on the fully processed fleet data used as input to condition the model and are present by country. In most cases, the fleets affected by the addition of FU 3–4 were choked by cod in the WGMIXFISH-ADVICE 2023 scenario runs with witch being the next most restrictive stock. Overall, *Nephrops* FU 3–4 represents a substantial proportion of the landings of a small number of fleets and leads to the creation of two new fleets.

The addition of FU 3–4 results in a new Danish fleet, DK_FDF, which lands primarily *Nephrops* from FU 3–4 with very small proportions of witch and saithe (Figure A3.5). The addition of FU 3–4 noticeably affects the landing compositions of DK_Otter<24, DK_Otter>=24, DK_OTH, and to a much smaller degree, DK_Seine and DK_Static. At the metier level, the bulk of the FU 3–4 landings were added through new metiers due to the majority of landings being in subdivision 21 though smaller proportions of landings were added to some existing metiers (Figure A4.6).

For Sweden, the addition of FU 3–4 affects the composition of the only Swedish fleet (SW_Otter) but also adds a new fleet (SW_Static) (Figure A4.7). The new SW_Static fleet now reaches the 1% threshold value for stock landings meaning it is not aggregated into the MIS_MIS fleet. This SW_Static fleets primarily lands Nephrops from FU 3–4 with smaller proportions of brill, haddock, NS plaice, witch, cod and saithe. Similar to Denmark, the additional landings are primarily added to these fleets through the creation of new metiers (Figure A4.8).

Of the 8 Norwegian fleets, landings of FU 3–4 are added mostly to the NO_Otter10–24 fleet. In contrast to Denmark and Sweden, Norwegian landings of FU 3–4 are added to existing metiers rather than creating new ones.

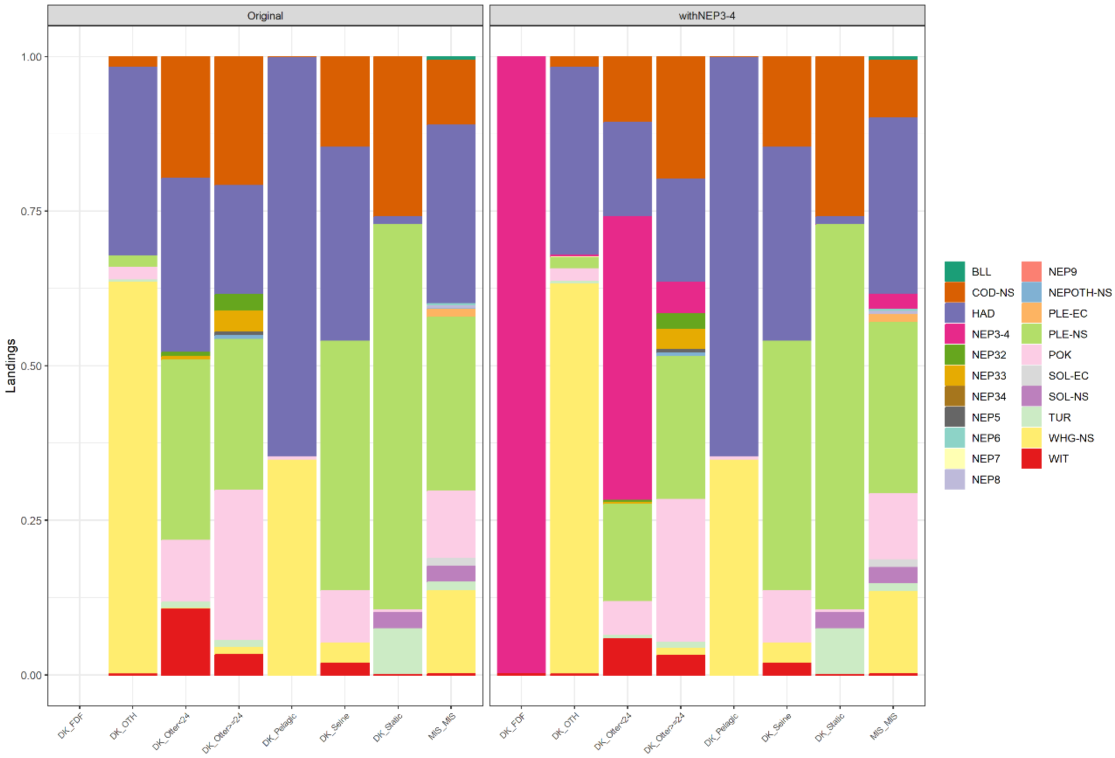

Figure A4.5: Landings composition of Danish fleets from WGMIXFISH-ADVICE 2023 (Original) and with the addition of FU 3–4 (withNEP3–4).

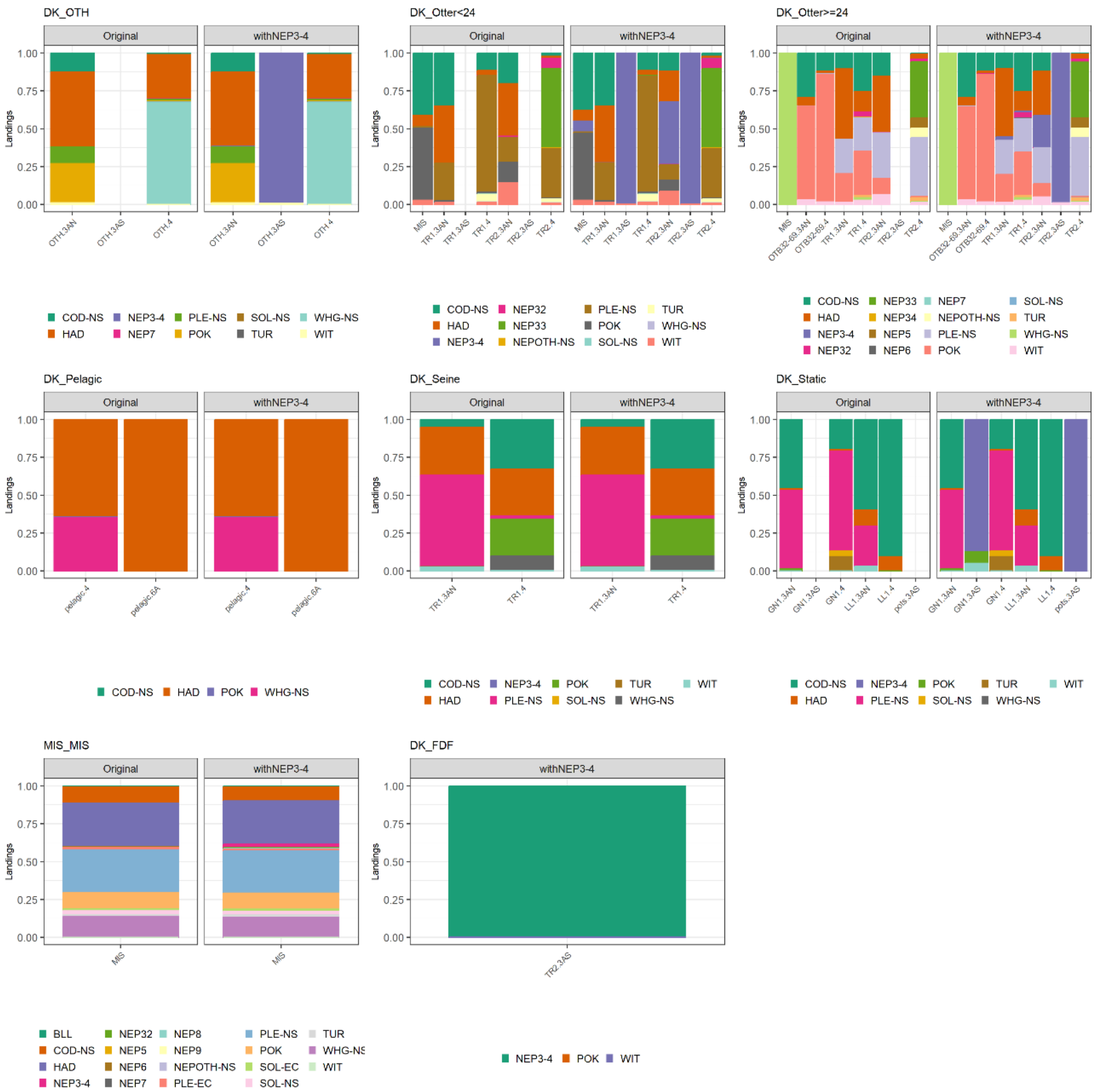

Figure A4.6: Landings composition of metiers within each Danish fleet from WGMIXFISH-ADVICE 2023 (Original) and with the addition of FU 3–4 (withNEP3–4).

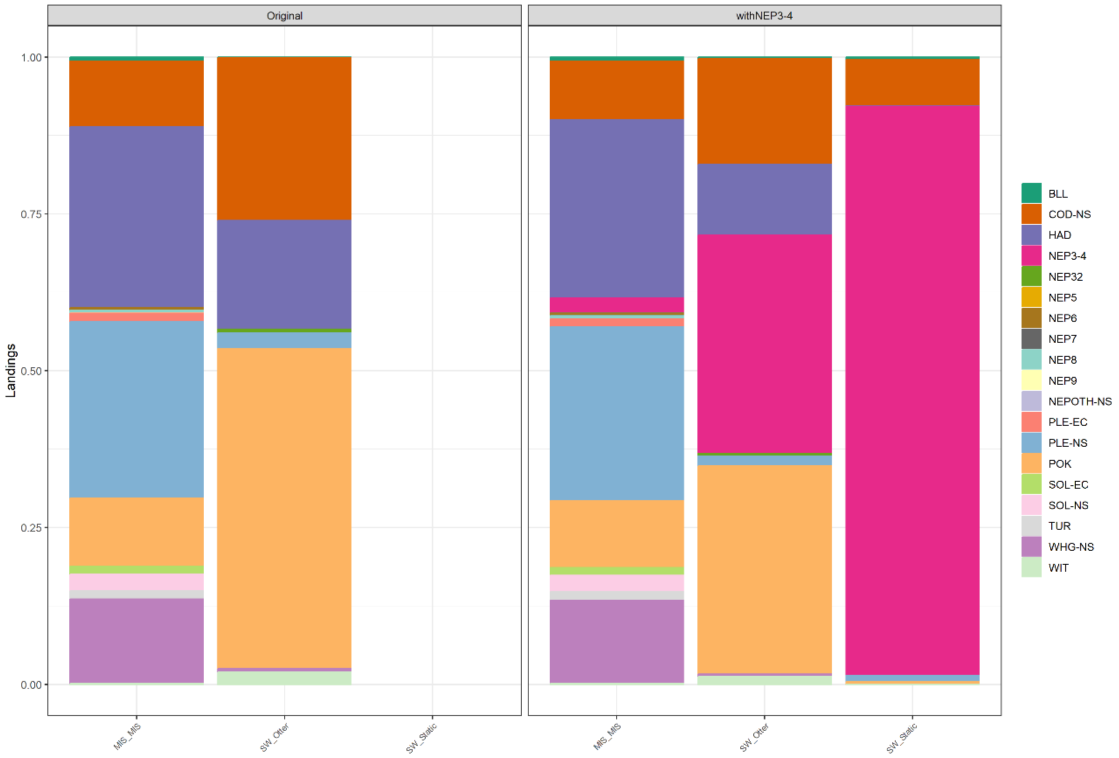

Figure A4.7: Landings composition of Swedish fleets from WGMIXFISH-ADVICE 2023 (Original) and with the addition of FU 3–4 (withNEP3–4).

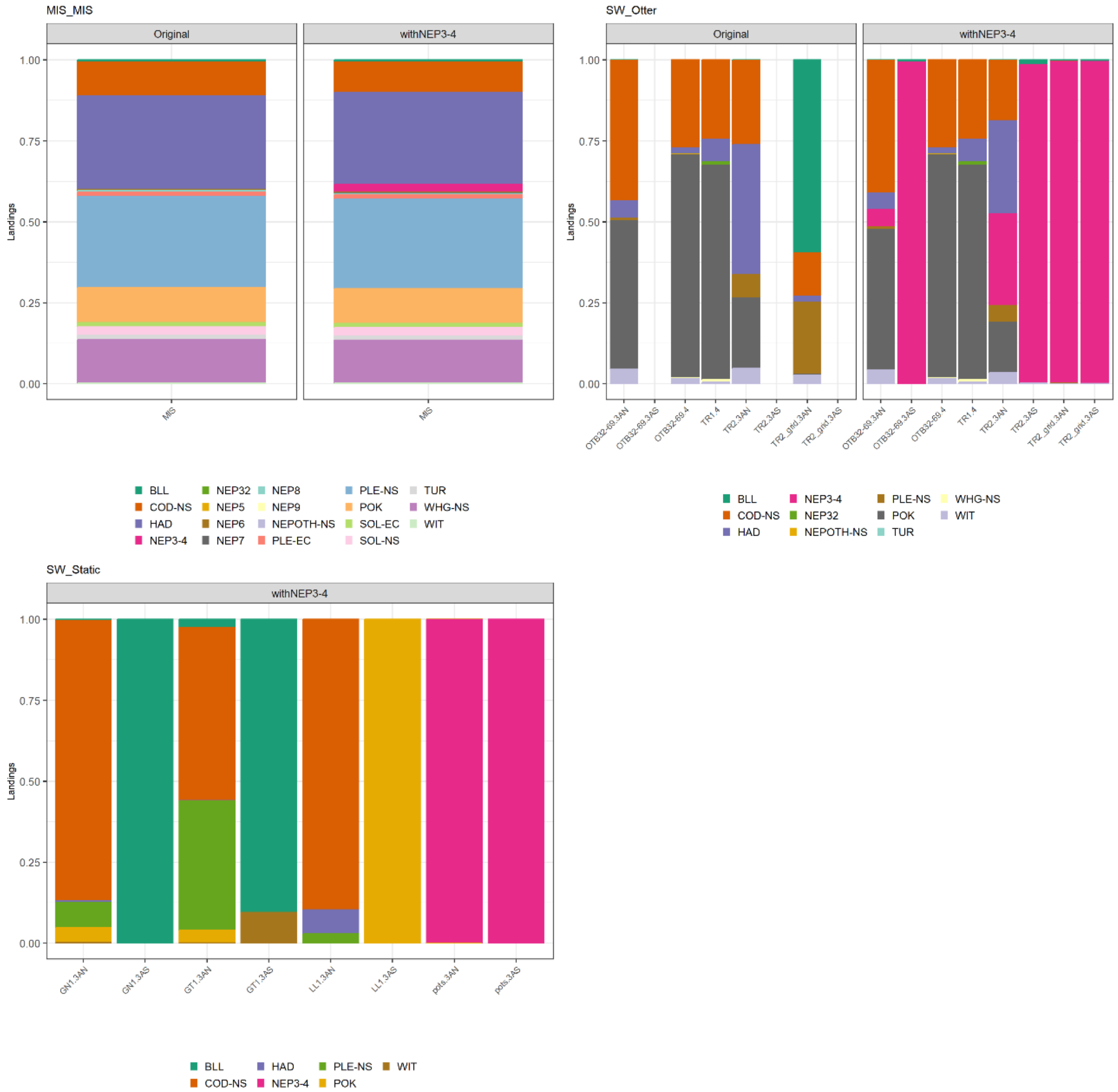

Figure A4.8: Landings composition of metiers within each Swedish fleet from WGMIXFISH-ADVICE 2023 (Original) and with the addition of FU 3–4 (withNEP3–4).

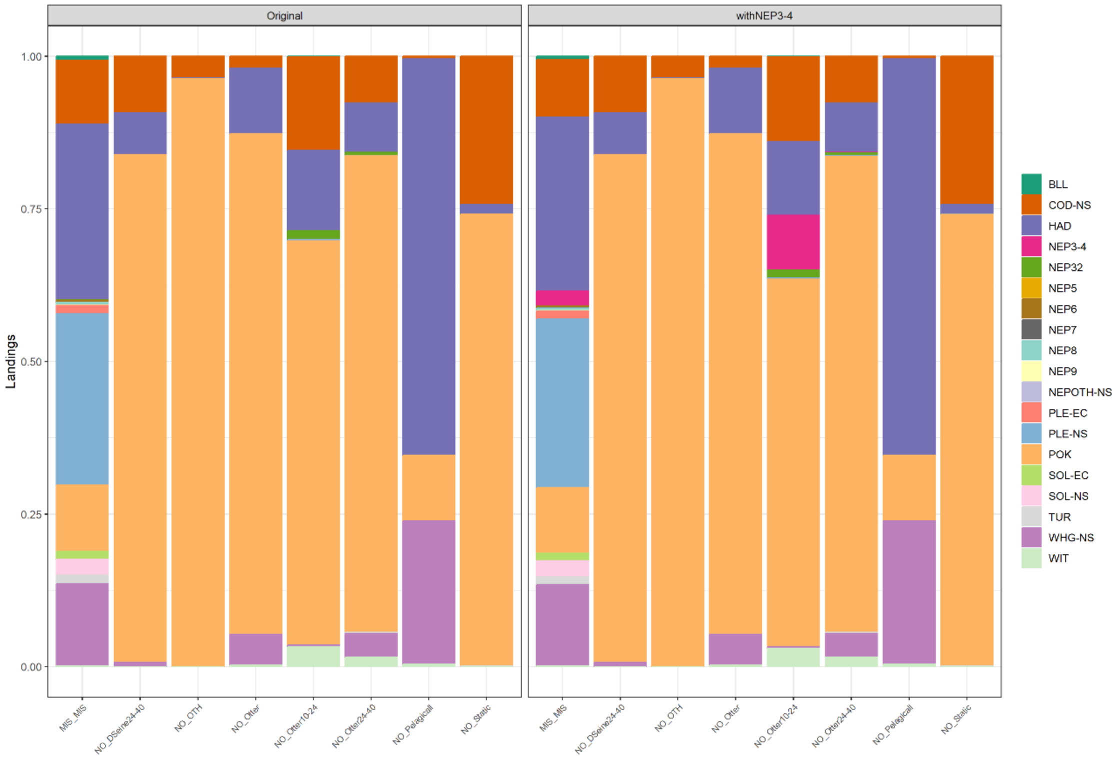

Figure A4.9: Landings composition of Norwegian fleets from WGMIXFISH-ADVICE 2023 (Original) and with the addition of FU 3–4 (withNEP3–4).

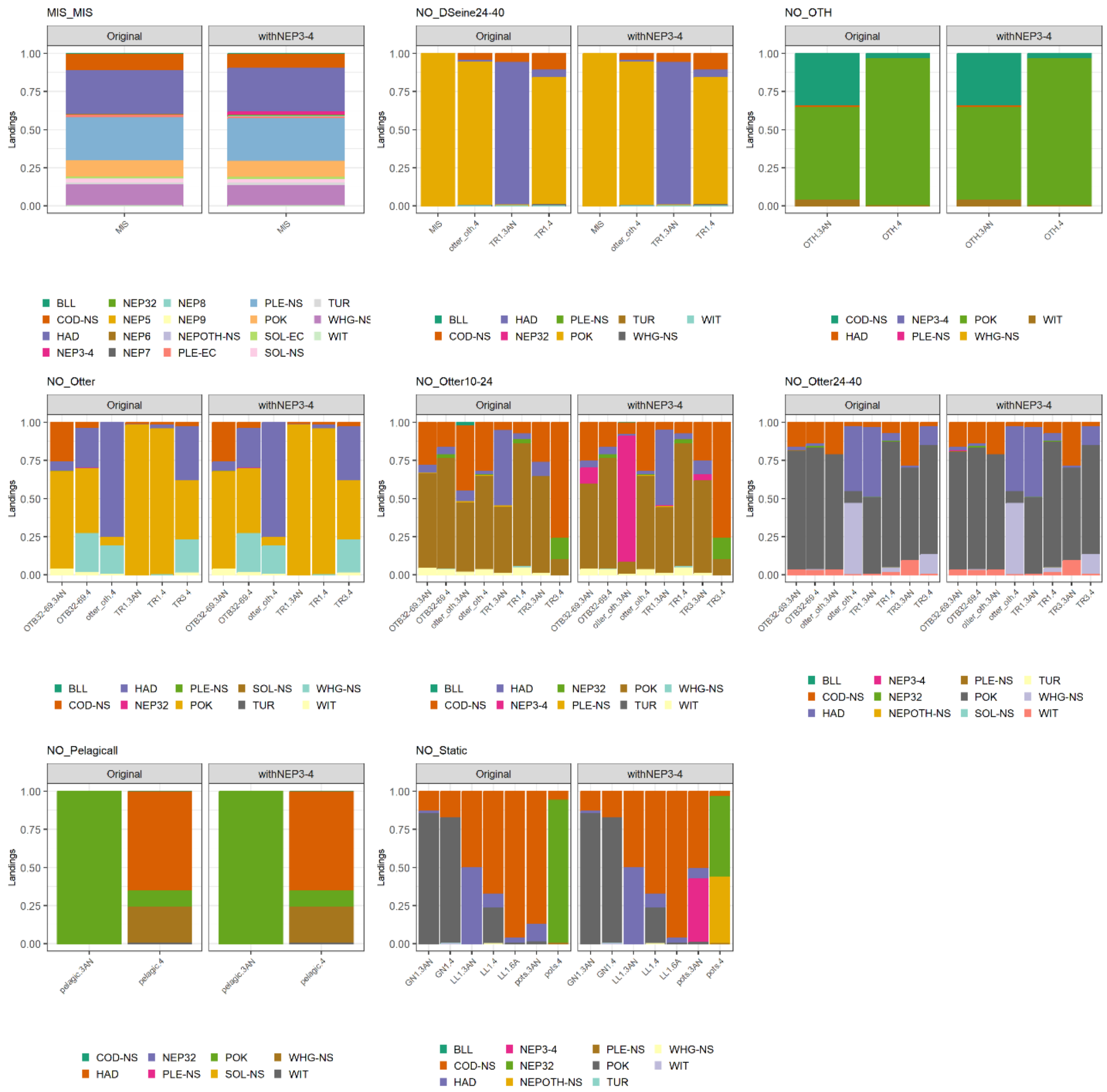

Figure A4.10: Landings composition of metiers within each Norwegian fleet from WGMIXFISH-ADVICE 2023 (Original) and with the addition of FU 3–4 (withNEP3–4).

Annex 5: Bio-economic IAM application to the Bay of Biscay at WGMIXFISH-METHODS

ESP	STOCK –STOCK ICES MIXFISH	Modélisation IAM
SOL	Sole 8abde - sol.27.8ab	Dyn
BSS	Seabass 8ab - bss.27.8ab	Dyn
HKE	Hake 78ab - hke.27.3a46-8abd	Dyn
ANK	budegassa - ank.27.78abd	Dyn
MON	pisc ratio ICES - mon.27.78abd	Dyn
LEZ	Megrims 8 (MEG+LEZ)- meg.27.7b k8abd -	Dyn
MAC	Mackerel 27	Dyn
HOM	H. mackerel- hom.27.2a4a5b6a7a-ce-k8	Dyn
WHB	Blue whiting- whb.27.1-91214	Dyn
NEP	N. lobster 8ab - nep.fu.2324	CPUE cstt
PIL	Pilchard 8ab +	CPUE cstt
ANE	Anchovy 8ab +	CPUE cstt
POL	Pollack 8ab- pol.27.89a	CPUE cstt
WHG	Whiting	CPUE cstt
RAYS	"RJO","RJB","SKA","RJG","RJA","RJC","RJU"	CPUE cstt
CTC	Cuttlefish – seiche commune	CPUE cstt
SQZ	Squids - encornet	CPUE cstt
OCC-	OCC et OCT en zone 8	CPUE cstt
MUR	Surmullet – rouget barbet	CPUE cstt
ALB	Germon	CPUE cstt
MGR	Meagre - maigre	CPUE cstt
BFT	bluefin tuna- thon rouge	CPUE cstt
SDV	sdv.27.nea- smooth Hound- émissole	CPUE cstt
ZZ	OTHER SPECIES	CPUE cstt

Table A5.1: detailed list of stocks modelled in IAM

METIER LIST
GN_CEP
GN_DEF
GN_OTH
GTR_CEP
GTR_DEF
GTR_OTH
L_OTH
LL_DEF
LL_OTH
OTB_CEP
OTB_CRU
OTB_DEF
OTB_OTH
OTH_
OTT_CEP
OTT_CRU
OTT_DEF
OTT_OTH
PS_OTH
PTB_OTH
SDN_OTH
TBB_DEF
TM_OTH

Table A5.2: detailed list of métier modelled in IAM

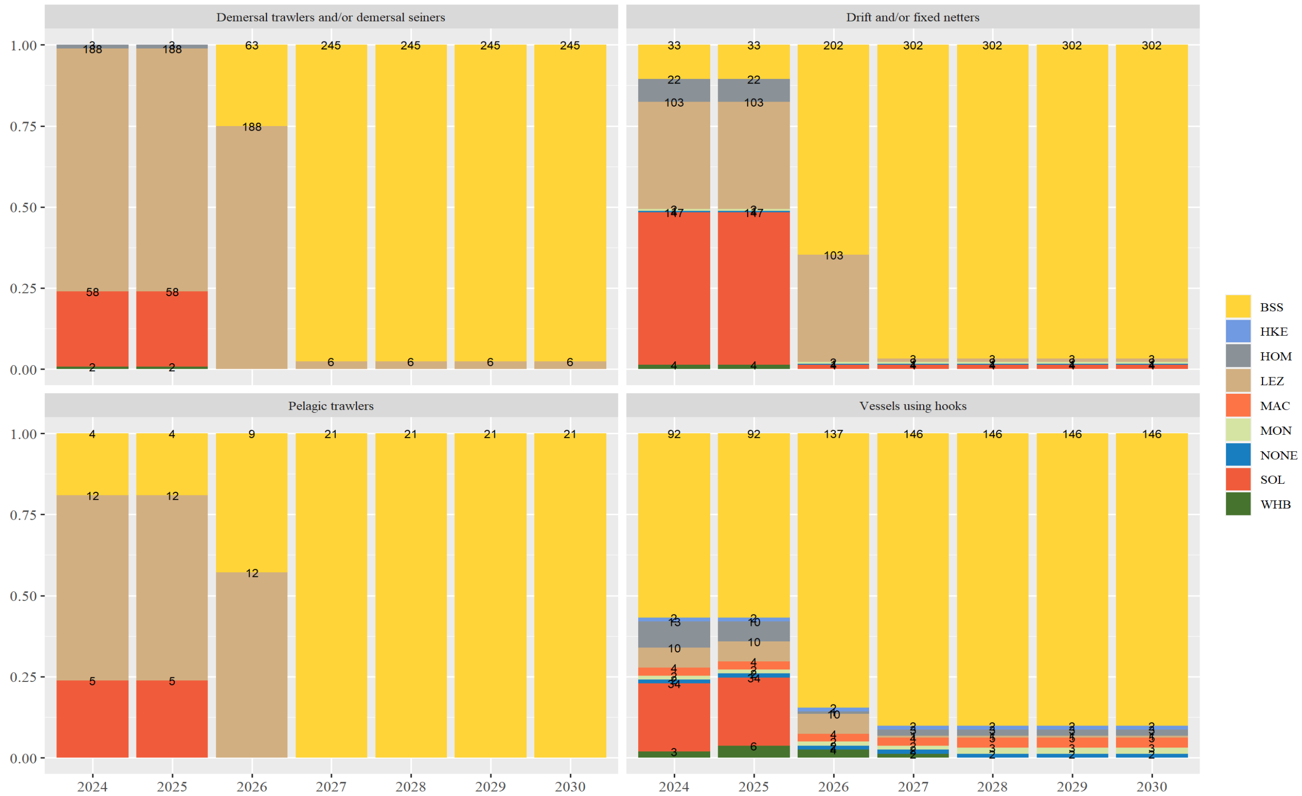

Figure A5.1: Example of preliminary results for the MIN scenario– Identification of the number of vessels by choke species by year and main fleet

! RESULTS NOT FOR USE FOR ADVICE – due to the inconsistent parameterization (2022 stock data with 2023 Effort/landings data) done only as a first approach for the proof of concept

Figure A5.2: Example of preliminary results for the MIN scenario – Identification of the percentage of vessels with positive and negative gross profit by year and main fleet.

! RESULTS NOT FOR USE FOR ADVICE – due to the inconsistent parameterization (2022 stock data with 2023 Effort/landings data) done only as a first approach for the proof of concept