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

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Harriet Cole • Marc Taylor

Authors

Alessandro Orio • Bernhard Kühn • Ching Villanueva • Claire Machar • Claire Moore • Dorleta Garcia
Gianfranco Anastasi • Harriet Cole • Hugo Mendes • Jasper Bleijenberg • Johnathan Ball • Klaas Sys
Kristiina Hommik • Lionel Pawlowski • Luca Lamoni • Marc Taylor • Margarita María Rincón
Mathieu Merzereaud • Matthew Pace • Mikel Aristegui • Neil Maginnis • Paul Dolder • Ruth Kelly
Santiago Cerviño • Sigrid Lehuta • Sonia Sánchez-Maroño • Thomas Brunel • Vanessa Trijolet
Youen Vermard

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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 2023 included improving workflows for the advice process, presenting methodological advances, developing new ecoregions and responding to issues encountered during WGMIXFISH-ADVICE 2022. Additionally, key developments arising from the Second Scoping Workshop (WKMIXFISH2) were discussed.

The primary development affecting data workflows related to developing a proactive response to the planned introduction of RDBES for stock assessment purposes. The introduction of RDBES will affect WGMIXFISH by replacing InterCatch and the current data call as a data source. The data access requirements and steps needed to transfer workflows to using RDBES as a data source were outlined and aligned with the timetable for the phased introduction of RDBES.

Several methodological advances were presented, many of which derive from either the STAR-MIXFISH project, the outcomes of the Second Scoping Workshop (WKMIXFISH2) or have been identified as a priority by WGMIXFISH. These analyses explored sensitivity to model assumptions, incorporating uncertainty in model parameters and novel methods for using spatial data to define métiers. Additionally, the application of mixed fisheries methods in externally developed models of the Bay of Biscay and Western Mediterranean were presented.

Significant improvements were progressed for the Iberian Waters and North Sea models. For the Iberian Waters, the potential for adding pelagic stocks such as mackerel and blue whiting to the model was explored with further work planned in the near future. In the North Sea, developments were made to the fleet data processing workflow to improve consistency with other ecoregions and plans were made to incorporate North Sea brill into the model following its recent move to a category 2 assessment. Additionally, work was conducted to explore feasible options for incorporating the new Northern Shelf cod assessment, which consists of 3 sub-stocks, following the recent benchmark of North Sea cod.

Finally, mixed fisheries analyses for the Baltic Sea were initiated and involved a review of existing data available to WGMIXFISH and the evaluation of alternative data sources. Planned work in this region in 2023 aims to provide an analysis of catch compositions for the ecoregion which will be presented in the Baltic Sea fisheries overview.

ii Expert group information

Expert group name	Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS)
Expert group cycle	Annual
Year cycle started	2023
Reporting year in cycle	1/1
Chair(s)	Marc Taylor, Germany
	Harriet Cole, UK
Meeting venue(s) and dates	19-23 June 2023, San Sebastian, Spain (30 participants, hybrid)

1 Introduction

Working Group on Mixed Fisheries Advice Methodology

The Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS) was formed in response to the need to further develop how ICES provides mixed fisheries advice and to progress the application of methods, independent of the annual advisory meeting (ICES, 2014). Annually this meeting focuses on the development and improvement of mixed fisheries analysis and advice.

WGMIXFISH-METHODS - Working Group on Mixed Fisheries Advice Methodology

2022/2/FRSG16 The Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS), chaired by Marc Taylor, Germany, and Harriet Cole, UK, will hold a hybrid meeting in San Sebastián, Spain, on 19–23 June 2023, to:

a. Continue the improvement of WGMIXFISH-ADVICE data call, data processing, 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 2023 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, workflow, auditing, updating associated documentation and increasing transparency

2.1 Summary of WGMIXFISH data submission

2.1.1 Accessions submission

Landing and effort data were submitted through the 2023 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 Norway. A submission from Norway will potentially be received before the Advice meeting in October.

Several new métiers appeared for the first time in the data for 2022:

Métier	Denmark	Lithuania	Netherlands	UK (England)	UK (Northern Ireland)
FYK_DEF->0_0_0		6			
GNS_ANA_>0_0_0		10			
GNS_ANA_110-156_0_0		6			
GNS_ANA_90-109_0_0		3			
GNS_DEF_32-89_0_0		4			
GNS_DEF_90-99_0_0_all	25				
GNS_SPF_32-89_0_0		8			
GNS_SPF_90-109_0_0		2			
HMD_MOL_>0_0_0			13		
OTB_CEP_32-69_0_0_all					1
OTB_SPF_16-31_0_0_all				24	
OTM_SPF_32-39_0_0			9		

The submissions received were processed within the *2023_wgmixfish_accessions* repository on GitHub. Here, simple fixes such as fixing typos, were made to the raw data across the whole time series. Furthermore, two new QC reports were made from the data. The first was a simplified version of the existing QC report that is used to give feedback to national data submitters. The second was a new, ecoregion report which aims to present an ecoregion-specific summary of the accessions data as well as compare the accessions data to that held in InterCatch for each stock included in the mixed fisheries models.

2.1.2 Methodologies for fishing effort calculations

The exact methodology used by national data submitters to calculate fishing effort for the WGMIXFISH data call is assumed to vary between countries. As a result, WGMIXFISH are unable to make comparisons of fishing effort between countries. However, as methodologies are consistent within countries, trends in fishing effort by country can be assessed. To bring some clarity, WGMIXFISH asked for information on the methodology used to calculate the number of days at sea, fishing effort in KWdays and the number of vessels in the 2023 data call.

In 2016, the report on the 2nd Workshop on Transversal Variables set down guidance and definitions for calculating fishing effort (STECF, 2016) This guidance is often referred to as "fecR" logic. Under this guidance, active gears are assumed to happen sequentially, and so fishing effort is split proportionally across all fishing operations taking place in a day whereas static gears can be used in parallel and so are each fishing operation in a day gets allocated 1 fishing day. The definition used for days at sea is the time absent from port in sequential 24-hour periods whereas a fishing day is defined as any day on which a fishing operation takes place.

Following the data call, we received submissions from 8 out of 17 submitters - Belgium, Germany, Spain (AZTI), Finland, Northern Ireland, Netherlands, Poland and Sweden. The results are summarised in Table 2.1. In many cases the "fecR" logic is used although not across all countries. Often the calculation method used for days at sea is the same method used when calculating fishing effort in KWdays although there are a few cases where the fecR definitions are used (absences days vs days with fishing operations). In all cases the number of vessels reported links to the stratum requested and so if a vessel partakes in multiple métiers or areas then it will be counted several times across the whole dataset.

This information provides a useful reference for WGMIXFISH and it is encouraging to see that many countries are following the recommendations made by the 2nd Workshop on Transversal Variables (Castro Ribeiro *et al*., 2016). We will ask for this information again in 2024 to obtain it from all countries.

Country	Number of days at sea	Fishing effort in KWdays, i.e. total métier engine power in kW times fishing days	Number of vessels executing this activity at this level of aggregation
Spain-AZTI	days with fishing operations. Days with multiple fishing operations still count as 1 day.	kw * days with fishing operations	Vessels may operate using multiple gears and in multiple areas, in this case they are included in the count of vessels in each métier and area in which they operate.
Germany	Absence days from the moment they leave and return to port.	kw * absence days from the moment they leave and return to port.	Vessels may operate using multiple gears and in multiple areas, in this case they are included in the count of vessels in each métier and area in which they operate.
UK-Northern Ireland	Absence days from the moment they leave and return to port.	kw * days with fishing operations using fecR logic.	Vessels may operate using multiple gears and in multiple areas, in this case they are included in the count of vessels in each métier and area in which they operate.

Country	Number of days at sea	Fishing effort in KWdays, i.e. total métier engine power in kW times fishing days	Number of vessels executing this activity at this level of aggregation
Finland	For vessels less than 10 metres in length, days at sea = soaking time. For vessels over or 10 metres length = absence days divided equally between fishing operations (fecR logic).	For vessels less than 10 metres in length = kw * soaking time. For larger vessels = kw * days with fishing operations using fecR logic.	Vessels may operate using multiple gears and in multiple areas, in this case they are included in the count of vessels in each métier and area in which they operate.
Belgium	Absence days from the moment they leave and return to port.	For static gears – kw * fishing days calculated using fecR logic. For active gears – kw * fishing days based on fecR logic but fishing days are divided over the ICES rectangles proportionally to fishing hours per rectangle.	Vessels may operate using multiple gears and in multiple areas, in this case they are included in the count of vessels in each métier and area in which they operate.
Netherlands	Absence days from the moment they leave and return to port.	kw * absence days then divided by each catch registration record.	Vessels may operate using multiple gears and in multiple areas, in this case they are included in the count of vessels in each métier and area in which they operate.
Poland	Absence days from the moment they leave and return to port using fecR logic.	kw * days with fishing operations using fecR logic.	Based on stratum requested.
Sweden	Absence days from the moment they leave and return to port using fecR logic.	kw * absence days using fecR logic.	Vessels may operate using multiple gears and in multiple areas, in this case they are included in the count of vessels in each métier and area in which they operate.

Table 2.1: Summary of methodologies used per country to calculate fishing effort data.

2.2 Suitability of available data to realize next generation of mixed fisheries models

Over the next few years, the RDBES will come online and replace InterCatch as the database for stock assessment purposes. This will be a phased introduction over the next few years (detailed in Table 2.2) with InterCatch becoming obsolete by 2027. As such, WGMIXFISH needs to start planning to update our data processing flows alongside the phased introduction of RDBES. In the first instance this means becoming familiar with the RDBES data model and the Transparent Assessment Framework (TAF). WGMIXFISH will also need to request access to the scripts used to raise the catch data as well as the resulting raised catch data for WGCSE, WGNSSK and WGBIE stocks which are included in our mixed fisheries models.

Furthermore, WGMIXFISH will need to work with national data submitters to develop common scripts to reproduce the data provided through current WGMIXFISH data call. This would also be an opportune moment to request additional information that would help improve the input data to our models. In the shorter term this would include disaggregating métier level data by national fleet segment, accurate information on fleet capacity, requesting information on "Fishing Technique" as defined by Annual Economic Report and requesting additional species. In the longer term, WGMIXFISH will need to work with national institutes to manage confidentiality issues to enable access to data at smaller spatial and temporal scales (i.e., statistical rectangle and haul level). This will facilitate our ability to properly characterize technical interactions at an appropriate scale.

	2023	2024	2025	2026	2027
InterCatch	Data uploaded & download	Data uploaded & download	Data uploaded & download	Data uploaded & download	Data download
RDBES	Data uploaded & download	Data uploaded & download	Data uploaded & download	Data uploaded & download	Data uploaded & download
Data Calls	RDBES data call - 2022 data (sept) Recreational data call (in excel) IC data call WGBYC data call	RDBES data call - 2023 data (TBD) RDBES older data (2020, 2021)? Recreational data call IC data call WGBYC data call	RDBES datacall - 2024 data RDBES older data? (TBD) Recreational DC IC DC WGBYC DC	RDBES datacall - 2025 data RDBES older data? (TBD) Recreational DC IC DC	RDBES datacall - 2026 data RDBES older data? (TBD) Recreational DC
Use of RDBES in stock assessment	Countries can start using RDBES data for estimations. AWG can request CL and CE data. Test the use of RDBES data in the assessment	Use of RDBES data in the assessment for selected stocks (preferably in TAF)	Use of RDBES data in the assessment for selected stocks (preferably in TAF)	Use of RDBES data in the assessment for all stocks (preferably in TAF)	Use of RDBES data in the assessment for all stocks (in TAF)

Table 2.2: Summary of the phased introduction of RDBES.

2.3 Advice plan

As per last year an Advice meeting 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 ecoregion have been identified and allocated members of the group. The Baltic Sea has been added to WGMIXFISH as a new ecoregion this year and work has started to analyse the available data ahead of developing a mixed fisheries model over the next few years. The aim for this year is to produce summary plots for the mixed fisheries section of the Baltic Sea Fisheries Overview at the 2023 Advice meeting.

An online meeting has been scheduled (early September 2023) ahead of the WGMIXFISH-ADVICE 2023 meeting (2-6 October 2023) 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. Further to this, an Advice follow-up meeting will be scheduled two weeks after the start of the Advice meeting. This follow-up meeting will be used to address any outstanding issues from the Advice meeting such as changes to the *Nephrops* advice following ADGNEPH (9-13 October 2023) and corrections to any single stock assessment errors found by WGMIXFISH.

Baltic Sea

Advice 2023	No	Summary plots for Fisheries Overview to be provided
TAF repo	Yes	https://github.com/ices-taf/2023_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 2023	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/2023_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 Altuna, maltuna@azti.es	

Celtic Sea

Advice 2023	Yes	ank.27.78abd, cod.27.7e-k, had.27.b-k, whg.27.7b-ce-k, 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, sol.27.7e
TAF repo	Yes	https://github.com/ices-taf/2023_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 Mikel Aristegui-Ezquibela, Mikel.Aristegui@Marine.ie Paul Dolder, paul.dolder@cefas.gov.uk Johnathan Ball, johnathan.ball@cefas.gov.uk	

Iberian Waters

Advice 2023	Yes	ank.27.8c9a, mon.27.8c9a, ldb.27.8c9a, meg.27.8c9a, hke.27.8c9a, hom.27.9.a
TAF repo	Yes	https://github.com/ices-taf/2023_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 2023	Yes	cod.27.7.a, had.27.7.a, whg.27.7.a, NEP.FU.15, NEP.FU.14
TAF repo	Yes	https://github.com/ices-taf/2023_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 2023	Yes	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, bll.27.3a47de, 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/2023_NrS_MixedFisheriesAdvice
Stock Annex	Yes	North Sea Mixed Fisheries Annex (ices.dk)
Subgroup leader	Vanessa Trijoulet, vtri@aqua.dtu.dk	
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 Vanessa Trijoulet, vtri@aqua.dtu.dk Marieke Desender, marieke.desender@cefas.co.uk Jasper Bleijenberg, jasper.bleijenberg@wur.nl	

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

3.1 WKMIXFISH2 summary

The outcomes of Second Scoping workshop on the next generation of mixed fisheries considerations (WKMIXFISH2), held in March of this year (ICES, 2023a; WKMIXFISH2), were summarised during this year's WGMIXFISH-METHODS meeting. The objectives of WKMIXFISH2 included: 1. Continue a dialogue with advice recipients, stakeholders, and scientists on developing mixed fisheries science and advice to meet management needs; 2. Establish the current use and utility of mixed fisheries considerations and identify priority areas for future development; and 3. Identify concrete actions that can be taken forward to a future WKMIXFISH3, to be held in 2024.

In particular, the WKMIXFISH2 meeting identified several areas of potential improvements in methodology and communication, which WGMIXFISH has added to its list of goals for the coming years (see Section 5 in ICES, 2023a). Many of these goals coincide with ongoing topics previously identified by WGMIXFISH, as well as topics currently being addressed within projects currently underway (e.g., STARMIXFISH). These include improvements in the presentation of mixed fisheries considerations, such as more clearly worded assumptions and guide to interpretation, as well as rationale for stock inclusion in the model and additional summary graphics. Technical improvements, which largely overlap with topics of ToR C, include: 1. Fleet and métier definitions; 2. Quota share distributions among fleets; 3. Effort share among métiers in a given fleet; 4. Treatment of uncertainty; and 5. Further scenarios to inform decision making. It was also suggested that other advisory products could be offered that aid in how stakeholders interpret and respond to WGMIXFISH-ADVICE, e.g., spatial information on catch distributions and technical interactions, and more interactive advice products (see Section 3.3).

3.2 WKFO2 summary

A summary of the work conducted at the second Workshop on Fisheries Overviews (WKFO2) to improve the plots presenting mixed fisheries information and the exploration of the RDBES as an alternative database was presented. Further details can be found in the WKFO2 report (ICES, 2023e; WKFO2, *in preparation*).

3.3 Interactive advice

The ICES Secretariat has initiated work on an online application to support the work of WGMIXFISH. The objective of this app is support the usage of Mixed Fisheries Considerations by providing customisable viewing options for users. This will allow for users to explore the data underpinning the published advice to a greater level of detail than is possible in the published document. It is hoped that the ability to focus on and explore areas of particular interest will enhance understanding of Mixed Fisheries Considerations building greater confidence in it and accelerate its utilisation. The app will initially focus on reproducing and standardising the figures common across the ecoregions for which Mixed Fisheries Considerations is provided, supplementing these where possible with figures that facilitate easier interpretation of the data. At the outset the app is planned as a stand-alone app, though the appropriateness and feasibility of integrating the final product into the existing AdviceXplorer can be assessed at a later date. A first version of the app is planned to be available for ADGMIXFISH in October 2023.

3.4 Methodological framework and best practice

Clear, consistent communication and clear explanations of methodological choices and scenario results were identified at WKMIXFISH2 as important to improving confidence in our modelling framework. To address this, a Methodological Framework document was started last year to provide written explanations of the methodological choices made across the ecoregion models. This year, this was taken a step further to start defining "best practice" in our methodologies with the intention to move towards implementing these consistently across the ecoregions. The best practice topics discussed this year are detailed below.

3.4.1 Definitions and naming convention for miscellaneous fleets

Currently, all ecoregions modelled by WGMIXFISH have a number of miscellaneous or "other" métiers and fleets often called "MIS", "OTH", or "OTH_OTH". However, the naming, definition and purpose of these miscellaneous métiers and fleets vary between the ecoregions. The purpose of these métiers and fleets fall into two basic categories: métiers/fleets that encompass the smallest proportion of total catches; and pseudo-fleets that account for the difference between the catches reported by the single stock assessment and the catches contained within our fleet data (obtained from the WGMIXFISH data submission).

The definitions used by each ecoregion to define the métiers and fleets responsible for smaller catches are described in Table 3.1. The general approach is to aggregate métiers and fleets that only account for a small proportion of the total catches together under a "OTH" / "MIS" / "OTH_OTH" métier or fleet based on their contribution to the total landings. As such, these miscellaneous fleets consist of real fleet data and enable us to capture the majority of fleet dynamics in the lowest number of fleets and métiers.

There is some variation in how this approach is applied across the ecoregions. Firstly, the threshold proportion applied is ecoregion-specific, often defined through conducting a sensitivity analysis. Secondly, this threshold can be applied to métiers within a fleet or métiers across all fleets. Thirdly, some ecoregions choose to allocate a miscellaneous fleet by country whereas other ecoregions aggregate the smaller catches from all countries together. These country-specific miscellaneous fleets are used when very different fishing behaviour and landings profiles are observed between countries.

	"OTH" métier/"MIS" métier	"OTH_OTH" fleet/"MIS" fleet
North Sea	Métiers that fail to catch at least 1% of the total landings for any stock in the data year	Fleets that contain only the "OTH" métier.
Celtic Sea	Métiers within a fleet that contribute less than 10% of the total landings of any stock caught by the fleet, in the last 3 years.	Fleets catching less than 1% of the total landings of any stock caught, in the last 3 years.
Bay of Biscay	Métiers within a fleet that contribute less than 2% to a stock's landings for that fleet, in the last 3 years. ("MIS" métier).	Fleets catching less than 1% of the total landings of all stocks considered, in the last 3 years (country specific "MIS" fleet).
Iberian Waters	Métiers associated with the small, artisanal, multi-gear are combined under one métier ("MIS"). Métiers within a fleet that contribute less than 2% to a stock's landings for that fleet, in the last 3 years ("MIS" métier).	Fleets catching less than 1% of the total landings of all stocks considered, in the last 3 years (country specific "MIS" fleet).

Irish Sea	Métiers that fail to catch at least 1% of the total landings for any stock ("OTHER").	"OTH_OTH" fleet combines all small fleets and métier with landings < 1% for any stock in the model.

Table 3.1: Definitions used by each ecoregion to define métiers and fleets responsible for landings that account for a small proportion of the total catches.

The cases where pseudo-fleets are used to account for the difference between the catches reported by the single stock assessment and the total fleet data catches by stock are detailed in Table 3.2. These pseudo-fleets do not contain information from actual fleet data and exist to ensure that the total removals by stock put into the mixed fisheries models are equal to the single stock assessment. Most often these pseudo-fleets are stock specific although in the case of the North Sea, where most missing catches are due to incomplete data from Norway, it is difficult to separate out of area catches (e.g., saithe in 27.6.b) from the missing Norwegian fleet segments.

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

Table 3.2: Sources of, and method for, accounting for missing catches by ecoregion.

Several suggestions were made to provide some consistency in the definition, naming and purpose of the miscellaneous métiers and fleets:

- Implement a consistent naming convention using "MIS" for métiers and fleets responsible for smaller catches, based on real fleet data and "OTH" for fleets accounting for differences in observed catches between our fleet data and the single stock assessment.
- Consider if using country specific "MIS" fleets would be more appropriate (North Sea, Celtic Sea, Irish Sea).
- Test effect of applying "MIS" métier threshold within a fleet rather than across all fleets (North Sea, Irish Sea).
- Investigate the sources of missing observed catches in the North Sea to assess if the current "OTH_OTH" fleet can be separated into a "MIS" fleet for smaller métiers and a "OTH" fleet to account for missing catches.

Additionally, stakeholders and advice requestors at WKMIXFISH2 requested clearer information on the allocation of métiers and fleets in the model. As a result, tables will be added to the WGMIXFISH-ADVICE report that detail the allocation of the raw fleet data received in the data call to the métier and fleet designation used as input to the model for each ecoregion.

3.4.2 Fleet scaling procedure for consistency with single stock advice

During the fleet building process described above, a top-up of catches is made when the fleet data catches, based on InterCatch and WGMIXFISH Accessions data, are less than the reported, *observed* catches in the single stock assessment. However, to ensure consistency with the single stock advice, the catches *estimated* by the stock assessment models are used as input to the initial conditioning of the mixed fisheries model. This is to ensure that mixed fishery forecasts match as closely as possible to the assumptions of the single stock assessments.

First, discrepancies between observed catches used by the stock assessment and those of the fleet data are likely due to missing country submissions or out-of-area catches. Out-of-area catches may result in cases where a stock's definition is only partly covered by a given case study's defined model domain. Both missing country submissions and out-of-area catches are best covered by topping-up catches by other fleets ("OTH"), as described in the section above.

Second, after disparities in observed catches are accounted for, a final scaling procedure is advised in order to account for differences in observed versus estimated catches during the stock assessment. Estimation of catches may be done in cases where the input catch data is expected to contain errors ("observation error"). As stock assessments do not typically define catches by fleets, scaling of fleet catches in mixed fishery models will likely need to be scaled up or down uniformly across fleets such that their catches in aggregate equal those estimated by the stock assessment.

In summary, the suggested procedure is as follows:

- Conditioning fleet to observed catches.
    - Process fleet data as usual to make fleet and métier designations. Aggregate métiers and fleets responsible for smaller proportions of the total catches.
    - Add pseudo fleets for out-of-area catches and missing fleet segments. This should be done by comparing total catches by stock in the fleet data to the **observed** stock assessment catches.
- Scaling fleet to estimated catches.
    - For each stock, compare total catches in the fleet data to the total catches **estimated** by the single stock assessment model. If fleet data totals exceed the stock assessment totals, apply a scaling factor to all fleets such that totals match that of the stock assessment.
    - Differences of +/-10% or less are generally acceptable. If the difference exceeds 10% then the stock assessor should be contacted for an explanation and more information to explain the mismatch (e.g., does it concern certain fleet segments or age classes).
- After scaling the total catches the catchabilities (q) should be recalculated.
- If this scaling procedure was required, then a description should be added to the WGMIXFISH-ADVICE report stating the degree and reason for mismatches.

3.4.3 Replacement for "range" scenario

At last year's Advice meeting, the "range" scenario results were not presented in mixed fisheries consdierations following concerns over its interpretation. The "range" scenario was a two-step process. First, a mixed fisheries optimization procedure was used to find an optimal suite of target Fs across several stocks by minimizing the difference between the "min" and "max" scenario results using the F_{MSY} ranges as upper and lower limits on the target F. Then, these target F's were used in a single stock forecasting framework to derive the corresponding target catches. However, although this scenario appears to result in a multi-stock, mixed fisheries solution in terms of target catches, the results should not be interpreted in this way. This is because the optimization procedure is only driven by the differences in catch of the most and least limiting stocks whereas the F solutions for intermediate stocks were not seen to be stable within the optimization.

Despite this, the premise of F_{MSY} ranges that form the basis of the "range" scenario remain available to managers as a tool to alleviate choking in mixed fisheries. The F_{MSY} ranges were derived from ideas such as "pretty good yield" (Rindorf *et al.*, 2016) and are formalized in the MAPs where the use of the upper F_{MSY} range to alleviate choking is permitted when a stock is in good status (SSB > MSY $B_{trigger}$). Currently, the MAPs are not the agreed basis of advice for most stocks although the F_{MSY} ranges are often requested by advice recipients as a catch option in the single stock advice. Therefore, a mixed fisheries scenario based on the use of the upper F_{MSY} range for stocks of good status is likely of interest to clients that receive the advice.

A new "range" (named "pgy" (pretty good yield) here) scenario was presented where the target catch is set to the advised $F_{MSY\ upper}$ catch option, where available, for stocks with SSB above MSY $B_{trigger}$. This scenario aims to demonstrate if using the $F_{MSY\ upper}$ range would help alleviate choking effects. This scenario would likely be more intuitive and therefore have less chance of being misinterpreted. It is also done wholly within the mixed fisheries model and is therefore directly comparable with the existing mixed fisheries scenarios. Additionally, it avoids being interpreted as an optimal TAC solution by remaining just an additional scenario. Wanting a focus on scenarios rather than solutions was a key outcome from WKMIXFISH2.

An example of the results is given below for the North Sea 2023 mixed fisheries considerations (Figure 3.1 and Table 3.3). In this example we can see that the "pgy" scenario results are identical to the "min" scenario results. This is because all fleets are limited by a stock whose status is below $B_{trigger}$ (wit.27.3a47d (n=32), cod.27.47d20 (n=6), sole.27.4 (n=4), nep.fu.6 (n=1), and pok.27.3a46 (n=1)), which prevents the use of the upper F_{MSY} range. It is expected that the "pgy" scenario results will usually be the same as the "min" scenario as the choke stock is usually caught by the majority of the fleets and is often in poor biological healthy. In this case, the key message would be that choke stocks need to be recovered back to good status before any advantage given by the upper range can be used to alleviate choking. However, giving similar results to the "min" scenario may not happen every year depending on stock development year to year. Furthermore, there may be a minority of fleets in the model which are choked by a health stock and so may benefit under the "pgy" scenario, and these fleets could be identified from the model and reported.

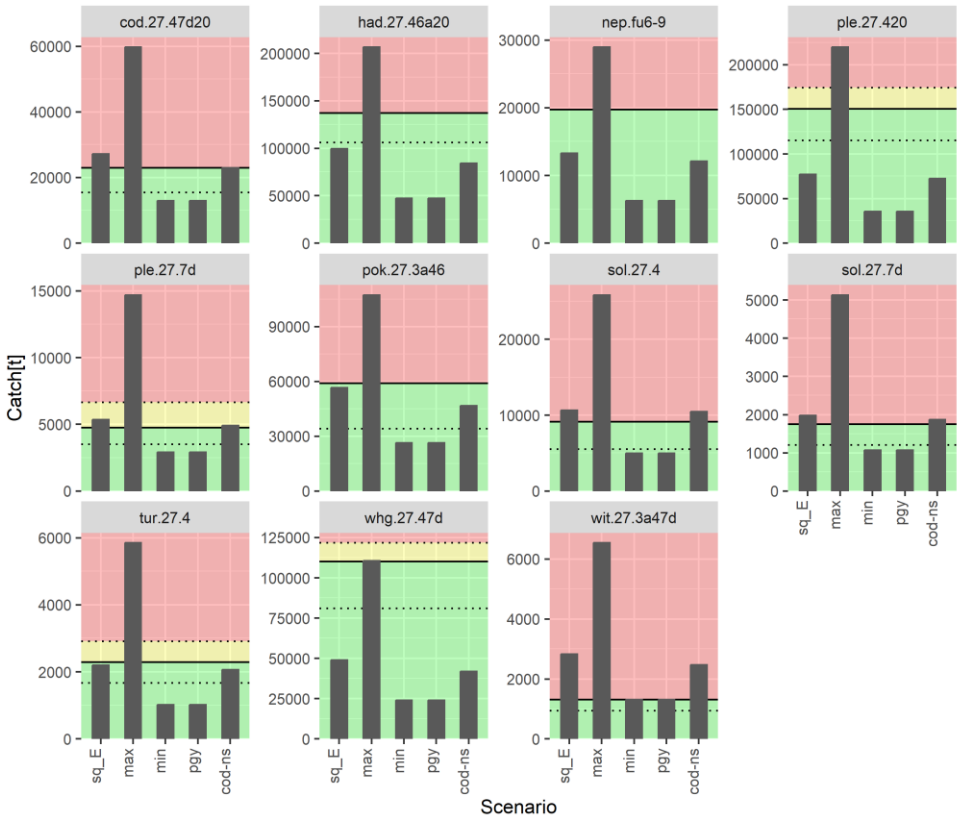


Figure 3.1: Mixed fisheries scenario results for catches in 2023 for stocks in the North Sea. The single stock advised catch (MSY approach) is given by the solid horizontal line. Dashed horizontal lines denote the F_{MSY} upper and lower ranges, where available. The upper range is not available for stocks with poor stock status (cod.27.47d20, wit.27.3a47d, sole.27.4, sole.27.7d, pok.27.3a46) and is equal to F_{MSY} for some stocks (had.27.46a20). The background colours indicate where catches fall below F_{MSY} (green), between F_{MSY} and F_{MSY} upper (yellow) and above F_{MSY} upper (red).

Stock	Single-stock catch advice (2023)	Catch per mixed-fisheries scenario (2023)				
		sq_E	max	min	pgy	cod-ns
cod.27.47d20	22 946	27 190	59 747	12 884	12 884	22 946
had.27.46a20	137 058	99 633	206 697	47 316	47 316	84 362
ple.27.7d	4738	5336	14 689	2912	2912	5018
ple.27.420	150 705	77 207	219 811	35 639	35 639	72 476
pok.27.3a46	58 912	56 586	107 288	26 385	26 385	46 694
sol.27.7d	1747	1976	5133	1073	1073	1920
sol.27.4	9152	10 637	25 846	4957	4957	10 458
tur.27.4	2432	2202	5848	1023	1023	2066
whg.27.47d	110 172	48 865	110 594	23 911	23 911	41 888

Table 3.3: Mixed fisheries scenario results for catches in 2023 for stocks in the North Sea with the addition of the proposed "pretty good yield" (*pgy*) mixed fisheries scenario.

3.4.4 Advice sheet updates

A clear outcome of WKMIXFISH2 was a request for clearer and more consistent communication of mixed fisheries considerations. WGMIXFISH-METHODS responded to this by discussing ways to give clearer explanations for choices made in the results presented as well as providing more detail in interpreting the scenario results.

Specific examples where this is needed are:

- Presentation of ecoregion specific scenarios: each ecoregion generally has a specific scenario which is particularly relevant to the mixed fisheries issues that exist in the area and is presented alongside the standard scenarios ("sq_E", "min", "max"). However, sometimes it is not very clear why a particular additional scenario has been presented. A sentence to explain this will be added to each advice sheet in 2023.
- Interpreting the headline result: the core assumption in the mixed fisheries models is that fishing behaviour at fleet level in the scenarios is assumed to be equal to the recent past. Thus, the scenario results can be interpreted as highlighting the incompatibilities that exist in the single stock advice when placed a mixed fisheries context, given no change from the recent past in fishing behaviour or decisions. Changes to the text in the headline section of each advice sheet will be made to explicitly highlight this core assumption.
- Explanation of standard scenario results: greater attention will be given to the advice sheet text that interprets the results of the standard scenarios to ensure that the information given is pertinent and understandable.

3.5 Roadmap

Topics for methodological development within WGMIXFISH have been identified both internally by the working group as well as through consultation with stakeholders, and have been categorised according to short-, medium-, and long-term goals (ICES, 2023a). In the short-term, the group is engaged with topics that deal with improved communication of mixed fisheries considerations and the definition of best-practices for greater consistency of methodologies among case studies (e.g., definition of scenarios, definition of fleets/métiers, inclusion of stocks, data merging procedures).

In addition to the advancements presented in this report, the WGMIXFISH members are involved with other projects (e.g., STARMIXFISH) and working groups (WGMIXFISH-ADVICE, WKMIXFISH2) that relate to these methodological developments. The EU-funded project STARMIXFISH is focussing on several aspects relating to the testing of model assumptions and their robustness in forecasting. The project is planned for completion in September 2023, upon which a report will be published. The annual Advice meeting will be in October 2023, with the WGMIXFISH-ADVICE report scheduled to be published in November 2023. The group plans to include several advancements in the mixed fisheries considerations and accompanying report, as proposed during this meeting and by WKMIXFISH2; including guiding text / preamble on its interpretation; refined scenarios (e.g. species-specific, range); additional documentation of métier data matching procedures to facilitate stakeholder feedback on fleet/métier definitions.

A follow-up scoping workshop on next generation of mixed fisheries considerations (WKMIXFISH3) is planned for spring 2024, where the group will again meet with stakeholders to present these recent advances.

Other areas of development include establishing new data flows from RDBES. The use of RDBES for stock assessment will be phased in over the next few years and aims to be used for all stocks by 2027. The RDBES will replace InterCatch and the WGMIXFISH data call as our data sources and so work is needed to establish access to the correct data and develop scripts for data processing and extraction. Alongside this, the RDBES will give WGMIXFISH access to new information pertinent to defining fleets in a way that relates to economic factors or national designations (e.g., “fishing technique”, “fleet segment”). Additionally, work conducted for the STARMIXFISH project to develop methods for objectively describing métiers will be available in the medium term for application to the RDBES data.

Key events and planned developments described in the text above are summarised in the table below.

	2023	2024	2025+
Key events	STARMIXFISH report	WKMIXFISH3 workshop	InterCatch becomes download only (2027)
Key RDBES events	CE and CL available to AWGs but aggregated.	Some stocks now using RDBES for catch estimation.	3 years of CL and CE will be available in RDBES in 2025. All stock assessments will use RDBES for catch estimation from 2026.
RDBES tasks	Define access needs and request access to data and scripts.	CE and CL data exploration. Work with national data submitters to recreate current accessions data call submission. Develop procedure to extract raised catch information from RDBES for relevant stocks.	Explore sampling table (CS) data if available. Continue to refine and expand use/extraction of data from RDBES.
Communication	Initiate best practice/methods framework document. Adjust advice sheet language and terminology. Include table to detail métier/fleet definitions from raw data per ecoregion. Make improvements through WKFO2 to mixed fisheries information in Fisheries Overviews. First release of interactive MF considerations goes live.	Develop and implement best practice/methods. Present advances and future proposals to WKMIXFISH3 for feedback. Further development of interactive MF considerations goes live.	Continue to develop and implement best practice.
Fleet/métier designations	Identify data needs and human resources for workshop.	Data call: add call for information on fleet segment and/or fishing technique. Compare national fleet designations to MF designations. Further development of métier description methodologies.	Proposed workshop on métier definitions: test methodologies to best describe métiers and incorporate stakeholder feedback/views.
Model performance	Investigation of sensitivity to fleet/métier definitions. Investigation of sensitivity to uncertainty in input parameters. Development of hindcasting/validation techniques.	Present findings at WKMIXFISH3. Further development and implementation of hindcasting methods. Consider methods for presenting sensitivity information in MF considerations.	…
New scenarios/ecoregions	Implement new “range” scenario. Baltic Sea – produce catch compositions plots for Fisheries Overview.	Baltic Sea - build fleets, start on exploratory model.	Baltic Sea - model refinement, conduct review process. Possible first release of Baltic Sea MFC in 2026. Exploration of defining stock rebuilding scenarios

4 ToR C: Exploration of developments in methodology and advice

This section describes methodological developments presented at this year's meeting. Many of these items relate to work being undertaken as part of the STARMIXFISH project (Study to Assess the Robustness of Mixed Fisheries Scenario Assumptions, EASME/EMFF/2018/011), as a response to the outcomes of WKMIXFISH2 or from needs identified within WGMIXFISH. However, the last section summarizes broader mixed fisheries work being undertaken by external projects.

4.1 Advice on interactions among different stocks

Technical interactions in fisheries occur where a fishing operation catches more than one stock at the same time. This can range from stocks that are often caught together to stocks that are seldom caught together. There is an identified need to develop and apply methods that can describe the strength of the interactions between stocks, both quantitatively and qualitatively, to inform on what fisheries may impact on the management outcome for other stocks.

A presentation highlighted the main features necessary to address this goal, that the method must be:

- Qualitative but ideally quantitative, i.e., it must identify whether an interaction is strong or weak, and ideally estimate the strength of the interaction,
- It must be a general approach that can be applied to readily available data across all regions of interest,
- It must be able to take account spatial and temporal variability, and gear effects.

Correlation based approaches: Simple correlation-based approaches were first reviewed, where the spatial correlation among pairs of stocks were first estimated based on international landings data at the ICES statistical rectangle level (STECF FDI, 2020a) and then clustered using hierarchal clustering of the corelations to identify groups of species (Figure 4.1).

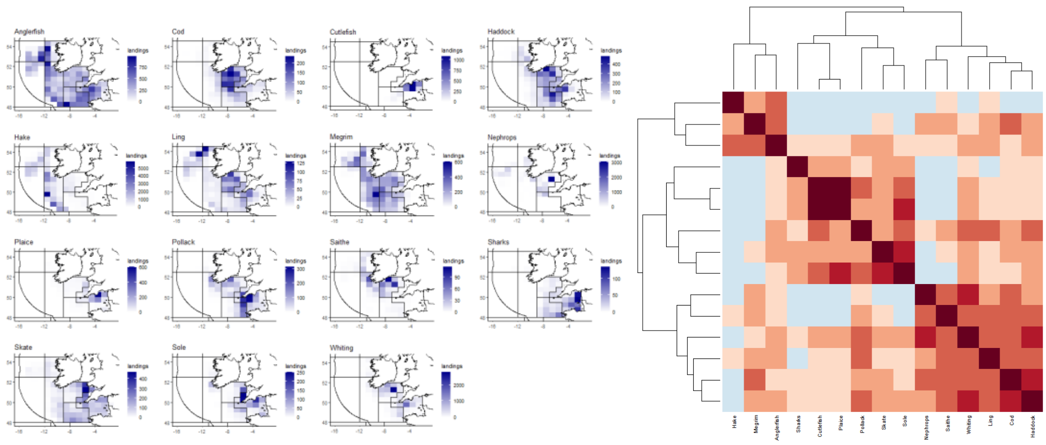


Figure 4.1: Spatial distribution of landings of key species in the Celtic Sea (left panel) along with the estimated spatial correlations on a qualitative scale clustered to identify groups of species with higher correlations (right panel).

The advantage of the approach is the ease of implementation and interpretation, the degree to which it can capture spatial variations and present these in a simple to understand way. However, concerns about statistical violations (non-normality, zero-skewed and high leverage from individual data points) were identified. By only dealing with spatial variation and aggregating across gear and time it's possible that interactions are also overestimated.

Proportion based approaches: A method that has been used to describe technical interactions in the North Sea in the past few years as part of the Fisheries Overview (page 24, ICES, 2022c) was then reviewed. Briefly, the approach identifies what proportion of a species landings are taken alongside significant (defined by the threshold) quantities of another species. By summing across all strata (or fisheries) a scaled value (0-1) is obtained which describes the strength of the interaction between a target stock and a bycatch stock (see ICES, 2022c for full details). The output is a matrix of interactions between pairs of species on a qualitative scale (low, medium, high) (Figure 4.2). However, as the method have not been tested with data for other ecoregions, and because the choice of a threshold can influence interpretation of whether an interaction is identified as significant, the method is being reviewed to refine the approach and make any changes necessary for more general application.

The approach, while a little more complex to interpret, provides a relatively simple method to identify the importance of interaction between stocks. By reading down columns, it is then possible to identify (in rows) the interactions a fishery for a given species has with other species.

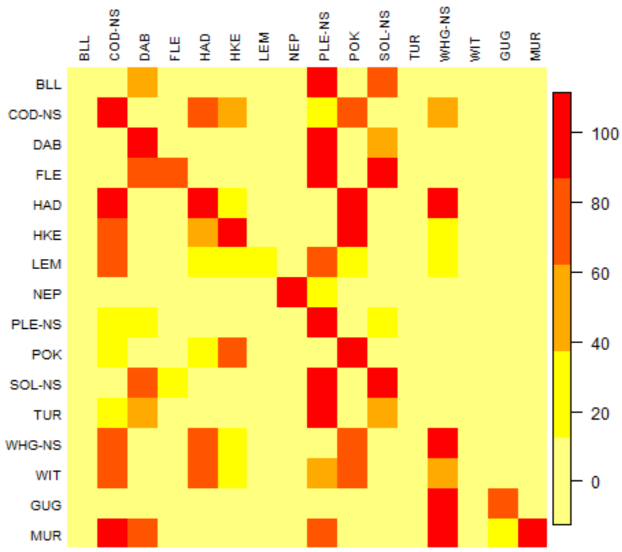


Figure 4.: Interactions among fisheries targeting a species (in columns) with other species (in rows) for the Greater North Sea.

An issue identified through discussions at WKFO2 was that the emphasis of the analysis is from the perspective of the importance of the bycatch stock to the strata/fishery rather than the importance of the impact of the fishery/strata on the bycatch stock. This means that where a stock is highly depleted or simply a low biomass compared to the target stock, the importance of the interaction is downweighted. An alternative was proposed which puts more emphasis on the bycatch stock, by weighting by the proportion of the bycatch stock taken by the fishery. This method change is being tested, to evaluate the impact on identified interactions. In addition, ideally the method would move away from using subjectively defined thresholds to infer interactions, by e.g., integrating across thresholds or weighting the results. These changes are also being investigated.

Data issues: All methods are subject to limitation from the data availability. The following challenges were identified:

- **Data aggregation –** ideally should be haul level, rarely available.

- **Data availability-** issues of confidentiality, missing countries, no common source across ecoregions.
- **Discards** – unavailable at a highly disaggregated level, but large share of catch for some species/fisheries

The consequences of data aggregation were analysed by starting at the most disaggregated data available (ICES rectangle, quarter, vessel length, mesh size range, target assemblage, gear type, ICES subdivision) and sequentially aggregating the data and re-estimating correlations between pairs of stocks. As expected, the correlations were stronger the more aggregated the data, but qualitatively the interactions identified remained similar up to the point of target assemblage being combined. This implies that it may be reasonable to use data at some level of aggregation, provided results are interpreted qualitatively. Ideally the analysis should be repeated starting at the haul-level, which is something that is being explored using a smaller scale national dataset.

Finally, a model-based approach was presented which is looking to combine landings data with covariates to identify groups of stocks that have strong interactions and identifies the factors contributing to those. This may allow more descriptive conditional maps to identify factors contributing to interactions, and where they are stronger or weaker (Figure 4.3). Such an approach may support reducing the technical interactions among stocks where mixed fisheries considerations identifies an imbalance in advice.

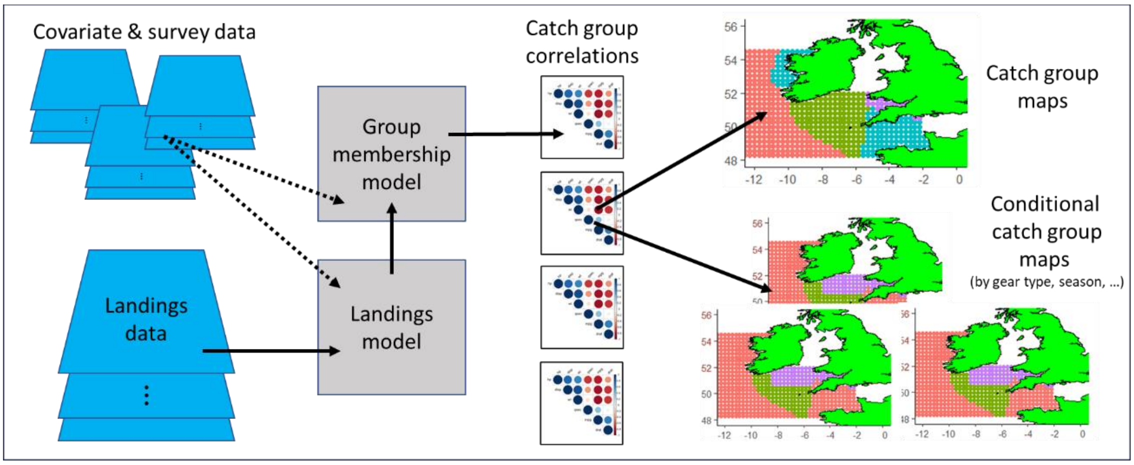


Figure 4.3: Schematic diagram of a model-based framework to identify stocks with strong interactions and conditional maps of occurrence.

4.2 Incorporating VMS data into mixed fisheries models to improve métier definitions

Following on from the work presented by Gianfranco Anastasi at WGMIXFISH-METHODS 2022 (ICES, 2022e; WGMIXFISH-METHODS), we have looked to develop the spatially defined clusters into spatially defined métiers that can be incorporated into a mixed fisheries model. The method put forward at WGMIXFISH-METHODS 2022 is soon to be published in a forthcoming paper by Anastasi et al. (paper in preparation). This method uses constrained hierarchical clustering acting on species composition from the landings (elogbooks) to define clusters of fishing activity for UK bottom otter trawls and beam trawls. Only vessels over 12 m are required by law to use VMS; for this example, the cluster analysis was taken to be representative of the whole UK beam and bottom trawl fleet.

The cluster analysis uses VMS (Vessel Monitoring System) data in the international data format (“tacsat” and “eflalo”) and the associated package VMStools (Hintzen *et al.*, 2012, Hintzen, Bastardie and Beare, 2012). The data are then assigned to a Csquare (0.05° latitude * 0.05° longitude) using the method described at WGMIXFISH-METHODS 2022 (ICES, 2022e) to define spatial explicit fishing activities which can be assigned back to an anonymised dataset for use in an ICES mixed fisheries model. The cluster métiers (*nei* clusters) utilise all species present in the landings data and produce métiers informed on the complete composition of the landings in a given area (Table 4.1).

The spatial representation of the cluster métiers opens the possibility for examination of changes in interactions with closed areas or area defined technical measures. Such features could be overlayed onto a map (Figure 4.4) for quick comparison. Such interactions are not currently modelled in the mixed fisheries models and would be strictly post hoc but could be implemented as a powerful tool for mangers and stakeholders.

The difference between the current approach to métiers and the use of cluster-defined métiers can be seen in Figure 4.5. The TBB_DEF_27.7.e métier for example can actually be split into two large and two small métiers.

In the context of a mixed fisheries model this opens the possibility for smaller, emergent, spatially-clustered métiers to act independently and may allow for a reduced choking effect under some circumstances. This does presume that choking can be moved to the individual métiers whereas, currently, choke effects act on the fleet.

An added benefit to defining métiers using spatial clustering is that it includes all species recorded in the elog (contributing to 90% of the landings) in the determination. Mixed fisheries models typically only include stocks of interest, and this remains true here as incorporating cluster-defined métiers carries with it the implicit inclusion of other species while not being explicitly modelled. This would provide the possibility of post hoc examinations of considerations on non-modelled stocks, albeit, in an unsophisticated manner.

The principal advantage over traditional métier definitions is the use of a spatial component which allows for finer granularity in métier composition. It can be considered a more accurate representation of location compared to the current resolution of the ICES rectangle, as data is being assigned from 0.5*1 degree grid to a 0.05*0.05 degree grid. This is possible due to the VMS pings available in the tacsat component of the VMS data which enable logbook recorded landings to be distributed out to the ping track for a given voyage, using the "splitAmongPings" functions in "vmstool".

The important assumption when using this function are:

- Level of match, day, ICES statistical rectangle, trip (described as first, second and third order in Niels *et al*., 2012)
- Fishing activity pings (commonly determined as the speed between pings depending on gear type)

This function also comes with some caveats associated with the data and assumptions made as to the recording and distribution of landings in the elog. This will vary between country and agency and so a recommendation is to provide a body of evidence in a formalised setting to support any assumptions made around this function as part of utilising VMS data at the ICES level. VMS will log an entire fishing trip and so it is necessary to identify pings associated with fishing activity. For some gears this is relatively straightforward as there are known speeds for towed gears that can be attributed to fishing however, there is still a level of uncertainty around these assumptions and the timing between pings will also be a factor in determining accuracy of allocation. For static gears, identifying when and for how long a gear had been soaking can be complicated and so the method may not be suitable for these gear types if the actual fishing activity cannot be determined.

Distributing logbook data to VMS pings even with these caveats still represents an improved picture of fishing activity compared to an aggregation to ICES statistical rectangle. To this end, spatially cluster defined métiers could be defined at a national level and submitted alongside the currently defined métiers (Data collection framework level 6) as an additional column alongside a likewise defined fleet. Therefore, there would be no requirement to submit actual spatial information to WGMIXFISH as the cluster-defined métiers contain this information implicitly (Figure 4.6).

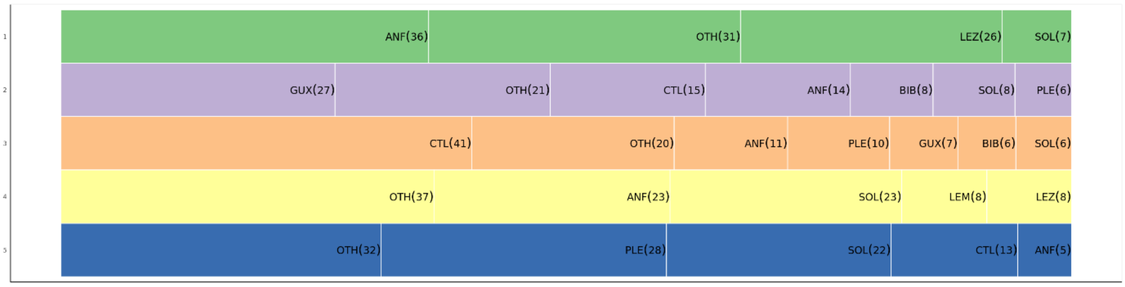


Table 4.1: Species composition of cluster for beam trawls defined in the Celtic Sea, OTH refers to aggregated species that accounted for less than 90% of the total landings. These species were also excluded from the hclust to focus on the predominantly caught species.

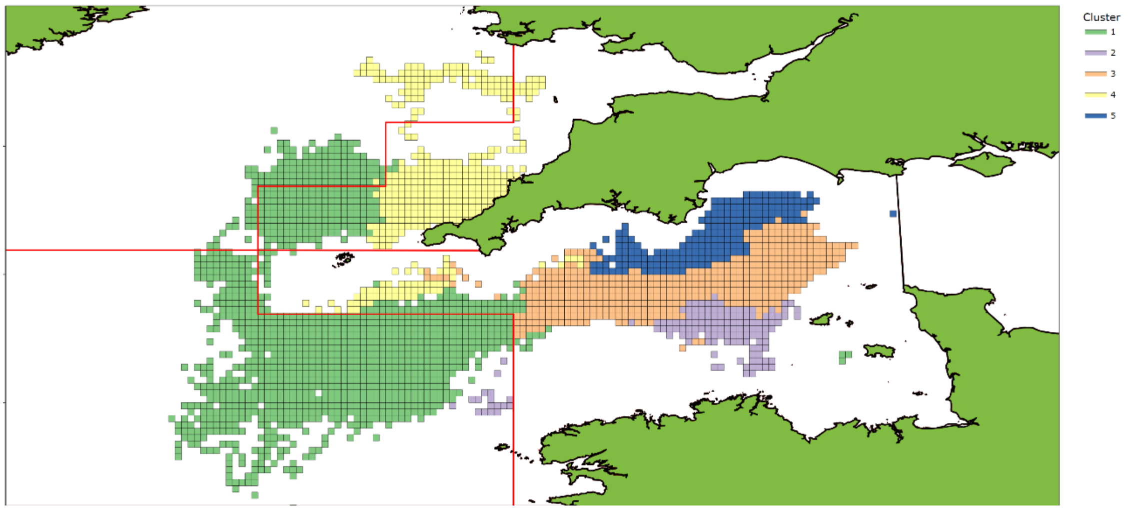


Figure 4.4: Beam trawl clusters defined in the Celtic Sea and represent at Csquare (0.05° latitude * 0.05° longitude)

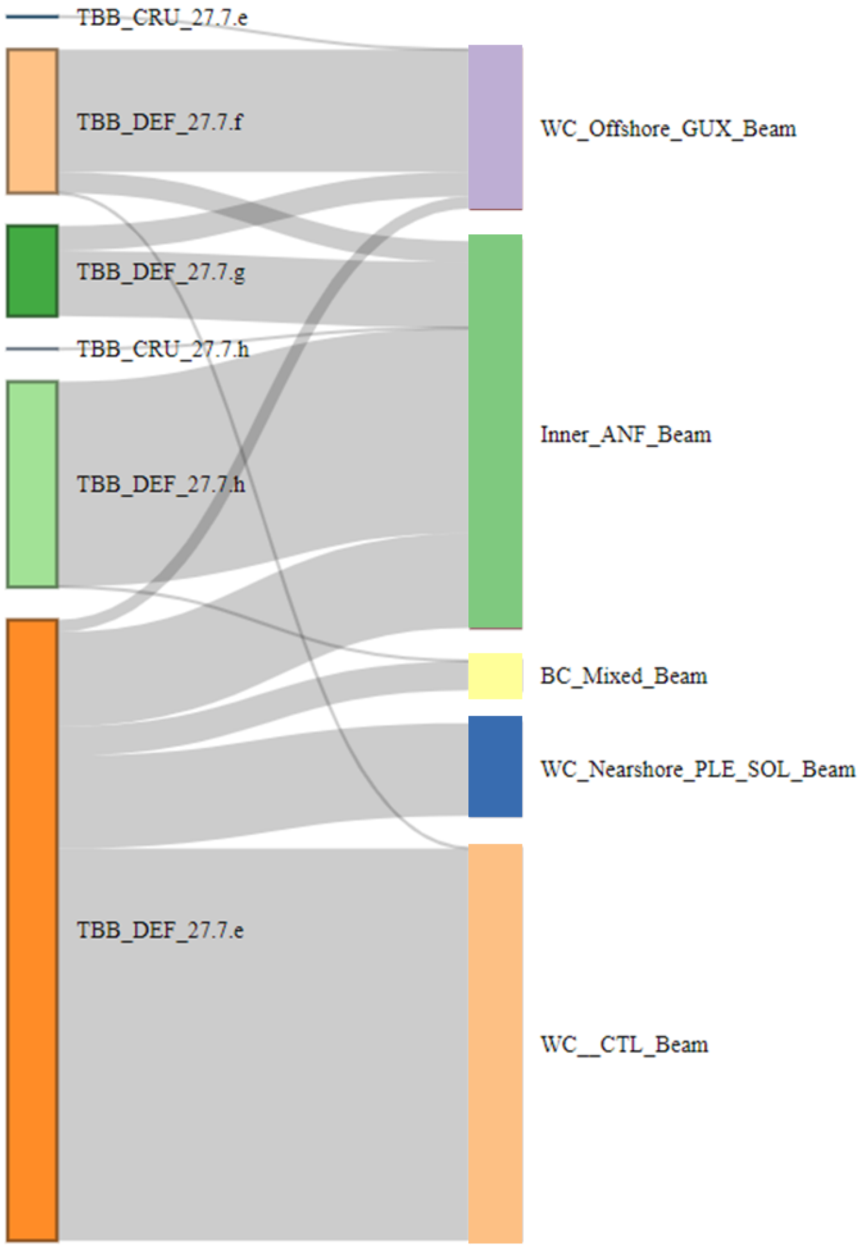


Figure 4.5: Sankey plot showing differences between Celtic Sea métiers (left) and spatially cluster métiers (right).

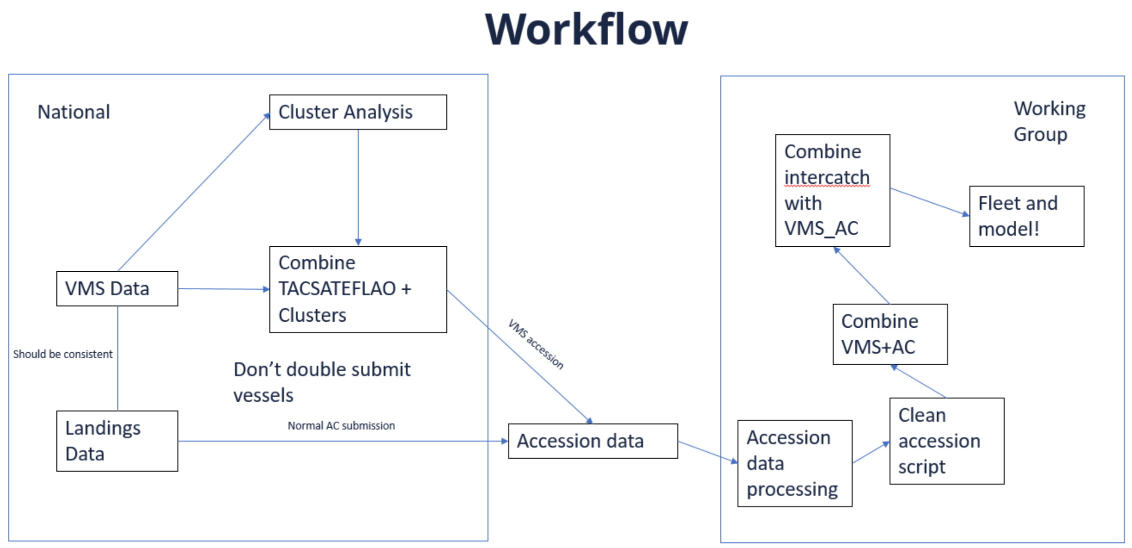


Figure 4.6: Possible workflow for incorporating spatially clustered métiers into current WGMIXFISH workflows. Finalised spatially defined clusters would be submitted as part of the WGMIXFISH data call with vessels aggregated to clusters.

Defining the clusters at national level has a number of benefits so long as a comparable or standardised methodology is adopted. It sidesteps GDPR (Global Data Protection Requirements), possible breaches of confidentially and allows institutes to rationalise and constitute their métiers based on a described cluster analysis and some level of intimate knowledge and expert opinion.

A key point to this approach would be the presentation of clusters in a formalised benchmark setting with the appropriate level of independent review and oversight and a fixed period of application and review. Noting that patterns in landings and fishing activities do change over time and there will be a need for periodic updates to capture changes in fishing behaviour.

A formalised and standard approach to defining métiers and fleets used in mixed fisheries will contribute to addressing a long running complaint against mixed fisheries considerations from stakeholders in that the current métiers do not present an accurate representation of the underlying truth in the fisheries. The current process where data is reduced to DCF level 4 (OTB_DEF) and then appended with a region and country is masking substructures in the fleets and métiers that may be more on less constrained by TACs under our current mixed fisheries model framework.

In order to make the method as reproducible as possible for testing and critique, a series of scripts and RMD/QMD documents have been produced which explain the steps taken to translate VMS data to a cluster analysis and then incorporated into mixed fisheries code. There are five scripts (uploaded to the WGMIXFISH-METHODS 2023 SharePoint), EFLALO 1-3 which format the tacsat and eflalo data for the constrained hclust analysis and TACSATEFLALO 0-1 which take the products of the analysis and apply it back to the original VMS data and prepare it for inclusion in the Celtic Sea case study data processing workflow.

While the skeleton for analysis and implementation is present in the example code scripts, work is needed to further refine and address weaknesses and possible improvements to the method and implementation. This would include replicating the cluster analysis with other countries (currently being undertaken within the Celtic Sea case study), addressing questions and concerns over the vmstools functions that distribute landings and producing a model run comparison between the current métiers and spatially clustered métiers.

4.3 Sensitivity of projections to uncertainties in input parameters

4.3.1 North Sea case study

One of the goals of the STARMIXFISH project is to evaluate the sensitivity and uncertainty in the projections of mixed fisheries models as a function of uncertainty in the forecast conditioning. Three aspects of model conditioning were scrutinized: future catchabilities, effort proportions, and the landing proportion. The approach for the North Sea case study consisted first in quantifying the uncertainty in these input parameters, first set as currently done at WGMIXFISH, but also exploring alternative assumptions. Then in the future steps of this work, mixed fisheries projections are to be run for both using the assumed and real parameter values, and the output is to be compared.

Review of assumptions

For the three parameters, the same assumption is used, whereby the parameter values used for the projection period in the mixed fisheries model (current year and next year) is set equal to the value in the last available data (one year before current year). The uncertainty associated with this assumption on the future parameter values was examined by computing retrospectively the values corresponding to the assumption for a given year and comparing it to the actual value based on the data. The analyses were based on data from the 2022 ICES WGMIXFISH-ADVICE meeting which contained information on landings, effort and catchabilities per fleet and métier for the period from 2012 to 2021. The predicted values based on these assumptions were calculated for each fleet and each stock for the years 2017 to 2021 (in order to leave enough years to fit the AR1 and lm models – see below for details).

In addition to the assumptions used at WGMIXFISH, three alternative assumptions were tested. The assumptions tested were:

- sQ: the parameter values in year y+1 (for a given fleet and a given stock) is based on the values observed for y-1. This is the current WGMIXFISH assumption.
- AR1: the parameter values in year y+1 (for a given fleet and a given stock) is based on the prediction of an autoregressive model fitted on the values for the years 2012 to the year y-1.
- Ave: the parameter values in year y+1 (for a given fleet and a given stock) is based on the average of the three previous years.
- lm: the parameter values in year y+1 (for a given fleet and a given stock) is based on the prediction from a linear model fitted on the values for the years 2012 to the year y-1.

In order to compare the performance of the four assumptions in predicting the parameter values, different criteria were analysed: the prediction error was calculated for each data point, and the four assumptions were ranked on this basis. From which the following performance descriptors were derived:

- The percentage of the data points (year/fleet/stock combination) for which each assumption ranked first;
- Computing the average rank for each assumption; and
- Looking at the average prediction error (mean absolute proportion error) for each assumption.

The main conclusion is that the current assumption seems to provide a generally unbiased prediction for future parameter values (although some bias can occur for some stocks). The magnitude of the error overall comprised 20% and 50% (mean absolute percentage error) but in some instance it can be much higher. There is also a large variability around these overall values. Overall, autocorrelation in error is negative, meaning that a larger error one year tends to be followed by a small error (or possibly of the opposite sign) the following year.

The assumptions alternative to sQ do not, overall, provide a better basis. The ranking of the assumptions gives a clear advantage to the currently one used. This means that although the parameters are difficult to predict, the best approximation for future values is the latest observed one. On a fleet-by-fleet basis, there is a small percentage of the cases where an alternative assumption performs better than the one currently used by WGMIXFISH. However, it does not seem realistic to use case specific assumptions (e.g., the best performing one for each fleet/stock combination), as the best assumption may vary from year to year, and this can only be assessed retrospectively.

Regarding the landing proportions, the project also explored the use of an official database on quotas (before and after exchange) to formulate alternative assumptions for future TAC allocation between countries. None of the two alternative assumptions to predict future landing proportions based on quotas from FIDES provided a better basis than the one based on recent landing data currently used at ICES WGMIXFISH. The country initial quota percentages before exchanges are clearly not a good basis for assumptions on future landings proportions, as countries generally exchange large quantities to accommodate the needs of their fleets (to increase their fishing opportunities of their target stocks or anticipate the risk of being choked by certain stocks). Final quotas after exchange are also not a better basis, as countries maybe still – consistently through the years – under (or, less likely, over) utilize their fishing opportunities.

Evaluates Scenarios	Proportion of being best	Median relative error (%)	Mean rank
sQ	0.523	-0.462	1.869
Ave	0.135	-1.331	2.860
lm	0.252	-1.392	2.432
AR1	0.189	-1.811	2.839

Table 4.2: Performance metrics for the assumptions on catchability

Evaluates Scenarios	Proportion of being best	Median relative error (%)	Mean rank
sQ	0.615	0.064	1.762
Ave	0.176	-0.167	2.753
lm	0.217	-0.747	2.505
AR1	0.164	-0.379	2.981

Table 4.3: Performance metrics for the assumptions on effort proportions

Evaluates Scenarios	Proportion of being best	mean absolute percentage error (%)	Mean rank
sQ	0.553	37.9	1.8
Ave	0.157	43.4	2.7
lm	0.195	52.6	2.6
AR1	0.156	48.1	2.9

Table 4.4: Performance metrics for the assumptions on landing proportions

Future work: alternative scenarios

In order to assess the sensitivity of the mixed fisheries forecast to the assumptions on catchability, effort proportions and landing proportions, sensitivity tests will be conducted for each of these three parameters, in which the model will be run using the current assumption and alternative one and the different model output (landings per stocks, fleet efforts) will be compared.

Considering that none of the alternative assumptions provided a better basis than the current assumption used by ICES WGMIXFISH, none of these assumptions will be used as the basis for a sensitivity test. Instead, as a way to quantify the impact of the actual error in the current assumption for each parameter, the sensitivity tests will consist of comparing runs in which the sQ assumption is used in the projections with runs in which the actual observed parameter values are used. This will be done by using the data from the 2022 ICES WGMIXFISH assessment (last data year 2021) and running three-year projections starting at different at 5 different historical times (from 2020 back to 2016) and for each of the three main mixed fisheries scenarios of fleet behaviour (i.e., status quo, min and max). This consists in five projection runs per effort scenario. These sensitivity runs will be done separately for the three model input parameters.

An additional, sensitivity test will consist in re-running the model with the same configuration as for the 2022 ICES considerations, but replacing the sQ assumption by an assumption in which landings proportions at the country level are based on initial quota shares from FIDES. This second sensitivity analysis will be completed as, although this was not observed in the results (nor was it carefully analysed), one can imagine situations where landing proportions based on official allocation keys (initial quotas in FIDES) could represent a plausible (or at least worth investigating) scenario. For example, in cases where a stock suddenly becomes limiting for all fleets (after a strong drop in advised catche for example), countries normally trading their quotas may tend to keep it to prevent any potential choke effect.

4.3.2 Celtic Sea case study

Mixed fisheries considerations are based on model forecasts that explicitly account for technical interactions among fleets and characterise the quota underutilisation or overshoot that may occur for given assumptions around fleet activity. Following the Second Scoping Workshop on Next Generation of Mixed Fisheries Advice (ICES 2023a; WKMIXFISH2) there is growing stakeholder appetite for more robust incorporation of fishery uncertainties into mixed fisheries forecasts. Here, we present work on the propagation of fleet parameter uncertainty in mixed fisheries forecasts using the Celtic Seas FCube model as a case study. Analyses are based on data from the 2022 ICES WGMIXFISH-ADVICE meeting (ICES 2022d; WGMIXFISH-ADVICE), which contains information to 2021.

We focused on three major sources of fishing fleet parameter uncertainty:

1. Catchability of each métier for each stock
2. Proportional share of fleet effort across métiers
3. Proportional share of stock quota across fleets

The objectives are two-fold. Firstly, to develop a generic set of methods to condition parameter uncertainty that will perform well in most cases and are robust to moderate levels of missing and noisy data. Secondly, to evaluate how forecasted parameter ranges impact model outputs compared with current deterministic condition approaches.

For each parameter type, we use historical variation to estimate future parameter uncertainty. For métier-stock catchability and métier effort-share, observation data are derived from landings and effort accessions data. However, there are few good data sources for quota allocation to fleets. Currently, the historic shares of stock landings are used as a proxy for quota-share, assuming that quota-allocations and fishing patterns are stable from year to year. However, stakeholders have highlighted that recorded landings are not necessarily an accurate reflection of quota-share for several quota-limited stocks (ICES, 2023a; WKMIXFISH2), and historical under-utilisation of quota could therefore lead to unrealistically conservative estimates of future quota-share and potentially erroneous choke stock identification. (ICES, 2022e; WGMIXFISH-METHODS) highlighted the potential value of the Fisheries Data Exchange System (FIDES), the official register of quota and quota exchanges in the European Union at the national level, to inform the forecast of quota-share for quota-limited stocks. We therefore explore the effects of using FIDES in conjunction with landings data, compared to current historical landings-share methods.

The use of time-series observations means that the analysis must account for temporal correlations and observation uncertainty. Improving on methods presented at ICES WGMIXFISH-METHODS 2022, we adopt a simple state-space modelling approach consisting of a random walk on the latent temporal process and an observation noise model. Models were developed using TMB (Template Mode Builder; (Kristensen *et al.*, 2016)), which facilitates Automatic Differentiation using C++ templates, and fitted using maximum likelihood techniques.

Similar modelling approaches were adopted for each of the three parameter types.

Catchability

The underlying vector of "true" catchabilities $\boldsymbol{q}_t^*$ at time t, where $\boldsymbol{q}_t^* = (q_{1,t}^*, \cdots, q_{s,t}^*)$ for s exploited stocks, follows a random walk on a log-scale with multivariate normal distributed increments $\boldsymbol{\eta}$:

$$\log \boldsymbol{q}_t^* = \log \boldsymbol{q}_{t-1}^* + \boldsymbol{\eta}_t, \text{ where } \eta_t \sim \mathbf{N}(0, \Sigma)$$

where Σ is the variance-covariance matrix for the multivariate normal distribution. Catchabilities are observed with error. Observation error $\epsilon_{i,t}$is independent and assumed to take a univariate normal distribution:

$$\log q_{i,t} = \log q_{i,t}^* + \epsilon_{i,t}, \text{ where } \epsilon_t \sim N(0, \sigma_i)$$

where $q_{i,t}$ is the observed catchability of the i'th stock at time t, and σ_i is the standard deviation of observation noise. One benefit of the state-space approach is that missing observations can be estimated as additional parameters.

Métier effort-share and fleet quota-share

The proportional share of effort across métier and the proportional share of stock quota allocated to each fleet are more challenging to model because these data are compositional time-series. For both variables, the data at each time interment are a vector $\boldsymbol{y}_t = (y_{1,t}, \cdots, y_{K,t})$, where $y_{1,t} + \cdots + y_{K,t} = 1$ and $y_{1,t} \in [0,1]$.

The Dirichlet distribution, denoted via $\boldsymbol{y}_t \sim Dir(\boldsymbol{\alpha}_t)$, is a popular choice for modelling compositional data and takes the positive continuous parameter vector $\boldsymbol{\alpha}_t = (\alpha_{1,t}, \cdots, \alpha_{K,t})$, which contains information on both the expectation and variance of each data component. The expectation of the i'th component, $E(y_i)$, is given by:

$$E(y_i) = \alpha_i/\tau$$

where τ is a concentration parameter given by $\tau = \sum_{i=1}^{K} \alpha_i$. It is challenging to directly model $\boldsymbol{\alpha}_t$because this implies non-constant variance in the error distribution. Instead, we assume that the expectation $E(\boldsymbol{y}_t)$ follows a random walk with multivariate normal distributed increments and a multinomial logit link function:

$$\text{logit}\, E(\boldsymbol{y}_t) = \text{logit}\, E(\boldsymbol{y}_{t-1}) + \nu_t, \text{where } \nu_t \sim \mathbf{N}(0, \Sigma)$$

The choice of multivariate normal distributed increments allows for correlations in the compositional element time-series dynamics. In contrast, τ is time-invariant and is directly related to observation error via:

$$\boldsymbol{y}_t \sim Dir(\boldsymbol{\alpha}_t), \text{where } \boldsymbol{\alpha}_t = E(\boldsymbol{y}_t) \cdot \tau$$

One shortcoming is that the Dirichlet distribution cannot accommodate exact zero or one values. Hence, we impute a small value (10^{-6}) to cases of zero values and proportionally distribute the cost of this increment according to the magnitude of the remaining non-zero components. Although this changes the compositional data vector, the adjustments to each component are small.

FIDES

The Fisheries Data Exchange System (FIDES) provides annual records of initial quota, calculated on the basis of 'relative stability', and final quota following national exchanges. Three alternative conditioning approaches are compared. Firstly, the current approach of calculating historical landings-share as a proxy for quota-share, where the landings-share $LS_{s,f,c}$ for stock s captured by fleet f from country c in year y is:

$$QS_{s,f,c,y}^{landings} = \frac{Landings_{s,f,c,y}}{\sum_f \sum_c Landings_{s,f,c,y}}$$

Secondly, initial FIDES quota allocations to countries in year y are partitioned by the landings-share for stock s captured by fleets from each country:

$$QS_{s,f,c,y}^{initFIDES} = initialFIDES_{s,c,y} \frac{landings_{s,f,c,y}}{\sum_f Landings_{s,f,c,y}}$$

Thirdly, final FIDES quota allocations to countries in year y are partitioned by the landings-share for stock s captured by fleets from each country:

$$QS_{s,f,c,y}^{finalFIDES} = finalFIDES_{s,c,y} \frac{landings_{s,f,c,y}}{\sum_f Landings_{s,f,c,y}}$$

Application

Given the complexity of FLR fleet data structures in mixed fisheries models, manually fitting, validating and forecasting for each parameter time series is prohibitive in the cost to user time, and we therefore develop automated methods that could applied model templates to fleet structures with limited need for user intervention. These automated methods crudely evaluate cases where model misfit or optimisation failure occurs and attempt to either correct the underlying model issues or feedback information to the user (Figure 4.7).

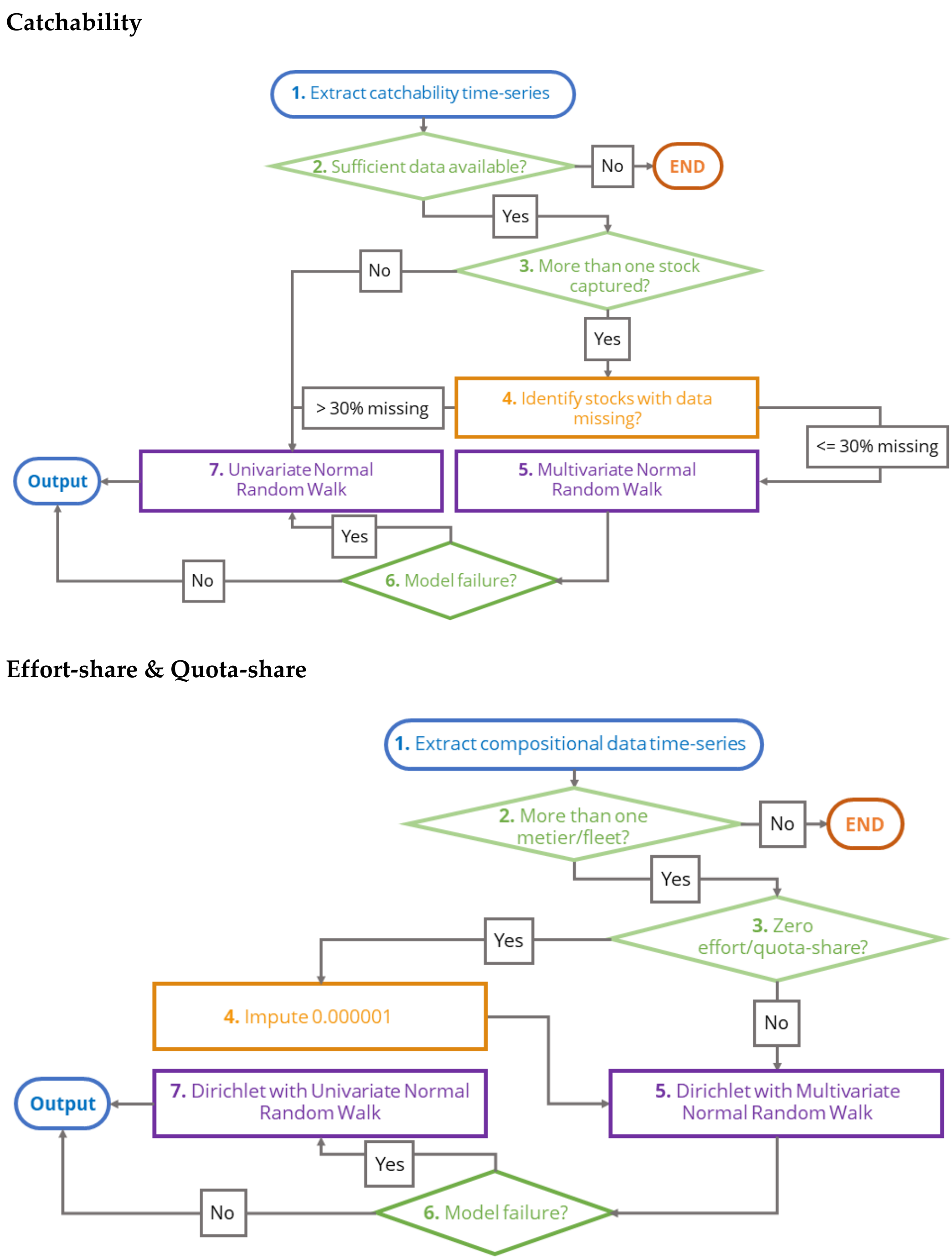


Figure 4.7: Illustration of the algorithms used to fit state-space models to historical time series of (top) catchability, (bottom) effort-share and quota-share.

Application of these methods is largely successful with model fitting issues impacting a relatively small proportion of overall historical catches by weight. Issues were frequently related to large proportions of missing observations or erroneous values and may be addressed through additional data pre-processing and manual model fitting. Figure 4.8 is an example of a successful random walk and noise model fit to a catchability time-series with stochastically sampled future catchability for each exploited stock and demonstrates how uncertainty increases as the data are projected further into the future.

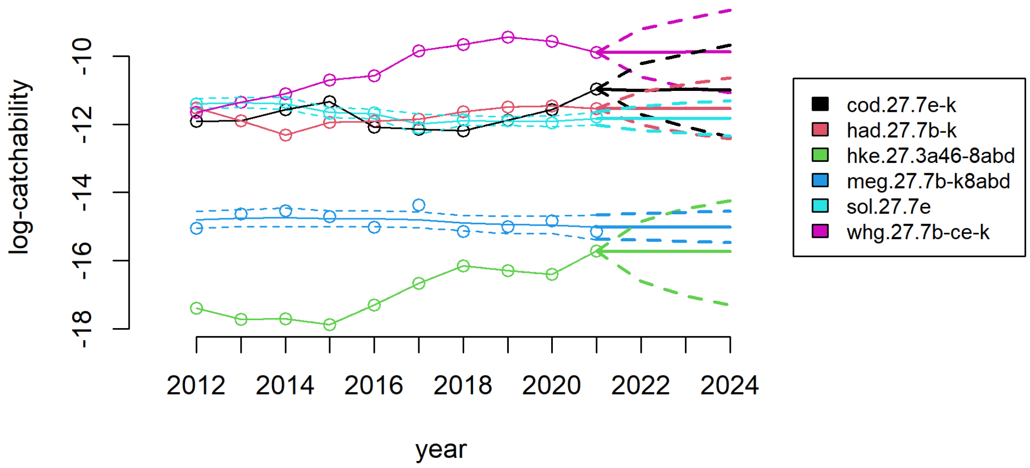


Figure 4.8: Observed (hollow circles) and maximum likelihood (solid lines) stock catchability for métier 'OTB_DEF_27.7.e' operated by French bottom otter trawlers of vessel length 10 < 24m. Forecasts for 2022, 2023 and 2024 are shown with 95% confidence intervals (dashed lines).

Simulation results

Mixed fisheries simulations were carried out under four effort scenarios:

- (i) Min: fleet activity stops when the quota for any stock is consumed
- (ii) Status quo: fleet activity is the average of the most recent three data years
- (iii) Haddock: fleet activity is the effort required to consume haddock quota (or status quo if haddock is not exploited)
- (iv) Whiting: fleet activity is the effort required to consume whiting quota (or status quo if whiting is not exploited)

The impact of fleet parameter uncertainty on model outputs varied depending on the stock and the effort scenarios considered (Figure 4.9 for illustrative example). For instance, cod is the chief limiting stock in the Celtic Sea and very little variation is observed under the 'min' scenario. However, technical interactions with haddock and whiting in many métiers means that uncertainty in catchability translates to large variation in the forecasted landings under the haddock and whiting scenarios.

For Celtic Sea cod, simulations using deterministic conditioning fall within the 90% uncertainty envelope, although overall output uncertainties are large. However, there are large deviations between outputs from deterministic and stochastic conditioning for sole, suggesting that existing conditioning approaches are not adequately capturing the historical quota-share dynamics for this stock.

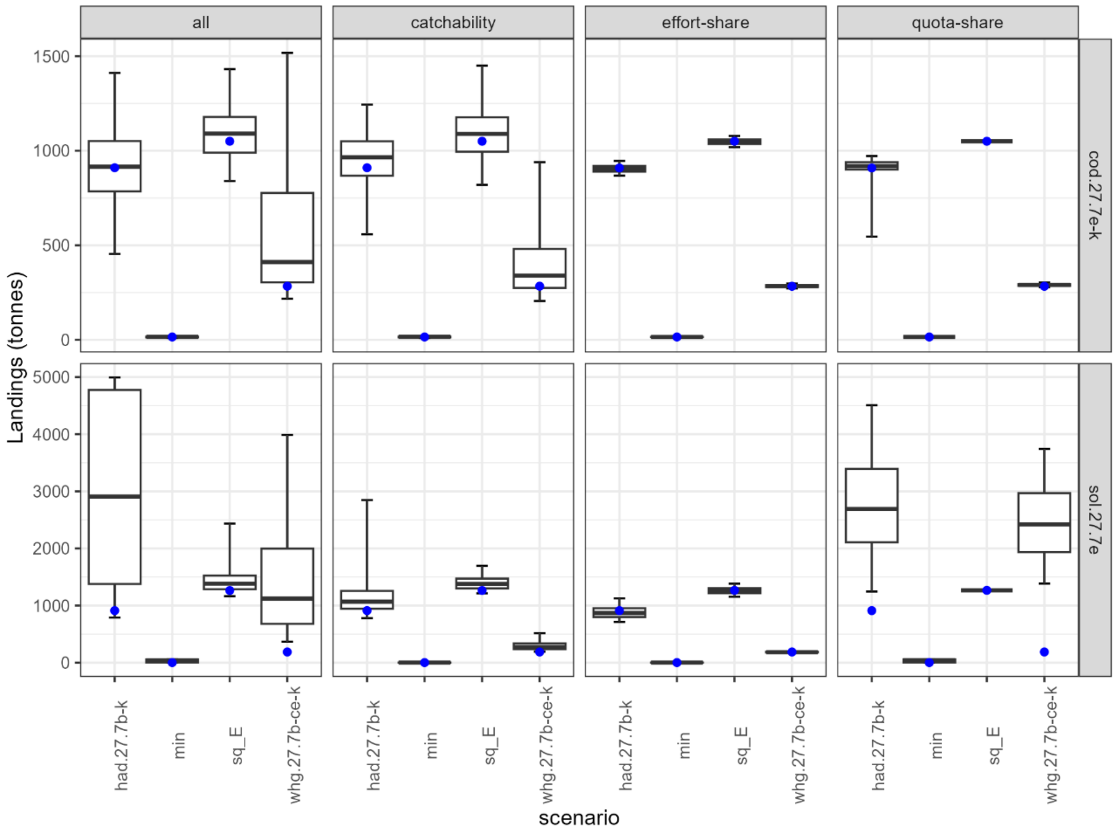


Figure 4.9: Variation in landings of cod (cod.27.7e-k) and sole (sol.27.7e) given uncertainty in métier-stock catchability, métier effort-share and fleet-stock landings-share under different effort scenarios. Boxes and whiskers span the 50% and 90% confidence intervals, respectively. Median values are shown as black tick-marks within boxes. Blue points are outputs under current deterministic methods.

These outputs may be easily integrated into the existing headline message in the mixed fisheries considerations to provide context around reported choking patterns under each effort scenario. Confidence intervals help to bracket predictions and highlight the key system uncertainties to stakeholders. Disaggregated sources of uncertainty are complementary to a more comprehensive sensitivity analysis and help to highlight where more precise data are needed.

In conclusion, these are a set of generic methods that could be applied to the conditioning of any mixed fisheries model and accommodate potentially noisy and poor-quality input data. These methods are already built into functions that can be readily applied to FLFleet objects and generate performance log and diagnostics to screen for model fitting issues. Future work will improve the realism of forecasts, such as the use of auto-regressive functions to constrain sampled projection values, as well as improve the robustness of model fitting and expand the toolbox of user-friendly functions.

4.3.3 Bay of Biscay case study

One of the goals of the STARMIXFISH project is to evaluate the sensitivity and uncertainty in the projections of mixed fisheries models as a function of uncertainty in the forecast conditioning. For the Bay of Biscay demersal mixed fisheries case study, an uncertainty analysis is carried out to ensure an effective conditioning of the model which can better represent the output uncertainty, and a Global Sensitivity Analysis for characterising this uncertainty. Focusing the analysis on catchability, quota-share and effort proportion by métier for two reference fleets: French bottom otter trawlers 10 to 24 m in length and Spanish 24 to 40 m bottom trawlers, using data for the period 2014-2021.

Input factors conditioning

- Catchability: As the FLBEIA model is used with a Cobb-Douglas function, catchability is given by the function

$$q_{fl,mt,st,a} = \frac{C_{fl,mt,st,a}}{E_{fl} \cdot efs_{fl,mt} \cdot B_{st,a}}$$

  where fl , mt , st and a are the subscripts for fleet, métier, stock and age respectively. C denotes total catch, q catchability, E effort at fleet level, efs effort proportion of fleet fl in métier mt and B total biomass of stock st and age a.

  In order to incorporate the effects of interspecies interactions occurring within each métier, unidimensional year effects per stock were extracted (intensity) from the age effect (selectivity): $q_{st,y,a} = S_{st,y,a} \cdot I_{st,y}$, where $I_{st,y}$ is the mean of the yearly catchabilities over the reference ages.

  Uncertainty estimates for the intensity were obtained by employing a multivariate lognormal distribution based on the within métier variance-covariance matrix. While selectivity uncertainty was derived from a generalized additive model (GAM) in which age was incorporated as a spline covariate and assuming a gamma distribution for selectivity.
- Effort proportion: Uncertainty in effort proportion was simulated using a Dirichlet distribution (extension of the beta distribution commonly used to model proportions across several dimension) to model the proportions, specifically a null model was fitted (i.e. only intercept model).
- Quota-share: The same approach as for effort proportion was used.

Uncertainty analysis

At the moment, only preliminary results for the uncertainty analysis are available. Figures 4.10 to 4.12 present the simulated uncertainties in the selected parameters.

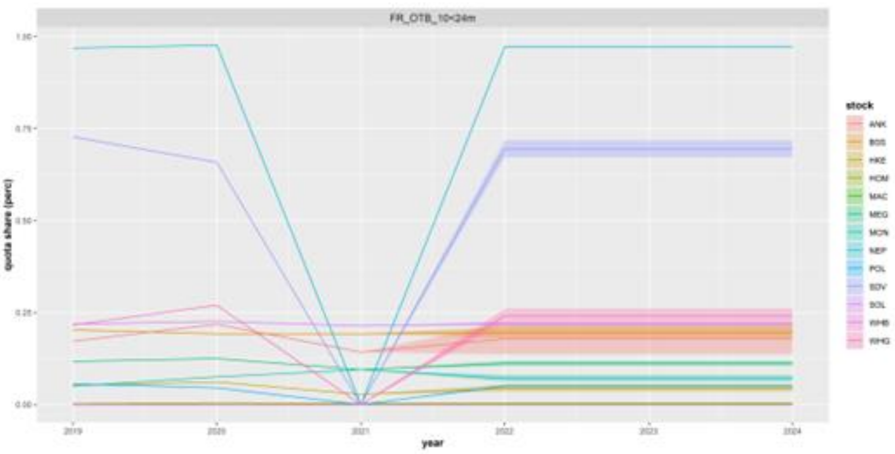


Figure 4.10: Observed (2009-2011) and modelled (2012-2014) quota shares for French bottom otter trawlers of vessel length between 10 and 24 m. Modelled values are shown with 90% confidence intervals.

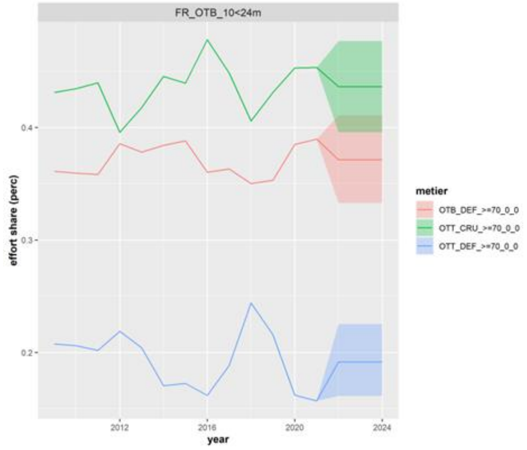


Figure 4.11: Observed (2009-2011) and modelled (2012-2014) effort proportions by métier for French bottom otter trawlers of vessel length between 10 and 24 m. Modelled values are shown with 90% confidence intervals.

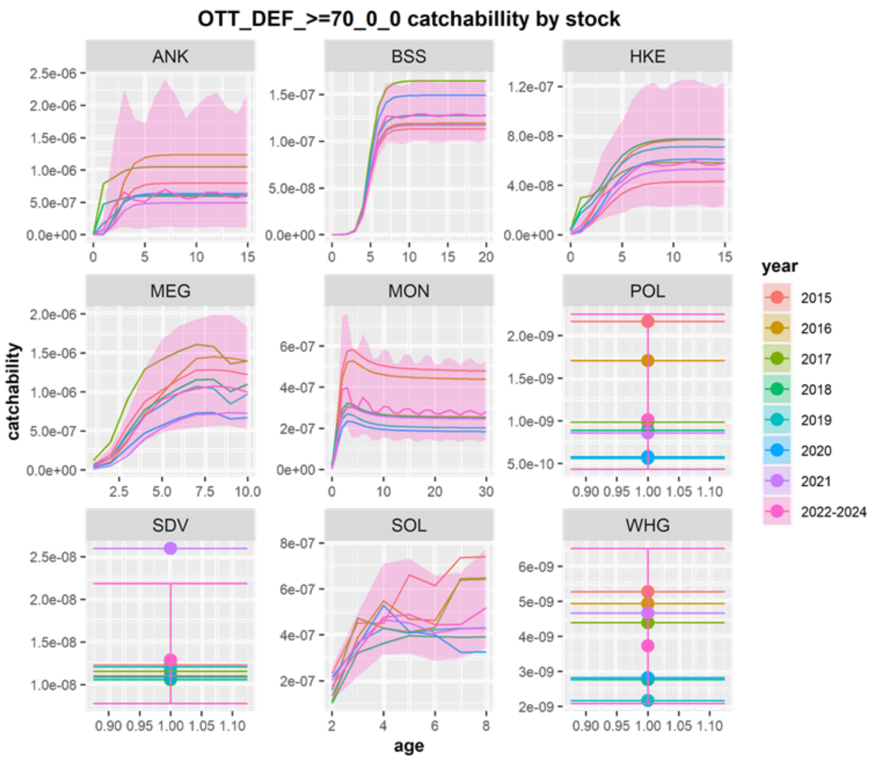


Figure 4.12: Observed (2009-2011) and modelled (2012-2014) catchabilities-at-age for the stocks targeted by French bottom otter trawlers of vessel length between 10 and 24 m. Modelled values are shown with 90% confidence intervals.

Mixed fisheries simulations were carried out under the following effort scenarios:

- max: fleet activity stops when the quota for all stocks is consumed.
- min: fleet activity stops when the quota for any stock is consumed.
- min-exhom: fleet activity stops when the quota for any stock is consumed, excluding horse mackerel that has zero catch advice.
- sq_E: fleet activity is the average of the most recent three data years.

The impact of fleet parameter uncertainty on model outputs varied depending on the effort scenarios considered (Figure 4.13 and Figure 4.14). Very little variation is observed in most of the scenarios, except for the 'max' scenario where very large variation is observed. This large variation in forecasted landings is likely coming from the uncertainty in catchability coupled with the technical interactions among different stocks.

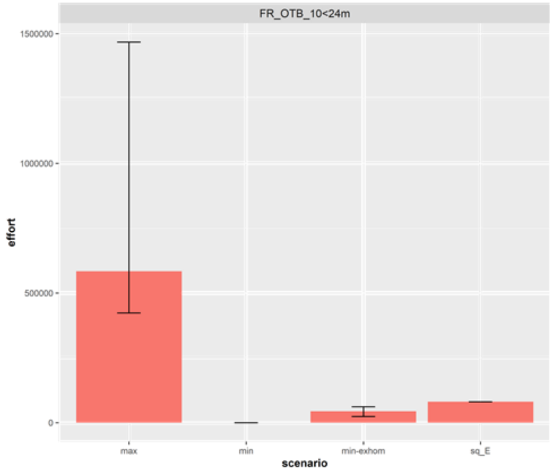


Figure 4.13: Variation in effort for French bottom otter trawlers of vessel length between 10 and 24 m, given uncertainty in stocks' catchability, effort proportions by métier and quota shares by fleet and stock under alternative mixed fisheries scenarios. Bars represent median values and vertical lines the 90% confidence intervals.

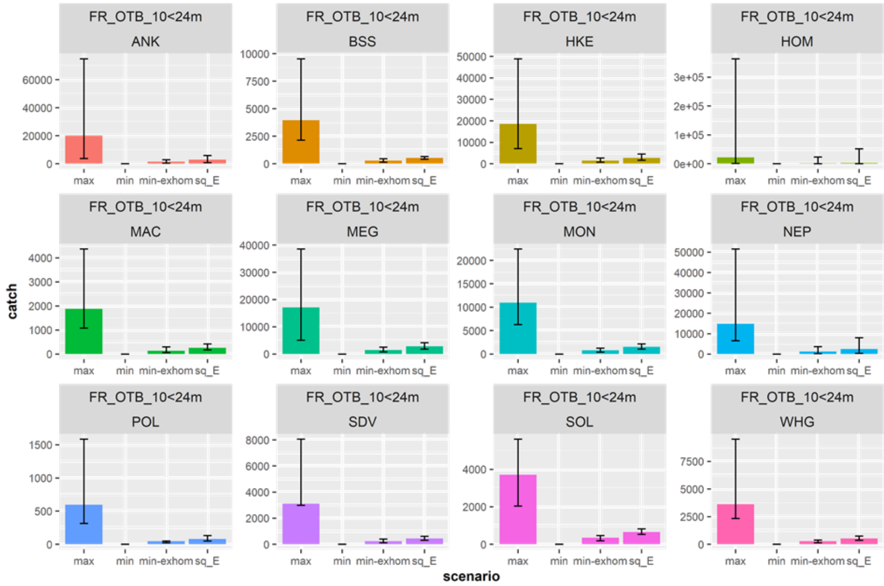


Figure 4.14: Variation in catches by stock for French bottom otter trawlers of vessel length between 10 and 24 m, given uncertainty in stocks' catchability, effort proportions by métier and quota shares by fleet and stock under alternative mixed fisheries scenarios. Bars represent median values and vertical lines the 90% confidence intervals.

GSA configuration and implementation

The work is still ongoing. Further details will be provided once the STARMIXFISH project is finalised (Study to Assess the Robustness of Mixed Fisheries Scenario Assumptions, EASME/EMFF/2018/011 Specific Contract Lot 1 No.12 and Specific Contract Lot 2 No.13).

4.4 Implications of Pope's Approximation on technical interactions and choking

Single-species stock assessment models are typically formulated in continuous-time, where fishing mortality F and natural mortality M processes are expressed as instantaneous rates, and utilise the Baranov catch production function to translate fishing mortality into catch C in a given year y:

$$C_y = \frac{F_y}{F_y + M_y}\left(1 - \exp(-(F_y + M_y)\right)N_y$$

where N is the number of fish at the beginning of the year. The Baranov catch production function is a non-linear equation and the realised catch at a given fishing mortality rate depends on the natural mortality rate. Numerical optimisation methods must therefore be used if the objective is to find the fishing mortality rate that corresponds to a target catch, and this becomes necessary when implementing catch-based advice as part of a short-term forecast.

The inclusion of multiple fleets and stocks in mixed fisheries models makes this a non-trivial problem. The partial fishing mortality contributions of each fleet are additive and the realised catch for a given fleet is therefore dependent on the natural mortality and the activity of all other fleets.

One convenient way to discretise mortality and make this an analytically tractable problem is Pope's Approximation:

$$C_y = F_y\left(1 - \exp\left(-\left(\frac{M_y}{2}\right)\right)\right)N_y$$

Here, half instantaneous natural mortality is applied in the first half of the year and fleet catches occur instantly in the middle of the year. Hence, the catches for a given fleet are no longer entangled with natural mortality or the activity of other fleets. Fishing mortality is simply a proportion of the surviving fish that are harvested.

As a result, Baranov and Pope's Approximation have differing Catch – Effort relationships; this is highlighted in the inter-benchmark reports on changing the operating models for the Celtic Sea and North Sea (ICES, 2021b; IBPMIXFISH). However, to date, the implications of these catch production functions for mixed fisheries technical interactions has yet to be investigated.

The scope of this work is a high-level analysis exploring the behaviour of the equations, rather than an attempt to realistically simulate any specific fishery. I use arbitrary values for stock numbers, catchability and natural mortality (Table 4.5) and generate simple simulation scenarios to understand how and where the Baranov and Pope's Approximation catch production functions differ.

Parameter	Stock A	Stock B
Stock numbers	2000	2000
Natural mortality	0.2	0.2
Fleet 1 catchability	0.01	0.01
Fleet 2 catchability	0.1	0.01

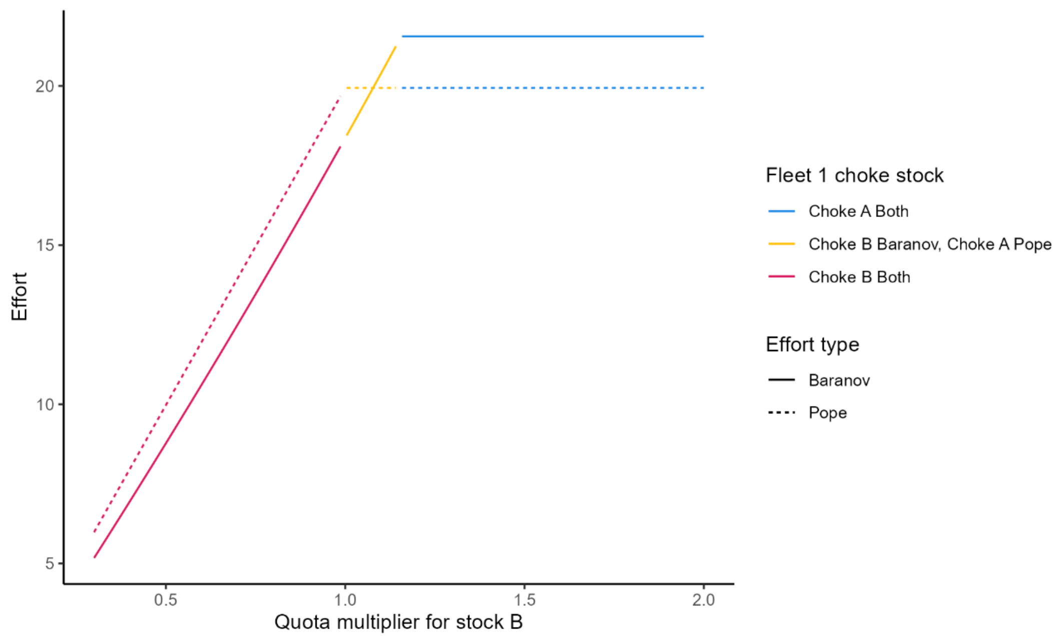
Table 1.5: Fixed parameter values for a simple scenario where two fleets (1 and 2) catch two stocks (A and B)

Consider a scenario where two fleets (Fleet 1 and Fleet 2) catch two stocks (Stock A and Stock B). Stock A quota for Fleet 1 and Fleet 2 is fixed at 300 and 500 respectively, and simulations are carried out where the total Stock B quota is scaled between 180 and 1200 with a fixed share of 50% for Fleet 1 and Fleet 2. The effort required to catch the first quota differs between the Baranov and Pope's Approximation functions (Figure 4.15), in part because the catches of a given fleet are impacted by the activity of other competing fleets under the Baranov formulation.

Stock A chokes Fleet 2 effort under both functions because the catchability for this stock is an order of magnitude higher than for Stock B (Table 4.5). However, there is a mismatch between the choke stocks identified for Fleet 1 under the two catch production functions. This is because under Pope's Approximation, the Stock A begins to choke Fleet 1 as soon as the quota availability for stock B exceeds that of Stock A. However, under the Baranov formulation, Fleet 2 competes with Fleet 1 for catches of both stocks. The higher Fleet 2 catchability and quota for Stock A means that Fleet 1 per unit effort catches of Stock A are lower than stock B. This means that Fleet 1 can accommodate a higher quota for Stock B than Stock A and remain choked by Stock B. The tipping point for choking by Stock A depends on the difference in catch per unit effort that is driven by Fleet 2 activity.

The analysis demonstrates how the decoupling of dependencies among fleet harvesting under Pope's Approximation leads to differences with Baranov in realised fleet catches for a given level of fleet effort. Consequently, the identified effort-limiting stock may differ between the two catch production functions. The simulations do not aim to emulate reality, there are clear mismatches in quota-share given the differences in fleet catchabilities, so it remains unclear how these findings map onto real-world management strategies. Nevertheless, simulations showed that discrepancies increased at high stock exploitation levels, and this has implications for catch-advice-based mixed fisheries models using Pope's Approximation, especially when considering stocks with poor status.

Fleet 1



Fleet 2

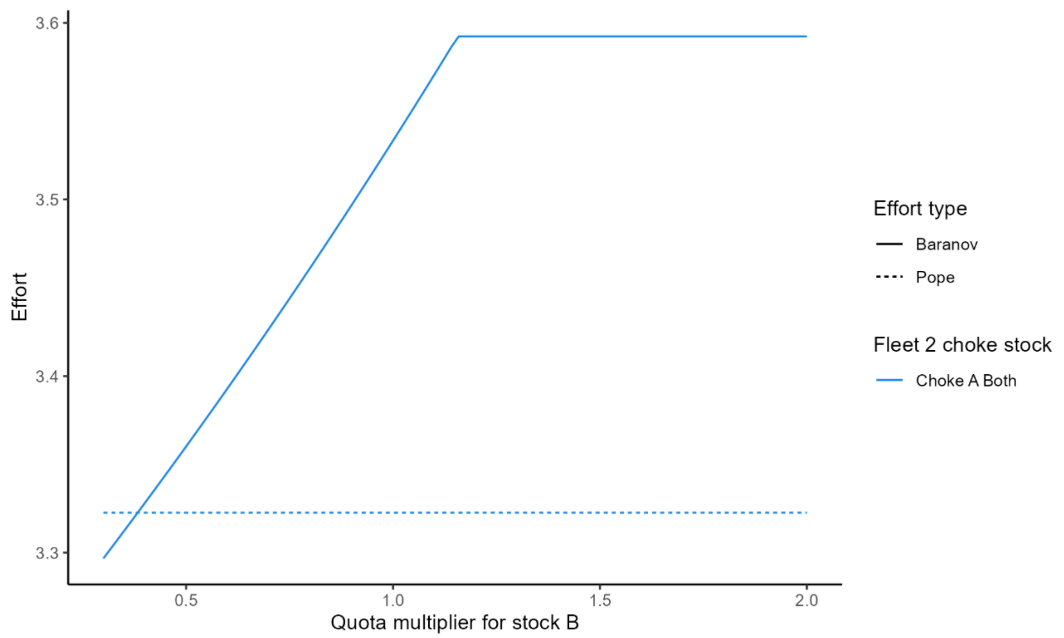


Figure 4.15: Effort dynamics in a simple scenario where two fleets (1 and 2) catch two stocks (A and B). (Top) Fleet 1 effort required to consume choke stock quota as a function of stock B quota availability for both fleets. (Bottom) Fleet 2 effort required to consume choke stock quota as a function of stock B quota availability for both fleets.

4.5 Using past data to assess 'prediction skill' of mixed fisheries models

The section explores the potential to use past data to assess the predictive skill of mixed fisheries models in terms of predicted catch. Specifically, an approach is proposed which assesses how much mixed fisheries catch forecasts, over a 5-year period, differ from the observed catches once these are known. This work is motivated by a need for a metric with which to measure the relative performance of models to aid in decision making in model development, as well as to develop a framework for communicating the degree of predictive accuracy with managers and other stakeholders. It is this second objective which forms the basis for focus on catch estimates, rather than other variables in the forecasts, however, a similar approach could be taken for the comparison of model predictive skill on other key parameters such as forecasted fleet effort.

Measures of 'prediction skill' differ from sensitivity and uncertainty testing in that they are designed to assess past model performance against a specific objective, rather than estimate the overall uncertainty in parameter estimates or sensitivity of predictions to model formulation or parameters. Together with sensitivity and uncertainty, predictive skill is a key component of model testing, and one which is increasingly being considered in fisheries research (e.g. Carvalho et al., 2021; Cooper et al., 2022).

To understand the approach employed here it is first necessary to reflect on the potential use of mixed fisheries scenarios in the fisheries management. Mixed fisheries scenarios are frequently based on the single-stock advice; and predict the catches of other stocks based on the predicted changes in fishing effort if the catch advice for a single-stock were strictly implemented. These scenarios are designed to inform policy makers and managers about the likely implications of single-stock advice (if it were realised) on catches of other stocks in the fishery. This in turn, is based on the management assumption that the catch opportunities of one stock can be used as a tool to manage catches of other stocks where these occur in mixed catches. The importance of this management assumption is illustrated by the existence of the EU standing request on catch scenarios for zero TAC stocks; which requests additional catch options for stocks with zero catch advice on an annual basis from ICES. Catch options for these stocks are frequently based on the expected by-catch from other fisheries (e.g. whiting as a by-catch of the *Nephrops* fishery in the Irish Sea (ICES, 2022a), or cod as a by-catch of the haddock fishery in the Celtic Sea (ICES, 2022f)). The capacity of mixed fisheries models to predict the catches of each stock based on the catches of another, is therefore a key feature which requires testing.

To address this need, we propose the use of past data, to assess how well models applied to recent years would have estimated catches of other stocks based on observed catches of individual stocks. The proposed method, uses the observed catches of an individual stock (hereafter, the 'target stock') as a target for the mixed fisheries model, and generates a set of catch estimates for all other stocks in the model. In practice, this is analogous to the use of catch advice for a target stock in the standard single-stock scenarios used by WGMIXFISH, but by using the known observed catches in recent years rather than advised catches for future years, the predictions of the model for the catches of other stocks can be compared against observed catches. For example, to test the model's ability to predict catches of other stocks based on the catches of *Nephrops,* the observed catches of *Nephrops* in the most recent data year would be used as a target for the mixed fisheries model. The catches of other stocks estimated by the model are then compared against the observed catches for each stock, and the difference between the predicted and observed catches for each stock is used to measure the model's predictive skill for this purpose. Because this method relies on observed catch data, it can only be carried out on forecasts into past years where the 'true' catches are already known. For example, a standard WGMIXFISH-ADVICE model conducted in 2021 would forecast catches into 2022, then in 2023 it is possible to assess the predictive skill because the 'true' 2022 catches are available. In this case, the observed catches of each stock in 2022 are used as 'target stocks' for the model scenarios, and the model is run using the data which would have been available in 2021 (e.g. up-to-2020), with intermediate year assumptions applied for 2021. The outputted predicted catches can then be compared with the observed catch data in 2022.

Additionally, it may be of interest to run a 'status quo' scenario based on the same input data and assumptions. Comparing predicted catches from the 'status quo' scenario with observed catches, provides information about the predictive skill of this scenario (which assumes no-change in fleet effort), and also provides a comparison for stock-based models.

Here, we provide an illustrative example of the application of these methods using the Irish Sea mixed fisheries model, with predictions into each of the years 2017-2021. The model is the same as that presented in the ICES advice report 2022 (ICES, 2022d), except that catch-shares of fleets and métiers are based on a 3-year average of catch-shares rather than landings-shares in all scenarios. This improvement was implemented in the model, due to the large proportion of discards in some Irish Sea stocks, and the fact that fishing opportunities (eg TACs and quotas) are based on catches rather than landings. For each assessment year, the observed catches in the following year were used as the 'target catches' for each scenario. The data years used in the model were from the three preceding years. The values for assessment year for fleets and métiers were based on the same assumptions as the standard Irish Sea model (i.e., intermediate year effort per fleet, fishing patterns and catch share were the mean of the preceding three years). Intermediate year assumptions in the stock objects used in the FLR catch forecasts as part of the mixed fisheries model (e.g. recruitment and stock weights) were the same as those in the single-stock assessments in that model year. Testing was conducted using all stocks in the model as target scenarios (i.e. cod.27.7a, had.27.7a, ple.27.7a, sol.27.7a, whg.27.7a and *Nephrops* FU14-15). It should be noted that the predicted catches of each stock, reflect both the predicted changes in the effort of fleets which catch the target stock, and the continued fishing effort at 'status quo' of fleets which do not catch the target stock.

Protocol for testing predictive skill of observed 'catch' scenarios:

- Take 5 recent assessment years (e.g. 2016 - 2020).
- For the most recent year (2020), run scenarios with the observed catch of each stock in the forecast year (2021) as the target scenario.
- Note data years for the mixed fisheries model will be the three preceding years (e.g. 2017-2019).
- Compare values of predicted catches of other stocks against observed values.
- Repeat for five years, updating target catches and data years to match those used in the assessment.

Visualising differences between predicted and observed catches

Decisions about how best to visualise outputs of any analysis will depend on management and communication aims. Here, we provide an example based on the management aim of predicting the catches of Irish Sea whiting based on the observed catches of *Nephrops* and other gadoid stocks (haddock and cod).

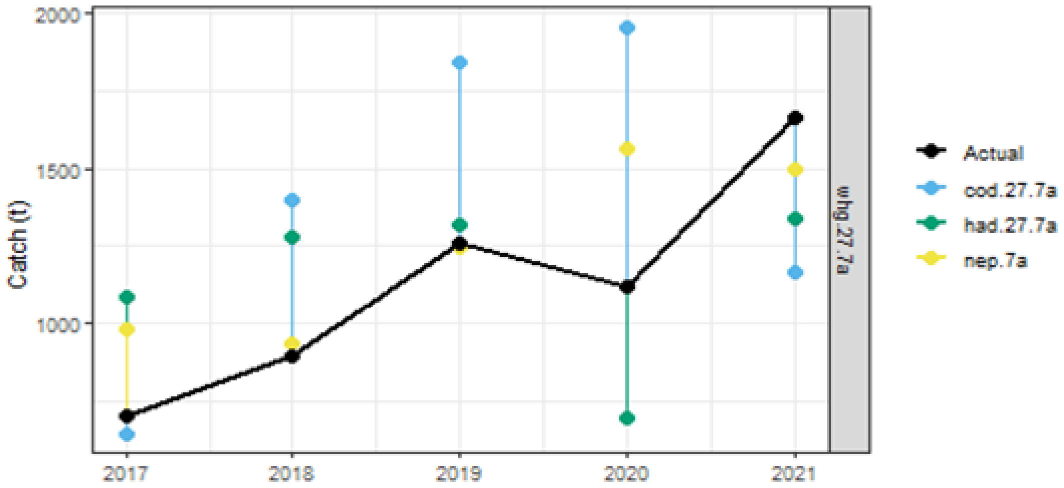


Figure 4.16: Observed versus predicted catches of whiting (whg.27.7a), black points show observed catches, coloured points show mixed fishery model predictions of catches under different 'target stock' scenarios. Pale blue, green and yellow points show predicted catches from model scenarios based on observed catches of cod, haddock and *Nephrops* respectively. All predictions are one-year forecasts (e.g. coloured points in 2021, are from a mixed fisheries model based on the 2020 assessment year). Coloured lines indicate the difference between predictions and observations in tonnes per scenario.

Figure 4.16 above illustrates how well the Irish Sea FCube model predicts the catches of whiting scenarios if catches of other stocks were known (e.g., conceptually equivalent to a situation where those catches had been enforced fishing opportunities). The distance between coloured points and the black points indicate the error (in tonnes) between the prediction and observation in a given year. From this visualisation we gain insights into which scenarios may best for predicting the catches of other stocks. In this example, the *Nephrops* scenario (yellow points) are consistently closer to the observed values than those of cod or haddock, indicating that *Nephrops* based catch scenarios may be most useful for predicting whiting catches. Under this *Nephrops* scenario the error in the estimates of whiting catches varies between 16t and 443t (mean = 188t). The mean observed catches of whiting over the same period was 1,128t, increasing from 704t in 2017 to 1,662t in 2021. In relative terms the mean difference between the predictions based on observed *Nephrops* catch and mixed fishery model predictions ranged between 1% and 40% (mean = 19%), with the largest differences seen in the earliest year of the time-series and in 2020. The large differences seen in 2020, may be attributable in part to Covid related changes in fishery behaviour in that year.

In Figure 4.16, we have focused on one key by-catch stock for which catch options are requested annually under the EU standing request for catch options for zero-TAC stocks. However, as the analysis is conducted across all scenarios and stocks, data may be visualised to show differences between model predictions and observations for all stocks and years (Figure 4.17). This may be useful for understanding which scenarios are best for predicting catches across stocks, or detecting time periods during which stocks were poorly predicted.

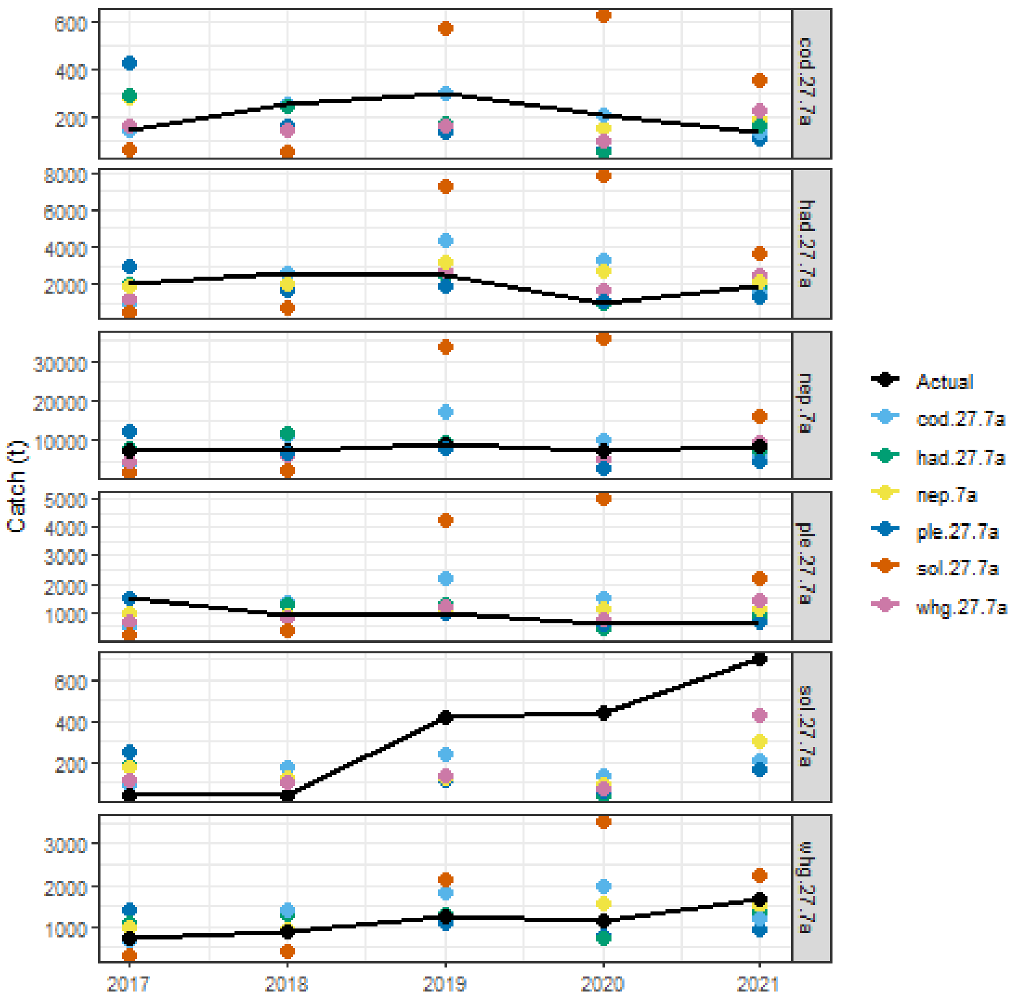


Figure 4.17: Observed versus predicted catches from historic validation runs of the Irish Sea mixed fisheries model. Each panel represents a single predicted stock, indicated to the right of the panel. Black points show observed catches, coloured points show mixed fishery model predictions of catches under different 'target stock' scenarios. Pale blue, green, yellow, blue, orange and pink points show predicted catches from model scenarios based on observed catches of cod, haddock, *Nephrops*. plaice, sole and whiting respectively. All predictions are one-year forecast (e.g. coloured points in 2021, are from a mixed fisheries model based on the 2020 assessment year). On each panel the scenario matching the stock matches exactly with the observed catches, as this is fixed as the catch target for the scenario. Note y-axes are on different scales.

The visualization presented in Figure 4.17, illustrates that the error of the model differs between focal stocks and scenarios, with some scenarios such as *Nephrops* catches being a relatively good predictor of the catches of other stocks except sole. The extent to which a scenario is useful in the prediction of other stocks catches via the mixed fisheries model, is a due to a multitude of factors including the strength of the technical interactions between pairs of stocks, the relative magnitude of the fisheries, the appropriateness of the parameterisation of the mixed fishery model and the continuity of the fishing opportunities available for each stock. For example, the differences between the observed catches of sole and the model predictions of all scenarios between 2019-2021 most likely relates to a large increase in the available fishing opportunities for this stock. In 2019 ICES advice for Irish Sea Sole increased from zero-catch to 414 t, further increasing to 768 t in 2021. The sole fishery in the Irish Sea is a targeted fishery carried out by a small number vessels operating with beam trawl gear, and increases in the fishing activity of this fleet are largely decoupled from the demersal fish and *Nephrops* fisheries. Furthermore, only 10% of landings of Irish Sea sole come from gears other than beam trawls in the Irish Sea (ICES, 2023d), hence the behaviour of the largest fleets in the model have little impact on the total predicted catch. This may explain why the current Irish Sea mixed fisheries model, based on fishery patterns in the preceding three years, would not predict the observed increase in catches of sole based on the catches of other stocks, and implies that other sources of information such as the single-stock advice (or fishing opportunities) for sole itself may have been a better predictor of the sole catches over this period.

Metrics of mixed fishery model predictive skill

Here, we propose the use of two metrics to communicate these differences between model predictions and catch observations, Mean Absolute Error (MAE) and a version of Mean Absolute Scaled Error (MASE) for the mixed fisheries context which we call '$MASE_{MF}$'. Each of these metrics may be calculated on scenario, stock or annual basis to provide insights into the predictive capacity of individual scenarios, predictability of individual bycatch stocks, or changes over time. Or a single metric of model 'predictive skill' may be obtained by applying the metric across all stock-based scenarios and years.

The first of these metrics (MAE) is calculated as the average distance between each catch prediction and the observed catch across all scenarios, stocks and years (excluding self-predictions, i.e. where the target stock of the catch scenario and the predicted stock are the same). These differences are illustrated by the coloured lines on Figure 4.16 above. MAE is a standard measure of forecast accuracy, and has the advantage of being relatively easy to communicate as its units are the same as the forecast property (i.e. tonnes) (Hyndman, 2006). This may make it a useful starting point for discussion with a range of interested parties, including policy makers, NGO's and fishing industry. It is relatively easy to explain and is useful for illustrating the changes over time or between target stock scenarios for predicting individual stocks. However, it has two main drawbacks. The first is that stocks with lower catches tend to have smaller absolute errors (in tonnes) meaning that the importance of these differences may be underweighted when MAE is averaged across stocks at the level of the model. This drawback may be overcome, either by using MAE as a metric of model performance for individual stocks only, or by converting the absolute differences into percentages of the observed catches before averaging between stocks and years (this is referred to as Mean Absolution Percentage Error, MAPE). The second drawback of MAE, is that it doesn't compare model predictions to any 'baseline' expectation of model fit, (i.e., it doesn't provide information on whether a model estimate is 'good' or 'bad' relative to a baseline). For this reason, it was proposed that a mixed fisheries Mean Absolute Scaled Error ($MASE_{MF}$) should also be used to assess the predictive skill of mixed fisheries models.

Mean Absolute Scaled Error estimates performance skill of a model relative to a baseline 'naïve' expectation (Hyndman, 2006). MASE values have been previously proposed for use in single-stock assessment, and have the advantage of giving a relatively interpretable value of model performance relative to the naïve model with values of <1 indicating that the model predictions are better than those of the 'naïve' expectation (Carvalho et al., 2021). MASE values also scale directly such that a value of 0.5 is twice as good as the naïve model, and value of 2 is half as good etc. The main challenge with applying a MASE approach, is in determining the appropriate 'naïve' model with which to make comparisons. The most commonly used naïve model in statistics is the most recent observed value, e.g., the weather tomorrow will be similar to the weather today. In the mixed fisheries context the equivalent would be that: catches next year will be the same as catches last year. This represents the simplest (i.e., most naïve) model available to the assessor at the time of the assessment (as current year catches are unknown). MASE, is calculated by dividing the observed absolute error of each prediction, by the absolution error of the prediction based on the naïve model (excluding self-predictions, i.e. where the target stock of the catch scenario and the predicted stock are the same). More formally, the Mean Absolute Scaled Error $MASE_{MF}$ of the model is equal to the $\frac{|'mixed\ fish'\ predicted\ catch - observed\ catch|}{|'naive'\ predicted\ catch - observed\ catch|}$ across scenarios, stocks and years (Figure 4.18). As with MAE, $MASE_{MF}$ can be calculated for individual scenarios, years or stocks depending on the intended purpose of the investigation.

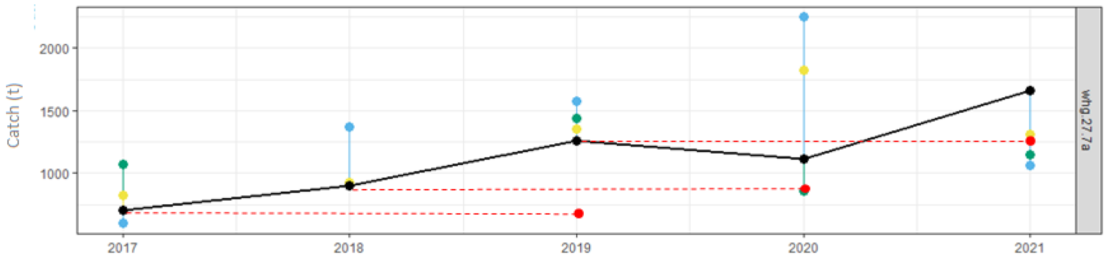


Figure 4.18: 'Predictive skill' of the Irish Sea mixed fisheries gadoid and *Nephrops* models relative to a 'naïve' model. Black points show observed catches, coloured points show mixed fishery model predictions of catches under different 'target stock' scenarios. Pale blue, green and yellow points show predicted catches from model scenarios based on observed catches of cod, haddock and *Nephrops* respectively. Red points indicate the predictions of the mixed fisheries 'naïve' model, that catches next year will the same as last year (i.e., 2 year time lag). Mixed fisheries estimates are considered to be better than the naïve model where these are closer to the observed values (black points).

The $MASE_{MF}$ provides a measure of how good the model is relative to the best guess based on last year's catches. A key advantage of this approach is that it gives a measure of 'prediction skill' relative to a naïve expectation, and it has an easily interpretable scale (i.e. models with $MASE_{MF}$ < 1, are considered to have 'prediction skill'). It is important that this naïve model to which the mixed fisheries model is compared is not partly derived from the same mixed fisheries model, as this makes it possible to compare different models and approaches to the same baseline 'naïve' model. Furthermore, the simple 'naïve' model used here, may aid in communication and interpretation due to its simplistic formulation. One of the main drawback of $MASE_{MF}$ as an approach is that this naïve model needs to be agreed upon and standardised for use across ecoregions and scientists before it can be applied on a widespread basis. At present there is no agreed naïve model, and one alternative which was discussed at WGMIXFISH was the use of the 'status quo' scenario from the mixed fisheries model. This would have advantages in terms of separating the influence of different parts of the model (i.e. fleets continuing under 'status quo' behaviour, from those changing behaviour), and would be particularly useful to model developers. However, it would be less generalisable for comparisons between models and approaches, as individual models would be compared against different naïve model estimates.

Work on the development of prediction skill metrics will continue intersessionally, with a view to more widespread implementation of approaches which utilize past observations to validate mixed fisheries models in future.

4.6 Application of alternative models for mixed fisheries management

Experiences in mixed Fisheries with IAM (Impact Assessment Model for fisheries management) – a bio-economic point of view

A presentation of different works conducted on mixed fisheries issues with the participatory bio-economic modelling framework, IAM, has highlighted possible perspectives for mixed fisheries considerations by accounting for socio-economic issues related to scenarios explored.

The presentation first highlighted the stakes related to the flexibility existing in joint productions in mixed fisheries with possible variations due to management and fishing strategies. It underlines the question of the level of aggregation required to address mixed fisheries issues.

A general presentation of the bio-economic modelling framework IAM was then proposed. IAM was developed up to 2009 within a partnership approach with stakeholders to tackle the challenges of operational bio-economic impact assessment of management strategies. The model has been developed based on existing data and knowledge, with a modular structure coded in R and C++ and a set of R routines developing the input parameter files for fleet or vessel and métier based on available economic and effort and catch data by species, fleet and métier. Where available, the model uses the inputs for short term predictions from stock assessments and a Baranov production function. It can also simulate a global biologic model based on SPiCT assessment or a constant CPUE function of the effort. The model is used in STECF context to support management plan impact assessments in western Waters (STECF 2011, 2015) and Mediterranean Seas (STECF, 2020b, 2021, 2022). It has also been used to support special requests from ICES on the Bay of Biscay sole (ICES, 2013) and to explore socio-economic impacts of alternative TAC options in the Bay of Biscay demersal fisheries in a national, French context. Applications were also developed in Australian Fisheries to support management in mixed fisheries by dealing with flexibility (Briton *et al*. 2021).

Four foci on conceptual and methodological points of potential interest to WGMIXFISH were then developed :

1. Fleet/vessel/métier aggregation issues: Applications developed in strong collaborations with stakeholders in the Bay of Biscay led to identify a set of species to be explicitly modelled according to their economic importance or their potential choke effects and to define finest level of aggregation of fleets and métier based on DCF aggregates. This step of definition of the model dimensions and level of aggregation was of importance to the legitimacy and salience of the impact assessment produced.
2. Linking biology and economics: Development of internal calibrations of partial F by fleet and métier based on existing data and procedures to allocate fishing mortality among métier and fleet also contributed to the operationality of the modelling framework developed and to link biology to economics by explicitly considering the fleet or vessel level.
3. Socio-economic impacts of scenarios and assumptions: Simulation of short and longer term socio-economic impacts of alternative sets of TAC options as in the STECF Management Plan Impact Assessment led to identifying alternative effort allocation behaviours following habits or profit maximisation and alternative possible assumptions regarding allocation of quotas among fleets – to minimize socio-economic impacts i.e. uniform decrease in quota or decrease in pro-rata of contribution to fishing mortality. It identified the added value of including stakeholder knowledge on possible reallocation behaviours according to market, management or technical constraints.
4. Flexibility and eco-viability : co-viability approach developed in the Bay of Biscay and in Australian fisheries was presented as a new paradigm to manage mixed fisheries by identifying possible domains defined as feasible set of fishing mortality of several species also satisfying biological and socio-economic viability of the mixed fishery.

The presentation concluded on potential perspectives for mixed fisheries considerations to account for socio-economic issues by accounting explicitly for the fleet/métier level, include alternative behaviours and consider short- and longer-term perspectives.

Progress and hurdles in using a spatial model (ISIS-Fish) for operational advice

Lehuta,S.; Vaz, S.; Phan,T-A; Hopkins, S.; Leforestier, S.; Genu, M.; Pataccini, M.; Mahévas,S.

Gulf of Lion fisheries are currently facing several challenges related to fisheries management and competition for space in the area. Indeed, overexploitation of commercially important species (such as hake) led to the implementation of a management plan (West-Med plan) including effort reductions and maximum catch limit, a novelty in Mediterranean Sea. Marine spatial planning is also becoming a priority because of the simultaneous development of marine protected areas aimed to manage and conserve species and habitats and of marine renewable energies. ISIS-Fish, a spatial simulation platform of the dynamics of mixed fisheries has been proposed as a tool to assess the effect of spatial measures as a complement to other non-spatial bio-economic models within the STECF framework. The development and use of such a complex model, and its transition from the academic arena to operational advice has faced various challenges pertaining to: i) the need to align model objects with the advice requirements, ii) the availability of data at the required scale, iii) the timing of parameterisation and calibration with regard to management agenda. The first challenge related to the fact that the introduction of space and seasons as well as more processes in ISIS-Fish made it less data-driven than usual operational models and it does not perfectly fit data even after calibration. Consequently, some quantities of interest for management such as fishing mortality of spawning stock biomass cannot be directly compared with assessment results or management targets. Also, a finer description of the fishery's dynamics in space and time is needed than usually done, for instance accounting for harbours for fleets, fishing grounds for métiers, growth, habitats and migrations for the stocks. Data requirements are therefore higher and not addressed by current data calls that had to be completed with ad hoc demands. Finally, the model needs to be updated on an annual (or less) basis to support decision-making. So far, parameterisation and calibration were largely based on modeller decisions and manual operations that the very short time between data release and working groups occurrence did not allow. A large effort of automation of the parameterisation process has therefore been conducted which also allowed to approach ICES standards in terms of documentation and reproducibility, although not required at STECF.

mizer as a multispecies biological operating in FLBEIA

Some ongoing work that aims to use the size-spectrum model mizer (Scott *et al.* 2014) as a biological operating model in FLBEIA (Garcia *et al.* 2017) was presented.

Mizer is a size-based multispecies model that has explicit mechanistic representation of fish growth, maturation, and biological interaction. Biological interactions are driven through changes in natural mortality from predator-prey interactions among species. These mechanistic, size-based, interactions result in emergent dynamics for a fish community under different scenarios for fishing levels and primary productivity.

A North Sea mizer model was calibrated with life history parameters, stomach data and species overlap to define a feeding matrix. The model was fitted to survey and catch time-series for 12 species in the North Sea for the period 1986-2018 and projected forwards 30 years under two different CMIP6 climate projections (RCP 2.5 and RCP 8.5) for future primary productivity in the North Sea (Spence *et al.* 2022) to estimate future Multispecies Maximum Sustainable Yield (MMSY) levels.

The fitted catches for each stock in the mizer model were disaggregated to 39 fleets and 169 métier using ICES accessions data, to condition an FLFleetsExt object for use in FLBEIA. New mizer and FLBEIA functions (https://github.com/CefasRepRes/FLBEIA/mizer_functions.R) were defined to:

- Convert the length-based outputs from mizer to age-based outputs,
- Condition FLBiols and FLFleetsExt using the ouputs of mizer and fleet and métier disaggregated catch and effort data,

- Update the FLBiol objects based on a new 'mizerGrowth' function for the new weights and natural mortalities,
- Project forward the stocks by driving mizer using the catch estimates in FLBEIA (converted to at-age fishing mortalities) taking account of the fleet-level choking behaviours – this was undertaken by including the mizer model as a covariate in the 'covars.om' of FLBEIA,
- Defining a new 'IcesHCRmizer' function to generate catch-based advice under the biological dynamics of mizer, replacing the existing IcesHCR function.

There were technical challenges in the process, particularly in converting the length-based outputs from mizer to age-based inputs for FLBEIA, which created some inconsistency in cohorts and computed fishing mortalities. As such, work is ongoing to improve the implementation. However, preliminary outputs showed feedback between the choking effects on some stocks (from technical interactions) and higher biomasses of those stocks resulting changes in multi-species interactions (higher natural mortalities from biological interactions), which in turn affected MSY attainment. As such the use of mizer as a biological operating model within FLBEIA demonstrated promise as a tool for accounting for technical interactions and biological interactions together.

Fostering WGECON and WGMIXFISH collaboration

The annual WGECON meeting took place in parallel to WGMIXFISH-METHODS, which provided motivation for continued discussion regarding possible future collaboration and coordination regarding common goals. As part of early discussions, members that participate in both groups acted to help facilitate this collaboration and discussion during the meeting.

The overall objective of ICES WGECON is to address the challenge of bringing fisheries economics into ICES science and advice. Among the identified key issues, as outlined in Thebaud et al. (2023), is the question of mixed fisheries management, which relates to other topics, like TAC setting, fishing rights allocation, and adjustment of capacity or diversification strategies.

A number of integrated bio-economic models have been developed and applied (also in operational contexts as in STECF Impact Assessment processes) to explore the alternative management of mixed fisheries. A review of those models is proposed in Nielsen et al. (2018). Modelling interactions in fisheries between fleets (or vessel) by allocating their effort to different metiers and stocks, they explore biological and socio-economic consequences of alternative scenarios. The distributional effects of scenarios among fleets are of particular interest. These kinds of integrated applications have not however been used within an ICES advice process to date.

Other works have been developed in connection to WGECON objectives based on existing databases with the goal of providing a more complete description of fisheries dynamics from an economic point of view. These aspects could contribute to the Fisheries Overview and Ecosystem Overview, providing auxiliary information regarding mixed fisheries interactions, including the socio-economic consequences of choke effects to the different fleets. The use in ICES advice of this kind of integrated work considering biological and socio-economic issues associated with mixed fisheries management could be further developed through cooperation between WGMIXFISH and WGECON.

Such collaboration could be fostered through the coordination of physical annual meeting locations between WGECON and WGMIXFISH-METHODS, which would enable joint discussions and the sharing of views and relevant work regarding mixed fisheries management issues. Co-operation could also occur within WGMIXFISH-ADVICE, through the development of specific case study applications. The Bay of Biscay case study was highlighted in particular for this due to existing work developed with IAM (see Macher et al. 2018; Briton et al. 2020, 2021), which could aid further development of the FLBEIA model used within WGMIXFISH. This in turn could inform on potential, multi-criteria consequences of mixed fisheries scenarios. This exercise could provide concrete examples of added value of such integrated advice on particular case study, aiding in the advancement of the methodologies, identify-cation the data requirements, and to exploration potential outputs.

Advancing economic considerations in WGMIXFISH area would also address expressed wishes from stakeholders for additional economic information (ICES 2023a), which could result in more salient advice. Among identified issues to advance integration of economic advice in WGMIXFISH is the need to include the DCF fleet level in the data call to be able to assess impacts at fleet level and facilitate connection between the Annual Economic Report and the fleets-metier in WGMIXFISH.

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

5.1 Bay of Biscay

Reproduction of short-term forecast

Differences obtained in the short-term forecast between that carried out for mixed fisheries considerations and the one performed by the assessment working groups have been analysed for hake and seabass.

- Hake: Alternative input data were used to check which one was able to reproduce more accurately the short-term forecast: i) taking the outputs of SS using available FLR functions; ii) same data but making some corrections in the mean weights to have same total catches as reported in the assessment; iii) rescaling catch numbers in (i) to get observed catches; and iv) as in (iii) but with mean weights from (ii). Finally, the best performance was achieved when making corrections to the mean weights-at-age in the catches. However, there are still issues with the catch allocation among landings and discards, that need to be further investigated.
- Seabass: The procedure used requires changing mean weights "manually", as when they are extracted in the FLStock object from Stock Synthesis, these are incorrect. Issues persist on the catch allocation, as for hake.

In both cases, variables (SSB, F, catches and landings) are within the accepted levels of error (except discards). Nevertheless, this is considered as a limiting issue to carry out the mixed fisheries analysis, as the advice for both stocks is based on catches.

Additional developments

Some of the tasks defined for the Bay of Biscay case study given the outcomes and issues encountered during WGMIXFISH-Advice 2022 are planned to be done intersessionally. These are:

- **Fleet structure:** Based on latest data available the fleet configuration is being revised complying with the criteria defined by the group under the methodological framework (see ToR b, section 3.4). The fleet definition is expected to change mainly for the French fleets. At the same time, the importance of the demersal species in the catches of the pelagic fleets will be analysed to reconsider including them in the model or not.
- **Modelled stocks:** The rays data quality has been checked and we are considering including the stocks again if possible.
- **Scenarios:** Sensitivity runs to assess the impact of combined TACs will be considered. Additionally, the range scenario will be implemented given the latest defined procedure (see ToR b, section 3.4).

Finally, the inclusion of fleet dependent age structure in the conditioning of the model for some stocks remain of interest to the Bay of Biscay but are expected to take place over a longer time frame. Probably beginning with hake as example following the procedure used in the North Sea case study.

5.2 Celtic Sea

Continue work on the implementation of FLBEIA model

During the recent Interbenchmark (ICES, 2021b) the feasibility of moving to using FLBEIA as the basis for mixed fisheries considerations in the Celtic Sea was evaluated. A process for generation of age-disaggregated catch data at the fleet and métier level was developed, as needed to implement an FLBEIA model, and an FLBEIA model conditioned to produce mixed fisheries scenarios. Ultimately, however, it was decided not to switch advisory model from FCube due to (i) inconsistencies between the implemented Cobb-Douglas catch production equation in FLBEIA and the single stock Baranov catch equation under plausible levels of catches for the region and, (ii) the way discards weights are conditioned based on recent observations was causing some further inconsistent outputs. These two issues need to be addressed to move the Celtic Sea considerations to an age-based framework.

Work on this has been undertaken intersessionally and is presented elsewhere under ToR C (see section 4.4) where a method to implement a fleet-based Baranov catch equation. The Celtic Sea subgroup will continue to assess how this can be implemented for the case study.

Alternative ways of conditioning discard weights have been also considered. In principle, discards can be partitioned into those under minimum legal size or due to a lack of market, or those that are due to a lack of quota available. It was considered the latter discards were more likely to have mean weights at age that are closer to the landings mean weights at age. Ways to implement this change are being considered.

Streamline code, repository and results tables and figures in TAF

Work was undertaken to clean the current code in preparation for the advisory meeting later in the year. This mainly involved altering the code to produce clearly labelled and documented settings for each model run, to avoid potential mistakes where results from the wrong model run are picked up. Further work to automatically produced the tables and figures was also undertaken.

Conduct further development of the “range” scenario

This was addressed under ToR B (see section 3.4.3) so not elaborated on further here.

5.3 Iberian Waters

Exploratory analysis on new species for mixed fisheries considerations

The wide distributed stocks *Scomber scombrus* (mac.27.nea) and *Micromesistius poutassou* (whb.27.1-91214) have their southernmost distribution in the area and small quantities are taken along the coast of Portugal and Spain when compared with the other areas of distribution of these large stocks.

It was discussed within the case study group that these stocks exhibit distinct seasonal distributional and migration patterns which can be amplified in the southernmost distributional area of the stocks. Furthermore, due to their pelagic or semi-pelagic habitat, they give rise to a distinct fishing activity in the region that can primarily target these species, resulting in minimal technical interaction with other demersal species. However, analysis of the main species landings in the area from 2019-2021 showed that in the Spanish demersal fleets the main landed species in weight are blue whiting and mackerel, followed by hake, horse mackerel, anglerfishes, and megrims. Three pelagic/semi-pelagic species (blue whiting, mackerel, and horse mackerel) constitute 61% of the total landings in the demersal métiers. The same analysis performed for the Portuguese trawl demersal métiers indicate that the most important species are horse mackerel, mackerel, hake, and blue whiting. The three pelagic/semi-pelagic species (blue whiting, mackerel, and horse mackerel) constitute 41% of the total landings in the demersal métiers (ICES, 2022b). Blue whiting and mackerel are also found in the majority of analysed demersal fisheries and are particularly significant within the trawl métiers in the area.

Because of the importance of these stocks in the total landings and to further explore the fishing activity for blue whiting and mackerel in the region during the WGMIXFISH-METHODS meeting, exploratory preliminary analysis was performed using the Portuguese trawl logbooks provided by the Portuguese fisheries administration (Directorate-General for Natural Resources, Safety and Maritime Services – DGRM) compiled and revised for the period 1988-2022.

Table 5.1 shows the number of vessels, the total number of fishing days recorded, trawling hours, mean vessel engine power, blue whiting, mackerel and total mean catch and the percentage zero catches for the two species. In the final dataset comprising 417,148 records, the mean catch showed some year-to-year variations and was higher for blue whiting, except during the period of 1989-1991, where mackerel showed greater catches. The average proportion of zeros was 83% and 79% for blue whiting and mackerel, respectively. These relatively high mean percentage of zeros could be a result of the previously mentioned seasonal/spatial catch dynamics for both species and the computation of these summary statistics at level 2 métier (gear trawl).

Year	Number vessels	Number days	Trawling hours	Average power (kW)	Average Tot Catch (kg)	Average catch WHB	Average catch MAC	Percent zeros WHB	Percent zeros MAC
1988	33	3527	47460	529.3	1364.4	114.4	83.8	86.3	77
1989	18	1565	21655	550.4	1729.7	38.1	111.1	94.4	82.7
1990	52	5875	74489	543.4	1757.7	119.6	123.9	87.6	70.1
1991	54	4418	55332	546.5	1679.6	176.5	136.3	82.7	63.7
1992	47	6964	85599	530.9	1150.2	126.1	70.3	88.1	70.9
1993	67	11905	144027	517.6	1001.2	46.4	31.8	90	80.1
1994	73	11489	136724	525.8	839.7	123	38.4	84	81.7
1995	73	11568	143620	525.4	868.1	139.5	43.5	86.4	80.7
1996	76	11449	143111	524.2	791.6	190.2	35.9	86.3	81
1997	77	13945	178204	518.2	756.9	120.7	19.9	91.6	85.2
1998	79	13812	179761	529.5	894.1	95.2	49.4	88.5	70.5
1999	87	12001	150440	518.1	865.7	180.9	46.3	84.4	75
2000	69	12964	167766	522.5	1061.9	123.1	72.9	77.8	67.5
2001	35	6127	79932	551.9	1201.1	148.5	79.3	68.6	63.5
2002	61	7226	83608	564.5	1139.2	141.7	89.7	75.1	68.5
2003	84	14067	178974	490.8	836.5	90.2	50.1	79	75.2
2004	65	12358	151957	511.9	874.4	71.1	60.3	81	67.5
2005	85	8874	110074	495.5	949.3	103.4	58.1	77.4	69.2
2006	87	8302	106836	463	741.4	109	18.5	82.4	88.9
2007	88	17017	211659	474.5	849.2	183.3	16.6	77.2	87.6
2008	94	16074	207795	470	1050.9	221.4	20.6	78	86.5
2009	90	15566	201138	453.3	903.4	113.1	22.7	82.3	87.6

Year	Number vessels	Number days	Trawling hours	Average power (kW)	Average Tot Catch (kg)	Average catch WHB	Average catch MAC	Percent zeros WHB	Percent zeros MAC
2010	76	14322	185823	439.4	929.8	88.6	18.7	83.8	88.3
2011	79	13634	180402	441.1	932.5	47.8	30.5	89.6	80.6
2012	75	13967	164551	458	928.4	123.8	13.5	82.5	90.8
2013	80	13945	157158	447.9	1163.5	144.4	14.8	80	86.8
2014	79	13555	152391	432.6	1141.2	94.1	26.6	81.3	81.2
2015	80	14544	161143	432.8	1161.6	116.2	50	82.6	80.6
2016	79	15114	166251	431.1	1404.8	139.2	52.8	80.7	91.5
2017	78	14981	167616	419.2	1407.6	138	30.8	78.6	80.8
2018	82	15605	177604	424.5	1065.9	113.3	44.6	84	79.7
2019	81	15158	171779	421.7	1143.1	129.8	30.4	83.4	80.7
2020	82	14921	166567	408.3	1104.5	132.3	23.1	85.3	80.5
2021	80	16310	188378	409.6	1026.4	73.4	39.4	85.9	79.7
2022	80	13999	173944	415.4	967.3	129.9	41.3	84.5	77
Aver-age	**72**	**11919**	**144965**	**483.97**	**1076.65**	**121.32**	**48.45**	**83.18**	**78.82**

Table 5.1 Summary of the data obtained from the Portuguese trawl logbooks for the description of blue whiting (WHB) and mackerel (MAC) fishery.

Figure 5.1 shows the aggregated catches (1988-2022) of blue whiting and mackerel by month and three distinct Portuguese mainland areas; northwest, southwest and south. These areas are well-known regions in the study area, delineated based on specific characteristics such as topography, type of seabed), depth (corresponding to identified benthic and fish communities), and the intensity of coastal upwelling. Mackerel catches are mostly concentrated in the northern area, and they peak during the winter season. On the other hand, blue whiting appears to be predominantly found along the western coast of Portugal, with higher catches observed during the summer months, although catches occur throughout the entire year. Blue whiting is caught across all mesh sizes. On the other hand, mackerel is almost exclusively caught in trawls equipped with mesh sizes of 65-69mm and >=70mm. The analysis of the aggregated Portuguese trawl logbook catches reveal distinct patterns in the spatial and seasonal distribution of mackerel catches which are not as apparent in the case of blue whiting.

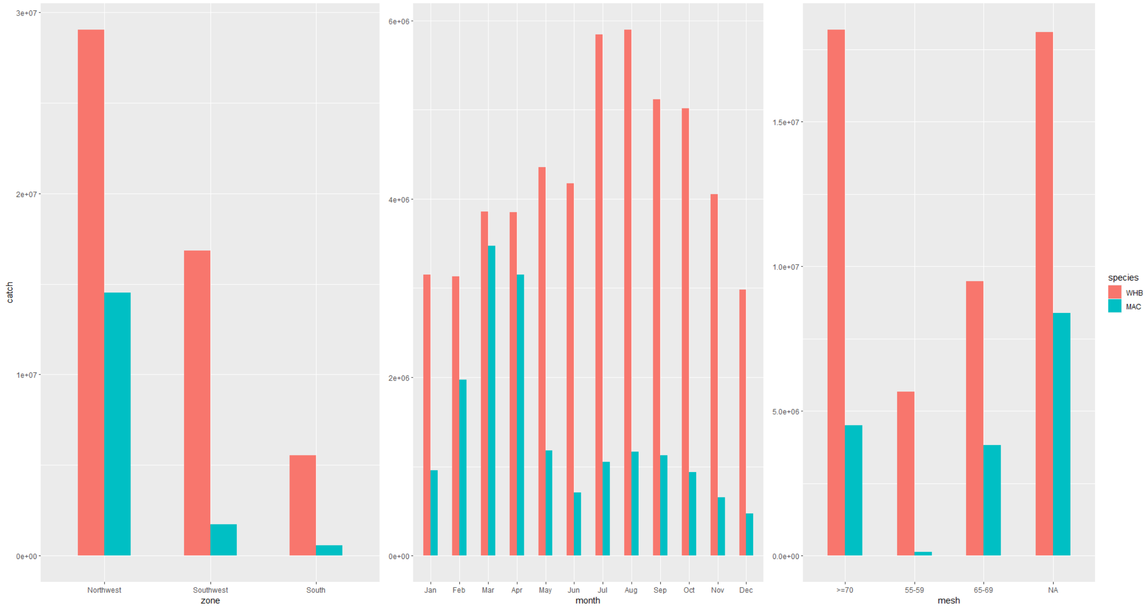


Figure 5.1. Total catches (kg) of blue whiting (WHB) and mackerel (MAC) by zone (left panel), month (middle panel) and trawl mesh(mm) size (right panel).

Modelling catch proportions with Beta Regression

The following step of this analysis focused on characterizing fishing hauls with the presence of blue whiting and mackerel trying to understand the fishing choices made by trawl vessels and assessing the level of technical interaction with other species during the capture of these two species. The behaviour of the fishery was analysed by assessing the proportion of mackerel and blue whiting in each trawling haul using a beta regression which assumes that the dependent variable has a beta distribution. Preliminary analysis (not shown) on the density distribution of the proportions of mackerel and blue whiting catches show that this flexible distribution could be suitable for the observed proportion variability. However, the response variable can vary between 0 and 1, but no observation can equal exactly zero or exactly one, that is, proportion of 0 and 1 were excluded from the dataset. Beta regression parameters (mean and dispersion) were fitted with the R *betareg* package (Cribari-Neto and Zeileis, 2010) assuming that the dependent variable follows a beta distribution and that its mean is related to a set of exploratory variables through a linear predictor with unknown coefficients and a logit function.

The exploratory variables considered in the analysis included categorical variables zone, month, mesh size and continuous variables, LOA, gross tonnage and engine power of the vessels. Potential collinearity between the independent variables (vessels characteristics) was analysed and only vessel engine power was retained and also categorized (*cat_power*). A categorical variable, *target*, was added based on the target species observed in each haul. This categorization was done when the catch proportion of a particular species/group exceeded 50% relative to others and included horse mackerel (*hom*), hake (*hke*), *rays*, cephalopods (*ceph*) and either blue whiting (*whb*) or mackerel (depending on the model response). Hauls where no single species/group dominated were classified separately as *mix*.

Mackerel

Beginning with a simple Model 1 where the mean proportion of catch varies with the year, models were selected through a sequential inclusion of significant variables and based on the Akaike

Information Criterion (AIC) and residual diagnostics. Table 5.2 summarizes the sequential inclusion steps for modelling the proportion of mackerel in hauls. The included variables in each step are described and in categorical variables their respective factor levels are in brackets. The estimated dispersion parameter also known as precision parameter is showed for each model. The AIC column displays the corresponding decrease in AIC compared to Model 1 for each step. The inclusion of a categorized engine power variable (Model 5) had better performance compared to using a continuous variable (Model 4). Additionally, while mesh size (Model 6) was significant, because of the large number of NA´s in this variable its inclusion led to a substantial decrease in observations and increase in the AIC and therefore not retained in the final model. The final Model 7, with the *target* species variable, substantially decreased the AIC contributing for model accuracy.

Model	Variable	dispersion	rdf	AIC Decrease
1.betareg(mac ~ year)	year	4.37	83068	
2.betareg(mac ~ year+zone)	zone(northwest, southwest, south)	4.46	83066	1507.4
3.betareg(mac ~ year+zone+month)	month(January to December)	4.54	83055	2893.6
4.betareg(mac ~ year+zone+month +power)	engine power	4.60	83053	3764.4
5.betareg(mac ~ year+zone +month+power_cat)	engine power (0-400;401-800, >801kW)	4.62	83054	3973.1
6.betareg(mac ~ year+zone+month+ power_cat+mesh size)	mesh size (55-59, 65-69 and >=70mm)	5.49	45123	-51328.1*
7.betareg(mac ~ year+zone+month+ power_cat + target)	**target(hom, hke, whb ceph, rays, mix)**	**5.21**	**83048**	**12010.4**

***Different number of observations, non-comparable to Model 1**

Table 5.2: Summary of beta models tested for the proportion of mackerel in hauls. In the "variable" column, categorical variables are shown with their factor levels in brackets. The "dispersion" and "rdf" column indicates the estimated dispersion parameter and the residual degree of freedom (number of observations -number of estimated variables) and the "AIC decrease" column represents the decrease in AIC compared to Model 1 at each step.

The estimated marginal means and confidence intervals for the proportion of mackerel in hauls for predictors *zone*, *engine power*, *month* and *target* in Model 7 are shown in Figure 5.2. Estimated marginal means show that the proportion of mackerel in hauls is significantly higher in the Northwest region compared to the other two areas. Vessels with 0-400kW and 401-800kW engine power have similar mean estimates for the proportion of catches, while vessels with higher engine power have lower catch proportion. The proportion of mackerel reaches relatively higher proportions in Winter and Summer. The *target* variable by definition has a significant effect in the proportion level, with the *mix* level showing the highest proportion as expected. The lowest observed proportion occurs in the *whb* level factor, with the remaining levels showing similar estimated proportions. The large confidence interval observed in *rays* is associated with a non-significant coefficient linked to this level factor (p =0.57).

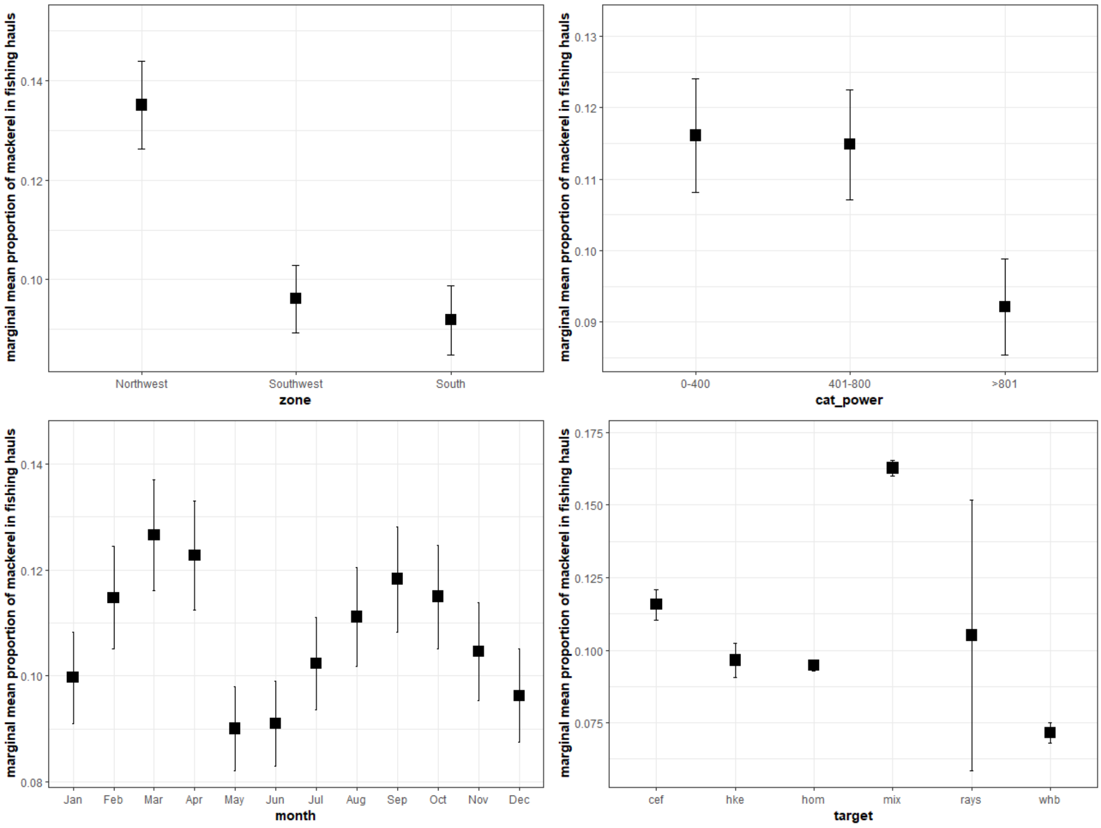


Figure 5.2: Estimated marginal means with confidence intervals for the proportion of mackerel in hauls for categorical predictors zone, engine power (kW), month and target species.

Blue whiting

Table 5.3 summarizes the sequential inclusion steps for modelling the proportion of blue whiting in hauls. The inclusion of the continuous engine power variable (Model 4) resulted in a slightly reduced performance compared to Model 3. However, and again using the categorized variable showed a larger decrease in AIC (Model 5). Despite the substantial number of NAs in the mesh size variable, which considerably reduced the degrees of freedom, the model performance showed a substantial improvement. In a trade-off between the number of observations and model performance, we decided to retain the mesh size variable in the final Model 8, which, with the addition of the target variable, exhibited considerable improvements in performance.

Model	Variable	Dispersion	RDF	AIC Decrease
1.betareg(whb ~ year)	year	1.35	72081	
2.betareg(whb ~ year+zone)	zone(northwest, southwest, south)	1.45	72079	5191.71
3.betareg(whb ~ year+zone+month)	month(January to December)	1.48	72068	6664.62
4.betareg(whb ~ year+zone+month +power)	engine power	1.50	72066	6715.11
5.betareg(whb ~ year+zone +month+power_cat)	engine power (0-400;401-800, >801kW)	1.74	72067	7325.93

Model	Variable	Dispersion	RDF	AIC Decrease
6.betareg(whb ~ year+zone+month+ power_cat + target)	target(hom, hke,whb ceph, rays, mix)	1.45	72061	17757.36
7.betareg(whb ~ year+zone+month+ power_cat+mesh size)	mesh size (55-59, 65-69 and >=70mm)	1.45	49997	3173.53*
8.betareg(whb ~ year+zone+month+ power_cat+mesh size +target)	**target(hom, hke,whb ceph, rays, mix)**	**1.61**	**49992**	**8315.57***

***Different number of observations, non-comparable to Model 1**

Table 5.3: Summary of beta models tested for the proportion of blue whiting in hauls. In the "variable" column, categorical variables are shown with their factor levels in brackets. The “dispersion” and "rdf" column indicates the estimated dispersion parameter and the residual degree of freedom (number of observations -number of estimated variables) and the "AIC decrease" column represents the decrease in AIC compared to Model 1 at each step.

The estimated marginal means and confidence intervals for the proportion of blue whiting in hauls for predictors *zone*, *engine power*, *month*, *mesh size* and *target* in Model 8 are shown in Figure 5.3. The Model 8 estimated means show that the proportion of blue whiting in hauls is higher in the Southwest region compared to the other two areas. Vessels with engine power >801kW have higher catch proportions. The proportion of blue whiting seems to be relatively higher in the Autumn. The *target* variable by definition has a significant effect in the proportion level, with the *mix* level showing the highest proportion as expected, with the remaining levels showing similar estimated proportions. The large confidence interval observed in *rays* is associated with a non-significant coefficient linked to this level factor (p =0.07).

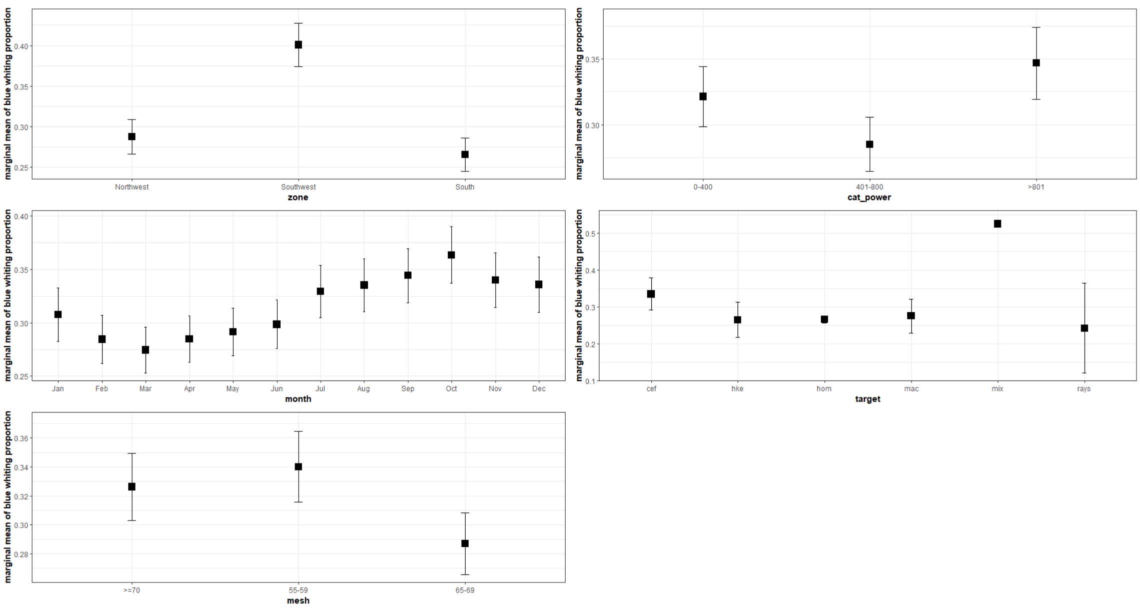


Figure 5.3: Estimated marginal means with confidence intervals for the proportion of blue whiting in hauls for categorical predictors zone, engine power (kW), month, target species and mesh size (mm).

While some experiments were conducted involving interactions, such as e.g., mesh size|engine power and target|month, the final models were defined without including interactions. However, it is important to note that further analysis should be undertaken to test the potential impact of interactions on the model’s predictions on the mean proportion of catches that can potentially improve the overall model fit and accuracy and reveal other patterns.

In this exploratory analysis we employed a beta regression model assuming that the variability of the proportion of catch of blue whiting and mackerel follows a beta distribution, shaped by mean and dispersion parameters. While this distribution offers considerable flexibility, alternative methods or distributions should also be considered, especially those with the potential to include the presence of 0's observations.

We observed that catch proportions from other species/groups had a significant effect on the mean estimated proportions in each haul. The substantial decrease in AIC upon including this variable highlights its significant contribution to model accuracy, suggesting potential interactions between mackerel and blue whiting proportions with several other species. These interactions may also reflect variations in trawl fleet behaviour. The significance of the variables month, engine power, and mesh size (for blue whiting) suggests their potential usefulness in identifying the appropriate métier for these specific stocks. The model results also revealed varying levels of interaction as measured by the proportion level of catches in each haul. For example, blue whiting seems to occur in "cleaner hauls" (higher proportions) but is consistently present in the west coast, with a peak in the Autumn/Winter months but also abundant throughout the year and captured by different types of trawl vessels (characterized by mesh size and engine power) which increases the potential for interactions. On the other hand, mackerel despite occurring in mixed hauls with lower proportions and with higher potential for increased interaction with other species is limited to the northwest area and exhibits a distinct seasonal pattern, leading to a potential reduced level of interaction. Modelling the proportion of catches revealed the significant influence of multiple factors. However, to gain a comprehensive understanding of the observed dynamics, further investigation is required into these factors.

This analysis was based on revised logbook data from 1988-2022, despite providing a large amount of information have some known issues of e.g., misreporting and combining catches from different hauls or fishing operations. Particularly, blue whiting catches have lower market value in the area, leading fishermen to target this species strategically as a means to work around current legislation, mostly percentage restrictions on bycatch species or closed-season species and aiming to improve catch opportunities for these valuable species. Furthermore, logbook data in the analysed time period suffered format changes that could have led to inconsistent reporting which may lead to biased estimates.

It is important to acknowledge that there are indications suggesting distinct fleet dynamics for the mackerel and blue whiting fisheries in Spanish waters that should be further analysed to assess the inclusion of these species in the Iberian Waters mixed fisheries considerations.

5.4 Irish Sea

Landings for gadoid stocks to be submitted to WGMIXFISH accessions for the same areas as used in the single stock assessment

Single-stock assessments and advice for cod, haddock and whiting in the Irish Sea (27.7.a) excludes data from the southernmost rectangles (33E2 and 33E3). For biological reasons, cod, haddock and whiting caught in these rectangles are considered part of the cod.27.7e-k, had.27.7b-k and whg.27.7.b-c,e-k respectively. In previous years, the data submitted to WGMIXFISH accessions by Ireland did not exactly match with that used in the single-stock assessment because catches from these rectangles had not been reallocated. This has been discussed and clarified with the relevant data submitters and the landings data was resubmitted by Ireland to match the data used in the single-stock assessment. A review of the 2023 accessions data shows a good match between WGMIXFISH accessions data and InterCatch data for these stocks in the 2022 data year.

Implement the 'range' scenario following further development to be conducted in other regions

The implementation of 'range' scenarios in mixed fisheries models is discussed in section 3.4 above. This section demonstrates a new method of utilizing the F_{MSY} ranges from single-stock advice in the mixed fisheries framework. This change in method aims to simplify the approach due to concerns about the interpretation of the previously used 'range' scenario. The new approach, termed the 'pretty good yield' (pgy) scenario utilizes the $F_{MSY\ upper}$ option (where available, for stocks with SSB above MSY $B_{trigger}$) within a mixed fisheries 'min' scenario (i.e., a scenario where – for each fleet, fishing stops when the catch for any one of the stocks meets the fleet's stock share).

This 'pgy' scenario will be run as an additional scenario for the Irish Sea in the 2023 WGMIXFISH-ADVICE meeting. However, the output of this scenario is not expected to differ much (if at all) from the standard 'min' scenario for the Irish Sea region. This is because the results of the 'min' scenario are driven by the most limiting stocks for each fleet. In last years' 'min' scenario for the Irish Sea, all fleets were limited by the zero-catch advice for whiting. Zero-catch advice for whiting has been issued by ICES again for 2024 and 2025. If fishing fleets in 2022 show similar catch compositions to preceding years, then changes in the target catches for stocks with $F_{MSY\ upper}$ catch options in the FCube model will not affect the outcomes in a 'min' scenario, because fleets will still be limited by zero-catch advice for whiting. However, as noted in section 3.4 this 'pgy' approach remains a useful scenario in illustrating the potential impacts of F_{MSY} ranges in the single-stock advice in the mixed fisheries context, particularly in regions where some fleets are not limited by stocks which are below MSY $B_{trigger}$.

Investigate of further scenarios based on alternative catch management options for zero-catch advice stocks

Options for including alternative scenarios for stocks with zero-catch advice were discussed, considering the zero-catch advice for whiting (whg.27.7a) and sole (sol.27.7a) in the Irish Sea, and for cod (cod.27.7b-k) and whiting (whg.27.7.b-c,e-k) in the Celtic Sea (ICES, 2023c). Zero-catch advice was also issued by for pollack (pol.27.6-7) which is not currently included in any mixed fisheries model (ICES, 2023c). In the case of zero-catch advice stocks, there is an annual "EU standing request" for additional catch scenarios relating to the expected bycatch of these stocks. For the Irish Sea these have previously been issued outside of the WGMIXFISH process. This year, given that there is now an approved FCube model for the Irish Sea, it is expected that a response to this EU standing request will be issued for sol.27.7a and whg.27.7a following the WGMIXFISH-ADVICE meeting in Autumn. This is similar to the process which has been used in recent years to provide alternative catch options for cod.27.7b-k in response to this standing request in the Celtic Seas region.

The Irish Sea FCube model has been previously tested with alternative whiting catch targets including stable SSB and increasing SSB by 20% (ICES, 2022e), based on the catch options applied for this stock in previous technical services (e.g., ICES, 2021a; ICES, 2022a). By contrast, technical services for cod.27.7b-k run using the Celtic Sea mixed fisheries model in 2022, focused on the likely bycatch of cod and implications for its SSB, if haddock (had.27.7b-k) were fished at the F_{MSY} advice, $F_{MSY\ lower}$ or midpoint between these values in 2023. There are advantages to either approach, with the former (based on the SSB of zero-catch stock) focusing more directly on the conservation of the bycatch stock, whilst the later (implications of F_{MSY} advice of another stock) focusing more directly on the expected bycatch of the fishery. These options will be discussed further at the WGMIXFISH-ADVICE meeting, and scenarios based on these catch options will be developed for the ICES whg.27.7a technical service. Using the Irish Sea FCube model for this purpose is considered to be appropriate as whiting has been shown to have strong technical interactions with the main fisheries in the region. Sole fisheries in the Irish Sea are more targeted, and are mainly caught in different gears (e.g., beam trawls) and fleets, from the gadoid and *Nephrops* fisheries. As a result, it may be more appropriate to describe catch scenarios for sole in the Irish Sea in the zero-TAC technical service without the use of the current Irish Sea FCube model. If this were to be the case, catch scenarios for this stock would instead be based on additional catch options from the single-stock model, augmented with descriptive data on fleets and gears from the WGMIXFISH accessions data. This will be further investigated prior to the WGMIXFISH-ADVICE meeting.

Additional developments

Progress work on historic model validation techniques: Further work has been conducted intersessionally on model validation techniques. This work was presented and discussed in this meeting and is described in section 4.2 above.

The following points, raised for further development at the 2022 Advice meeting, remain of interest to the Irish Sea but are expected to take place over a longer time frame.

- Investigate the potential for implementation of an age-based model (e.g., FLBEIA/age-based FCube model) and compare with current FCube approach.
- Investigate differences in catch compositions of fish-stocks between *Nephrops* FUs if data sources allow.

5.5 North Sea

Scottish fleet analysis

To aid the development of mixed fisheries modelling and analysis there is a need to analyse and characterise fishing behaviour at a national level. An analysis of the Scottish demersal fishing fleet was presented at WGMIXFISH-METHODS. This analysis was conducted on 2016-2021 data extracted from the UK national iFish database which incorporates logbook data and sales information. To define the Scottish demersal fleet the data were restricted to Scottish registered vessels and to trips landing demersal fish species or *Nephrops*. Trips landing predominately (>=80%) other taxa groups were excluded. Records of some species were grouped together to a higher taxonomical level (e.g., squids, skates and rays, dogfish). Additionally, vessels were allocated to one of the WGMIXFISH vessel length categories (<=10m, 10<24m, 24<40m, >40m).

The first step in this analysis looked at consistency in the behaviour and fishing choices of individual vessels. The behaviour of individual vessels was analysed by calculating the proportion of vessels engaging in various activities. Overall, most vessels seem to exhibit the same pattern of behaviour over time and the majority of vessels do not exhibit a wide variety of behaviours. The vast majority of vessels are fishing in just 1 ICES division (60%), targeting up to 2 assemblages (92%), using just one type of gear (74%) with up to 2 different mesh sizes (88%). Although most vessels fish all year round (45%), significant proportions of vessels fish in either 1, 2 or 3 quarters (~20%) indicating some seasonality to fishing activity in some vessels. Causes include bad weather, migration patterns, the timing of *Nephrops* burrowing, vessel maintenance schedules, market seasonality. The majority of the fleet comprises of vessels less than 24 m in length (80%) with an almost equal split between those less than 10m (38%) and those between 10m and 24m (42%). A very low percentage of vessels in the demersal fleet are over 40m (1%).

The methodology used for the analysis follows that of Moore et al., (2019). This methodology used a Principal Component Analysis (PCA) to identify the best level of data aggregation to adequately capture the variability in the landing profiles. A Hierarchal Agglomerative Clustering (HAC) analysis is then performed on the aggregated data to define coherent clusters from the landing profiles. Before running these analyses, the landings data were process to reduce unnecessary complexity. Gear types and individual records with low contributions to the total landings (<0.1% of landings and <1% of the cumulative total landings) were binned to the "MIS_MIS_0_0" métier. To focus on only the most important species in terms of landings, only the top 20 species (accounting for 98% of total landings) were considered in the analysis with other species being binned to an "OTH" group. Finally, trips where landings of "OTH" species were more than 80% of the total landings were removed.

A Principal Component Analysis (PCA) was conducted on the data at various levels of aggregation across the available trip variables. First, the landings data were converted to proportion of landings that each species contributes for each fishing unit (defined by the variables used to define the level of aggregation) to create a landings profile. A non-normalised PCA was then conducted on these landing profiles. A non-normalised PCA was used to allow for species dominance. The PCA reduces the dimensionality of a dataset and identifies the main reoccurring species combinations that explain the greatest variance. The optimal level of aggregation was determined by the amount of variation explained by the first 4 Principal Components.

The results of the PCA runs were then put through a Hierarchical Agglomerative Cluster (HUC) analysis (HAC, utilising Euclidean distance and Ward's algorithm (Ward, 1963)). All of the principal components resulting from the PCA were used in the HAC to retain enough variation arising from the complexity within the data. The HAC builds a hierarchy from individuals to a single group by creating successive clusters from previously identified clusters (Davie and Lordan, 2011; Holley and Marchal, 2004; Moore *et al*., 2019; Pelletier and Ferraris, 2000). In previous studies, the appropriate number of clusters from the HAC was taken to be that at which the increase in the proportion of variance explained plateaus (defined as <0.5% increase in variance explained with each additional cluster) (Ulrich and Andersen, 2004).

Run 7 achieved the most variation in the first 4 PCs (79.46%) identifying area (ICES division) and gear type as the major drivers of clustering. The plot of PC1 and PC2 show separation of fishing units dominated by *Nephrops*, hake and haddock/anglerfish (Figure 5.4). The plot of PC3 vs PC4 shows further separation this time of haddock, anglerfish and OTH (Figure 5.5). The HAC resulted in 19 clusters that in total explain 94% of the total variance.

Some examples of the landing profiles falling into these clusters are given in Figure 5.6 and the spatial distribution of trips falling into these clusters is shown in Figure 5.7. Some clusters identified by the analysis have distinct landings profiles though represent a small portion of the total landings across the demersal Scottish fleet. These distinct clusters represent fishing activity that is focussed on the continental shelf edge and target slope species using gillnets and/or long lines (e.g., Cluster 1: Figure 5.7). However, the bulk of the landings are taken in clusters with very mixed landings profiles (clusters 10 and 12: Figure 5.6) consisting of the major target species for Scotland (cod, haddock, whiting, anglerfish, saithe, *Nephrops*). Although, some clusters do show dominance by a single target species, for example, haddock in cluster 16 and *Nephrops* in cluster 17 (Figure 5.6). This is due to the effect of area since cluster 16 contains activity mostly focussed at Rockall and cluster 17 contains activity mostly focussed around *Nephrops* FUs (Figure 5.7).

Interestingly, these clusters show a north-south divide in the North Sea indicating that it may be prudent to separate fishing activity in 4.a, 4.b and 4.c in the North Sea mixed fisheries model rather than grouping them together as currently done. This is especially true for division 4.c which is often grouped with activity in the English Channel rather than the rest of the North Sea (cluster 7 and 8 in Figure 5.7).

These results indicate that the area and gear variables are enough to capture variability in landings profiles and produce distinct clusters of fishing activity. The mean number of clusters per individual vessel is 2.29 and the mean number of clusters per individual fishing trip was 1.06 indicating that most vessels and trips fall into only 1 or 2 clusters. This agrees with the high consistency seen in individual vessel behaviour seen in the first part of this analysis.

These clusters could form a starting point for defining units of fishing activity in the Scottish demersal fleet for future mixed fisheries modelling. Further work is planned to make better use of the spatial information (i.e., ICES rectangle) in the iFish database and to see if considering other trip variables could separate out some of the more mixed-catch clusters. These analyses will help to inform future work by WGMIXFISH when developing best practice methods for defining fleets and métiers from RDBES data.

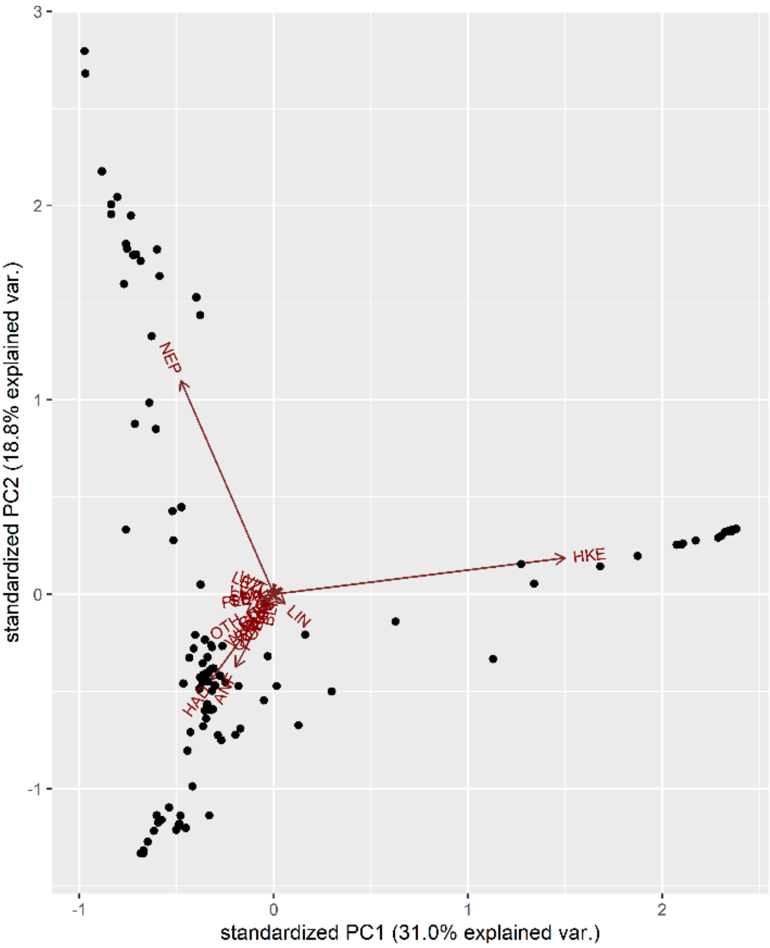


Figure 5.4: Principal component (PC) 1 versus PC2 for Run 7 (area and gear). Points plotting near a species code indicate a dominance of that species in the data record.

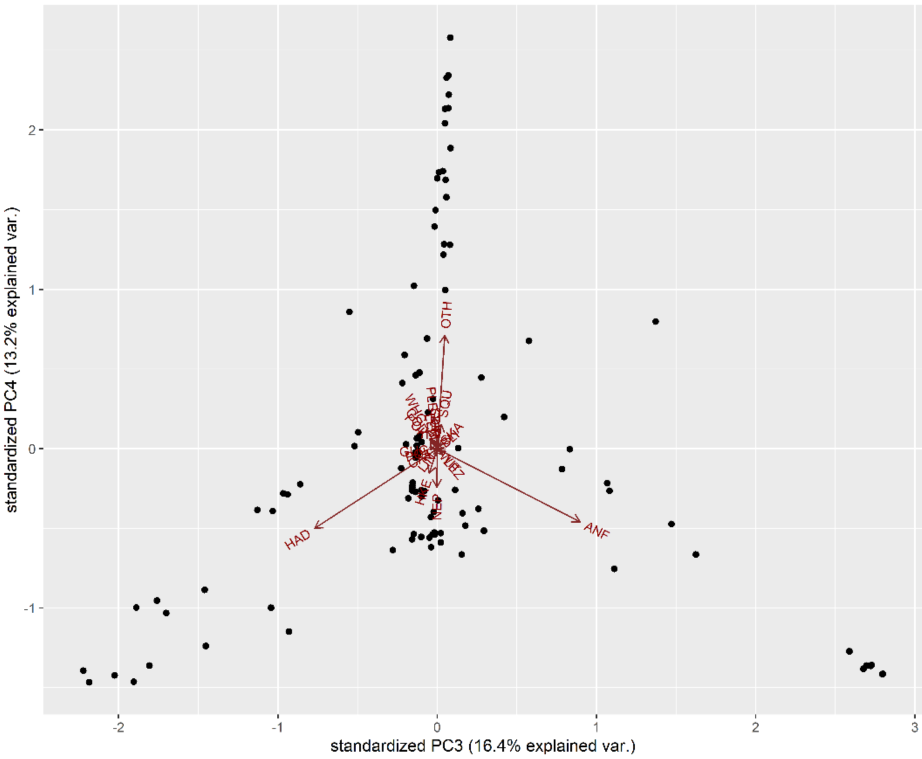


Figure 5.5: Principal component (PC) 3 versus PC4 for Run 7 (area and gear). Points plotting near a species code indicate a dominance of that species in the data record.

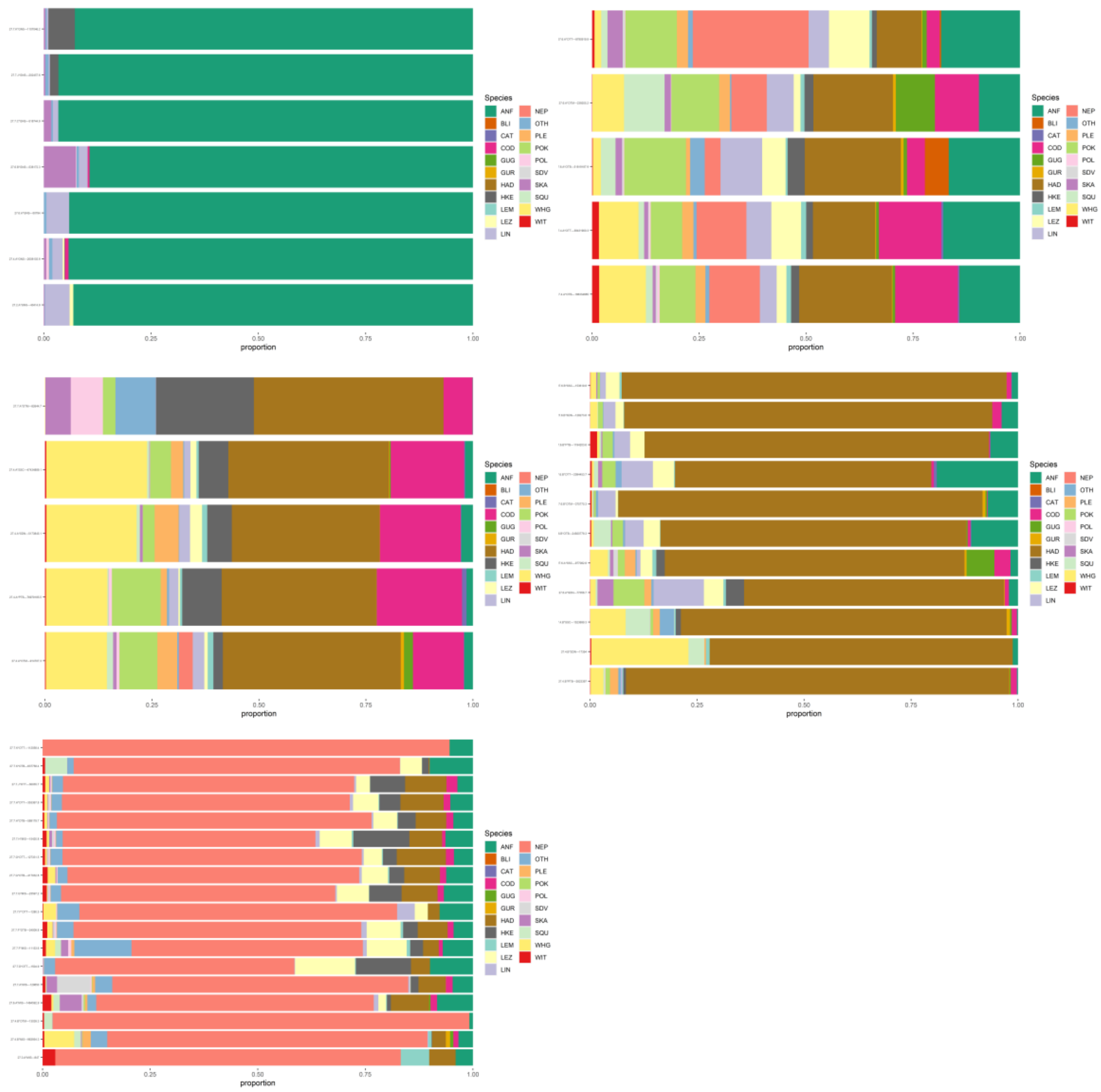


Figure 5.6: Landing profiles (species proportion) from example clusters from Run 7 (area and gear): cluster 1 (top left), cluster 10 (top right), cluster 12 (middle left), cluster 16 (middle right) and cluster 17 (bottom left).

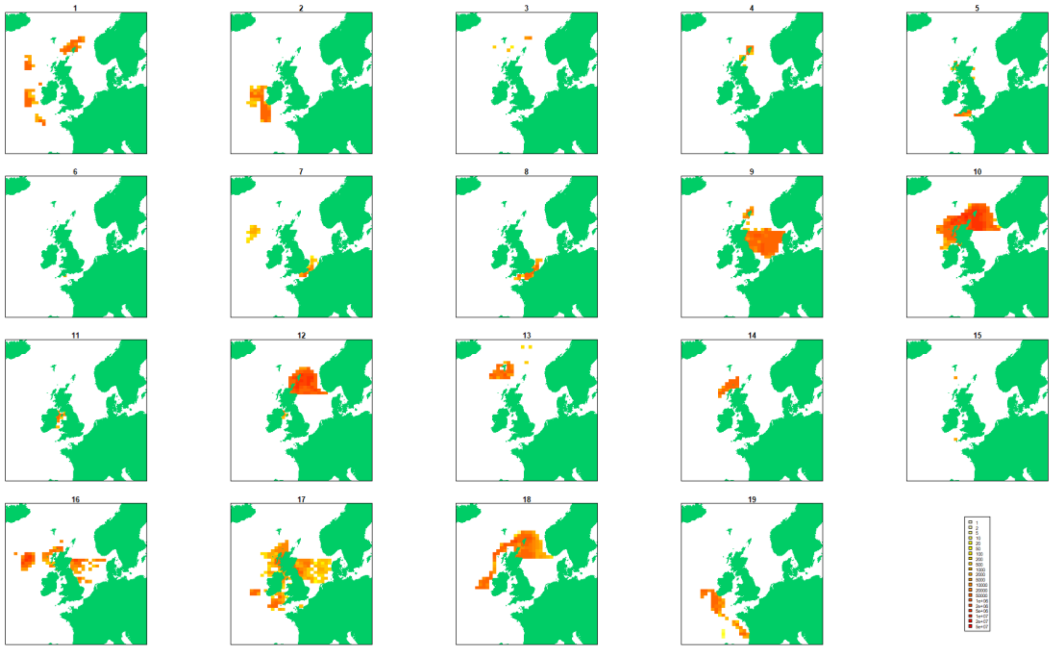


Figure 5.7: Spatial distribution of landings from records attributed to each cluster. The cluster number is indicated above each subplot. The colour scale indicates the landings total, in tonnes, across all species by ICES rectangle.

Fleet building: automated data merging procedure

A key part of processing WGMIXFISH data is merging the fleet data (landings and effort by métier) with the discard rates and age distributions reported in InterCatch. This merged dataset is then used to condition the fleet objects used as input to the mixed fisheries models.

In the North Sea model, the merging happens in two steps: first to match up records between the landing and effort data (i.e., fleet data) and then to match the fleet data records to InterCatch. With both of these steps data records are merged where there is an exact match by year, country, area, métier and stock. For records without an exact match a manual match is made, based on expert knowledge, to obtain an appropriate discard rate and age distribution from InterCatch. However, this manual matching process is prone to error and can be inconsistent year to year therefore, an automated procedure is needed.

The Celtic Sea model uses an automated merging procedure where InterCatch data on discard rates and age distributions are allocated to the fleet data using a hierarchy of assumptions. This procedure has been replicated for the North Sea as follows:

1. First, the consistency between the records of landings and effort data are checked. If the percentage of landings records without a direct match to an effort record is small then these records can be removed.
2. The métier names between the fleet data are InterCatch data are then checked for consistency and simple naming mismatches can be corrected (e.g., adding "_all" to the end of a level 6 métier code).
3. InterCatch records are matched to the fleet data on the basis of year, country, area, gear, target and mesh size (i.e., direct match). Discard rates and age distributions from InterCatch are then transferred to the fleet data to calculate discard tonnage and numbers-at-age for landings and discards.
4. Where a direct match cannot be made, variables are dropped in sequence and records are matched on the remaining variables in a hierarchy of assumptions until a match is obtained. The order in which the variables are dropped is:

   a. Year, country, area, gear, target, (drop mesh size).
   b. Year, country, area, gear, (drop target, mesh size).
   c. Year, country, area, (drop gear, target, mesh size).
   d. Year, country, (drop area, gear, target, mesh size).
   e. If there is still no match, then the stock assessment values for discard rate and age distributions are used.
5. The landings and discards reported from all strata in InterCatch that match the remaining variables are first aggregated before calculating the discard rate and proportions at age for landings and discards. These average values are then transferred to any unmatched fleet data that match on the remaining variables.

A high degree of consistency exists between the landings and effort data in the North Sea. There are only two instances of landings records that lack a direct match to an effort record and account for less than 0.0005% of the total landings in the years they are reported. These two records were removed from the dataset as they make up a very small contribution to the total landings. Between 2016 and 2021 an average of 4% of total effort did not have a corresponding landings record. However, effort is expected to be reported without landings if these fishing activities did not catch any of the stocks included in the North Sea model.

The majority of the mismatches in data records between the fleet data and the InterCatch data result from simple métier naming mismatches such as the suffix "_all" (e.g., OTB_CRU_70-99_0_0 vs OTB_CRU_70-99_0_0_all). Once these are corrected the consistency between the data is high. For age-aggregated data 78% of the landings have a direct match between the datasets. When the data are disaggregated by age (and thus restricted to category 1 fish) this consistency rises to 98%.

Figure 5.8 shows a comparison of discard tonnage over time by stock from the "original" (i.e., manual matching) procedure, the "test" (i.e. automated matching) procedure and from InterCatch for age-aggregated data. For the majority of stocks, the discard tonnage in the test procedure matches closely with the original procedure. Where differences are seen the test procedure is often closer to the total discards reported in InterCatch. Figures 5.9 and 5.10 show a comparison of biomass -at-age for landings and discards from age-disaggregated data for plaice in the Eastern Channel. These figures show similar results to Figure 5.8 in that the results from the test procedure match closely with the original procedure. This conclusion is true for all stocks in the North Sea model. The high agreement between the original and test procedure is likely driven by the high degree of consistency between the original datasets which cover the majority of the fleets responsibly for the bulk of the landings. Therefore, we conclude that the automated, hierarchy of assumption-based procedure can be used to replicate, and even offer a small improvement, the original, manual procedure.

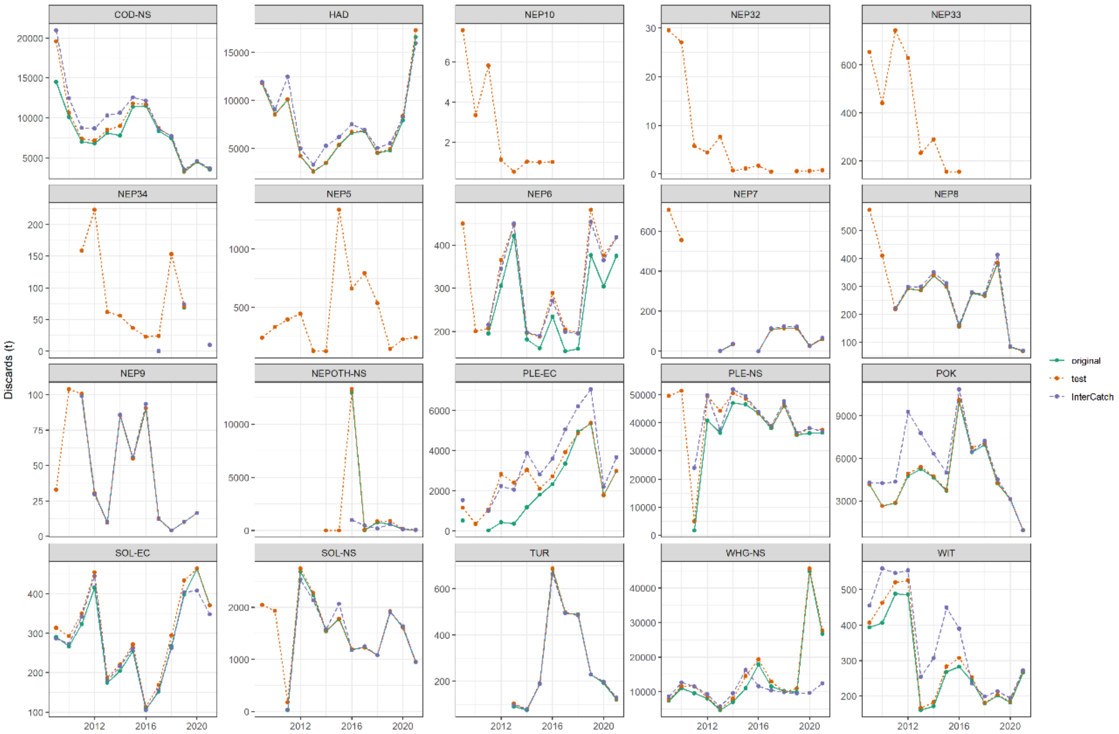


Figure 5.8: Total discards by stock for age-aggregated data calculated by the original procedure (green, solid line), test procedure (orange, dashed line) compared to the total discards by stocks in InterCatch (purple, solid line).

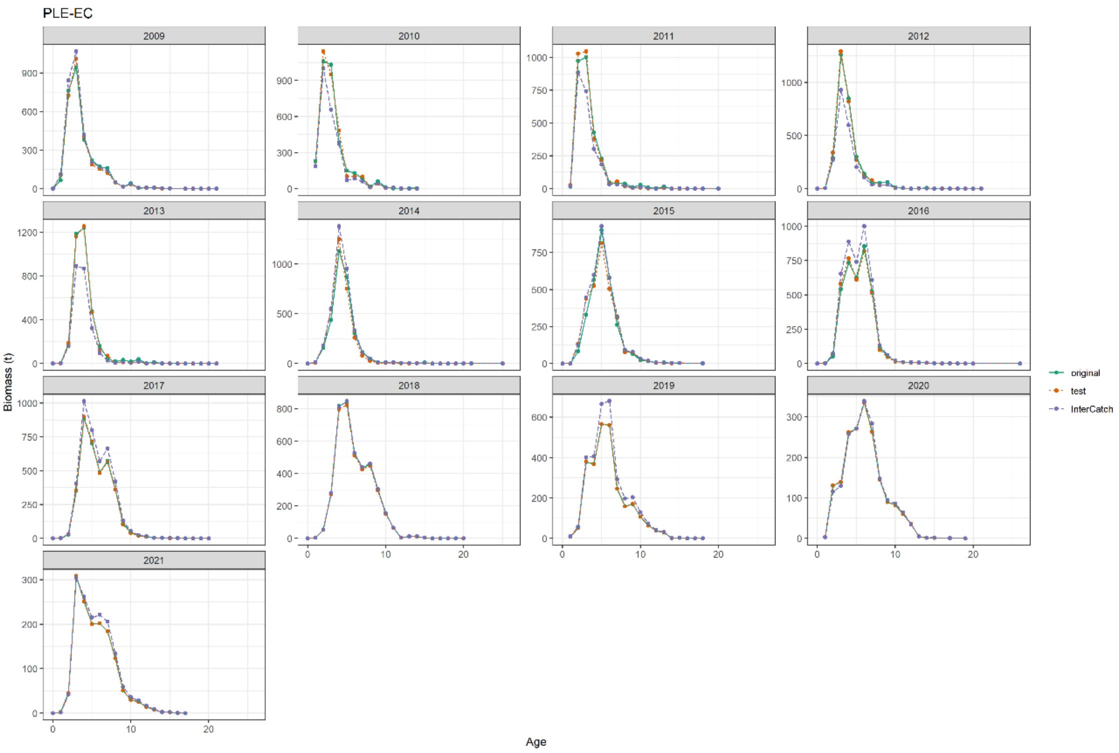


Figure 5.9: Biomass-at-age for landings from age-disaggregated data for plaice in the Eastern Channel as calculated by the original procedure (green, solid line), test procedure (orange, dashed line) compared to the biomass-at-age for the landings reported in InterCatch (purple, solid line).

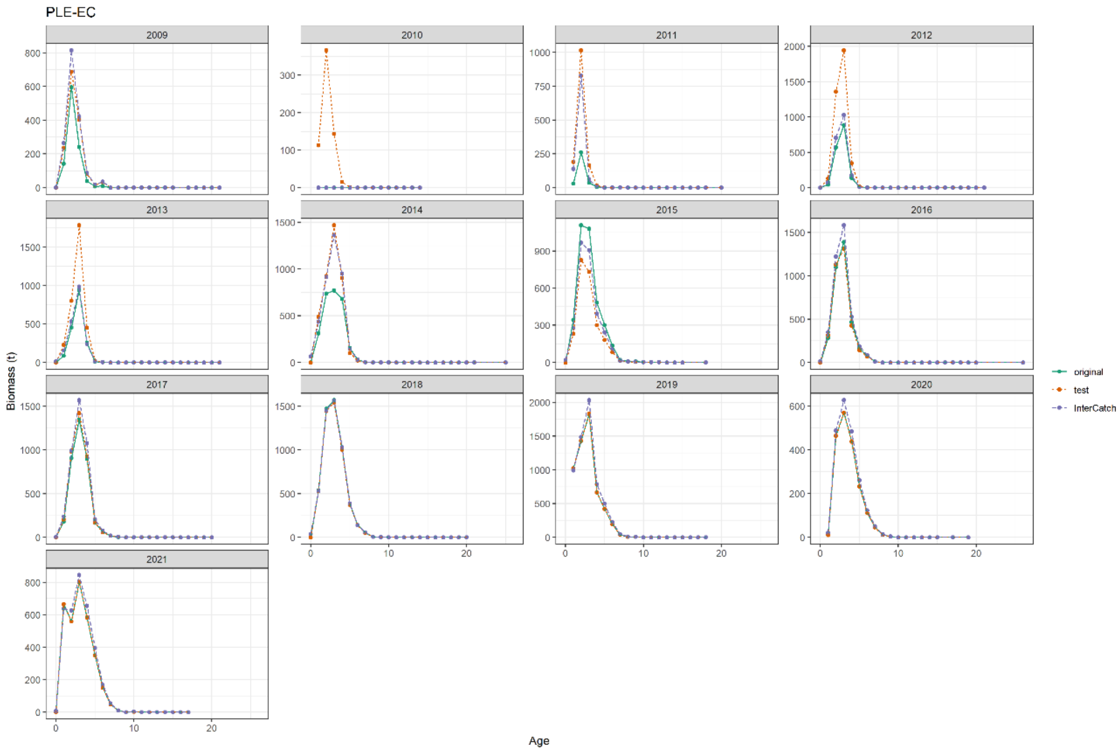


Figure 5.10: Biomass-at-age for discards from age-disaggregated data for plaice in the Eastern Channel as calculated by the original procedure (green, solid line), test procedure (orange, dashed line) compared to the biomass-at-age for the discards reported in InterCatch (purple, solid line).

Fleet and métier definitions

During the analysis to test the new, automated data merging procedure described above it was discovered that the final list of fleets and métiers were different to those listed from the original, manual procedure. At the fleet level, the automated procedure resulted in 9 less fleets compared to the original procedure. This is because the automated procedure considered only the stocks which are included in the North Sea model whereas the manual procedure considered a wider range of stocks. This makes a significant difference to the métier definitions as any métier than contributes less than 1% of the total landings of each stock is grouped together into an "OTH" métier. Then, any fleets (based on country, main gear type and vessel length group) that contains only the "OTH" métier are binned together into an "OTH_OTH" fleet. Under the automated procedure, due to the smaller range of stocks considered for the 1% threshold, more métiers and therefore fleets fall under the 1% criterion and are now included under the "OTH_OTH" fleet. Previously, under the manual procedure these métiers and fleets would have been kept separate because they were responsible for landings at least 1% of a single stock, although not any stock that is included in the North Sea model. Additionally, under the automated procedure there are some differences in the métier group that some data records get assigned too as there is better preservation of the mesh size information from the raw data. Under the original procedure the manual matches were made by overwriting the raw data with the InterCatch métier it was being matched to, therefore losing its original mesh size information.

Both of these factors explain the differences seen in the total effort by fleet and métier (Figure 5.11 and 5.12) and total landings by fleet and métier (Figures 5.13 and 5.14) between the original and new (test) procedures. In these figures it can be seen that though the new procedure results in substantial changes to the total effort by fleet and métier the changes in total landings are minimal. Although the new procedure results in changes to the final list of fleets and métiers these changes are considered to be beneficial as they capture the effort and landings of stocks of interest in the minimal number of fleets as well as making more accurate métier group designations.

In addition to the new fleet naming convention described in section 3.4 some further investigation and testing of métier and fleet allocations will be made ahead of the Advice meeting. This will explore using threshold criteria for landings within a fleet to define the "OTH" métier and to investigate the feasibility of separating out the OTH_OTH fleet into fleets responsible for a small percentage of the total catch and pseudo fleets that account for missing catches (see section 3.4 for more details).

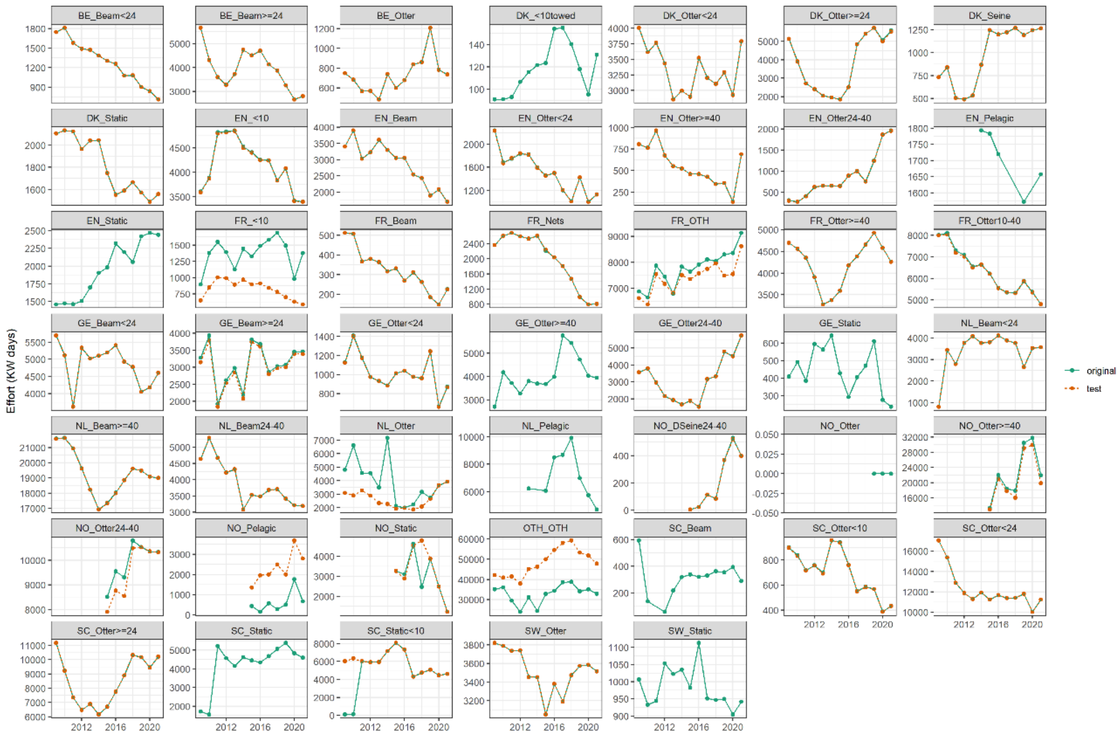


Figure 5.11: Total effort (KW days) by fleet resulting from the original data merging procedure and the test merging procedure.

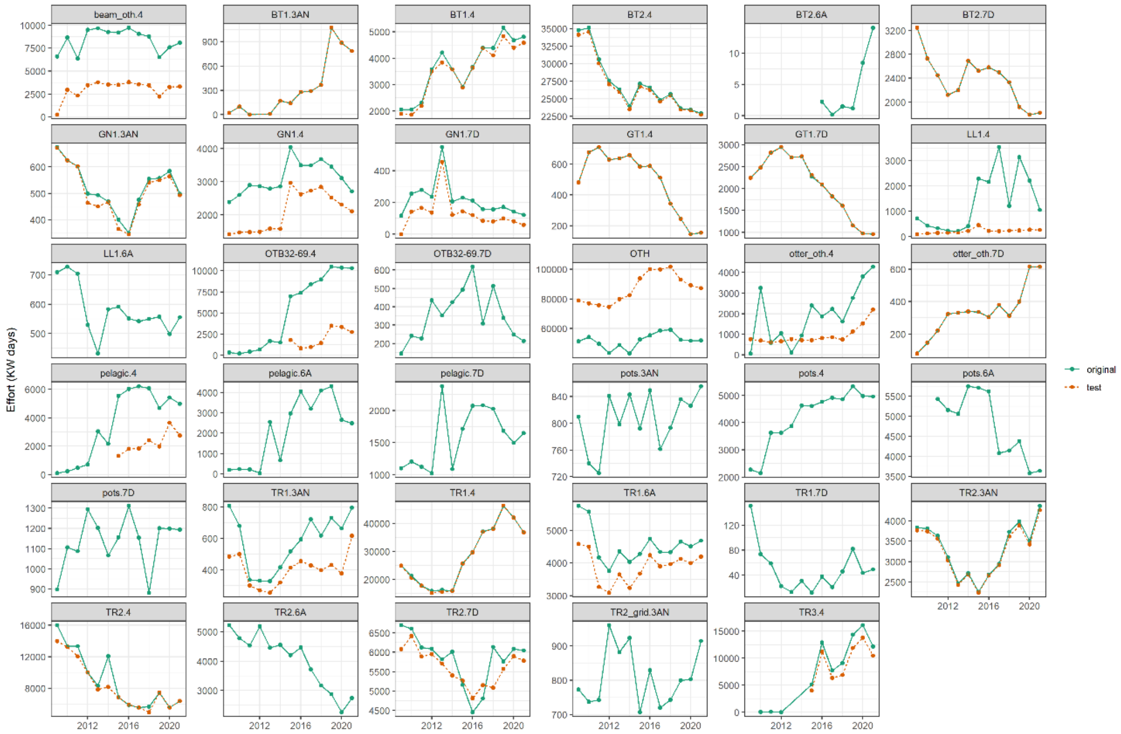


Figure 5.12: Total effort (KW days) by métier resulting from the original data merging procedure and the test merging procedure.

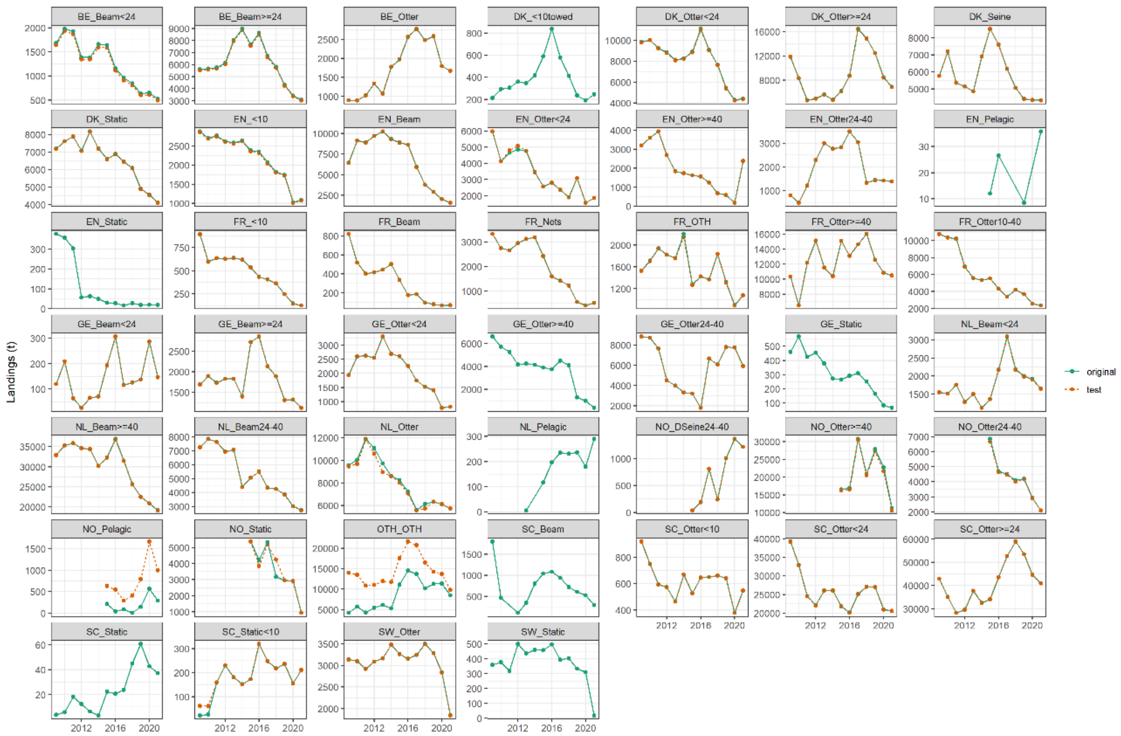


Figure 5.13: Total landings by fleet resulting from the original data merging procedure and the test merging procedure.

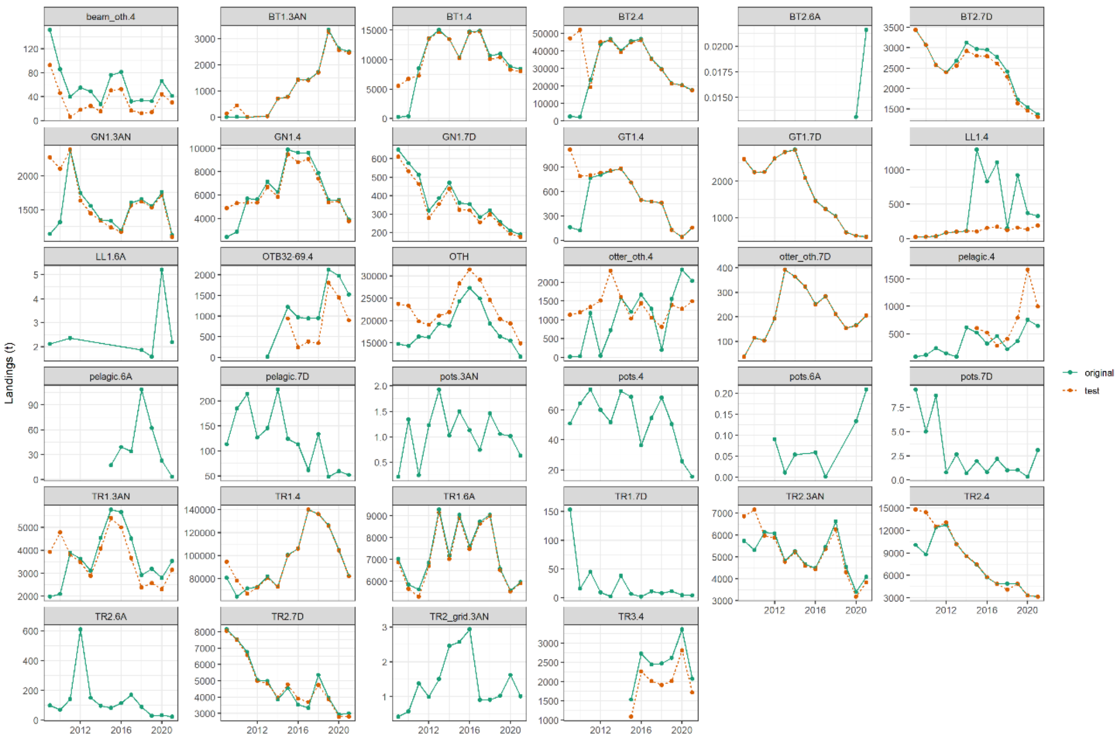


Figure 5.14: Total landings by métier resulting from the original data merging procedure and the test merging procedure.

Sensibility of the North Sea mixed fisheries model to our assumptions on catchability, effort share, and quota share

Some work is ongoing regarding testing the robustness of the above assumptions in the mixed fisheries model. Progress was presented during the meeting (see summary in ToR C, section 4.2). The main conclusion of the work done to date is that the current status quo assumption for these parameters in the North Sea model is the best. Future work will look at the impact on the mixed fisheries simulations.

Brill as new stock in the North Sea mixed fisheries model

Brill has been through a benchmark in 2023 and moved to a category 2 assessment using SPiCT (previously category 3 with chr rule). There is therefore the possibility of adding it to the mixed fisheries model, which is notably relevant because of its common TAC management with North Sea turbot. Some code is already ready for the inclusion of SPiCT assessed stocks in the model so including brill is planned for this year's mixed fisheries considerations.

The group discussed during the meeting the possibility of merging the catch advice of North Sea turbot with the one of brill to reproduce management. The decision was to keep them separated for now given that ICES recommends that the advice is given at the stock level. In addition, we currently do not merge the *Nephrops* stocks catch advice despite some of them being under a combined TAC. If brill and turbot catch advice are merged in the future, it should also be considered for the *Nephrops* stocks that have a common TAC.

New assumption for the "stock" scenario

In the North Sea, a cod scenario is usually presented in the considerations. A "stock" scenario assumes that all fleet effort in the advice year corresponds to the effort needed to take their "stock" share, regardless of other stock catches. Since the use of FLBEIA as mixed fisheries model for the North Sea, for a "stock" scenario, if a fleet does not catch this stock, then its effort is set to the maximal effort. However, other case studies use the status quo effort instead. This is considered not to be an important problem for the cod scenario we presented in the considerations in the past two years because most fleets in our model catch cod. However, for consistency with other studies and to create a more realistic effort assumption, the script was modified during the meeting to use the status quo effort assumption when a stock is not caught in a fleet.

Integration of newly benchmarked North Sea cod into the mixed fisheries model

North Sea cod has been through a benchmark in 2023, resulting in the stock being split into 3 sub-stocks (ICES, 2023b). The integration of these stocks in the mixed fisheries model is hampered by the fact that spatially explicit data do not currently exist at the métier level and the sub-stocks mix during the year, thus hindering the assigning a cod catch to a specific métier/sub-stock interaction.

The group discussed in detail what would be the best way forward for the integration of cod in the model. Two possibilities were retained: either inclusion as a merged stock object, with some loss of consistency with the single stock advice forecasts, or complete removal.

The concern with the inclusion of a merged stock object is the loss of sub-stock advice considerations based on differing biological status (e.g., SSB either above or below MSY $B_{trigger}$). This disparity could lead to potentially different choke situations that would not be captured by a merged stock object in the mixed fisheries forecasts. This can potentially affect the credibility of our projections as it is inconsistent with the cod advice based on independent sub-stocks.

Despite this drawback, the group felt it necessary to evaluate the technical feasibility of merging the 3 sub-stocks into a single stock. The results of this merging test will be presented in the WGMIXFISH ADIVCE 2023 report.

However, the results of the merging test will not resolve the issue that a merged object would fail to detect differences in choking behaviour among the sub-stocks. Nevertheless, given that cod is the stock that motivated the development of the mixed fisheries model in the North Sea, it was generally felt that its exclusion might diminish the relevance and utility of the mixed fisheries considerations. Until future data allows for the direct integration of sub-stocks and differentiation among fleet catches, a feasible compromise for the present would be to proceed with a merged cod stock object and to add clarifying text explaining the deviation from the stock advice and the possible consequences for the mixed fisheries considerations. The group also discussed the possibility of treating the cod stock differently than the other stocks in the model (e.g., exclude it from the list of restrictive stocks), or running an extra more restrictive scenario using the smallest of the three sub-stock catch advice. The inclusion of these possible extra scenarios will be further evaluated during the Advice meeting.

Additional developments

- At the time of the meeting, Norway had not yet uploaded its mixed fisheries (Accessions) data needed to considered Norwegian fleets in the North Sea model. An effort was made during and after the meeting to check if these data could be submitted. If the data are available for the Advice meeting, the Norwegian fleets will be considered in the considerations similarly as last year. If not, their catches will be aggregated in the OTH_OTH fleet.

- A new table illustrating our fleet/métier definition will be generated for the Advice report and use as discussion point at the next scoping workshop in 2024.
- The OTH métier will be replaced by MIS for consistency with other ecoregions.
- The group discussed the new assumption used from last year that fixed the population numbers in the intermediate year. It was confirmed as a good option to avoid discrepancy with the single stock advice and will therefore continue to be used at the Advice meeting this year.
- The new range scenario (“pgy”) will be added to the North Sea projections before the Advice meeting (model_04 R script).
- If possible, the group will try to edit the relevant scripts during their update so some of the information (e.g., advice catch, reference points) are obtained directly from the icesASD and icesSAG R-packages. This would save time updating the scripts every year (currently manually done).
- The Rmd creating the diagnostics will be updated before the Advice meeting (notably relevant for the code using the mixtools R-package due to recent updates for this latter).

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

6.1 Baltic Sea

A review of data held for the Baltic Sea was conducted last year at WGMIXFISH-METHODS (ICES, 2022e) to assess the potential for developing mixed fisheries considerations for the ecoregion. The results of this found that most countries submitting data for the Baltic were reporting using relatively high-level métier codes (i.e. “active”, “passive”) rather than level 6 métier codes. Although these high-level métiers match the métier codes using in InterCatch for this ecoregion (as requested in the data call), the grouping of multiple métiers in this way may lead to false technical interactions being apparent in the data. This limits our ability to provide high quality mixed fisheries information for this region.

Requesting a refresh of the entire time series would have invoked a large burden on national data submitters. Therefore, we decided to explore alternative data sources, especially as the data call will be superseded by the RDBES in a few years. An extraction of RDB effort and landings data were provided to WGMIXFISH-METHODS to conduct a comparison with our accessions data. The RDB landings data were reduced to include just the species listed in the WGMIXFISH data call and both datasets were filtered for the Baltic region (ICES subdivisions 21 to 32).

A comparison of total landings by country is shown in Figure 6.1. A comparison was also made of landings by ICES subdivision and by species for each country. Overall, the total landings in each database were practically identical for most countries. However, a small number of discrepancies existed:

- Poorer matches were seen for species with a low volume of landings.
- For Lithuania, between 2010-2012, the discrepancy relates particularly to landings of cod.
- For Latvia, in 2018 and 2020, the differences relate to landings of herring, particularly in subdivision 28.
- RDB landings appeared to be missing from Germany in the Kattegat for several years.
- Our accessions landings had some sporadic missing species from some countries (e.g., Brill from Denmark and Sweden).
- Our accessions landings were missing all data for Lithuania in 2018 and data for some species in 2021.

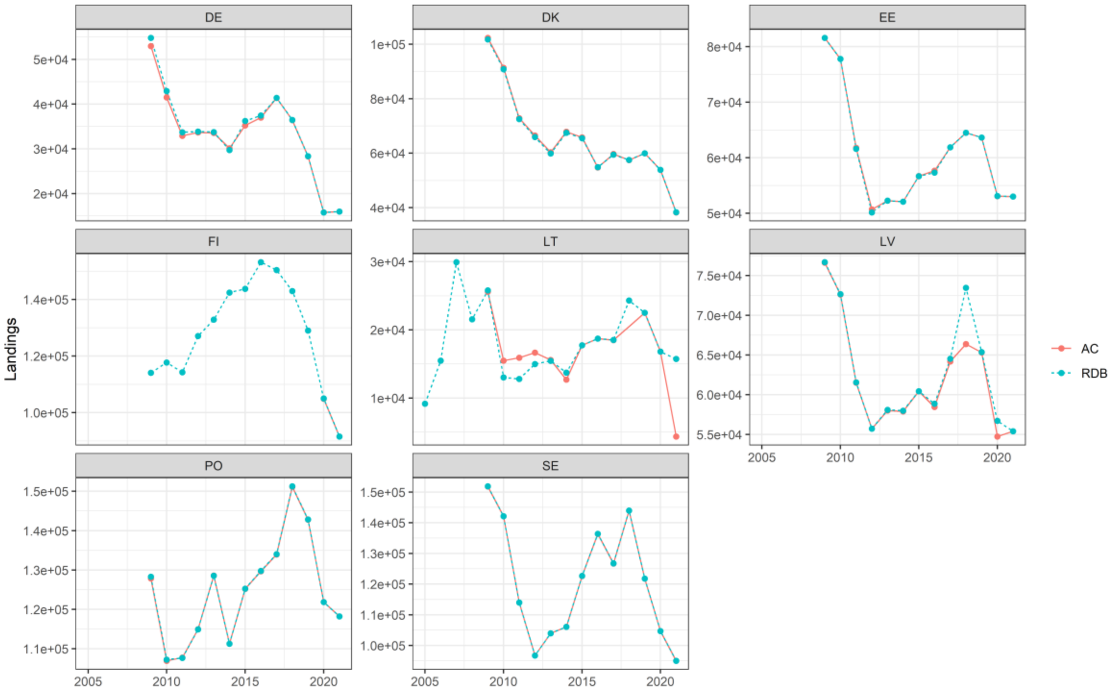


Figure 6.1: Comparison of total landings (tonnes) for the Baltic Sea by country from the Regional DataBase (RDB) and WGMIXFISH accessions data (AC).

Figure 6.2 shows the comparison of total effort by country. Additional comparisons by ICES divisions were also made for each country. Overall, similar trends are seen in both datasets for most countries although there are clearly some odd individual data points (e.g., Germany in 2017, Latvia in 2019 and Lithuania in 2012). Often, mismatches in the overall trends were driven by differences in specific subdivisions. Further investigation revealed that mismatches in these regions were likely being driven by differences in the calculation of fishing effort for active and static gear types. In the case of Estonia, a better match between the datasets is seen in later years as the number of métiers reported to RDB has increased over time.

Overall, this comparison shows that the RDB data closely matches the accessions data for total landings and follows similar trends for total effort. Therefore, the RDB data appears to be a suitable alternative for use in our exploratory work in the Baltic Sea. By using the RDB dataset we avoid adding to the burden of national data submitters through asking for a resubmission of the entire accessions time series. Ultimately, landings and effort data will be sourced from the RDBES as it comes online over the next few years.

The exploratory work planned for the 2023 Advice meeting will focus on producing catch composition plots for the Baltic Sea Fisheries Overview.

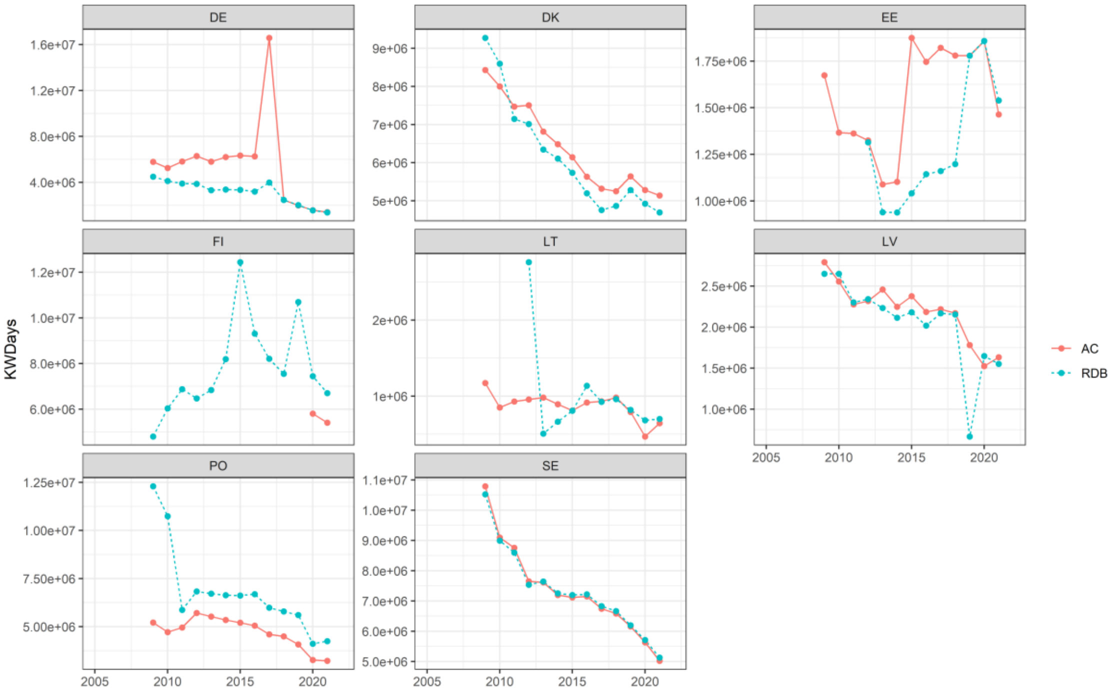


Figure 6.2: Comparison of total effort (KWdays) for the Baltic Sea by country from the Regional DataBase (RDB) and WGMIXFISH accessions data (AC).

6.2 Irish Sea

In 2022, the first ICES WGMIXFISH advice product was issued for the Irish Sea ecoregion, this outlined mixed fisheries scenarios, based on advised catches for cod, haddock, *Nephrops* and whiting in the region, and min, max and status quo effort scenarios for the aforementioned stocks and plaice and sole. The process followed by WGMIXFISH in developing the model and advice product for this region was presented, and was agreed to be an example of best practice for generating mixed fisheries considerations for new regions by WGMIXFISH.

The Irish Sea mixed fisheries model (FCube) was developed in conjunction with WGMIXFISH, over a period of four years (2019-2022), and model developments were documented in the WGMIXFISH reports over this period. This enabled scientists working on the Irish Sea model to benefit from the expertise, analyses, code and experiences developed in other regions. Unlike in the ICES single-stock assessment process, there is presently no formal requirement for a model benchmark prior to mixed fisheries advice products being issued for new regions. However, in the case of the Irish Sea and for other regions going forward it was WGMIXFISH agreed that a more formal review process was desirable. Therefore, the following steps were followed prior issuing the first advice product for the Irish Sea: i) an internal WGMIXFISH model review meeting, ii) production of a review report and stock annex iii) the review report, draft stock annex and fully reproducible model code were sent to an external expert by ICES for review and approval.

The internal WGMIXFISH review took place on the 22/08/2023 and was attended by 15 members of the WGMIXFISH group. The presentations and report of the meeting covered: model background, software, data sources, treatment of *Nephrops* functional units, fleet and métier definitions, ability to reproduce advice and advice scenarios for 2022 (with estimated values for *Nephrops* used where surveys and advice were not yet available). The draft stock annex was also included as an appendix to the report for external review. These documents along with fully reproducible model code were made available to the external reviewer on the ICES SharePoint, and the reviewer was selected and contacted by the ICES professional officer for WGMIXFISH. The review was conducted in mid-September 2023, which allowed sufficient time for the model and advice product to be included in the WGMIXFISH advice meeting in October 2023, and advice production in November 2023 (ICES 2022d: WGMIXFISH-ADVICE). This process ensured a high degree of model scrutiny and external quality assurance prior to publication of the advice product by ICES. Therefore, it was agreed by WGMIXFISH to be a good template for the development of advice products for new regions in future.

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Annex 1: List of participants

Name	Institute	Country (of institute)	Email
Alessandro Orio	SLU Aqua	Sweden	alessandro.orio@slu.se
Bernhard Kühn	Thünen Institute of Baltic Sea Fisheries	Germany	bernhard.kuehn@thuenen.de
Ching Villanueva	Ifremer (Bretagne)	France	ching.villanueva@ifremer.fr
Claire Machar	Ifremer (Bretagne)	France	claire.macher@ifremer.fr
Claire Moore	Marine Institute	Ireland	claire.moore@Marine.ie
Dorleta Garcia	AZTI	Spain	dgarcia@azti.es
Gianfranco Anastasi	Centre for Environment, Fisheries and Aquaculture Science	UK	gianfranco.anastasi@cefas.gov.uk
Harriet Cole (chair)	Marine Directorate of the Scottish Government	Scotland, UK	harriet.cole@gov.scot
Hugo Mendes	Portuguese Institute for Sea and Atmosphere	Portugal	hmendes@ipma.pt
Jasper Bleijenberg	Wageningen Marine Research	The Netherlands	jasper.bleijenberg@wur.nl
Johnathan Ball	Centre for Environment, Fisheries and Aquaculture Science	UK	johnathan.ball@cefas.gov.uk
Klaas Sys	Flanders Research Institute for Agriculture	Belgium	klaas.sys@ilvo.vlaanderen.be
Kristiina Hommik	University of Tartu	Estonia	kristiina.hommik@ut.ee
Lionel Pawlowski	Ifremer (Lorient)	France	lionel.pawlowski@ifremer.fr
Luca Lamoni	ICES	Denmark	luca.lamoni@ices.dk
Marc Taylor (chair)	Thünen Institute of Baltic Sea Fisheries	Germany	marc.taylor@thuenen.de
Margarita María Rincón	IEO-CSIC	Spain	margarita.rincon@csic.es
Mathieu Merzereaud	Ifremer (Bretagne)	France	Mathieu.Merzereaud@ifremer.fr
Matthew Pace	Centre for Environment, Fisheries and Aquaculture Science	UK	matthew.pace@cefas.gov.uk
Mikel Aristegui	Marine Institute	Ireland	Mikel.Aristegui@marine.ie
Neil Maginnis	ICES	Denmark	Neil.Maginnis @ices.dk
Paul Dolder	Centre for Environment, Fisheries and Aquaculture Science	UK	paul.dolder@cefas.gov.uk
Ruth Kelly	Agri-food and Biosciences Institute (AFBI)	Northern Ireland, UK	ruth.kelly@afbini.gov.uk
Santiago Cerviño	IEO	Spain	santiago.cervino@ieo.es
Sigrid Lehuta	Ifremer (Nantes)	France	Sigrid.Lehuta@ifremer.fr

Sonia Sánchez-Maroño	AZTI	Spain	ssanchez@azti.es
Thomas Brunel	Wageningen Marine Research	The Netherlands	thomas.brunel@wur.nl
Vanessa Trijolet	DTU Aqua	Denmark	vtri@aqua.dtu.dk
Youen Vermard	Ifremer (Nantes)	France	youen.vermard@ifremer.fr