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

VOLUME 3 | ISSUE 100

ICES SCIENTIFIC REPORTS

RAPPORTS
SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
CIEM CONSEIL INTERNATIONAL POUR L'EXPLORATION DE LA MER

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

ISSN number: 2618-1371

ICES Scientific Reports

Volume 3 | Issue 100

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

Recommended format for purpose of citation:

ICES. 2021. Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS). ICES Scientific Reports. 3:100. 53 pp. https://doi.org/10.17895/ices.pub.6007

Editor

Claire Moore

Authors

Michel Bertignac • Paul Bouch • Thomas Brunel • Paul Dolder • Mikel Aristegui Ezquibela • Niall Fallon Dorleta Garcia • Ruth Kelly • Alexandros Kokkalis • Sarah Kraak • Mathieu Lundy • Hugo Mendes Alessandro Orio • Lionel Pawlowski • Alfonso Pérez-Rodríguez • Sonia Sánchez-Maroño • Cristina Silva • Klass Sys • Marc Taylor • Vanessa Trijoulet • Youen Vermard

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

Contents

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 advice. In this report the group provides a summary of the work completed in 2021.

Work continued on the full review and documentation of the mixed fisheries advice production process, including workflows, code repositories, stock annexes, data, and associated documentation for all advice regions.

Working group participants responded to the outcomes and issues encountered during WGMIXFISH-Advice 2020 for Bay of Biscay, Celtic Sea, Iberian Waters, and North Sea. A full list of issues and solutions were collated and discussed during the meeting. Additionally, work continued on the development of mixed fisheries advice for on the Irish Sea.

The working group responded to the outcomes of the Scoping workshop on next generation of mixed fisheries advice (WKMIXFISH 2020), identifying timelines and requirements to meet the growing needs for mixed fisheries advice. To support these growing needs the group members presented and discussed new techniques in the field of mixed fisheries.

ii Expert group information

Expert group name	Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS)
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chair	Claire Moore, Ireland
Meeting venue and dates	21-25 June 2021, by correspondence (22 participants)

1 Introduction

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

The revised version of the resolution was approved 21 January 2021

2020/2/FRSG17 The Working Group on Mixed Fisheries Methods (WGMIXFISH-METHODS), chaired by Claire Moore, Ireland, will meet online 21 – 25 June 2021, to:

a) Continue the improvement of WGMIXFISH-ADVICE workflow, updating associated documentation and increasing transparency;
b) Respond to the outcomes of the Mixed Fisheries Scoping Meeting;
c) Horizon scanning for future developments in methodology and advice
d) Respond to the outcomes and issues encountered during WGMIXFISH-Advice;
e) Review of updated data call, and data processing procedures, identifying possible areas of improvements;
f) Develop mixed fisheries models for sea regions not currently covered in the mixed fisheries advice;
g) Continue the development of the combined implementation of FCube and FLBEIA in conjugation with STECF/WGECON economists.
h) Develop guidance for auditing of mixed fisheries advice.

WGMIXFISH-METHODS will report by 30 July 2021 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 workflow, updating associated documentation and increasing transparency

Work continued on the development of fully documented and transparent advice production process for all cases studies.

2.1 Advice sheet development

Time was dedicated to the development of proposals for a revised advice sheet structure based on the outcomes of WKMIXFISH (ICES, 2021a), WGMIXFISH-Advice (ICES, 2021b) and WKFO (ICES, 2021c). End users of the mixed fisheries advice typically find the sheet too long, making it difficult to identify important information and headline advice. During the 2020 ADGFO it became clear that there were a number of inconsistencies between each of the mixed fisheries advice sheets, in terms of format and content. This pattern of inconsistency can be very difficult for end-users, but also for auditors, and could in the future present a source of human error. These inconsistencies are driven by the lack of guidelines for the production of mixed fisheries advice. The single species advice produced by ICES is an established process and is supported by official ICES guidelines. These guidelines promote consistency in the advice products produced by individual working group. This consistent structure is familiar and therefore more accessible to the end users of the advice, providing a succinct and informative advice product. Based on the established history of the single species advice production process, WGMXIFSH endeavours to develop a mixed fisheries advice product which is simple, accessible and informative. A product which is also supported by guidelines, thus providing harmonization between the mixed fisheries case studies.

In 2021 the focus will be on decluttering of the advice sheets, ensuring that key information is highlighted and explicit, and headings improved, so that a clear, accessible story is being told. Main areas of improved will be:

1. **Mixed fisheries consideration section** - The working group acknowledge that the mixed fisheries consideration section (the beginning of the sheet) is needlessly extensive as end users are experienced fisheries management and understand the variables being present. Therefore, paragraphs on the data, methods, and assumptions used in the individual case studies should be removed or transferred to a more appropriate sections, i.e. 'Methods and Data'. As the 'Mixed fisheries consideration' section is at the very beginning of the advice sheet it should contain a few standard sentences with highlight the headline advice and frame the key message of the advice sheet. Opinions differed strongly on what this should include (e.g. catch advice, choke species or number of fleets that are choked), and whether it should highlight one specific mixed fisheries scenario. The group concluded the contents of this section would depend on the year, stocks and scenarios being produced. This section should have meaning and the advice producers should be able to explain the main findings and narrative for the advice succinctly here. Headline advice should have really plain English and include simplistic descriptions.

2. **Scenarios section** – There is a need to provide a better summary of the scenarios produced. Although the figure presenting the scenarios captures the complex outcomes of each scenario relative to each other, an accompanying bullet pointed summary is also required to improve the end-user's ability to correctly interpret the plot and the outcomes of each scenario. This would require the text and plot to be on the same page, or in close proximity so that the reader

does not need to search the advice sheet for explanations. This text needs to be succinct and clear so that the key messages around trade-offs are clear.

There are potentially too many scenarios present on the mixed fisheries advice sheets. Scenarios themselves may need to be removed, in order to declutter the front page of the advice. Each case study should be free to add or remove scenarios within a given year depending on the headline advice that needs to be given. For example, some case studies would like to remove the value scenario as it is not a true economic evaluation of the fisheries. While other case studies would like to would like to add a min scenario excluding the 'min' scenario excluding the zero TAC stocks which choke the fishery immediately. Any potential scenarios removed could still be presented in the report.

3. **Range scenario -** Complementary information on the outcome of the range scenario should be provided in the section on 'Management Considerations'. This would help to avoid any misinterpretation of this very important scenario. This information could include target fishing mortality values resulting from the optimization procedure, and the corresponding TACs.

Details on the difference in the outcome of the mixed-fisheries forecasts when parameterised with the optimised F which is calculated in the range scenario may be of interest to end users. Figure 2.1 illustrates the potential differences in the outcomes of the minimum scenario can be in comparison to the single species advice. These differences vary between stocks, and in some case reduce lost fishing opportunities. This analysis is based on based on the 2020 North Sea mixed-fisheries advice (ICES 2021b) and helps to visualise the extent by which applying the range option would reduce the potential undershoot (especially for PLE-NS and POK).

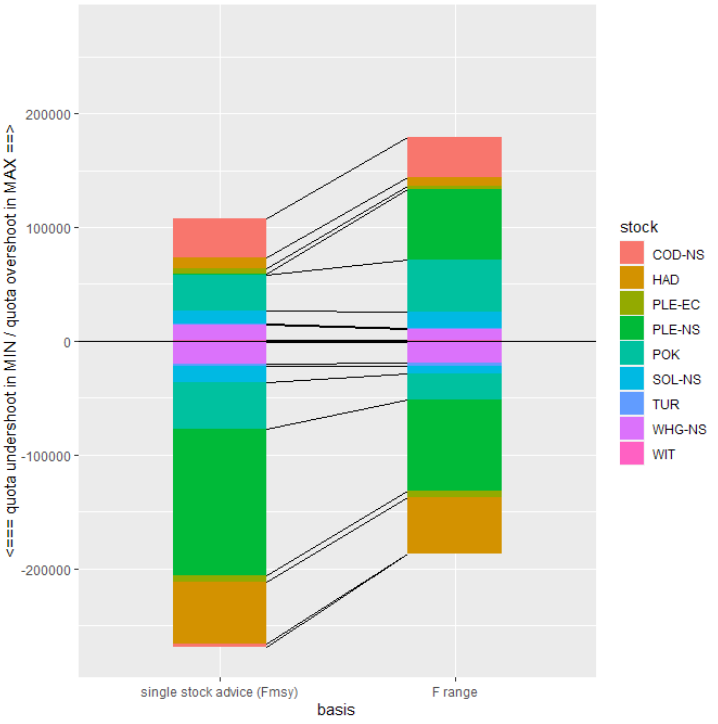

Figure 2.1. Quota undershoot (negative values, lost fishing opportunities) from min scenario and quota overshoot (positive catch, over quota catch) from max scenario per stock from mixed-fisheries forecasts using TACs as defined for the single-species advice (left) or TACs calculated based on the F_{MSY} range option (right). Based on the 2020 North Sea mixed-fisheries advice (ICES, 2021b).

4. **Additional information**: There are a number of key assumptions implemented in the modelling process that are not currently addressed in the advice sheets, i.e. intermediate year assumptions. A summary table with catch, F, and SSB at the start of the TAC year by stock should be included. This will provide useful information on how the stock status (at the start of the advice year) in the mixed fisheries advice deviates from the stock status (at the start of the advice year) in the single species advice. Substantial deviations can be highlighted in a separate section (i.e. issues relevant for the advice).

The working group concluded that members of the working group should develop these proposals further intersessionally, focusing on the development of guidelines and the simplification of the advice sheet. There should also be a revaluation of the range scenario and ways of improving the way it is disseminated.

2.2 Transparent assessment framework (TAF)

Work continued on the development of TAF repositories for all advice products, focusing on the FAIR principles (**F**indability, **A**ccessibility, **I**nteroperability, and **R**euse of digital assets) and implementing what was learned during an MIXFISH TAF workshop (1-2 February 2021, online).

2.2.1 Bay of Biscay

The members of the Bay of Biscay case study are exploring the possibility to adapt the currently available code to follow the principles of TAF. The structure outlined for the Celtic Sea case study is considered appropriate also for our case study.

2.2.2 Celtic Sea

In preparations for the move FLBIEA the members of the Celtic Seas case study focused on the development of code that can be used for the inter benchmark and which follows the principles of TAF. The structure of this repository is outlined in Figure 2.2.2.1, the scripts, their input, outputs and description can be found in Table 2.2.2.1. Code was streamlined as much as possible with the development of functions to carry out annual tasks and lookup tables (Table 2.2.2.2)

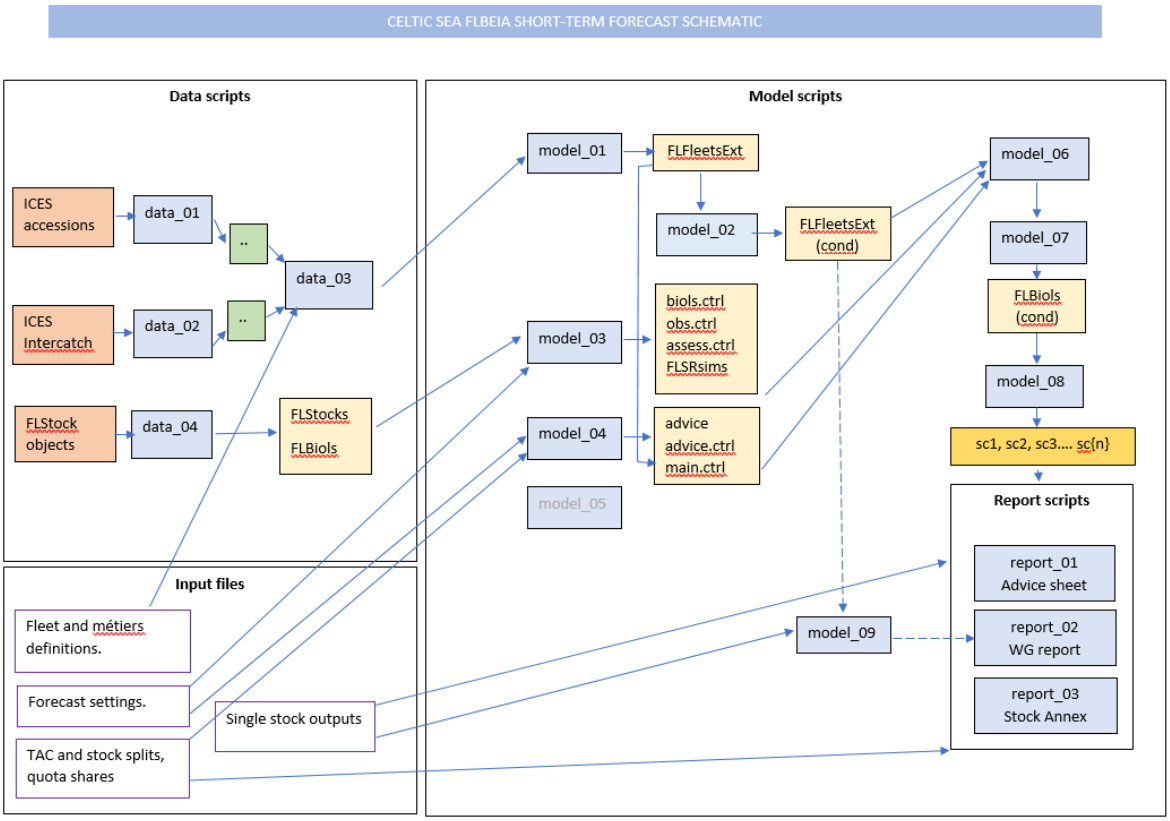

Figure 2.2.2.1. Schematic of Celtic Sea code to process the data inputs and model to produce the FLBIEA short-term forecast

Table 2.2.2.1. List of scripts used to implement the data preparation and model for the FLBIEA short-term forecast, details of inputs, outputs and summary notes on each scripts function.

Code	Input	Output	Notes
Data scripts			
data_01_clean_accessions.R	1) ICES accessions files 2) Fleet and métier lookup table	1) .RData of combined, cleaned accessions files	Use shared lookup tables to ensure consistency between accessions and InterCatch Ideally in future include fleet definitions.
data_02_clean_intercatch.R	1) ICES InterCatch files 2) Fleet and métier lookup table	1) .RData of combined, cleaned InterCatch files	Use shared lookup tables to ensure consistency between accessions and InterCatch
data_03_combine_accession_intercatch.R	Output from data_01 Output from data_02	1) .RData of fleet, métier, stock input variables	Per fleet: effort capacity Per fleet, métier: Effort share Per fleet, métier, stock:

Code	Input	Output	Notes
			landings.n landings.wt discards.n discards.wt price
data_04_make_FLBiols.R	1) FLStock objects	1) .RData of FLStocks() object list, 2) .RData FLBiols() object list.	Check stock object and biol object variables are all valid. Creates FLStocks() and FLBiols() objects.

Code	Input	Output	Notes
Model scripts			
model_01_make_FLFleetsExt.R	Output from data_03	1) FLFleetsExt object	
model_02_fleet_conditioning.R	1) output from model_01	1) Conditioned FLFLeetsExt object 2) fleets.ctrl	
model_03_stock_conditioning.R	1) Growth models 2) Observation models (NULL) 3) assessment models (NULL) 4) Recruitment forecast settings	1) biols control 2) obs control 3) assess control 4) List of FLSRsim objects	
model_04_advice_conditioning.R	1) Output from model_01 2) Relative stability shares 3) FIDES data 4) TACs (intermediate and advice years)	1) advice object 2) advice control	Options are i) landings shares, ii) relative stability shares, iii) post swap shares.
model_05_covars.R	NULL	NULL	
model_06_model_validation.R	All objects	Validity checks passed	
model_07_intermediate_year.R	Outputs from 1) model_01 2) model_02 3) model_03 4) model_04	1) Updated FLBiols to start TAC year.	Options are 1) fixedEffort, 2) Other common assumption 3) Independent Single stock Fs
model_08_MIXFISH_scenarios.R	Outputs from model_01 model_02	1) FLBEIA models (1 per run)	What about range scenario? Could use 'min'/'max' optimisation routine, or Garcia *et al.* approach.

Code	Input	Output		Notes
		model_03 model_04 model_06		
model_09_reproduce_the_advice.R		Outputs from 1) model_01 2) model_02 model_03 model_04		
Report				
report_01_advicesheet.R		Output from 1) model_08	Production of advice sheet figures and tables	Things to produce:
report_02_WGreport.R		Output from 1) model_08	Production of QA/QC figures and tables	Things to produce:
report_03_stockannex.R				Things to produce:

Table 2.2.2.2. List of support files used to implement the data preparation and model for the FLBIEA short-term forecast.

Lookup tables:	
Fleet and métier	Consistent definitions
Forecast settings	Intermediate year assumptions and TACs
Single stock outputs	Results of single stock STF
TAC splits, quota shares	Assumptions to deal with spatial differences in management and assessment areas
Biological Reference Points	Collected directly form the single species advice sheets

2.2.3 Iberian Waters

TAF skeleton for year 2021 has been created and some work for the automatization of data input has been done. Data has been directly downloaded from the SharePoint (http://community.ices.dk/ExpertGroups/WGMIXFISH-ADVICE/2021%20Meeting%20Documents/06.%20Data/Iberian%20Waters) using icesSharePoint library in R and it has been stored into the bootstrap/data folder. Original data input source is also specified at the tittle field in the DATA.bib file . An entry was also created in the SOFTWARE.bib file for FLBEIA v1.15.5. The following data is missing in the TAF bootstrap/data folder to properly run the script 01_MixFish21_IW_Data.R up to June 2021:

- catch and effort data submitted by countries (Portugal and Spain) that should be available at http://community.ices.dk/ExpertGroups/WGMIXFISH-ADVICE/WGMIXFISH%20Accessions/Data%20Call%202021

- Intercatch file available at http://community.ices.dk/ExpertGroups/WGMIXFISH-METH/2021%20Meeting%20Documents/06.%20Data/2021%2006%2023%20CATON%20for%20stocks%20without%20distributions%20for%20all%20WG%202002-2020.zip
- File created by Cristina for 2021 similar to "2020_WGMIXFISH_PT_catch.csv"

Some lines have been added to the report.R script to create the "report" directory and put all files available in bootstrap/data there for model run. Also the script 01 is copied to folder report and it is supposed to be run from there. Table 2.2.3.1 outlines the requirements and functionality of the data input scripts up to June 2021 on the 2021_IW WKMIXFISH github repository in TAF.

Table 2.2.3.1 List of scripts used to implement the data preparation up to June 2021 for the FLBIEA short-term forecast, details of inputs, outputs and summary notes on each scripts function.

Code	Input	Output	Notes
Data scripts			
00_Data_download.r	Data available up to July 2021: 1) catch_effort.Rdata from previous year 2) Data required for the assessment available at the Data folder of WKMIXFISH-ADVICE 2021 SharePoint: -caa_MEG2020.xlsx -ANK2020.xlsx -HKE2020.xlsx -MEG2020.xlsx -caa_LDB2020.xlsx -MON2020.RData -LDB2020.xlsx 3) Entry for FLBEIA v1.15.5 software	1) All the input files available for the model at the bootstrap/data folder in the TAF repository	It's necessary to add manually the entries in the DATA.bib file, one for each file in bootstrap/data
01_MixFish21_IW_Data.R	1) catch_effort.Rdata from previous year 2) ICES InterCatch files 3) File created by Cristina with Portuguese catches	1) catch_effort.Rdata file for the next year and some plots	Changes made in this file up to line 49 assuming it will be run inside the report folder with all data required as input in the same folder
report.R	1) All data available and all model scripts	2) A report folder created with all the data and model scripts inside	Script to move data from bootstrap/data and model scripts to the report folder. Up to date only moves the script 01

2.2.4 North Sea

In preparation for the move to FLBIEA the members of the North Sea case study focused on the development of code that can be used for the inter benchmark and which follows the principles of TAF. The structure of this repository is outlined in Figure 2.2.4.1, the scripts, their input, outputs and description

can be found in Table 2.2.4.1. Code was streamlined as much as possible with the development of functions to carry out annual tasks and lookup tables.

Table 2.2.4.1 List of scripts used to implement the data preparation and model for the FLBIEA short-term forecast, details of inputs, outputs and summary notes on each scripts function.

Code	Input	Output	Notes
Data scripts			
data_00_Standardising_FLStocks_FLBEIA.R	1)WG advice Stock Objects	1) FLStocks objects	Takes output from stock assessment for each stock and creates separate FLStocks objects
data_01_get_catch_effort_data.R	1) ICES accessions files 2) Fleet and métier lookup table	1) .RData of combined, cleaned accessions files	Use shared lookup tables to ensure consistency between accessions and intercatch Ideally in future include fleet definitions.
data_02_make_fleet_aggregation_with_age_dist.R	1) ICES Intercatch files 2) Fleet and métier lookup table	1) .RData of combined, cleaned intercatch files	Use shared lookup tables to ensure consistency between accessions and intercatch
data_03_make_new_fleets_aa_ad.R	Output from data_01 Output from data_02	1) .RData of fleet, métier, stock input variables. Age dissagregated output when possible.	Per fleet: effort capacity Per fleet, métier: Effort share Per fleet, métier, stock: landings.n landings.wt discards.n discards.wt price
data_04_ReadFides.R	1) QUOTA from FIDES	1) Fides_output.RData	Recalculate quota after swaps based on FIDES data.
model_00_settings.R		1) RData object with model settings	The scripts controls the model settings and scenarios
model_01_ReproduceTheAdvice_2020 modif for SAM stocksR	1) Output from data_00	1) RData with the reproduced advice using FLR	This scripts contains a modification to solve the differences between FLR and SAM assessments
model_02_FLBEIA_condition.R	1) output from model_01, data_00 and data_03	1) Conditioned FLFLeetsExt object 2) FLBiols	Takes post-conditioned FLFleets and FLStocks from WGMIXFISH and produces FLBiols and FLFleetsExt for use in FLBEIA
model_03_FLBEIA_condition_scenario.R	1) output from model_01 and model_02	3) FLStocks, FLbiols, FLfleets, SPICTS, SRs, indices, covars, BRPs,	Imports conditioned biols and fleets. Adds further FLBEIA scenario control inputs

Code	Input	Output	Notes
		biols.ctrl, fleets.ctrl, covars.ctr, obs.ctrl, assess.ctrl, advice.ctrl, main.ctrl.	
model_04_FLBEIA_stf_projections.R	1) Output from model_03	1) RData with the results of the simulations of short term projections with different scenarios.	Runs different simulations with FLBEIA assuming status quo effort, min or max scenarios for the intermediate year, which are then combined with the min and max scenarios in the advice years
model_05_FLBEIA_range_projection.R	1) Output from model_03	1) RData with the results of the simulations of short term projections with the optimal F scenarios.	Search for the combination of Fs for the different stocks that minimize the differences between the min and the max scenarios
output_01_FLBEIA_extract_results.R	1) Output from model_04 and model_05	2) RData and csv tables with the output from FLBEIA	Prepares the output of the simulations run with FL BEIA to be used by the RMarkdown scripts to produce the reports.
report_01_advicesheet.R	Output from 1) model_06	Production of advice sheet figures and tables	Things to produce:
report_02_WGreport.R	Output from 1) model_06	Production of QA/QC figures and tables	Things to produce:

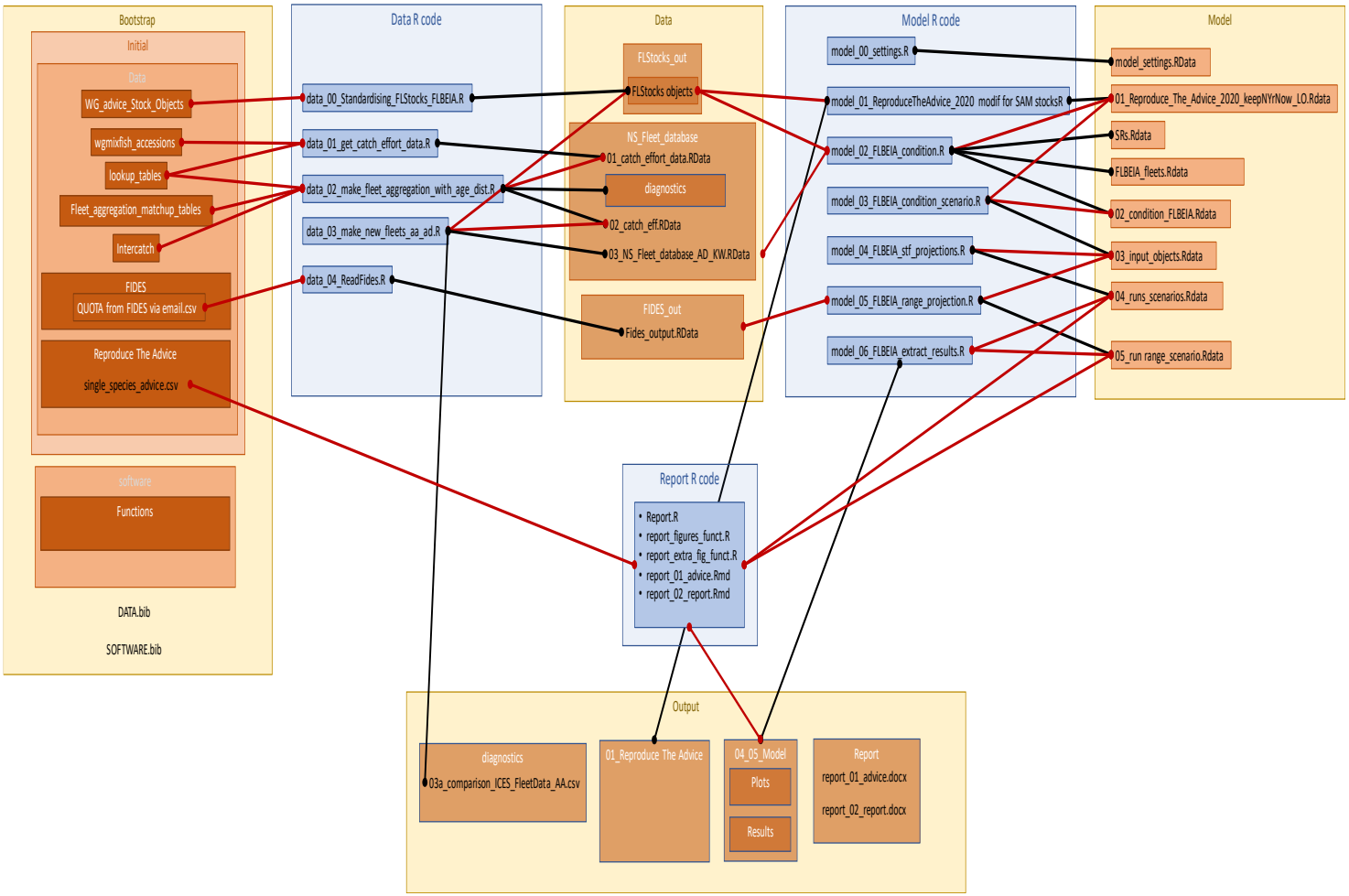

Figure 2.2.4.1 Schematic of North Sea code to process the data inputs and model to produce the FLBIEA short-term forecast

A new data and model script were created to pre-process the FIDES data and create a model configuration file, respectively. The FIDES script standardizes the stock names, and calculates the quota by state. The model script creates an RData object that contains the appropriate values for the data, assessment and forecast years, the scenarios (i.e. FIDES) and the stock names. This RData object is loaded at the start of the other model scripts. This improves the readability of the code and makes it less error prone.

To further improve the automation of the report and advice, a new single Rmd file was created (report.Rmd). The file combines the figures and tables already present in the previous two Rmds (report_01_advice.Rmd and report_02_report.Rmd). The file was organized to follow the outline of the current report and advice sheet to simplify the extraction of the different figures and tables by sections. Also, a new table is proposed for the advice sheet that illustrates the intermediate year assumption in the mixed fisheries projections (see example Table 2.2.4.2., containing intermediate year assumptions used in last year advice). Given that some differences may exist for the intermediate year assumptions between the single species advice and the mixed fisheries advice, these would be made clearer for the advice readers. A more detailed side by side comparison is presented in the report, as in previous years. Also it would help the MIXFISH group to clearly identify these differences if they exist (see also ToR D).

Table 2.2.4.2. Intermediate year assumptions used in the mixed fisheries projections.

	Fbar in 2020	Landings in 2020	Discards in 2020	Catches in 2020	SSB in 2021
cod.27.47d20	0.638	28777	6115	34892	61012
had.27.46a20	0.175	25820	11162	36982	209776
ple.27.7d	0.329	4511	6230	10741	37168
ple.27.420	0.166	57634	54333	111967	1302883
pok.27.3a46	0.460	74118	4690	78808	146230
sol.27.4	0.272	15451	3023	18474	87094
tur.27.4	0.402	3695	0	3695	8857
whg.27.47d	0.208	17903	12573	30476	179206
wit.27.3a47d	0.205	2365	164	2529	5142
nep.fu.5	NA	1134	NA	NA	NA
nep.fu.6	0.165	4189	NA	NA	NA
nep.fu.7	0.057	7139	NA	NA	NA
nep.fu.8	0.203	4094	NA	NA	NA
nep.fu.9	0.150	1479	NA	NA	NA
nep.fu.10	NA	20	NA	NA	NA
nep.fu.32	NA	185	NA	NA	NA
nep.fu.33	NA	1560	NA	NA	NA
nep.fu.34	NA	1147	NA	NA	NA

	Fbar in 2020	Landings in 2020	Discards in 2020	Catches in 2020	SSB in 2021
nep.27.4outFU	NA	700	NA	NA	NA

2.2.5 Irish Sea

A TAF repository has been created for the Irish Sea 2021 advice code at: https://github.com/ices-taf/2021_IrS_MixedFisheriesAdvice The Irish Sea group will use the in github repository https://github.com/ices-eg/wg_WGMIXFISH/Irish Sea as a sandbox for code and model development through 2021, and transfer the final versions to the ices-taf repository when issuing the advice.

2.3 Advice plan

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

2.3.1 Bay of Biscay

Advice 2021	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, rjc.27.8, rjn.27.678abd, rju.27.8ab, sdv.27.nea, sol.27.8ab, whb.27.1-91214, whg.27.89a
TAF repo	Yes	https://github.com/ices-taf/2021_BoB_MixedFisheriesAdvice
Stock Annex	Yes	https://www.ices.dk/sites/pub/Publication%20Reports/Stock%20Annexes/2021/mix.BoB_SA.pdf
Advice Plan	Yes	On Teams
Advice Meeting Participants		Sonia Sanchez, ssanchez@azti.es Dorleta García, dgarcia@azti.es Youen Vermard, youen.vermard@ifremer.fr

2.3.2 Celtic Sea

Advice 2021	Yes	cod.27.7e-k, had.27.b-k, whg.27.7b-ce-k, sol.27.7e, sol.27.7fg , nep.27.7bk , hke.27.3a46-8abd, meg.27.7b-k8abd ,mon.27.78abd
TAF repo	Yes	https://github.com/ices-taf/2021_CS_MixedFisheriesAdvice
Stock Annex	Yes	https://www.ices.dk/sites/pub/Publication%20Reports/Stock%20Annexes/2021/mix.cs_SA.pdf
Advice Plan	Yes	On Teams
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.co.uk Johnathan Ball, johnathan.ball@cefas.co.uk

2.3.3 Iberian Waters

Advice 2021	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/2021_IW_MixedFisheriesAdvice
Stock Annex	Yes	https://www.ices.dk/sites/pub/Publication%20Reports/Stock%20Annexes/2021/mix.ibw_SA.pdf
Advice Plan	Yes	On Teams
Advice Meeting Participants	Hugo Mendez hmendes@ipma.pt Margarita Rincón Hidalgo margarita.rincon@csic.es Cristina Silva csilva@ipma.pt Hugo Mendes hmendes@ipma.pt Paz Sampedro paz.sampedro@ieo.es	

2.3.4 North Sea

Advice 2021	Yes	cod.27.47d20, had.27.46a20, ple.27.7d, ple.27.4, pok.27.3a46, sol.27.4, tur.27.4, whg.47d, 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/2020_NrS_MixedFisheriesAdvice
Stock Annex	Yes	https://www.ices.dk/sites/pub/Publication%20Reports/Stock%20Annexes/2021/mix.ns_SA.pdf
Advice Plan	Yes	On Teams
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 Niall Fallon niall.fallon@gov.scot Thomas Brunel thomas.brunel@wur.nl Vanessa Trijoulet vtri@aqua.dtu.dk Youen Vermard youen.vermard@ifremer.fr Marieke Desender marieke.desender@cefas.co.uk	

2.3.5 Irish Sea

Advice 2021	Yes	cod.27.7.a, had.27.7.a, ple.27.7.a, sol.27.7.a, whg.27.7.a, NEP.FU.15, NEP.FU.14
TAF repo	Yes	https://github.com/ices-taf/2021_IrS_MixedFisheriesAdvice
Stock Annex	No	In development
Advice Plan	Yes	On MS Teams
Advice Meeting Participants	Ruth Kelly ruth.kelly@afbini.gov.uk Mathieu Lundy mathieu.lundy@afbini.gov.uk	

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

The WKMIXFISH workshop was held at ICES Headquarters on 3-5 March 2020 (ICES 2021a) to review the current mixed fisheries advice and identify future direction given the changing needs of the advisory system. It provided a forum for researchers, managers and stakeholders to jointly identify the key challenges and drivers for advice on mixed fisheries, review how current methods and approaches meet their needs and identity future priority areas. WKMIXFISH brought together scientists, managers, and stakeholders to undertake a scoping exercise to identify future advisory and research priorities for mixed fisheries. The meeting highlighted several areas where methodological developments could transfer to improve the type and breadth of advice provided on mixed fisheries, and WGMIXFISH-Methods is an opportunity to discuss any progress or updates.

The following progress was addressed during this WGMIXFISH Methods meeting:

Data streamlining: Much progress has been made on improving data processes and QC/QA of the data going into mixed fisheries models. The move to TAF has helped, along with the development of QA scripts and reports for each countries data submission. Work continues making code clearer and more accessible – which the move to FLBEIA should help with.

Scenarios: There was a discussion on the appropriate scenarios to present and the need to ensure clarity of message from mixed fisheries advice. It was considered one option was to present in the main figure on a limited number of scenarios, allowing for an expanded set of scenarios presented in the tables – in a similar way to single stock advice. For example, managers have shown interest in understanding the effects of changes in selectivity on mixed fisheries outcomes (for example, being able to decouple catches of depleted stocks from target stocks by 10% or 20%) and these could be included in tables as a scenario.

Descriptive spatial analysis: Discussions have taken place with one of the chairs of the ICES working group on spatial fisheries data (WGSFD) on convening a workshop or series of workshops to discuss what data products could be developed to support mixed fisheries analysis using fine-scale data. Such data, generated by combining Vessel Monitoring Systems (VMS) and logbooks, has the potential to give greater understanding of spatiotemporal dynamics in mixed fisheries which could support spatial management considerations. It would likely require a workshop to scope out ideas, another to consider data requirements and availability and another to apply methods to understand what could be achieved.

Gear selectivity and impact of technical measures: Contact with ICES working group on fishing ear and fish behaviour (WGFGFB) has been made to get together a smaller group of people that can consider how we might combine experimental gear trial data and mixed fisheries models to understand the impact of specific gear changes on mixed fisheries outcomes. Several initiatives were highlighted as having already investigated this issue – including implementation in research projects. It was agreed that lessons from these applications should be considered. In the meantime, it was considered that hypothetical gear-based scenarios could be explored to inform on potential solutions to reduce imbalances in mixed fisheries scenarios. Examples of this were presented earlier using FLBEIA in the PROBYFISH project.

Table 3.1 Action points form WKMIXFISH and rough timeline for implementation buy WGMIXFISH

Scenario / rough timeline to advice	1-2 years	3-5 years	5 years +
Data streamlining: Develop workflows that can require minimum intervention so that advisory meetings can focus on discussing scenarios and how this translates to advice. We still spend too much time addressing data issues (this might be extended to code curation too).	X		
Scenarios: Mixed-fishery considerations will continue to be scenario-based, but can we give more consideration to the types of scenarios given the policy context. E.g. replacing the max. scenario with those based on bycatch TACs for zero advice species. Should there be fleet-specific rules? Do we know better than "everyone fishes their entire Saithe TAC"? Can we simplify (declutter) the advice sheets, to communicate the advice better?	X		
Descriptive advice: What are the key spatial interactions, species correlations and other dynamics that tell the story of the fisheries? How to incorporate in fisheries overviews and elsewhere (e.g. in an app type interface). We can link up with ICES SFD here (Roi Martinez chair of the Working Group on Spatial Fisheries Data (CEFAS) has been approached).		X	
Stocks in advice: General recognition of importance of *right* stocks rather than every stock. Analysis by area on key stocks driving interactions? What can we say for other species without explicitly including all species, e.g. "based on catch correlations in the fisheries and increase in effort required for A and B, we can expect higher mortality on X, Y and Z" ?	X		
Spatial adaptation: Recognised that fishers will adapt and we see changes in catchability in the historical data. This has a direct effect on our forecasts, how to factor into the advice? We're unlikely in the short-medium term to be predicting behavioural response, but could such considerations inform scenarios (e.g. max adaptation within min scenario, or using catchability in previous years to bound)?		X	
Economics: Could this take the form of an impact assessment approach to mixed fishery scenarios? Complementary work to be undertaken by WGECON based on existing mixed-fishery models. To work up an "economic impact of scenarios" section?		X	
Selectivity: Managers are keen to understand potential impact of selectivity changes, but a big evidence gap. How might we move to scenarios that include selectivity changes? What would be needed?			X
MSEs: Again, a focus on incorporating scenarios including technical measures, potential behaviour adaptations and sensitivities to these assumptions. How can these be incorporated? Case study MSE applications at MIXFISH Methods?			X

4. ToR C - Horizon scanning for future developments in methodology and advice

In order to respond to the needs raised during WKMIXIFSH (ICES, 2021a), and to continue horizon scanning for future developments in mixed fisheries methodology and advice, time was given at the working group to present and discuss advances in the field and ongoing work. The summary of these presentations and discussions are detailed below.

4.1. Updates from Probyfish and Pandora projects (North Sea)

Marc Taylor

Summary: The presentation included adaptations of the North Sea mixed fisheries scenarios conducted within two projects: PROBYFISH (*Protecting bycaught species in mixed fisheries*) and PANDORA (*PAradigm for New Dynamic Ocean Resource Assessments and exploitation*). The PROBYFISH project results presented were presented of scenarios looking at gear and métier based approaches to improve stock health (for both target and bycatch stocks) while addressing possible impacts to fleets. Gear changes (i.e. increased mesh size) showed some improvements to stock status (F/Fmsy, B/Blim ratios), although these changes were relatively small given that HCR-derived quotas remained at similar levels. Shifts in reference points were not addressed, although selectivity changes have the potential to influence these. Impacts to fleets were more apparent given that the decreased selectivity required higher fishing effort to achieve quotas. From the PANDORA project, results were presented for ongoing scenarios looking at the bioeconomic consequences of climate change. For these scenarios, fleets have been conditioned with economic data from the Scientific, Technical and Economic Committee for Fisheries (STECF), with additional considerations of projected changes to costs (e.g. fuel prices) and revenue (e.g. fish prices) under climate change. In addition, environmentally-mediated stock recruitment relationships are used to address possible shifts in stock productivity under future conditions. Additional details of the bioeconomic conditioning procedure are outlined in TOR g (section 8).

Presentation: https://community.ices.dk/ExpertGroups/WGMIXFISH-METH/2021%20Meeting%20Documents/05.%20Presentations/WGMIXFISH-Methods_projects_update_Taylor_20210621.pptx

4.2. Outcomes of ProbyFish project in Bay of Biscay CS

Dorleta Garcia

Summary: This work was carried out for the evaluation of multi annual management plans for Bay of Biscay mixed fisheries as part ProbyFish project was presented. One of the main goals of the project was to identify the bycatch species that are protected by the management of target species and propose adequate management measures for those that were not protected. Bycatch species are usually data-limited species and lack mathematical models able to produce reliable estimates of abundance and exploitation level. Thus, the incorporation of those species to simulation frameworks represents a challenge from a modelling perspective.

The stocks to be included in the simulation were selected using a productivity susceptibility analysis. For those in ICES category 1, the conditioning of the operation model was based on ICES assessment models. Those in category 3 or beyond were conditioned using stock reduction analysis or statistical catch at age analysis in DLMTool and Fla4a libraries respectively accounting for the main uncertainty in biological parameters and catch data. The results were highly driven by the implementation or not

of landing obligation. While under landing obligation only red mullet and black anglerfishes were the only stocks with biomasses below safe biological limits in the simulation, without landing obligation only Cuckoo ray was protected, apart of the target stocks in category 1. The harvest control rules used by ICES for category 3 stocks was not able to maintain stocks in sustainable levels and it was necessary to use the harvest control rules used for category 1 stocks to exploit the stocks sustainably. For red mullet fishing to be sustainable it was necessary to close the fishery for several years which implied closing the activity of some of the fleets.

We analysed the sensitivity of the results to the productivity parameters and the management strategy using generalized linear models. Overall, for target stocks the variability in the results was highly driven by the implementation of landing obligation. On the contrary, for bycatch stocks the parameters of the stock recruitment relationship explained a great part of the output variance. Initial condition and virgin biomass did not have almost any impact on the results. Finally, red mulled was the stock which biomass was most impacted by the management strategy used.

Presentation: https://community.ices.dk/ExpertGroups/WGMIXFISH-METH/2021%20Meeting%20Documents/05.%20Presentations/ProbyFish_BoB_MixFish_WG.pptx

4.3. Multifleet SAM for Celtic Sea gadoids

Matt Pace

Summary: For many stocks, single species assessment approaches treat recorded fisheries catches as observations with error. This leads to discrepancies with mixed fisheries forecasts where input catch data does not match assessment outputs. Preliminary outputs were presented from a multi-fleet state-space assessment model (SAM; Neilson and Berg, 2014) for Celtic sea haddock with up to six defined commercial fleet segments, delineated by nation and gear type, that account for the majority of catches. The model convergence issues encountered with increasing the number of commercial fleets and the adjustments implemented were discussed, and the performance of the single stock and multi-fleet assessment models compared. The approach yielded partial fishing mortalities and fitted catches for each fleet with estimates of associated uncertainty. This can be extended other gadoid stock using identical fleet definitions to investigate age-specific fishing mortality correlations among different stocks for a given fleet segment.

Presentation: https://community.ices.dk/ExpertGroups/WGMIXFISH-METH/2021%20Meeting%20Documents/05.%20Presentations/MattPace-MIXFISH_2021June_multifleetCShaddock.pptx

4.4. BIM model

Paul Dolder, Claire Moore, Jonathan Ball, Angela Muench, Mikel Aristegui-Ezquibela and Olga Kalinina

Summary: Work was presented on a 47 stock FLBEIA short-term forecast model for Irish fleets covering ICES areas 6 and 7. The project, a collaboration between Cefas and the Marine Institute for Bord Iascaigh Mhara, developed a model to run scenarios to assess the bioeconomic impact of the landing obligation, different TACs and selectivity measures. The work included developing functions and methods to automate production of FLBiol and FLFleet objects through processing of logbook, InterCatch, assessment outputs and STECF Annual Economic Review data on Irish fleet activity. The model results were presented through a ShinyApp from the perspective of fleets, métier, stocks and downstream economic impacts at the port, county and direct and indirect employment level.

A series of simple functions and inputs developed to allow additional scenarios to be evaluated by the user, with the results automatically incorporated within the App output. The importance of defining fleets in a way that could link economic data to activity was highlighted, along with novel ways of

presenting choke risks for individual fleets that could be incorporated within approaches taken by WGMIXFISH

Presentation: https://community.ices.dk/ExpertGroups/WGMIXFISH-METH/2021%20Meeting%20Documents/05.%20Presentations/FLBEIA%20Celtic%20Seas%20model%20and%20data%20dissemination.pptx

4.5. Analysis the impact of several assumptions on the Bay of Biscay case study

Sonia Sánchez-Maroño and Dorleta García

Summary: This analysis tested the sensitivity of the Bay of Biscay mixed fisheries simulations to some model assumptions. The performance tested the replicability of the single stock advice, the outcomes of the mixed fisheries advice and the adequacy of current management system.

Firstly, the impact of replacing the Cobb-Douglas model for generating the catches (where it is assumed that the catches are extracted instantaneously at the middle of the season) with the Baranov equation (where it is assumed that catches are taken continuously and constantly along the whole season) was assessed. Secondly, the impact of considering the TAC for the anglerfishes (*Lophius* spp.) separately as in the ICES advice or jointly as it is currently set was evaluated.

When the Baranov catch equation is used instead of the Cobb-Douglas production function, in the short term, very similar results are obtained. However, some deterioration was observed for hake when using the Baranov equation, in the replication of the advice. Since some improvement was expected for VPA-type assessments, further investigation is required. Furthermore, systematic differences were observed between the TAC and total simulated catches. Consequently, this approach is not considered valid for the production of mixed fisheries advice. Main issue is the assumption on the others' fleets fishing mortality when estimating catches for a specific fleet giving its effort.

Regarding the consideration of combined TACs for anglerfishes, it implies an expected decrease of black-bellied anglerfish (ANK) catches by 2% and an increase of white anglerfish (MON) catches by 1%. The ANK decrease would imply a reduction of the overshoot levels of the rest of the species compared to the case when we consider separated TACs. With just the contrary effect for MON (i.e., decrease of the overshoot for other species). Therefore, although we observe some changes in other species expected catches, we conclude that under current conditions it makes no significant difference to have a joint TAC for ANK and MON or separated ones in the Bay of Biscay. If any of the stocks were a choke stock for any of the fleets in the Bay of Biscay, the impact of a combined TAC would increase.

Presentation: https://community.ices.dk/ExpertGroups/WGMIXFISH-METH/2021%20Meeting%20Documents/05.%20Presentations/BoB_MixFish_alternatives_WKMIXFISHmethods_20210624.pptx

4.6. Description of FIDES procedure (North Sea)

Youen Vermard

Summary: Not available at time of publication.

Presentation: https://community.ices.dk/ExpertGroups/WGMIXFISH-METH/2021%20Meeting%20Documents/05.%20Presentations/presFIDES.pptx

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

The outcomes and issues encountered during the mixed fisheries advice production process are dealt with during this meeting. Details of these issues are dealt with below, either as a case study specific issue or in individual sections due to the importance and wider implications.

4.1 Bay of Biscay

During the production of advice in 2020 a number of issues were encountered in relation to the modelling process. A summary of these issues, their level of priority are outline in Table 5.1.1, followed by a detailed description of the work conducted during the meeting.

Table 5.1.1 Summary of issues encountered during the advice production process 2020 for the Bay of Biscay.

Issue	Priority (High/Med /Low)	Address during this method meeting	Lead	Notes
Differences in the short-term forecast	High	YES	Sonia Sanchez	Test the performance with Baranov catch equation. Results to be presented in present WG.
Including fleet dependent age structure in the conditioning.	Med	NO		Check if data available of catches-at-age by fleet to link those to the métier's considered in the case study. For WGMIXFISH-Methods 2022.
Improve fleet structure.	Med	NO		Fleet structure is improved in some way every year given new data. A deeper analysis will be completed in the subsequent years.
Include blue whiting.	High	YES	Sonia Sanchez	Advice will not be available until 30th September, as for mackerel and horse mackerel.
Analyse stability of main model parameters.	Med	NO		Will be addressed at WGMIXFISH-Methods 2022.
Analyse the relevance of existing scenarios and identify new relevant ones.	Med	NO		Main obstacles: Management scenarios: need clearly defined objectives at fleet level before defining new scenarios. For consistency in TACs, we should operate at fleet level, but the TACs are global. Required changes (assignment of quotas by fleet given their specific requirements) would be in contradiction with the general stability principle.

4.1.2 Differences in short-term forecast

During the 2020 working group it was not possible to reproduce exactly the single species short term forecast of a number of stocks within the Bay of Biscay mixed fisheries framework. A number of differences were found in the results of white anglerfish, seabass, and mackerel. With the of reducing the encountered differences, the Bay of Biscay subgroup tested if an improvement would be possible by replacing the function currently used for generating catches (the Cobb-Douglas equation: Cobb and Douglas, 1928) by the Baranov equation (Baranov, 1918). This would imply assuming that catches are taken continuously along the whole season, in contrast to previous assumption that there were caught in the middle of the season, which is more in line with the assumptions of the VPA-type assessments.

When trying to reproduce the advice, similar results were obtained. However, some deterioration was observed for hake when using the Baranov equation (Table 5.1.1.1). Furthermore, we observe systematic differences between the TAC and total simulated catches (Table 5.1.1.2) which invalidates the use of Baranov equation as it is computed now. Therefore, it is required a revision of the assumption made for calculating the total fishing mortality required for estimating catches for a specific fleet giving its effort. See more details in Section 4.5. Further investigations are required on the issue for trying to achieve an improved reproducibility the single species short-term forecast.

Table 5.1.1.1. Bay of Biscay: Comparison of fishing mortality (F) and Spawning Stock Biomass (SSB) values between baseline run and ICES advice, with two assumptions on how catches are produced (Cobb-Douglas production function or Baranov equation). Comparison of the baseline run (that use the same assumptions as the forecasts leading to ICES advice) to the ICES short-term forecast used for giving advice.

stock	scenario	F_2019	F_2020	F_2021	SSB_2019	SSB_2020	SSB_2021
BSS	Cobb-Douglas	1	1	1.04	1	1.05	1.05
BSS	Baranov	1	1	1.04	1	1.05	1.06
HKE	Cobb-Douglas	1.03	0.99	0.95	1.01	1.05	1.04
HKE	Baranov	1.03	0.98	0.94	1.01	1.06	1.07
HOM	Cobb-Douglas	1	1	1	1	1	1
HOM	Baranov	1	1	1	1	1	1
MAC	Cobb-Douglas	1.03	1.01	1	1.08	1.09	1.1
MAC	Baranov	1.03	1.01	1	1.08	1.09	1.11
MEG	Cobb-Douglas	0.99	1	0.97	0.99	1	1
MEG	Baranov	0.99	1	0.97	0.99	1	1.01
MON	Cobb-Douglas	1	0.93	0.94	1.01	1.03	1.04
MON	Baranov	1	0.93	0.94	1.01	1.03	1.04
SOL	Cobb-Douglas	1.01	0.98	1.02	1	1.01	1
SOL	Baranov	1.01	0.98	1.02	1	1.01	1

Table 5.1.1.2. Expected percentage of TAC consumed of each of the stocks in the scenario where the fishery stops when the TAC of this stock is exhausted.

	Cobb-Douglas	Baranov
BSS	1.00	1.03
HKE	1.00	1.08
HOM	1.00	1.04
MAC	1.00	1.06
MEG	1.00	1.07
MON	1.00	1.11
SOL	1.00	1.23

4.1.3 Including blue whiting

Blue whiting stock was not considered in WGMIXFISH-Advice 2020 due to the fact that assessment outputs were not received on time for their inclusion. The plan for WGMIXFISH-Advice 2021 is to include blue whiting and any other species that is considered of importance for the Bay of Biscay fleets among the ones for which ICES gives advice.

4.2 Celtic Sea

The Celtic Sea case study focused on the work required to move from the current model, FCube, to FLBEIA for the provision of mixed fisheries advice. While there were several issues identified during WGMIXFISH-Advice (Table 5.2.1), these were largely dealt with as part of the considerations of the IBP.

4.2.1 Transparent Assessment Framework (TAF):

A TAF repository was built for the IBP. This repository was designed based on TAF principles and built in the format that would be used to produce mixed fisheries advice for the Celtic Sea. In the event that this case study does not change models, this new framework can still be used to process data and produce plots for an FCube model. This framework has improved the way in which the data is processed, model results summarised and report (section 2.2), with dedicated scripts for each stage of the process. Successful implementation of this framework would during the advisory working group less time would be spent producing the outputs and more time on testing assumptions of the model, the implications for advice and developing appropriate scenarios. Therefore, a series of functions were developed for this purpose, which automate the production of the figures and tables required for the Celtic Sea mixed fisheries advice and report. This is a two-step process: i) the figures and tables are generated, and ii) a markdown file formats and annotates the tables for insertion in the advice sheet and report. The functions developed were:

Plotting functions

- **underOverPlot**: Function to plot estimates of potential catches of stock given mixed fishery scenarios.
- **plotEffortLim**: Function to plot the effort required by fleets to reach single-stock advice.

- **plotScenSBB**: Function to plot estimated scenario SSB expressed as ratio to single-stock advice forecast.
- **plotMetierLandings**: Function to plot the landings distribution of species by metier.
- **plotPieLandings**: Function to plot the total landings by stock for the last data year in the form of a pie chart.

Summary table functions:

- **tableNomfun**: Function to generate table on nomenclature that is used in the advice and reporting documents.
- **tableSSB**: Function to generate table for SSB from single stock advice and mixed fishery scenarios.
- **tableCatch**: Function to generate table for catch from single stock advice and mixed fishery scenarios.
- **tableFbar**: Function to generate table for mean fishing mortality from single stock advice and mixed fishery scenarios.
- **tableRelCatch**: Function to generate table showing estimated catch in each scenario relative to single stock advice.

5.2.2. Data

Considerable effort was applied to refining the data processing procedures and to work up age-disaggregated data as input to FLBEIA. This work is ongoing and will be completed intersessionally, prior to the benchmark. An initial process map for working up the data was drawn up which would use as a guide, with some issues that need to be addressed identified (Table 5.2.2).

5.2.3. Diagnostics

Code was developed to automate the quality control procedures within of input data and output data. Particular focus was placed on the consistency between the totals of landings and discards, in terms of tonnage and number) in the mixed fisheries fleet object and single species assessment object. The code highlights any years and stocks that do not align (e.g. Figure 5.2.1).

Table 5.2.1. List of issues identified during the WGMIXFISH-Advice 2020 for the Celtic Sea case study

Issue	Priority (High / Med / Low)	This year?	Notes
Including hake and other stocks	Med	No	Will be considered for inclusion as part of the IBP.
Intermediate year assumption	High	No	It was considered important to explore alternative hypotheses at the advice working group, document and clarify rationale for the decisions made.
Zero TAC advice bycatch methods	High	Yes	Alternative approaches were discussed, such as providing scenarios that considered potential decoupling of the zero TAC stocks from other stocks through technical measures. At present these scenarios would not be informed by gear trials and the implied effect, but this is something that could be explored in future.
Fleet data – cleaning and improving script to work-up data.	High	Yes	Revised as part of the IBP.

Issue	Priority (High / Med / Low)	This year?	Notes
Data checks – automated detection of any issues prior to running the model.	Med	Yes	There is an ongoing need to automate data checks, and where possible this would be embedded as part of the IBP.
Treatment of stocks that are distributed outside of Celtic Sea (e.g., hake, megrim, anglerfish) and/or overlaps with other regional advice.	High	Yes	This was discussed and a presentation made on the current inconsistencies between case studies in how catches are treated across the different areas, for example, with anglerfish and megrims in the Celtic Sea and Bay of Biscay advice. It was considered that combining the models but presenting the results separately would be the best way to ensure consistency and easier to do in the FLBEIA framework. This would be considered as part of the IBP (Section 5.8)
Treatment of stocks that are two species within a TAC	Med	Yes	Anglerfish and megrim consistent of two species in a single TAC – we assume that a proportion of the landings (which are not at the species level) are from each species, and this assumption should be revisited each year.
New scenarios / less scenarios.	Med	No	This was not addressed at the meeting, but considerations for new scenarios include: How can we take account of the fact that we know certain fleets are not targeting certain stocks? How to convey potential of technical measures to improve the situation?
Are Rmarkdown documents the best approach with TAF?	Low	Yes	Revised as part of the IBP.

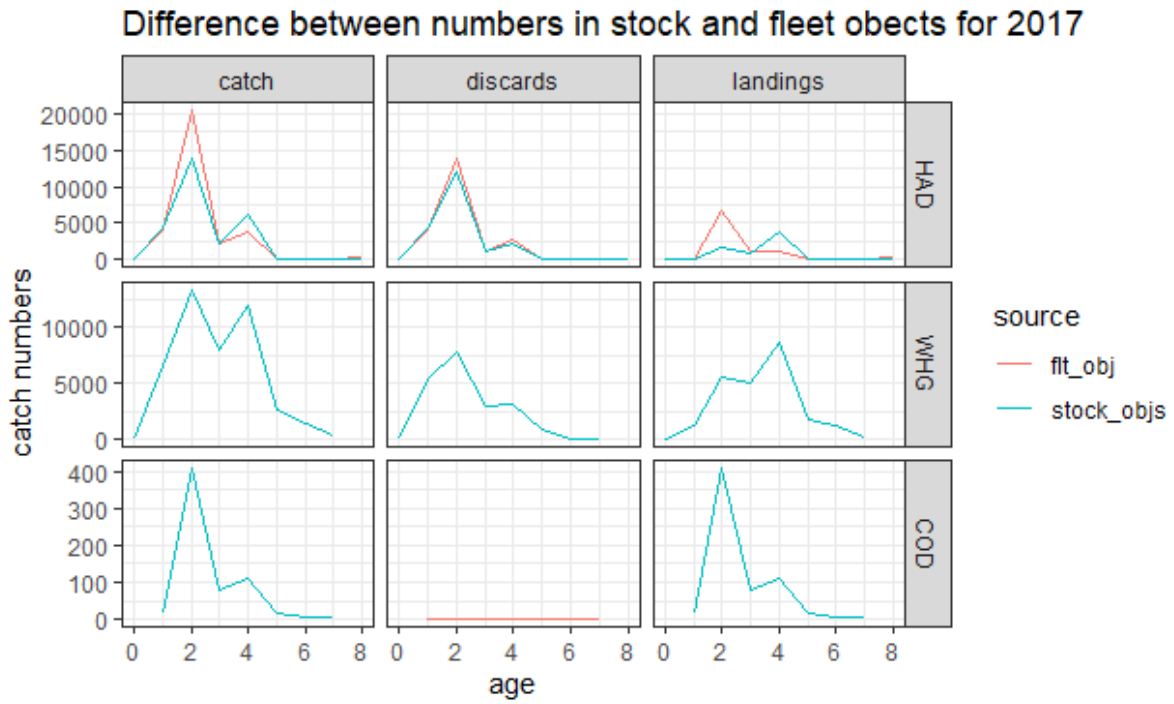

Figure 5.2.1. Example application of diagnostic process for checking consistency between numbers-at-age in the fleet object and numbers-at-age in the assessment.

Table 5.2.2 Initial process map for producing age-disaggregated data for the Celtic Sea FLBEIA model.

DATA		STEP 1: LANDINGS	STEP 2: DISCARDS	STEP 3: CHECKS AND EFFORT	OUTPUTS
"True" landings and effort (source: data_01)	Accessions – landings (TONNES) & effort (KW DAYS) Métier & stock	For each métier and stock: **Landings per accession record:** 1. Match accessions landings to IC métier-level landings by: country, gear, mesh, area, quarter. 2. If missing, assume a "generic" age-structure for unsampled / mismatched métier. * Hierarchy of assumptions: - Drop quarter > area > country > mesh > gear > everything (stock level dist.). 3. Compute numbers-at-age, mean weight-at-age (including plus group). 4. Check SOP (N x WT) matches accessions data. 5. Ensure a value for each age and weight in stock assessment (incl. 0 Ns, fill wts. with stock level).	For each métier and stock: **Discards:** 1. Convert IC métier-level discards by: country, gear, mesh, area, quarter to relative D:L by weight per age for each accession record. 2. If missing, assume "generic" age-structure for unsampled métier. * Same hierarchy of assumptions in step 1. 3. Compute discards numbers-at-age, mean weight-at-age. 4. Check SOP (N x WT) matches IC CATON data. 5. If not (4) standardise discards numbers against CATON for each métier. 6. If no discards, assume zero or average discard rate?? 7. Ensure value for each age in stock assessment.	**Checks at stock level:** 1. SOP of landings- numbers at age and discards numbers at age should match stock-level data. 2. SOP landings (N x wt) and discards (N x wt) should match stock-level data. 3. Each catch record must have corresponding effort. If not, what? Some will be down to other area catches; can we use a "other" fleet? Will want to be consistent with BoB for shared stocks. Area 8 fleet? What if more catches in accessions than stock? **Fleet allocations:** 1. Need to assign métier to fleets. On what basis? Gear-type used previously.	QC/QA'd: • Landings number-at-age per fleet / métier. • Landings weight-at-age per fleet / métier / stock. • Discards numbers-at-age per fleet / métier / stock. • Discards weight-at-age per fleet / métier / stock. The output landings and discards numbers per age (Sum fleet/métier) should match the stock level. The output SOP (L*wt and D*wt) across all fleets and métier should match the stock level. Tolerance or differences allowed?
"True" age-distribution (N-at-age) (source: data_02)	IC – landings (CANUM) Métier & stock				
"True" age-dist (wt-per-age *relative* to landings) (source: data_02)	IC – discards (CANUM) Métier & stock				
"True" discard fraction (source: data_02)	IC – Discards (CATON) Métier & stock				

4.3 Iberian Waters

Continued development of all processes in this new region of advice.

4.4 North Sea

4.4.1 Transparent Assessment Framework (TAF)

The workflow for the North Sea case study was reviewed during this meeting and several improvements have been made to more fully comply with TAF guidelines. These improvements include:

- Improved separation of model and output routines
- Review of global settings definitions to be used by all subsequent scripts,
- Documentation of structure and workflow of scripts (see section 2.2.4),
- Unification of Rmarkdown scripts for automated reports, and revision of SOFTWARE.bib document for declaring R package versions (only uncommon packages are now loaded into a local TAF library, while others are simply documented as entries but commented out to facilitate runtime of the server).

4.4.2 Diagnostics

A new summary table was created for the advice sheet illustrating the intermediate year assumption for the mixed fisheries projections. This includes fishing mortality, landings, discards and catches for the intermediate year under the mixed fishery model assumptions (i.e. status quo effort), as well as the SSB at the start of the advice year This will allow us to clearly identify the possible differences with the single species advice assumptions (see section 2.2.4).

Currently the WGMIXFISH-ADVICE report presents as, a standard output, the discrepancies between the results of single stock advice calculated by the stock assessment working groups and the reproduction of this advice within the FLR framework at the basis for mixed fisheries forecasts. In the same manner, a comparison of the results in the intermediate year of the single species deterministic forecast and mixed fisheries forecast can help visualize and understand the origin of the differences in the abundances at age at the start of the advice year which are linked to the difference in assumptions used for the forecast (e.g. single stock: status quo fishing mortality or catch constraint vs. mixed fisheries: status quo effort or value scenario). These differences are shown on the figure 5.3.1, for the 2020 MIXFISH advice. In the 2020 MIXFISH advice, the largest discrepancy is observed for COD-NS, for which the mixed fisheries assumption of constant effort for all fleets corresponds to a fishing mortality in the intermediate year of 120% larger than the WGNSSK assumption (catch in 2020 equal to TAC2020). This means that the mixed fisheries forecast starts the advice years with smaller abundances at age than in the single stock advice (SSB in the advice year is about 20% lower). Consequently, the fishing mortality that corresponds to the TAC set for COD-NS in the mixed fisheries forecast is higher than the Ftarget apply to compute the TAC. This has ultimately implications for the effort of each fleet, and will therefore influence to which extend COD-NS will choke the different fleets. The differences overserved for PLE-EC, SOL-NS,TUR and WIT are in the same direction as for COD-NS, but have a much smaller magnitude.

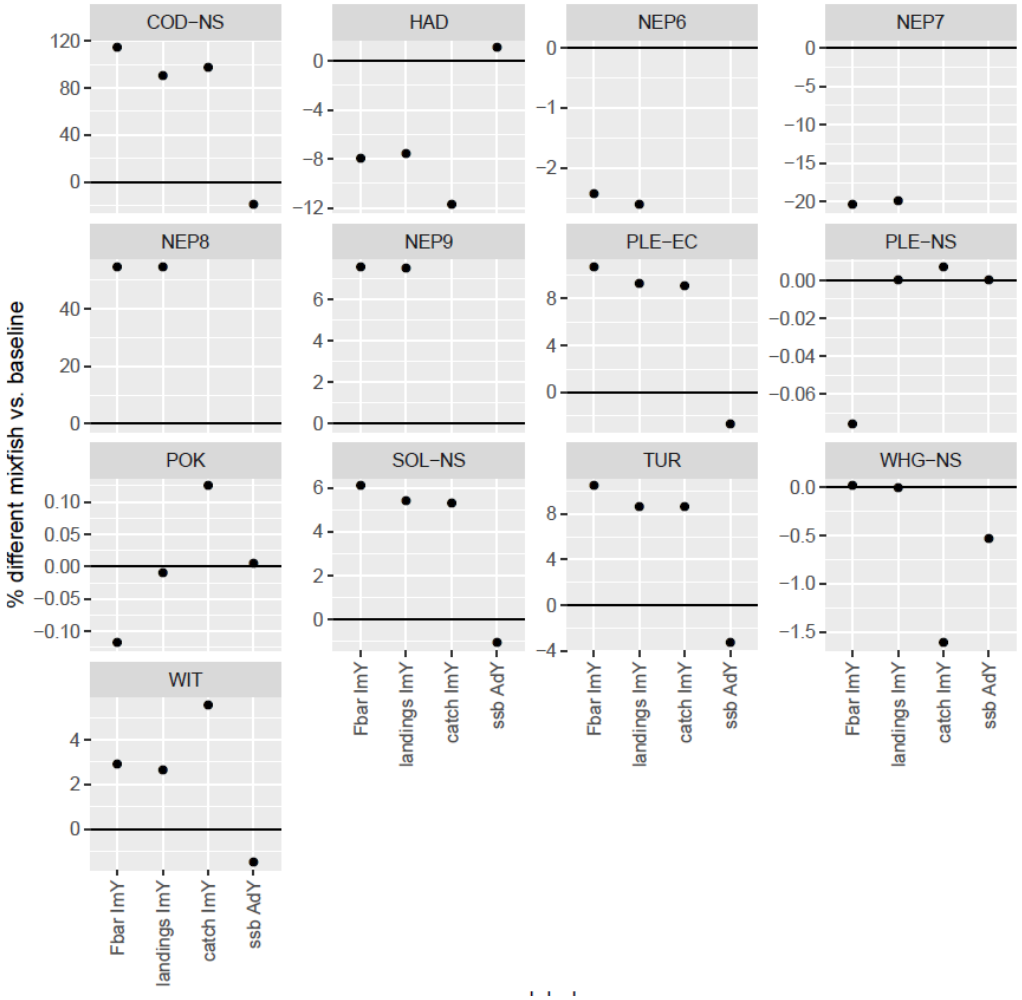

Figure 5.3.1. percentage differences between the mixed fisheries forecast and the single stock forecast for the fishing mortality, landings and catches in the intermediate year of the forecast and SSB in the advice year.

Diagnostic tables and figures used for the evaluation of model conditioning and outcomes are still being revised and several new options will be used during the inter-benchmark process scheduled for later in 2021.

4.4.3 Data

Each year the WGMIXFISH North Sea case study asks that WGNSSK stock coordinators of quantitatively-assessed stocks provide a summary of their assessments in the form of an FLStock object (FLR, *Fisheries Library in R*, https://flr-project.org). We have historically created similar objects for *Nephrops* (NEP) stocks ourselves using the advice reports; yet, in order to ensure better quality control in the future, we would like NEP stock coordinators to be more involved in this process and to assist us in maintaining the input information going forward. A Rmarkdown document was created during the meeting that outline the procedures for FLStock creation, as well as data quality checks to conduct before submission to WGMIXFISH. The guidelines have been sent out to *Nephrops* stock coordinators for review and commenting before future implementation.

4.4.4 Methodology

FIDES – see section 4.6

Intermediate year assumptions – A retrospective investigation of intermediate year catch assumptions was identified as a useful exercise to explore possible biases in the mixed fishery intermediate year assumption (e.g. stats quo effort). The resulting intermediate year catch assumptions for both WGMIXFISH advice and single species ICES advice were compared with the most up-to-date catch data for each stock (hereafter "actual catch") over the past five years (2016-2020). For finfish stocks, the most recent actual catch data includes 2020, and these values were obtained from FLStock objects submitted to WGMIXFISH for the purpose of updating the North Sea assessment. For *Nephrops* functional units, the most recent available actual catch values run up to 2019, and values were taken from assessment summaries in each advice sheet. The WGMIXFISH and single species intermediate year catch assumption values for each of the last five years were obtained from the outputs of each year's WGMIXFISH North Sea assessment (the 2018 object was not available at the time of this analysis).

Values are presented both as assumed and actual catches (Figure 5.3.1), and as percent deviation of assumed catches from actual catches (all years except 2018; Figure 5.3.2). For six out of ten finfish stocks, the mean absolute percentage deviation was greater for the WGMIXFISH assessment than for the single species assessment. For *Nephrops*, seven out of ten functional units had a higher mean percentage deviation in the catch assumptions for WGMIXFISH than single species assessment. However, given that the multispecies model assumption is implemented across all species simultaneously, the percentage deviations are not substantially different between assessment approaches across the time series. The retrospective approach provided a nice framework for comparing the accuracy of our assumptions, and will likely be repeated in future methods meetings or as a diagnostic by which to address possible modifications to intermediate year assumptions.

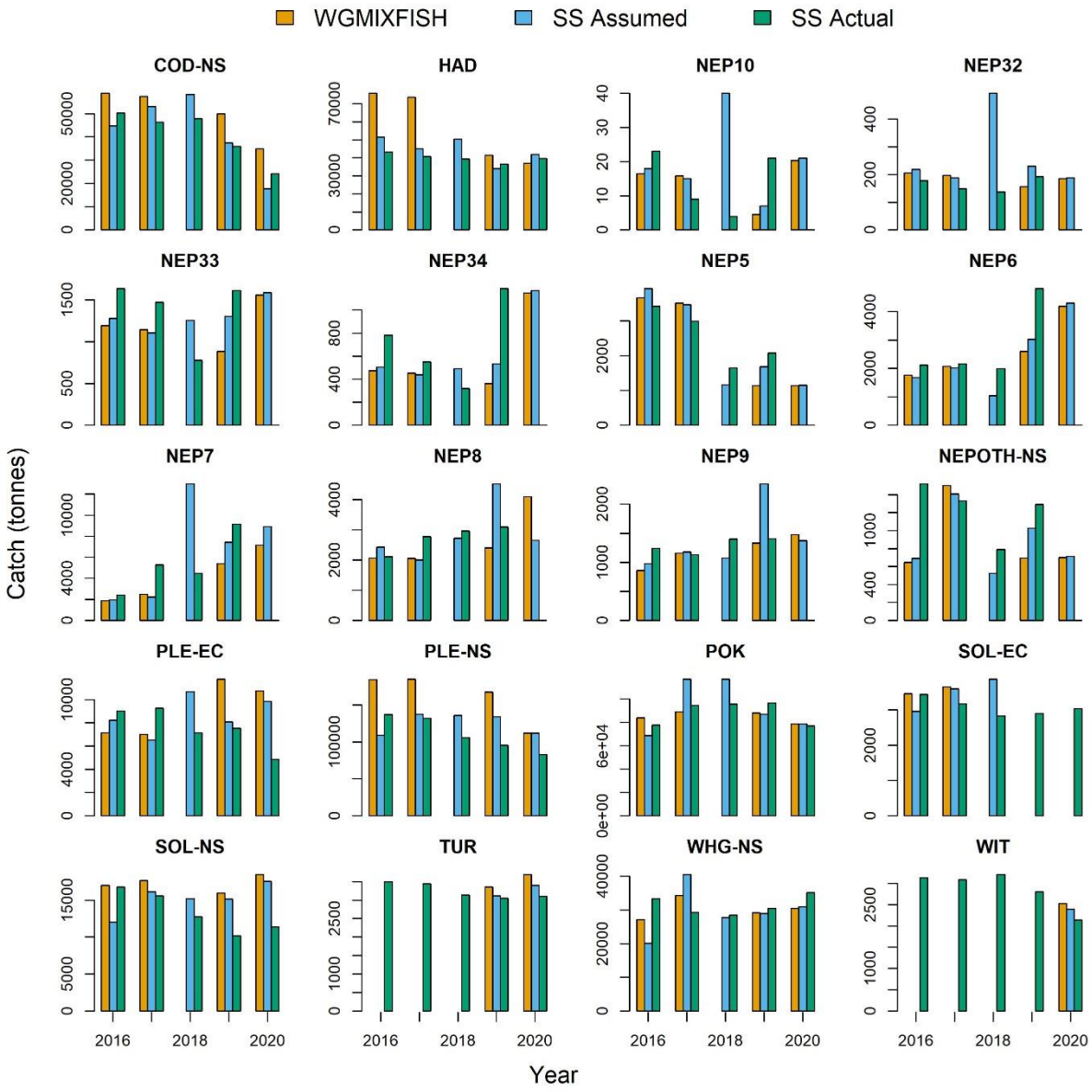

Figure 5.3.1. Intermediate year catch assumptions (tonnes) for WGMIXFISH (orange) and single species ("SS Assumed"; blue) assessments, and actual catch values ("SS Actual"; green), as per most recently available single species assessments.

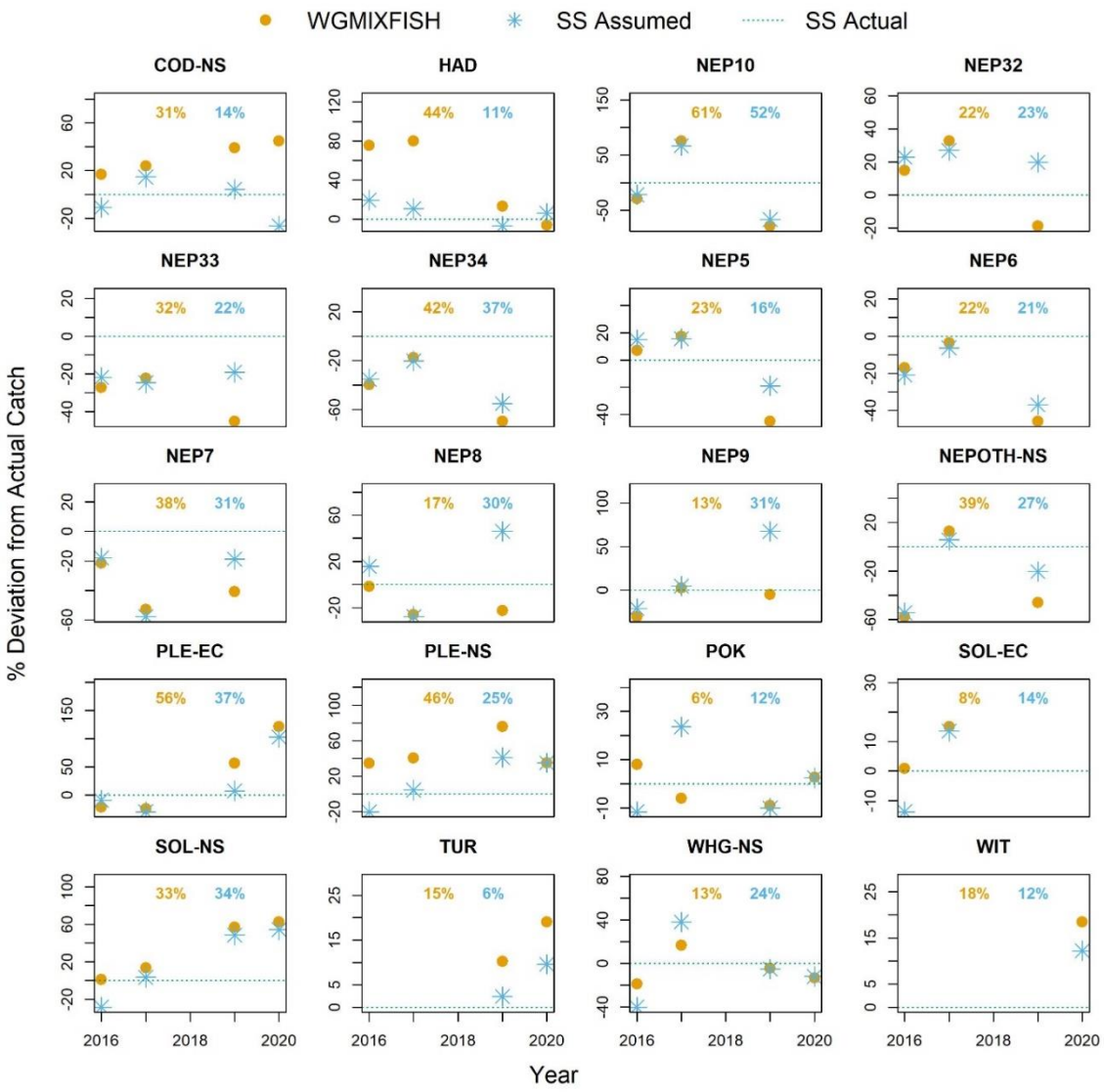

Figure 5.3.2. Percentage deviation of intermediate year catch assumptions for WGMIXFISH (orange) and single species ("SS Assumed"; blue) assessments from actual catch values ("SS Actual"; green), as per most recently available single species assessments. Mean absolute percentage deviation for each assessment is included in each panel with colours corresponding to data points.

4.4.5 Report and Stock Annex

Several RMarkdown-produced Word documents are now used to create advice- and report-ready tables and figures. These will be further maintained and streamlined into a single RMarkdown script. Please see ToR A for additional details.

4.4.6 Transition to FLBEIA

The current year's methodology now includes the option to condition an age-disaggregated FLFleet object for use in FLBEIA. Thus, using a common data conditioning procedure, FCube and FLBEIA will be able to be compared during the transition to FLBEIA. In preparation of the Inter-Benchmark later in 2021 (IBPMIXFISH), models will be compared in terms of stock trajectories and fleet behaviour under similar forecast scenarios. An example of stock forecasts under a "min" scenario is shown in Figure 5.3.3 for both mixed fishery models and the single stock

advice. Such comparisons will allow for the evaluation of consistency in outcomes regarding intermediate year catches and mortality, and advice year SSB. Additional comparisons will be made on the fleet/métier level concerning consistencies in, for example, choking behaviour and effort estimates under different forecast scenarios. The FLBEIA model is currently operational, but some scenarios are still in the process of being translated from existing FCube scripts (e.g. "value" and "range" scenarios).

Figure 5.3.3. Comparison of catch, fishing mortality (f) and spawning biomass (ssb) forecasts by single species advice (red), FCube (blue) and FLBEIA (green). Mixed fishery forecasts (FCube & FLBEIA) are for the "min" scenario (fleet effort limited by most limiting stock quota). Differences between FCube and FLBEIA are due to differences in the model to derived catches (Baranov and Cobb-Douglas, respectively) and conditioning procedure for estimating catchabilities (q) by age. 5.4 Timing of the advice

4.5 Special requests

The standing special request from the European Commission for ICES to produce catch scenarios for zero TAC advice stocks has been addressed for cod 27.7e-k in recent years using runs of the Celtic Sea mixed fisheries model. Scenarios that take account of different levels of TAC for haddock based on F_{MSY}, $F_{MSY\ lower}$ and intermediate values have been presented, with projected catches of cod and the resultant Fs and SSBs. As part of an Inter-benchmark Procedure the Celtic Sea mixed fisheries model is planned to move to a full age-based approach from 2021, which provided an opportunity to assess the implications of changes in catchability (e.g. through gear, or spatial measures) on the level of cod catches under the zero TAC advice requests. While no data or gear comparison trials are available to inform scenarios, a series of illustrative catch levels for cod based on the assumption of 10%, 20%, 30% etc. decoupling of cod from the other species caught in the mixed fisheries complex could be presented to inform management considerations in 2022. The move to FLBEIA will greatly facilitate this change.

4.6 Fisheries Overviews

Annually WGMIXIFISH contribute to the information provided in the fisheries overviews. During the workshop on fisheries overviews (ICES 2021c) it was recommended that this process take a more formal structure, with current WGMIXFISH inputs being produced through TAF. Additional WGMIXFISH were asked to explore the possibility of providing data for a number of other plots which are currently produced using STECF Fisheries dependant information.

The Celtic Seas case study tackled this recommendation by identifying and summarising the plots within the fisheries overview which are currently built with WGMIXFISH data and these which are not. Over the coming year a formalised TAF repository will be developed to produce

these plots annually, and where possible plots made with STECF data will be replaced with WGMIXFISH data (Table 5.4).

Table 5.4 Summary of the figures presented in the 2020 Celtic Seas Fisheries Overview which are not currently produced using WGMXIFSH data.

Figure number	Possible to reproduce using WGMIXFISH data?	Comments
Figure 7 Landings (thousand tonnes) from ICES subareas 6 and 7 (excluding Division 7.d). This approximates to the majority of the Celtic Seas ecoregion in 1950–2019, by (current) country. The nine countries having the highest landings are shown individually and the remaining countries are aggregated and displayed as "other".	YES - partially	Landings available only from 2009 to 2020. No all data are available for the countries in the figure 7
Figure 8 ICES subareas 6 and 7 (excluding Division 7.d). Fishing effort (1000 kW hours at sea) in 2015–2018 for the main countries fishing in the ecoregion. Confidential values have been reported from Ireland, Portugal and France.	YES - partially	Effort available only from 2009 to 2020. No all data are available for the countries in the figure 7
Figure 9 Landings (thousand tonnes) from ICES subareas 6 and 7 (excluding Division 7.d) in 1950–2019, by fish category. Table A1 in the Annex details the species that belong to each fish category.	YES - partially	Landings available only from 2009 to 2020. Not divided by fish category but only by species
Figure 10 Landings (thousand tonnes) from ICES subareas 6 and 7 (excluding Division 7.d) in 1950–2019, by species. The eleven species having the highest cumulative landings over the entire time-series are displayed separately; the remaining species are aggregated and labelled as "other".	YES - partially	Landings available only from 2009 to 2020. Not sure data include all species in the figure 10
Figure 11 Commercial landings (thousand tonnes) from ICES subareas 6 and 7 (excluding Division 7.d) in 2015–2018, by gear type (LL = longline) for EU Member States. Confidential values have been reported from Ireland, Portugal and France.	YES - partially	Nominal effort available from 2009 to 2020. Data divided by Intercatch metier tag
Figure 12 ICES subareas 6 and 7 (excluding Division 7.d). Left panel (a): Discard rates in 2015–2019 by fish category, shown as percentages (%) of the total annual catch in that category. Middle panel (b): Landings (green) and discards (orange) in 2019 by fish category (in thousand tonnes) only of those stocks with recorded discards. Right panel (c): Landings (green) and discards (orange) in 2019 by fish category (in thousand tonnes) of all stocks, including stocks with zero.	YES – partially	Landings and discards available only from 2009 to 2020. Not divided by fish category but only by species
Figure 13 ICES subareas 6 and 7 (excluding Division 7.d). Fishing effort (thousand kW hours at sea) in 2015–2018, by gear type for EU Member States. Confidential values have been reported from Ireland, Portugal and France.	Not clear – as there may be an error in the label of the plot.	Y label says landings, but figure caption says fishing effort.
Figure 14 Spatial distribution of average annual fishing effort (MW fishing hours) in the Celtic Seas ecoregion during 2015–	NO	

Figure number	Possible to reproduce using WGMIXFISH data?	Comments
2018, by gear type. Fishing effort data are only shown for vessels > 12 m having vessel monitoring systems (VMS), this will bias the distributions, particularly in coastal areas.		
Figure 15 The spatial distribution of the landings for the main pelagic, benthic, gadoid, and shellfish species in the Celtic Seas ecoregion. Landings (tonnes) are represented proportionately within each panel, but not between panels. Based on data for > 10 m EU vessels, 2015–2018. Source: STECF FDI (https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter).	YES – partially	Landings for the area available (2015 – 2018) Not divided by fish category but only by species. They need to be split into pelagic, benthic, gadoid, and shellfish
Figure 18 Temporal trends in F/F_{MSY} and SSB/MSY $B_{trigger}$ for Celtic Sea benthic, crustacean, demersal, and pelagic stocks. Only stocks with defined MSY reference points are considered. For full stock names, see Table A1 in the Annex.	NO	
Figure 20 Description of technical interactions of demersal TAC species in the Irish Sea. The left panel (a) shows the species composition of the main demersal métiers (landings > 100 tonnes) operating in the Irish Sea. The label incorporates the country code, métier, and mean annual (2017–2019) landings (tonnes). The right panel (b) shows the proportion of the landings of each species accounted for by the different demersal métiers. The label includes the mean annual landings (2017–2019).	Maybe – partially	Maybe it is partially reproducible
Figure 21 Description of technical interactions of demersal TAC species in the Celtic Sea and west of Ireland. The left panel (a) shows the species composition of the main demersal métiers (landings > 100 tonnes) operating in the Celtic Sea and west of Ireland. The label incorporates the country code, métier, and mean annual (2017–2019) landings (tonnes). The right panel (b) shows the composition of the landings of each species accounted for by the different demersal métiers. The label includes the mean annual landings (2017–2019).	Maybe – partially	Maybe it is partially reproducible
Figure 22 Description of technical interactions of demersal TAC species for the west of Scotland. The left panel (a) shows the species composition of the main demersal métiers (landings > 100 tonnes) operating in these seas. The label incorporates the country code, métier, and mean annual (2017–2019) landings (tonnes). The right panel (b) shows the proportion of the landings of each species accounted for by the different demersal métiers. The label includes the mean annual landings (2017–2019).	Maybe – partially	Maybe it is partially reproducible

4.7 Handling stocks across case studies

The issue of stocks that are included in more than one mixed fisheries advice case study was discussed. Figure 5.5.1 shows several examples where stocks are incorporated independently in Celtic Sea case study (orange ellipses) and Bay of Biscay case study (blue ellipses). In these cases, the stock area is much larger than the individual mixed fisheries advice areas. At present, an

assumption is made that catches of the stock from outside the individual advice area are included in an "others" fleet with a constant effort. For example, in the Celtic Sea model catches of anglerfish from the Bay of Biscay are assumed to be based on constant effort in the other area across all modelled scenarios and *vice versa*. Different assumptions could also be made, such as constant catch, constant proportion of catch or full TAC uptake. However, the current approach creates an inconsistency in that there are different catches in the 'max' scenario in the Celtic Sea advice (where there was a large projected overshoot) and the Bay of Biscay advice (where there was a smaller projected overshoot) for this stock (Figure 5.5.2). The level of bias this introduces is dependent on the relative level of catches in each area (Table 5.5.1). This makes interpreting the mixed fisheries advice across the two case studies impossible.

The solution discussed were as follows:

- Continue as at present,
- Present only catches for the region of the advice not the stock level (though Fs, SSBs etc... would still need to be presented at stock level),
- Coordinate advice so that one model informs the catch in the others fleet for the other model (technically challenging)
- Combine the models together to run consistent scenarios across both areas, splitting results out for the advice sheet.

After some discussion, it was considered that the fourth solution was the most promising option as it results in least compromises and consistent advice. It is also facilitated using FLBEIA where most objects are stored as lists which can be combined once the data was compiled in each respective region. It was agreed to test this approach either as part of the IBP or ahead of this year's advice meeting.

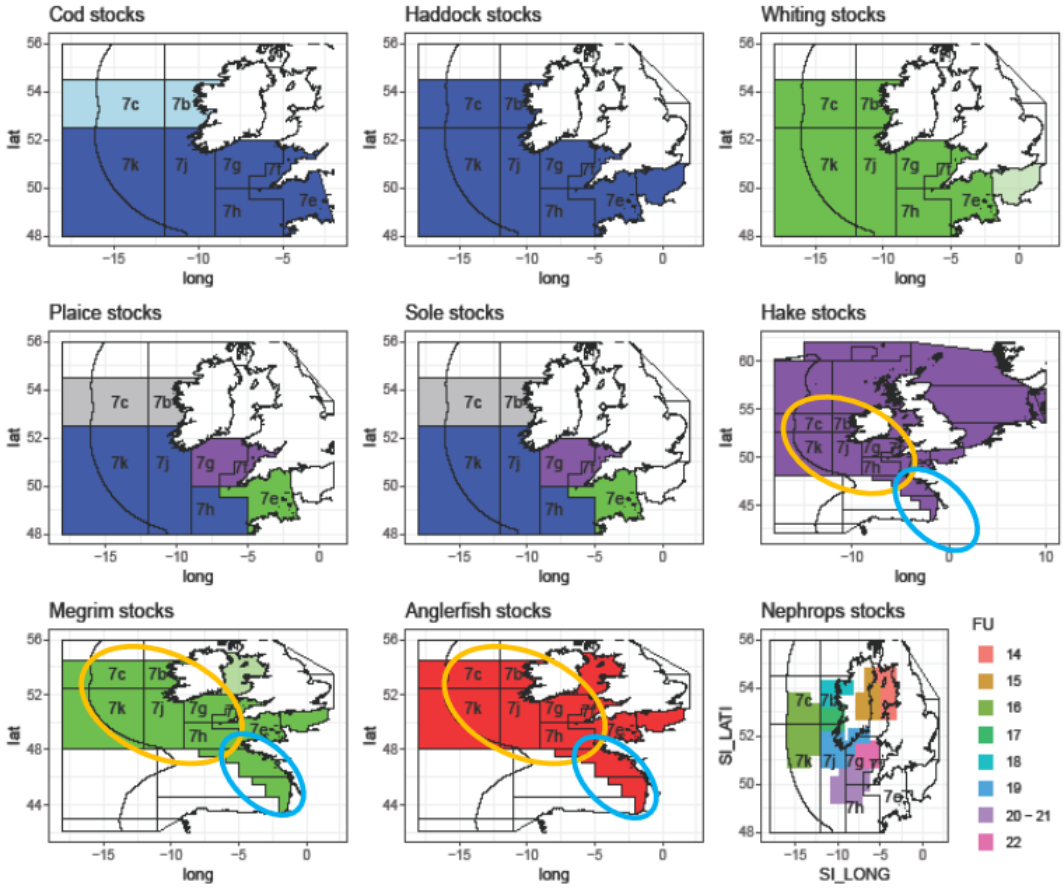

Figure 5.5.1. Overlap of stocks with different ICES areas and stock boundaries. The Celtic Sea model area is indicated by the named ICES subdivisions, while the stock boundaries are shown as different colours for each species and the management units outside of stock boundaries indicated by a lighter shaded area. Ellipses illustrate the Celtic Sea (orange) and Bay of Biscay (blue) mixed fisheries model boundaries in relation to some of the shared stocks.

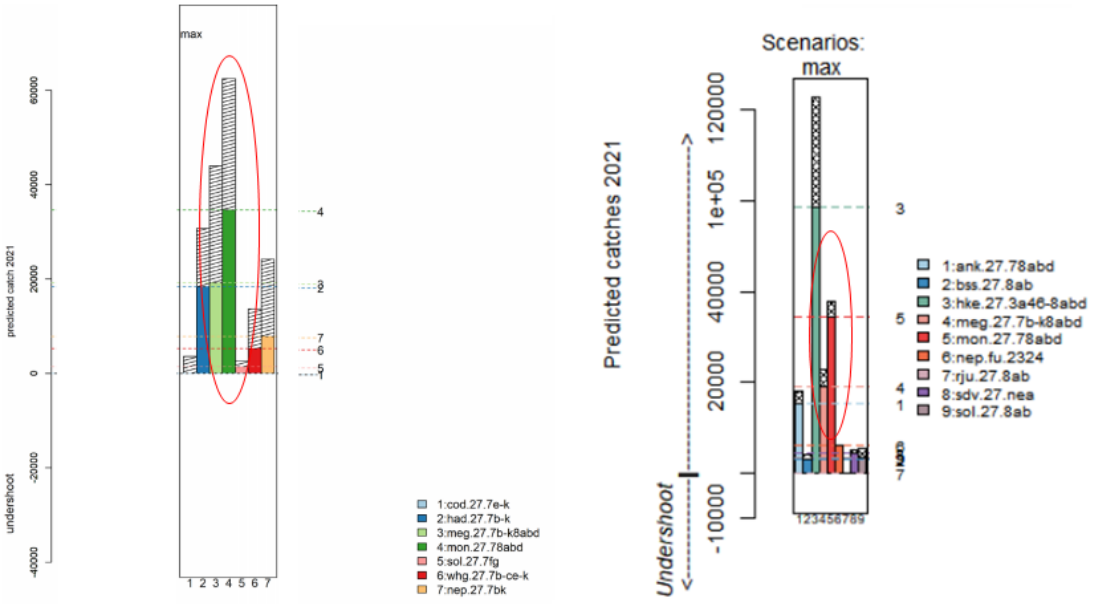

Figure 5.5.2. Differences in catch of mon.27.8abd in the 2020 Celtic Sea mixed fisheries advice (left) and the Bay of Biscay advice (right).

Table 5.5.1. Landings and TAC shares for anglerfishes and hake across ICES area 7 and ICES area 8.

Stock	Area 7*	Area 8*
White anglerfish (*Lophius piscatorius*) in Subarea 7 and in divisions 8.a–b and 8.d Black-bellied anglerfish (*Lophius budegassa*) in Subarea 7 and in divisions 8.a–b and 8.d	Landings (2020): 18 226 t (90%) Landings (2020): 6502 t (75%) Landings (joint 2020): 24 728 t (86%) TAC (joint 2020): 35 299 t (80%)	Landings (2020): 1852 t (9%) Landings (2020): 2174 t (25%) Landings (joint 2020): 4026 t (14%) TAC (joint 2020): 9008 t (20%)
Hake (*Merluccius merluccius*) in subareas 4, 6, and 7, and in divisions 3.a, 8.a–b, and 8.d	Landings (2020): 35 100 t (48%) TAC (2020)*: 63 325 t (56%) * 5b,6 and 7	Landings (2020): 19 700 t (27%) TAC (2020): 42 235 t (37%)

5 ToR E - Review of updated data call, and data processing procedures, identifying possible areas of improvements

This year's data call requested a submission of the mixed fisheries dataset for 2020. Ideally, any data cleaning issues should be followed up and corrected with data submitters rather than being addressed by the WGMIXFISH group. This will enable group members to focus their time on advancing the mixed fisheries advice that is produced rather than spending it on addressing data issues.

To review the submissions from the new data call a quality control (QC) report was produced for each country that submitted data. These individual country specific reports break the data down by ecoregion and plot the data time series to aid group members with checking that the codes submitted match those listed in the data call (covering countries, areas, metiers, years, quarters, FDF flags, units of data, consistency between files). Any discrepancies were reported in a feedback form which will be sent back to national data submitters to request updates to their submissions.

Common issues found so far include:

- Some duplication of records;
- Reporting of non-standard area codes (i.e. not at ICES division level);
- Data separated by semi-colon rather than comma separated;
- Confusion on how to report catch for *Nephrops* functional units (functional unit should be indicated in the species code and not in the area code).

This review process should be completed and data submitters notified within a week. As getting this data is key to being able to start progress on the production of mixed fisheries advice the data submitters will be given a week to respond.

6 ToR F - Develop mixed fisheries models for sea regions not currently covered in the mixed fisheries advice

Building on the Irish Sea FCube model development conducted in 2018 and 2019, WGMIXFISH aims to deliver a mixed fisheries model for the Irish Sea (27.7.a) suitable for advice in 2021. Seven stocks are managed by TACs in Division 7.a; cod.27.7.a, had.27.7.a, her.27.7.a, ple.27.7.a, sol.27.7.a, whg.27.7.a, NEP.FU.15 and NEP.FU.14. It is expected that all stocks except her.27.7.a (herring) will be included in the mixed fisheries model. Herring has been excluded from the current model, due to differences both in the fishery and species ecology, which are thought to reduce the degree of mixed fishery interactions with this stock.

Single species advice for these stocks is issued annually by the ICES Working Group for the Celtic Seas Ecoregion (WGCSE). Category 1 analytical assessments are conducted for all fish stocks except cod, which was changed to a category 3 assessment in 2019. Cod is currently assessed using a trends based assessment based on the NIGFS scientific survey. *Nephrops* stocks are assessed using UWTV based stock assessment models.

6.1 Model Scenarios

The mixed fisheries advice model for the Irish Sea will describe the following standard scenarios:

- 'min' – each fleet stops fishing when any single stock's TAC limit is reached
- 'max' – each fleet stops fishing when TAC limit is reached for all stocks
- 'species-specific models' – each fleet stops fishing when the TAC limit is reached for the species of interest (run for all stocks)
- 'Status quo effort' – each fleet fishes with effort equal to that observed in the most recent data year

Further scenarios may be considered as appropriate.

6.3 Methods development

Key issues were identified for model development during the 2020 advice meeting. Each of these issues was discussed and considered during this 2021 meeting, and the prioritization of these tasks and resulting actions are described in Table 7.1 below.

Issue	Priority (High / Med / Low)	Timeline	Actions
Methods for the inclusion of stochastic assessment methods (SAM) to replicate the single-species assessment of Ple.27.7.a	High	2021	Two alternative solutions were proposed based on current practices within the working group. Firstly, a new version of the 'fwd' function used in the North Sea model which does not overwrite stock numbers in the intermediate year was supplied for use in the Irish Sea model by Thomas Brunel. Alternatively, the Celtic Seas replicate SAM forecasts within the FCube process using the 'stockassessment' package in R. Both methods are likely to better replicate the results of the single species stock assessment for Plaice in 7a and will be tested in for use in the Irish Sea model.
Methods for the inclusion category 3 stocks necessary for the inclusion of Cod.27.7.a	Med	2021	The current single-species advice approach for Irish Sea Cod was presented to the working group, and the working group discussed how category 3 stocks and currently implemented within the different regions. Two approaches were identified in the discussion, an FCube based approach in which the impacts of different scenarios on the catches of a category 3 stock can be projected and an FLBEIA approach. The former has been previously used in North Sea FCube models, but may not allow for the Category 3 stock to be the 'limiting' species in the model, the latter is used by the Bay of Biscay and Iberian regions and is broadly applicable. A third approach based on the West of Scotland model (model in development by Harriet Cole of MSS) was later discussed. This approach allows for a more complete inclusion of category 3 stocks in a FCube framework, and allows for these stocks to be 'limiting' to other stocks in the model. In 2021, the feasibility these methods for the inclusion of Cod in the model will be assessed. It is also noted, that Cod 27.7.a will be benchmarked in early 2022, and is likely to return to a full analytical category 1 assessment.
The use of FIDES information on quota uptake	Low	2022 onwards	The use of FIDES information on quota uptake by different countries to inform the 'min' and 'range' scenarios is not currently considered a high priority for the Irish Sea mixed fisheries model due to the smaller number of countries fishing the area. However, it is likely to be considered again as a model refinement in future years.
Improvements to fleet structures	High	2020/2021	In December 2020, intersessional work was conducted to refine the fleet structures used in the Irish Sea FCube model. Changes were based on expert knowledge of the Irish Sea fleet, and are considered to better reflect the fishing practices and fisher behaviour in the Irish Sea. Further refinements to these fleet structures are likely to be considered during model development in 2021.
Potential improvements to the methods for the inclusion of *Nephrops*	Med	2021 onwards	The division of TACs between *Nephrops* FU's within the Celtic Sea and Irish Sea regions (for which a single combined TAC is issued) was further discussed. It was agreed that this must follow a consistent method between regions. This will be further exam-

stocks in the mixed fisheries assessments.	ined during the Celtic Seas and North Seas regions Inter Benchmark in 2021 and the Irish Sea model will follow the decision mark in that process. *Nephrops* is the main demersal species landed by Irish Sea fisheries, and is considered to have mixed fisheries implications for both Cod and Whiting. As such, the spatial aspects of *Nephrops* fisheries are an important area for future model development in the region.

6.4 Summary

The Irish Sea subgroup addressed a number of core methodological issues during the working group and aims to develop a mixed fisheries model suitable for the delivery of advice for the region for the first time in 2021. A TAF repository for the advice has been set up at https://github.com/ices-taf/2021_IrS_MixedFisheriesAdvice and will be used for the final model. Key methodological developments (Table 7.1.) were discussed and prioritised, and will be developed with continued advice from experts working in other regions during 2021.

7 ToR G - Continue the development of the combined implementation of FCube and FLBEIA in conjugation with STECF/WGECON economists

7.1 Introduction

The WGMIXFISH data call provides information on fishing effort by fleet/métier, as well as landings and prices by fleet/métier/stock. This data is merged with InterCatch data for additional information on age-specific landings and discards in order to more fully describe stock-fleet interactions. Specifically, using information on stock numbers with associated fishing effort and catches, catchabilities (q) for each fleet/métier/stock interaction can be estimated, forming the basis of future advice scenarios. Fish prices are only currently used as a weighting factor in one of the WGMIXFISH-Advice scenarios ("value"), although there is interest to ultimately integrate landings value (i.e. revenue) with other economic variables to provide additional information on the possible economic consequences of mixed fishery scenarios.

A full bioeconomic analysis requires additional information on associated fixed and operation costs of the fleets. The most promising existing data set for this information is that of the STECF, which is reported in the Annual Economic Report (AER) (European Commission. Joint Research Centre. & Scientific, Technical and Economic Committee for Fisheries., 2019). Data is aggregated by fleets based on country, main gear and vessel length. These aggregations largely overlap with many of the fleets defined for the North Sea mixed fishery model, but some mis-matching is likely for several reasons: 1) data is aggregated for the entire FAO Area 27 rather than ICES-specific regions; 2) landings value is aggregated across all species, and thus may include species not considered by the mixed fishery model (e.g. from catches outside the model area or other valuable bycatch species); and 3) finer gear segmentation (e.g. mesh size) is not specified. As a result of these differences, the total costs and revenues are not expected to perfectly align with the fleets and fishing activities considered by the North Sea model, and may only be used as a general proxy for a given fleet's operations.

The following sections outline the approach used to integrate these two datasets in order to explore the feasibility of bioeconomic analyses in the future.

7.2 Methodology

7.2.1 Base model description

The FLBEIA (Garcia *et al.*, 2017) model version of the North Sea case study was used for the conditioning of economic data. This model relies on the same input data as the FCube model, currently-used for WGMIXFISH-Advice, but differs in its some aspects relating how catchability is modelled. The main advantages are its developed bioeconomic modules, which allow for the integration of additional economic variables; specifically, fixed and variable costs, which are described further below.

The example model is conditioned with historical data up to 2018, and stocks are defined using the assessments conducted in 2019 (ICES, 2019). STECF data covered the years of 2009-2016, but was more complete for recent years. Thus, the average economic values from the last 3 available

data years (2014-2016) were used to condition economic parameters in the FLBEIA model for the most recent historical data year (2018).

7.2.2 Costs and revenue

The economic variables related to costs in the FLBEIA model are split into fixed costs, variable costs, and crew share. The following STECF data categories were used for each category:

Fixed costs – Calculated as the sum of "Consumption of fixed capital" and "Other non-variable costs". "Consumption of fixed capital" was referred to as "Annual depreciation costs" in previous versions of the STECF data. These costs are defined at the fleet level in the FLBEIA model, and are constant over time (i.e. we do not assume any changes in the fleet size).

Variable costs – Calculated as the sum of "Energy costs", "Value of unpaid labour", "Repair and maintenance costs" and "Other variable costs". These costs are defined at the métier level in the FLBEIA model, and are a function of changes in fleet effort over time multiplied by the effort share of a given métier.

Crew share costs – A large part of salaries paid to fishers is in the form of a proportion of the landings value. These rates are not provided within the STECF data, but were assumed to make up the bulk of the "Personnel costs" category, which is technically defined as the "*Total remuneration, in cash or in kind, payable by an employer to an employee (regular and temporary employees as well as home-workers)*". Thus, the crew share was calculated as the ratio of *Personnel costs* / *landings value*.

Revenue – Revenue is simply the total landings value. STECF data provides total revenue, but this is not broken down by landings value per stock. Thus, fish prices from the WGMIXFISH data call were used in the calculation of revenue. Prices are provided at the fleet/métier level for each stock, but does not differentiate price for different sizes (i.e. ages) of a given stock.

7.2.3 Data merging

The first step for data merging was to create a look-up table, whereby each FLBEIA fleet/métier combination was linked to a specific set of STECF data variables (country_name, supra_reg, fishing_tech, vessel_length). This was done manually, primarily through the identification of a fleet's country, main gear and range of vessel sizes. In most cases, no differentiation could be made among métiers of a given fleet, and thus variable costs are the same for all métiers of that fleet. One exception was the case of fleets/metiers associated with specific static gears, for which STECF allowed for the differentiation of fishing operations associated with long-line versus trap/pot gears.

An initial attempt at merging costs data focused on deriving costs on a unit per effort basis. This makes most sense for variable effort, which is in terms of costs per unit effort; however, the same scaling was used for fixed costs in order to account for possible differences in vessel numbers between the matched categories. Using the total effort from the WGMIXFISH accession data associated with each fleet, their total fixed and variable costs were initially estimated based on simple multiplication with these ratios. However, using effort as the scaling factor for costs resulted is large discrepancies in the profitability of the fleets (i.e. ratio of costs to revenue). Therefore, we have chosen to use the original ratios of costs to revenue of the STECF data in order to condition the fleets with approximately the same level of profitability. For each mixed fishery fleet, the total fixed and variable costs, as well as revenue, were summed and the ratios *fixed costs* / *revenue* and *variable costs* / *revenue* were calculated for each fleet/métier. These were in turn multiplied by the revenues reported for each fleet/métier in the FLBEIA model in order to derive the fixed and variable costs. The resulting profitability of the fleets was thus consistent with their

matched STECF segments for the starting conditions of the mixed fishery model. With this concession, the final results of the model may need to be presented in relative rather than absolute terms.

7.3 Results

As mentioned above, the STECF-defined fleets are more coarsely aggregated, and thus we would expect their fleet segments to be associated with a larger amount of fishing operations than those matched fleets in the mixed fishery model. This was in fact the case, which can be seen by the relatively larger total costs and revenue for STECF fleet aggregates (Figure 8.3.1). Fleets whose activities are more generally confined to the model area, such as beam trawlers, were found to be better represented by the STECF segments than those with more widely distributed activities (e.g. demersal otter trawlers).

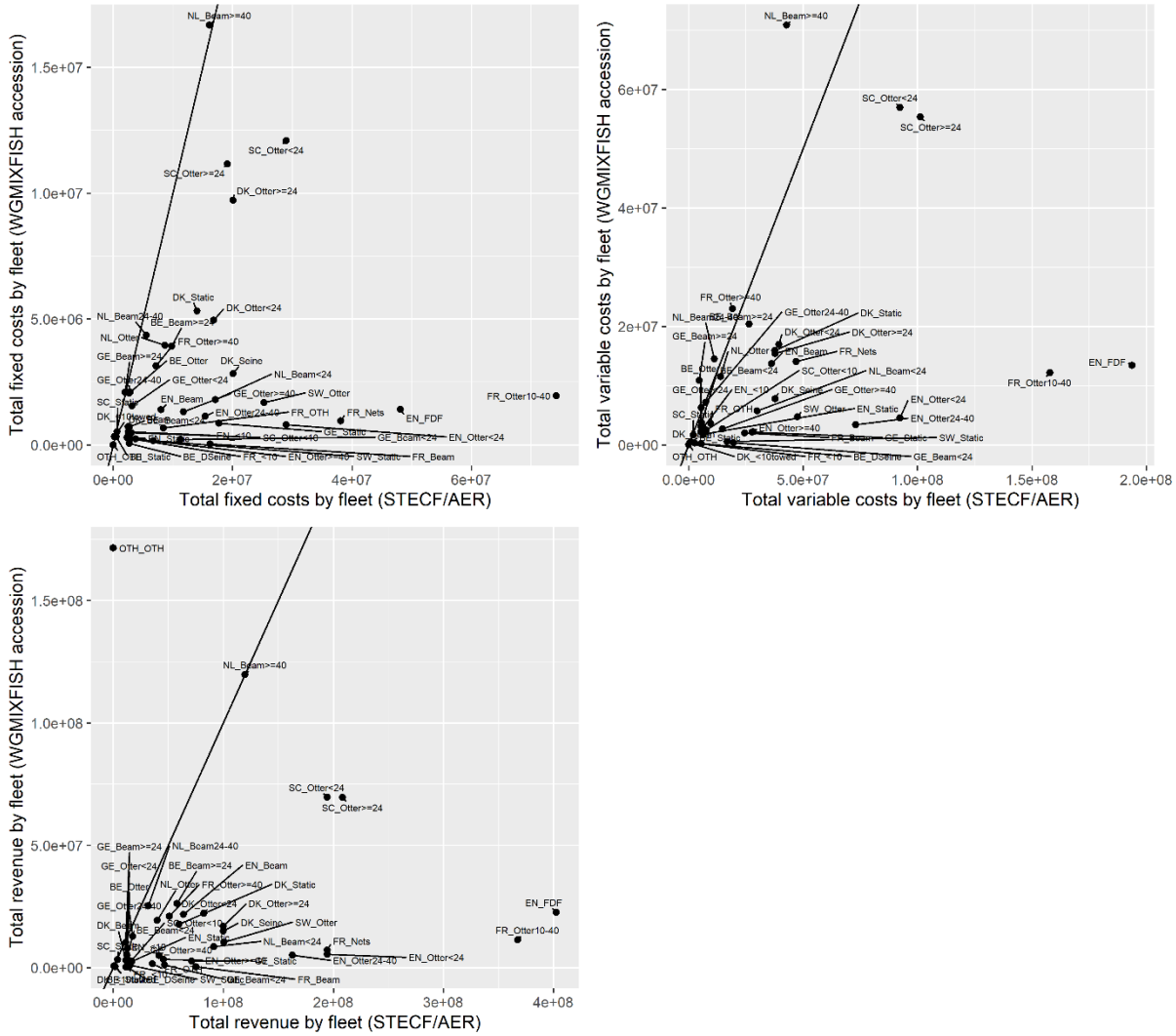

Figure 8.3.1. Total fixed costs (top left panel), variable costs (top right panel), and revenue (bottom panel) by fleet. The 1:1 line is shown for reference.

Some additional quality controls were performed to check the realism of the resulting costs. A large range of variable costs were observed across the fleets, which are in part explained by differences in their component parts. In particular, the proportion of variable costs attributable to energy costs (i.e. fuel) was one of the more variable components, which is seen to be, in part, determined by the type of fishing operation; e.g. use of either active gears (trawl nets) are associated with higher proportions of energy costs than passive gears (e.g. long-lines, pots) (Figure 8.3.2). Further variability is likely due to vessel size, and thus efficiency.

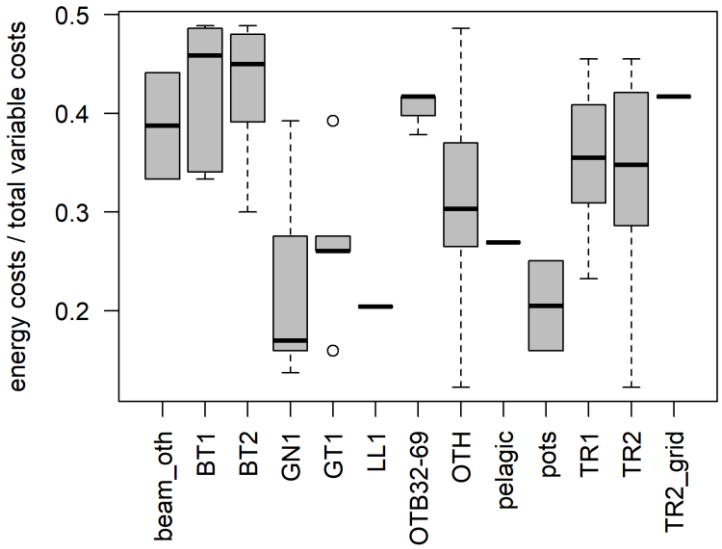

Figure 8.3.2. Distribution of energy costs ratios, as a fraction of total variable costs, by fishing gear. Passive gears (e.g. gillnets – "GN1", longlines – "LL1", traps – "pots") are associated with lower energy usage, and thus costs.

Crew share was quite stable over time (Figure 8.3.3) among fleets, which lends support for our assumption to link this to the "Personnel costs" category. Furthermore, crew shares (20-40%) were roughly on the order of values reported in other fleets (Guillen *et al.,* 2017).

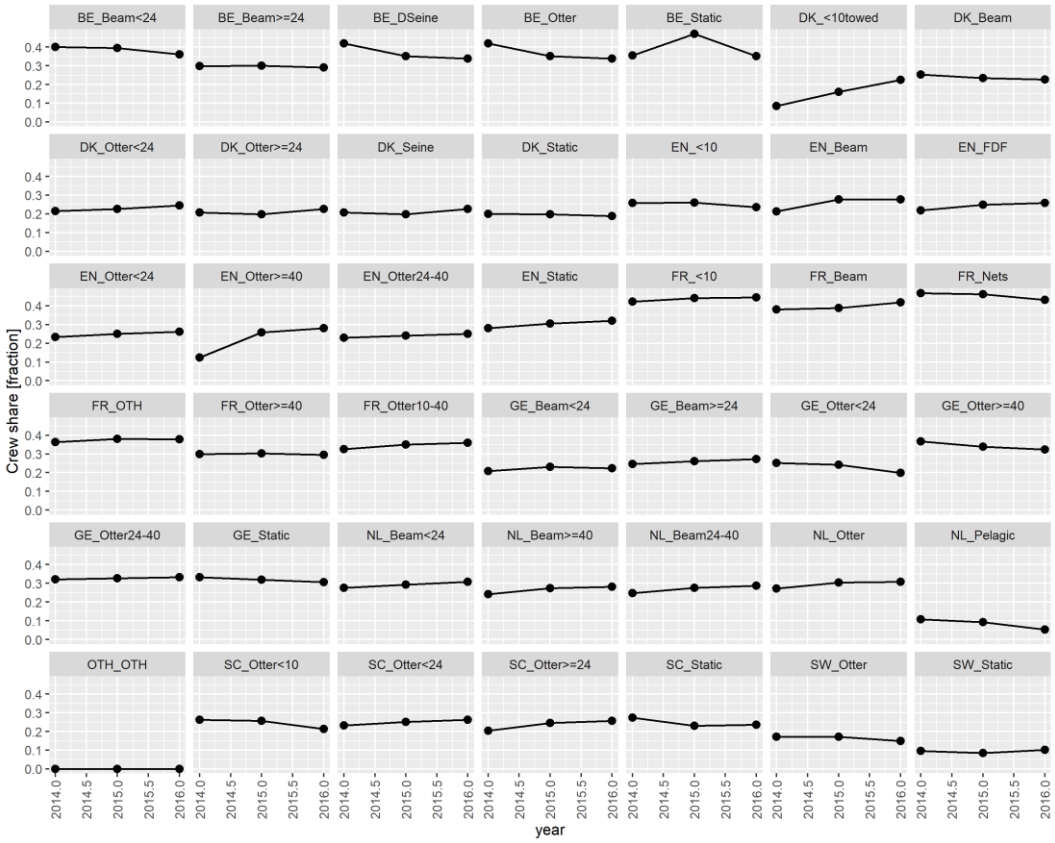

Figure 8.3.3. Crew share by fleet as calculated from the ratio of personnel costs / landings value as reported in the STECF data.

Figure 8.3.4 shows the resulting breakdown in costs and revenue for the historical years (2014-2018) and for a three-year projection under a "min" fleet control scenario. This scenario limits each fleet's effort by the most restrictive (i.e. choking) stock quota. For the last historical data year (2018), the ratio of revenue to total costs can be seen to be close to 1.0 for most fleets, and these ratios reflect the ratios of their associated fleets in the STECF data precisely.

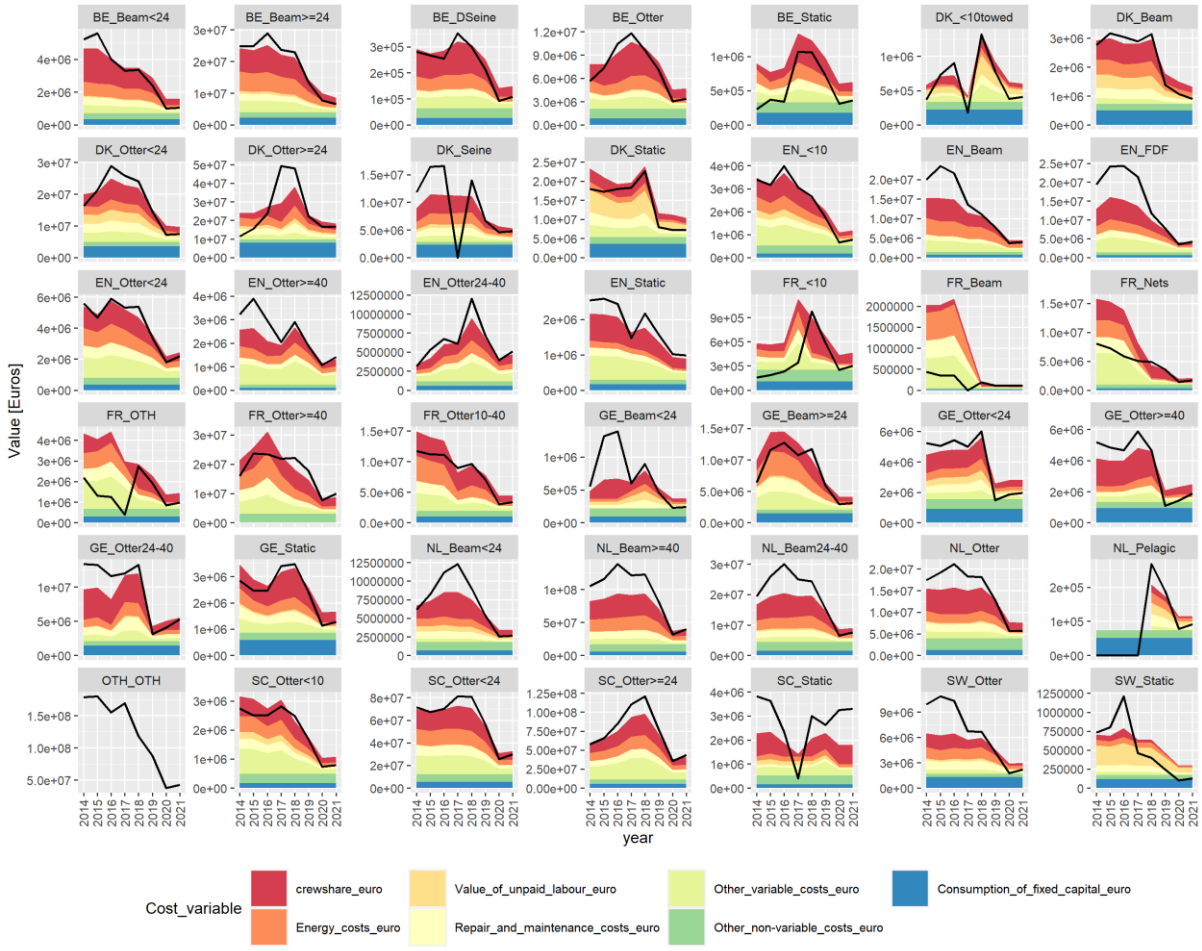

Figure 8.3.4. Contribution of different cost categories (stacked and coloured) and revenue (black line) by fleet. Historical years (2014-2018) and projected years (2019-2021) are shown for a scenario where fleet effort is limited by the most restrictive (i.e. *choking*) stock quota.

7.4 Conclusions

Although the STECF/AER data is aggregated according to differing fleet definitions than those used by WGMIXFISH, the data still provides meaningful insight into the possible bioeconomic consequences of mixed fishery scenarios. Whether these outputs are useful for management and policy negotiations will need to be determined thorough further stakeholder interactions, and the specific metrics for presentation in advice need to be further refined. Until inconsistencies in data aggregations between the two data sets can be resolved, it may be more appropriate to present the relative changes in economic outcomes rather than absolute ones. Further work to develop a more consistent methodology for fleet definitions in WGMIXFISH is currently underway, and this may greatly help future integration of the two data sets. Specifically, this may be achieved through the use fleet definitions in WGMIXFISH that are consistent with those defined by data providers to STECF, as these are based with economic considerations in mind with more clearly distinguished vessel associations. For example, the WGMIXFISH accession data includes vessel numbers associated with effort, yet the data submission does not control for multiple entries across different métiers by the same vessel, which could lead to "double counting" and overestimation of the fleet size. Consistency with STECF categories would simplify this process, yet additional investigation is required in order to determine if important information on smaller fleet segmentation would be lost.

8 References

Baranov, I.E. (1918) On the question of the biological basis of fisheries. Nauchnyi Issledovatelskii Ikhtiologicheskii Institut Isvestia 1, 81-128.

Cobb, C.W., Douglas, P.H. (1928) A Theory of Production. American Economic Review 18, 139-165.

Garcia, D., Sánchez, S., Prellezo, R., Urtizberea, A., & Andrés, M. (2017). FLBEIA : A simulation model to conduct Bio-Economic evaluation of fisheries management strategies. SoftwareX, 6, 141–147. https://doi.org/10.1016/j.softx.2017.06.001

Guillen, J., Boncoeur, J., Carvalho, N., Frangoudes, K., Guyader, O., Macher, C., & Maynou, F. (2017). Remuneration systems used in the fishing sector and their consequences on crew wages and labor rent creation. Maritime Studies, 16(1), 3. https://doi.org/10.1186/s40152-017-0056-6

ICES. 2014. Report of the Working Group on Mixed Fisheries Advice for the North Sea (WGMIXFISH-NS), 26-30 May 2014, ICES HQ, Copenhagen, Denmark. ICES CM 2014/ACOM:22. 95 pp.

ICES. (2019). Working group on the assessment of demersal stocks in the North Sea and Skagerrak (WGNSSK). ICES Scientific Reports, 1(7), 1271. https://doi.org/10.17895/ices.pub.5402

ICES. 2021a. Scoping workshop on next generation of mixed fisheries advice (WKMIXFISH; outputs from 2020 meeting). ICES Scientific Reports. 3:54. 23 pp. https://doi.org/10.17895/ices.pub.6016

ICES. 2021b. Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE; outputs from 2020 meeting). ICES Scientific Reports. 3:28. 204 pp. https://doi.org/10.17895/ices.pub.7975

ICES. 2021c. Workshop on Fisheries Overviews (WKFO). ICES Scientific Reports. 3:45. 98 pp. https://doi.org/10.17895/ices.pub.8077

Nielsen, A., and Berg, C. W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries Research, 158: 96 –101.

Annex 1: List of participants

Name	Address	Email
Alessandro Orio	SLU Aqua, Sweden	alessandro.orio@slu.se
Alexandros Kokkalis	DTU Aqua, Denmark	alko@aqua.dtu.dk
Alfonso Pérez-Rodríguez	Institute of Marine Research, Bergen, Norway.	alfonso.perez-rodriguez@hi.no
Claire Moore (Chair)	Marine Institute, Ireland	claire.moore@marine.e
Cristina Silva	Portuguese Institute for Sea and Atmosphere (IPMA), Portugal	csilva@ipma.pt
Dorleta Garcia	AZTI, Spain	dgarcia@azti.es
Hugo Mendes	Portuguese Institute for Sea and Atmosphere (IPMA), Portugal	hmendes@ipma.pt
Klass Sys	Flanders Research Institute for Agriculture, Belgium	klaas.sys@ilvo.vlaanderen.be
Lionel Pawlowski	Ifremer Lorient Station, France	lionel.pawlowski@ifremer.fr
Marc Taylor	Institute of Sea Fisheries, Thünen Institute, Germany	marc.taylor@thuenen.de
Mathieu Lundy	Agri-food and Biosciences Institute (AFBI), Northern Ireland, UK	Mathieu.Lundy@afbini.gov.uk
Michel Bertignac	Ifremer, France	michel.bertignac@ifremer.fr
Mikel Aristegui Ezquibela	Marine Institute, Ireland	Mikel.Aristegui@Marine.ie
Niall Fallon	Scottish Government, UK	niall.fallon@gov.scot
Paul Bouch	Marine Institute, Ireland	Paul.Bouch@Marine.ie
Paul Dolder	Centre for Environment, Fisheries and Aquaculture Science, UK	paul.dolder@cefas.co.uk
Ruth Kelly	Agri-food and Biosciences Institute (AFBI), Northern Ireland, UK	Ruth.kelly@afbini.gov.uk
Sarah Kraak	Thünen Institute of Baltic Sea Fisheries, Germany	sarah.kraak@thuenen.de
Sonia Sánchez-Maroño	AZTI, Spain	ssanchez@azti.es
Thomas Brunel	Wageningen Marine Research, The Netherlands	thomas.brunel@wur.nl
Vanessa Trijoulet	DTU Aqua, Denmark	vtri@aqua.dtu.dk
Youen Vermard	Ifremer Boulogne-sur-Mer, France	youen.vermard@ifremer.fr

Annex 2: Next meeting's draft resolution

WGMIXFISH-METHODS - Working Group on Mixed Fisheries Advice Methodology

The Working Group on Mixed Fisheries Methods (WGMIXFISH-METHODS), chaired by Marc Taylor, Germany, and Harriet Cole, Scotland, will meet in Nantes 20 – 24 June 2022, to:

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

b) Exploration of developments in methodology and advice, and addressing outcomes of WKMIXFISH, WKFO and IBPMIXFISH;

c) Respond to the outcomes and issues encountered during WGMIXFISH-Advice;

d) Develop mixed fisheries models for sea regions not currently covered in the mixed fisheries advice;

WGMIXFISH-METHODS will report by 30 July 2022 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.

Annex 3: Recommendations

None.