WORKING GROUP ON MIXED FISHERIES ADVICE (WGMIXFISH-ADVICE; outputs from 2021 meeting)

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WORKING GROUP ON MIXED FISHERIES ADVICE (WGMIXFISH-ADVICE; OUTPUTS FROM 2021 MEETING)

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International Council for
the Exploration of the Sea

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Contents

i   Executive summary

The ICES Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE) met remotely to produce mixed fisheries forecasts for the Bay of Biscay, Celtic Sea, Iberian Waters and North Sea. Mixed fisheries advice highlights the potential implications of single-stock (total allowable catch and effort) management on the catches of multiple stocks caught together in mixed fisheries. It takes into account past fishing patterns and catchability of the different fleets, and the TAC advice produced by the single-stock advice groups, to provide quantitative forecast of over- and under-exploitation of the different stocks given mixed fishery interactions. The mixed fisheries forecasts were produced using the "FCube" (Fleet and Fishery Forecasts) methodology for the Celtic Sea, and on the "FLBEIA" (Fisheries Library Bio-Economic ImpaPrct Assessment) methodology for the Bay of Biscay, Iberian Waters and North Sea.

The Bay of Biscay mixed fisheries projections consider the single-species advice of 14 demersal stocks (ank.27.78abd, hke.27.3a46-8abd, hom.27.2a4a5b6a7a-ce-k8, mac.27.nea, meg.27.7b-k8abd, mon.27.78abd, nep.fu.2324, pol.27.89a, sdv.27.nea, sol.27.8ab, whb.27.1-91214 and whg.27.89a. Based on current fishing patterns and single-stock catch advice, the most limiting stock for Bay of Biscay demersal fisheries is pollack, whose quota is first reached for 15 of 22 defined fleets. The least limiting stock is black-bellied anglerfish (11 of 22 fleets).

The Celtic Sea mixed fisheries projections consider the single-species advice for 12 demersal stocks (cod.27.7e–k, had.27.7b–k, whg.27.7bce–k, nep.fu.16, 17, 19, 20–21, 22, and outside FUs, sol.27.7fg, mon.27.78abd, and meg.27.7b–k8abd). Based on mixed-fisheries considerations and single-stock catch advice, cod is the most limiting stock for Celtic Sea demersal fisheries. This is due to the zero-catch advice for cod and because almost all fisheries operating with demersal gears catch cod.

The Iberian waters mixed fisheries projections consider the single-species advice for 5 demersal stocks (ank.27.8c9a, hke.27.8c9a, lbd.27.8c9a, meg.27.8c9a and mon.27.8c9a). Based on mixed fisheries considerations and single-stock catch advice, hake is the most limiting stock for Atlantic Iberian waters demersal fisheries, corresponding to an undershoot of the advised catch for the other stocks considered in the mixed fisheries analysis. Conversely, anglerfish stocks are the least limiting stocks, corresponding to an overshoot of the advised catch for the other stocks. If fleets set their effort in order to catch their anglerfish stock shares, overshoot and reduction of SSB is more noticeable in hake and the four-spot megrim stock, possibly due to an increased technical interaction between this species and the anglerfish stocks.

The North Sea demersal mixed fisheries projections consider the single-species advice for 15 demersal stocks (cod.27.47d20, had.27.46a20, whg.27.47d, pok.27.3a46, ple.27.420, ple.27.7d, sol.27.4, tur 27.4, wit.27.3a47d, nep.fu.5–10, 32, 33, 34, and 4 outFU). Based on current fishing patterns and single-stock catch advice, the most limiting stock for North Sea demersal fisheries is cod, whose quota is first reached for 37 of 40 defined fleets. Whiting is the least limiting stock in 25 of 40 fleets making it overall the least limiting stock.

Additional work included progress towards the development of mixed fisheries advice for the Irish Sea, and contributions by the working group to the fisheries overviews for a number of regions and a technical request.

ii Expert group information

Expert group name	Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE)
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chair	Claire Moore, Ireland
Meeting venue and dates	25-29 October 2021, by correspondence (25 participants)

1   Introduction

This report documents WGMIXFISH-ADVICE 2021 meeting outputs. The ICES Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE) chaired by Claire Moore, Ireland, met by correspondence on 21–29 October 2020 to apply mixed fisheries forecasts to the 2020 single-species advice for the Bay of Biscay, Celtic Sea, Iberian waters, and North Sea. Progress was made on the development of mixed fisheries advice for the Irish Sea. This working group also contributed to the fisheries overviews for a number of regions and a technical request.

Within Europe, most fisheries management is undertaken on a stock-by-stock basis, using tools such as total allowable catch (TAC). This form of management does not reflect the reality of most mixed fisheries where multiple species are caught together. Particularly in the case of demersal fisheries where fishers have limited flexibility to discriminate between species caught during fishing operations. This mismatch between the multispecies outcomes of fishing operations and the single-species catch advice can produce a number of challenges for management, including discarding, the emergence of choke species, and missed fishing opportunities.

Within a European context, the need for mixed fisheries advice arose in 2002, when the conflicting states of the various demersal stocks in the North Sea made the limitations of the traditional, single-species approach to advice particularly apparent. These circumstances led to the introduction of management measures, such as effort restrictions and single-species multiannual management plans. The 2014 revision of the CFP-Common Fisheries Policy (EU, 2013), further highlighted the limitation of the single-species advice structure, with the introduction of two additional management measures: the landings obligation and the regional multiannual management plans for mixed fisheries. The introduction of these management measures fundamentally changed how fisheries were managed. Therefore, since 2016 the ICES advice on fishing opportunities have been provided in the context of catch, rather than landings. As mixed fisheries objectives are still are under development, they cannot be incorporated in the mixed fisheries forecasts, which must build on the existing legal and management system.

ICES Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE) produces management advice and options that take into account the consequences of technical interactions in multi-stock, multi-gear fisheries. This advice is produced using two different models, depending on the advice region, FCube and FLBIEA. Mixed fishery advice is based on the Common Fisheries Policy (CFP) TAC regime and is consistent with relative stability.

1.1   Definitions

Two key descriptive terms form the foundation of mixed fisheries advice, the fleet (or fleet segment), and the métier. Their definition has evolved over time, but the most recent official definitions are provided by the CEC's Data Collection Framework (DCF, Reg. (EC) No 949/2008 and Commission Decision 2010/93/UE), and are adopted here:

A fleet segment is a group of vessels with the same length class and predominant fishing gear during the year. Vessels may have different fishing activities during the reference period, but might be classified in only one fleet segment. A métier is a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area, and characterised by a similar exploitation pattern. Since 2012, WGMIXFISH has requested catch and effort data from countries data according to aggregations based on the definitions of the EU Data Collection Framework (DCF). The data call allowed merging across DCF métiers and as such national data entries were sometimes not by métier in

the strict sense. Merging of métiers to reduce to a manageable number going forwards in the forecasts further leads to the formation of combined or 'supra-métiers'.

1.2 Terms of reference

Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE), chaired by Claire Moore (Ireland) will meet online 25-29 October 2021 to:

a) Carry out mixed fisheries projections for the Bay of Biscay taking into account the single species advice and the management measures in place for 2021 for anglerfish, megrim, sea bass, hake, sole, Norway lobster, whiting and pollack that is produced by WGBIE in May 2021; for mackerel, horse mackerel, and blue whiting produced by WGWIDE in September 2021 and rays and smooth hound produced by WGEF in October 2021.

b) Carry out mixed demersal fisheries projections for the Celtic Sea taking into account the single species advice and the management measures in place for 2021 for cod, haddock, whiting, hake, megrim, monkfish, and *Nephrops norvegicus* that is produced by WGCSE and WGBIE in 2021.

c) Carry out mixed fisheries projections for Iberian waters taking into account the single species advice and the management measures in place for 2020 for hake, four-spot megrim, megrim and white anglerfish that is produced by WGBIE in May 2021, and further develop mixed fisheries analyses for the region.

d) Carry out mixed demersal fisheries projections for the Irish Sea (27.7.a) taking into account the single species advice for cod, haddock, whiting, plaice, sole, and *Nephrops norvegicus* that is produced by WGCSE in 2021.

e) Carry out mixed demersal fisheries projections for the North Sea taking into account the single species advice and the management measures in place for 2021 for cod, haddock, whiting, saithe, plaice, sole, turbot, *Nephrops norvegicus*, sole 7.d and plaice 7.d that is produced by WGNSSK in May 2021;

f) Produce draft mixed-fisheries sections for the ICES advisory report 2021 that includes a dissemination of the fleet and fisheries data and forecasts for the North Sea, Celtic Sea, Bay of Biscay, and Iberian waters.

WGMIXFISH-Advice will report by 30 November 2021 for the attention of ACOM.

Supporting Information

Priority:	The work is essential to ICES to progress in the development of its capacity to provide advice on multispecies fisheries. Such advice is necessary to fulfil the requirements stipulated in the MoUs between ICES and its client commissions.
Scientific justification and relation to action plan:	The issue of providing advice for mixed fisheries remains an important one for ICES. 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 Bay of Biscay

2.1 Background

2.1.1 The fisheries

The Bay of Biscay covers ICES divisions 8.a,b,d. These fisheries target a large range of species with different gears and in many cases are highly mixed. The trawl fisheries use otter, beam and pelagic trawl. Otter trawl is the main gear used in demersal fisheries in this ecoregion. The species caught depends on the area and on the range of depths fished, as well as on the cod-end mesh size. The main species caught in these fisheries are hake, anglerfish, megrim, Norway lobster, sole, horse mackerel, mackerel, blue whiting, sea bass, pollack, red mullet and cephalopods (cuttlefish and squid). Set net fisheries target sole, hake, pollack, seabass, anglerfishes and crustacean species. While the longline fishery targets hake with bycatch of other deep-water species. The fisheries are mainly carried out by French and Spanish vessels with the addition of some vessels from Ireland, UK and Belgium.

Hake caught in ICES Division 3.a and Subareas 4, 6 and 7, and megrim and anglerfishes in Subarea 7 are also included in the current analysis to account for the whole fishing mortality on that species.

2.1.2 Management measures

In the context of the new CFP, the EU has developed a multiannual management plan (MAP) for the management of the Western Waters demersal mixed fisheries, which has been in force since 2019 (EU 2019), replacing the former single-stock long term management plans with an unique framework defining objectives and constraints for both target and bycatch demersal species. Among the stocks with analytical assessment included in the Bay of Biscay mixed fisheries analysis, several are either shared between the EU and non-EU member states (which are not involved in the EU-MAP) or not included in the EU-MAP. In those cases, ICES gives advice based on the ICES MSY approach or precautionary approach (PA).

The landings obligation was introduced in 2016 (Commission Delegated Regulation (EU) 2015/2438). This regulation prohibits the discarding of certain species on a fishery-by-fishery approach. From 1 January 2019, catches of all quota species in the Bay of Biscay are subject to the EU landing obligation rule, except if an exemption is in place.

2.2 FLBEIA

2.2.1 Software

The analysis was conducted using the FLR framework (Kell *et al.*, 2007; www.flr-pro-ject.org; FLCore 2.6.15; FLAssess 2.6.3) and was run with R version 4.0 (R Development Core Team, 2021). All forecasts were projected using the FLBEIA package (version 1.15.5)(García *et al.*, 2017). FLBEIA is an FLR package that facilitates the bio-economic evaluation of management strategies in a multi-stock and multi-fleet framework. A total of 12 stocks were considered in the present analysis. 7 stocks are assessed as an ICES category 1 (with one *Nephrops* stock assessed based on UWTV survey) and the 5 remaining stocks are assessed as ICES category 3, 5 and 6.

The list of species considered and the software used in the single-species assessments and forecasts are summaries in Table 2.1.

Table 2.1. Summary of stocks incorporated in this mixed fisheries analysis for the Bay of Biscay, the assessment model and forecast used to produce the single species advice.

Stocks	Assessment	Forecast
WHITE ANGLERFISH 7, 8.a–b and 8.d	a4a	FLR-STF
HAKE 3.a, 4, 6, 7 and 8.a,b,d	SS3	SS3 (ad hoc R code)
SOLE 8.a-b	FLR-XSA	FLR STF
MEGRIM 7.b-k and 8.a-b,d	Bayesian statistical catch at age model	ad hoc R code
NORWAY LOBSTER FU 2324	UWTV survey	Ad-hoc (excel sheet)
HORSE MACKEREL in the Northeast Atlantic	SS3	FLR-STF
MACKEREL in the Northeast Atlantic and adjacent waters	SAM	FLR-STF
BLACK-BELLIED ANGLERFISH 7, 8.a-b,d	Survey trend (Category 3)	No
POLLACK 8 and 9.a	None (Category 5)	No
SMOOTH-HOUND in the Northeast Atlantic and adjacent waters	Survey trend (Category 3)	Ad-hoc (excel sheet)
BLUE WHITING in the Northeast Atlantic and adjacent waters	SAM	SAM
WHITING 8 and 9.a	None (Category 5)	No

2.2.2 Scenarios

The basis of the model is to estimate the potential future levels of effort of fleet corresponding to the fishing opportunities (TACs by stock and/or effort allocations by fleet) available to that fleet, based on fleet effort distribution and catchability by métier. This level of effort was used to estimate landings and catches by fleet and stock, using standard forecasting procedures.

The advice basis for stocks with analytical single species assessments was given in terms of the EU multiannual plan (MAP) for Western Waters when it is applicable, or alternatively, according to MSY approach (for the stocks shared with non-EU members for instance). For the stocks with no analytical assessments (Category 3, 5 and 6 stocks), the advice was based on the precautionary approach. A total of 17 scenarios were produced:

Table 2.2. Summary of scenarios produced for the mixed fisheries analysis of the Bay of Biscay.

	Scenario
max	"Maximum": For each fleet, fishing stops when all stocks have been caught up to the fleet's stock shares *. This option causes overfishing of the single-stock advice possibilities for most stocks.
min	"Minimum": For each fleet, fishing stops when the catch for any one of the stocks meets the fleet's stock share*. This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks.
ank	"Black-bellied anglerfish PA approach": All fleets set their effort corresponding to their black anglerfish quota share, regardless of other catches.
hke	"Hake MSY approach": All fleets set their effort corresponding to their hake quota share, regardless of other catches.
hom	"Horse mackerel MSY approach": All fleets set their effort corresponding to their horse mackerel quota share, regardless of other catches.
mac	"Mackerel MSY approach": All fleets set their effort corresponding to their mackerel quota share, regardless of other catches
meg	"Megrim MSY approach": All fleets set their effort corresponding to their megrim quota share, regardless of other catches
mon	"White anglerfish MSY approach": All fleets set their effort corresponding to their white anglerfish quota share, regardless of other catches.
nep	"Norway lobster MSY approach": All fleets set their effort corresponding to their Norway lobster quota share, regardless of other catches.
pol	"Pollack MSY approach": All fleets set their effort corresponding to their pollack quota share, regardless of other catches.
sdv	"Smooth-hound PA approach": All fleets set their effort corresponding to their smooth-hound quota share, regardless of other catches.
sol	"Sole MSY approach": All fleets set their effort corresponding to their sole quota share, regardless of other catches.
whb	"Blue whiting MSY approach": All fleets set their effort corresponding to their blue whiting quota share, regardless of other catches.
whg	"Whiting PA approach": All fleets set their effort corresponding to their whiting quota share, regardless of other catches.
sq_E	"Status quo effort": The effort is set equal to the average effort in the most recent three years recorded for which landings and discard data are available (2018-2020).

* Throughout this analysis, the term "fleet's stock share" or "stock share" is used to describe the share of the fishing opportunities for each particular fleet, which has been calculated based on the single-stock advice for 2022 and the historical proportion of the stock landings taken by the fleet (2018–2020).

2.3   Stock input data and recent trends

2.3.1   Stocks
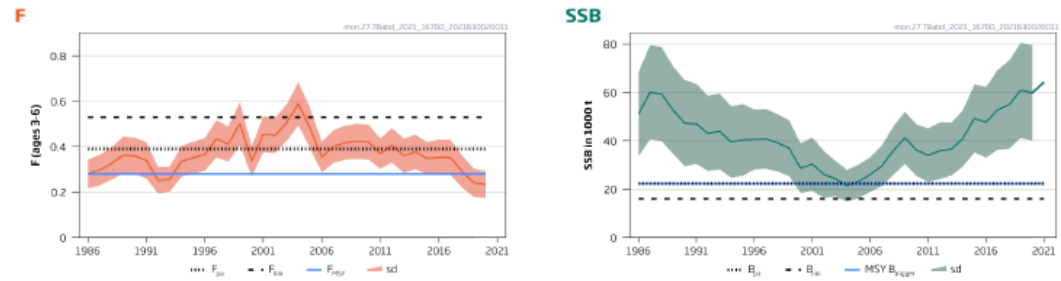
2.3.1.1   Data
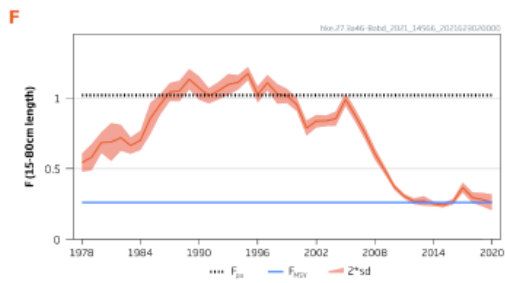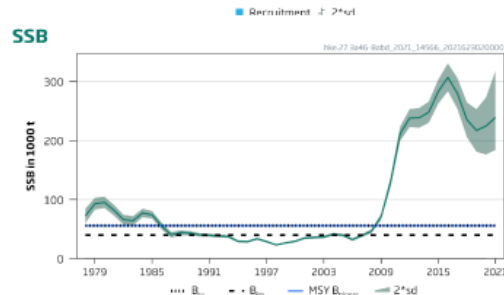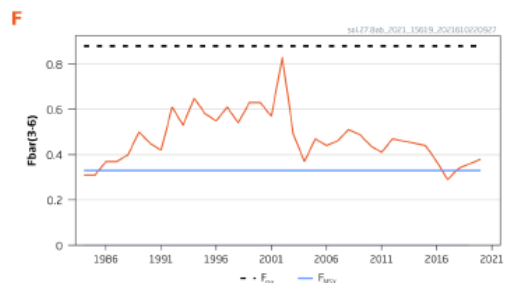
The single species assessment data for the different stocks were provided by the ICES Working Group for the Bay of Biscay and the Iberian Coast Ecoregion (WGBIE) (ICES 2021a), ICES Working Group on Elasmobranch Fishes (WGEF) (ICES, 2021b) and ICES Working Group on Widely Distributed Stocks (WGWIDE) (ICES, 2021c). A number of the stocks considered within this mixed fisheries analysis are being assessed using stochastic assessments. Northern hake stock and the stock of horse mackerel in the Northeast Atlantic, SAM for the stock of mackerel in the Northeast Atlantic and adjacent waters, a Bayesian statistical catch at age model for the stock of megrim in the west and southwest of Ireland and the Bay of Biscay and a4a for the stock of white anglerfish in the southern Celtic Seas and the Bay of Biscay. Some of those assessments are length based and/or seasonal and for some of these stocks the advice is based on stochastic projections. All this cannot currently be fully replicated in the deterministic FLBEIA software. However, the projections carried out with FLBEIA are routinely compared to those carried out in the single-species assessment working group to assess the potential impact of using different approaches and results are reasonably similar (see Section 2.5.1.1 below); as such, WGMIXFISH does not consider that the difference impacts significantly the mixed fisheries advice and the projections.

2.3.1.2   Trends and advice
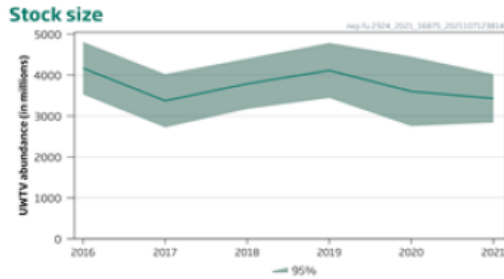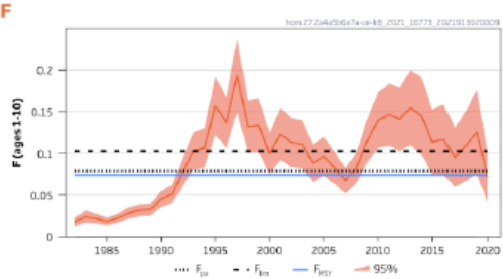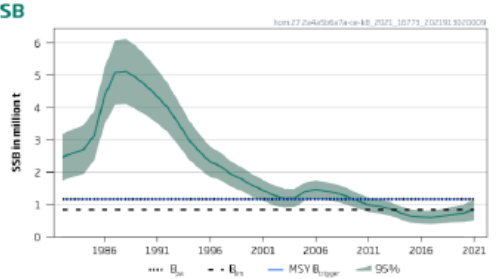
The advice for these stocks was drafted by the WGBIE (ICES 2021a), WGEF (ICES 2021b) and WGWIDE (ICES 2021c) under considerations by ACOM. In order to give a global overview of all Bay of Biscay demersal stocks of interest to this analysis, this information is summarised in the Table 2.2 based on the single species advice.

Table 2.2. Summary of stock status and ICES advice for the stocks included in the mixed fishery analysis

Species	Area	Stock status	Advice 2021
mon.27.78abd (White anglerfish)	Subarea 7 and divisions 8.a–b and 8.d	 **Summary:** Fishing pressure on the stock is below F_{MSY}, and stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 34 275 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock. Management of catches of the two anglerfish species, *Lophius budegassa* and *L. piscatorius*, under a combined species total allowable catch (TAC), prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species.

Species	Area	Stock status			Advice 2021
hke.27.3a46-8abd (Hake)	subareas 4, 6, and 7, and in divisions 3.a, 8.a–b, and 8.d	 **Summary:** Fishing pressure on the stock is below F_{MSY}, and stock size is above MSY $B_{trigger}$.			ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 75 052 tonnes. ICES notes the existence of a precautionary management plan developed and adopted by one of the relevant management authorities for this stock.
sol.27.8ab (Sole)	divisions 8.a–b (northern and central Bay of Biscay)	 **Summary:** Fishing pressure on the stock above F_{MSY} but below F_{pa}, and stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.			ICES advises that when the EU multiannual plan (MAP) for the Western waters and adjacent waters is applied, catches in 2022 that correspond to the F ranges in the plan are between 1265 tonnes and 3097 tonnes.

Species	Area	Stock status	Advice 2021
meg.27.7b-k8abd (Megrim)	divisions 7.b–k, 8.a–b, and 8.d (west and southwest of Ireland, Bay of Biscay)	 **Summary:** Fishing pressure on the stock is below F_{MSY}, and stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 22 964 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock. Management of catches of the two megrim species, *L. whiffiagonis* and *L. boscii*, under a combined species TAC prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species.

Species	Area	Stock status	Advice 2021
nep.fu.2324 (Norway lobster)	divisions 8.a and 8.b, functional units 23–24 (northern and central Bay of Biscay)	**Summary:** Fishing pressure on the stock is below F_{MSY}, and no reference points have been defined for the stock size of this stock.	ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 6075 tonnes.
hom.27.2a4a5b6a7a-ce-k8 (Horse mackerel)	Subarea 8 and divisions 2.a, 4.a, 5.b, 6.a, 7.a–c, and 7.e–k (the Northeast Atlantic)	**Summary:** Fishing pressure on the stock is below F_{MSY}, and stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 71138 tonnes.

Species	Area	Stock status		Advice 2021
mac.27.nea (Mackerel)	subareas 1–8 and 14, and in Division 9.a (the Northeast Atlantic and adjacent waters)			ICES advises that when the MSY approach is applied, catches in 2022should be no more than 794920 tonnes.
		Summary: Fishing pressure on the stock is below F_{MSY}, F_{pa} and F_{lim} and stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}.		
ank.27.78abd (Black-bellied anglerfish)	Subarea 7 and divisions 8.a–b and 8.d (Celtic Seas, Bay of Biscay)			ICES advises that when the precautionary approach is applied, catches in 2022 should be no more than 18 661 tonnes.
		Summary: Fishing pressure on the stock is below F_{MSY}, and no reference points have been defined for stock size.		Management of catches of the two anglerfish species, *Lophius budegassa* and *L. piscatorius*, under a combined species total allowable catch (TAC), prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species.
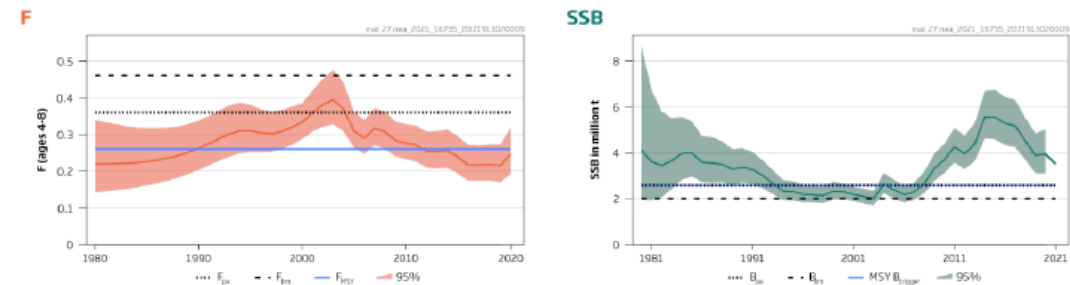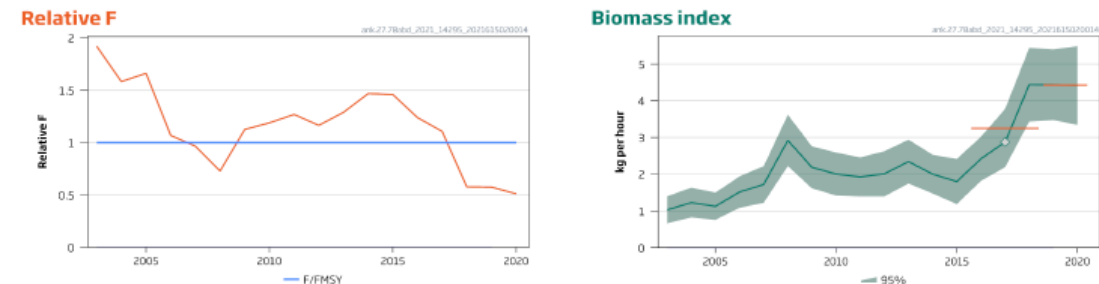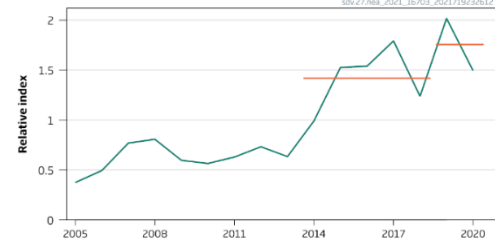
Species	Area	Stock status	Advice 2021
pol.27.89a (Pollack)	Subarea 8 and Division 9.a (Bay of Biscay and Atlantic Iberian waters)	**Summary:** Not possible to assess the stock and exploitation status relative to MSY and precautionary approach (PA) reference point because information needed to define reference points is not available.	ICES advises that when the precautionary approach is applied, commercial catches in each of the years 2022 and 2023 should be no more than 905 tonnes. All commercial catches are assumed to be landed. ICES cannot quantify the corresponding total catches because the recreational catches cannot be quantified.
sdv.27.nea (Smooth hound)	subareas 1–10, 12, and 14 (the Northeast Atlantic and adjacent waters)	**Summary:** Not possible to assess the stock and exploitation status relative to MSY and PA reference points because reference points are undefined.	ICES advises that when the precautionary approach is applied, landings should be no more than 4441 tonnes in each of the years 2022 and 2022. ICES cannot quantify the corresponding catches.

Species	Area	Stock status	Advice 2021
whb.27.1-91214 (Blue whiting)	Subareas 1–9, 12, and 14 (Northeast Atlantic and adjacent waters)	 **Summary:** Fishing pressure on the stock is above F_{MSY} and F_{pa} but below F_{lim}; spawning-stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}.	ICES advises that when the long-term management strategy agreed by the European Union, the Faroe Islands, Iceland, and Norway is applied, catches in 2022 should be no more than 752 736 tonnes.
whg.27.89a (Whiting)	Subarea 8 and Division 9.a (Bay of Biscay	**Summary:** Fishing pressure on the stock is below F_{MSY}, and no reference points of stock size has been defined for this stock.	ICICES advises that when the precautionary approach is applied, catches should be no more than 2276 tonnes in each of the years 2022 and 2023.

2.4   Fleets and métiers

2.4.1   Catch and effort data

The WGMIXFISH data call requests landings and effort data consistent with the definition of DCF métiers and with data submitted to InterCatch (though with additional vessel length disaggregation), disaggregated into vessel length categories.

Discard data were not requested by vessel length categories, as national observer sampling programmes do not distinguish between vessel lengths, so discard ratios for the various métiers aggregated across all vessel lengths could be extracted from InterCatch and applied to the landings of the corresponding métiers in the vessel length specific data.

Age distribution is assumed equal to the one used in the assessment for all métiers. However, the information by métier and area is now available in InterCatch and could integrated in the MIXFISH data in future assessments. The relative size of catches of the stocks incorporated in the mixed fisheries projections is shown in Figure 2.1.

The final dataset extracted from InterCatch includes discards estimates (either imported or raised) for all stocks and métiers. These InterCatch estimates have been used to estimate a discard ratio by métier, which allows allocating discards for all WGMIXFISH fleets and métiers with matching names, such that:

$$d* = \frac{Dl}{L}$$

Where d* is the discard value for the métier used by FLBEIA, l is the weight of landings for the métier used by FLBEIA and L and D are the weight of landings and discards entered for the (vessel length aggregated) métier in InterCatch.

This year France resubmitted data for the entire time series of the WGMIXFISH data cal. This revision effect the métier labelling and resulted in a huge increase in the proportion of effort and landings being allocated to the FR_MIS fleet (Figure 2.2), and a corresponding reduction in other métiers relative to the patterns observed last year. Although this does not affect the outcomes of the alternative fishing scenarios produced this year, there is a need to work intersessional with French data submitters to ensure a complete data set with consistent and realistic metier labelling is available to WGMIXFISH for next year's meeting.

The working group concluded that it was not possible to include rays in this mixed fisheries analysis due to a suspected species mislabelling by a number of member states. For example, France reported exclusively catches of raja undulate ray (rju.27.8ab) in the data-call while catches of other species appear in the official data, these are thornback ray (rjc.27.8) and cuckoo ray (rjn.27.678abd). In the case of Spain, all the ray catches were reported as of thornback and cuckoo rays, without any catches of undulate rays.

2.4.2   Definitions of fleets and métiers

The procedure to define the fleets and métier in the model are the following:

Fleets were defined by aggregating landing and effort across country, gear group and vessel length (where applicable).

Fleet landing small amount of any of the stocks included in the analysis was binned into another ("OT") fleet together with fleets from country fishing outside the Bay of Biscay to reduce the dimensions of the model.

Effort and landing files were matched to ensure consistency, métiers with effort and no landing were aggregated to the "Other fleet".

Within a fleet, métiers were defined as a combination of gear, target species (e.g. demersal fish, DEF, or crustaceans, CRU) and country.

The final data used contained 22 fleets, covering landing and effort for the years 2018 to 2020. These fleets engage in one or several different métiers, among a total of 30 métiers (Table 2.5). Several fleets still represent a small amount of catches and could be combined in order to reduce the total number of fleets. The distribution of landings by stock and métier is presented in Figure 2.1 and Figure 2.2 respectively.

2.4.3 Trends

Analyses of trends by fleet were carried out on 2018–2020 data. A number of exploratory graphs were produced to aid quality checking of the data once compiled into the final fleets object for catches, effort and catchability. Catchability plots by stock, fleet and métier are presented in figures 2.3 to 2.25.

2.5 Mixed fisheries forecasts

2.5.1 Description of scenarios

2.5.1.1 Baseline runs

The objectives of the single-species stock baseline runs were to:

- reproduce as closely as possible the single-species advice produced by ACOM, and
- act as the reference scenario for subsequent mixed fisheries analyses.

The various single-stock forecasts presented by WGBIE are performed using different software and setups (see 2.2.1 above). However, for the purposes of the mixed fisheries analyses, it is necessary to gather all forecasts into a single unified framework, which builds on the "FLBEIA" library (García *et al.*, 2017). The same forecast settings as in WGBIE are used for each stock regarding weight-at-age, selectivity and recruitment, as well as assumptions on the F in the intermediate year and basis for advice (MSY approach).

2.5.1.2 Mixed fisheries runs

The mixed fishery analysis used a status quo effort assumption for the intermediate year (2021), with the FLBEIA scenarios used for the TAC year (2022). The status quo effort assumption for the intermediate year is considered a plausible assumption because is in line with the standard single-stock short-term forecasting approach.

The projections were run assuming a full and perfect implementation of a discard ban (i.e. all quota species caught must be landed, with no exemptions, de minimis or inter-species flexibilities).

In summary, the FLBEIA runs followed the scheme below:

Single-stock assessment 2021
MSY approach
sq_E

Status quo
fishing effort 2021
(average 2018-2020)

Catch in 2021 & SSB at start of 2022

FLBEIA 2021

Single-stock ICES
advice for 2022
applied to FLBEIA
(sq_E)

max *min* *ank* *mon* *hke* *(…)* *whg* *sq_E*

Potential Over / Under quota utilisation (Difference between single species
advised catch and expected catch)
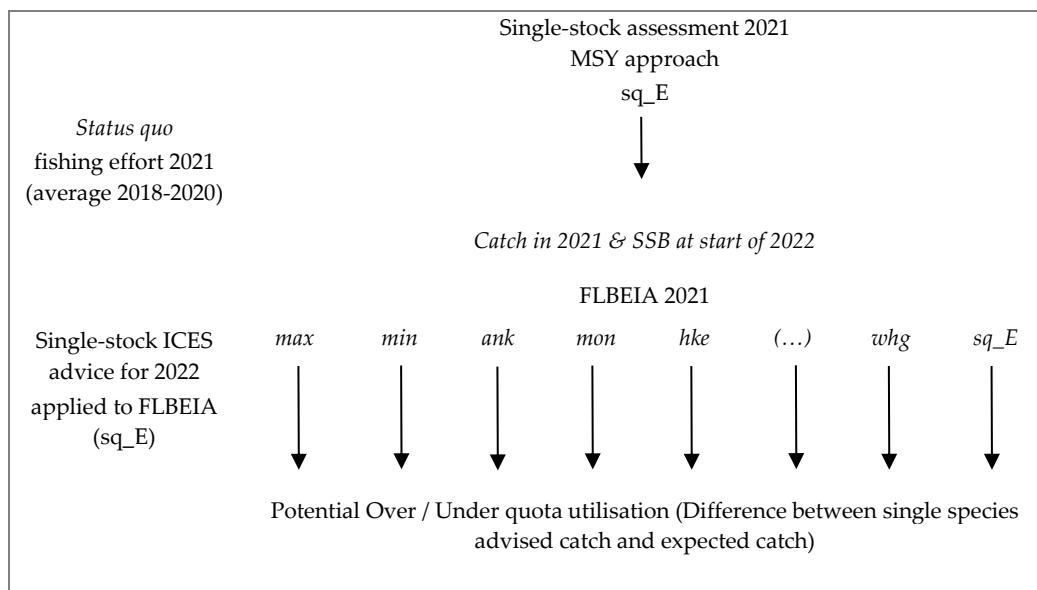
2.5.2 Results of FLBEIA runs

2.5.2.1 Baseline runs

As for some stocks, the population dynamics model used for the assessment differs from the one used in FLBEIA, some discrepancies were found between the FLBEIA baseline runs and the single-stock forecasts (tables 2.6, 2.7 and 2.8). The replicated forecast for the majority of stocks were almost identical to the single-stock advice (differences lower than 5%). Discrepancies were larger for hake, mackerel and blue whiting. Discrepancies in fishing mortality (F) were expected for hake because the length based seasonal models used in the stock assessments were approximated with annual age-based models in the mixed fisheries analysis. However, the reasons of discrepancies for mackerel and blue whiting are unknown and need to be investigated further.

In general, the differences observed this year were small (≤ 12%) for all stocks (except sea bass), and the WGMIXFISH deterministic forecast was considered close enough to the single-stock advice to be used as a basis for the mixed-fisheries projections.

Regarding the sea bass, very high discrepancies in F in 2021 and 2022 were observed (28 and 39% higher than those in the single stock forecast). SSB were however in line with the single stock assessment results. The discrepancies observed are probably related with the way the recreational catches are introduced in the model when carrying out the short-term forecast for providing the advice, but it has not been properly clarified to the WGMIXFISH members on time for providing mixed fisheries advice. As a consequence, the WG members decided to remove this stock from the analysis.

2.5.2.2 Mixed fisheries analyses

The full overview of the FLBEIA projections to 2023 is presented in Table 2.9, figures 2.26-2.28. The results for 2023 can be compared to each other as in a single-species option table. For ease of comparison, the landings relative to the single-stock advice are also presented (Table 2.9 and Figure 2.27).

Mixed-fisheries advice considers the implications of mixed fisheries operating under single-stock catch limits, taking into account the fishing pattern and catchability of the various fleets in recent years (2018-2020). The scenarios, therefore, do not assume any amount of quota balancing

through adaptation of fishing behaviour. Scenarios that result in under- or overutilization are useful in identifying the main mismatches between the fishing opportunities of the various stocks. They indicate the direction in which fleets may have to adapt to fully utilize their catch opportunities.

The "min" scenario is based on the assumption that the fishery stops for a fleet when any of the stock quotas is exhausted, representing a full implementation of the landing obligation. For 2022, the results of "pol" scenario are similar to the "min" scenario, indicating that the pollack is the limiting stock for the majority of fleets. The pollack and horse mackerel are restrictive for 18 fleets out of 22, corresponding to an undershoot of the advised catch for the other stocks considered in the mixed-fisheries analysis. They lead the largest loss of fishing opportunities, indicating that they are the most limiting stocks. As most limiting stock in the Bay of Biscay mixed-fisheries model, the pollack is estimated to constrain 15 out of the 22 fleets segments. This is due to the fact that catch advice for this stock has suffered a sharp reduction in 2022 (39%).

The "max" scenario is included to highlight the upper bound of potential fleet effort and stock catches, because it assumes all fleets continue fishing until all their stock shares are exhausted, irrespective of any economic viability or the violation of the landing obligation. For 2022, the results in none of the scenarios are similar to the "max" scenario, indicating that the least limiting stock varies from fleet to fleet. Black-bellied anglerfish, smooth-hound, and Norway lobster are the least limiting stocks, corresponding to an overshoot of the advised catch for the other considered stocks.

The status quo "sq_E sets the effort of each fleet in 2021 and in 2022 equal to the average of the effort in the most recently recorded three years for which data are available (2018-2020). This scenario investigates the mixed-fisheries outcomes if the situation remains the same in terms of total effort and effort allocation among métiers. This situation presents a potential 2022 TAC overshoot for blue whiting, hake, horse mackerel, pollack and sole.

Horse mackerel and, mackerel and blue whiting are included in these analyses as they are potential choke species for some fleets. However, catches taken by these fleets represent very low proportions of the overall catches from these stocks, so the impact of these fleets on the dynamics of the stocks of mackerel and horse mackerel is negligible.

Table 2.4. Bay of Biscay: Summary of the 2022 landings and target Fs, resulting from the Advice Approaches considered by ICES.

Stock	Total catch advice 2022	F 2022	SSB 2023	Rational
White anglerfish 7, 8.a–b and 8.d	34 275	0.28	82 203	MAP
Hake 3.a, 4, 6, 7 and 8.a,b,d	75 052	0.26	207 398	MSY
Sole 8.a-b	2233	0.28	9372	MAP
Megrim .7b-k and 8.a-b,d	22 964	0.191	138 512	MAP
Horse mackerel in the Northeast Atlantic	71 138	0.058	942 827	MSY
Mackerel in the Northeast Atlantic and adjacent waters	794 920	0.26	3 269 273	MSY
Blue whiting in the Northeast Atlantic and adjacent waters	752 736	0.32	4 052 163	MSY

Table 2.5. Métier categories used in the Bay of Biscay mixed fisheries analysis.

Acronym	Definition
GNS_DEF	Set gillnet targeting demersal fish
GNS_DEF_>=100_0_0	Set gillnet targeting demersal fish with mesh sizes larger than 100 mm
GNS_DEF_100-119_0_0_all	Set gillnet targeting demersal fish with mesh sizes within the range 100-119 mm
GNS_DEF_60-79_0_0	Set gillnet targeting demersal fish with mesh sizes within the range of 60–79 mm
GNS_DEF_all_0_0_all	Set gillnet targeting demersal fish
GTR_DEF_100-119_0_0_all	Trammel net targeting demersal fish with mesh sizes larger than 100 mm
GTR_DEF_40-59_0_0	Trammel net targeting demersal fish with mesh sizes within the range of 40-59 mm
GTR_DEF_all_0_0_all	Trammel net targeting demersal fish
LHM_DEF	Handline targeting demersal fish
LLS_DEF	Set longline targeting demersal fish
FR_MIS	Other gear types
OTB_CRU	Norway lobster bottom otter trawl
OTB_CRU_>=70_0_0	Norway lobster bottom otter trawl (at least 70 mm)
OTB_CRU_All_0_0_All	Norway lobster bottom otter trawl
OTB_DEF	Bottom otter trawl directed to demersal fish
OTB_DEF_<16_0_0_all	Bottom otter trawl directed to demersal fish with mesh sizes < 16 mm
OTB_DEF_>=70_0_0	Bottom otter trawl directed to demersal fish (at least 70 mm)
OTB_DEF_16-31_0_0	Bottom otter trawl directed to demersal fish with mesh sizes 16-31 mm
OTB_DEF_32-69_0_0	Bottom otter trawl directed to demersal fish with mesh sizes 32-69 mm
OTB_MCF_>=70_0_0	Bottom otter trawl directed to mixed cephalopods and demersal fish (mesh sizes of at least 70 mm)
OTB_MPD	Bottom otter trawl directed to mixed pelagic and demersal fish
OTM_DEF	Medium water otter trawl directed to demersal fish
OTM_DEF_32-69_0_0_all	Medium water otter trawl directed to demersal fish (mesh sizes between 32 and 69 mm)
OTM_DEF_70-99_0_0_all	Medium water otter trawl directed to demersal fish (mesh sizes between 70 and 99 mm)
OTT_DEF	Twin otter trawl directed to demersal fish
SP_GTR	Spanish trammel net
SP_LLS	Spanish longliners

Acronym	Definition
SP_PTB	Spanish bottom pair trawl directed to demersal fish (at least 70 mm)
SSC_DEF_70-99_0_0_all	Fly shooting seine with mesh sizes within the range 70–99 mm
SSC_DEF_All_0_0_All	Fly shooting seine

Table 2.6. Bay of Biscay: Baseline run outputs from the FLBEIA package.

	ANK	HKE	HOM	MAC	MEG	MON	NEP	POL	SDV	SOL	WHB	WHG
2021_Fbar	NA	0.28	0.07	0.35	0.19	0.25	NA	NA	NA	0.38	0.51	NA
2021_Fmult	NA	1	1	1	1	1	NA	NA	NA	1	1	NA
2021_Landings	9472	79660	81375	808809	17589	26586	2206	1482	3545	2806	1076524	1378
2021_SSB	0	207796	734333	4227766	99316	59807	0	0	0	10355	4151143	0
2022_Fbar	NA	0.26	0.058	0.26	0.191	0.28	NA	NA	NA	0.28	0.32	NA
2022_Fmult	NA	1	1	1	1	1	NA	NA	NA	1	1	NA
2022_Landings	17137	68302	71138	794920	20322	32489	6075	905	4441	2233	752736	1693
2022_SSB	0	218158	880266	3851518	135292	71211	0	0	0	9078	3434664	0
SSB_2023	0	212137	909063	3854448	136832	81748	0	0	0	9455	3708814	0

Table 2.7. Bay of Biscay: Comparison between baseline run and ICES advice. Figures for 2020 compare results from the baseline run – that use the same assumptions for F in the intermediate year as the forecasts leading to ICES advice–to the ICES intermediate year results.

	ANK	HKE	HOM	MAC	MEG	MON	NEP	POL	SDV	SOL	WHB	WHG
2021_Catch Baseline	10312	90778	116792	808809	20136	28615	2206	1540	3545	2807	1076524	1864
2021_Catch ICES	NA	87708	81375	1199103	20682	28882	NA	NA	NA	2955	1242727	NA
2021_% diff	NA	1.04	1.44	0.67	0.97	0.99	NA	NA	NA	0.95	0.87	NA
2022_Catch Baseline	18661	75052	71138	794920	22964	34275	6075	905	4441	2233	752736	2276
2021_Catch ICES	18661	75052	71138	794920	22964	34275	6075	905	4441	2233	752736	2276
2022_% diff	1	1	1	1	1	1	1	1	1	1	1	1

Table 2.8. Bay of Biscay: FLBEIA baseline run outputs for SSB and F relative to ICES advice.

Stocks	SSB_2021	SSB_2022	SSB_2023	F_2020	F_2021	F_2022
HKE	0.95	1.01	1.04	1.05	0.95	0.89
HOM	1	1	1	1	0.99	1
MAC	1.08	1.07	1.09	1.05	1.06	1.04
MEG	0.99	0.99	0.99	0.99	0.97	0.98
MON	1.01	1.01	1.02	1.01	0.96	0.95
SOL	1	1	0.99	1	1	1.02
WHB	0.99	0.96	0.88	0.98	0.99	1

Table 2.9. Results of running FLBEIA scenarios on the TAC year (2021). Comparison of the single-stock ICES advice and potential landings in the various FLBEIA scenarios.

Stock	Single stock catch advice 2022	max	min	ANK	HKE	HOM	MAC	MEG	MON	NEP	POL	SDV	SOL	WHB	WHG	sq_E
ANK	18661	1.04	0.81	1	0.86	0.85	0.87	0.88	0.89	0.95	0.81	0.91	0.84	0.86	0.89	0.55
HKE	75052	1.39	0.9	1.29	1	0.96	1.04	1.06	1.06	1.22	0.91	1.1	0.98	0.99	1.09	1.15
HOM	71138	1.02	1	1.01	1	1	1	1	1	1.02	1	1.01	1	1	1.01	1.66
MAC	794920	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.98
MEG	22964	1.19	0.91	1.13	0.97	0.95	0.98	1	1	1.09	0.91	1.02	0.95	0.97	0.99	0.96
MON	34275	1.1	0.95	1.07	0.98	0.98	0.99	1	1	1.05	0.95	1.01	0.97	0.99	1.01	0.9
NEP	6075	1	0.21	0.65	0.31	0.23	0.37	0.39	0.39	1	0.21	0.46	0.29	0.28	0.45	0.36
POL	905	2.8	1	2.6	1.57	1.54	1.7	1.73	1.79	1.97	1	2.1	1.38	1.68	2.1	1.7
SDV	4441	1.71	0.46	1.41	0.72	0.67	0.8	0.85	0.87	1.33	0.47	1	0.65	0.75	0.98	0.8
SOL	2233	2.4	0.72	2.2	1.21	1.14	1.23	1.27	1.37	1.64	0.72	1.55	1	1.21	1.5	1.23
WHB	752736	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1.3
WHG	2276	1.56	0.45	1.24	0.76	0.62	0.83	0.87	0.88	1.25	0.46	1.04	0.67	0.79	1	0.82
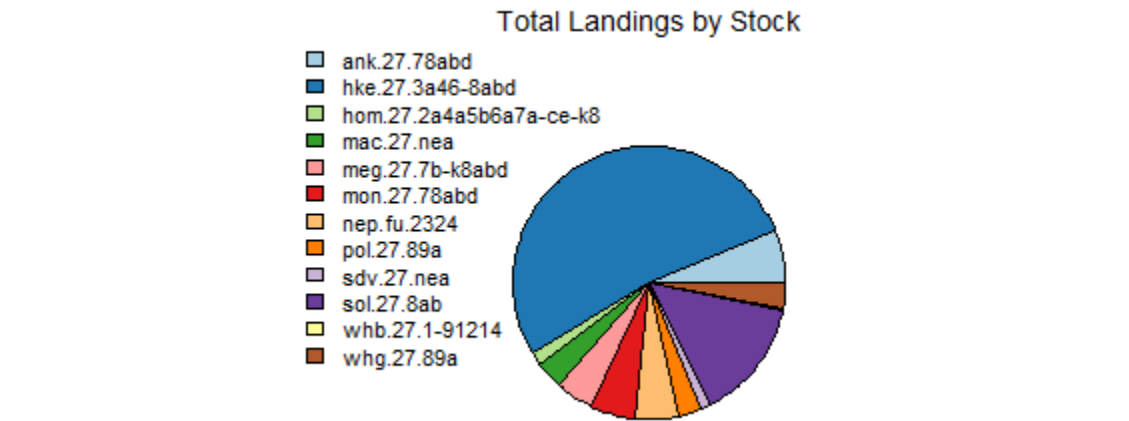
Figure 2.1. Bay of Biscay: Distribution of landings of the stocks included in the mixed fisheries projections.
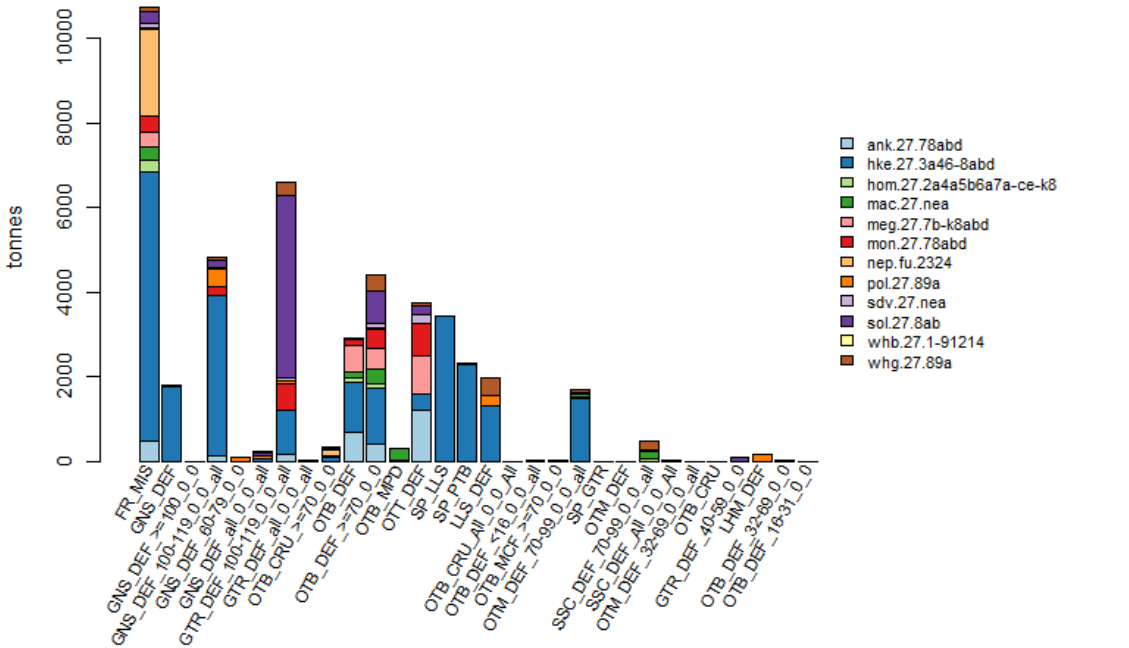
Figure 2.2. Bay of Biscay: Landings distribution of species by métier
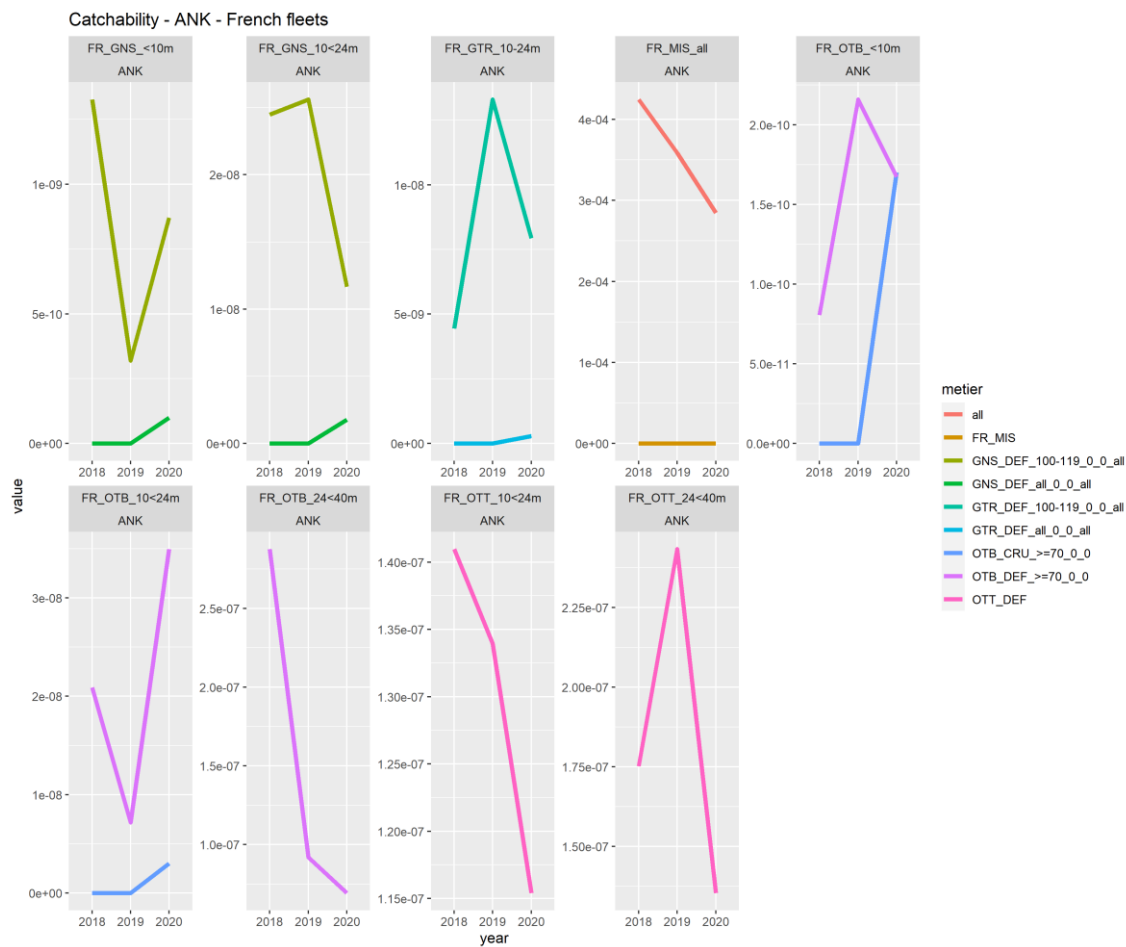
Figure 2.3. Bay of Biscay: trends of French catchability for black-bellied anglerfish (ank) by fleet and métier.
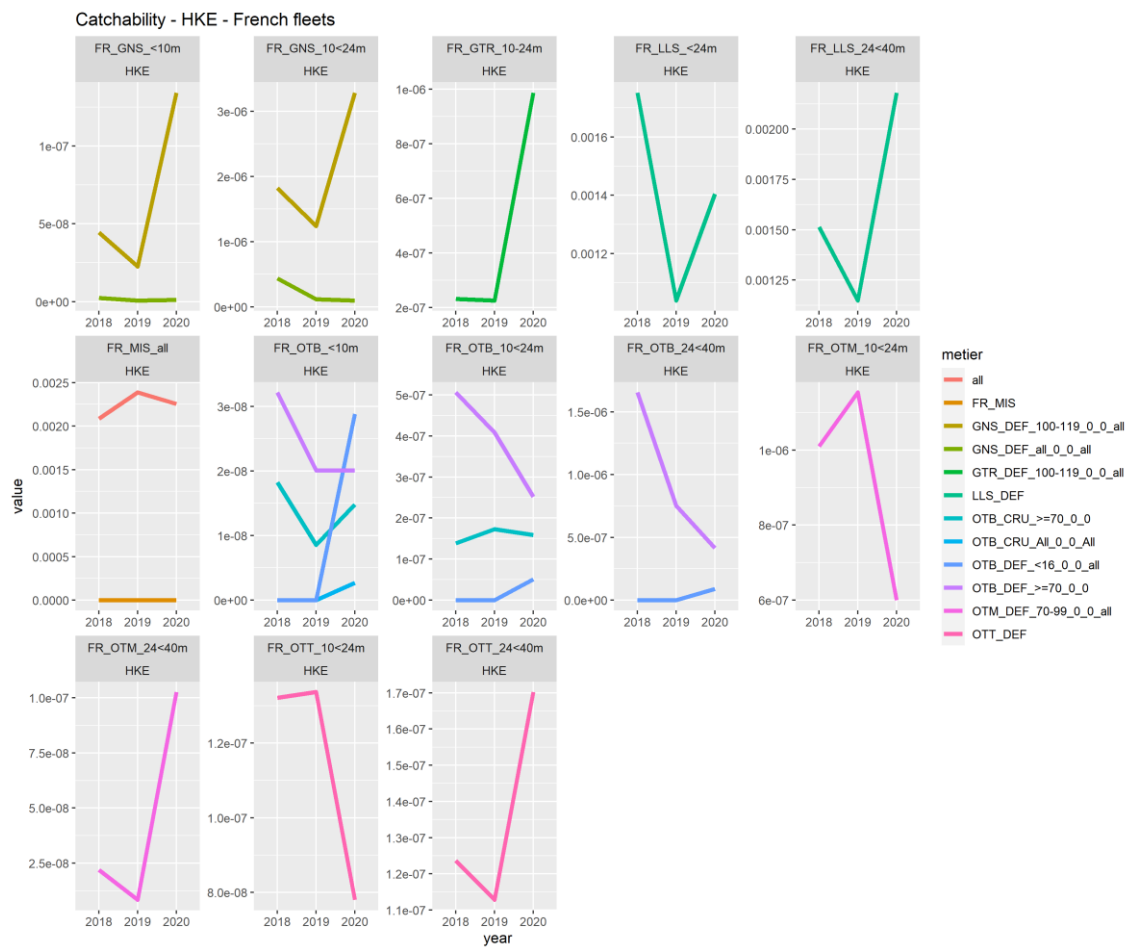
Figure 2.4. Bay of Biscay: trends of French catchability for hake (hke) by fleet and métier.
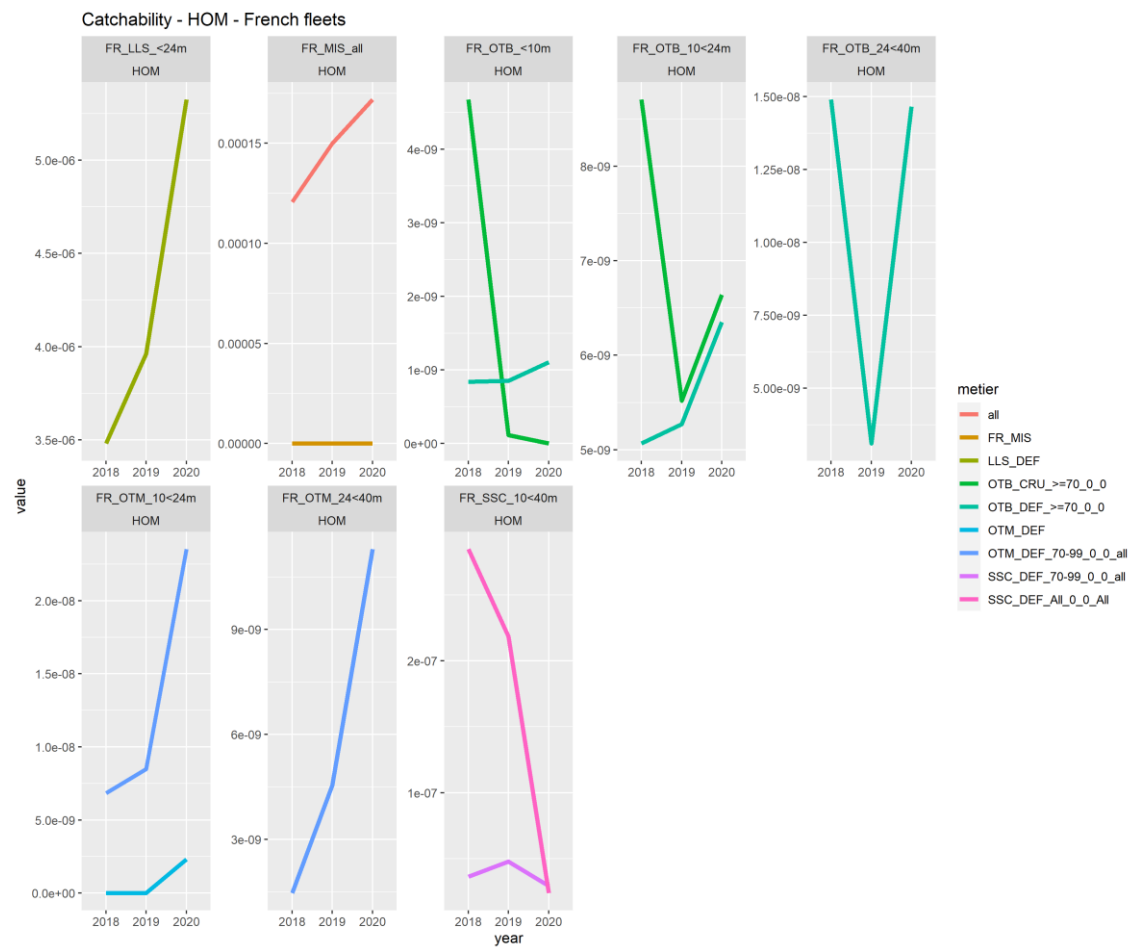
Figure 2.5. Bay of Biscay: trends of French catchability for horse mackerel (hom) by fleet and métier.
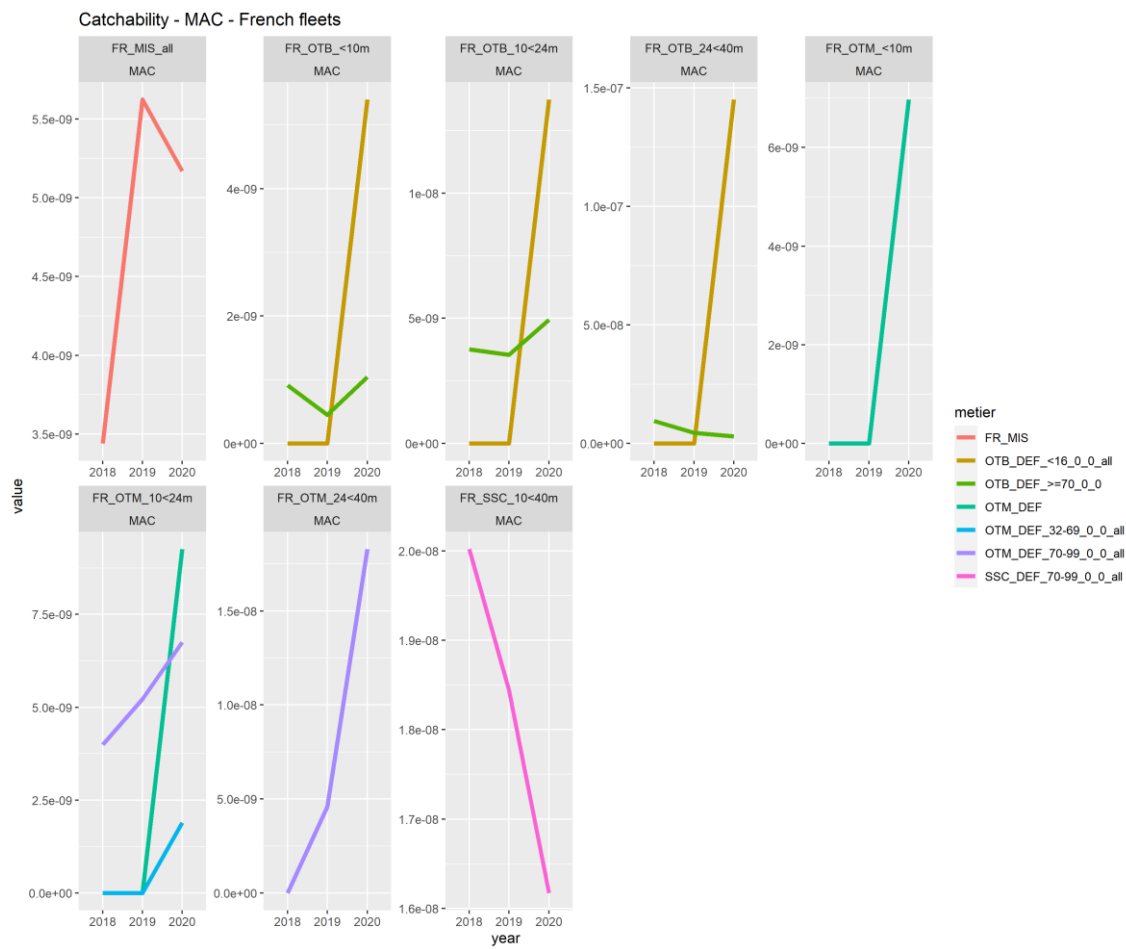
Figure 2.6. Bay of Biscay: trends of French catchability for mackerel (mac) by fleet and métier.
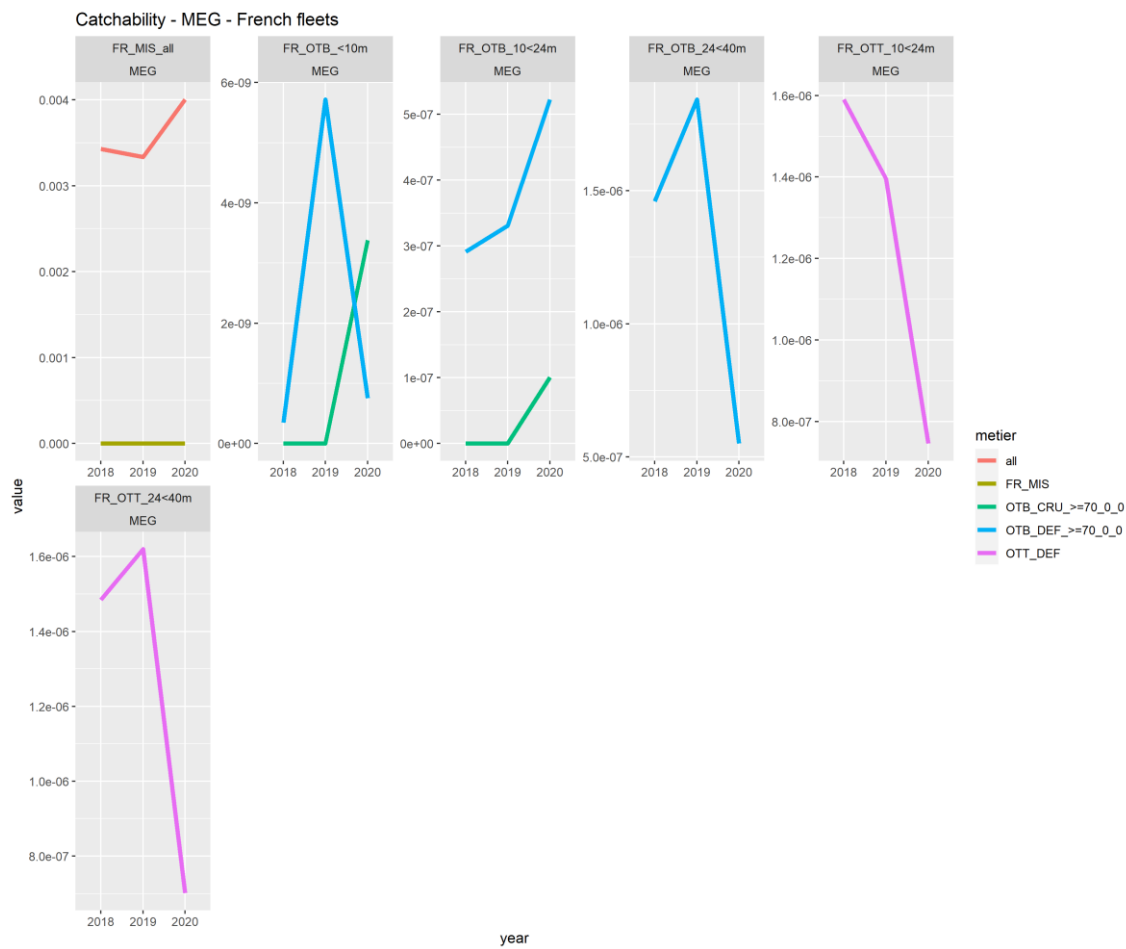
Figure 2.7. Bay of Biscay: trends of French catchability for megrim (meg) by fleet and métier.
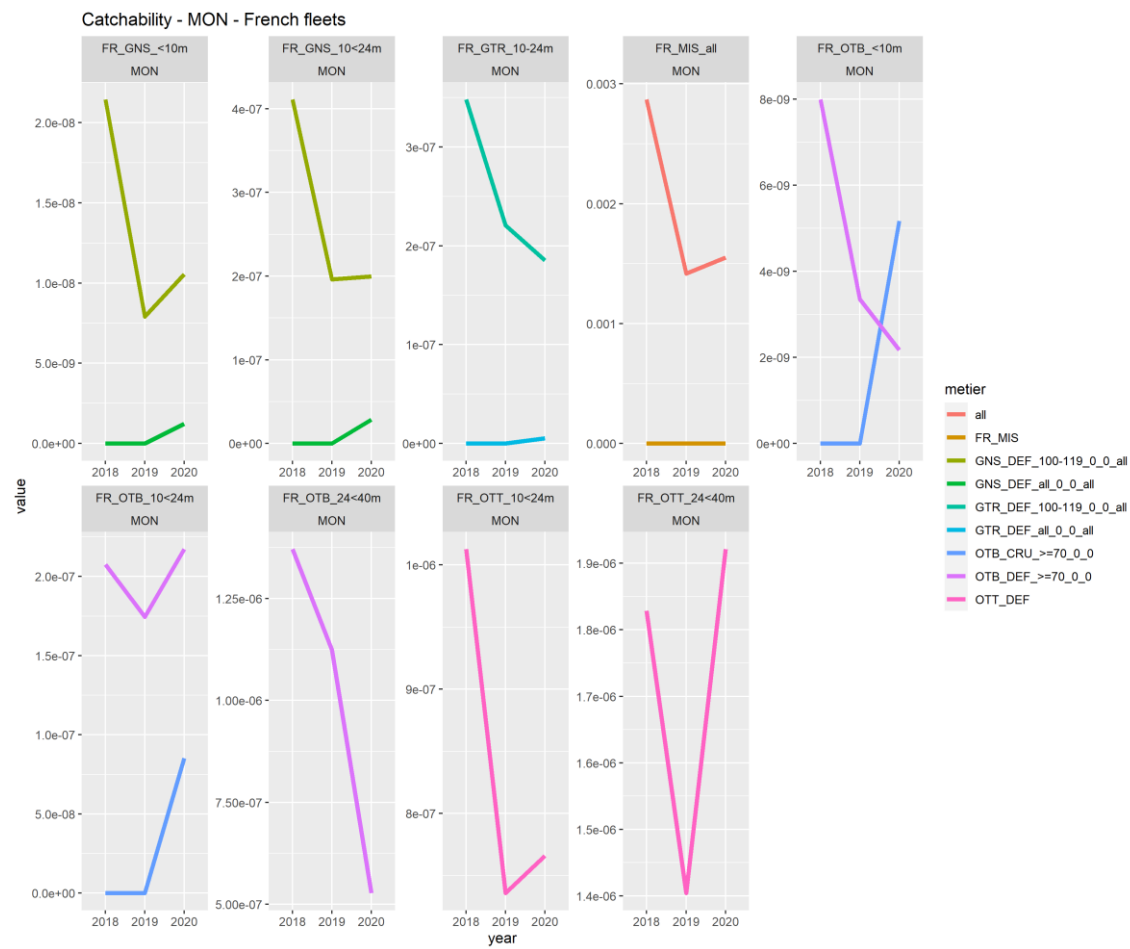
Figure 2.8. Bay of Biscay: trends of French catchability for monkfish (mon) by fleet and métier.
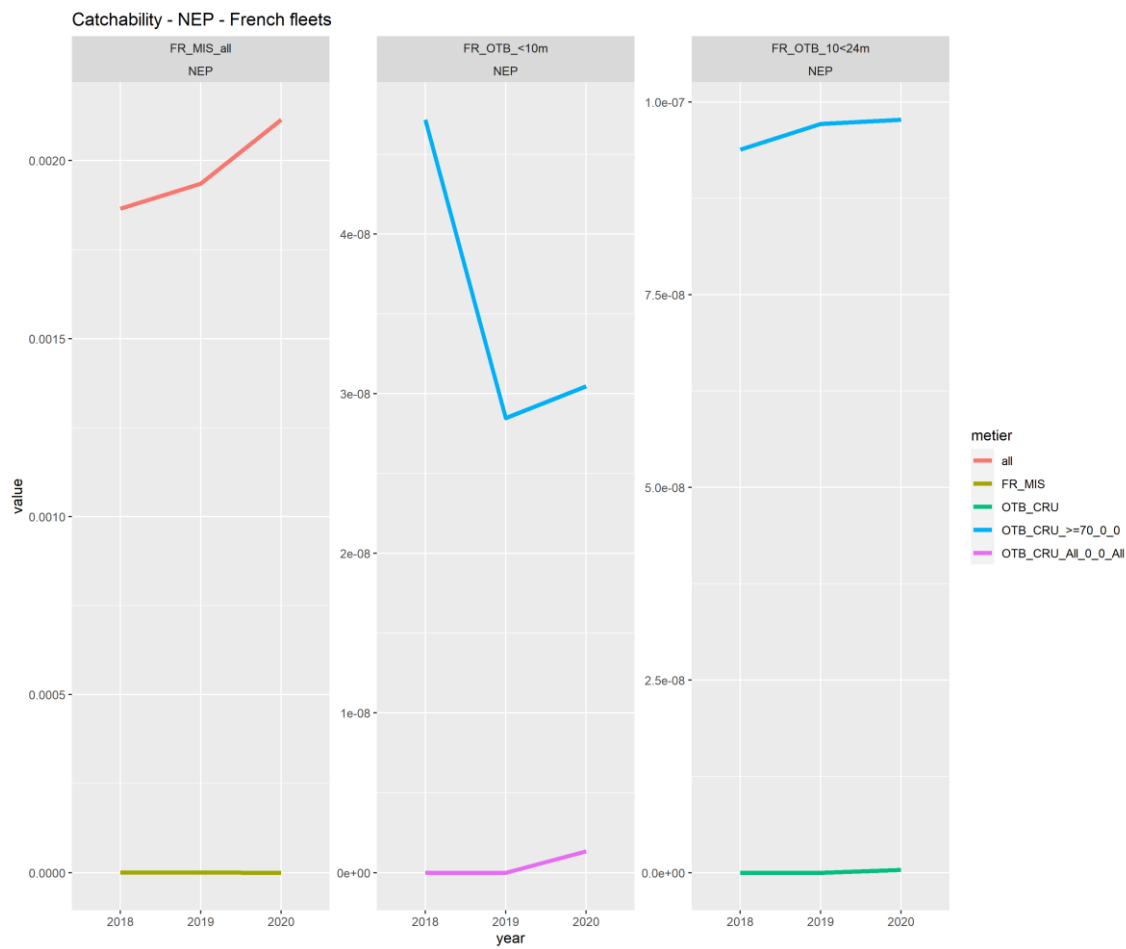
Figure 2.9. Bay of Biscay: trends of French catchability for Norway lobster (nep) by fleet and métier.
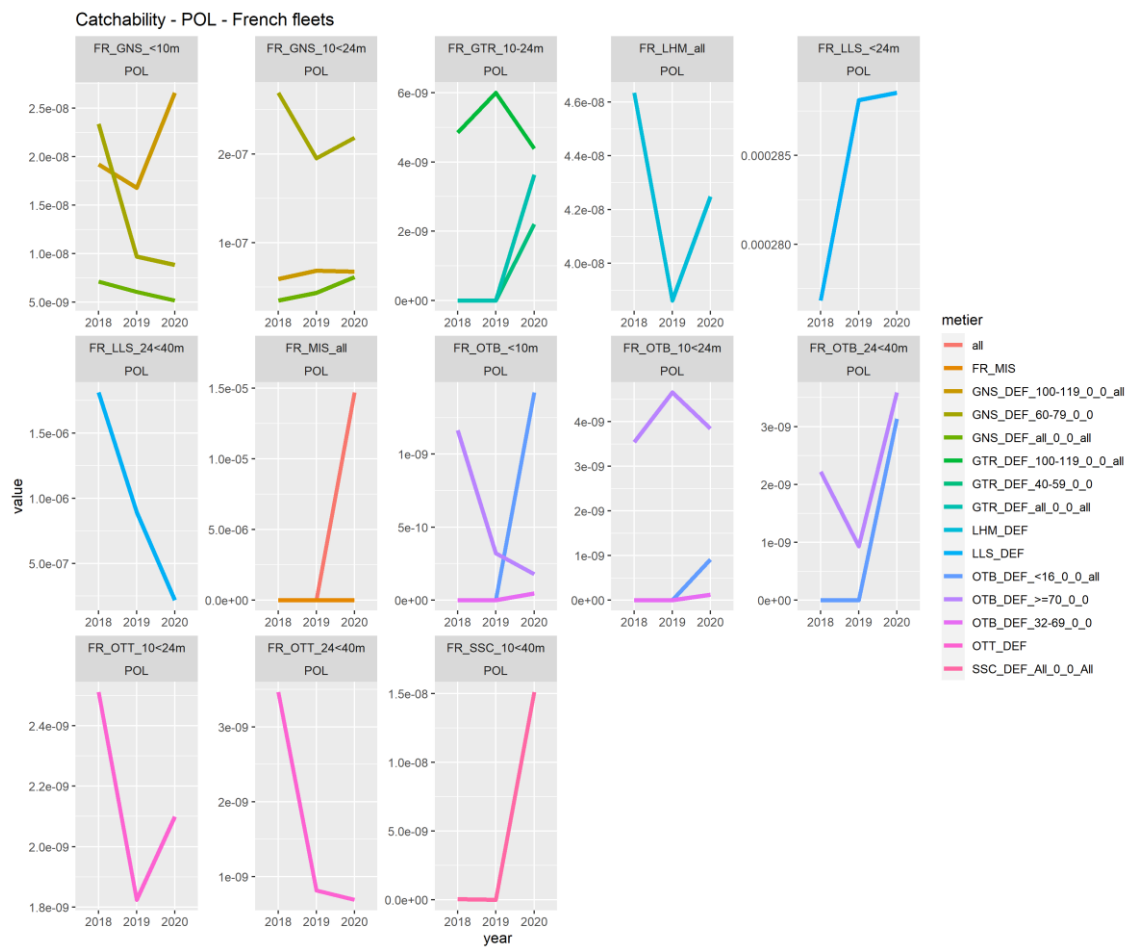
Figure 2.10. Bay of Biscay: trends of French catchability for thornback pollack (pol) by fleet and métier.
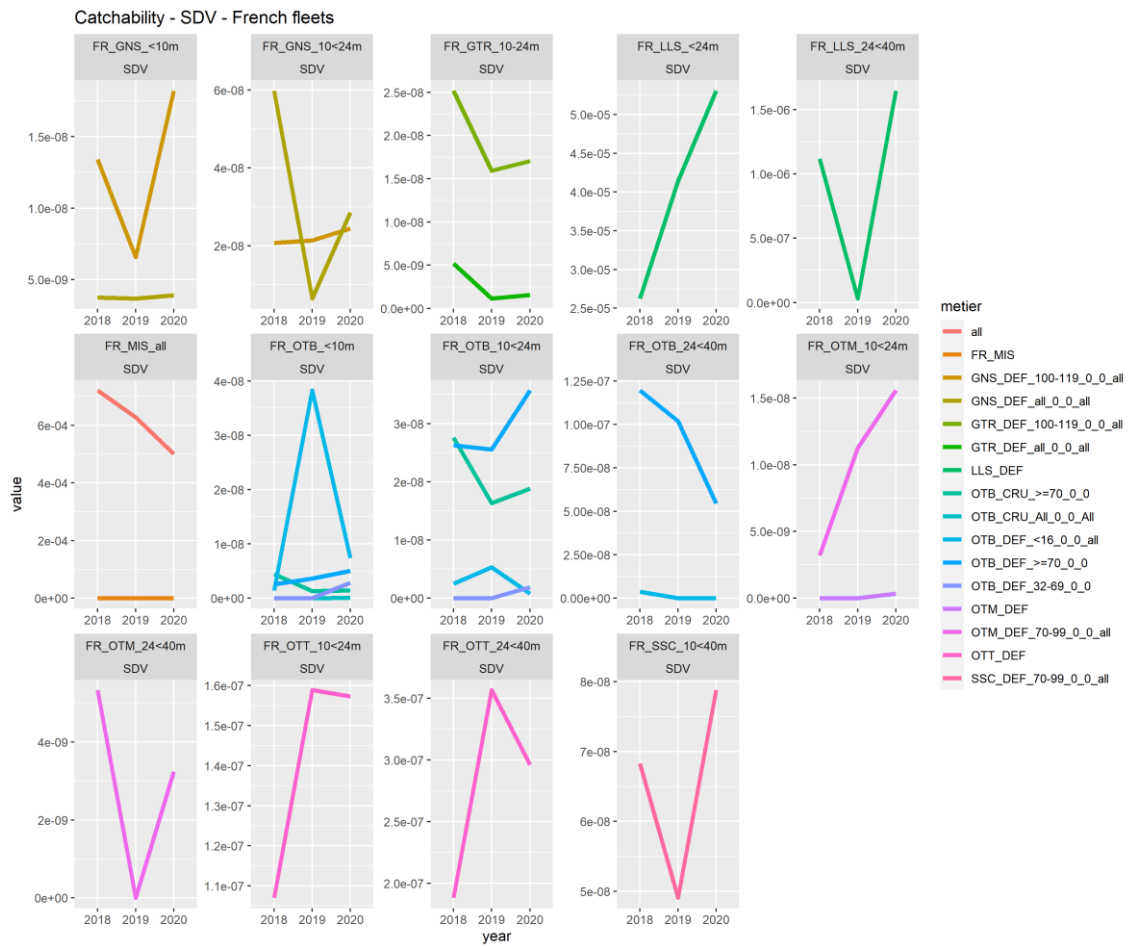
Figure 2.11. Bay of Biscay: trends of French catchability for smooth hound (sdv) by fleet and métier.
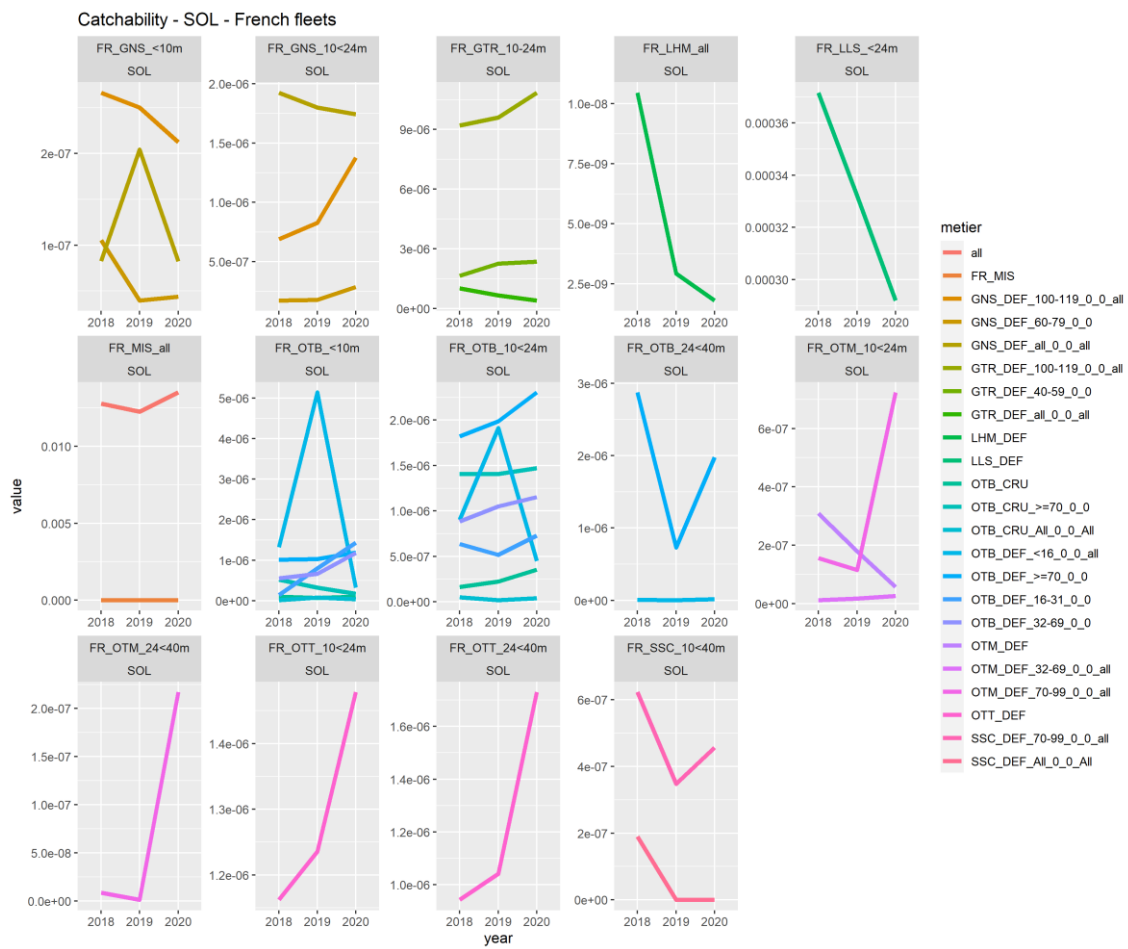
Figure 2.12. Bay of Biscay: trends of French catchability for sole (sol) by fleet and métier.
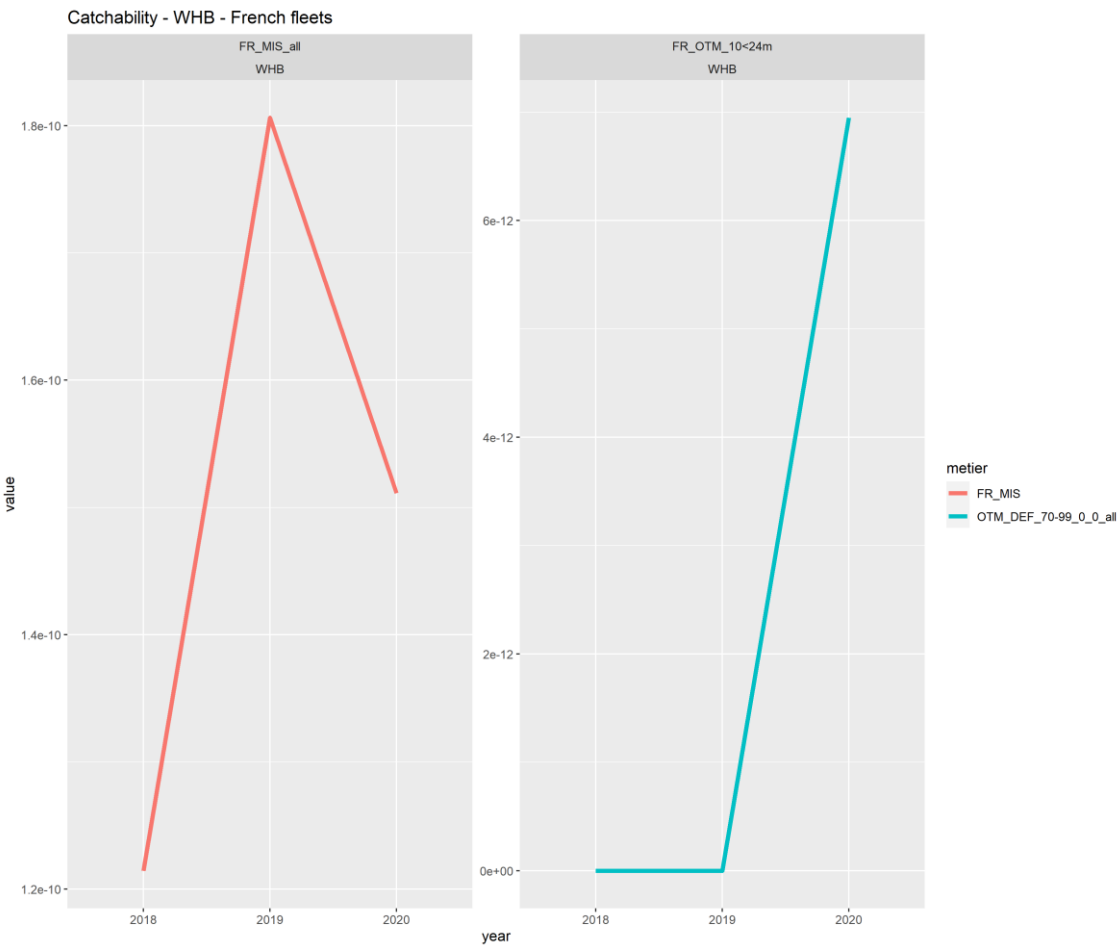
Figure 2.13. Bay of Biscay: trends of French catchability for blue whiting (whb) by fleet and métier.
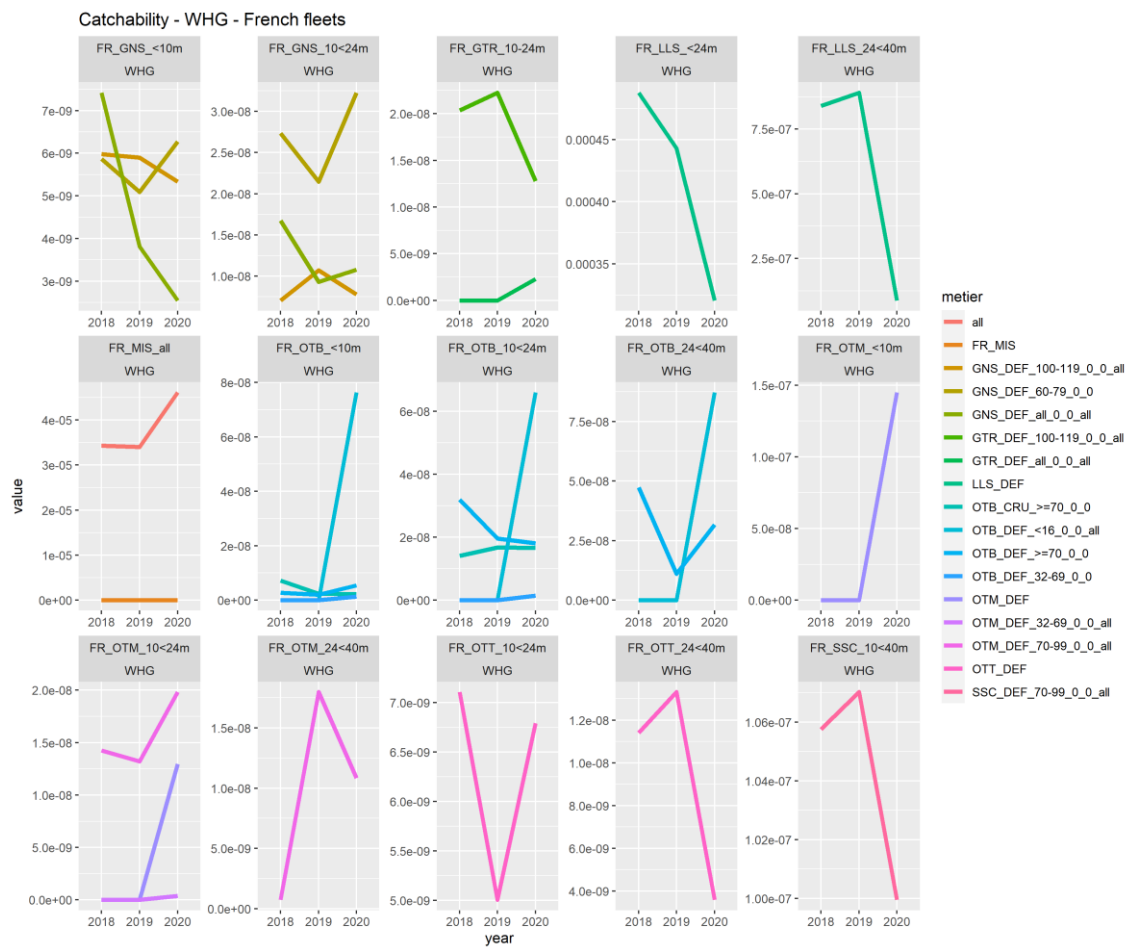
Figure 2.14. Bay of Biscay: trends of French catchability for whiting (whg) by fleet and métier.
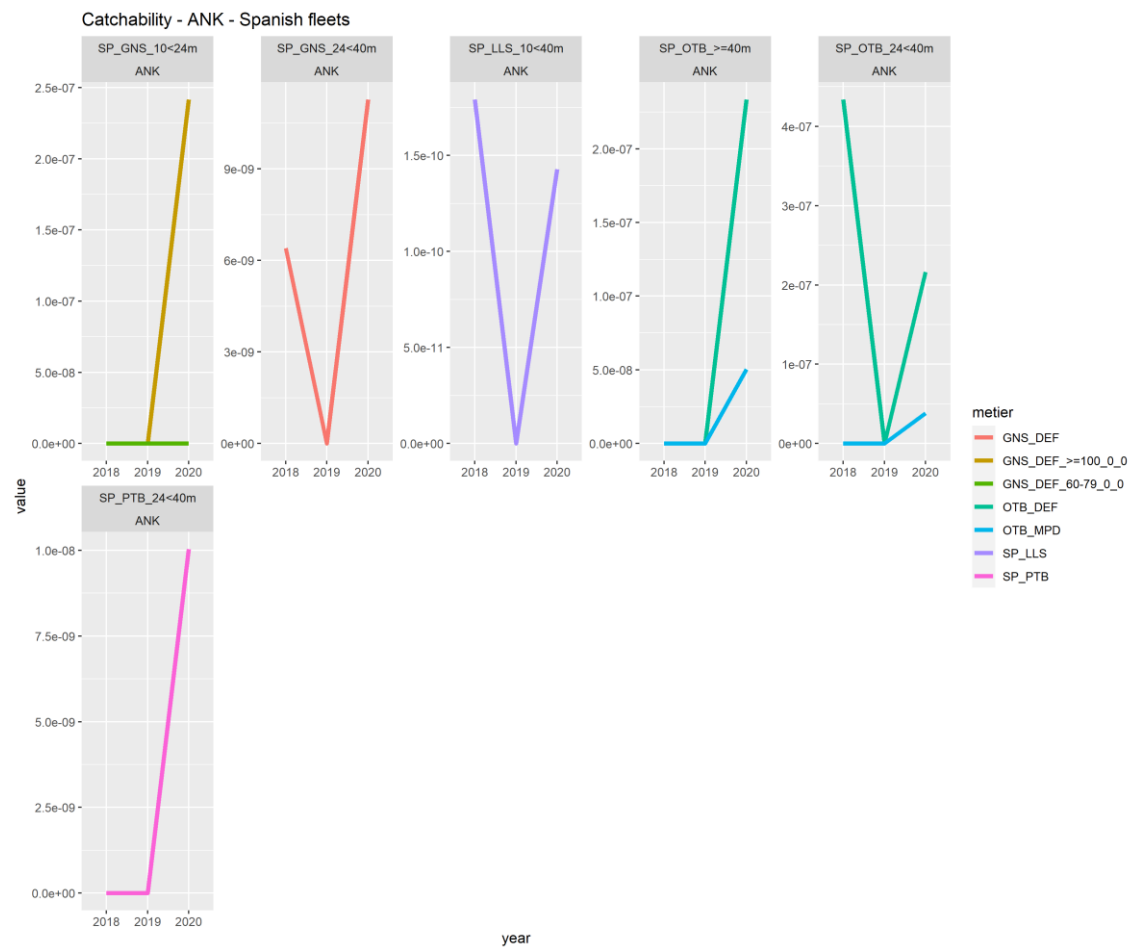
Figure 2.15. Bay of Biscay: trends of Spanish catchability for black-bellied anglerfish (ank) by fleet and métier.
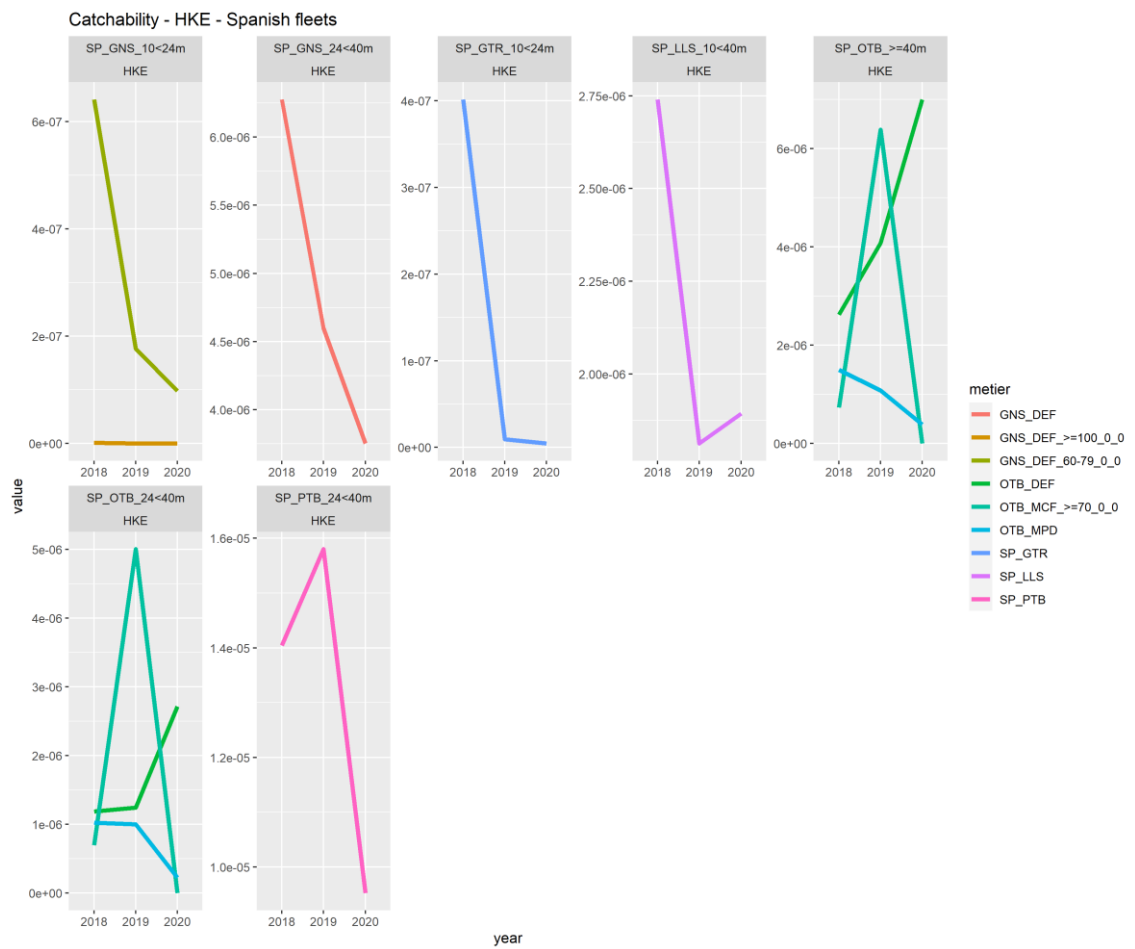
Figure 2.16. Bay of Biscay: trends of Spanish catchability for hake (hke) by fleet and métier.
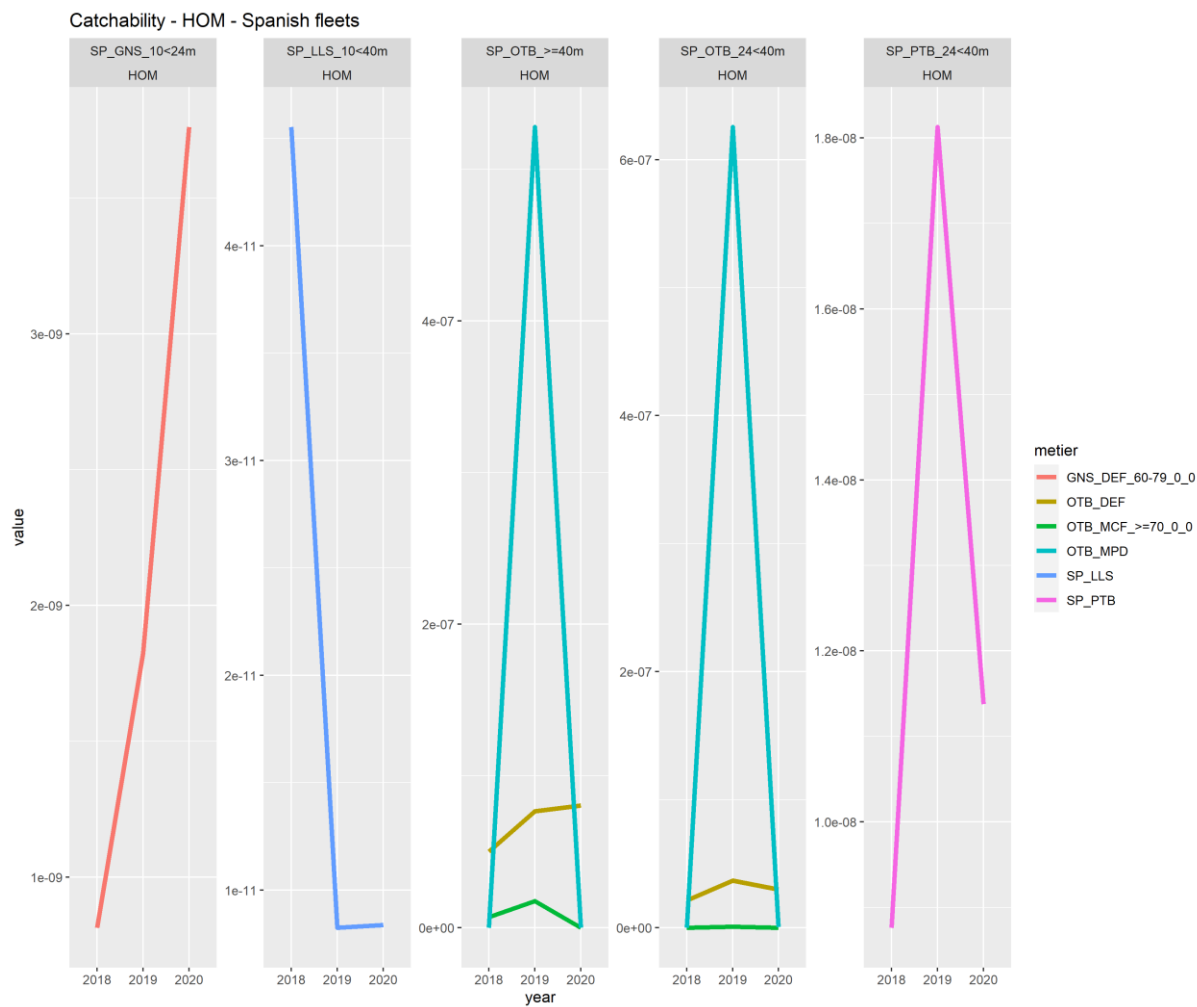
Figure 2.17. Bay of Biscay: trends of Spanish catchability for horse mackerel (hom) by fleet and métier.
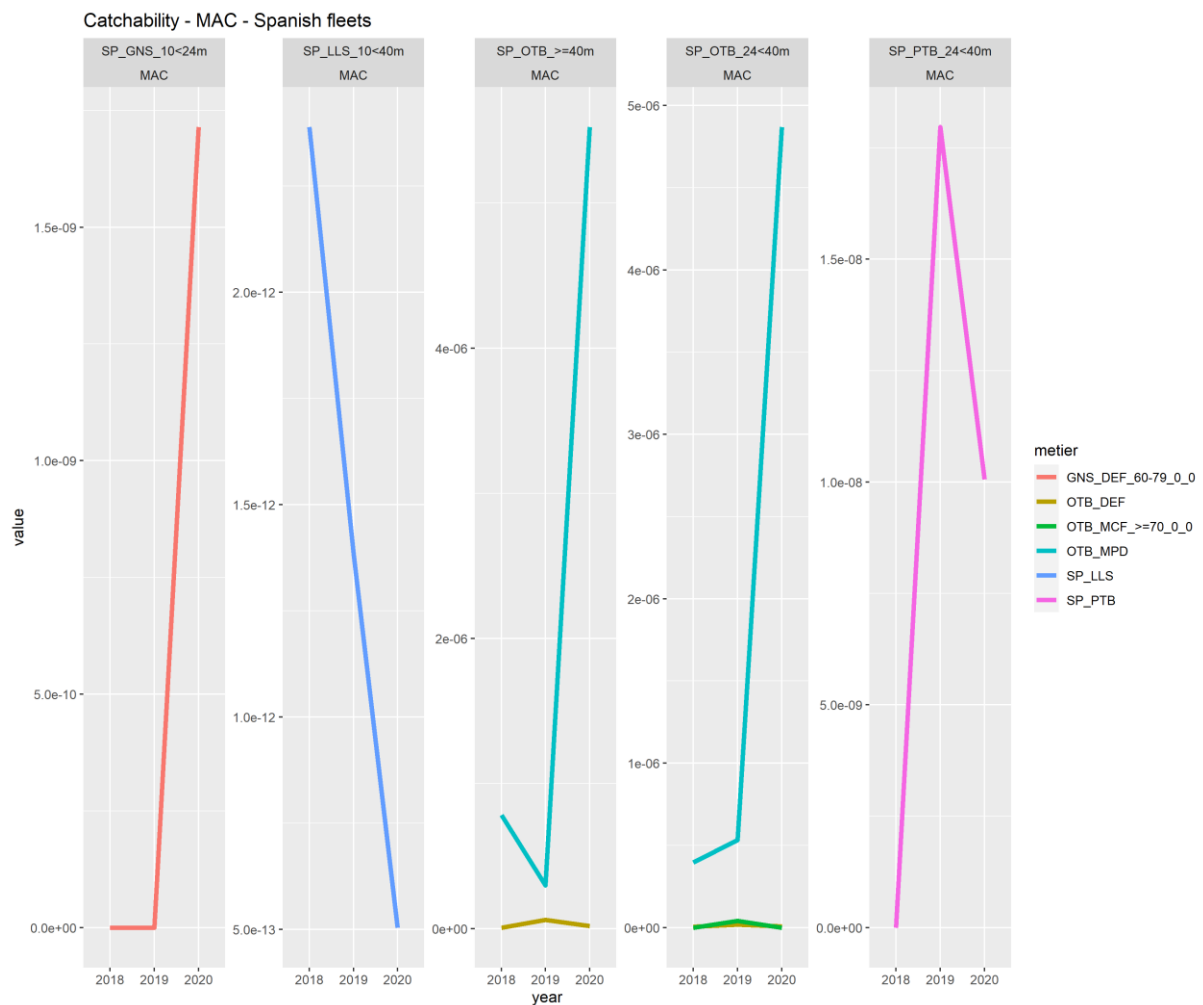
Figure 2.18. Bay of Biscay: trends of Spanish catchability for mackerel (mac) by fleet and métier.
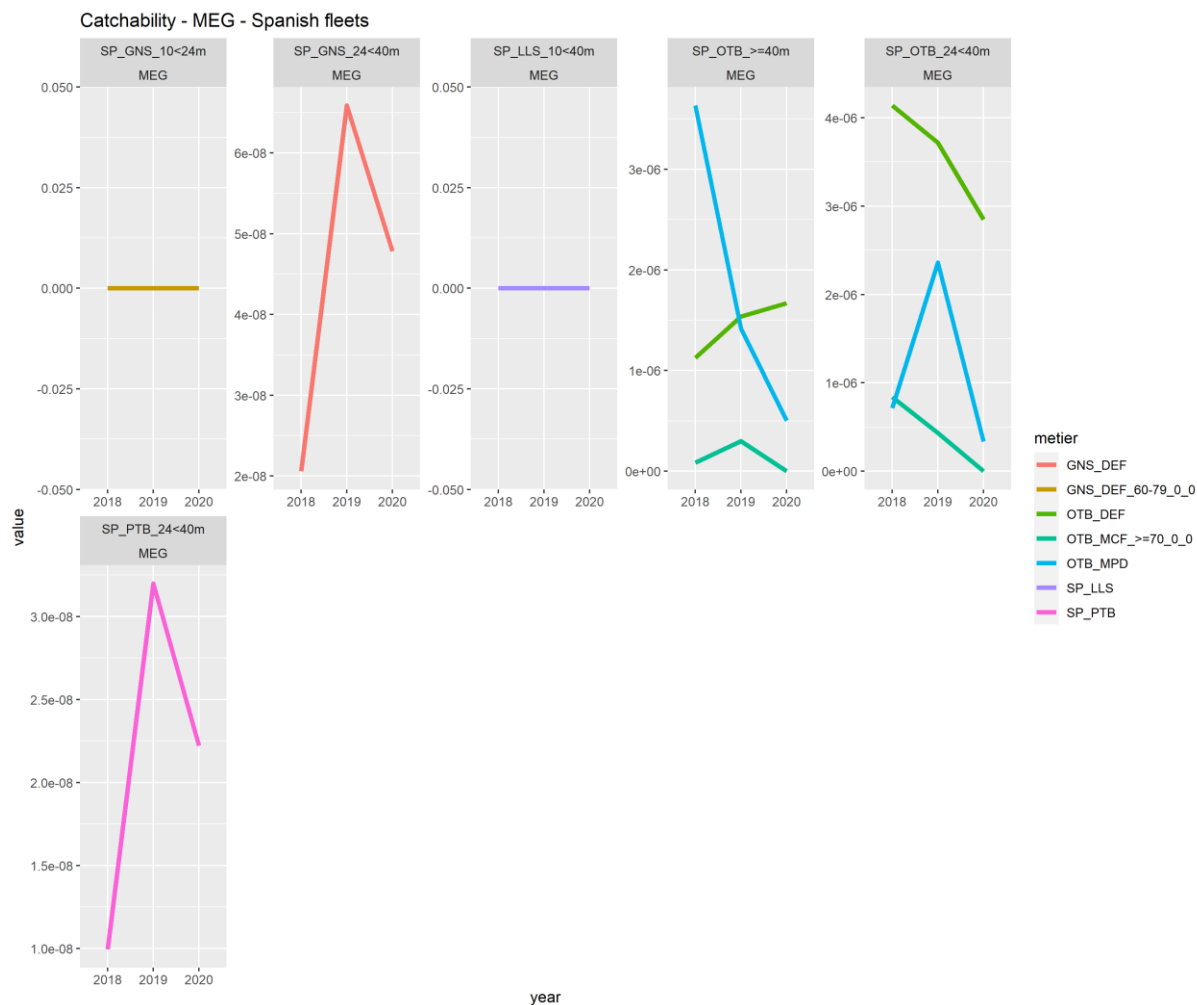
Figure 2.19. Bay of Biscay: trends of Spanish catchability for megrim (meg) by fleet and métier.
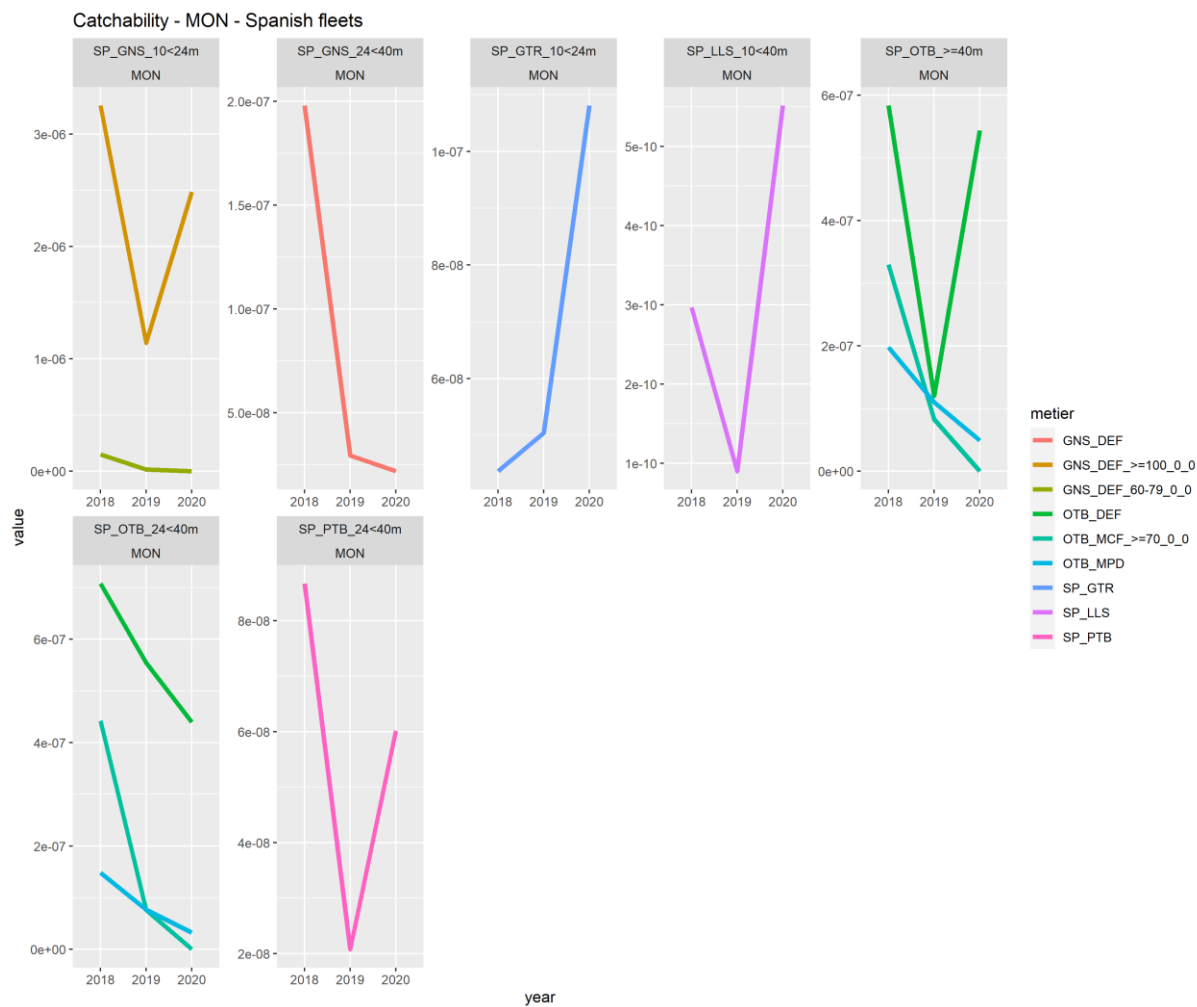
Figure 2.20. Bay of Biscay: trends of Spanish catchability for monkfish (mon) by fleet and métier.
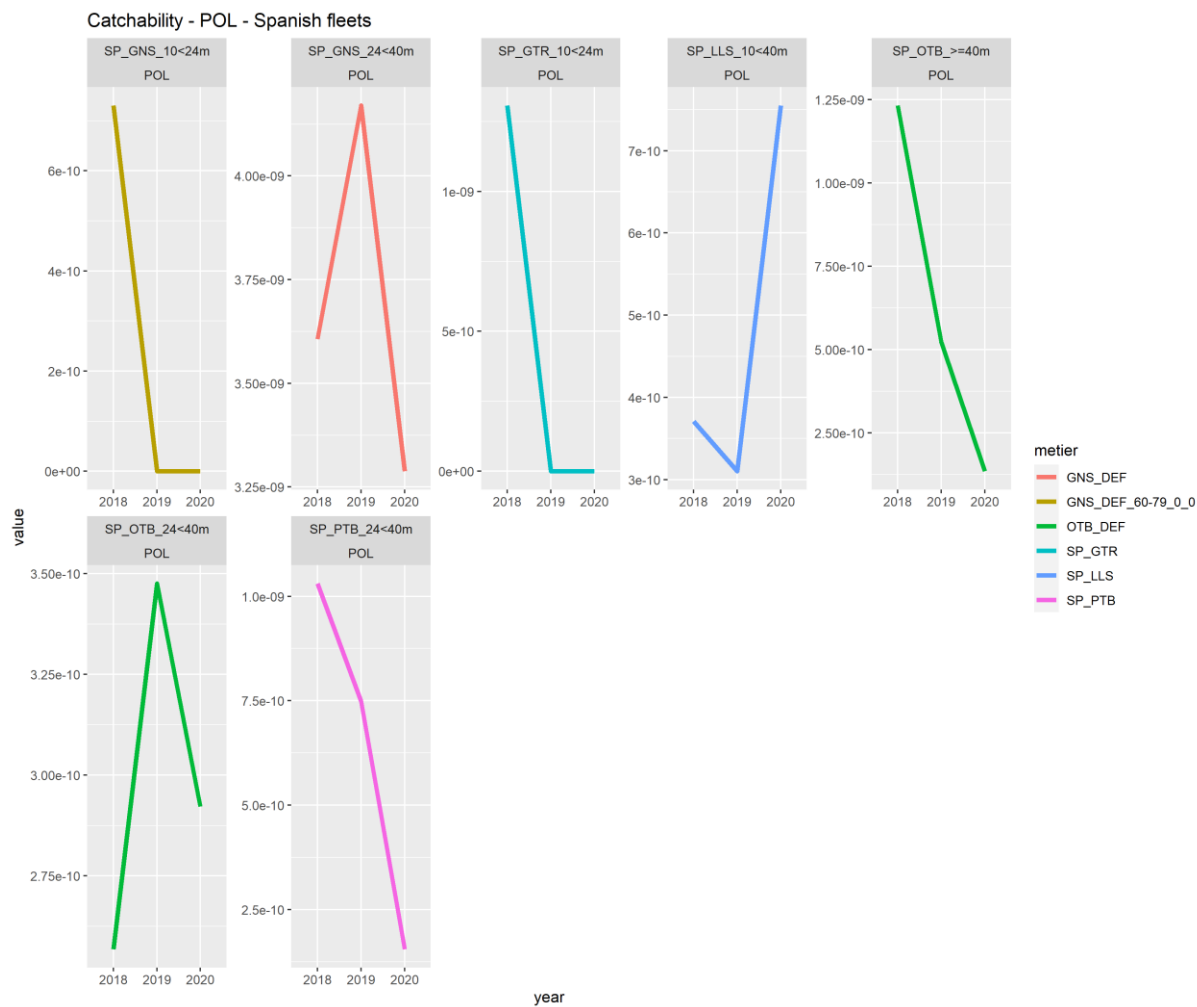
Figure 2.21. Bay of Biscay: trends of Spanish catchability for thornback pollack (pol) by fleet and métier.
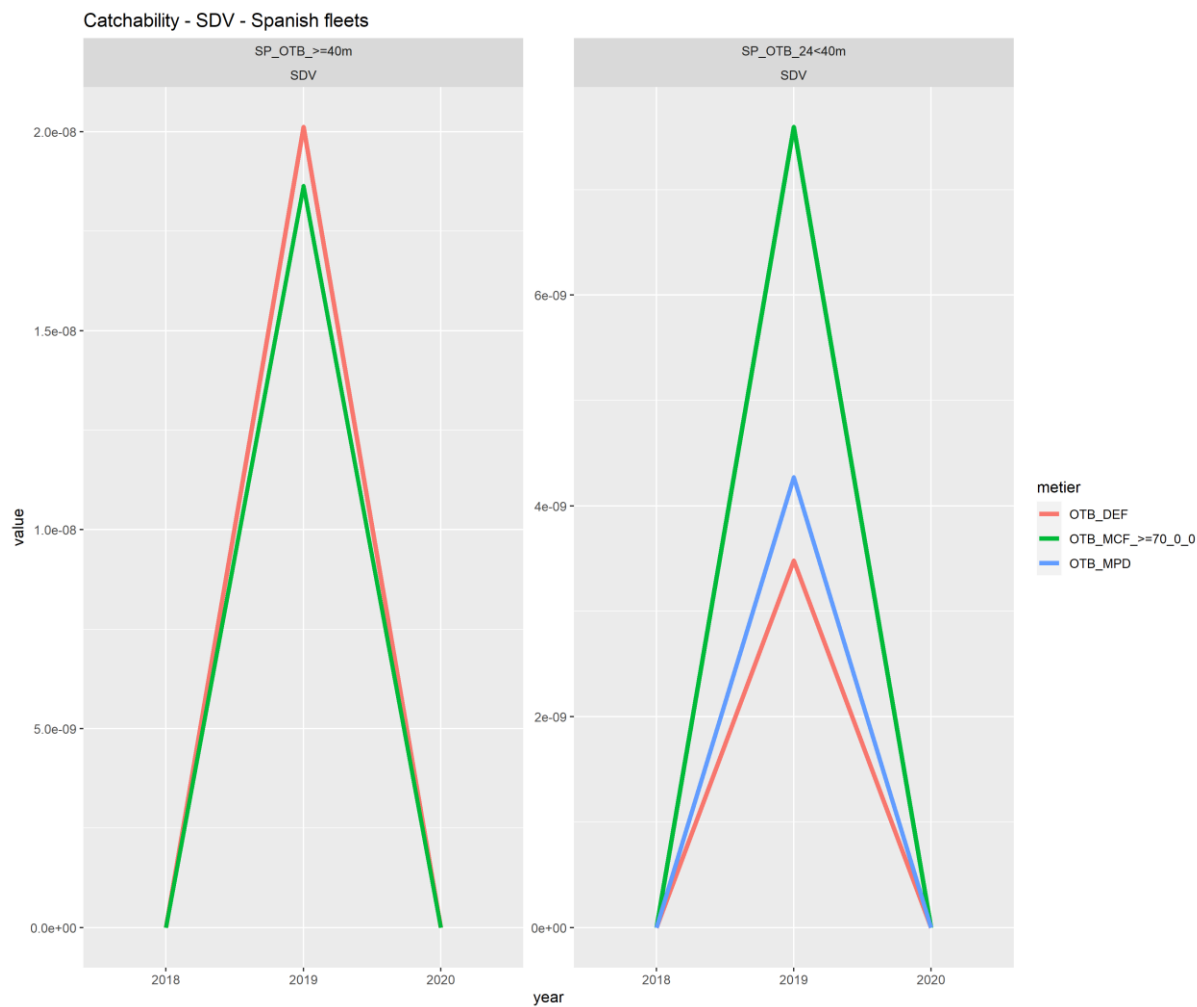
Figure 2.22. Bay of Biscay: trends of Spanish catchability for smooth hound (sdv) by fleet and métier.
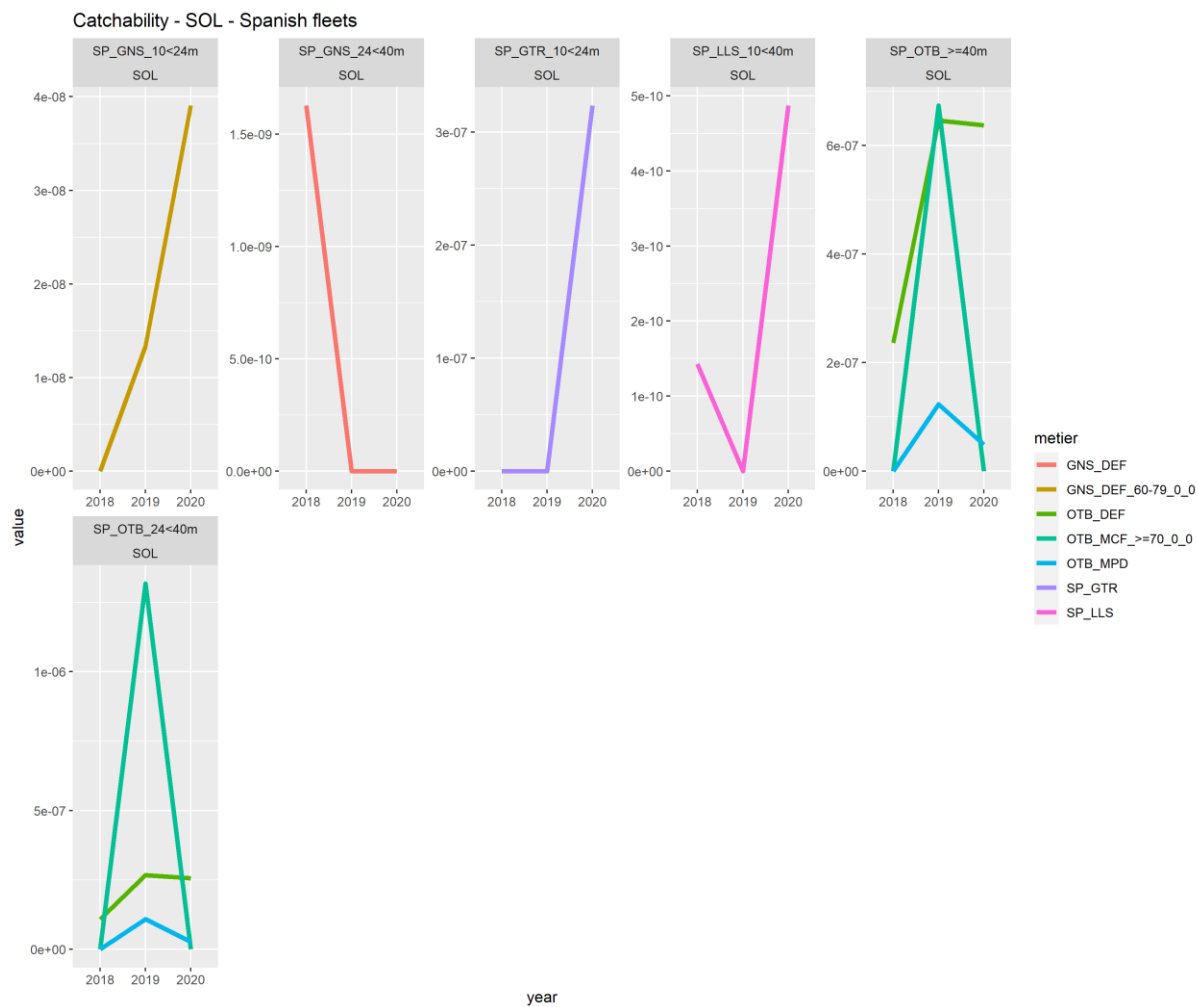
Figure 2.23. Bay of Biscay: trends of Spanish catchability for sole (sol) by fleet and métier.
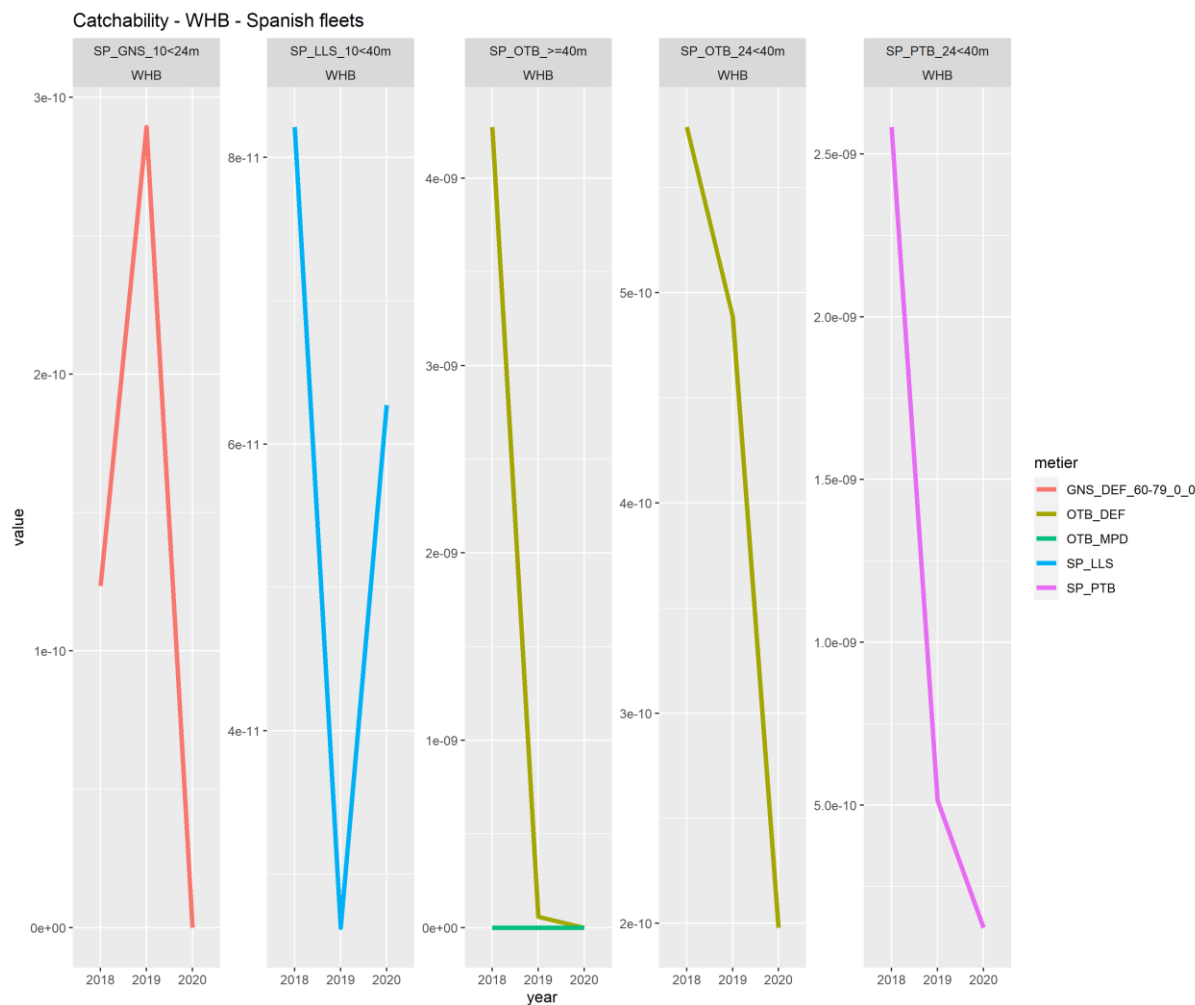
Figure 2.24. Bay of Biscay: trends of Spanish catchability for blue whiting (whb) by fleet and métier.
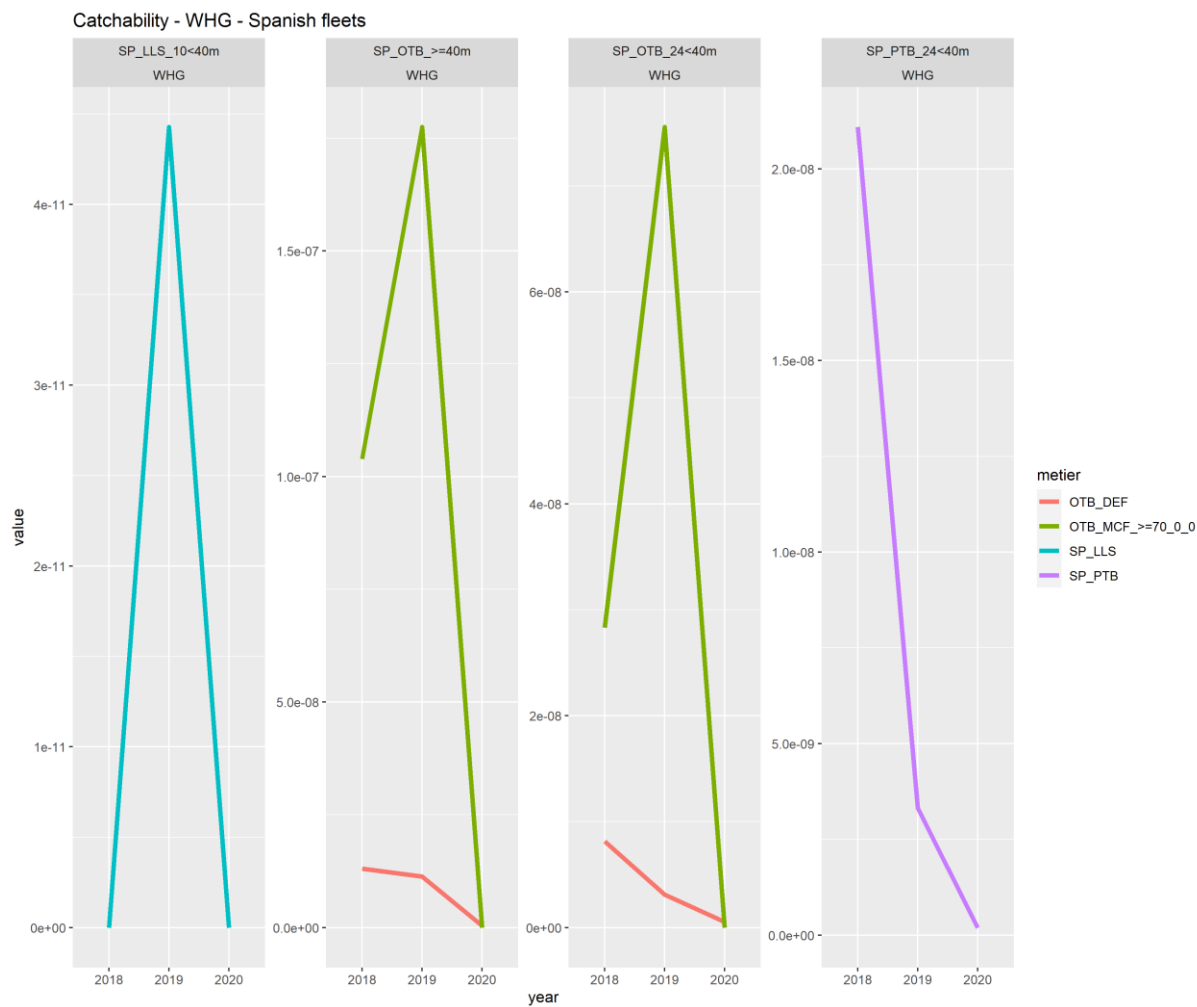
Figure 2.25. Bay of Biscay: trends of Spanish catchability for whiting (whg) by fleet and métier.
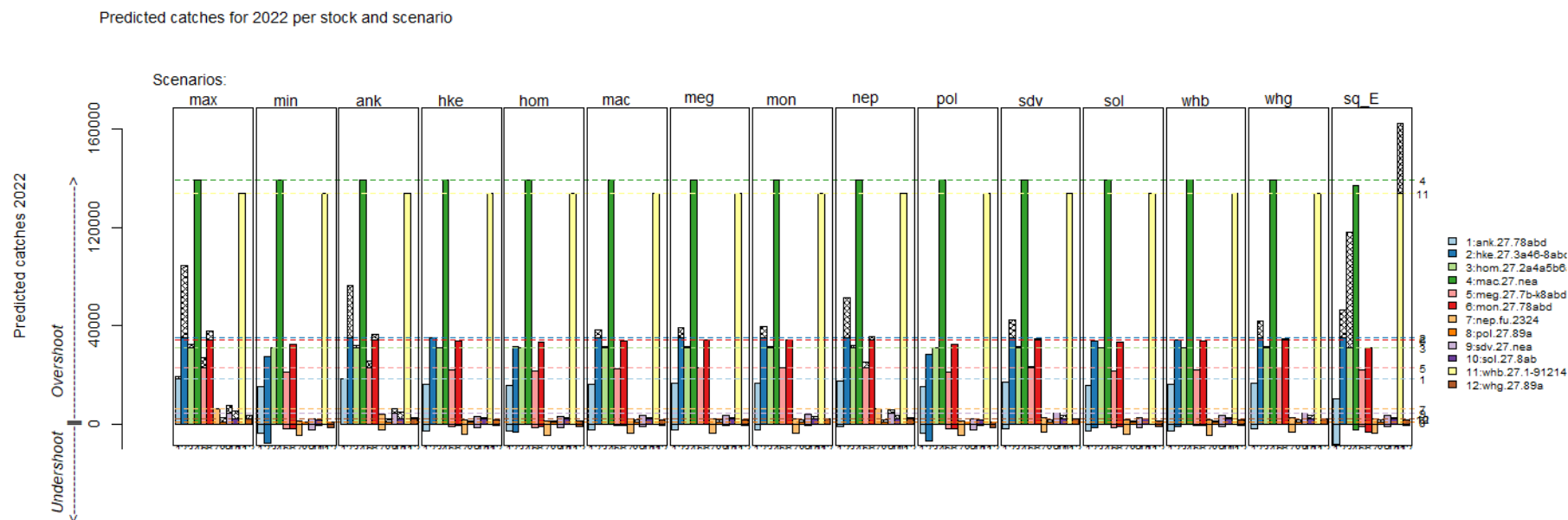
Figure 2.26. Bay of Biscay mixed fisheries forecasts: TAC year results (2022). FLBEIA estimates of potential catches by stock after applying the status-quo effort scenario to all stocks in the intermediate year followed by the FLBEIA scenarios (note that the y-axis has been truncated above 40000 tonnes). Horizontal lines correspond to the TAC set by the single-stock advice. Bars below the value of zero show the scale of undershoot (compared to the single species catch advice) in cases where catches are predicted to be lower when applying the scenario.
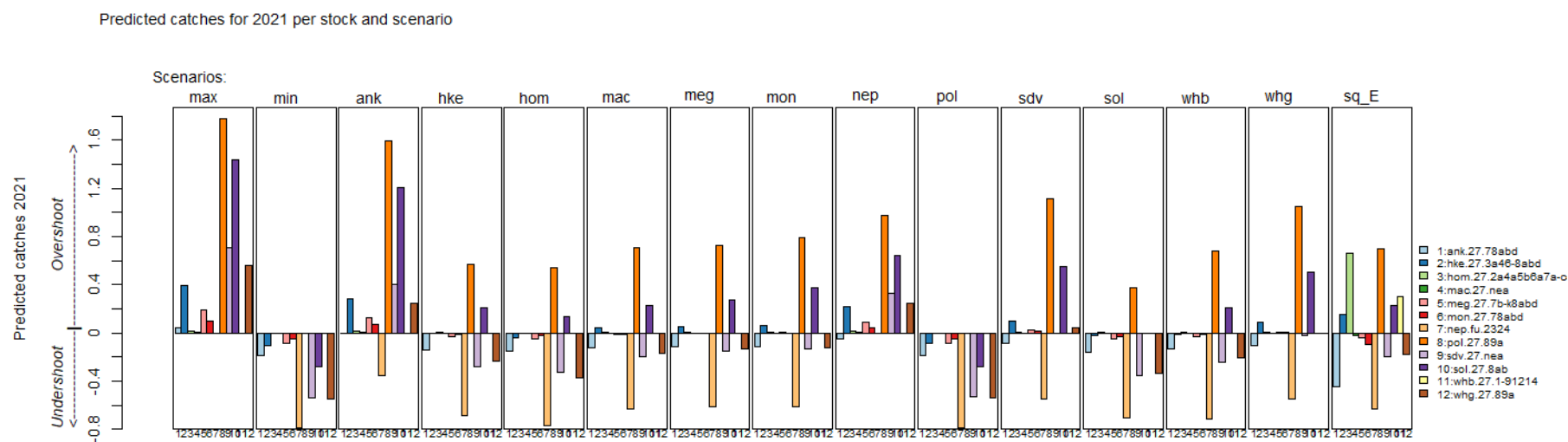
Figure 2.27. Bay of Biscay mixed fisheries forecasts: TAC year results (2022). FLBEIA estimates of potential percentage of catches change by stock (relative to the TAC advice) after applying the status-quo effort scenario to all stocks in the intermediate year followed by the FLBEIA scenarios. Horizontal line corresponds to the TAC advice for 2022 set by the single-stock advice. Bars below the value of zero show the percentage of undershoot (compared to the single species catch advice) in cases where catches are predicted to be lower when applying the scenario.
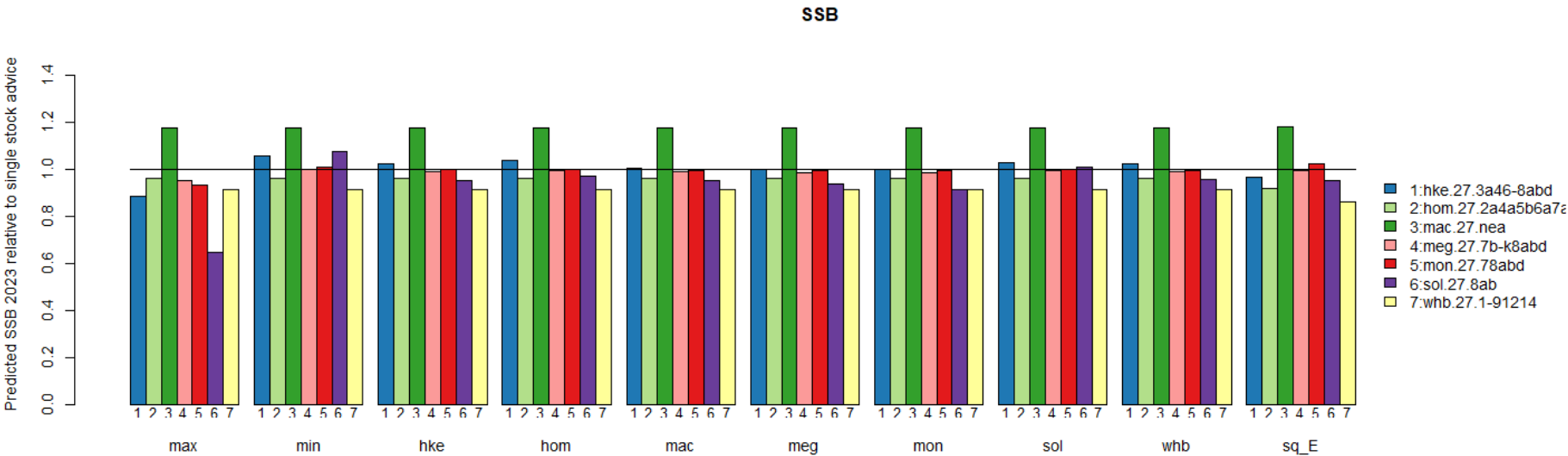
Figure 2.28. Bay of Biscay mixed fisheries forecasts: Estimates of potential SSB at the start of 2023 by stock after applying the mixed fisheries scenarios, expressed as a ratio to the single-species advice forecast. Horizontal line corresponds to the SSB resulting from the single-stock advice (at the start of 2023).
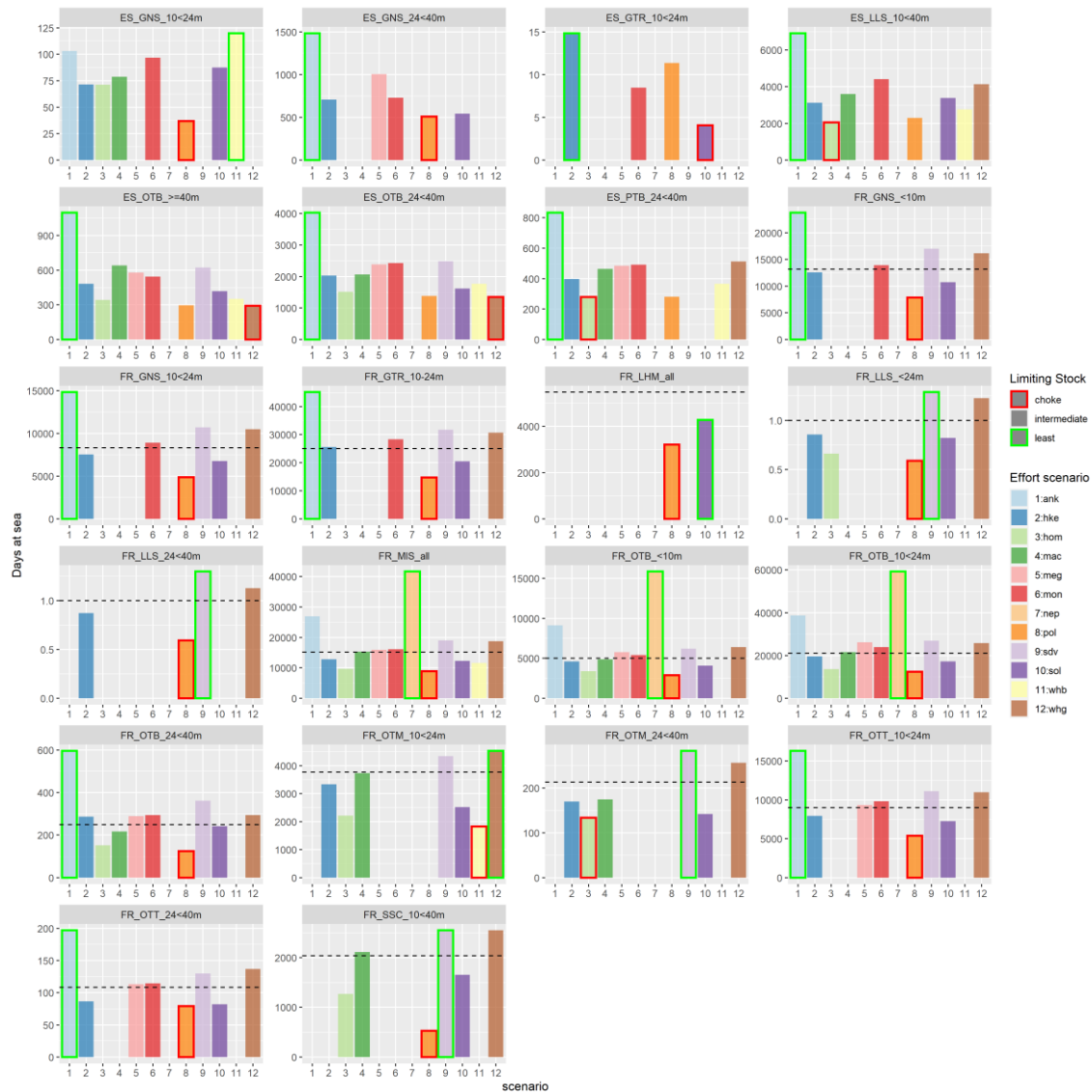
Figure 2.29. Estimates of effort by fleet needed to reach the single stock advices. Bars highlighted in red correspond to the most limiting species for that fleet in 2021 ("choke species"), whereas the green highlight correspond to the least limiting species. Horizontal dashed line corresponds to the status quo effort. Fleet names are given by country (FR = France, ES = Spain) and by meaningful combinations of main gear and vessel size differing across countries and based on homogeneous average fishing patterns. Vessels in the various fleet segments can engage in several fisheries (métiers) over the year.

3 Celtic Sea

3.1 Background

Fisheries in the Celtic Sea are highly mixed, targeting a range of species with different gears. Otter trawl fisheries target mixed gadoids (cod, haddock, and whiting), *Nephrops*, hake, anglerfishes, megrims, rays as well as cephalopods (cuttlefish and squid). Beam trawl fisheries target flatfish (plaice, sole, turbot), anglerfishes, megrim, and cephalopods (cuttlefish and squid), while set-net fisheries target flatfish, hake, pollack, cod, anglerfishes as well as some crustacean species. Beam trawling occurs for flatfish (in 7.e and 7.fg) and rays (7.f). The fisheries are mainly prosecuted by French, Irish, and English vessels with additional Belgian beam trawl fisheries and Spanish trawl and net fisheries along the shelf edge (7.hjk).

The mixed gadoid fishery predominately takes place in ICES areas 7.f and 7.g with these areas responsible for >75% of the landings of each cod, haddock and whiting. Landings are predominately by French and Irish vessels, though UK vessels also take significant landings of these species.

3.1.1 Management measures

In 2021, the ICES advice for all stocks considered in this model was given in terms of terms the ICES MSY approach. A multiannual management plan (MAP) for Western and adjacent waters has been adopted by the EU for stocks covered by this advice (EU, 2019) which ICES considers to be precautionary. However, there is no agreed shared management plan with UK for this stock. There are two species specific management plans in this region; a recovery plan for hake (Council Regulation (EC) No 811/2004) which implements a Total Allowable Catch (TAC) annually based on a defined Harvest Control Rule (HCR) and a management plan with both a HCR and effort management element for sole in the Western channel (7.e; Council Regulation (EC) No 509/2007). There are also a number of effort, technical and area closure measures in place, which are summarised below.

The EU western waters regulation (Council Regulation (EC) No 1954/2003) implements an effort ceiling for ≥ 15 m vessels fishing for demersal species in Subarea 7 with additional effort ceiling specifications for an area to the South and West of Ireland known as the 'Biologically Sensitive Area' for vessels ≥ 10 m.

A series of technical measures are in place for demersal trawl gears operating in various parts of the Celtic Sea. This includes maximum number of meshes in circumference, incorporation of a square mesh panel (SMP), and minimum mesh size in the cod end dependent on the target composition and/or area. Technical measures for the recovery of the stock of hake which includes Subarea 7. Commission regulation (EC) No 1162/2001, commission regulation (EC) No 2062/2001, and commission regulation (EC) No 494/2002.The most recent of which relates to incorporation of the SMP detailed in commission implementing regulation (EU) No 737/2012 of 14 August 2012. A summary of current measures is published by BIM of Ireland (https://bim.ie/fisheries/advisory-services/fisheries-management-chart)

Since 2005, three ICES rectangles (30E4, 31E4, and 32E3) have been closed during the first quarter (Council Regulations 27/2005, 51/2006, and 41/2007, 40/2008 and 43/2009) known as the Trevose closure, with the objective of reducing fishing mortality on cod. Another area closure was in place for EU fisheries in FU16 (the Porcupine bank) between 1 May – 31 July 2010-2012; however, the period of the EU regulatory close was reduced to only May between 2013 and 2019 (Council Regulation 2019/124), and has not been in force since 2020 (Council Regulation 2020/123).

As of the 1 January 2016, a European demersal species landings obligation was introduced (Commission Delegated Regulation (EU) 2015/2438). This regulation prevents the discarding of certain species on a fishery by fishery approach. From 1 January 2021, catches of all quota species in the Celtic Seas are subject to the EU landings obligation rule, except an exemption is in place. An overview of the exemptions of the landings obligation can be found below:

Exemptions to the landing obligation in 2021

Species	Exemption type	Area	Gear	Maximum de minimis exemption (% of total annual catch)
Albacore tuna	De minimis	7	Midwater pair trawls	5
Whiting	De minimis	7b -7k	Bottom trawls and seines ≥ 80 mm, Pelagic and beam trawls 80-119 mm	5
Sole	De minimis	7a, 7d -7h	Beam trawl 80-119 mm with Flemish Panel	3
Sole	De minimis	7d,e,f & g	Trammel nets and gillnets	3
Haddock	De minimis	7b,c & 7e-k	Bottom trawls and seines ≥ 100 mm, catches comprising ≤30% Nephrops	5
Haddock	De minimis	7b,c & 7e-k	Vessels using ≥ 80 mm, with catches comprising more than 30% Nephrops	5
Haddock	De minimis	7b,c & 7e-k	Beam trawls ≥ 80 mm with Flemish Panel	5
Haddock [1]	De minimis	6a	Nephrops bottom trawls using <119mm with HSG	3
Megrim [2]	De minimis	7	Beam Trawls 80-119mm & Bottom trawls	4
Horse mackerel	De minimis	6 & 7b-k	Bottom trawls, seines & beam trawls	3
Mackerel	De minimis	6 & 7b-k	Bottom trawls, seines & beam trawls	3
Boarfish	De minimis	7b,7c,7f-7k	Bottom trawls	0.5
Argentine	De minimis	EU 5b & 6	Bottom trawls ≥ 100 mm	0.6
Species	**Exemption Type**	**Area**	**Gear**	**Discard Release Notes**
Nephrops	Survivability	6 & 7	Pots, creels or traps	immediately & where caught
Nephrops	Survivability	7	Bottom trawls 70-99mm with HSG* or ≥100mm	immediately & where caught
Nephrops	Survivability	6a (<12nm)	Bottom trawls 80-110 mm	immediately & where caught
Skates & rays	Survivability	6 & 7	All gears	Released immediately
Plaice	Survivability	7d -7g	Trammel nets and otter trawls	Released immediately
Plaice	Survivability	7d -7g	Beam Trawls with flip up rope or benthic release panel (vessels > 221kW)	Released immediately
Plaice	Survivability	7a-7g	BT2 (vessels ≤221 kW or ≤24 m) inside 12 nm, tows ≤ 1:30 hour	Released immediately
All Species	Survivability	EU 5b; 6 & 7	Pots, creels and traps	Released immediately

[1] Applies ony to haddock <MCRS (30cm), [2] Applies ony to megrim <MCRS (20cm)
* See list of highly specific gears for Nephrops. ** Bottom trawls:70 to 99mm in 7f,7g, 7h North of 49.5ºN & 7j East of 11ºW - catches must comprise 55% whiting or anglerfish, hake & megrim combined; ≥100mm in the rest of 7

Reference: Commission Delegated Regulation (EU) 2020/2015

3.2 Model

3.2.1 Software

All analyses were conducted using the FLR framework (Kell *et al.*, 2007; FLCore 2.6.16, FLFleet 2.6.1, FLAssess 2.6.3, Flash 2.5.11) running with R4.1.0 (R Development Core Team, 2020). All forecasts were projected using the same fwd() function in the Flash Package. The FCube method is developed as a stand-alone script using FLR objects as inputs and outputs.

Software used in the single-species assessments and forecasts was as outlined in the table below:

Stock	Assessment	Forecast
cod.27.7.e–k	Age-based stochastic analytical assessment (SAM)	SAM
had.27.7.bc,e–k	Age-based stochastic analytical assessment (SAM)	SAM
whg.27.7.bc,e–k	Age-based stochastic analytical assessment (SAM)	SAM
meg.27.7b-k8abd	Bayesian statistical catch at age using catches in the model and forecast	Stochastic
mon.27.78abd	a4a	FLR STF
sol.27.7fg	Age-based stochastic analytical assessment (SAM)	SAM
nep.fu.16	Underwater TV survey	NA
nep.fu.17	Underwater TV survey	NA

Stock	Assessment	Forecast
nep.fu.19	Underwater TV survey	NA
nep.fu.2021	Underwater TV survey	NA
nep.fu.22	Underwater TV survey	NA
nep.out.7	Precautionary approach	NA

3.2.2 Scenarios

FCube (Ulrich *et al.,* 2008; 2011) was used to forecast several mixed fisheries scenarios. The basis of the model is to estimate the potential future levels of effort by a fleet corresponding to the fishing opportunities (catches by stock and/or effort allocations by fleet) available to that fleet, based on fleet effort distribution and catchability by métier. This level of effort was used to estimate landings and catches by fleet and stock, using standard forecasting procedures. The basis for each single-stock advice was retained in the current mixed fisheries framework.

The following seven options (or scenarios) were included in the advice:

	Scenarios
max	**"Maximum":** For each fleet, fishing stops when all stocks have been caught up to the fleet's stock shares*. This option causes overfishing of the single-stock advice possibilities of most stocks.
min	**"Minimum":** For each fleet, fishing stops when the catch for any one of the stocks meets the fleet's stock share. This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks.
had.27.7b-k	**"Haddock MSY approach":** All fleets set their effort corresponding to that required to catch their haddock stock share, regardless of other catches.
whg.27.7b-ce-k	**"Whiting MSY approach":** All fleets set their effort corresponding to that required to catch their whiting stock share, regardless of other catches.
sq_E	**"*Status quo* effort":** The effort of each fleet in the TAC year (2022) is set equal to the average effort in the most recent 3 years (2018-2020) for which catch and effort data are available.
cod_F_{AR}MSY	**"Reduced Cod F_{MSY}":** All fleets set their effort corresponding to that required to catch their cod stock share, where the cod TAC is set according to reduced F_{MSY} (F = 0.068, $F_{MSY} \times SSB_{2022}/MSY\ B_{trigger}$), regardless of other catches.
range	**"Range":** estimates a fishing mortality by stock (using the F_{MSY} ranges) which, if used for setting single-stock fishing opportunities, may reduce the gap between the most and the least restrictive TACs, thus reducing the potential for quota over- and undershoot. F_{MSY} ranges are bound by the ranges in the single species advice sheet where the F_{MSY} ranges is adjusted using the ICES advice rule when the stock is below MSY $B_{trigger}$. Unlike the other scenarios the range scenario does not assume fixed fishing patterns in the future i.e. technical interactions can be adjusted in each fleet independently.

* Throughout this document, the term "fleet's stock share" or "stock share" is used to describe the share of the fishing opportunities for each particular fleet, calculated based on the single-stock advice for 2022 and the historical proportion of the stock landings taken by the fleet (2018–2020).

3.3   Data compilation

Data used to produce the mixed fisheries forecasts comes from three sources: Following IBPMIXFISH 2021 (ICES 2021d), the data compilation R scripts were significantly revised to improve workflow, readability, and reproducibility. These revisions have been thoroughly detailed in the IBP report and annex. The input data source to these scripts remains the same, bar the inclusion of standard assessment graph data retrieved directly from ICES.

1.   Stock data: Stock abundance, age-structure, reference points, catch advice, and trends. This data is supplied by the single species assessment working groups, the data is also retrieved from the ICES Standard Assessment Graph (SAG) server on a stock by stock basis and used to validate data submissions to WGMIXFISH.
2.   Fisheries dependent data: fleet and métier trends in landings and effort. This data is sourced from the WGMIXFISH data call ("accessions data").
3.   Discard rates: InterCatch.
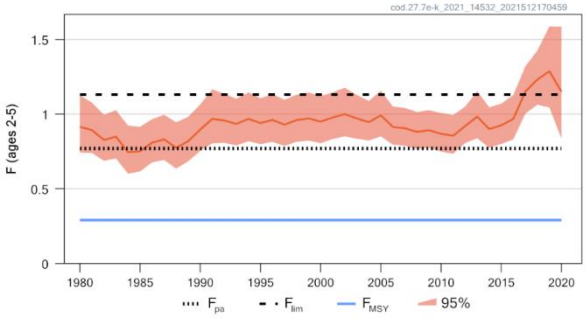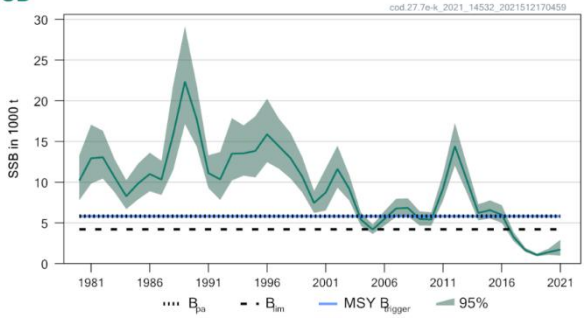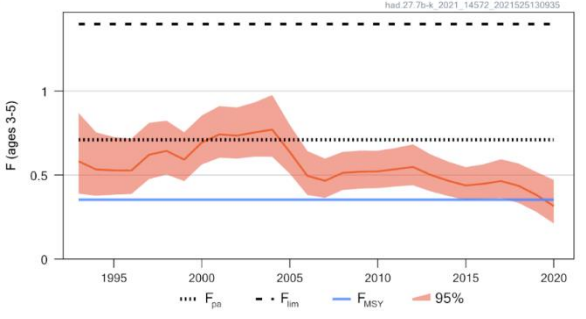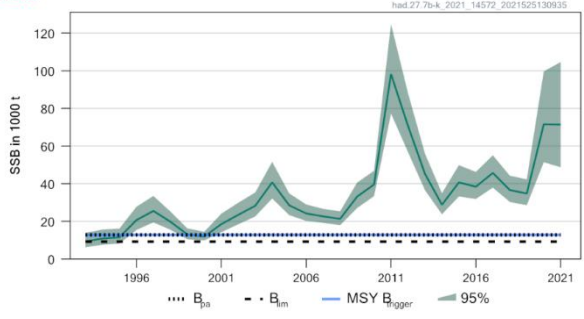
Details on the collection, structure and implementation of these data sources can be found in the relevant single species stock annexes. Below specific details of the data sources in 2021 have been described.
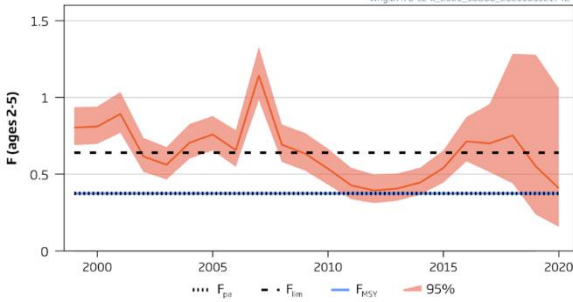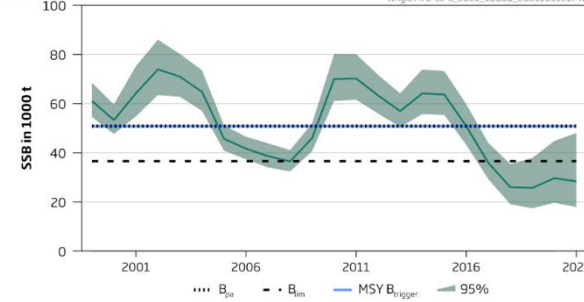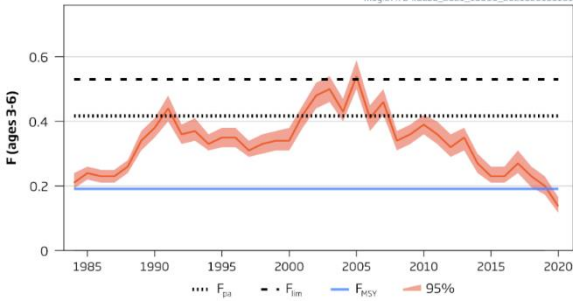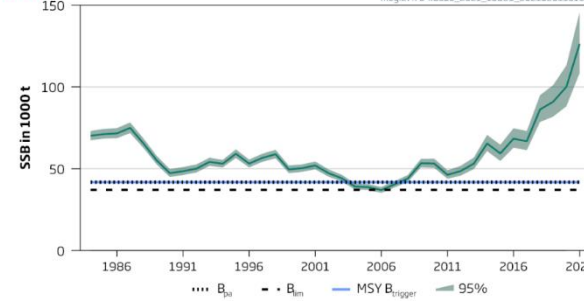
3.3.1   Stock data

Single species stock assessment outputs including abundance, fishing mortality, biological parameters (maturity, natural mortality) and age-structure was supplied by WGCSE (ICES 2021e) and WGBIE (ICES 2021a) in the form of FLR stock objects. Details of reference points, advice for 2022, TAC and trends in stock status were taken from the advice sheets. The consistent support and cooperation from the chairs and single species stock assessors has greatly eased the workload of WGMIXFISH in 2021. An overview of the trends and advice for demersal stocks included in Celtic Sea mixed fisheries analysis from the single species advice for these stocks is described below (ICES 2021e, 2021a) (Table 3.1)

Table 3.1. Summary of advice and stock trends for the stocks included in the Celtic Sea mixed fisheries model (ICES 2021b, 2021c)

Analytical stocks
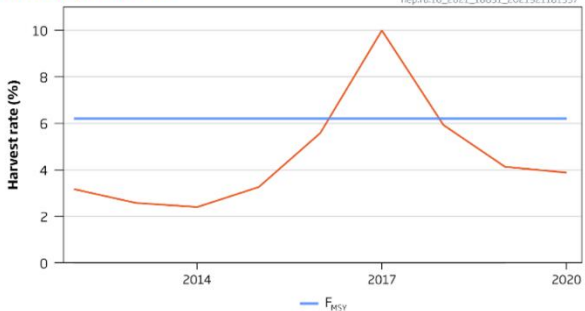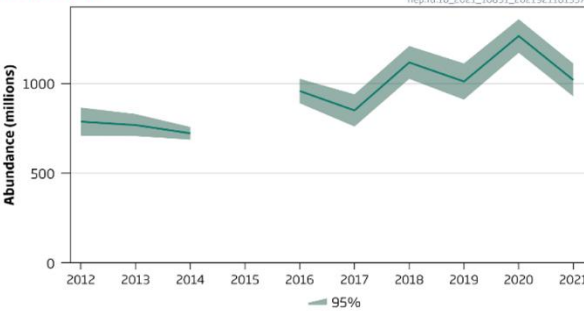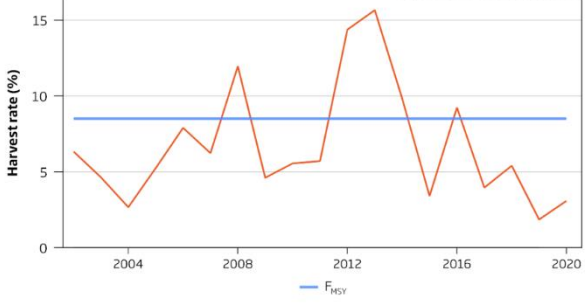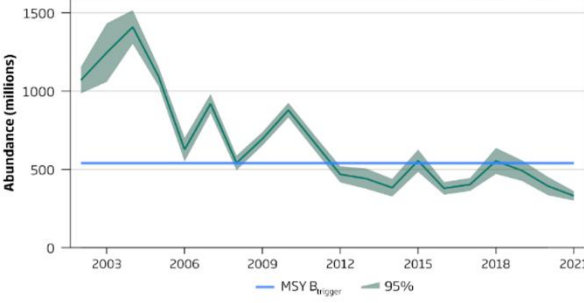
Species	Area	Stock status	Advice 2021
cod.27.7e–k (Cod)	Divisions 7. e–k (western English Channel and southern Celtic Seas)	**Summary**: Fishing pressure on the stock is above F_{MSY}, F_{pa}, and F_{lim}; spawning-stock size is below MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach and precautionary considerations are applied, there should be zero catch in 2022. ICES notes the existence of a precautionary management plan, developed and adopted by some of the relevant management authorities for this stock.
had.27b–k (Haddock)	Divisions 7.b–k (southern Celtic Seas and English Channel)	**Summary**: Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 15 946 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by some of the relevant management authorities for this stock.

Species	Area	Stock status	Advice 2021
whg.27.b–c, e–k (Whiting)	Divisions 7.b–c and 7.e–k (southern Celtic Seas and western English Channel)	**Summary:** Fishing pressure on the stock is above F_{MSY} and F_{pa} but below F_{lim}, the spawning-stock size is below MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 4 452 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.
meg.27.7b-k8abd (Megrim)	Divisions 7.b–k, 8.a–b, and 8.d (west and southwest of Ireland, Bay of Biscay)	**Summary**: ICES assesses that fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 22 964 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock. Management of catches of the two megrim species, *L. whiffiagonis* and *L. boscii*, under a combined species TAC prevents effective control of the single-species exploitation rates, and could lead to the overexploitation of either species.

Species	Area	Stock status	Advice 2021

mon.27.78abd (White anglerfish)

Subarea 7 and in divisions 8.a–b and 8.d (southern Celtic Seas, Bay of Biscay)

Summary: ICES assesses that fishing pressure on the stock is below F_{MSY}; spawning stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.

ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 34 275 tonnes.

ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.

Management of catches of the two anglerfish species, *Lophius budegassa* and *L. piscatorius*, under a combined species total allowable catch (TAC), prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species.

sol.27.7fg (Sole)

Divisions 7.f and 7.g (Bristol Channel, Celtic Sea)

Summary: Fishing pressure on the stock is above F_{MSY} but below F_{pa} and F_{lim}; spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.

ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 1 337 tonnes.

ICES notes the existence of a precautionary management plan, developed and adopted by some of the relevant management authorities for this stock.

Nephrops stocks

Species	Area	Stock status		Advice 2021
nep.fu.16 (*Nephrops*)	Divisions 7.b–c and 7.j–k, Functional Unit 16 (west and southwest of Ireland, Porcupine Bank)	**Summary:** Fishing pressure on the stock is below F$_{MSY}$, and no reference points for stock size have been defined for this stock.		ICES advises that when the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied, and assuming zero discards, catches in 2022 that correspond to the F ranges in the MAP are between 2 261 and 2 804 tonnes. The entire range is considered precautionary when applying ICES advice rule. To ensure that the stock in FU 16 is exploited sustainably, management should be continued at the FU level.
nep.fu.17 (*Nephrops*)	Division 7.b, Functional Unit 17 (west of Ireland, Aran grounds)	**Summary:** Fishing pressure on the stock is below F$_{MSY}$, and stock size is below MSY B$_{trigger}$.		ICES advises that when the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 that correspond to the F ranges in the MAP are between 313 and 360 tonnes. To ensure that the stock in Functional Unit (FU) 17 is exploited sustainably, management should be implemented at the FU level.

Species	Area	Stock status	Advice 2021
nep.fu.19 (*Nephrops*)	Divisions 7.a, 7.g, and 7.j, Functional Unit 19 (Irish Sea, Celtic Sea, eastern part of southwest of Ireland)	**Summary:** Fishing pressure on the stock is below F_{MSY}, and stock size is below MSY $B_{trigger}$.	ICES advises that when the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 that correspond to the F ranges in the MAP are between 363 and 407 tonnes. To ensure that the stock in Functional Unit (FU) 19 is exploited sustainably, management should be implemented at the FU level.

Species	Area	Stock status		Advice 2021

nep.fu.2021
(*Nephrops*)

Divisions 7.g and 7.h, functional units 20 - 21 (Celtic Sea)

Fishing pressure

Stock size

Summary: Fishing pressure on the stock is below F_{MSY}, and stock size is above MSY $B_{trigger}$.

ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 1 978 tonnes.

To ensure that the stock in functional units (FUs) 20–21 is exploited sustainably, management should be implemented at the level of the combined FU 20–21.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 7. ICES considers this plan to be precautionary when implemented at the FU level.

Species	Area	Stock status		Advice 2021
nep.fu.22 (*Nephrops*)	Divisions 7.g and 7.f, Functional Unit 22 (Celtic Sea, Bristol Channel)	**Fishing pressure** nep.fu.22_2021_16794_2021920175027	**Stock size** nep.fu.22_2021_16794_2021920175027	ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 1 257 tonnes.

Summary: Fishing pressure on the stock is below F_{MSY}, and stock size is below MSY $B_{trigger}$.

To ensure that the stock in Functional Unit (FU) 22 is exploited sustainably, management should be implemented at the FU level.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 7. ICES considers this plan to be precautionary when implemented at the FU level.

| nep.27.7out FU* (*Nephrops*) | Subarea 7, outside the functional units (southern Celtic Seas, southwest of Ireland) |

		Fishing pressure				Stock size			
		2018	2019	2020		2018	2019	2020	
Maximum sustainable yield	F_{MSY}	?	?	?	Unknown	MSY $B_{trigger}$	?	?	?	Unknown
Precautionary approach	F_{pa}, F_{lim}	?	?	?	Unknown	B_{pa}, B_{lim}	?	?	?	Unknown
Management plan	F_{MGT}	—	—	—	Not applicable	B_{MGT}	—	—	—	Not applicable
Qualitative evaluation	-		?	?	?	Unknown	-		?	?	?	Unknown

ICES advises that when the precautionary approach is applied, landings should be no more than 150 tonnes in each of the years 2021, 2022, and 2023. ICES cannot quantify the corresponding total catches.

* Format of nep.27.7outFU differs from other stocks because the advice was published in 2020

3.3.2 Fisheries dependent data

Information on fisheries is supplied according to the WGMXIFSH data call in the form of "accessions" data, which provides disaggregated fleet data at the level of métier which are consistent with the definitions outlined in the DCF. This includes landings (in tonnes) for defined species and fishing effort (in KW days). This year there was a new data call for WGMIXFISH, which changed the format in which the data was requested. Although the new structure of the data call greatly increased the quality and consistency of data provided, there were still a number of member state specific issues which were not fixed in time for the advice meeting. These issues were resolved with input from expert knowledge during the working group but will require a full resubmission during the 2022 data call.

3.3.3 Discard data

Discard ratios were calculated from InterCatch discard estimates (either raw country submission or raised) and applied to the landings data supplied by member states in the WGMIXFISH data call. All discard estimates were retrieved from InterCatch and assigned to the same métiers within the WGMIXFISH accessions files. However, this method relies on being able to match métier definitions between the two datasets. The conformity of métiers in MIXFISH and Inter-Catch was generally high and improving year after year, but it was still not possible to match a few métiers. It would be desirable for countries to keep improving the consistency between data uploaded to InterCatch and data submitted to WGMIXFISH.

3.3.4 Defining fleet and métier

The above data sources are then combined to produce the "fleet object" which is used as an input into FCube. Within this object the fleets were defined by aggregating catch and effort across country, gear group, and vessel length (where applicable). Any fleet catching < 1% of any of the stocks included the analysis was binned into an "others" ("OTH") fleet to reduce the dimensions of the model. Effort and catch files were matched to ensure consistency, métiers with effort and no catch were aggregated to the OTH fleet. Within a fleet, a métier was defined as a combination of gear, target species (e.g. demersal fish, DEF, or crustaceans, CRU) and ICES subarea (e.g. 7.b). The final data used contained 28 fleets (country * gear grouping * vessel length category), and an "other" fleet (OTH), from three years (2018 to 2020) and a megrim fleet and anglerfish fleet, which account for the catch of megrim and anglerfish from the Bay of Biscay. Each fleet engages in several of 35 different métiers each (métier * area) catching the stocks incorporated into this model (Table 3.2 and 3.3). The combination of stocks landed by each metier varies greatly (Figure 3.2). Similar aggregating procedure as for the fleets was performed, where any métier catching < 10% of a fleets catch of any stock was aggregated into an "OTH" métier. This results in a large number of fleets and métier due to the diversity of activity in the Celtic Sea. The data is future aggregated by grouping the ICES divisions within the Celtics Sea into the following groups 7bc; 7e; 7.fg; 7hjk, this has a useful benefit of reducing run time, but also reveals the net contribution of "smaller" fleets in a manner that is more comparable for end users.

3.3.5 Quality control

As a quality control procedure, the total landings and discards across all fleets were compared to the values estimated from the single-species stock assessments

(*These metiers have been included in the model to capture the crossover between the Bay of Biscay for Megrim and Monkfish, catches not significant to contribute meaningfully to a DCF metier and the residual difference between WGMIXFISH data and the working group data.

Table 3.4. Proportion of the stocks total landings and discards (from WGCSE) covered by the MIXFISH fleets. A ratio >1 means that the catch information collated by MIXFISH is higher than the information used by WGCSE.

Year	stock	Working Group Landings (WGCSE, WGBIE)	Working Group Discards (WGCSE, WGBIE)	Ratio of Landings	Ratio of Discards	WGMIXFISH Landings	WGMIXFISH Discards
2018	cod.27.7e-k	1483.58472	315.1796	1	1	1483.58472	315.1796
2019	cod.27.7e-k	1068.68322	299.25998	1	0.922079139	1068.68322	324.5491274
2020	cod.27.7e-k	921.70062	231.41212	1	1	921.70062	231.41212
2018	sol.27.7fg	851.9613333	141.18	1	1	851.9613333	141.18
2019	sol.27.7fg	1067.313333	145.333	0.998811	0.999907768	1068.58388	145.3464055
2020	sol.27.7fg	1532.678	105.8	1	1	1532.678	105.8
2018	whg.27.7b-ce-k	9003.450064	2141.679127	1	0.998588716	9003.450064	2144.705916
2019	whg.27.7b-ce-k	6588.88471	969.8900454	1	0.996215224	6588.88471	973.5748082
2020	whg.27.7b-ce-k	5930.703877	1266.220614	1	0.987944059	5930.703877	1281.67238
2018	had.27.7b-k	7047.72412	5765.189417	1	1	7047.72412	5765.189417
2019	had.27.7b-k	7657.220449	3583.947484	1	1	7657.220449	3583.947484
2020	had.27.7b-k	7859.292971	4260.467734	1	0.853352896	7859.292971	4992.621168
2018	meg.27.7b-k8abd	14458.1374	2221.038246	1	1	14458.1374	2221.038246
2019	meg.27.7b-k8abd	13172.90566	1751.729001	1	1	13172.90566	1751.729001

Year	stock	Working Group Landings (WGCSE, WGBIE)	Working Group Discards (WGCSE, WGBIE)	Ratio of Landings	Ratio of Discards	WGMIXFISH Landings	WGMIXFISH Discards
2020	meg.27.7b-k8abd	10722.14021	1401.347826	1	1	10722.14021	1401.347826
2018	mon.27.78abd	22816.42032	1355.558898	1	1	22816.42032	1355.558898
2019	mon.27.78abd	20128.00647	1478.058085	0.983337821	1	20469.06569	1478.058085
2020	mon.27.78abd	21567.00311	1155.876304	1	0.691856943	21567.00311	1670.686861
2018	nep.out.7	200	0	0.992657423	NA	201.4793779	0
2019	nep.out.7	216	0	1	NA	216	0
2020	nep.out.7	304	0	1	NA	304	0
2018	nep.fu.22	1974.4871	335.6799294	1	1	1974.4871	335.6799294
2019	nep.fu.22	2083.079	262.2172968	1	1	2083.079	262.2172968
2020	nep.fu.22	1475.5514	278.1203536	0.996386501	0.9963865	1480.90264	279.1289861
2018	nep.fu.2021	1802.6034	381.0814484	1	1	1802.6034	381.0814484
2019	nep.fu.2021	2723.3739	538.7097445	0.977455375	0.977455376	2786.18745	551.1348731
2020	nep.fu.2021	413.2606	34.15655659	1	1	413.2606	34.15655659
2018	nep.fu.16	2750.6881	NA	1	NA	2750.6881	0
2019	nep.fu.16	2228.9663	NA	1	NA	2228.9663	0
2020	nep.fu.16	1877.10818	NA	0.974595975	NA	1926.03728	0
2018	nep.fu.17	536.4751	106.0465913	1	1	536.4751	106.0465913

Year	stock	Working Group Landings (WGCSE, WGBIE)	Working Group Discards (WGCSE, WGBIE)	Ratio of Landings	Ratio of Discards	WGMIXFISH Landings	WGMIXFISH Discards
2019	nep.fu.17	166.5352	20.85645473	0.99042612	0.990426123	168.145	21.05806203
2020	nep.fu.17	221.875	53.90266584	0.997114827	0.997114827	222.517	54.05863436
2018	cod.27.7e-k	1483.58472	315.1796	1	1	1483.58472	315.1796
2019	cod.27.7e-k	1068.68322	299.25998	1	0.922079139	1068.68322	324.5491274
2020	cod.27.7e-k	921.70062	231.41212	1	1	921.70062	231.41212

Some landings may not be allocated to fleets, due to issues such as missing countries or areas or national landings with missing logbook information that cannot be allocated to a fleet. The landings coverage for all fish stocks is very high (above 95% of landings of each fish stock for each of the years 2018–2020 could be allocated to one of the fleets). To address the remaining small inconsistencies between fleet data used by WGMIXFISH and stock data, the differences between them were pooled into an "OTH" fleet (both landings and discards) and two stock specific "OTH" fleets for Megrim and Monkfish. This is to account for the overlap for these species with the Bay of Biscay. During data processing a difference in UK landings for *Nephrops* was noted for Fu 16 and FU 20 -21 in 2019 between InterCatch data and WGMIXFISH data call. After cross checking with the UK data provider it was determined that the InterCatch values where in error. As such the value for landings for these FU was taken from the accessions data for 2019. The issue has since been resolved and is not a factor in the 2021 data submission.

3.4   Mixed fisheries forecasts

3.4.1   Description of scenarios

Baseline runs

The objectives of the single-species stock baseline runs were to:

1.   reproduce as closely as possible the single-species advice produced by ACOM,
2.   and act as the reference scenario for subsequent mixed fisheries analyses.

The various single-stock forecasts produced by the single species working groups are performed using different software and setups (see Section 3.2.1 above). The FCube model has been coded as a method in R 64bits (R Development Core Team, 2008), as part of the FLR framework (Kell *et al.*, 2007, www.flr-project.org). Input data are in the form of FLFleets and FLStocks objects from the FLCore 2.6.16 package, and two forecast methods were used, stf() from the FLAssess (version 2.6.3) and fwd() from the Flash (version 2.5.11) packages. Stock objects were processed using Fla4a (version 1.8.2), FLXSA (version 2.6.4), stockassessment (version 0.11.0). As such, the input parameterisation as well as the stock projections are made externally using existing methods and packages, while only 3 steps are internalised in the method, thus keeping full transparency and flexibility in the use of the model. In the mixed-fisheries runs, all forecasts were done with either the FLR forecast method or the stockassessment forecast() method for SAM stocks. This ensured greater coherence between the single stock and mixed fishery forecasts.

The same forecast settings as the single species assessment are used for each stock regarding weight-at-age, selectivity, and recruitment, as well as assumptions on the F in the intermediate year and basis for advice (MSY approach and Management plan). Some differences can occur in the forecast calculations, (because of the diversity of single-stock assessment methods used) and the WG always investigates in depth the reasons for potential discrepancies. Adjustments to the FCube forecasts are made if necessary to minimise discrepancies to the largest extent possible.

The baseline runs therefore acted as a quality control procedure to ensure that the projections were set up correctly within the FCube script. The baseline run has the additional benefit of acting as a quality control check on the projections produced by the single species stock assessors.

Mixed fisheries runs

Two changes were made in producing mixed fisheries scenarios for 2022 in comparison to those in 2021:

1.   An effort based intermediate year assumption (average effort 2018-2020) was used instead of the single stock advice assumption.

This was considered more consistent with a mixed-fishery fleet-based hypothesis for catch than using the divergent single stock approaches and provides the same functional link between fishing effort and fishing mortality across all stocks.

2.   For the stock targets in the FCube scenarios a fishing mortality consistent with the catch advice in the TAC year was used to drive the mixed fisheries scenarios. This is different from last year, where the fishing mortality consistent with the single stock catch advice was used.

The difference between the two is that last year under a stock limiting scenario it was possible to not achieve the single stock catch advice for that stock due to a different intermediate year assumption (and therefore stock size in the TAC year, hence different catch for a given F); this year you the catch advice is always achieved but it may result in a different fishing mortality to the single stock advice. This was considered more in line with a "implementation error" type approach, given the single stock catch advice is fixed and intermediate year uncertain and impacting the TAC year.

Due to the potential differences both approaches were explored during the working group, but the new approach was preferred and in line with the approach in other regions. Catch forecasts based on the original method are also provided in this report for comparison (tables 3.9-3.11).

FCube analyses of the intermediate year (2021)
For the mixed fisheries advice, the intermediate year assumption used was status quo fishing effort (average (2018-2020)), with FCube scenarios applied in the TAC year.

FCube analyses for the TAC year (2022)
Six scenarios were run, as outlined in Section 3.2.2 above, in addition to the 'range' scenario.

In summary, the FCube runs followed the scheme below:

```
Single-stock assessment 2021 (data up to 2020)

Management Plan/ MSY approach


Status quo fishing effort: av-              sq_E
erage (2018-2020)
2021
                                             ↓

        Catch in 2021 and SSB at start of 2022

Single-stock Management    FCUBE 2022
Plans applied to FCUBE
(sq_E) results

                    min      max     cod.27.7 e–k   had.27.7b–   whg.27.7b–   sq_E
        ↓                                            k            c e–k
                    ↓        ↓        ↓               ↓            ↓           ↓

        Potential Over / Under quota utilisation
        (Difference between single-species advise TAC and expected landings)
```
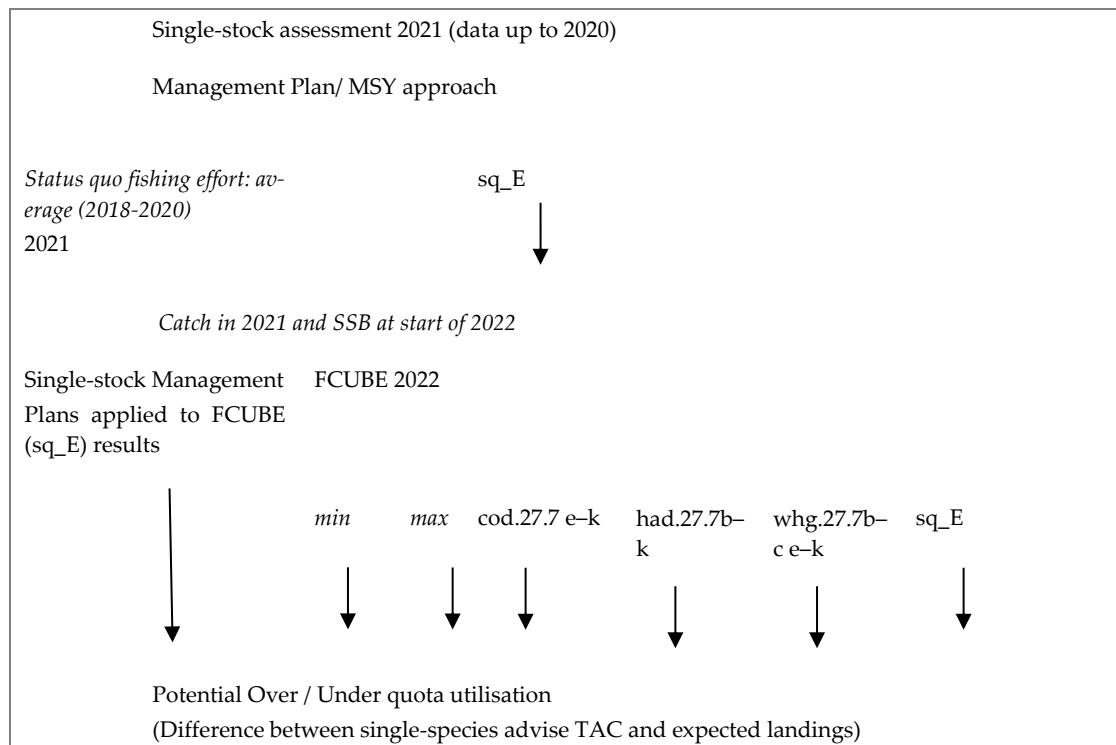
3.4.2   Results of FCube runs

Baseline run

Table 3.6 summaries the result of the baseline runs for each of the stocks included in the model. Figure 3.5 shows the required change in fishing mortality for each stock. This trend shows that cod requires the biggest reduction in F, indicating that the zero catch advice would lead to a choke for all the fisheries that catch cod. The results from these baseline runs are compared with the results from the corresponding ICES runs in Table 3.6 and summarised in Figure 3.6. The replicated forecast for cod, haddock, whiting and sole were replicated exactly, however some difference (<5%) were found when recreating anglerfish had small differences and megrim slightly larger.

Mixed fisheries analyses

Intermediate year

The full overview of the FCube projections to 2023 is presented in tables 3.7-3.9, Figure 3.7, and Figure 3.8. The results for 2022 can be compared to each other as in a single-species option table. For all baseline scenarios, WGMIXFISH assumed *status quo effort* in 2021.

TAC year FCube runs

The outcomes of the "minimum" and "maximum" scenarios are driven by which of the stocks will be most and least limiting for each individual fleet (Figure 3.9). The 2022 forecast with the cod catch advice at zero, implies that catches of all other stocks would also be zero ('min' scenario). Because the zero catch for cod results in the same outcome as the 'min' scenario, the cod scenario is not presented here. The 'max' scenario, leads to an overshoot for all stocks.

In order to provide a scenario with non-zero catch, a reduced cod F_{MSY} scenario is presented ('cod_F_{ARMSY}'). Applying the ICES Advice Rule (AR) gives an F (0.068) for cod and results in undershoots of all other stocks, as fishing is stopped when the cod quota is reached.

The 'max' scenario demonstrates the upper bound of potential fleet effort and stock catches, in that it assumes all fleets continue fishing until all their stock shares for haddock and whiting are exhausted, irrespective of the economic viability of such actions. The 'max' scenario demonstrates the upper bound of potential fleet effort and stock catches (Table 3.7, Figure 3.9), in that it assumes all fleets continue fishing until all their stock shares for all other stocks are exhausted, irrespective of the economic viability of such actions. In 2022, the 'max' scenario indicated that fleets have a number of least limiting stocks which results in over-quota catches of all other stocks (Figure 3.10). Anglerfish, megrim and *Nephrops* are the least limiting stocks for the highest number of fleets (4, 5 and 13 of the 24 fleets respectively,. It is important to note that the 'Sq_E' scenario shows catches higher than the 'max' scenario. This indicates that the current fishing effort is higher than available fishing opportunities for all three gadoid stocks, indicating other stocks may also play a role in driving effort dynamics in the fisheries.

Mixed fisheries catch scenarios can take specific management priorities into account, and these results indicate that it is not possible to achieve all single-species management objectives simultaneously. ICES single-stock advice for demersal stocks is based on ICES maximum sustainable yield (MSY) approach. Any catch of cod in 2022 is not considered precautionary as the stock is estimated to be and remain below B_{lim} (Table 3.9). The 'max' and 'Sq_E' scenarios result in whiting and haddock being fished above F_{MSY} in 2022 (Table 3.8). Whiting is also overfished in the 'haddock MSY approach'.

Scenarios that result in under- or overutilization are useful in identifying imbalance between the fishing opportunities of the various stocks. They indicate the direction in which fleets may have to adapt to fully utilise their catch opportunities without collectively exceeding single-stock fishing opportunities. Under the scenarios presented here, the 'max' scenario suggests that if all fleets' stock shares are to be fully utilised, catches of all other stocks would be considerably higher than advised in the single-stock advice. As all fleets catch cod to a greater or lesser extent, any fishing effort directed at catching haddock or whiting is likely to result in catches of cod above the single-stock advice (zero catch), with any catch of cod above the single-stock advice considered not precautionary. The 'cod_F_{ARMSY}' scenario, where the cod TAC is set at reduced F_{MSY}, results in catches of cod, and in underutilizations of both the haddock and whiting single-stock TACs.

Of the presented scenarios, the 'min' and 'range' scenarios meet the objective of all stocks being fished at or below F_{MSY}. In contrast to single-stock advice there is no single recommendation from this advice, instead a range of scenarios are presented. The ICES single-stock advice provides catch opportunities consistent with the ICES MSY approach. To be consistent with these objectives a scenario is necessary that delivers the SSB and/or F objectives of the single-stock advice for all stocks considered simultaneously. This is not possible in 2022 due to the cod stock being $< B_{lim}$ in 2023, even with a zero cod catch in 2022 and any fisheries for haddock and whiting likely to result in some catches of cod.

The 'min' scenario assumes that fishing stops when the catch for any one of the stocks meets the fleet's stock share. This is similar to the full implementation of the Landing Obligation. Supporting measures aimed at minimizing the misalignment between activity and stock shares for the fleets, such as changes in gear selectivity, spatiotemporal management measures, or reallocation of stock shares, may be required if fishing opportunities are to be fully taken under a fully implemented landing obligation.

Optimised range option

A "range" scenario is presented (Figure 3.11), this scenario as described in Ulrich *et al*. (2017) searches for the minimum sum of differences between potential catches by stock under the 'min' and the 'max' scenarios within the F_{MSY} ranges. The outcomes of this scenario are driven by the restrictive nature of the cod advice this year, with the minimum of the F_{MSY} range advice for haddock and whiting resulting from the need to reduce cod catches to a minimum. Other 'range' scenarios could be computed in the future, for example scenarios minimizing the potential for discarding (e.g. catching unwanted catch) or maximizing fleets' revenue or profit.

Relative stability

Relative stability as such is not directly included as an input to the model. Instead, an assumption that the relative landings share of the fleets are constant is used as a proxy, and in the scenarios above, this input is calculated as the average (2018-2020) landing share by fleet and stock. As a crosscheck, the landings by national fleets were summed over nation for each scenario, and the share by country was compared with this initial input (Figure 3.10). The results show some deviations across all scenarios which arise because (under the assumption of a full discard ban), fleets with a small share of a stock but high discard rate have their fishing activity limited by that stock, resulting in underutilization of their target stock(s) This can translate to underutilization at the national level, as seen by the change in landings share of the stocks by EU Member States in the mixed fisheries forecasts.

3.4.3 EU Technical request for zero catch advice stocks

In addition to the standard mixed fisheries scenarios ICES are asked to provide advice on potential catches of zero catch advice stocks given fishing opportunities for target stocks. For Celtic Sea cod, four additional scenarios were provided using the Celtic Sea mixed fishery model. Including catches:

1. Based on haddock fished at F_{MSY}
2. Based on haddock fished at F_{MSY} lower
3. Based on haddock fished at an intermediate level between F_{MSY} and F_{MSY} lower
4. Based on whiting fished at the reduced F_{MSY} level.

The level of catches (2022), fishing mortality (2022) and spawning stock biomass (2023) under each of these scenarios are provided in Tables 3.13-3.15.

The predicted catches under each of these scenarios depends on the assumption of catchability for cod compared to the target stocks. Catchability can change owing to implementation of technical measures such as gear changes or spatial measures or through differences in targeting behaviour by fishers. It is not possible to predict the effects of such measures, but by way of illustration the effect on catches, fishing mortality and SSB reductions in catchability for cod is provided under each of the four scenarios above (Figure 3.13).

Table 3.2. Celtic Sea. Summary of the 2022 ICES single-species advice. Target Fs are left justified; harvest ratios are right justified. Where a stock/Functional Unit does not have a management plan the landings follow ICES advice.

Species	Agreed TAC (summed TACs) 2021	Total Catch-advice for 2022	Projected landings-advice for 2022	F_{total}/Harvest ratio for 2022	F_{wanted}/ Harvest ratio for 2022	SSB 2022	SSB 2023	Rational
Cod 7. e–k	805*	0	0	0	0	1354	3449	MSY
Haddock 7.b–k	15000**	15946	11885	0.35	0.28	62437	56747	MAP
Whiting 7.bc, 7. e–k	8288***	4452	3539	0.228	0.189	30856	37372	MAP
Megrim 7.b–k, 8.a–b, 8.d	20526****	22964	20152	0.191	n/a	136377	138512	MAP
White anglerfish 7, 8.a-b, 8.d	44307	34275	32953	0.28	0.28	70972	82203	MAP
Sole 7.fg	1413	1337	1261	0.251	0.24	5953	5719	MAP
Nephrops FU16	3290 *****	2804	2804	6.2^	n/a	1018		MAP
Nephrops FU17	18026******	360	303	5.2^	n/a	331		MAP
Nephrops FU19	18026******	407	286	5.8^	n/a	270		MAP
Nephrops FU20-21	18026******	1978	1703	6.0^	n/a	1202		MSY
Nephrops FU22	18026******	1257	1083	8.5^	n/a	656		MSY
Nephrops 7 outside FU	18026******	150	150					n/a

* TAC applies to divisions 7.b–c and 7.e–k, subareas 8–10, and EU waters of CECAF 34.1.1.

** TAC applies to divisions 7.b–k and subareas 8–10.

*** TAC applies to Subarea 7 (except Division 7.a)

**** TAC Includes *L. boscii* and divisions 7.a and 8.e

***** '*of which limit*' from the total Subarea 7 TAC

****** TAC applies to whole of Subarea 7

^ Harvest ratio for Projected landings + Projected dead discards

Table 3.3. Celtic Sea. Métiers consistent with DCF métier level 5 and additional metiers in the model

Mixed-fisheries métiers	Gear	Target species
FPO_CRU	Pots	Crustaceans
GNS_DEF	Gillnets	Demersal fish
GTR_DEF	Trammel nets	Demersal fish
MIS_MIS	Miscellaneous	Any
OTH	Other gears	Any
OTB_DEF	Otter trawls	Demersal fish
OTT_DEF	Twin otter trawls	Demersal fish
OTB_CRU	Otter trawls	Crustaceans
OTT_CRU	Twin otter trawls	Crustaceans
SSC_DEF	Scottish seines	Demersal fish
TBB_DEF	Beam trawls	Demersal fish
Mixed-fisheries additional métiers*		
"meg.27.7b-k8abd_metier"	mixed	Demersal fish
"mon.27.78abd_metier"	Mixed	Demersal fish
"Other_Metier"	Mixed	All
"residual_metier"	mixed	All

*These metiers have been included in the model to capture the crossover between the Bay of Biscay for Megrim and Monkfish, catches not significant to contribute meaningfully to a DCF metier and the residual difference between WGMIXFISH data and the working group data.

Table 3.4. Proportion of the stocks total landings and discards (from WGCSE) covered by the MIXFISH fleets. A ratio >1 means that the catch information collated by MIXFISH is higher than the information used by WGCSE.

Year	stock	Working Group Landings (WGCSE, WGBIE)	Working Group Discards (WGCSE, WGBIE)	Ratio of Landings	Ratio of Discards	WGMIXFISH Landings	WGMIXFISH Discards
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2019	cod.27.7e-k	1068.68322	299.25998	1	0.922079139	1068.68322	324.5491274
2020	cod.27.7e-k	921.70062	231.41212	1	1	921.70062	231.41212
2018	sol.27.7fg	851.9613333	141.18	1	1	851.9613333	141.18
2019	sol.27.7fg	1067.313333	145.333	0.998811	0.999907768	1068.58388	145.3464055
2020	sol.27.7fg	1532.678	105.8	1	1	1532.678	105.8
2018	whg.27.7b-ce-k	9003.450064	2141.679127	1	0.998588716	9003.450064	2144.705916
2019	whg.27.7b-ce-k	6588.88471	969.8900454	1	0.996215224	6588.88471	973.5748082
2020	whg.27.7b-ce-k	5930.703877	1266.220614	1	0.987944059	5930.703877	1281.67238
2018	had.27.7b-k	7047.72412	5765.189417	1	1	7047.72412	5765.189417
2019	had.27.7b-k	7657.220449	3583.947484	1	1	7657.220449	3583.947484
2020	had.27.7b-k	7859.292971	4260.467734	1	0.853352896	7859.292971	4992.621168
2018	meg.27.7b-k8abd	14458.1374	2221.038246	1	1	14458.1374	2221.038246
2019	meg.27.7b-k8abd	13172.90566	1751.729001	1	1	13172.90566	1751.729001
2020	meg.27.7b-k8abd	10722.14021	1401.347826	1	1	10722.14021	1401.347826
2018	mon.27.78abd	22816.42032	1355.558898	1	1	22816.42032	1355.558898

Year	stock	Working Group Landings (WGCSE, WGBIE)	Working Group Discards (WGCSE, WGBIE)	Ratio of Landings	Ratio of Discards	WGMIXFISH Landings	WGMIXFISH Discards
2019	mon.27.78abd	20128.00647	1478.058085	0.983337821	1	20469.06569	1478.058085
2020	mon.27.78abd	21567.00311	1155.876304	1	0.691856943	21567.00311	1670.686861
2018	nep.out.7	200	0	0.992657423	NA	201.4793779	0
2019	nep.out.7	216	0	1	NA	216	0
2020	nep.out.7	304	0	1	NA	304	0
2018	nep.fu.22	1974.4871	335.6799294	1	1	1974.4871	335.6799294
2019	nep.fu.22	2083.079	262.2172968	1	1	2083.079	262.2172968
2020	nep.fu.22	1475.5514	278.1203536	0.996386501	0.9963865	1480.90264	279.1289861
2018	nep.fu.2021	1802.6034	381.0814484	1	1	1802.6034	381.0814484
2019	nep.fu.2021	2723.3739	538.7097445	0.977455375	0.977455376	2786.18745	551.1348731
2020	nep.fu.2021	413.2606	34.15655659	1	1	413.2606	34.15655659
2018	nep.fu.16	2750.6881	NA	1	NA	2750.6881	0
2019	nep.fu.16	2228.9663	NA	1	NA	2228.9663	0
2020	nep.fu.16	1877.10818	NA	0.974595975	NA	1926.03728	0
2018	nep.fu.17	536.4751	106.0465913	1	1	536.4751	106.0465913
2019	nep.fu.17	166.5352	20.85645473	0.99042612	0.990426123	168.145	21.05806203
2020	nep.fu.17	221.875	53.90266584	0.997114827	0.997114827	222.517	54.05863436

Year	stock	Working Group Landings (WGCSE, WGBIE)	Working Group Discards (WGCSE, WGBIE)	Ratio of Landings	Ratio of Discards	WGMIXFISH Landings	WGMIXFISH Discards
2018	cod.27.7e-k	1483.58472	315.1796	1	1	1483.58472	315.1796
2019	cod.27.7e-k	1068.68322	299.25998	1	0.922079139	1068.68322	324.5491274
2020	cod.27.7e-k	921.70062	231.41212	1	1	921.70062	231.41212

Table 3.5. Comparison between FCube baseline run and ICES advice. Figures for 2021 compare results from the baseline run to the ICES intermediate year results. The baseline run uses the same assumptions for F in the intermediate year as the forecasts leading to ICES advice.

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2021	cod.27.7e-k	catch	1881	1881	0
2021	cod.27.7e-k	Fbar	1.23	1.23	0.1
2021	cod.27.7e-k	Recruitment	NA	1526	NA
2021	cod.27.7e-k	ssb	1710	1710	0
2021	had.27.7b-k	catch	15291	15291	0
2021	had.27.7b-k	Fbar	0.32	0.32	0
2021	had.27.7b-k	Recruitment	NA	312600	NA
2021	had.27.7b-k	ssb	71393	71393	0
2021	meg.27.7b-k8abd	catch	20579	20682	-0.5
2021	meg.27.7b-k8abd	Fbar	0.19	0.19	0
2021	meg.27.7b-k8abd	Recruitment	NA	NA	NA
2021	meg.27.7b-k8abd	ssb	126779	126311	0.4
2021	mon.27.78abd	catch	28676	28882	-0.7
2021	mon.27.78abd	Fbar	0.25	0.25	0
2021	mon.27.78abd	Recruitment	NA	NA	NA
2021	mon.27.78abd	ssb	64190	64190	0
2021	nep.fu.16	catch	3569	3290	8.5
2021	nep.fu.16	discards	0	0	NaN
2021	nep.fu.16	discards.dead	0	0	NaN
2021	nep.fu.16	discards.surviving	0	0	NaN
2021	nep.fu.16	Fbar	0	0.06	-98.4
2021	nep.fu.16	landings	3569	3290	8.5
2021	nep.fu.16	Recruitment	NA	NA	NA
2021	nep.fu.16	ssb	NA	1264	NA
2021	nep.fu.17	catch	422	508	-16.9
2021	nep.fu.17	discards	0	72	-100
2021	nep.fu.17	discards.dead	0	54	-100

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2021	nep.fu.17	discards.surviving	0	18	-100
2021	nep.fu.17	Fbar	0	0.06	-95.2
2021	nep.fu.17	landings	422	436	-3.2
2021	nep.fu.17	Recruitment	NA	NA	NA
2021	nep.fu.17	ssb	NA	394	NA
2021	nep.fu.19	catch	473	595	-20.5
2021	nep.fu.19	discards	0	156	-100
2021	nep.fu.19	discards.dead	0	117	-100
2021	nep.fu.19	discards.surviving	0	39	-100
2021	nep.fu.19	Fbar	0	0.07	-95.7
2021	nep.fu.19	landings	473	439	7.7
2021	nep.fu.19	Recruitment	NA	NA	NA
2021	nep.fu.19	ssb	NA	320	NA
2021	nep.fu.2021	catch	786	1710	-54
2021	nep.fu.2021	discards	0	281	-100
2021	nep.fu.2021	discards.dead	0	211	-100
2021	nep.fu.2021	discards.surviving	0	70	-100
2021	nep.fu.2021	Fbar	0	0.06	-98.3
2021	nep.fu.2021	landings	786	1430	-45
2021	nep.fu.2021	Recruitment	NA	NA	NA
2021	nep.fu.2021	ssb	NA	1020	NA
2021	nep.fu.22	catch	2806	1560	79.9
2021	nep.fu.22	discards	0	188	-100
2021	nep.fu.22	discards.dead	0	141	-100
2021	nep.fu.22	discards.surviving	0	47	-100
2021	nep.fu.22	Fbar	0	0.1	-99
2021	nep.fu.22	landings	2806	1371	104.7
2021	nep.fu.22	Recruitment	NA	NA	NA
2021	nep.fu.22	ssb	NA	750	NA

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2021	nep.out.7	catch	578	150	285.3
2021	nep.out.7	discards	0	NA	NA
2021	nep.out.7	discards.dead	NA	NA	NA
2021	nep.out.7	discards.surviving	NA	NA	NA
2021	nep.out.7	Fbar	NaN	NA	NaN
2021	nep.out.7	landings	578	150	285.3
2021	nep.out.7	Recruitment	NA	NA	NA
2021	nep.out.7	ssb	NA	NA	NA
2021	sol.27.7fg	catch	1413	1413	0
2021	sol.27.7fg	Fbar	0.26	0.26	0
2021	sol.27.7fg	Recruitment	NA	5055	NA
2021	sol.27.7fg	ssb	6138	6138	0
2021	whg.27.7b-ce-k	catch	8678	8678	0
2021	whg.27.7b-ce-k	Fbar	0.49	0.49	0
2021	whg.27.7b-ce-k	Recruitment	NA	NA	NA
2021	whg.27.7b-ce-k	ssb	28381	28381	0
2022	cod.27.7e-k	catch	0	0	NaN
2022	cod.27.7e-k	Fbar	0	0	NaN
2022	cod.27.7e-k	Recruitment	NA	1488	NA
2022	cod.27.7e-k	ssb	1354	1354	0
2022	had.27.7b-k	catch	15946	15946	0
2022	had.27.7b-k	Fbar	0.35	0.35	0
2022	had.27.7b-k	Recruitment	NA	245785	NA
2022	had.27.7b-k	ssb	62437	62437	0
2022	meg.27.7b-k8abd	catch	23559	22964	2.6
2022	meg.27.7b-k8abd	Fbar	0.19	0.19	-0.5
2022	meg.27.7b-k8abd	Recruitment	NA	NA	NA
2022	meg.27.7b-k8abd	ssb	139961	136377	2.6
2022	mon.27.78abd	catch	34176	34275	-0.3

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2022	mon.27.78abd	Fbar	0.28	0.28	0
2022	mon.27.78abd	Recruitment	NA	NA	NA
2022	mon.27.78abd	ssb	70972	70972	0
2022	nep.fu.16	catch	2804	2804	0
2022	nep.fu.16	discards	0	0	NaN
2022	nep.fu.16	discards.dead	0	0	NaN
2022	nep.fu.16	discards.surviving	0	0	NaN
2022	nep.fu.16	Fbar	0.06	0.06	0
2022	nep.fu.16	landings	2804	2804	0
2022	nep.fu.16	Recruitment	NA	NA	NA
2022	nep.fu.16	ssb	NA	1018	NA
2022	nep.fu.17	catch	360	360	0
2022	nep.fu.17	discards	57	56	1.8
2022	nep.fu.17	discards.dead	42	42	0
2022	nep.fu.17	discards.surviving	14	14	0
2022	nep.fu.17	Fbar	0.05	0.05	0
2022	nep.fu.17	landings	303	303	0
2022	nep.fu.17	Recruitment	NA	NA	NA
2022	nep.fu.17	ssb	NA	331	NA
2022	nep.fu.19	catch	407	407	0
2022	nep.fu.19	discards	121	120	0.8
2022	nep.fu.19	discards.dead	90	90	0
2022	nep.fu.19	discards.surviving	30	30	0
2022	nep.fu.19	Fbar	0.06	0.06	0
2022	nep.fu.19	landings	286	286	0
2022	nep.fu.19	Recruitment	NA	NA	NA
2022	nep.fu.19	ssb	NA	270	NA
2022	nep.fu.2021	catch	1978	1978	0
2022	nep.fu.2021	discards	275	275	0

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2022	nep.fu.2021	discards.dead	206	206	0
2022	nep.fu.2021	discards.surviving	69	69	0
2022	nep.fu.2021	Fbar	0.06	0.06	0
2022	nep.fu.2021	landings	1703	1703	0
2022	nep.fu.2021	Recruitment	NA	NA	NA
2022	nep.fu.2021	ssb	NA	1202	NA
2022	nep.fu.22	catch	1257	1257	0
2022	nep.fu.22	discards	174	173	0.6
2022	nep.fu.22	discards.dead	130	130	0
2022	nep.fu.22	discards.surviving	43	43	0
2022	nep.fu.22	Fbar	0.09	0.09	0
2022	nep.fu.22	landings	1083	1083	0
2022	nep.fu.22	Recruitment	NA	NA	NA
2022	nep.fu.22	ssb	NA	656	NA
2022	nep.out.7	catch	150	150	0
2022	nep.out.7	discards	0	NA	NA
2022	nep.out.7	discards.dead	NA	NA	NA
2022	nep.out.7	discards.surviving	NA	NA	NA
2022	nep.out.7	Fbar	NaN	NA	NaN
2022	nep.out.7	landings	150	150	0
2022	nep.out.7	Recruitment	NA	NA	NA
2022	nep.out.7	ssb	NA	NA	NA
2022	sol.27.7fg	catch	1334	1337	-0.2
2022	sol.27.7fg	Fbar	0.25	0.25	0
2022	sol.27.7fg	Recruitment	NA	5218	NA
2022	sol.27.7fg	ssb	5961	5953	0.1
2022	whg.27.7b-ce-k	catch	4452	4452	0
2022	whg.27.7b-ce-k	Fbar	0.23	0.23	0
2022	whg.27.7b-ce-k	Recruitment	NA	NA	NA

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2022	whg.27.7b-ce-k	ssb	30856	30856	0
2023	cod.27.7e-k	Recruitment	NA	1488	NA
2023	cod.27.7e-k	ssb	3449	3449	0
2023	had.27.7b-k	Recruitment	NA	245785	NA
2023	had.27.7b-k	ssb	56747	56747	0
2023	meg.27.7b-k8abd	Recruitment	NA	NA	NA
2023	meg.27.7b-k8abd	ssb	144163	138512	4.1
2023	mon.27.78abd	Recruitment	NA	NA	NA
2023	mon.27.78abd	ssb	82203	82203	0
2023	sol.27.7fg	Recruitment	NA	5218	NA
2023	sol.27.7fg	ssb	5726	5719	0.1
2023	whg.27.7b-ce-k	Recruitment	NA	NA	NA
2023	whg.27.7b-ce-k	ssb	37372	37372	0

Table 3.6. Mixed-fisheries advice in the Celtic Sea. Catch (in tonnes) per mixed-fisheries scenario 2022, in absolute values.

Stock	Single_Stock_Advice	MAX	MIN_	sqE	COD_fmsy reduced	HAD	WHG
cod.27.7e-k	0	1775	0	1536	132	1543	834
had.27.7b-k	15946	19996	0	16281	1040	15899	7195
meg.27.7b-k8abd	22964	27832	5446	23015	6882	20691	12341
mon.27.78abd	34275	39775	2905	31701	4812	29742	15746
sol.27.7fg	1337	1615	0	1332	71	601	314
whg.27.7b-ce-k	4452	11187	0	9104	635	9240	4310
nep.fu.16	2804	3443	0	2113	116	2172	880
nep.fu.17	360	291	0	190	10	194	83
nep.fu.19	407	307	0	225	11	233	104
nep.fu.2021	1978	2639	0	1958	108	1880	870
nep.fu.22	1257	1967	0	1340	72	1361	586
nep.out.7	150	210	0	141	8	142	61

Table 3.7. Mixed-fisheries advice in the Celtic Sea. Fishing mortality per mixed-fisheries scenario 2022, in absolute values.

Stock	Single_Stock_Advice	MAX	MIN	sqE	COD_fmsy reduced	HAD	WHG
cod.27.7e-k	0	1.616	0	1.232	0.067	1.243	0.511
had.27.7b-k	0.353	0.493	0	0.385	0.021	0.374	0.154
meg.27.7b-k8abd	0.191	0.23	0.041	0.186	0.052	0.166	0.096
mon.27.78abd	0.28	0.335	0.021	0.258	0.035	0.24	0.12
sol.27.7fg	0.251	0.311	0	0.249	0.012	0.105	0.053
whg.27.7b-ce-k	0.228	0.749	0	0.571	0.032	0.582	0.236
nep.fu.16	0.062	0.076	0	0.047	0.003	0.048	0.019
nep.fu.17	0.052	0.044	0	0.029	0.002	0.029	0.012
nep.fu.19	0.058	0.05	0	0.036	0.002	0.038	0.017
nep.fu.2021	0.06	0.085	0	0.063	0.003	0.06	0.028
nep.fu.22	0.085	0.141	0	0.096	0.005	0.097	0.042
nep.out.7	NA	NA	NA	NA	NA	NA	NA

Table 3.8. Mixed-fisheries advice in the Celtic Sea. Spawning Stock Biomass per mixed-fisheries scenario 2023, in absolute values.

Stock	SSB_2023	MAX	MIN	sqE	COD_fmsy reduced	HAD	WHG
cod.27.7e-k	3449	880	3446	1200	3246	1189	2199
had.27.7b-k	56747	49606	71727	53528	70578	53919	63522
meg.27.7b-k8abd	138512	139749	163365	144816	161845	147262	156072
mon.27.78abd	82203	77983	103726	83561	102379	84919	94684
sol.27.7fg	5719	5455	7160	5750	7086	6521	6828
whg.27.7b-ce-k	37372	31007	40420	32676	39837	32565	36684

Table 3.9. Mixed-fisheries advice in the Celtic Sea (Alternative run: not used for advice). Catch (in tonnes) per mixed-fisheries scenario 2022, in absolute values.

Stock	Single_Stock_Advice	MAX	MIN	sqE	COD_fmsy reduced	HAD	WHG
cod.27.7e-k	0	1774	0	1536	133	1493	811
had.27.7b-k	15946	20021	0	16281	1050	15140	6959
meg.27.7b-k8abd	22964	27990	5601	23015	6892	19907	12121
mon.27.78abd	34275	39747	2873	31701	4830	28513	15389
sol.27.7fg	1337	1623	0	1332	72	569	303

Stock	Single_Stock_Advice	MAX	MIN	sqE	COD_fmsy reduced	HAD	WHG
whg.27.7b-ce-k	4452	11190	0	9104	642	8830	4174
nep.fu.16	2804	3447	0	2113	118	2050	849
nep.fu.17	360	291	0	190	10	183	80
nep.fu.19	407	307	0	225	11	220	100
nep.fu.2021	1978	2644	0	1958	110	1774	839
nep.fu.22	1257	1969	0	1340	73	1285	565
nep.out.7	150	210	0	141	8	134	59

Table 3.10. Mixed-fisheries advice in the Celtic Sea (<u>Alternative run: not used for advice</u>). Fishing mortality per mixed-fisheries scenario 2022, in absolute values.

Stock	Single_Stock_Advice	MAX	MIN	sqE	COD_F_{MSY} reduced	HAD	WHG
cod.27.7e-k	0	1.614	0	1.232	0.068	1.174	0.493
had.27.7b-k	0.353	0.494	0	0.385	0.021	0.353	0.149
meg.27.7b-k8abd	0.191	0.231	0.042	0.186	0.052	0.159	0.094
mon.27.78abd	0.28	0.335	0.021	0.258	0.036	0.229	0.118
sol.27.7fg	0.251	0.313	0	0.249	0.012	0.099	0.051
whg.27.7b-ce-k	0.228	0.749	0	0.571	0.032	0.549	0.228
nep.fu.16	0.062	0.076	0	0.047	0.003	0.045	0.019
nep.fu.17	0.052	0.044	0	0.029	0.002	0.028	0.012
nep.fu.19	0.058	0.05	0	0.036	0.002	0.036	0.016
nep.fu.2021	0.06	0.085	0	0.063	0.004	0.057	0.027
nep.fu.22	0.085	0.141	0	0.096	0.005	0.092	0.04
nep.out.7	NA	NA	NA	NA	NA	NA	NA

Table 3.11. Mixed-fisheries advice in the Celtic Sea (<u>Alternative run: not used for advice</u>). Spawning Stock Biomass per mixed-fisheries scenario 2023, in absolute values.

Stock	SSB_2023	MAX	MIN	sqE	COD_F_{MSY}_reduced	HAD	WHG
cod.27.7e-k	3449	882	3446	1200	3244	1259	2232
had.27.7b-k	56747	49587	71727	53528	70562	54738	63812
meg.27.7b-k8abd	138512	139583	163201	144816	161835	148089	156305
mon.27.78abd	82203	78002	103749	83561	102366	85773	94934
sol.27.7fg	5719	5446	7160	5750	7085	6556	6841
whg.27.7b-ce-k	37372	31006	40420	32676	39832	32892	36802

Table 3.12. Mixed-fisheries advice in the Celtic Sea (Technical request). Catch (in tonnes) per mixed-fisheries scenario 2022, in absolute values.

Stock	Single-stock catch advice (2022)	Catch per mixed-fisheries scenario (2022)			
		Haddock F_{MSY}	Haddock $F_{MSY\ lower}$	Haddock $F_{MSY\ lower}$ – F_{MSY}	Whiting F_{MSY}
cod.27.7e–k	0	1498	1109	1321	814
had.27.7b–k	15946	15166	10053	12671	6979
meg.27.7b–k8abd	22964	19907	14856	17407	12121
mon.27.78abd	34275	28513	20489	24566	15389
sol.27.7fg	1337	570	363	467	303
whg.27.7b–ce–k	4452	8813	5992	7463	4167
nep.fu.16	2804	2050	1284	1667	849
nep.fu.17	360	183	115	149	80
nep.fu.19	407	220	138	179	100
nep.fu.2021	1978	1774	1111	1443	839
nep.fu.22	1257	1285	804	1045	565
nep.out.7	150	134	84	109	59

Table 3.13. Mixed-fisheries advice in the Celtic Sea (Technical request). TAC year (2022) fishing mortality per mixed-fisheries scenario 2022, in absolute values.

Stock	Single-stock F advice (2022)	Fishing mortality per mixed-fisheries scenario (2022)			
		Haddock F_{MSY}	Haddock $F_{MSY\ lower}$	Haddock $F_{MSY\ lower} - F_{MSY}$	Whiting F_{MSY}
cod.27.7e–k	0.000	1.174	0.74	0.957	0.493
had.27.7b–k	0.353	0.353	0.221	0.287	0.149
meg.27.7b–k8abd	0.191	0.159	0.116	0.138	0.094
mon.27.78abd	0.28	0.229	0.16	0.194	0.118
sol.27.7fg	0.251	0.099	0.062	0.08	0.051
whg.27.7b–ce–k	0.228	0.549	0.344	0.447	0.228
nep.fu.16	0.062	0.045	0.028	0.037	0.019
nep.fu.17	0.052	0.028	0.017	0.022	0.012
nep.fu.19	0.058	0.036	0.022	0.029	0.016
nep.fu.2021	0.06	0.057	0.036	0.046	0.027
nep.fu.22	0.085	0.092	0.058	0.075	0.04

Table 3.14. Mixed-fisheries advice in the Celtic Sea (Technical request). TAC year + 1 (2023) SSB per mixed-fisheries scenario 2022, in absolute values.

| Stock	Single-stock advice SSB (2023)	Spawning-stock biomass (2023)			
		Haddock F_{MSY}	Haddock $F_{MSY\ lower}$	Haddock $F_{MSY\ lower} - F_{MSY}$	Whiting F_{MSY}
cod.27.7e–k	3449	1262	1812	1509	2242
had.27.7b–k	56747	55101	60639	57785	63977
meg.27.7b–k8abd	138512	148089	153417	150725	156305
mon.27.78abd	82203	85773	91363	88519	94934
sol.27.7fg	5719	6552	6770	6660	6834
whg.27.7b–ce–k	37372	32924	35249	34025	36791

Total Landings by Stock
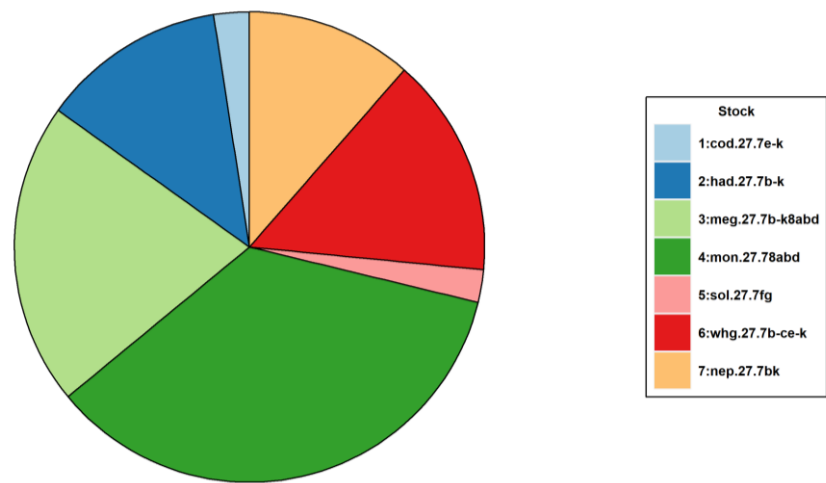
Figure 3.1. Celtic Sea. Distribution of landings of those stocks included in the mixed fisheries projections.

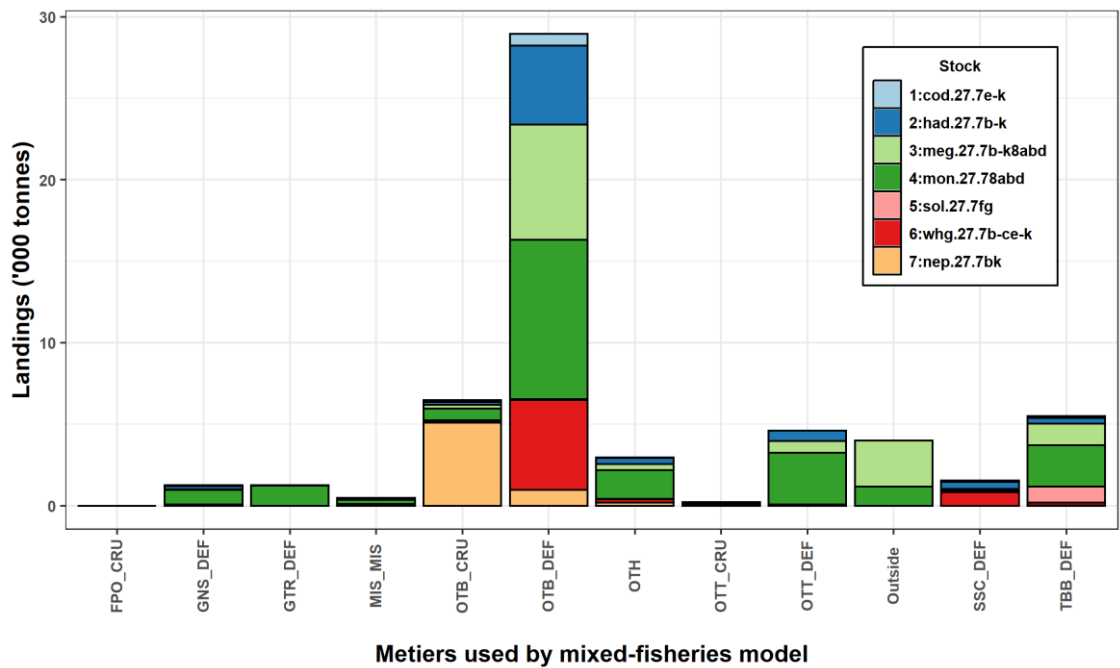

Figure 3.2. Celtic Sea. Landings distribution of species by métier with landings consisting of ≥ 1% of any of the stocks (1-7)(average from 2018-2020) Note: The "other" (OTH) displayed here is a mixed category consisting of (i) landings without corresponding effort and (ii) landings of any combination of fleet and métier with landings < 1% of any of the stocks 1–7)(average from 2018-2020).
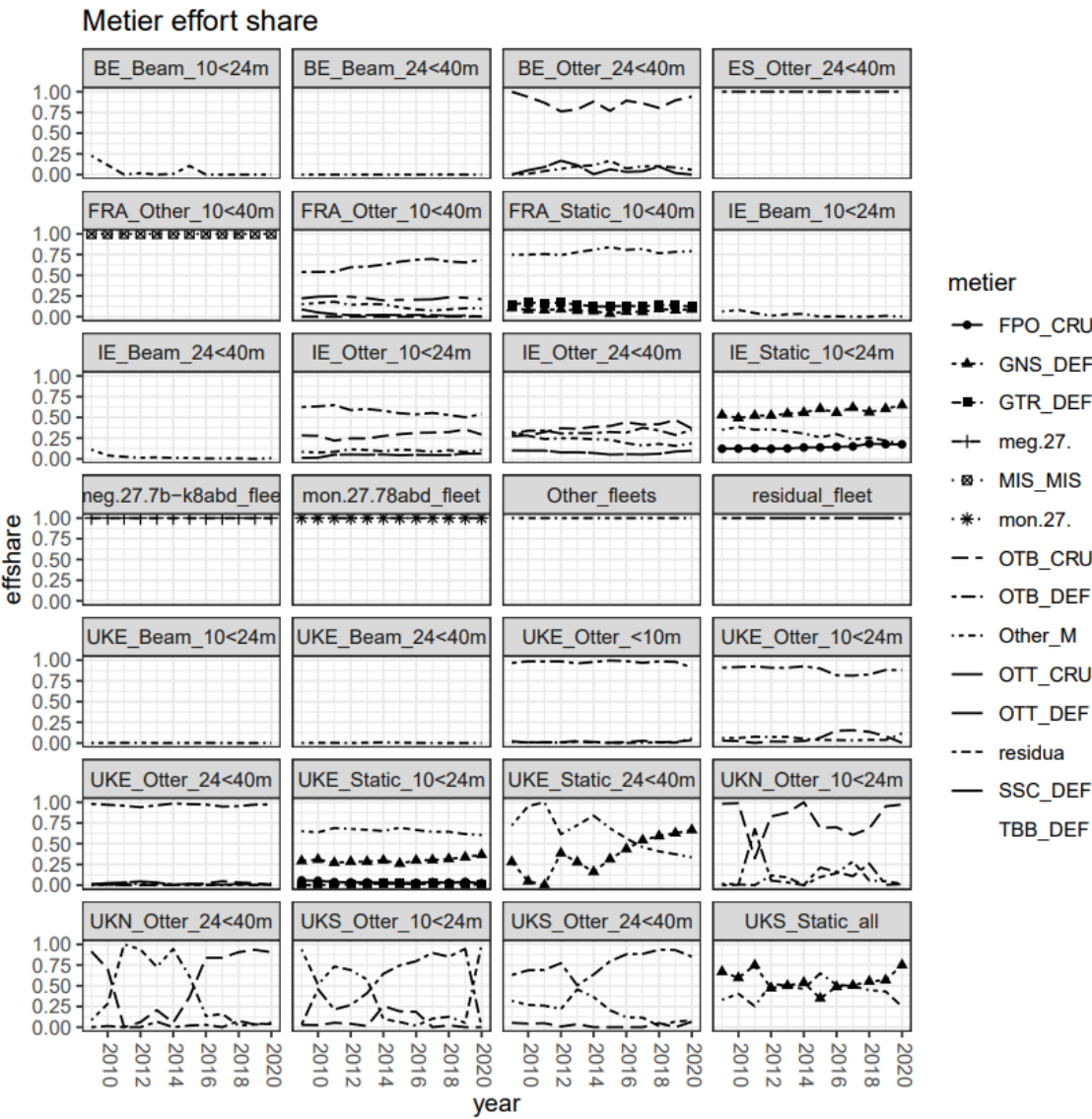
Metier effort share

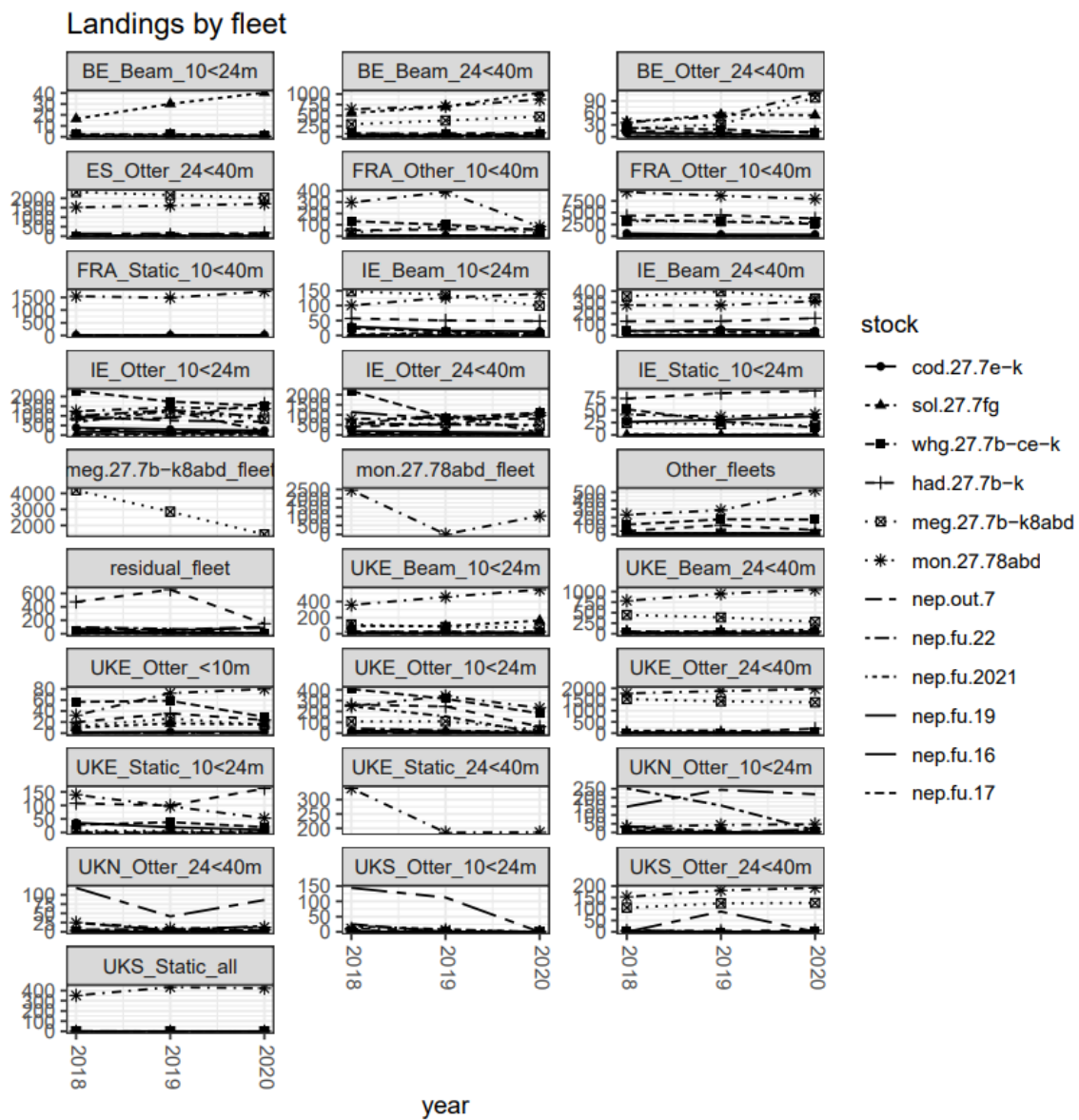Figure 3.3. Effort share (in proportion) by métier and by year for each fleet.

Figure 3.4. Landings by fleet, stock and year. Note: different scales on the y-axis.
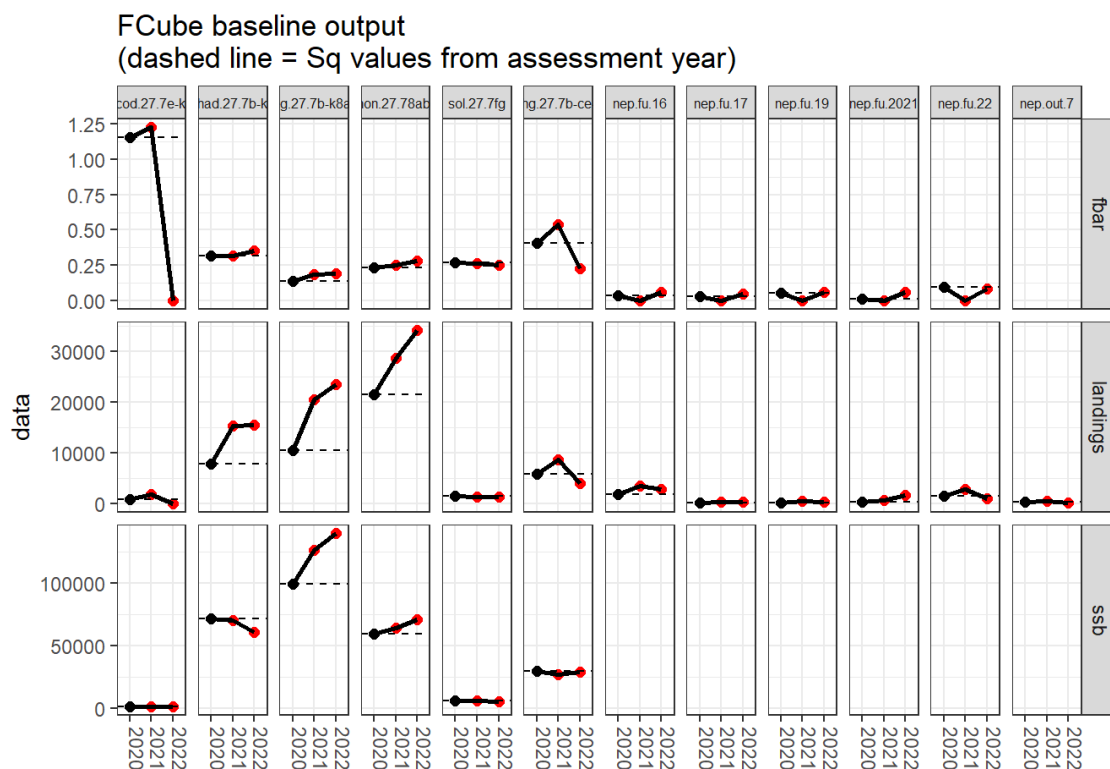
Figure 3.5. Change in fishing mortality (Fbar), landings (tonnes) and SSB (tonnes) assumed in the intermediate year (2021) and required for the TAC year (2022) under the single-stock forecast assumptions consistent with the MSY approach.
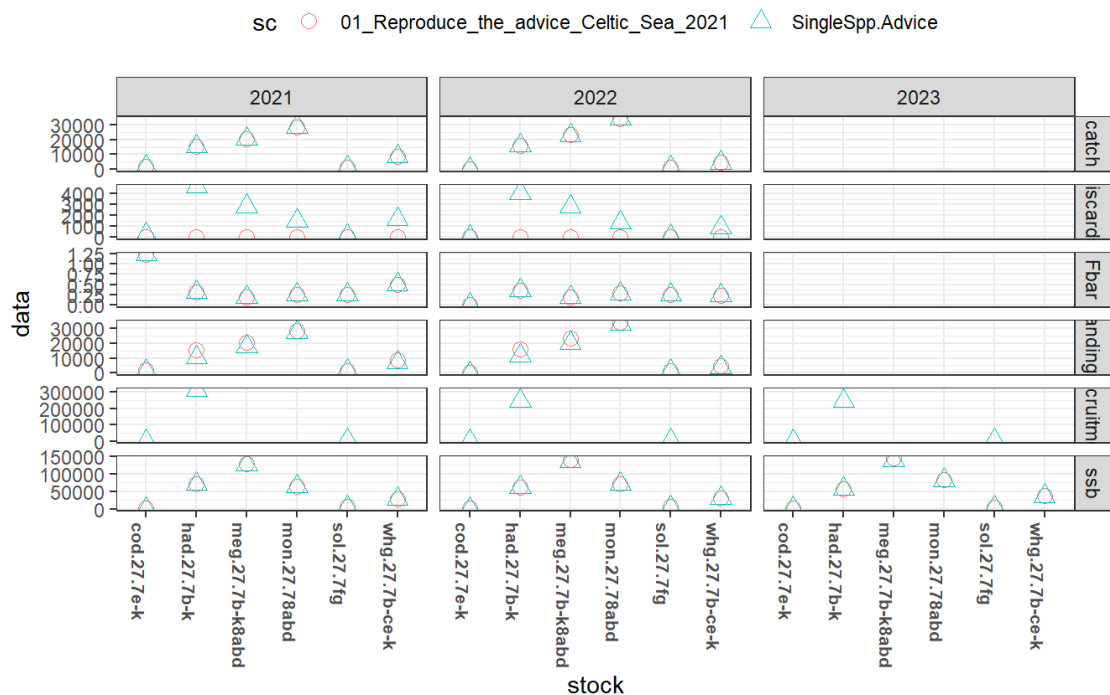
Figure 3.6. Celtic Sea. Difference between FCube baseline run and single-species advice for finfish stocks, showing Fbar (2020–2021), catch, discards and landings (2020–2021) and SSB (2019–2022).
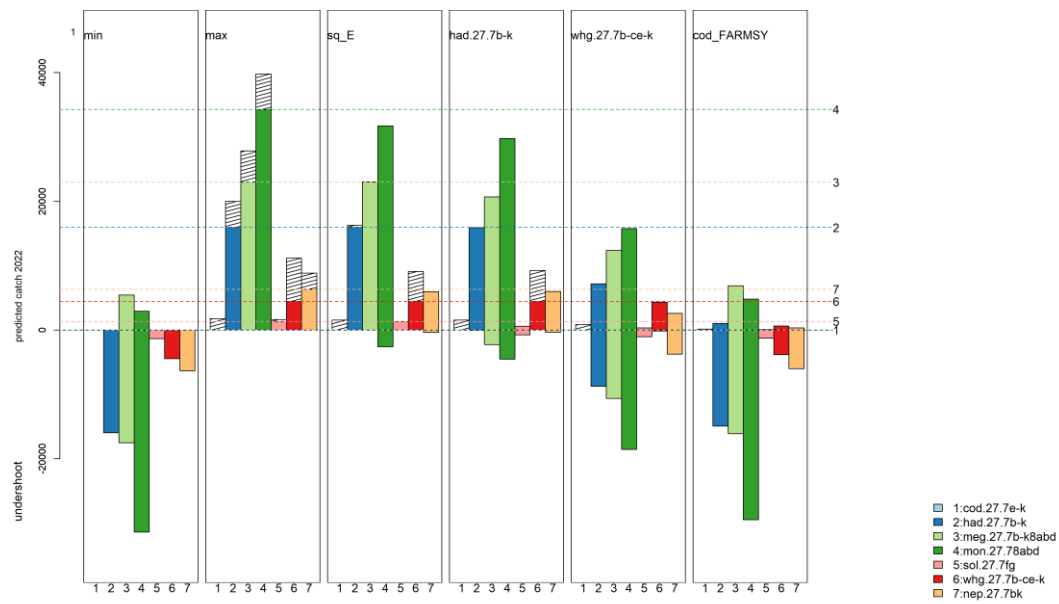
Figure 3.7. Celtic Sea. TAC year results (2022). FCube estimates of potential landings by stock after applying the status quo effort scenario to all stocks in the intermediate year followed by the FCube scenarios. Horizontal lines correspond to the TAC set by the single-stock advice. Bars below the value of zero show the scale of undershoot (compared to the single-species TAC) in cases where landings are predicted to be lower when applying the scenario.
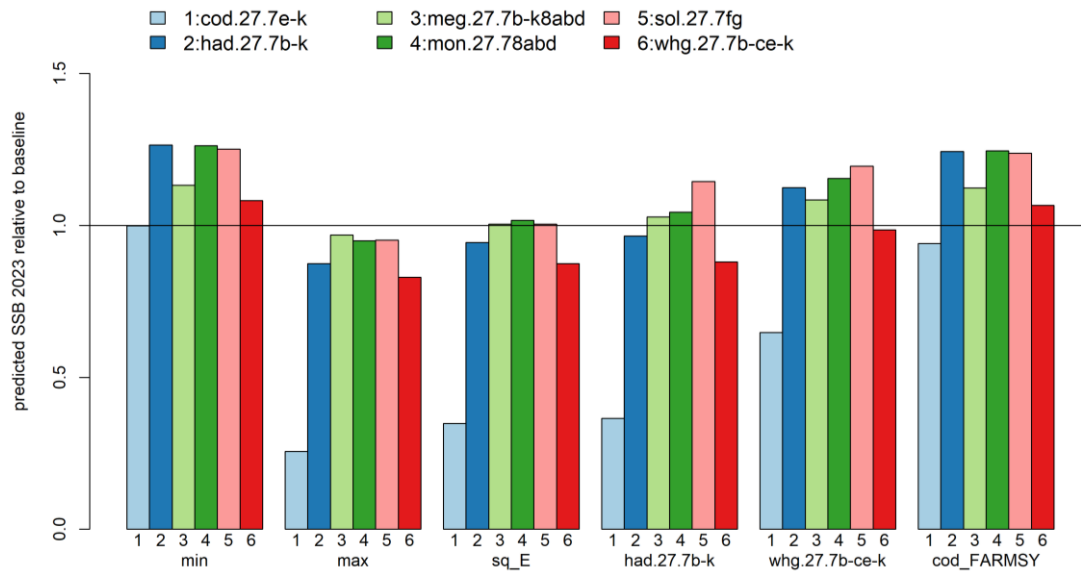
Figure 3.8. Mixed fisheries advice for divisions 7.b–c and 7.e–k. Estimates of potential SSB at the start of 2023 by stock after applying the mixed fisheries scenarios, relative to SSB resulting from the single-stock advice forecast (the horizontal line).
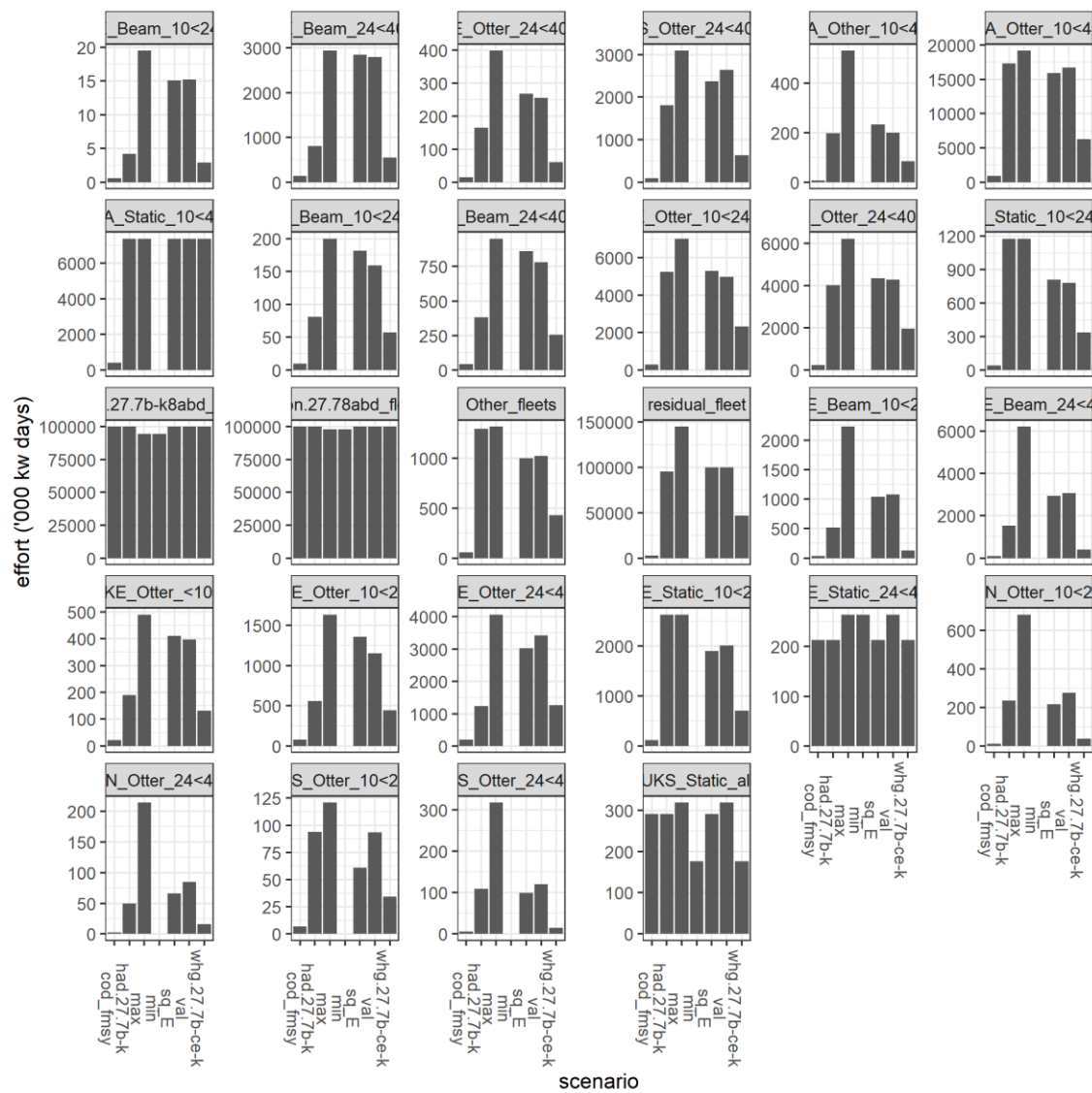
Figure 3.9. Celtic Sea. FCube estimates of effort by fleet corresponding to the individual "quota share" (or partial target F) by stock in 2022 (baseline run).
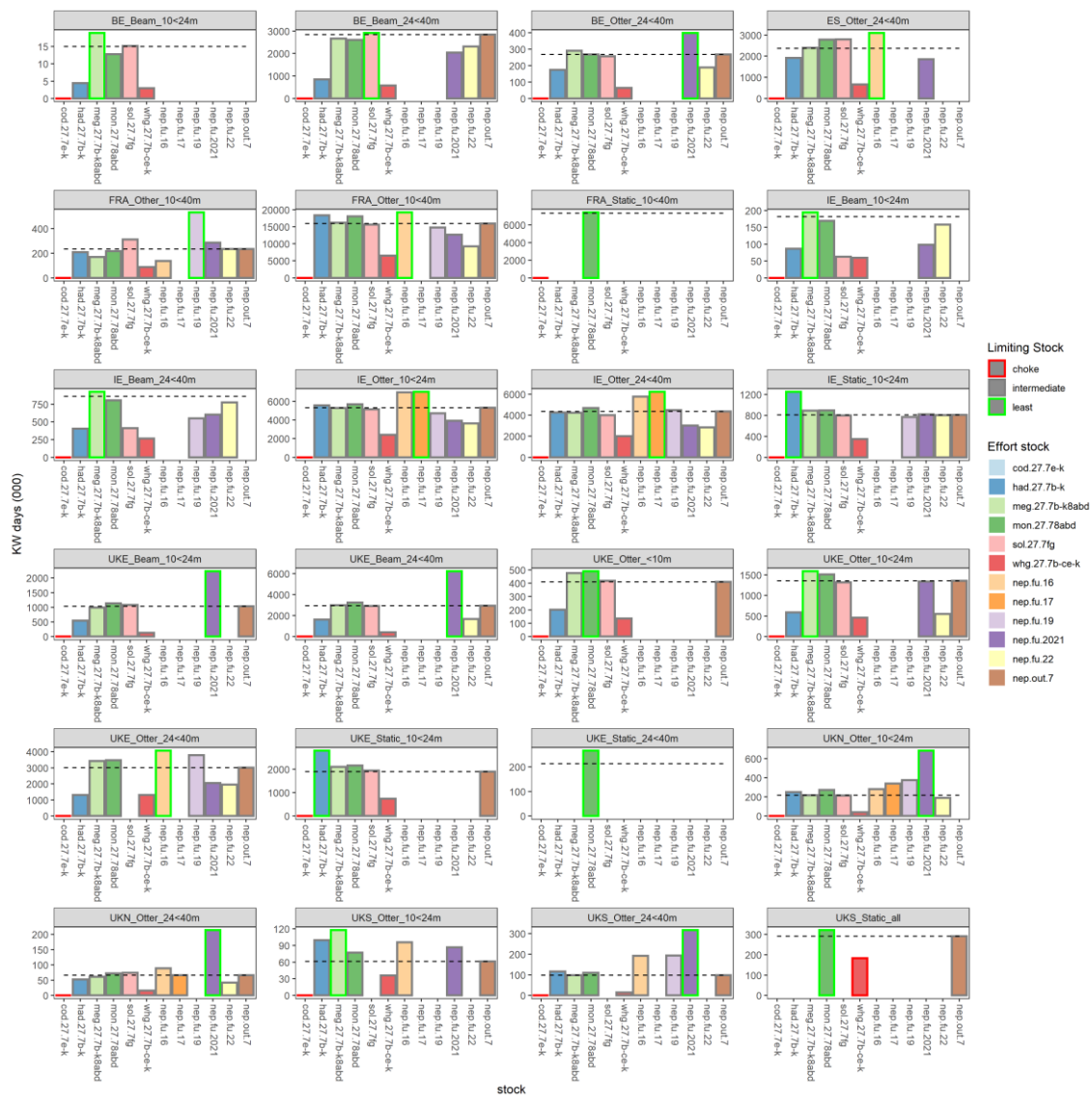
Figure 3.10 Estimates of effort by fleet needed to reach the single-stock advices. Bars highlighted in red correspond to the most limiting species for that fleet in 2022 ("choke species"), whereas the green highlight correspond to the least limiting species.
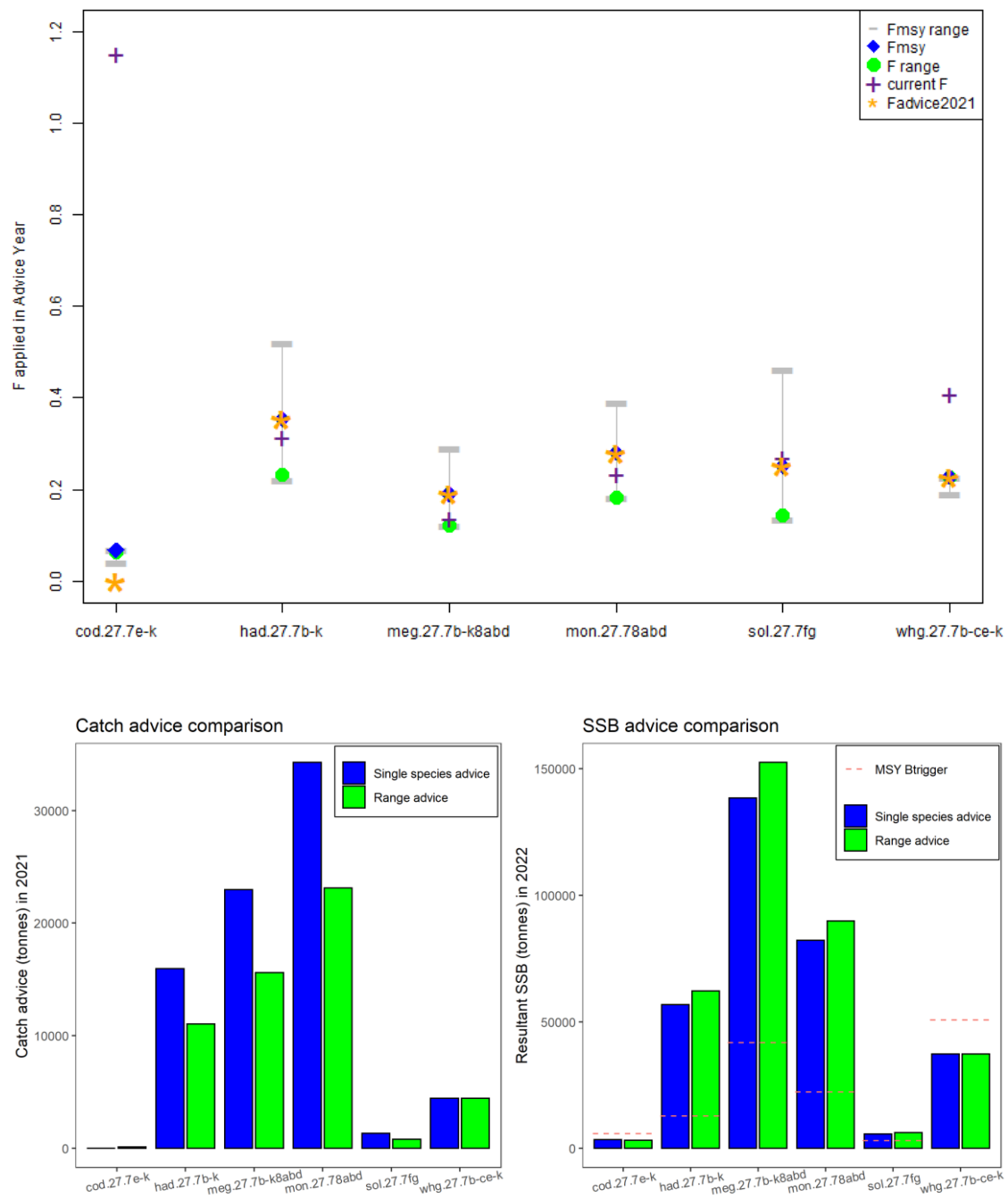
Figure 3.11. Range scenario advice for divisions 7.b–c and 7.e–k. Left: the fishing mortality rates for each stock which reduce the mismatch between opportunities for the three stocks (green point), along with the current fishing mortality (purple cross), the fishing mortality corresponding to the single-stock advice (yellow star) and the F_{MSY} (blue rotated square) and the F_{MSY} ranges (grey lines). Right: Comparison of the outcomes in terms of total catches in 2022 (top) and SSB in 2023 (Bottom) between the F_{MSY} -based single-stock advice and the F-range based forecast

cod.27.7e-k

had.27.7b-k

meg.27.7b-k8abd

mon.27.78abd
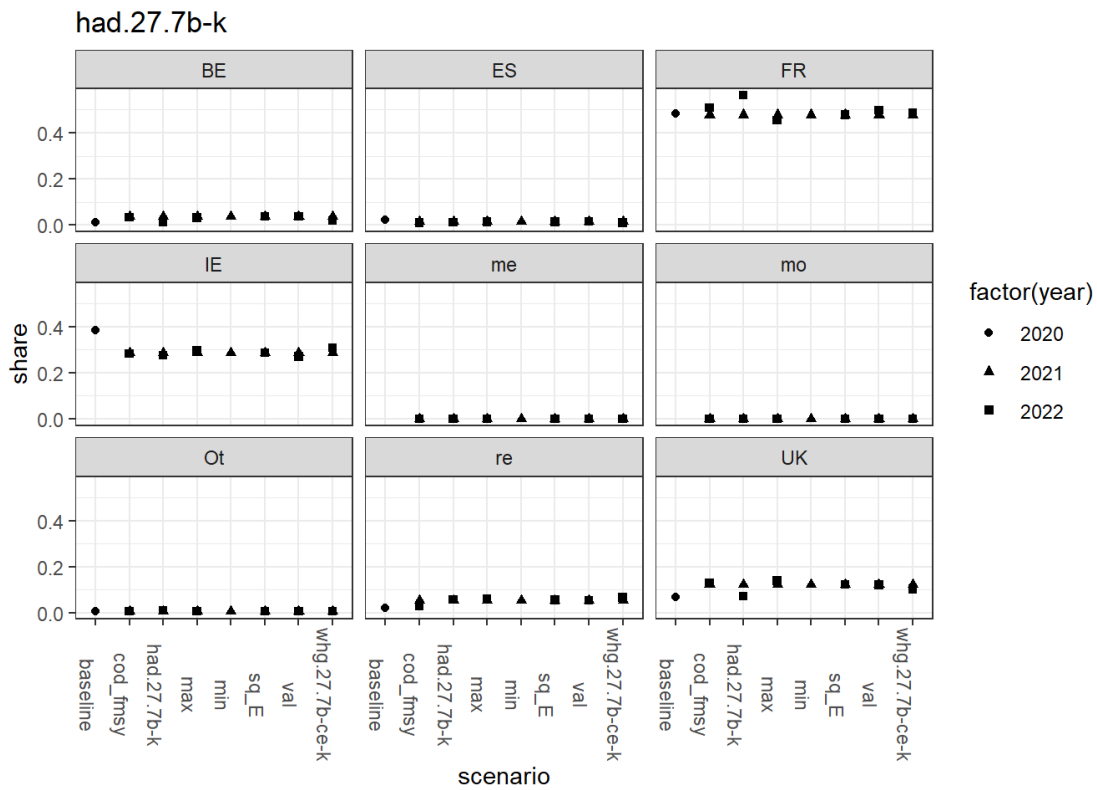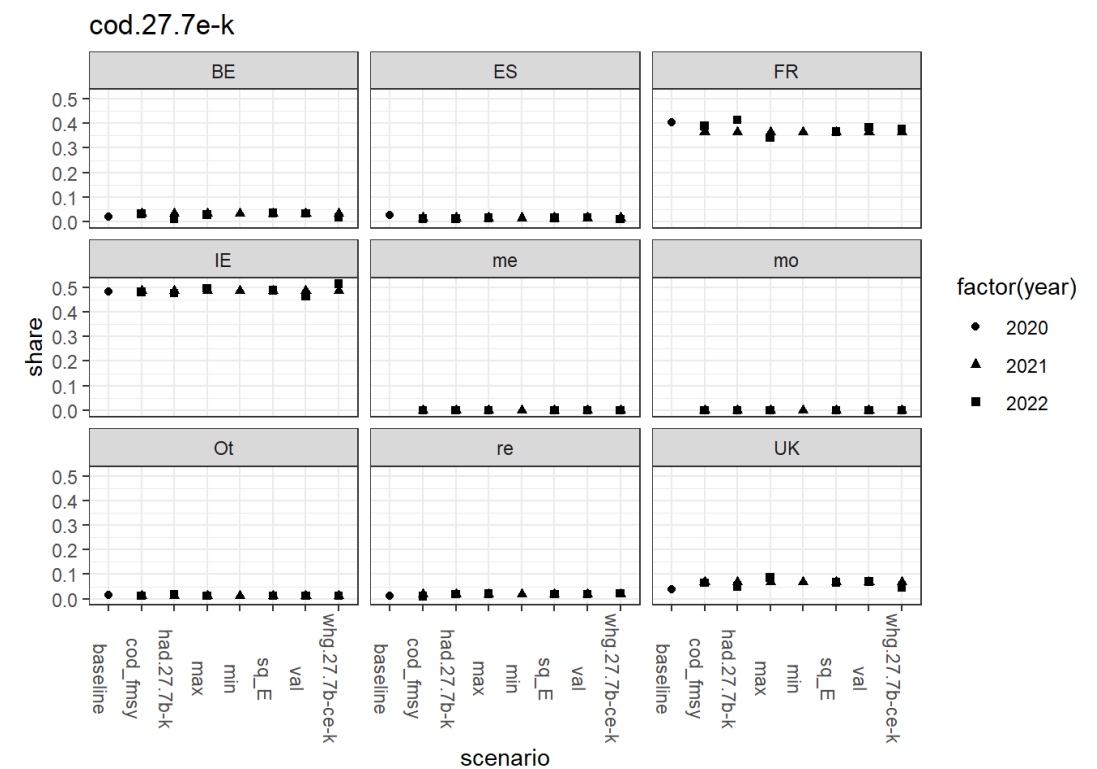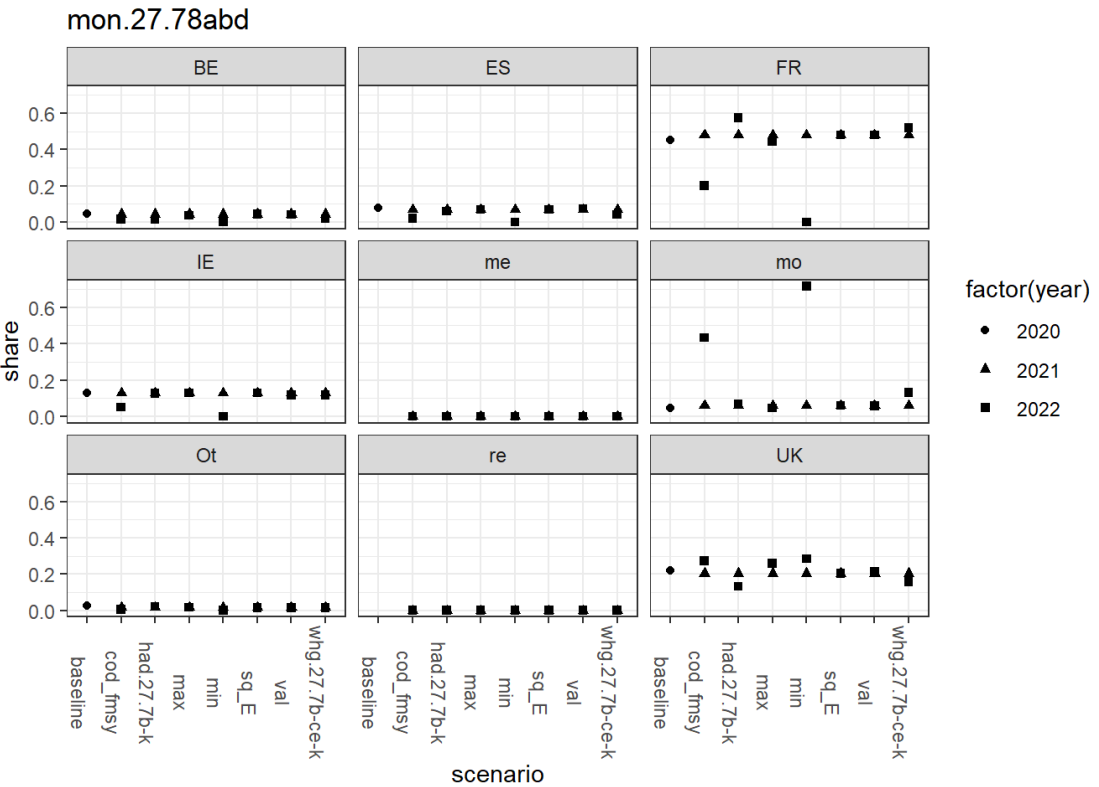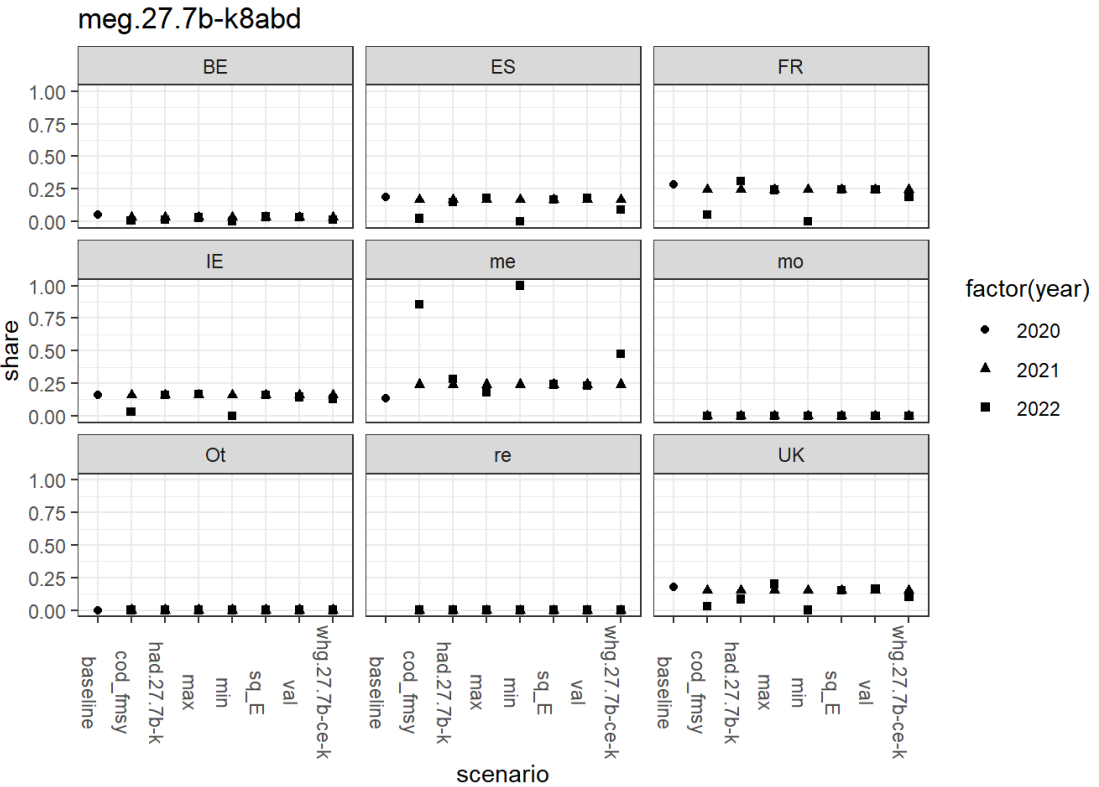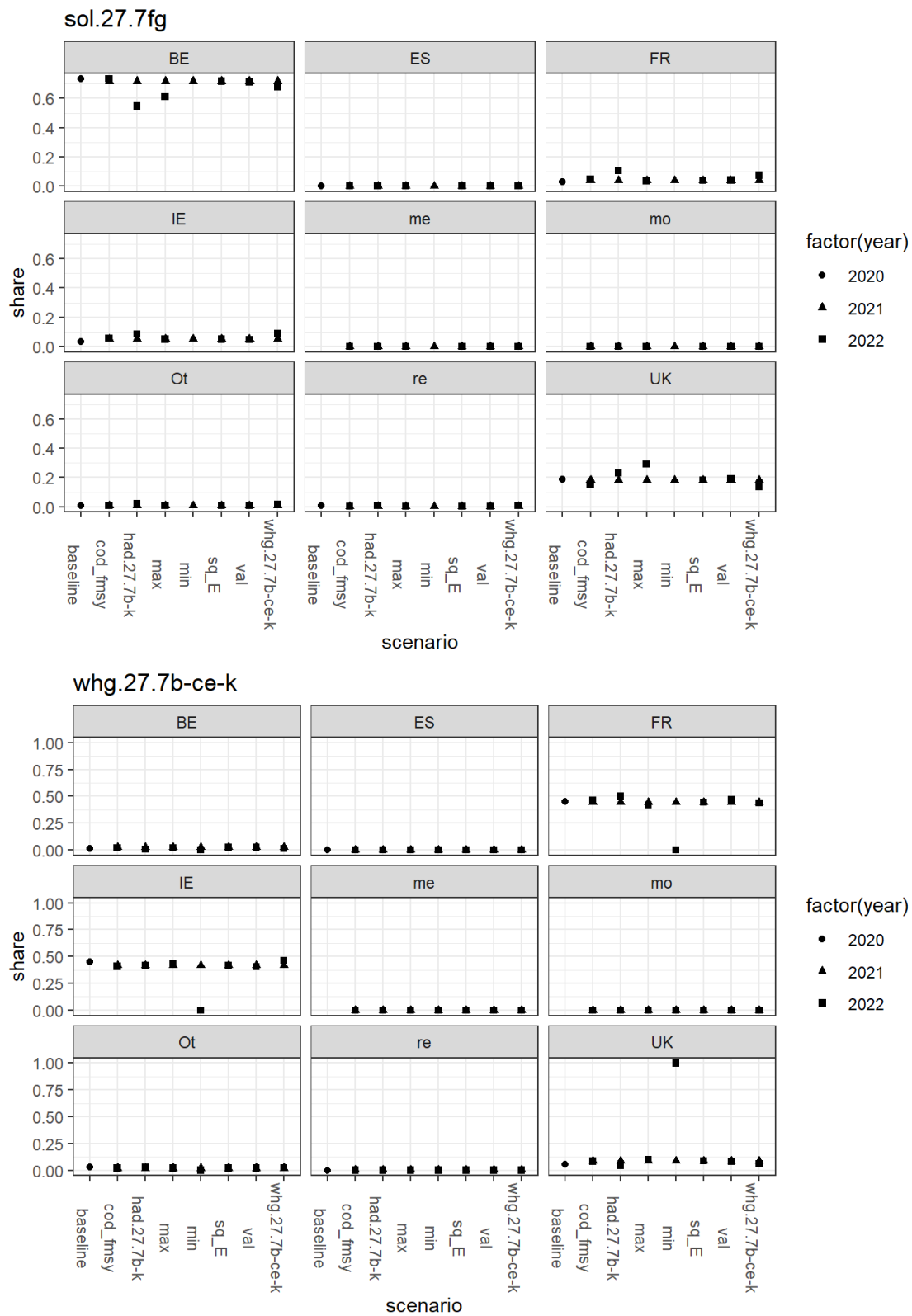
Figure 3.12. Test for relative stability. Changes of relative share of species' landings by country in 2020 and 2022 compared to the 2021 share, for the 'baseline' and 6 FCube scenarios.

Forecast catch of cod from mixed fishery model
Scenarios in panel, haddock (had.27.7b-k) limitation with varying levels of haddock quota or whiting (whg.27.7b-ce-k) limitation

Figure 3.13. Illustrative examples of the effect of change in catchability for cod (on x-axis, relative to baseline of 1) on cod catches (2022), fishing mortality (2022) and SSB (2023) under each of four different mixed fishery scenarios (shown in lines), and assumptions about the limiting 'choke' stocks (shown in panels). Values for catch, F and SSB (y-axis) are given by the points (2023).

4   Iberian waters

4.1   Background

Fisheries operating within the Atlantic Iberian Coast Ecoregion catch a wide range of different species, including those considered to be demersal, pelagic, wide-ranging and deep sea. Various elasmobranch species are also caught.

Portuguese and Spanish demersal fisheries are typically mixed, catching a wide variety of species, reflecting the biological diversity of the areas they exploit. These fisheries are executed using a number of different gear types different gears. Trawl fisheries (using otter or pair trawls) land *Nephrops*, hake, anglerfishes, megrims, blue whiting, mackerel, horse mackerel as well as cephalopods (cuttlefish and squid). Gillnet fisheries target sole, hake, pollack and anglerfishes, while a longline fishery targets mainly hake. Analyses of the Spanish demersal fleets in divisions 8.c and 9.a show that the main target species are hake, anglerfishes, megrims, *Nephrops*, horse mackerel, mackerel, and blue whiting. Three pelagic/semi-pelagic species (blue whiting, mackerel, and horse mackerel) constitute more than half of the total landings in these demersal métiers. For the Portuguese demersal métiers the most important species caught by the demersal fish trawlers are horse mackerel, blue whiting, and hake. The crustacean trawlers target mainly Norway lobster, rose shrimp, and blue whiting. Hake, anglerfishes, sole and rays are present in trawl catches but they are mainly caught by artisanal métiers using gill- and trammel nets.

There is a large small-scale multi-gear fleet operating in the area which uses a diversity of gears that allow exploitation of ecological communities in different habitat types, depths, and substrata. The composition of the landi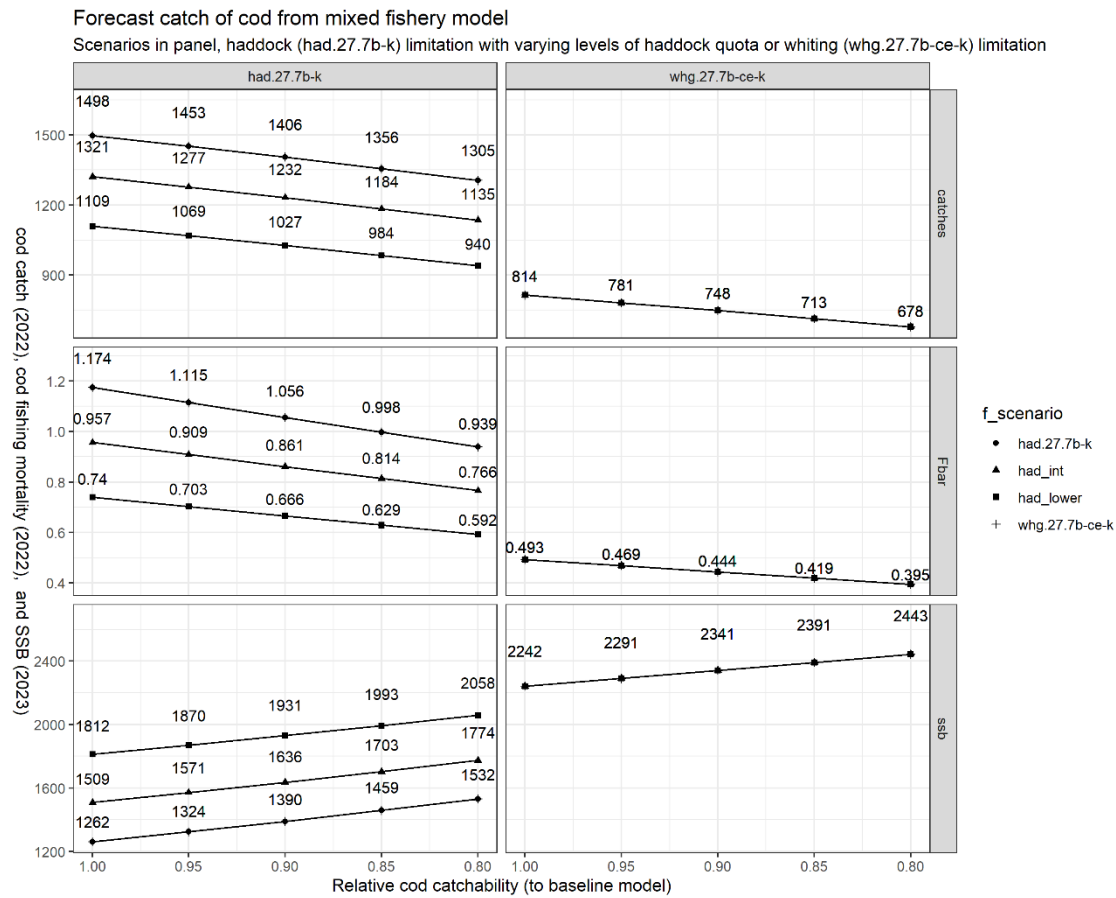ngs depends largely on the fishing gear used and on the ecological community of the fishing grounds visited, which may change seasonally. Fleet segmentation of this large small-scale fleets presents a challenge in the area.

The fisheries are mainly carried out by Portuguese and Spanish vessels, with a small participation of French vessels

4.1.1   Management measures

Total allowable catch (TAC) is the main fishery management tool in this region. These were introduced for most stocks in the 1980s, but the TACs (and quotas) were generally not restrictive until the early 1990s. The 2013 reform of the Common Fisheries Policy aimed to eliminate discarding through the introduction of the EU landing obligation (LO). The LO was introduced for pelagic species in 2015 and has been phased in for demersal TAC species since 2016. From 2019 the LO will apply to all TAC species, although there are some exemptions. A large number of technical measures are in place. These include measures to improve the selectivity of towed gears (partly in order to reduce bycatch) and gear restrictions (ICES, 2020).

Spatial management also occurs, both for fisheries and for ecosystem reasons. Closed areas/seasons are used to protect spawning and juvenile fish, for example. Protected areas have also been designated for habitats and species listed by EU Nature Directives (ICES, 2020). Fishery regulations are in place to restrict certain fisheries that may affect vulnerable habitats

The Regulation (EU) 2019/472 of the European Parliament and of the Council, published in 19 March 2019, has established a multiannual plan for stocks fished in the Western Waters and adjacent waters, and for fisheries exploiting those stocks, repealing the Southern hake and Norway lobster recovery (EC Nº 2166/2005) which set effort reduction measures. Fishing opportunities for 2020 were presented in EU Reg. 2020/123. The new multiannual management plan (EU

Regulation 2019/472) includes 36 demersal and deep-sea stocks including 15 Norway lobster FUs in Western Waters, 7 of those stocks (FUs) are caught in ICES division 8c and 9a. The five stocks considered in the mixed fisheries analysis of Iberian Waters (hake, megrim and four-spot megrim, black-bellied and white anglerfishes) are included in this new multiannual management.

4.2 FLBEIA

4.2.1 Software

All analyses were conducted using the FLR framework (Kell *et al.*, 2007); www.flr-pro-ject.org; FLCore 2.6.15; FLAssess 2.6.3;) running with R 4.0.1 (R Development Core Team, 2020). All forecasts were projected using the FLBEIA Package (v1.15.5) (García *et al.*, 2017). FLBEIA is an FLR package that facilitates the bioeconomic evaluation of management strategies in a multi-stock and multi-fleet framework. It can be used to produce both short and long-term simulations.

Software used in the single-species assessments and forecasts was as outlined in the table below:

Stocks	Assessment	Forecast
BLACK ANGLERFISH 8c9	SPiCT	NA
HAKE 8c9ac	Cat 3 (index based)	NA
FOUR-SPOT MEGRIM 8c9a	XSA	MFDP
MEGRIM 8c9a9a	XSA	MFDP
WHITE ANGLERFISH 8c9a	SS3	SS3 (ad hoc R code)

4.2.2 Scenarios

The basis of the model is to estimate the potential future levels of effort by a fleet corresponding to the fishing opportunities (TACs by stock and/or effort allocations by fleet) available to that fleet, based on fleet effort distribution and catchability by métier. This level of effort was used to estimate landings and catches by fleet and stock, using standard forecasting procedures.

In 2021, ICES single-stock catch advice was given according to MSY approach for all stocks, except hake and black anglerfish for which the precautionary approach was applied (Table 24.1). Therefore, the same basis was retained in the current mixed fisheries framework, in which the following eight scenarios are considered in the advice:

Scenario code	Scenarios
max	**"Maximum":** For each fleet, fishing stops when all stocks have been caught up to the fleet stock shares*. This option causes overfishing of the single-stock advice possibilities of all stocks.
min	**"Minimum":** For each fleet, fishing stops when the catch for any one of the stocks meets the fleet stock share. This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks.
ank	**"Black anglerfish":** All fleets set their effort corresponding to that required to catch their black anglerfish stock share, regardless of other catches.
hke	**"Hake":** All fleets set their effort corresponding to that required to catch their hake stock share, regardless of other catches.
ldb	**"Four-spot megrim":** All fleets set their effort corresponding to that required to catch their four-spot megrim stock share, regardless of other catches.
meg	**"Megrim":** All fleets set their effort corresponding to that required to catch their megrim stock share, regardless of other catches.
mon	**"White anglerfish":** All fleets set their effort corresponding to that required to catch their white anglerfish stock share, regardless of other catches.
sq_E	***"Status quo* effort":** The effort of each fleet in the catch advice year (2022) is set equal to the average effort in the most recent three years (2018–2020) for which catch and effort data are available.

4.3 Stock input data and recent trends

4.3.1 Stock data

The final dataset extracted from InterCatch for use by WGBIE includes discards estimates for all stocks and some métiers, which are included in the assessment of hake and both megrims. Inter-Catch files also provided non-reported landings (ICES WGBIE estimates) besides the official landings. The fleet information specifically required by the WGMIXFISH, needed to split landings by fleet segment and métier, were provided by Spain and Portugal with official landings and economic value. France only provides landings that are considered negligible (1.5% of the total catch) and not considered for WGMIXFISH analysis. Discards and non-reported landings are added from the respective InterCatch files.

This year, Portugal provided a new series of effort and landings for the period 2015-2020, which utilised a new algorithm for metier classification. Some outdated métiers who had no catches in the last years where removed in the new series and no significant changes were detected in the gear grouping for mixed fisheries analysis. The landings proportion by species estimated by year, quarter and gear, based on sampling, was applied to correct Portugal anglerfishes and megrims landings at the species level.

For the period 2009-2016, Spain sent effort and official landings as a unique series. Data for the period 2017-2020 were sent by two laboratories, IEO and AZTI, independently. Landings for anglerfishes and megrims were not at the species level for the period 2009-2016. Time series of landings and discards were checked between single stock assessment and the data compiled by the WGMIXFISH from data call and InterCatch.
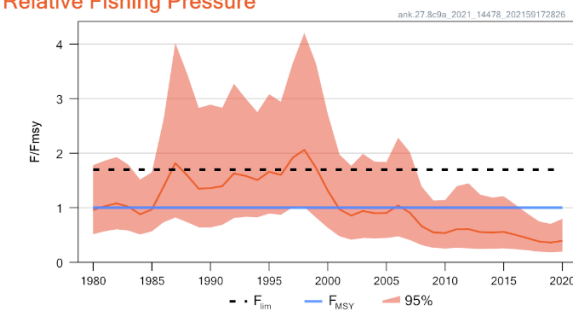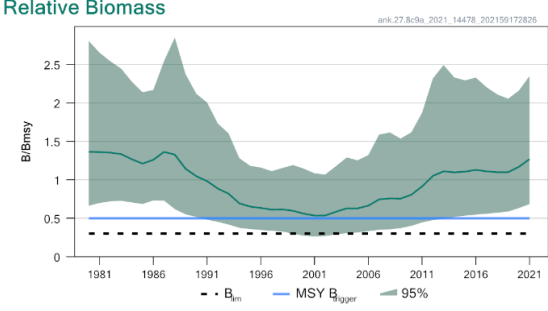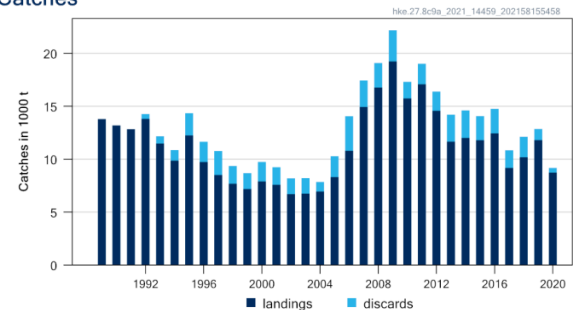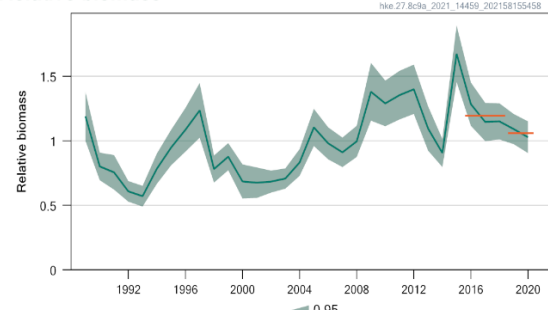
The assessment data for the stocks with analytical assessment were directly provided by the respective stock coordinators, as an FLStock object for white anglerfish and in excel files for both megrims. Additional information on stock structure and assumptions made to tackle covid-19

restrictions on sampling was supplied by WGBIE (ICES, 2021a). White anglerfish are being assessed using a Stock Synthesis length based statistical assessment. However, the implementation of FLBEIA requires an annual and age-based dynamics. This can lead to differences in the projections carried out with both approaches mainly due to the difference between the length-based model used for this stock and the age-based model applied in the mixed-fisheries analysis. The projections carried out with FLBEIA are routinely compared to those carried out in the single-species assessment working group to assess the potential impact of using different approaches. The black anglerfish stock is assessed with a stock production model (SPiCT) and hake with a biomass index and both results are only indicative of trends. The single-stock advice for hake and black anglerfish are provided following the ICES guidelines for category 3 and 2 stocks, respectively (ICES, 2021f).
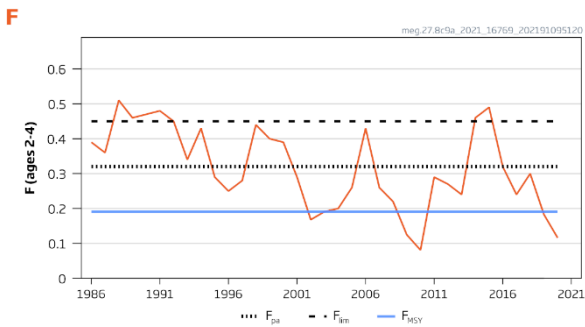
4.3.2 Stock trends and advice

Recent trends in SSB, F and recruitment are described on a stock-by-stock basis in ICES (2021a), and latest advice by stock is available on the ICES website. In order to give a global overview of the Iberian demersal stocks included in this analysis, this information is summarised below. Table 4.1 summarizes the catch, SSB and target Fs, resulting from the advice approaches considered by ICES (2021a) and Table 4.1 provides an overview of the advice and F and SSB trends for the stocks included in the mixed-fisheries advice.

Table 4.1. Summary of stocks included in the mixed-fisheries advice.

Species	Area	Stock status		Advice 2021
ank.27.8c-9a (black-bellied anglerfish)	Divisions 8.c and 9.a (Cantabrian Sea, Atlantic Iberian waters)	Relative Fishing Pressure	Relative Biomass	**Summary:** Fishing pressure on the stock is below F_{MSY} and biomass is above MSY $B_{trigger}$ and B_{lim}. **Advice:** ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 1969 tonnes.
hke.27.8c-9a (Hake)	Divisions 8.c and 9.a (Cantabrian Sea, Atlantic Iberian waters)	Catches	Relative biomass	**Summary:** The stock size and fishing pressure status relative to candidate reference points is unknown. **Advice:** ICES advises that when the precautionary approach is applied, catches in 2022 should be no more than 6947 tonnes.

Species	Area	Stock status		Advice 2021
ldb.27.8c-9a. (Four-spot Megrim)	Divisions 8.c and 9.a (Cantabrian Sea, Atlantic Iberian waters)			**Summary:** ICES assesses that fishing pressure on the stock is below F_{MSY}; spawning-stock size is above MSY $B_{trigger}$, Bpa, and B_{lim}. **Advice:** ICES advises that when the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied, catches in 2022 that correspond to the F ranges in the MAP are between 1283 tonnes and 2724 tonnes. According to the MAP, catches higher than those corresponding to F_{MSY} (1892 tonnes) can only be taken under conditions specified in the MAP, while the entire range is considered precautionary when applying the ICES advice rule.

Species	Area	Stock status			Advice 2021
meg.27.8c-9a (Megrim)	Divisions 8.c and 9.a (Cantabrian Sea, Atlantic Iberian waters)				**Summary:** ICES assesses that fishing pressure on the stock is below F_{MSY}; spawning stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.

F

SSB

Advice: ICES advises that when the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied, catches in 2022 that correspond to the F ranges in the MAP are between 371 tonnes and 672 tonnes. According to the MAP, catches higher than those corresponding to F_{MSY} (553 tonnes) can only be taken under conditions specified in the MAP, whilst the entire range is considered precautionary when applying the ICES advice rule

Species	Area	Stock status			Advice 2021
mon.27.8c-9a (white anglerfish)	Divisions 8.c and 9.a (Cantabrian Sea, Atlantic Iberian waters)	F		SSB	**Summary:** Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY Btrigger, Bpa, and Blim. **Advice:** ICES advises that when the EU multiannual plan (MAP) for Western waters and adjacent waters is applied, catches in 2022 that correspond to the F ranges in the MAP are between 1345 tonnes and 2507 tonnes. According to the MAP, catches higher than those corresponding to F_{MSY} (1899 tonnes) can only be taken under conditions specified in the MAP, while the entire range is considered precautionary when applying the ICES advice rule

4.4 Fleets and métiers

4.1.1 Catch and effort data

Métier-based landings and effort files requested by the WGMIXFISH data call were provided by the three countries with fleets operating in Atlantic Iberian waters, i.e. Spain, Portugal and France. InterCatch data files are used to compile discards and non-reported landings (WGBIE estimations) which are not provided in the MIXFISH data call. Proportion of landings for stocks considered in the mixed fisheries projections is presented in Figure 2.1. Hake was the dominant species, comprising of 77% of total landings, followed by black anglerfish (7%), white anglerfish (6%), four spot megrim (6%) and megrim (3%).

4.4.1 Definitions of fleets and métiers

Fleet and métier categories used in the mixed-fisheries analysis are based on the EU Data Collection Framework (DCF) level 6 categories provided by Spain, Portugal and France. This year, Portugal provided a new series of effort and landings for the period 2015-2020, using a new algorithm for metier classification, different from those previously used. Some outdated métiers who had no catches in the last years where removed in the new series and no significant changes were detected in the gear grouping for mixed fisheries analysis.

The classification of fleet segments did not include vessel size categories for Spanish trawlers as the disaggregation by métier already captures this information. In the case of Portugal, the contribution of the small vessels was minor, and their catch profile was similar to the largest vessels profile, hence a single fleet was used for the three categories. With respect to the fleet segments used in the mixed fisheries analysis, these were defined combining the country and the fishing gear group (first three letters of the métier acronym, e.g. ESP_DEF_>=55_0_0).

Total catches (in weight) were obtained by multiplying the catch-at-age in numbers by the average weight at age used as input in the WGMIXFISH analysis are compared with the total catches (in weight) used by WGBIE in the single-species assessments (Table 4.5b. Gear-groups used to define fleet names for mixed-fisheries analysis.

Acronym	DCF definition	Description
GN1	Gillnets / SP	≥ 100 mm / demersal fish
GN2	Gillnets / SP	≥ 80 mm and < 99 mm / demersal fish
GN_GT	Gillnets, trammel nets / SP	≥ 60 mm and < 79 mm / demersal fish
GN_GT2	Gillnets, trammel nets / PT	Any / demersal fish
LL_GN_GT	Longlines, gillnets, trammel nets / PT; SP	Any / demersal fish
OT_CRU	Otter trawls / PT	≥ 55 mm / crustaceans
OT_DEF	Otter trawls / PT; SP	≥ 65 mm / demersal fish
OT_MCD	Otter trawls / SP	≥ 55 mm / crustacean; demersal fish
OT_PT_MPD	Otter and pair trawls / SP	≥ 55 mm / pelagic; demersal fish
MIS	Miscellaneous / PT;SP	Any

Table 4.6). All discrepancies are lower than 1%.

More than 40 métiers were reported, from these, 14 métiers were chosen based on their relevance for the Portuguese and Spanish fisheries, and on the species catchability considered for advice. France which accounts for less the 2% of the catch is contained in the "OTH" fleet and métier. This métier list is then regrouped according to their target assemblage of species and the technical characteristics of the fishing gear (Table 4.1a), resulting in 10 gear-groups used to define fleets for mixed-fisheries analysis (Table 4.2b). The miscellaneous "MIS" métier represents the artisanal multi-gear fleet occurring in the area. These multi-gear fleets use a diversity of gears that allow exploitation of different fish communities in different habitats and depths. The "Others" métier sums up the landings of all the remainder small métiers (Figure 4.2).

Southern hake stock provides the highest catches in all métiers. Megrims are mainly caught by the bottom otter trawl métier targeting demersal fish (OT_DEF) and anglerfishes by several bottom otter trawl and gillnets gear groups ().

In order to improve harmonization between the Portuguese and Spanish fleets, further analysis should be done on an additional and refined algorithm for gear grouping used to define fleets for mixed-fisheries analysis.

4.1.2   Trends
Analyses of trends by fleet were carried out for 2018–2020 data. A number of exploratory graphs were produced to aid quality checking of the data once compiled into the final fleets object for catches, effort and catchability. The catchability plots by stock, fleet and métier for Spain () and Portugal (Figure 4.4) for 2018-2020 are included in this report and the key assumption in the projections is that catchability by stock and métier and effort distribution (share) in 2021 and 2022 is the average of the last three years. In reality, fishing patterns may change over time but no assessment has been made on the impact of this variability on the simulations. Visual inspection was performed on the catchability patterns from 2014-2020 of the 14 métiers considered (Table 4.2a) for the mixed-fisheries gear grouping and no trend was evident.

4.5   Mixed fisheries forecasts

Some discrepancies were found between the FLBEIA baseline runs and the single-stock forecasts for Category 1 stocks. No differences were found in catches in 2022 and 2023 (

Table 2.). The estimates at the start of the advice year were all consistent with the single-stock forecasts with minor differences and the differences in the SSB and F are considered low, slightly higher in the advice year (SSB at the beginning of 2023 and estimated F in 2022). The largest observed difference were 8% for megrim in SSB at the start of 2023 and 7% for F in 2021 for white anglerfish (Table 4.6). These are to be expected mainly because of the difference between the length-based model used for this latter stock and the age-based model applied in the mixed-fisheries analysis. All other differences (below 10%) were considered acceptable for modelling the technical interactions between stocks and fleets in the mixed-fisheries scenarios.

4.5.1 Description of scenarios

4.5.1.1 Baseline runs

The objectives of the single-species stock baseline runs were to:

1. reproduce as closely as possible the single-species advice produced by ACOM, and
2. act as the reference scenario for subsequent mixed fisheries analyses.

The various single-stock forecasts presented by WGBIE are performed using different software and setups (see Section 4.2.1 above). However, for the purposes of the mixed fisheries analyses, it is necessary to gather all forecasts into a single unified framework, which builds on the "FLBEIA" library (García *et al*., 2017). The same forecast settings as in the stock annex for each Category 1 stock regarding weight-at-age, selectivity and recruitment, as well as assumptions on the F in the intermediate year and basis for advice (MSY approach). For Category 3 hake stock, intermediate year catch was assumed equal to latest catch. In the case of Category 2 black bellied-anglerfish, assessed with surplus production model (SPiCT), the catch estimates in the ICES advice sheet under status quo F/F_{MSY} was used. The Fsq estimates provided in the ICES advice sheets were used for the stocks with analytical assessment.

4.5.1.2 Mixed fisheries runs

The mixed fishery analysis used a *status quo* effort assumption for the intermediate year (2021), with the FLBEIA scenarios used for the advice year (2022). The *status quo* effort assumption for the intermediate year is considered a plausible assumption because is in line with the standard single-stock short-term forecasting approach. As last year, the projections were run assuming a full and perfect implementation of a discard ban (i.e. all quota species caught must be landed, with no exemptions, *de minimis* or inter-species flexibilities).

In summary, the FLBEIA runs followed the scheme below:
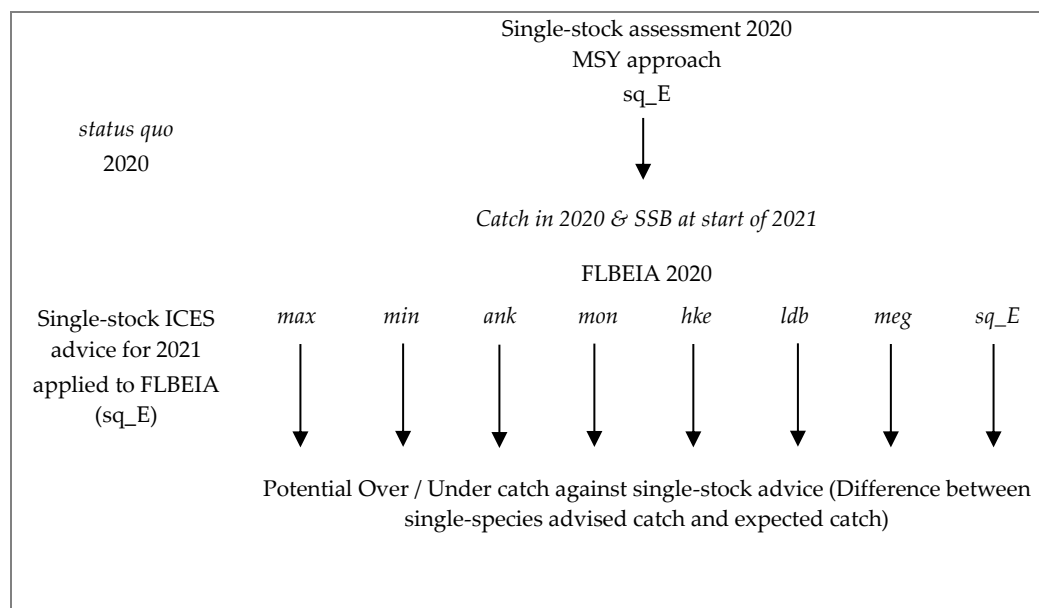
4.5.2   Results of FLBEIA runs

4.5.2.1   Baseline runs

The rationale behind the single-species baseline runs is given in Section 2.3.1.2. The ICES single-stock advice for four stocks in 2021 (ICES, 2021a) is based on the maximum sustainable yield (MSY) approach and on precautionary approach for hake. The issues and problems encountered in replicating the single-species advice for each species are identified below. The results from these baseline runs are compared with the results from the corresponding ICES runs in Table 4.4 (baseline outputs), Table 4.5. (Catch differences) and Table 2.4.6. (SSB and F differences)

There are some minor differences between the single-stock catch and SSB values, and the values obtained from the baseline run scenario although lower than 3%.

Black-bellied anglerfish: Category 2 stock, F and biomass projections are relative to F_{MSY} and B_{MSY}. Discrepancies around 2% for catches in the interim year 2021 and none in advice year 2022.

Hake: No discrepancies for catches in the interim year 2021 and none in advice year 2022. No F and SSB projections for Category 3 stocks.

Four-spot megrim: No discrepancies are found in catch 2021, 2022. Discrepancies in SSB were below 3% and 6% in F between FLBEIA run and single stock advice forecast.

Megrim: No discrepancies are found in catch 2021, 2022. 8% discrepancies in the SSB at the start of 2023 and 10% in F at 2022 between FLBEIA runs and single stock advice forecast.

White anglerfish: No discrepancies are found in catch 2021, 2022. Minor discrepancies of 4% in SSB 6% for F were obtained for white anglerfish. The assessment of this stock is performed by applying the SS3 model (Methot, 2000) disaggregated by length.

The outputs of the scenarios at the start of the advice year were all consistent with the single-stock forecasts of Category 1 stocks with minor differences. The differences were considered acceptable regarding the modelling of the technical interactions between stocks and fleets.

4.5.2.2   Mixed fisheries analyses

The full overview of the FLBEIA scenarios and projections for 2022 is presented in Figure 4.7 to illustrate trade-offs in catches and the potential for quota overshoot and undershoot linked to the most and the least restrictive single-stock fishing opportunities for 2022. For ease of comparison, the landings relative to the single-stock advice are also presented.

Figure 4.8 illustrates the estimates of potential SSB by stock in the mixed-fisheries scenarios. For ease of comparison, the SSB is expressed as a ratio to the single-stock advice forecast.

ICES single-stock advice (Category 1) provides catches expected to meet single-stock F_{MSY}, and expected to meet precautionary approach for Category 3 stocks. To be consistent with these objectives a scenario is necessary that delivers the SSB and/or F objectives of the single-stock advice for all stocks considered simultaneously. The **"min"** scenario meets this outcome. Additionally, this scenario assumes that fleets should stop fishing when their first stock share is exhausted, regardless of the actual importance of this stock share for the fleet. This scenario reflects the constraints that result from a strictly implemented discard ban. Fishing effort should be reduced more than 36% of its 2020 observed level to comply with this scenario, consistent with the reductions in fishing mortality advised for hake, and causing reductions of catches in the remaining species higher than those determined by their respective single-stock advice.

The **"max"** scenario is included to demonstrate the upper bound of potential fleet effort and stock catches because it assumes that all fleets continue fishing until all the stock shares are exhausted, irrespective of the economic viability of such actions.

Within the scenarios based on each of the stocks, the results of **"ank"** and **"mon"** scenario are pretty much the same of those of the "**max**" scenario indicating that both anglerfish would be the least limiting stocks. In these scenarios SSB is estimated to be lower than the single stock advice because of large TAC overshoot. The largest differences in SSB (

Figure 4.8) were found in these scenarios (and **"max"**) where SSB was estimated to be considerably lower than the single stock advice because of large TAC overshoot. The reduction of SSB is more noticeable in the four-spot megrim stock drawing attention to an increased technical interaction between this species and the anglerfish stocks.

The "**hke**" scenario gives the same result as the **"min"** scenario, showing hake as the choke species in this group. This scenario shows potential loss of fishing opportunities for black and white anglerfish and, in a lesser extent, for megrims.

The "**ldb**" and "**meg**" scenarios provide a similar perspective, increasing the fishing opportunities of the stocks in comparison with the "hke" scenario. Megrims and anglerfishes are mainly caught by bottom otter trawl gears, while hake occurs in the catches of almost all the Iberian métiers.

The "**mon**" scenario estimates effort levels close to those in "ank" and "max" scenarios. This scenario maintains the single-stock advice for white anglerfish, but multiplies by 3 the single-stock advice for hake and almost doubles the advice for both megrims.

The "**sq_E**" scenario is similar than the "ldb" scenario. Under this scenario the quota of megrim for 2022 would be caught and almost the entire quota of four-spot megrim. However, with this level of effort, the hake catches approach double the hake quota and anglerfishes catches would be around half of their quotas.

Relative stability

Relative stability as such is not directly included as an input to the model. Instead, an assumption that the relative landings share of the fleets are constant is used as a proxy, and in the scenarios above, this input was derived from the landings share by fleet and stock in 2020. The landings

by national fleets were summed over nation for each scenario, and the share by country was compared with this initial input. The results did not show big deviations across all scenarios (Figure 4.8).

Table 4.3. Iberian waters: Summary of the 2022 catch and target Fs, resulting from the advice approaches considered by ICES (2021a). TACs refer to total catches, as they are used in the assessment model, except for black and white anglerfish, which represent only landings (n/a – not available).

Stock	TAC 2022	F 2022	SSB 2023	Rational
Black anglerfish 8c9a	1969 t	n/a	n/a	Precautionary approach
Hake 8c9a	6947 t	n/a	n/a	Precautionary approach
Four-spot megrim 8c9a	1892 t	0.19	8676 t	MSY approach
Megrim 8c9a	553 t	0.19	2449 t	MSY approach
White anglerfish 8c9a	1899 t	0.24	10506 t	MSY approach

Table 4.4a. Detailed description of the métier categories used in the Iberian waters mixed fisheries analysis.

Acronym	DCF definition	Description
GNS_DEF_>=100_0_0	Set gillnet targeting demersal fish with mesh sizes larger than 100 mm	Spanish set gillnet ("*rasco*") targeting white an-glerfish in ICES Division 8c with mesh size of 280 mm
GNS_DEF_0_0_0	Set gillnet targeting demersal fish	Artisanal Portuguese fleet using set gillnets
GNS_DEF_60-79_0_0	Set gillnet targeting demersal fish with mesh sizes within the range 60–79 mm	Spanish small set gillnet ("*beta*") targeting a variety of demersal fish in north-western Spanish waters
GNS_DEF_80-99_0_0	Set gillnet targeting demersal fish with mesh sizes within the range 80–99 mm	Spanish set gillnet ("*volanta*") targeting hake with nets of 90 mm mesh size in north-western Spanish waters
GTR_DEF_0_0_0	Trammel net targeting demersal fish	Artisanal Portuguese fleet using trammel nets
GTR_DEF_60-79_0_0	Trammel net targeting demersal fish with mesh sizes within the range 60–79 mm	Spanish trammel net targeting a variety of demersal species in north-western Spanish waters
LLS_DEF_0_0_0	Set longline targeting demersal fish	Spanish set longline targeting a variety of demersal fish in Spanish Iberian waters
MIS_MIS_0_0_0_HC	Miscellaneous	Portuguese and Spanish artisanal fleet not covered by other métiers
OTB_CRU_>=55_0_0	Bottom otter trawl targeting crusta-ceans using mesh sizes larger than 55 mm	Portuguese bottom otter trawl targeting *Nephrops* and rose shrimp
OTB_DEF_>=55_0_0	Bottom otter trawl targeting demer-sal fish using mesh sizes larger than 55 mm	Spanish bottom otter trawl targeting hake, an-glerfish, and megrim using "*baca*" nets of 70 mm mesh size in Divisions 8c and 9a
OTB_DEF_>=65_0_0	Bottom otter trawl targeting demer-sal fish using mesh sizes larger than 65 mm	Portuguese bottom otter trawl targeting demersal fish in Division 9a

Acronym	DCF definition	Description
OTB_ MCD_>=55_0_0	Bottom otter trawl targeting mixed crustaceans and demersal fish using mesh sizes larger than 55 mm	Spanish bottom otter trawl targeting a variety of fish and crustaceans using nets of 55 mm mesh size in south-western Iberian waters (Gulf of Cadiz and Southern Portuguese waters)
OTB_MPD_>=55_0_0	Bottom otter trawl targeting mixed pelagic and demersal fish using mesh sizes larger than 55 mm	Spanish bottom otter trawl targeting pelagic (horse mackerel, mackerel…) and demersal fish (hake) by using "*jurelera*" nets of 55 mm mesh size in north-western Spanish waters
PTB_ MPD _>=55_0_0	Bottom pair trawl targeting mixed pelagic and demersal fish using mesh sizes larger than 55 mm	Bottom pair trawl targeting pelagic (blue whiting, mackerel…) and demersal fish (hake) by using nets of 55 and 70 mm mesh size in north-western Span-ish waters

Table 4.5b. Gear-groups used to define fleet names for mixed-fisheries analysis.

Acronym	DCF definition	Description
GN1	Gillnets / SP	≥ 100 mm / demersal fish
GN2	Gillnets / SP	≥ 80 mm and < 99 mm / demersal fish
GN_GT	Gillnets, trammel nets / SP	≥ 60 mm and < 79 mm / demersal fish
GN_GT2	Gillnets, trammel nets / PT	Any / demersal fish
LL_GN_GT	Longlines, gillnets, trammel nets / PT; SP	Any / demersal fish
OT_CRU	Otter trawls / PT	≥ 55 mm / crustaceans
OT_DEF	Otter trawls / PT; SP	≥ 65 mm / demersal fish
OT_MCD	Otter trawls / SP	≥ 55 mm / crustacean; demersal fish
OT_PT_MPD	Otter and pair trawls / SP	≥ 55 mm / pelagic; demersal fish
MIS	Miscellaneous / PT;SP	Any

Table 4.6. Iberian waters: Proportion of the stocks total catches (from WGBIE) covered by the WGMIXFISH fleets. A ratio >1 means that the catch information in WGMIXFISH is larger than the information used by WGBIE.

YEAR	STOCK	WGBIE	WGMIXFISH	DIFFERENCE	RATIO
2020	ANK	793	793	0	1
2020	HKE	9172	9172	0	1
2020	LDB	792	791	-1	1
2020	MEG	320	320	0	1
2020	MON	722	722	0	1

Table 4.7. Iberian waters: Baseline run outputs from the FLBEIA package.

	ANK	HKE	LDB	MEG	MON
2021_Fbar	NA	NA	0.128	0.199	0.093
2021_Fmult	NA	NA	1.19	1.72	1.12
2021_Landings	793	8520	710	315	722
2021_SSB	0	0	8392	2699	11753
2022_Fbar	NA	NA	0.193	0.191	0.24
2022_Fmult	NA	NA	1.51	0.96	2.6
2022_Landings	1969	6337	1641	513	1899
2022_SSB	0	0	8803	2511	11771
SSB_2023	0	0	8454	2242	10939

Table 4.8. Iberian waters: Comparison between baseline run and ICES advice. Figures for 2021 compare results from the baseline run - that use the same assumptions for F in the intermediate year as the forecasts leading to ICES advice–to the ICES intermediate year results.*category 3 WGMIXFISH methodology

	ANK*	HKE*	LDB	MEG	MON
2021_Catches Baseline	774	7825	1274	569	760
2021_Catches ICES	793	7825	1274	569	760
2021_% diff	-	-	1	1	1
2022_Catches Baseline	1969	6947	1892	553	1899
2022_Catches ICES	1969	6947	1892	553	1899
2022_% diff	1	1	1	1	1

Table 4.9. Iberian waters: FLBEIA baseline run outputs for SSB and F relative to ICES advice.

	SSB_2021	SSB_2022	SSB_2023	F_2021	F_2022
LDB	0.99	0.98	0.97	1.05	1.06
MEG	0.97	0.94	0.92	1.06	1.1
MON	1.01	1.02	1.04	0.93	0.94

Table 4.10. Results of running FLBEIA scenarios on the advice year (2022). Comparison of the single-stock ICES advice and potential landings in the various FLBEIA scenarios.

	Single-stock	max	min	ank	hke	ldb	meg	mon	E_sq
ank.27.8c9a	1969	1969	2040	458	1969	464	1063	690	1991
hke.27.8c9a	6947	6947	30742	6921	29734	6947	17265	9921	29611
ldb.27.8c9a	1892	1892	3003	801	2972	801	1892	1310	2961
meg.27.8c9a	553	553	726	334	725	334	599	553	723
mon.27.8c9a	1899	1899	2276	468	2019	472	1407	693	1899
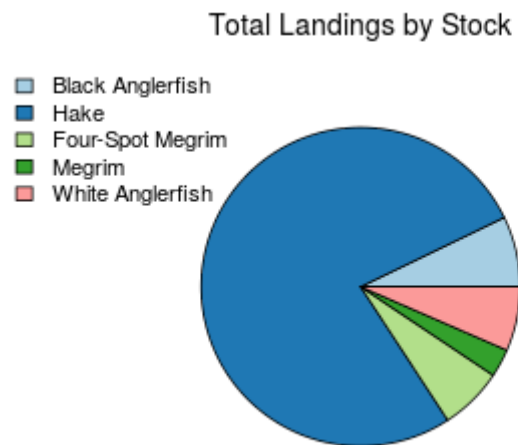
Figure 4.6. Mixed fisheries for the Atlantic Iberian Waters. Catch distribution by the stocks included in the mixed fisheries projections: Hake (77%), black anglerfish (7%), white anglerfish (6%), four spot megrim (6%) and megrim (3%)
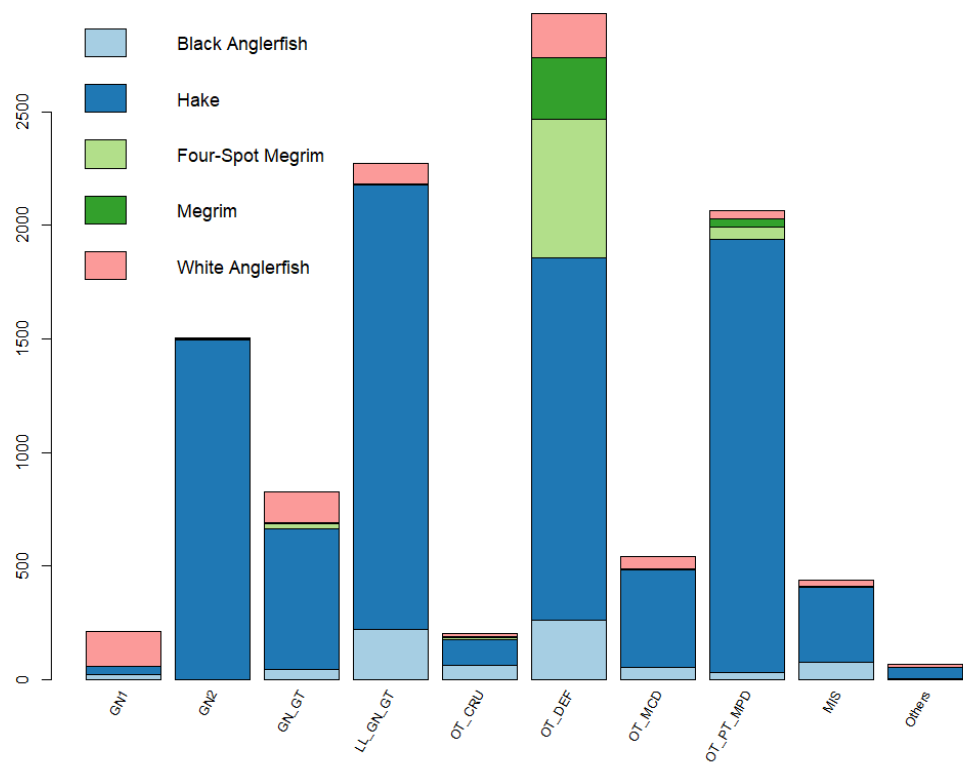
Figure 4.7. Mixed fisheries for the Atlantic Iberian waters. Landings distribution of species by gear group in 2020 (list of gear groups are available in table 4.2a) according to the target assemblage and the technical characteristics of the fishing gears of the Spanish and Portuguese fleets.
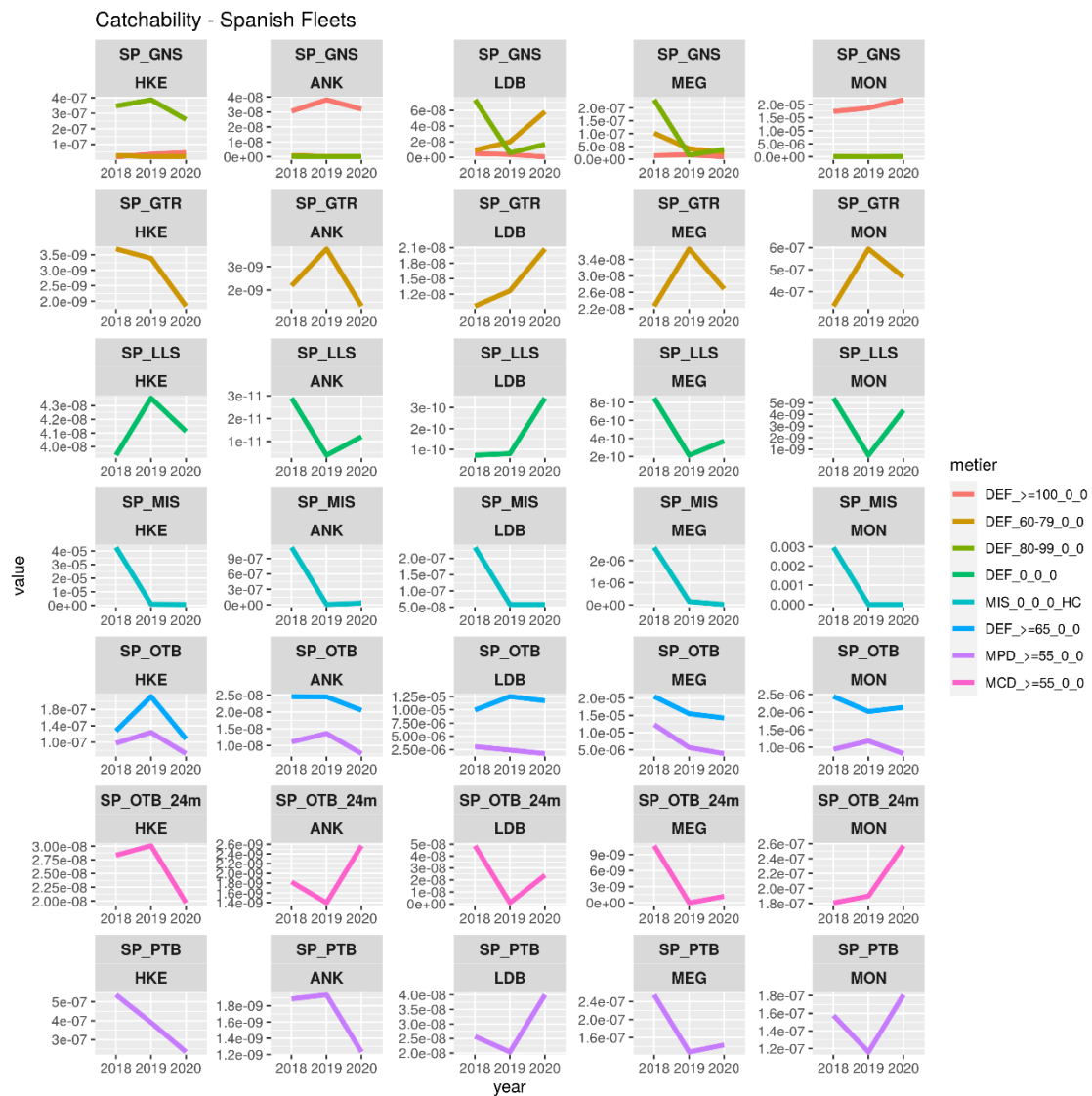
Figure 4.8. Iberian waters: trends of Spanish catchability by stock, fleet and métier from 2018-2020.
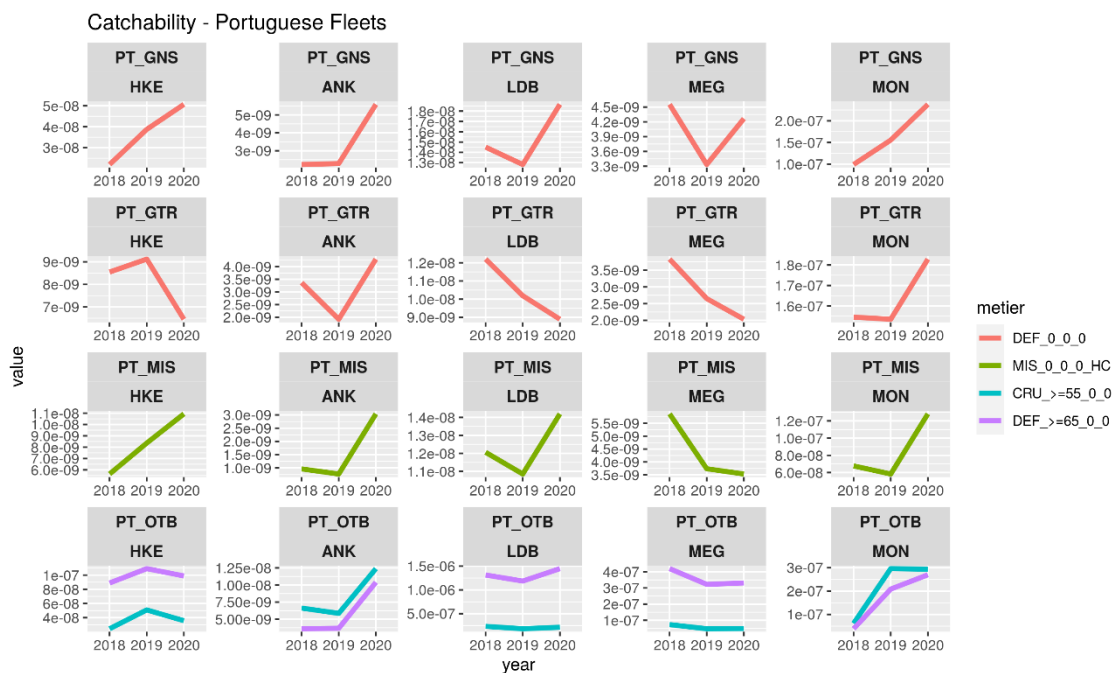
Figure 4.9. Iberian waters: trends of Portuguese catchability by stock, fleet and metier from 2018-2020.
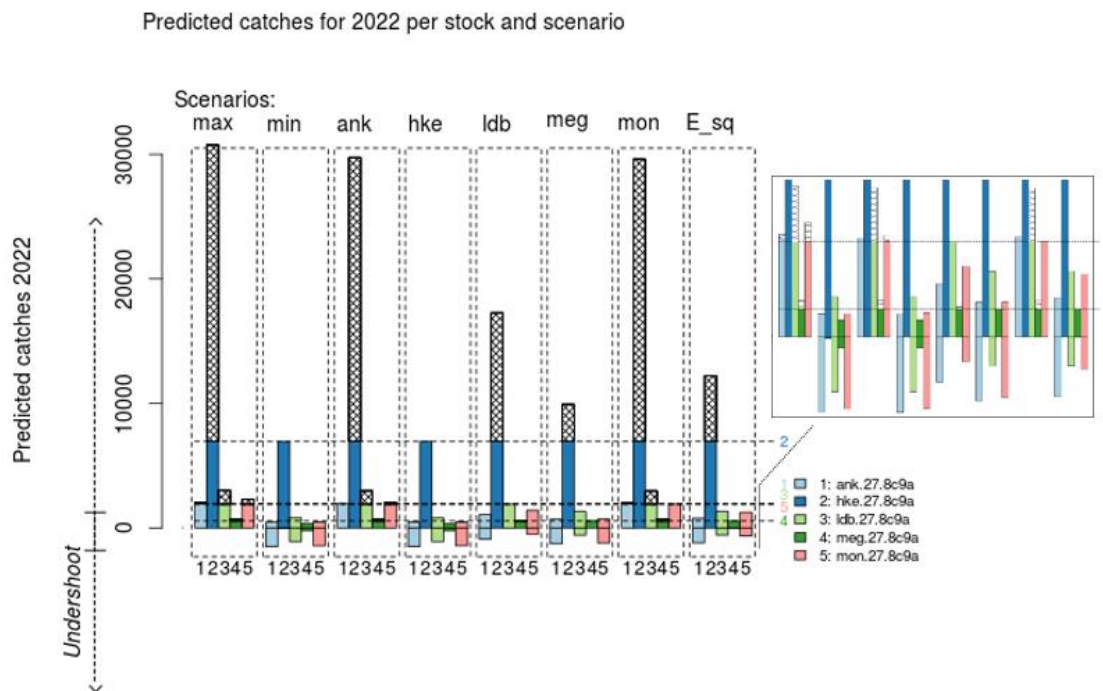
Figure 4.7. Iberian waters mixed fisheries forecasts: Advice year results (2022). FLBEIA estimates of potential catches by stock after applying the status-quo effort scenario to all stocks in the intermediate year followed by the FLBEIA scenarios. Horizontal lines correspond to the catch set by the single-stock advice. Bars below the value of zero show the scale of undershoot (compared to the single-species catch advice) in cases where catches are predicted to be lower when applying the scenario. The right panel is magnified so that the y-axis shows the interactions between the megrims and anglerfishes stocks.
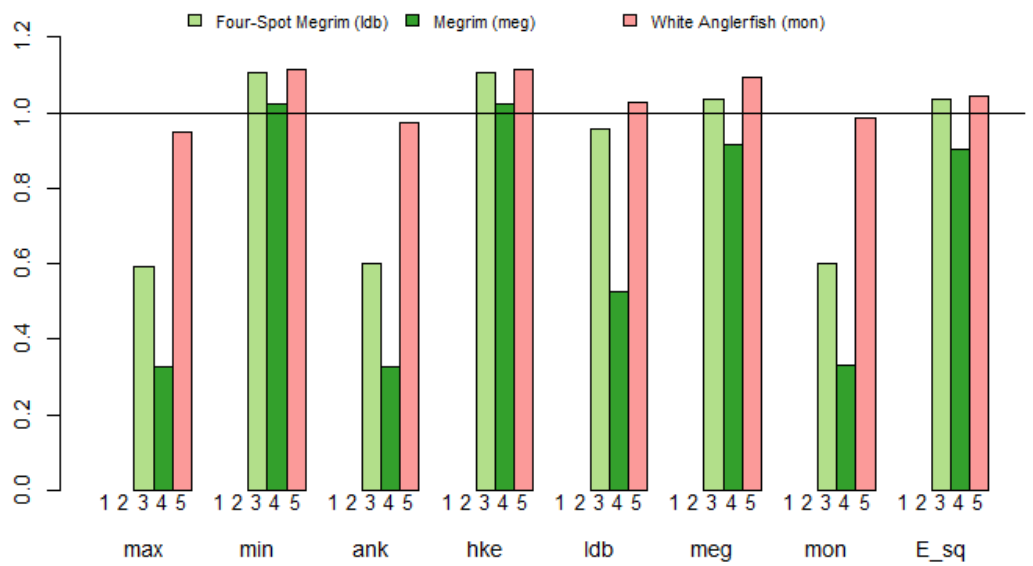
Figure 4.8. Iberian waters mixed fisheries forecasts: Estimates of potential SSB at the start of 2023 by stock after applying the mixed fisheries scenarios, expressed as a ratio to the single-species advice forecast. Horizontal line corresponds to the SSB resulting from the single-stock advice (at the start of 2023).
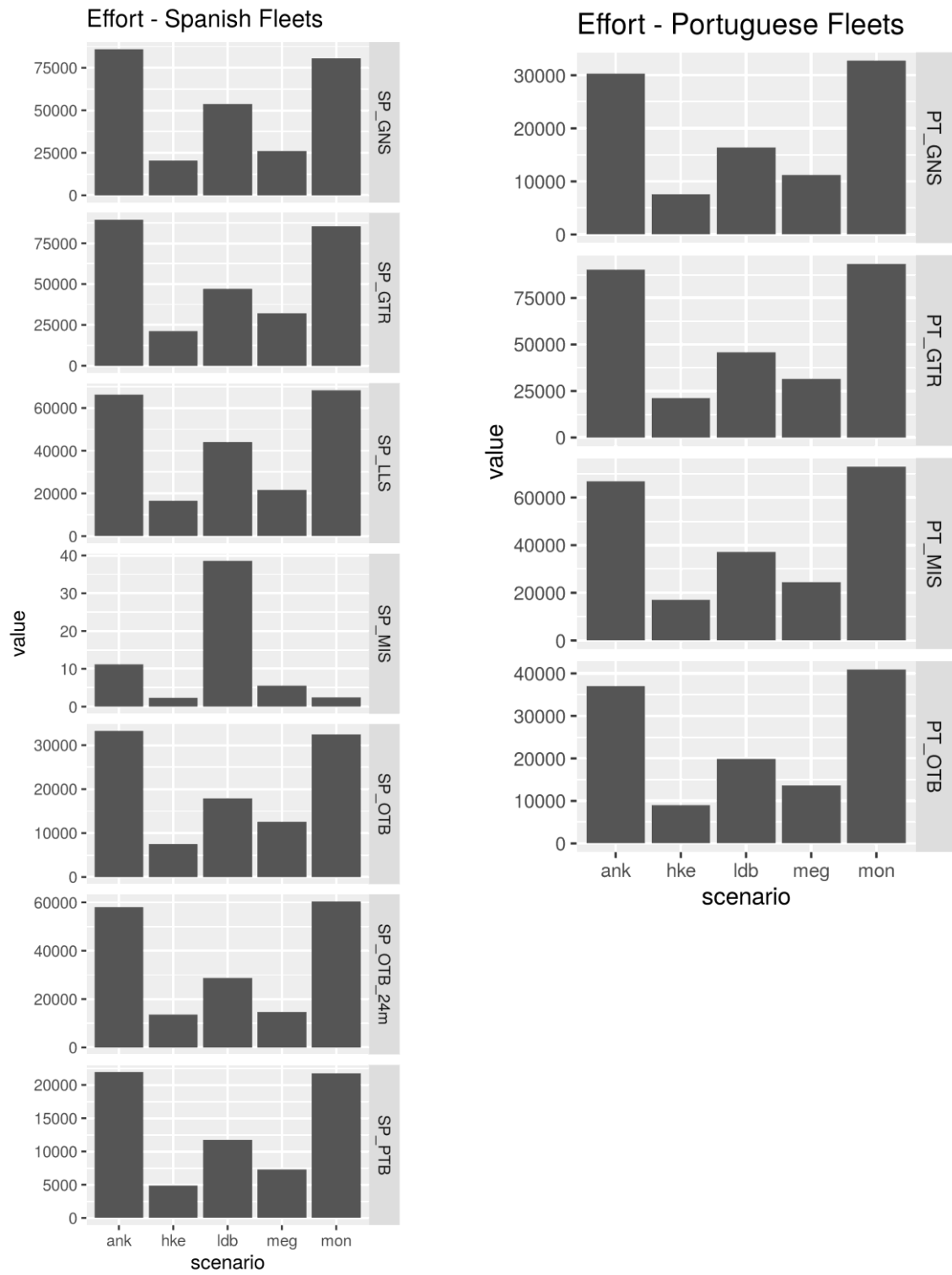
Figure 4.7. Iberian waters mixed-fisheries forecasts: Advice year results (2022). FLBEIA estimates of effort by fleet corresponding to the individual "quota share" (or partial target F) by stock in 2022 (baseline run).
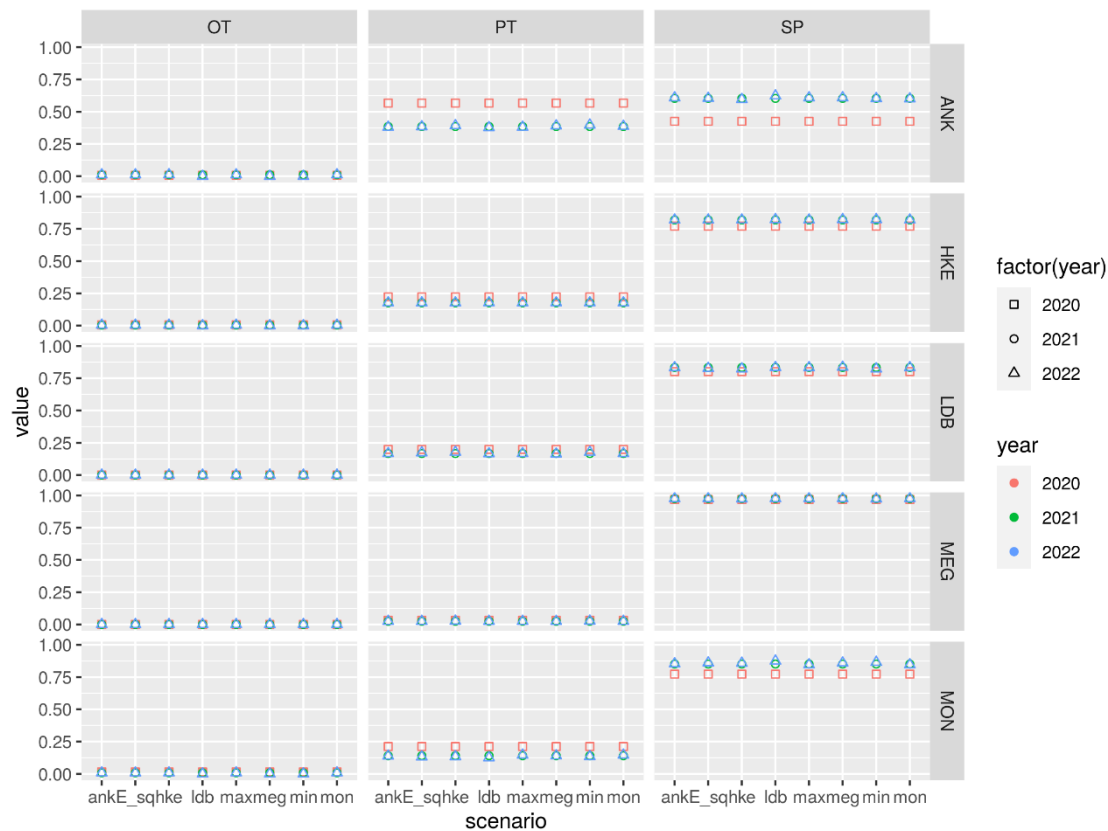
Figure 4.8. Iberian waters mixed fisheries forecasts: Test for relative stability. Changes of relative share of landings by country in 2021 and 2022 compared to the 2020 share for the eight FLBEIA scenario.

5 Irish Sea

5.1 Background

The Irish Sea, ICES Division 7.a, is a relativity enclosed sea basin situated between Ireland/Northern Ireland and Great Britain. It is connected to the Celtic Sea (7.g) in the south by St George's Channel, and in the north, it is linked to the West of Scotland (6.a) by the Northern Channel. Within the Irish Sea there are distinct habitat patches formed from a combination of bathymetry, topographical features and hydrography. The area contains a deeper channel in the west with a maximum depth exceeding 275 m, and eastern bays have depths less than 50 m. A large well-defined deep-water mud basin is located in the north-western region close to the Northern Irish and Irish coastline. There is another distinct mud habitat in the east of the division. These two mud habitats are identified as two separate *Nephrops* functional units (FU14 and FU15).

5.2 Management considerations

The primary catch species managed by TACs in the Irish Sea (ICES division 7.a) are: cod, haddock, herring, plaice, sole, whiting, and *Nephrops* (FU14 and FU15). 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 quarter 1 Northern Irish Groundfish Survey (NIGFS-WIBTS-Q1). *Nephrops* stocks are assessed using UWTV based stock assessment models. Irish Sea cod will be benchmarked in early 2022, with the aim of re-establishing a Category 1 assessment for that stock.

Nephrops is the main demersal species landed by Irish Sea fisheries. *Nephrops* is mainly targeted using otter trawls (OTB) with mesh size in the range 70–99 mm. This fishery is primarily focused in the north west of the Irish Sea, with > 95% of landings in 2020 caught in FU 15. Of demersal species haddock accounts for the second highest landings and is mainly caught in otter trawls (OTB) and mid-water otter trawls (OTM). Plaice accounts for the third highest landings in the Irish Sea, and is mainly targeted by beam trawls (TBB) which are also the primary gear landing of sole.

Cod and whiting are managed as by-catch only in the Irish Sea, with no directed fishery of either species permitted in the area. As such they are likely to have considerable mixed fisheries implications, as catches may be impacted by adjusting the fishing opportunities permitted for other species in addition to technical measures such as area closures and technical devices such as highly selective gears. At present ICES advice is zero catch for whiting 2022 and 2023 whilst average catches during 2018–2021 has been 1093 t. The current fishing opportunities for cod and whiting are set at 206 t and 721 t respectively to allow for by-catch from other fisheries (EU, 2021). Catches of whiting are primarily observed in *Nephrops* directed otter-trawl fisheries, with a smaller proportion from fin-fish directed otter-trawls and other gears. Catches of cod are primarily observed in demersal fish directed otter-trawl fisheries (both OTB and OTM), with significant proportions from *Nephrops* directed otter trawls and beam trawls (Figure 5.1).

In addition to demersal fisheries, a seasonal pelagic herring fishery operates in late summer to early autumn in the pre and post spawning period. Dredge fisheries target king and queen scallops, with king scallops in coastal areas and the queen scallop fishery operating in the central

area south of the Isle of Man. To a lesser extent queen scallops are also targeted using trawl nets during the late summer when swimming activity is most pronounced.

Four nations dominate the fishing effort namely Northern Ireland, Republic of Ireland, England and Belgium. There is variation in the landings profiles of each métier at the country level, reflecting different fishing patterns, practice, and quota shares (figures 5.2 and 5.3).

5.3 Model

5.3.1 Software

The FCube model for these species was developed using the FLR framework (Kell et al., 2007; FLCore 2.6.17, FLFleet 2.6.1, FLAssess 2.6.3, Flash 2.5.11) running in R 4.1.1 (R Development Core Team, 2021). Forecasts for fish stocks with analytical assessments (haddock, plaice, sole and whiting) were projected using the fwd() function in the Flash Package. The FCube method is developed as a stand-alone script using FLR objects as inputs and outputs. All code is stored on github at: https://github.com/ices-taf/2021_IrS_MixedFisheriesAdvice

Table 5.1. Software used by WGCSE in the single-species assessments and forecasts

Stock	Assessment	Forecast
cod.27.7a	Category 3 Trends based assessment	NA
had.27.7a	ASAP (Age-Structured Assessment Programme; NOAA)	FLR STF
nep.fu.14	Underwater TV survey	NA
nep.fu.15	Underwater TV survey	NA
ple.27.7a	Age-based stochastic analytical assessment (SAM)	SAM
sol.27.7a	Age-based analytical assessment (XSA)	FLR STF
Whg.27.7a	ASAP (Age-Structured Assessment Programme; NOAA)	FLR STF

5.3.2 Scenarios

FCube (Ulrich *et al.* 2008; 2011) was used to forecast a number of mixed fisheries forecasts. The basis of the model is to estimate the potential future levels of effort by a fleet corresponding to the fishing opportunities (TACs by stock and/or effort allocations by fleet) available to that fleet, based on fleet effort distribution and catchability by métier. This level of effort was then used to estimate landings and catches by fleet and stock, using the standard forecast assumptions and procedures from the single-species assessment (with the exception of plaice which was forecast using FLR rather than SAM). The basis for each single-stock advice was retained in the current mixed fisheries framework.

The mixed fisheries model development includes cod, haddock, plaice, sole, whiting and *Nephrops* FU14 and FU15. All of these stocks are included in the fleet object and reproduction of the single-species advice forecasts. However, in the final FCube model runs the results for plaice and the corresponding plaice scenario were deemed to be unreliable. In particular, in the plaice scenario projected landings were much higher than expected based on single-species advice. This is most likely due to differences in the representation of the stock in single species assessment forecast and the FCube based forecast. Therefore, we do not present the results of a plaice

scenario or the standard 'max' scenario in this report (the 'max' scenario is dependent on plaice). This issue will be further investigated intersessionally, and is not thought to impact on the results for other scenarios or species.

The following options (or scenarios) were included in the advice:

	Scenarios
Min	**"Minimum":** For each fleet, fishing stops when the catch for any one of the stocks meets the fleet's stock share. This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks.
COD-IS	**"Cod MSY approach":** All fleets set their effort corresponding to that required to catch their cod.27.7.a stock share, regardless of other catches.
HAD-IS	**"Haddock MSY approach":** All fleets set their effort corresponding to that required to catch their had.27.7.a stock share, regardless of other catches.
NEP14	**"*Nephrops* FU14 MSY approach":** All fleets set their effort corresponding to that required to catch their nep.fu.14 stock share, regardless of other catches.
NEP15	**"*Nephrops* FU 15 MSY approach":** All fleets set their effort corresponding to that required to catch their nep.fu.15 stock share, regardless of other catches.
SOL-IS	**"Sole MSY approach":** All fleets set their effort corresponding to that required to catch their sol.27.7.a stock share, regardless of other catches.
WHG-IS	**"Whiting MSY approach":** All fleets set their effort corresponding to that required to catch their whg.27.7.a stock share, regardless of other catches.
sq_E	**"*Status quo* effort":** The effort of each fleet in the TAC year (2021) is set equal to the average effort in the most recent 3 years (2018-2020) for which catch and effort data are available.

Note that throughout this document, the term "fleet's stock share" or "stock share" is used to describe the share of the fishing opportunities for each particular fleet, calculated based on the single-stock advice for 2022 and the historical proportion of the stock landings taken by the fleet (2018-2020).

5.4   Data compilation

Data used to produce the mixed fisheries forecasts comes from three sources:

1.   Stock data: Stock abundance, structure, reference points, advice and trends (ICES, 2021e).
2.   Fisheries dependent data: fleet and métier trends in landings and effort (2018-2020), are sourced from the WGMIXFISH data call.
3.   Discard data: from the ICES InterCatch database, and individual WGCSE stock coordinators.

5.4.1   Stock data

Single species stock assessment outputs including biomass, fishing mortality, biological parameters (maturity, natural mortality) and age-structure was supplied by WGCSE (ICES 2021e) in the form of FLR stock objects (with the exception of plaice which was supplied as a SAM object). Details of reference points, advice for 2022, TAC and trends in stock status were taken from the advice sheets. The consistent support and cooperation from the chairs and single species stock assessors has greatly eased the workload of WGMIXFISH in 2021. An overview of the trends and advice for stocks included in Irish Sea mixed fisheries analysis from the single species advice sheets for these stocks is described below (ICES 2021e) (Table 3.)

5.4.2   Fisheries dependent data

Information on fisheries is supplied according to the WGMIXFISH data call in the form of "accessions" data, this provides disaggregated fleet data at the level of métier which are consistent with the definitions outlined in the DCF. This includes landings (in tonnes) for defined species and fishing effort (in KW days). Landings and effort métiers for the model stocks were checked for consistency within countries and years, and effort data was available for 100% of the métiers for which landings were reported. For comparison of accessions data and other data sources see section 5.3.7 Quality Control.

5.4.3   Discard data

Discard ratios were calculated per country, métier (level 6 where possible e.g. OTB_CRU_70-99_0_0_all) and year from InterCatch discard estimates (either raw country submission or raised) and applied to the landings data supplied in the WGMIXFISH data call.
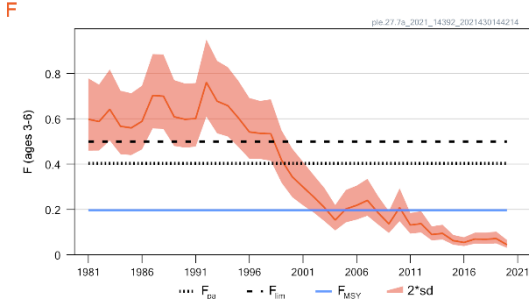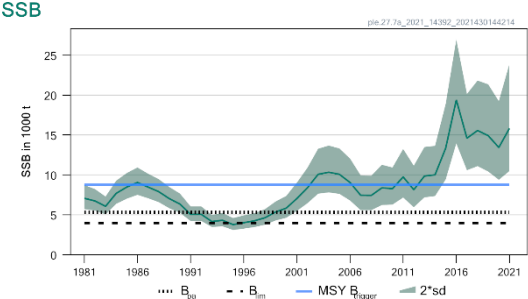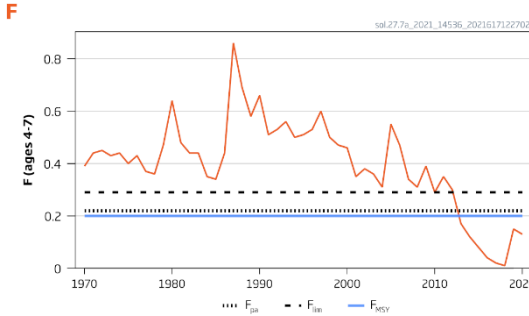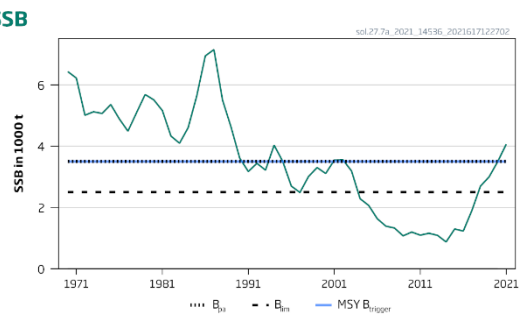
For some 7a stocks InterCatch discard data is not consistent with that used in the assessment (namely; sol.27.7.a and whg.27.7.a), and in these cases discard data in InterCatch formats were sourced directly from the stock coordinators of these stocks. In the case of sol.27.7.a this is standard practice, whilst in the case of whg.27.7.a this related to changes in data processing to accommodate incorporation of other sampling sources in in 2020 due to Covid-19. In *Nephrops* FU14 there was no discard available in 2020 due to the Covid-19 pandemic. Therefore, discard rates were estimated as the mean value of the three preceding years (per country and métier), this matches the procedure in the 2021 single species assessment for this stock.

Overall, the conformity of métiers in MIXFISH and InterCatch was high, however, it would be desirable for countries to continue improving the consistency between data uploaded to Inter-Catch and data submitted to WGMIXFISH (for details see 5.3.7 Quality Control).

Table 5.2. Summary of advice, fishing pressure/harvest rate and stock trends for the stocks included in the Irish Sea mixed fisheries model (ICES 2021)

Fish stocks
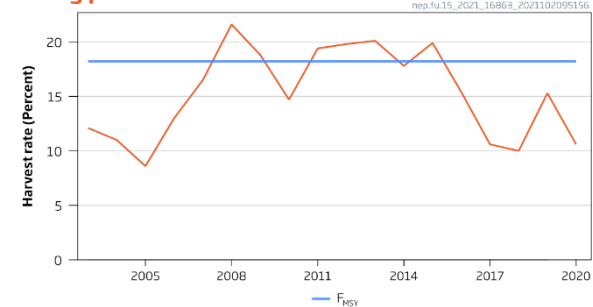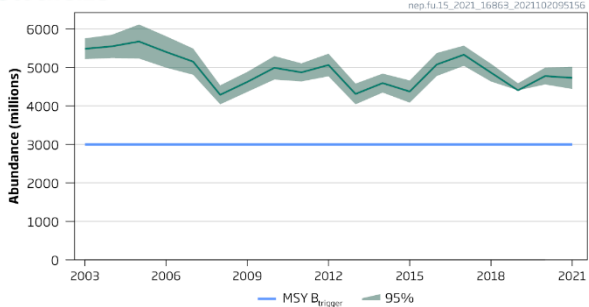
Species	Area	Stock status		Advice 2021
cod.27.7.a	Irish Sea – Division 7a (excluding rectangles 33E2 and 33E3)	**Harvest Rate**	**Biomass index**	ICES advises that when the precautionary approach is applied, catches in 2022 should be no more than 74 tonnes.
		Summary: The biomass index (NIGFS-WIBTS Q1) is used as an indicator of stock size. The orange horizontal lines indicate the average of the biomass index for 2017 to 2019 and 2020 to 2021. Harvest rate is calculated as scaled catches divided by survey index. ICES cannot assess the stock and exploitation status relative to the maximum sustainable yield (MSY) and precautionary approach (PA) reference points because the reference points are undefined.		
had.27.7a (Haddock)	Irish Sea – Division 7a (excluding rectangles 33E2 and 33E3)	**F**	**SSB**	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 3038 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by some of the relevant management authorities for this stock.
		Summary: Fishing pressure on the stock is below F_{MSY} and spawning–stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.		

Species	Area	Stock status		Advice 2021
ple.27.7a (Plaice)	Irish Sea – Division 7a			ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, total catches in 2022 should be no more than 2747 tonnes.
		Summary: Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.		
sol.27.7a (Sole)	Irish Sea – Division 7a			ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 787 tonnes.
		Summary: Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.		

Species	Area	Stock status		Advice 2021
Whg.27.7a	Irish Sea – Division 7 a (excluding rectangles 33E2 and 33E3)	F whg.27.7a_2021_14474_202150120757 SSB whg.27.7a_2021_14474_202150120757 F_{pa} F_{lim} F_{MSY} 95% B_{pa} B_{lim} MSY $B_{trigger}$ 95%		ICES advises that when the MSY approach and precautionary considerations are applied, there should be zero catches in 2022 and 2023.

Summary: Fishing pressure on the stock is above F_{MSY}, F_{pa}, and F_{lim}; spawning-stock size is below MSY $B_{trigger}$, B_{pa}, and B_{lim}.

Nephrops stocks

Species	Area	Stock status		Advice 2021
nep.fu.14 (*Nephrops*)	Divisions 7.a, Functional Unit 14 (Irish Sea, West)	**Fishing pressure** nep.fu.14_2021_16852_2021929123736 Harvest rate (percent) F_{MSY}	**Stock size** nep.fu.14_2021_16852_2021929123736 Abundance (millions) MSY $B_{trigger}$ 95%	ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2017–2019, catches in 2022 should be no more than 835 tonnes. To ensure that the stock in Functional Unit (FU) 14 is exploited sustainably, management should be implemented at the FU level. ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 7.

Summary: Fishing pressure on the stock is below F_{MSY} and stock size is above MSY $B_{trigger}$.

Species	Area	Stock status		Advice 2021

nep.fu.15 (*Nephrops*)

Divisions 7.a, Functional Unit 15 (Irish Sea, West)

Fishing pressure

Stock size

Summary: Fishing pressure on the stock is below F_{MSY}, and stock size is above MSY $B_{trigger}$.

ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 11 785 tonnes.

To ensure that the stock in Functional Unit 15 is exploited sustainably, management should be implemented at the functional unit level.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 7.

5.4.4   Building the fleet

The above data sources are then combined to produce the "fleet object" which is used as an input into FCube. Within this object the fleets were defined by aggregating catch and effort across country, gear types and vessel length groups based on expert knowledge of fleet characteristics (eg. English otter-trawls, English beam trawls, Northern Irish Otter Trawls etc.). Fleets which did not land > 1% of any of the stocks included the analysis were then aggregated into an "others" ("OTH_OTH") fleet to reduce the dimensions of the model. The final data used contained 9 fleets and an "other" fleet (OTH_OTH) from three years (2018 to 2020). Within a fleet, métiers were defined using the Technical Regulation (TR) classes methodology (outlined in the long-term plan for cod stocks and the fisheries exploiting those stocks, Council Regulation (EC) 1342/2008). This is based on a combination of gear groupings and mesh sizes, a further grouping was used to separate mid-water and pelagic gears which are expected to differ in their catch composition. Specifically,

Gear groupings and assigned métiers in the FCube fleets:

(a)   Bottom trawls and seines (OTB, OTT, PTB, SDN, SSC, SPR) of mesh:

TR1 equal to or larger than 100 mm,

TR2 equal to or larger than 70 mm and less than 100 mm,

TR3 equal to or larger than 16 mm and less than 32 mm;

(b)   Beam trawls (TBB) of mesh:
BT1 equal to or larger than 120 mm
BT2 equal to or larger than 80 mm and less than 120 mm;

(c) Gill nets, entangling nets (GN);

(d) Trammel nets (GT);

(e) Longlines (LL).

A further gear grouping of 'mid-water and pelagic gears' was added to this list to represent the mid-water otter-trawl and pelagic trawl fisheries (OTM and PTM). A similar aggregation procedure as for the fleets was performed, where any métier which did not land > 1% of any stock was aggregated into an "OTH" métier. 5 métier classes were included in the final fleets (TR1, TR2, BT2, midwater/pelagic and other), and the number of combinations of these métiers differed between fleets. The combination of stocks landed by each métier varies greatly (Figure 5.1). In general, the number of métiers employed by individual fleets was low compared with other regions, however, this may be an artefact of the way in which the fleets and métier were classified. Furthermore, the model only operates in a single ICES division (7a), leading to a lack of disaggregation in spatial structure of métiers compared to other regions group métiers according to ICES divisions (e.g. OTB_CRU * 7b, OTB_CRU * 7c within the Celtic Seas model). Future model refinement will investigate the spatial structuring of fisheries within the Irish Sea region within a mixed fisheries context, particularly with regard to the *Nephrops* fishing grounds. This is likely to require different sources of input data, e.g. further disaggregated landings or VMS data.

5.4.5   Quality control

5.4.5.1   Métier coding – WGMIXFISH vs. InterCatch

Where possible discard estimates were retrieved from InterCatch and assigned to the same métiers within the WGMIXFISH accessions files. However, this method relies on being able to match métier definitions between the two datasets. Where exact match was not possible, expert knowledge was used to apply discard rates from similar InterCatch métiers for 8 country métier combinations (see Table 5.3). These métier year combinations accounted for less than 2% of the total accessions landings for the stocks in the model.

5.4.5.2   Matching Accessions, InterCatch and ICES official landings.

Early in the data 'cleaning' process a mismatch was noted between the WGMIXFISH data for the gadoid stocks (cod, haddock and whiting), and the landings in the stock objects used in the single species assessments. This disparity resulted from the difference between the single stock assessment area for the gadoid stocks (cod, haddock and whiting) which exclude rectangles 33E2 and 33E3 from the ICES area 7a. In order to better match the single species stock assessment the Irish accessions data on landings was requested and resubmitted for these stocks without those rectangles, during the working group meeting. This corrected to the mismatch between the landings data for these stocks. It was not possible to investigate the impact of this difference in assessment areas on the corresponding effort data for the fleets landing these stocks in those two rectangles during the advice meeting. This will be further investigated during 2022 in collaboration with data submitters for the region. The current working solution in a direct corollary of that used in the mixed fisheries model for the Celtic Sea, where landings from these two Irish Sea rectangles are added to the total landings for the gadoid stocks in the adjacent Celtic Sea areas.

After this correction the match between the accessions landings and official landings data for all stocks was perceived to be good (Figure 5.4). InterCatch landings were also similar for all stocks, except for whiting in 2018 where InterCatch landings were considerably lower than ICES official landings. This is thought to relate to landings where there is no discard sampling being included in the InterCatch data, most likely relating to pelagic gears. Further investigation will be carried out in conjunction with data submitters in 2022, to determine the exact source of the disparity. However, this is not thought to affect the current FCube model as the accessions landings, closely match the official ICES advice estimates, and raised discards used in the FCube model are only very slightly lower than the ICES advice when averaged across the data years (981t vs 1008t per year, < 3% difference). After raising the InterCatch discards to the accessions landings, there was a good match between raised discards, InterCatch discards and official ICES advice discards for all other stocks (Figure 5.5).

In the case of two 7a stocks, plaice and sole, discards are treated differently in the single species assessment. Specifically, for sole, no discards are included in the assessment or FLR forecast of the stock, but instead discards are added to the forecast post-hoc based on an estimated 10% discard rate (ICES, 2021). For plaice, discards are adjusted by an estimated 40% dead discard rate in the assessment to represent survivability of discarded catch (i.e. total discards x 0.6 = dead discards) (ICES, 2021). Discards of sole were therefore set to zero in the mixed fisheries fleet objects, and the dead discard rate applied to plaice discards on the country, year, métier level within the mixed fishery fleet objects. These procedures are intended to maximise consistency between the single-stock assessment and mixed fisheries model.

5.5 Mixed fisheries forecasts

5.5.1 Description of scenarios

5.5.1.1 Baseline runs

The objectives of the single-species stock baseline runs were to:

1. reproduce as closely as possible the single-species advice,
2. and act as the reference scenario for subsequent mixed fisheries analyses.

The various single-stock forecasts produced by the single species working groups are performed using different software and setups (Table 3.2.1 above). The FCube model has been coded as a method in R 64bit (R Development Core Team, 2008), as part of the FLR framework (Kell *et al.*, 2007, www.flr-project.org). Input data are in the form of FLFleets and FLStocks objects from the FLCore 2.6.16 package, and two forecast methods were used, stf() from the FLAssess (version 2.6.3) and fwd() from the Flash (version 2.5.11) packages. Stock objects were processed using FLa4a (version 1.8.2), FLXSA (version 2.6.5). As such, the input parameterisation as well as the stock projections are made externally using existing methods and packages, while only 3 steps are internalised in the method, thus keeping full transparency and flexibility in the use of the model. In the mixed-fisheries runs, all forecasts for analytical stocks were done with either the FLR forecast method. Future catches of *Nephrops* and cod, are estimated following the relevant single-stock procedures. This ensured greater coherence between the single stock and mixed fishery forecasts.

The same forecast settings as the single species assessment are used for each stock regarding weight-at-age, selectivity, and recruitment, as well as assumptions on the F in the intermediate year and basis for advice (MSY approach and Management plan). Some differences can occur in the forecast calculations, (because of the diversity of single-stock assessment methods used) and the WG always investigates in depth the reasons for potential discrepancies. Adjustments to the FCube forecasts are made if necessary to minimise discrepancies.

The baseline runs therefore acted as a quality control procedure to ensure that the projections were set up correctly within the FCube script. The baseline run has the additional benefit of acting as a quality control check on the projections produced by the single species stock assessors.

5.5.1.2 Mixed fisheries runs

FCube assumptions of the intermediate year (2021)
For the mixed fisheries scenarios, the intermediate year assumption used was status quo fishing effort (mean 2018-2020). This assumption is applied to all stocks in the intermediate year, derived from the FLFleet objects. This is similar to an intermediate year assumption of an average F over the preceding 3 years frequently used in single stock assessments. However, in the single stock assessments different intermediate year assumptions may be applied for different stocks. For example, of the Irish Sea analytical stocks in 2021, an intermediate year assumption of the mean F of the preceding three years was used for whiting and plaice, whilst the mean F between 2017-2019 was used for haddock and the landings corresponding with the 2021 TAC for sole.

FCube analyses for the TAC year (2022)
For the stock targets in the FCube scenarios a fishing mortality consistent with the fishing the single stock catch advice was used.

Nine scenarios were run, as outlined in Section 3.2.2 above,

In summary, the FCube runs followed the scheme below:
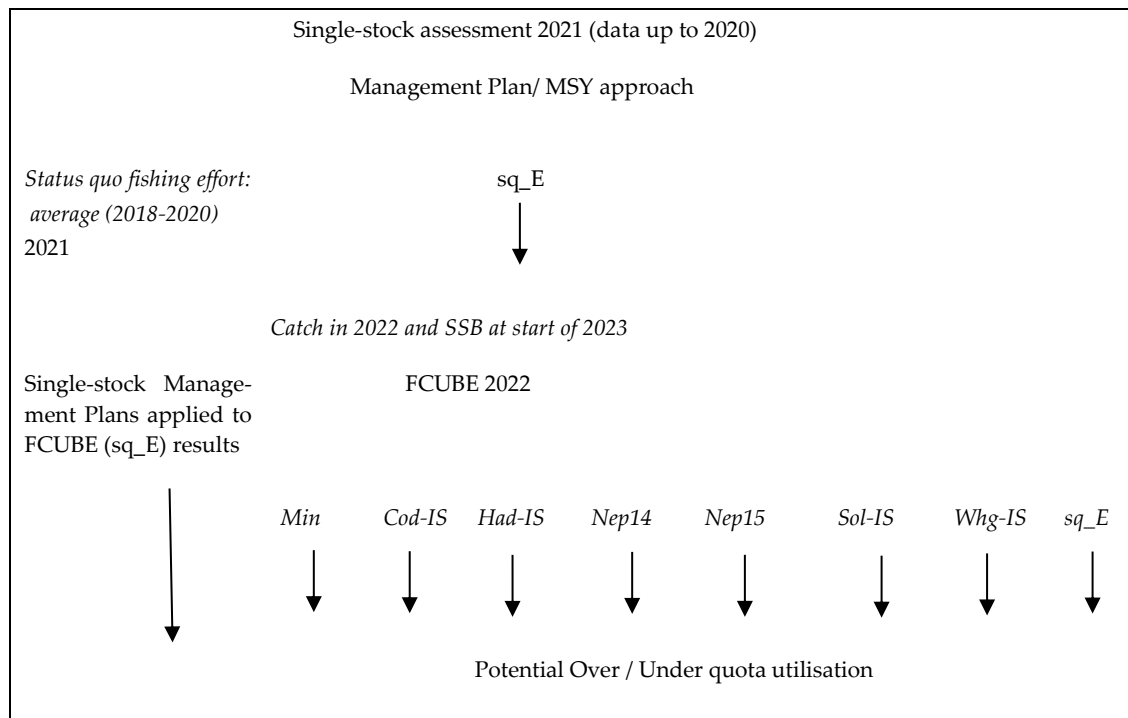
5.5.2 Results of FCube runs

5.5.2.1 Baseline run – reproducing the single stock advice

Overall consistency of results between single species stock assessments and FCube baseline runs was achieved, based on comparisons of predicted catches, landings, SSB and Fbar in 2021 and 2022 for analytical stocks (Table 5.5, Figure 5.6), and in 2022 for non-analytical stocks (Table 5.6, Figure 5.7). The largest disparity observed was with plaice (between 0 and 5.9 %). These disparities were higher (ca. + 5%) for catch and landings than for SSB (-2.1%). These minor disparities may be accounted for by differences in the forecasting methods, as the single species advice forecast uses a stochastic SAM forecasting method, whilst the WGMIXFISH method uses an FLR forecast. These differences, though relatively minor, will be investigated intersessionally and future FCube models for the region will likely include a SAM based forecast for this stock. Cod, haddock and sole forecasts were replicated exactly, and any differences in forecast values for NEP14, NEP15 and Sole were minor (< 0.2 %).

Figure 5.8 shows the required change in fishing mortality for each stock if the intermediate year assumptions (2021) and advice targets (2022) of the single species advice are to be met. A large reduction in Fbar would be required to meet the advice target of zero catch for whiting in 2022. Meanwhile, an increase in fishing pressure would be required to catch up to the advice of haddock, plaice and sole. This indicates a probable mixed fisheries conflict between the stocks, as the full advice for these fisheries is unlikely to be achieved without exceeding the advice for whiting. This is especially true for haddock fisheries, as this species tends to caught by similar fleets and gears/métiers. *Nephrops* fisheries are not shown in Figure 5.8, but similar issues are likely due to the fleets and gears utilised.

5.5.2.2 Mixed fisheries analyses

The overview of the FCube catch projections for each scenario is shown in Table 5.7 and Figure 5.9. These results should be considered indicative and maybe revised as the mixed fishery model

is improved and updated. At present ICES is not providing mixed fisheries advice based on this model in 2021. Further model testing, refinement and identification of key scenarios is required.

In contrast to single-stock advice there is no single advised catch level based on the mixed fishery approach, instead a range of scenarios are presented. Scenarios that result in under or overutilization are useful in identifying any imbalance between the fishing opportunities for the various stocks. They indicate the direction in which fleets may have to adapt to fully utilise their catch opportunities without collectively exceeding single-stock fishing opportunities.

The outcome of the "minimum" scenario is driven by the stocks which are most limiting for each individual fleet (figures 5.9 and 5.10). As the catch advice for whiting in 2022 is zero, and whiting is caught by all fleets (either as landings or discards), the whiting scenario is the same as the 'min scenario'. Of the presented scenarios presented, only the 'min' and 'whiting' scenarios meet the objective of all stocks being fished at or below F_{MSY}. This is similar to the full implementation of the Landing Obligation. The current analysis does not account for any national mismatch in stock shares which may occur in light of adopting mixed fishery based management of fishing opportunity. Fishery managers may need to consider additional measures aimed at minimizing the potential misalignment between activity and stock shares for the fleets, such as changes in gear selectivity, spatiotemporal management measures, or reallocation of stock shares, if fishing opportunities are to be taken under a fully implemented Landing Obligation.

The least limiting stock differed between fleets (Figure 5.10), with four of the ten fleets increasing their effort by the greatest amount when fishing up to the advice for *Nephrops FU 14*. This is likely to be because fleets mostly fishing outside of the *Nephrops FU* 14 area are less limited by the advice for this stock (e.g. NI_Otter). This highlights the need for further model refinement to accurately represent spatial patterns in fishing effort. This is especially evident within the *Nephrops* fisheries which are highly spatially separated between FU14 and FU15, but employ similar metiers. Due to differences in fishing fleets and locations, fishing effort and catches in FU14 and FU15 are unlikely to be linked in the way that the current FCube results for the *Nephrops* FU14 scenario imply.

The haddock scenario was least limiting to three fleets, probably due to the fact that haddock catches have been considerably below TAC's in the Irish Sea in recent years. Strong mixed fisheries considerations exist for this fishery, and the FCube forecast for the Haddock advice scenario resulted in catches above advice for cod, whiting and *Nephrops* in FU15 (Figure 5.9). The *Nephrops* FU15 advice scenario resulted in a similar overshoot in whiting, and a slightly smaller overshoot of cod. In both the Haddock and *Nephrops* scenarios cod catches are higher than estimated than expected under 'status quo effort' (2018-2020). The Sole scenario also resulted in an overshoot of all gadoid stocks (cod, haddock and whiting), and of *Nephrops* in FU15.

The 'Sq_E' scenario resulted in cod being fished above advised catch levels and whiting being fished above F_{MSY} in 2022 (Figure 5.9). The 'status quo effort' scenario also indicated that there was underutilisation of other stocks, indicating they these may be limited by factors other than TAC.

Mixed fisheries catch scenarios can take specific management priorities into account, and these results indicate that it is not possible to achieve all single-species management objectives simultaneously. ICES single-stock advice for demersal stocks is based on ICES maximum sustainable yield (MSY) approach. Any catch of whiting in 2022 is not considered precautionary as the stock is estimated to be and remain below B_{lim} (ICES, 2021).

5.5.2.3 The future of the Irish Sea mixed fishery model.

This report presents a standard set of scenarios for the Irish Sea region. During 2022, it is expected that further scenarios will be developed for the region based on alternative by-catch scenarios for whiting. Further model refinements are also expected.

Recommended future work:

Short-term

- Exploration of effort data correction to account for catch reallocation from 33E3 and 33E4 to the Celtic Sea.
- Identification of key scenarios for Irish Sea stocks
- Further investigation with the aim of including Plaice scenarios in the FCube model

Long-term

- Model refinement will to capture the spatial structuring of fisheries within the Irish Sea region, particularly with regard to the *Nephrops* fishing grounds.

Table 5.3. Mismatch between accessions and InterCatch métiers. Table shows the accessions métiers (WGMIXFISH) for which no matching métier was available from that country and year. InterCatch métiers from corresponding countries and years years to apply discard rates to these accessions métiers in the FCube fleet objects. Total landings, indicates total landings for that country, year and métier for the stocks in the model.

Country	Accessions métier	Year	Tonnes in accession	InterCatch métier
EN	FPO_CRU_0_0_0_all	2018	2.161	MIS_MIS_0_0_0
EN	OTB_CRU_100-119_0_0_all	2018	8.689	OTB_CRU_70-99_0_0_all
EN	OTB_DEF_100-119_0_0_all	2020	2.328	OTB_DEF_>=120_0_0_all
IE	DRB_MOL_0_0_0_all	2019	2.730	MIS_MIS_0_0_0
IE	FPO_MOL_0_0_0_all	2019	0.040	MIS_MIS_0_0_0
IE	OTB_DEF_>=120_0_0_all	2018	84.460	OTB_DEF_100-119_0_0_all
IE	OTB_DEF_>=120_0_0_all	2019	264.705	OTB_DEF_100-119_0_0_all
IE	OTB_DEF_>=120_0_0_all	2020	150.150	OTB_DEF_100-119_0_0_all
IE	OTB_DEF_70-99_0_0_all	2018	5.370	OTB_CRU_70-99_0_0_all
IE	OTB_DEF_70-99_0_0_all	2020	12.200	OTB_CRU_70-99_0_0_all
NI	FPO_MOL_0_0_0_all	2019	0.016	DRB_MOL_0_0_0_all
NI	OTB_DEF_70-99_0_0_all	2018	6.274	OTB_CRU_70-99_0_0_all

Table 5.4. Irish Sea. Summary of the 2021 ICES single-species advice. Target Fs are left justified; harvest ratios are right justified. Where a stock/Functional Unit does not have a management plan the landings follow ICES advice.

Species	Agreed TAC 2021	Total Catch-ad-vice for 2022	Projected landings-advice for 2022	F_{total}/Har-vest ratio for 2022	F_{wanted}/ Har-vest ratio for 2022	SSB 2022	SSB 2023
Cod 7a	296	74	57	*	*	**	**
Haddock 7a	3371	3 038**	2533	0.280	0.170	13 768	10 274
Nephrops FU 14	18 026***	853	785	0.110^	-	393^^	-
Nephrops FU 15	18 026***	11 785	9 924	0.182^	-	4 733^^	-
Plaice 7a	2 846	2 747	1 407	0.196	0.061	16 160	14 628
Sole 7a	768	787	708	-	0.20^^^	3 974	3 834
Whiting 7a	721	0	0	0	0	1326	2 334

* Single stock advice for Cod 7a is a category 3 assessment with no FLR forecast, and relative biomass indices and har-vest rates are used in place of SSB of *F* values for this stock.

** Revised advice value published 18-11-2021, replacing advice issued in June 2021

*** TAC applies to whole of Subarea 7. TAC's applied in FCube model at the FU level are based on proportion of land-ings within Subarea 7. This results in a TAC of 341t and 8992t respectively for FU14 and FU15 in the FCube model.

^ Harvest ratio for Projected landings + Projected dead discards

^^ Stock abundance in millions of individuals

^^^ F-target in the single stock forecast for Sole 7a is based on the landings (F_{wanted}).

Table 5.5 Comparison between WGMIXFISH reproduce the advice and ICES advice for analytical stocks. Figures for 2021 compare results from the baseline run to the ICES intermediate year results. The baseline run uses the same assumptions in the intermediate year as the forecasts leading to ICES advice.

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2021	HAD–IS	catch	1870.000	1870.000	0
2021	HAD–IS	Fbar	0.138	0.138	0
2021	HAD–IS	landings	1474.000	1474.000	0
2021	HAD–IS	ssb	17430.000	17430.000	0
2022	HAD–IS	catch	3038.000	3038.000	0
2022	HAD–IS	Fbar	0.280	0.280	0
2022	HAD–IS	landings	2533.000	2532.000	0
2022	HAD–IS	ssb	13768.000	13768.000	0
2023	HAD–IS	catch	NA	NA	NA
2023	HAD–IS	ssb	10274.000	10274.000	0
2021	PLE–IS	catch	857.000	898.000	−4.6
2021	PLE–IS	Fbar	0.061	0.061	0.0
2021	PLE–IS	landings	433.000	460.000	−5.9
2021	PLE–IS	ssb	15502.000	15830.000	−2.1
2022	PLE–IS	catch	2599.000	2747.000	−5.4
2022	PLE–IS	Fbar	0.196	0.196	0.0
2022	PLE–IS	landings	1349.000	1407.000	−4.1
2022	PLE–IS	ssb	15827.000	16160.000	−2.1
2023	PLE–IS	catch	NA	NA	NA
2023	PLE–IS	ssb	14500.000	14628.000	−0.9
2021	SOL–IS	catch	767.000	768.000	−0.1
2021	SOL–IS	Fbar	0.182	0.182	0.0
2021	SOL–IS	landings	691.000	691.000	0.0
2021	SOL–IS	ssb	4067.000	4067.000	0.0
2022	SOL–IS	catch	786.000	787.000	−0.1
2022	SOL–IS	Fbar	0.200	0.200	0.0
2022	SOL–IS	landings	708.000	708.000	0.0
2022	SOL–IS	ssb	3974.000	3974.000	0.0
2023	SOL–IS	catch	NA	NA	NA
2023	SOL–IS	ssb	3834.000	3834.000	0.0
2021	WHG–IS	catch	1309.000	1309.000	0
2021	WHG–IS	Fbar	0.647	0.647	0
2021	WHG–IS	landings	207.000	207.000	0
2021	WHG–IS	ssb	1393.000	1393.000	0
2022	WHG–IS	catch	0.000	0.000	0
2022	WHG–IS	Fbar	0.000	0.000	0
2022	WHG–IS	landings	0.000	0.000	0
2022	WHG–IS	ssb	1326.000	1326.000	0
2023	WHG–IS	catch	NA	NA	NA
2023	WHG–IS	ssb	2335.000	2334.000	0

Table 5.6 Comparison between WGMIXFISH reproduce the advice and ICES advice for *Nephrops* and Category 3 Cod stock. Figures for 2021 compare results from the baseline run to the ICES intermediate year results. The baseline run uses the same assumptions in the intermediate year as the forecasts leading to ICES advice. No comparison given for projected Fbar of Cod as this value is not used in the single stock advice. Fbar in mixed fisheries model is a proxy for fishing pressure corresponding to the catch/biomass index.

year	stock	value	FCube.baseline	Single.Spp.Advice	diff
2022	COD-IS	catch	74.000	74	0
2022	COD-IS	Fbar	532.432	NA	NA
2022	COD-IS	landings	57.000	57	0
2022	NEP14	catch	835.000	835.00	0.0
2022	NEP14	Fbar	0.110	0.11	0.0
2022	NEP14	landings	786.000	785.00	0.1
2022	NEP15	catch	11763.000	11785.000	−0.2
2022	NEP15	Fbar	0.182	0.182	0.0
2022	NEP15	landings	9903.000	9924.000	−0.2

Table 5.7 Indicative FCube scenarios for the in Irish Sea. Catch (in tonnes) for mixed-fisheries scenarios.

Scenarios/stocks	COD.7a	HAD.7a	SOL.7a	WHG.7a	NEP14	NEP15
min	0	0	0	0	0	0
COD-IS	264	1569	473	1586	700	9750
HAD-IS	594	3075	834	2538	718	22244
NEP14	671	3511	1628	2676	835	29753
NEP15	380	1856	757	1719	332	11679
SOL-IS	539	3354	843	2185	442	17557
WHG-IS	0	0	0	0	0	0
sq_E	208	1232	463	1182	166	7426
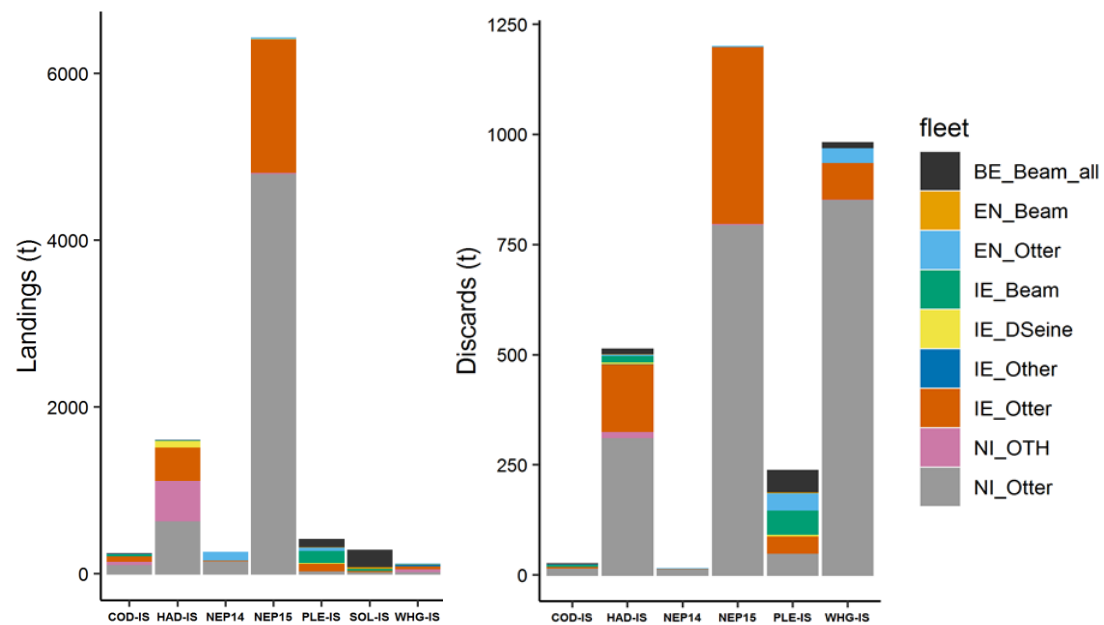
Figure 5.1. Landings and discards of stocks included in the FCube model by fleet, landings and discards are the average per fleet over the period 2018-2020. Y-axis scale differs between plots. Plaice discards are 'dead discards' only, calculated at the 40% survival rate as per the single species assessment. Sole discards are not included as these are not included in the FCube model as per single species stock assessment, and are instead calculated as 10% of catch by weight after the model forecast. Other fleets catching less than <1% of any stock are ommitted for visualisation reasons.
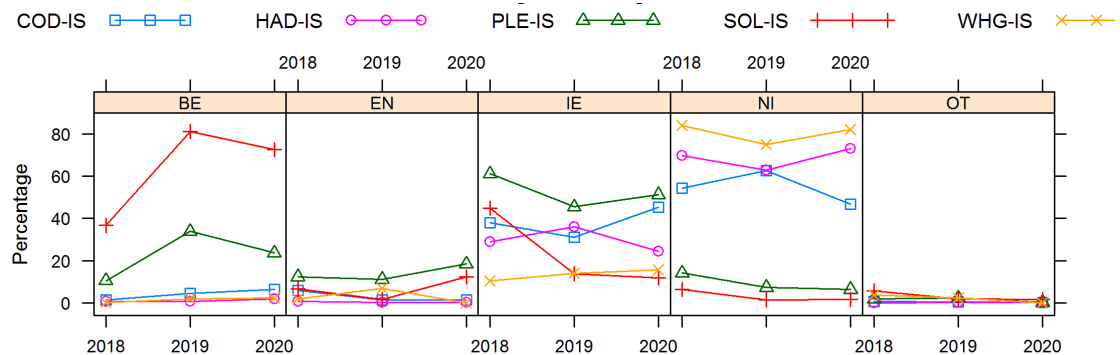
Figure 5.2. Percentage of total catches by country per fish stock 2018-2020. BE = Belgium, EN = England (UK), IE = Ireland, NI = Northern Ireland (UK). OT = fleets of any nationality landing < 1% of any stocks, which are omitted from final FCube model.
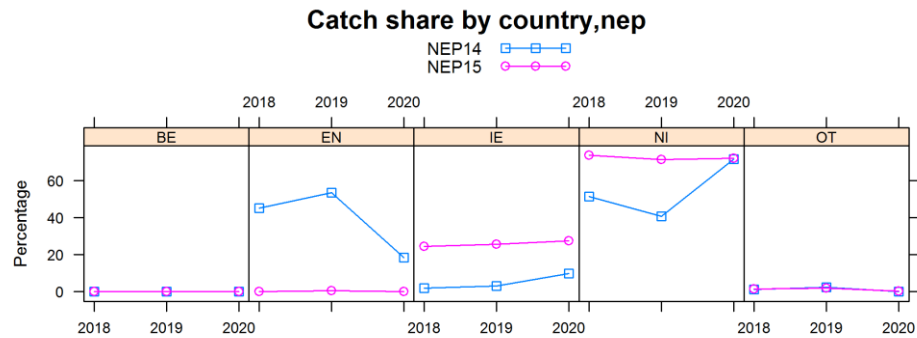
Figure 5.3. Percentage of total catches by country per *Nephrops* FU 2018-2020. BE = Belgium, EN = England (UK), IE = Ireland, NI = Northern Ireland (UK). OT = fleets of any nationality landing < 1% of any stocks, which are omitted from final FCube model.
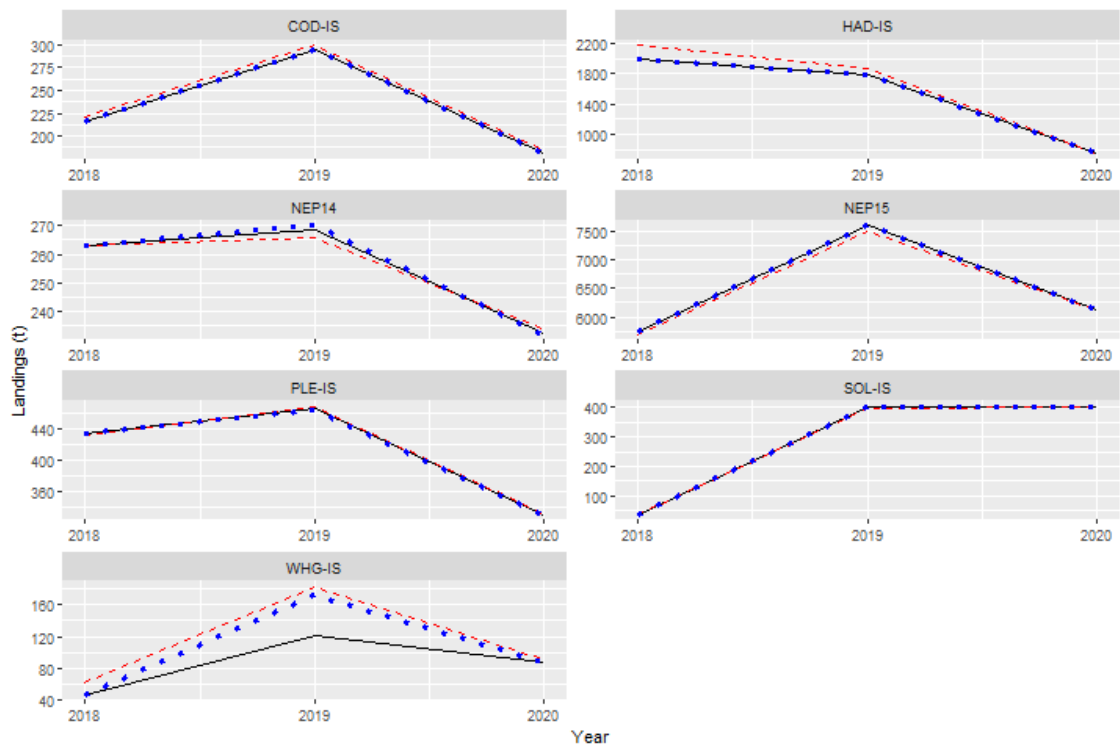
Figure 5.4. Quality control comparison of different sources of landings data. Blue dotted lines show ICES official landings from WGCSE advice sheets, dashed red line shows WGMIXFISH accessions landings data and solid black lines show landings reported in InterCatch data. Note differing scales on y-axes per stock.

Figure 5.5. Quality control comparison of different sources of discards data. Blue dotted lines show ICES official discards from WGCSE advice sheets, dashed red line shows WGMIXFISH discards data created by raising InterCatch discards per métier, country and year to accessions landings, and solid black lines show landings reported in InterCatch data. Note differing scales on y-axes per stock.
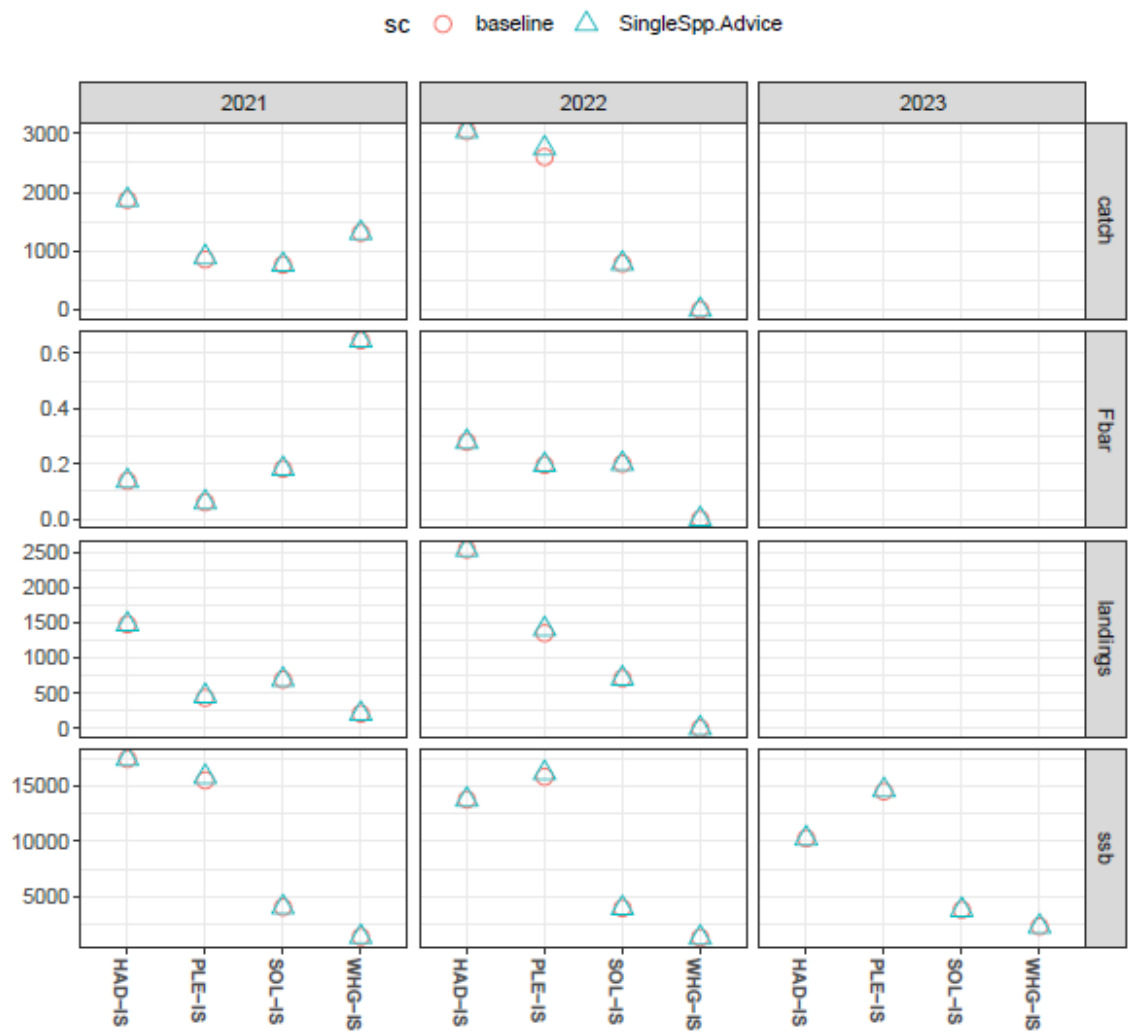
Figure 5.6 Difference between single species advice values and WGMIXFISH reproduce the advice baseline runs for analytical stocks.
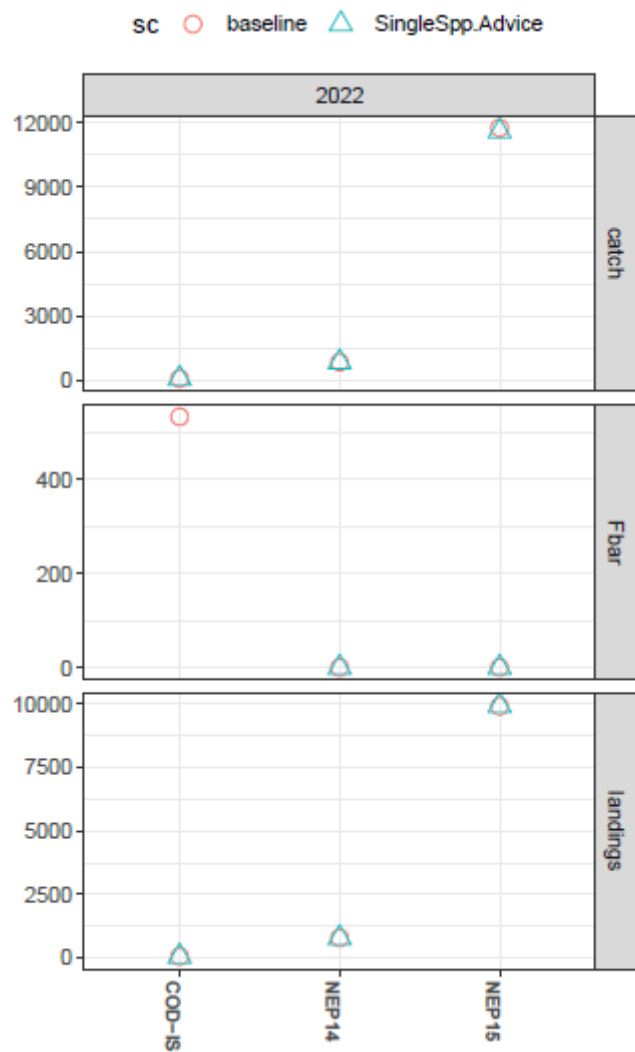
Figure 5.7 Difference between single species advice values and WGMIXFISH reproduce the advice baseline runs for analytical stocks. No comparison given for projected *F* of Cod as this value is not used in the single stock advice. F in mixed fisheries model is a proxy for fishing pressure corresponding to the catch/biomass index.
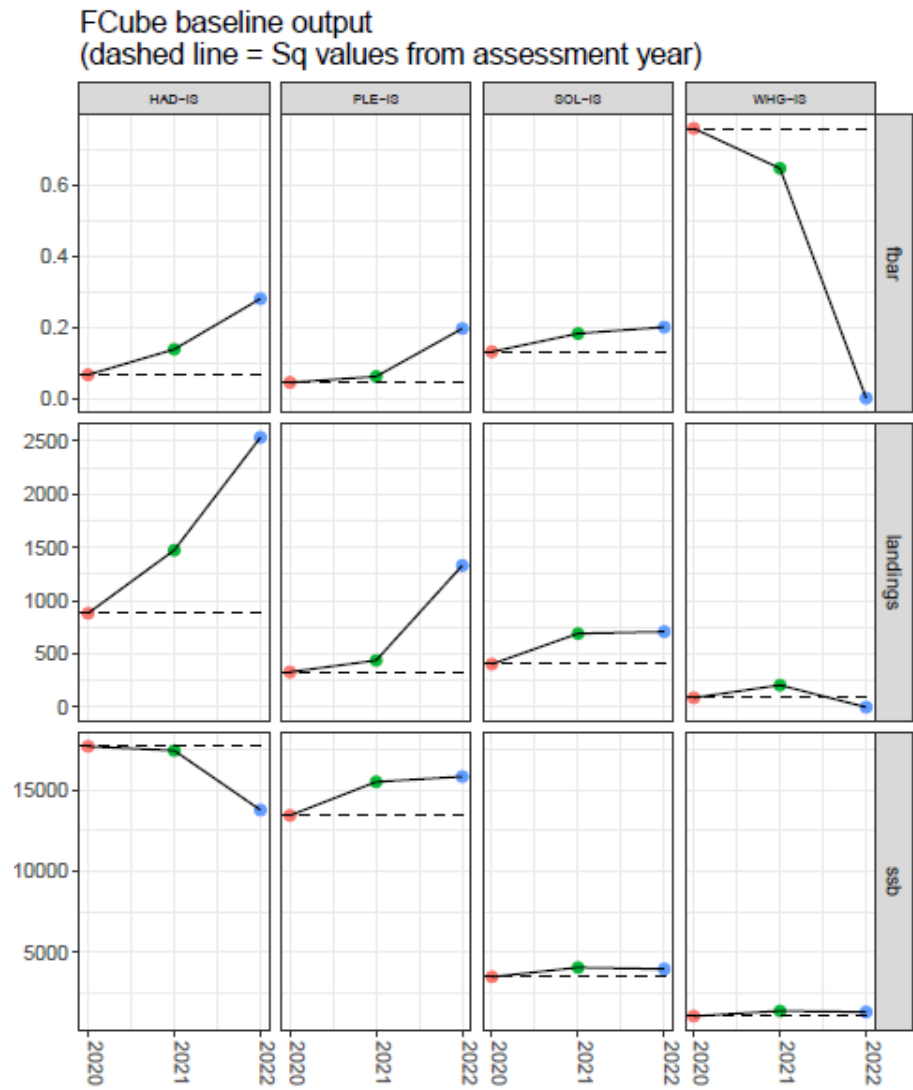
Figure 5.8 Change in fishing mortality (Fbar), landings (tonnes) and SSB (tonnes) assumed in the intermediate year (2021) and required for the TAC year (2022) under the single-stock forecast assumptions consistent with the MSY approach.
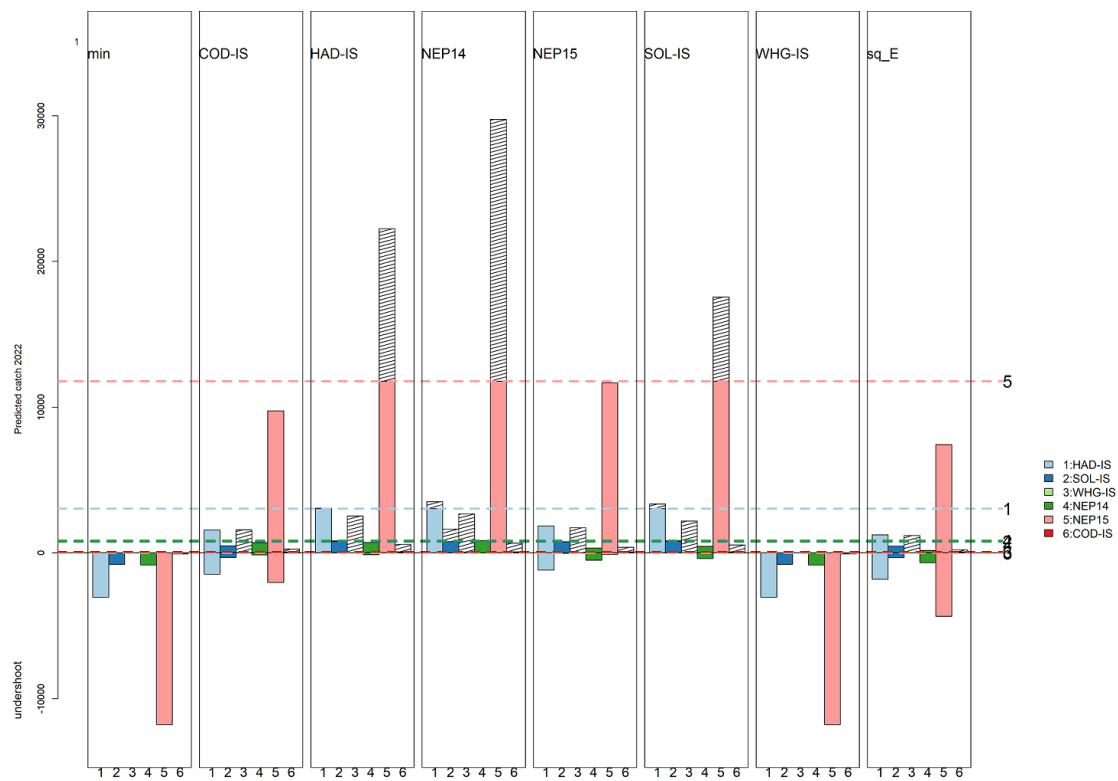
Figure 5.9. Irish Sea catch in FCube scenarios (2022). FCube estimates of potential catches by stock after applying the status quo effort scenario to all stocks in the intermediate year followed by the FCube scenarios. Horizontal lines correspond to the single-stock catch advice for 2022. Bars above the dashed lines are diagonally hashed to indicate an overshoot of the advised catch. Below the value of zero bars show the undershoot (compared to the single-species advice) in cases where catches are predicted to be lower when applying the scenario. Note: Due to differences in fishing fleets and locations, fishing effort and catches in FU14 and FU15 are unlikely to be linked in the way that the current FCube results for the *Nephrops* FU14 scenario imply (see main text).
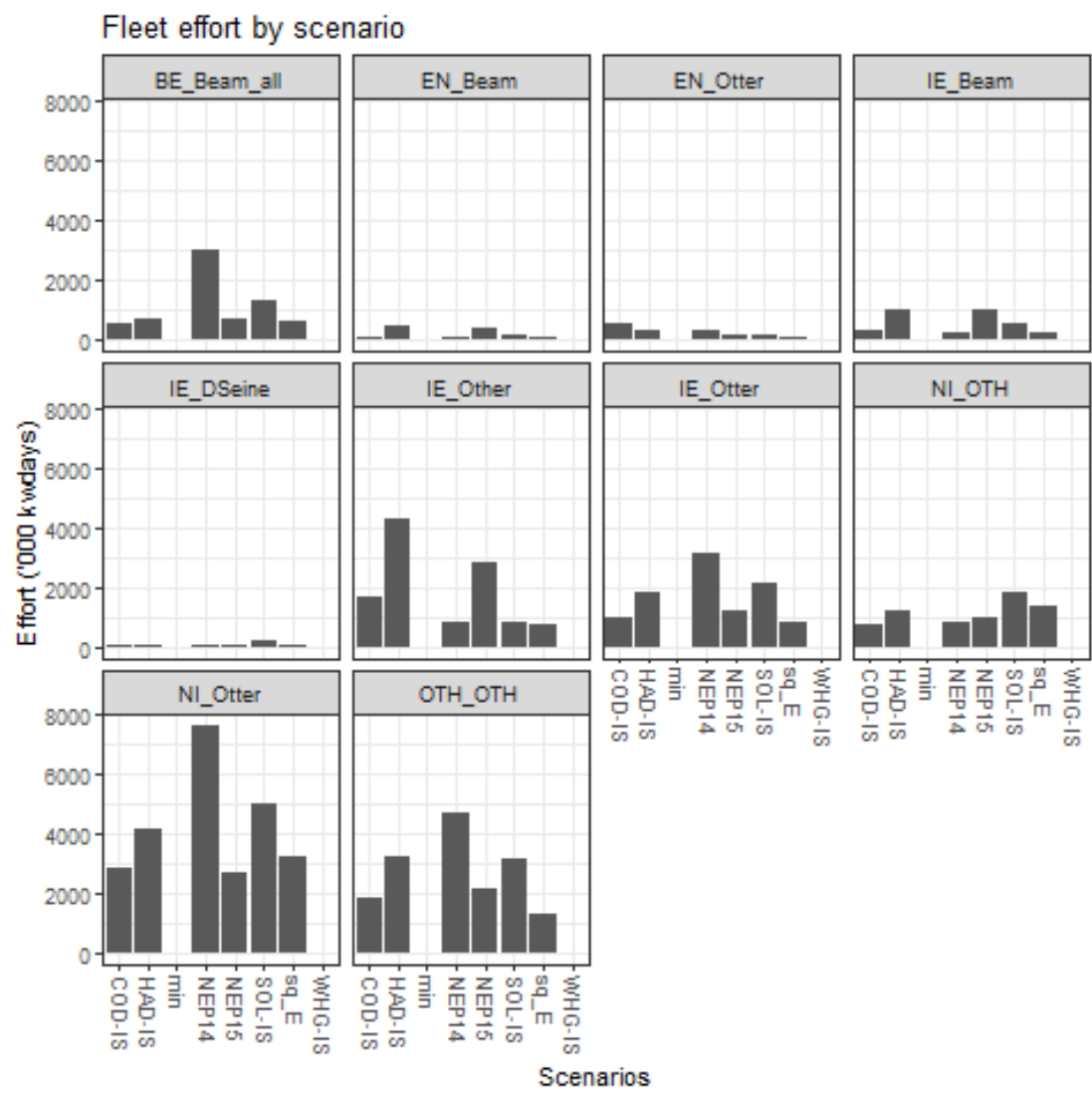
Figure 5.10 Irish Sea FCube estimates of effort by fleet corresponding to the individual "quota share" (or partial target F) by stock in 2022 under each FCube scenario.

6   North Sea

6.1   Background

Please refer to the North Sea Mixed Fisheries stock annex for a full description of the geographical area and the fishery.

6.1.1   Effort limitations

In previous years, WGMIXFISH advice has considered restrictions to effort in line with legislation related to the cod recovery plan (Council Regulation (EC) 1342/2008). Since 2018, in preparation with the full implementation of the landing obligation for all stocks in 2019, new legislation was issued that removed these restrictions (Council Regulation (EU 2019 amending EU 2018/973). Some limitations now exist in terms of fleet capacity rather than effort, but these are not considered in the current WGMIXFISH scenarios.

6.1.2   Stock-based management plans

In the context of the new CFP, the EU has developed a Multiannual management plan (MAP) for the management of the North Sea demersal mixed fisheries, which has been in force since 2018 (EU, 2018), and replacing the former single-stock long term management plans with a unique framework defining objectives and constraints for both target and bycatch demersal species. The majority of the stocks included in the North Sea demersal mixed fisheries analysis are shared between the EU, UK and Norway. As there is no agreement with Norway and the UK regarding the EU MAP, ICES gives advice based on the ICES MSY approach. Some of the stocks included in the mixed fisheries analysis are considered as bycatch under the MAP (North Sea turbot and witch). However, these stocks have now Category 1 assessments, and since they are stocks shared with UK and Norway, ICES also gives advice for the stocks on the basis of the ICES MSY framework (while according to the MAP, they should be managed according to the precautionary approach).

In the mixed fisheries simulations, it is assumed that TACs for 2022 will be based on the ICES advice and may therefore not correspond for all stocks to the application of the EU MAP. In practice, the TACs for shared stocks are agreed during EU/UK/Norway negotiations, and may deviate from the ICES advice.

6.2   FLBEIA

6.2.1   Software

All analyses were conducted using the FLBEIA model, coded as a method in R (R Core Team, 2020), as part of the FLR framework (Kell *et al.*, 2007; www.flr-project.org). Input data are in the form of FLFleetsExt and FLBiols objects inherited from the FLCore 2.6.16 package objects, and two forecast methods were used, stf() from the FLAssess (version 2.6.3) and fwd() from the Flash (version 2.5.11) packages. Both input parameterisation as well as the stock projections are made using FLBEIA functions and methods (version 1.15.6.8), that are flexible enough to allow covering different alternatives. FLBEIA source code is available at GitHub (https://github.com/flr/FLBEIA). The code, software and versions are part of the ICES

Transparent Assessment Framework (TAF) and can be fully reproduced from this repository (see https://github.com/ices-taf/2021_NrS_MixedFisheriesAdvice).

The baseline run is performed with the objective of reproducing as closely as possible the single-species advice produced by ACOM, and act as the reference scenario for subsequent mixed fisheries analyses. The single stock forecast is performed using the 'fwd()' method in FLR (FLash R add-on package). The same forecast settings as in WGNSSK are used for each stock regarding weight-at-age, selectivity and recruitment, as well as assumptions on the F in the intermediate year and basis for advice. Some stock assessments (e.g. cod 4,7d and 20; haddock 4, 6a and 20; whiting 4 and 7d) use data from the current year (intermediate year) and therefore produce stock abundance estimates for this year, which are used as the starting numbers for the short-term forecasts. The FLash fwd() function is not designed to use stock abundances provided in the first year of the projections and overwrites any existing values with the outcome of the survival equation, using numbers and mortality rates from the previous year. Therefore the FLash fwd() function was modified so that, if stock abundances-at-age are provided for the first year in the short term forecast, they are effectively used as starting values and not replaced.

Software and models used in the single-species assessments and forecasts are outlined in the table below. For the *Nephrops* stocks, the assessment methods are simpler and conducted on excel spreadsheets. This year, we also highlighted in the table what catch information is reported in the FLstocks.

Species	Assess-ment	Forecast	Catch in FLstock	Landings in Flstock	Discards in FLstock
COD 4, 3.a and 7.d	SAM	SAM	Observed	Observed	Observed
HADDOCK 4, 3.a and 7.d	TSA	MFDP	Observed	Estimated?	Observed
PLAICE 4	AAP	FLR 2.3, FLSTF	Estimated	Estimated	Estimated
SAITHE 4, 3.a and 6	SAM	SAM	Observed	Observed	Observed
SOLE 4	AAP	FLR 2.3, FLSTF	Estimated	Estimated	Estimated
WHITING 4 and 7.d	SAM	MFDP	Observed	Observed, proportion by-catch + landings (small differences)	Observed, proportion by-catch + landings (small differences)
PLAICE 7.d	AAP	FLR 2.x, FLSTF	Estimated	Estimated	Estimated
SOLE 7.d*	SAM	SAM	Estimated	Estimated	Estimated
TURBOT 4	SAM	FLR (fwd-routines)	Observed	Observed	Observed
WITCH 4, 3.a and 7.d	SAM	SAM	Observed	Observed	Observed

6.2.2   Scenarios

Single-species ICES advice for North Sea stocks of interest is given according to specific single-species options, existing management plan, ICES maximum sustainable yield (MSY) approach, or precautionary approach (PA). The basis for each single-stock advice is retained in the current mixed fisheries framework. Given fishing opportunities available for each fleet (e.g. TACs by stock or effort allocation by fleet), FLBEIA estimates the potential future levels of effort for each fleet, based on fleet effort distribution and catchability by métier. Based on this effort level, landings and discards (i.e. catches) by fleet are estimated using standard forecasting procedures.

For the catch advice year FLBEIA is used to run the scenarios:

	Scenario
"**max**"	For each fleet, fishing effort in 2021 stops when all stock shares* of that fleet have been caught up. This option causes overfishing of the single-stock advice possibilities of most stocks. The underlying assumption is that fishing stops for a fleet when all quota species are fully utilised for that fleet with quotas set corresponding to single-stock exploitation boundary for each species.
"**min**"	The underlying assumption is that fishing stops for a fleet when the catch for the first quota species for that fleet meets the corresponding single-stock exploitation boundary. This option causes underutilization of the single-stock advice possibilities of other stocks. This scenario can highlight some potential "choke species" issues.
"**sq_E**"	(*status quo* effort): The effort of each fleet in 2020 and 2021 is set equal to the effort in the most recently recorded year for which landings and discard data are available (2019).
"**val**"	(value): A simple scenario accounting for the economic importance of each stock for each fleet. The effort by fleet is equal to the average of the efforts required to catch the quota of each of the stocks, weighted by the historical catch value of that stock. This option causes overfishing of some stocks and underutilisation of others. The "val" scenario is a simple proxy balancing fishing opportunities by stock with their potential market value, in the absence of a formal economic behaviour model. For example, if a fleet would need 100 days fishing for catching its share of stock A, and 200 days fishing for catching its share of stock B, and if the value (tonnage × mean price) of that fleet's stock shares is 75% from stock A and 25% from stock B, then the resulting effort would be (100 × 0.75) + (200 × 0.25) = 125 days.
"**cod-ns**"	(Cod MSY approach): All fleets set their effort in 2020 and 2021 corresponding to their cod stock share, regardless of other catches. (There are small differences in the cod catches between this scenario and the single-stock advice because of the slightly different forecast methods used.) This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks. This scenario can highlight some potential "choke species" issues.
"**range**":	as described in Ulrich *et al.* (2017), this scenario searches for the minimum sum of differences between potential catches by stock under the "min" and the "max" scenarios within the F_{MSY} range for each stock.

Incorporating *Nephrops* into the mixed fisheries advice produces a number of complicating factors: For example, *Nephrops* are fished in distinct geographic areas or functional units (FU), only some of which receive an abundance estimate (necessary to calculate a catchability). This WG followed the approach adopted by ICES (2009) which is to perform the normal FLBEIA prediction for those FUs with absolute abundance estimates, then to calculate a ratio of change from the current yields to the ICES advice for the same FUs. For those FUs without absolute abundance estimates, landings resulting from the FLBEIA run were simply taken to be the most recently recorded landings multiplied by the same ratio R. To do this, landings for each métier had to be apportioned across the FUs. This was facilitated by the supply of effort and catch data by FU.

6.3 Stock input data and recent trends

6.3.1 Stock input data

The assessment data for the different stocks were supplied by ICES WGNSSK (ICES, 2021g). Similar to last year, all stock inputs formatted as FLR stock objects were directly provided to WGMIXFISH by the respective stock coordinators, and this eased greatly the quality of the process of collecting stock data.

An increasing number of WGNSSK stocks are being assessed using stochastic assessments (SAM model for North Sea cod, saithe, turbot, whiting, witch and eastern English Channel sole). A TSA assessment was used for Northern shelf haddock and AAP as used for both plaice stocks and for North Sea sole. Therefore, for some of these stocks the advice is based on stochastic forecasts, which cannot easily be fully replicated in the deterministic FCube software. Although FLBEIA is applied for the first time this year, FCube projections are still routinely compared to the median projections of the single-species stochastic forecasts on which single-stock advice is based and results are very similar (see Section 0 below); as such, WGMIXFISH does not consider the difference impacts significantly on the mixed fisheries advice.

Eastern English Channel sole was benchmarked in 2021 which altered the perception of the stock. The classification since 2019 as category 3 was upgraded to a category 1species and the assessment model used was Sam instead of XSA. Therefore, this stock is included in the WGMIXFISH considerations.
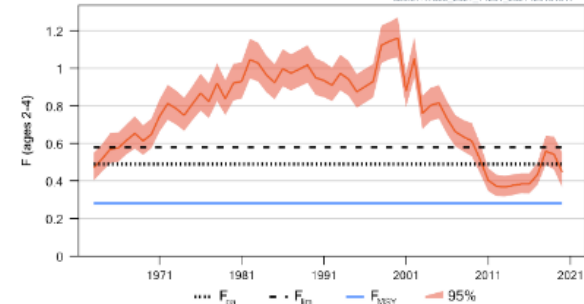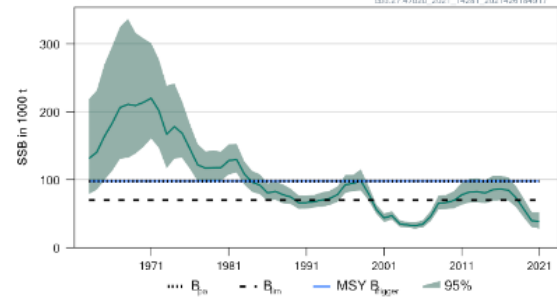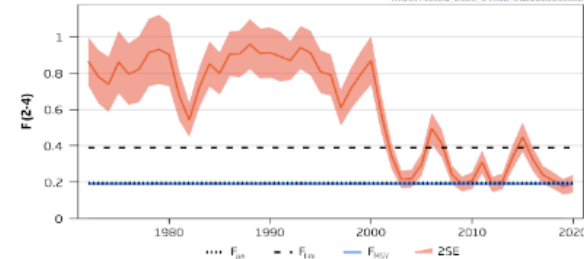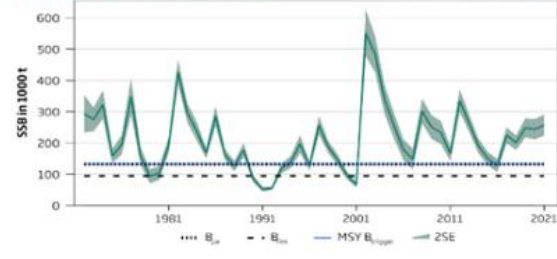
Nephrops stocks were incorporated in the evaluation by functional unit. For the *Nephrops* stocks in FU5, FU6, FU7, FU8, FU9, FU10, FU32, FU33, FU34 and *Nephrops* from areas outside the functional units, the ICES advices were taken for the F_{MSY} approach.
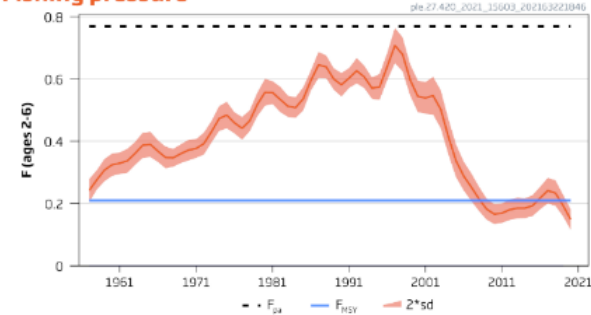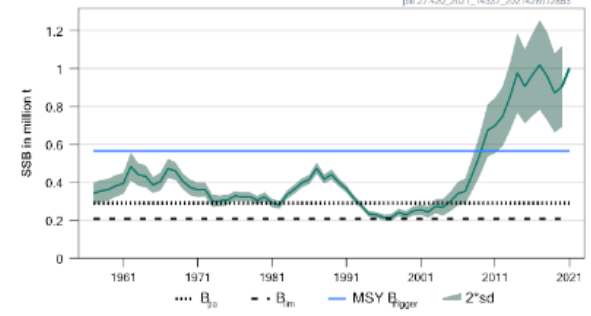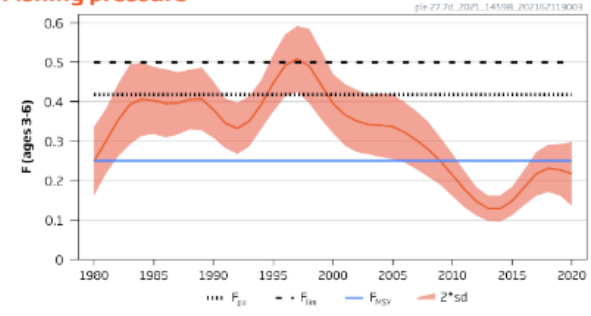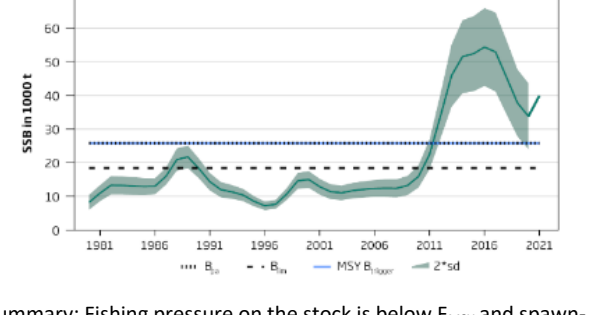
The functional units with separate stock indices and harvest rates from underwater surveys (FU6, FU7, FU8 and FU9) were treated as separate *Nephrops* identities in the projections whereas the five other functional units (FUs 5, 10, 32, 33 and 34) and catches outside the functional units in the North Sea were omitted in the projections.

6.3.2 Recent trends and advice
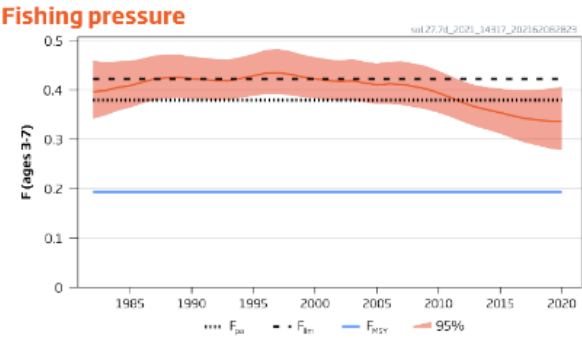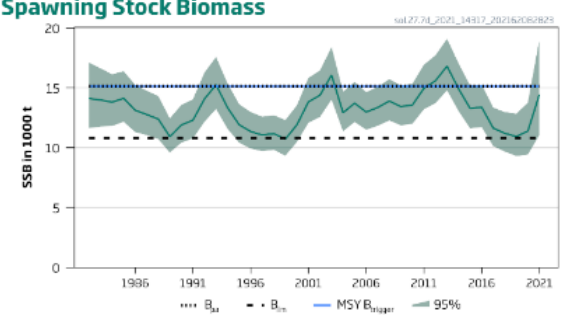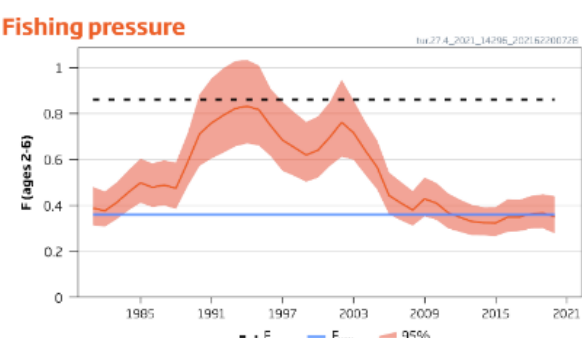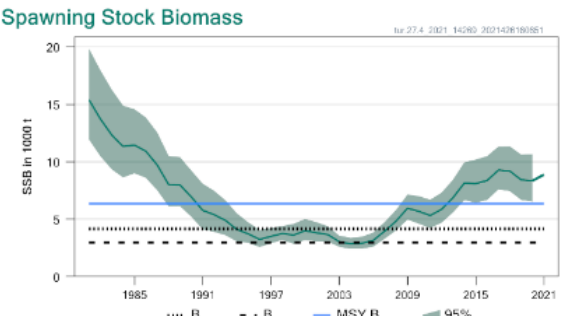
The advice for these stocks is drafted by the WGNSSK (ICES 2021g) under considerations by ACOM. Recent trends are described on a stock-by-stock basis in ICES (2021g), and latest advice by stock is available on the ICES website. An overview of mixed fisheries North Sea demersal stocks advice and trends are summarized below. It should be noted that although there is only one advice, additional management considerations are also listed in each single-species advice document.
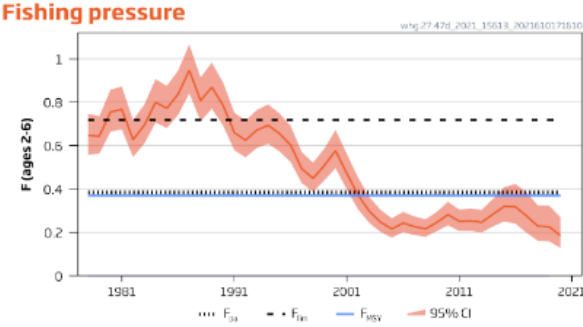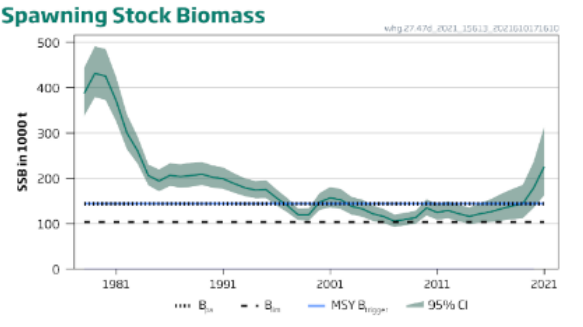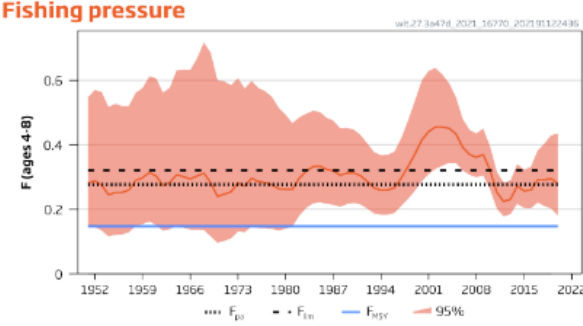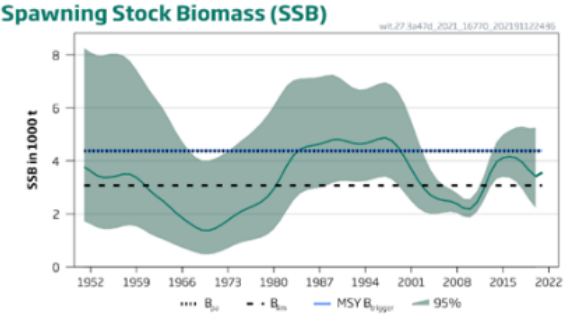
Analytical stocks

Species	Area	Stock status	Advice 2021
cod.27.47d 20 (Cod)	Subarea 4, Division 7.d, and Subdivision 20 (North Sea, eastern English Channel, Skagerrak)	Summary: Fishing pressure on the stock is above F_{MSY} but below F_{pa} and F_{lim}; spawning-stock size is below MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 14 276 tonnes.
had.27.46a 20 (Haddock)	Subarea 4, Division 6.a, and Subdivision 20 (North Sea, West of Scotland, Skagerrak)	Summary: Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, total catches in 2022 should be no more than 128 708 tonnes.

Species	Area	Stock status	Advice 2021
ple.27.420 (Plaice)	Subarea 4 (North Sea) and Subdivision 20 (Skagerrak)	 **Fishing pressure** **Spawning Stock Biomass** Summary: Fishing pressure on the stock is below F_{MSY}, F_{pa}, and Flim, and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and, B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 142 508 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.
ple.27.7d (Plaice)	Division 7.d (eastern English Channel)	 **Fishing pressure** **SSB** Summary: Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, catches from the Division 7.d plaice stock in 2022 should be no more than 6365 tonnes. This corresponds to catches of plaice in Division 7.d of no more than 7566 tonnes in 2022, assuming the same proportion of the Division 7.e and Subarea 4 plaice stocks is taken in Division 7.d as was estimated during 2003–2020. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.

Species	Area	Stock status	Advice 2021
pok.27.3a4 6 (Saithe)	Subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)	**Fishing pressure** **Spawning Stock Biomass** Summary Fishing pressure on the stock is above F_{MSY} but below Fpa and Flim; spawning-stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 49 614 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.
Sol.27.4 (Sole)	Subarea 4 (North Sea)	**Fishing pressure** **Spawning Stock Biomass** Summary: Fishing pressure on the stock is above F_{MSY} but below Fpa and Flim; spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim} in 2021.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 15 330 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.

Species	Area	Stock status	Advice 2021
sol.27.7d (Sole)	Division 7.d (eastern English Channel)	Summary: Fishing pressure on the stock is above F_{MSY} but below F_{pa} and F_{lim}; spawning-stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 2380 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.
tur.27.4 (Turbot)	Subarea 4 (North Sea)	Summary: Fishing pressure on the stock is below F_{MSY}; spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 3609 tonnes. Management of turbot and brill under a combined species TAC prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species. ICES advises that management should be implemented at the species level.
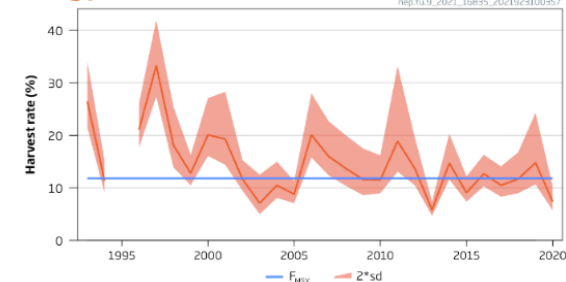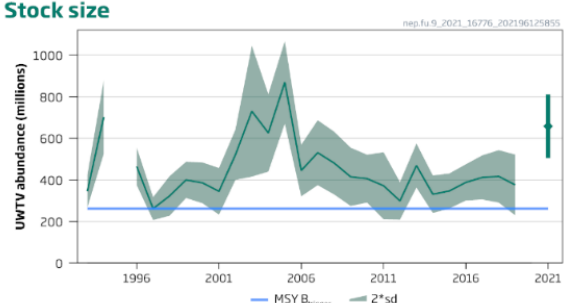
Species	Area	Stock status	Advice 2021
whg.27.47d (Whiting)	Subarea 4 (North Sea) and Division 7.d (Eastern Channel)	**Fishing pressure** **Spawning Stock Biomass** Summary: Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 88 426 tonnes. ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock. Management should be implemented at the stock level.
wit.27.3a47d (Witch)	(North Sea, Skagerrak and Kattegat, eastern English Channel)	**Fishing pressure** **Spawning Stock Biomass (SSB)** Summary: Fishing pressure on the stock is above F_{MSY} at F_{pa} and below and F_{lim}; spawning-stock size is below MSY $B_{trigger}$ and B_{pa} and above B_{lim}.	ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 1206 tonnes. Management of witch and lemon sole under a combined species TAC prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species. ICES advises that management should be implemented at the species level in the entire stock distribution area (Subarea 4 and divisions 3.a and 7.d).

Nephrops stocks

Species	Area	Stock status	Advice 2020 and 2021
Nephrops Nep.fu.5	Botney Gut-Silver Pit (FU 5)	The state of this stock is unknown. Preliminary stock surveys (2010 and 2012) indicate relatively high density compared to neighbouring FUs.	ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should be no more than 1570 tonnes.
Nephrops Nep.fu.6	Farn Deeps (FU 6)	**Summary**: Fishing pressure on the stock is above F_{MSY}, and the stock size is above MSY $B_{trigger}$.	ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 1940 tonnes. To ensure that the stock in Functional Unit (FU) 6 is exploited sustainably, management should be implemented at the functional unit level. Any substantial transfer of the current surplus fishing opportunities from other FUs to FU 6 could rapidly lead to overexploitation. ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level.

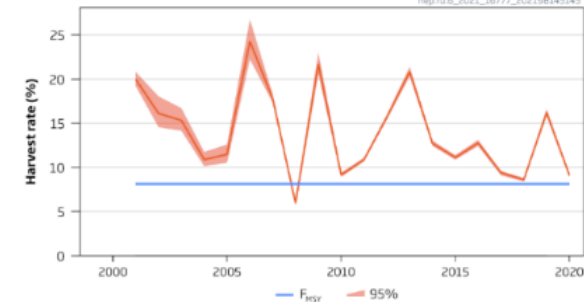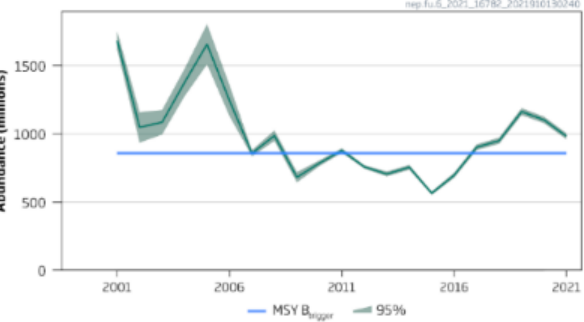| Species	Area	Stock status	Advice 2020 and 2021
Nephrops Nep.fu.7	Fladen Ground (FU 7)	**Fishing pressure** **Stock size** **Summary**: Fishing pressure on the stock is below F_{MSY} and stock size is above MSY $B_{trigger}$.	ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 14 803 tonnes. To ensure that the stock in Functional Unit (FU) 7 is exploited sustainably, management should be implemented at the functional unit level. The catch in FU 7 has been lower than advised in recent years, and if the difference is transferred to other FUs, this could result in non-precautionary exploitation of those FUs. ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level.
Nephrops Nep.fu.8	Firth of Forth (FU 8)	**Fishing pressure** **Stock size** **Summary**: Fishing pressure on the stock is below F_{MSY}, and stock size is above MSY $B_{trigger}$.	ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 3216 tonnes. To ensure that the stock in Functional Unit (FU) 8 is exploited sustainably, management should be implemented at the functional unit level. ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level.

Species	Area	Stock status	Advice 2020 and 2021
Nephrops Nep.fu.9	Moray Firth (FU 9)	**Fishing pressure** nep.fu.9_2021_16835_202192310037 **Stock size** nep.fu.9_2021_16776_202196125855 **Summary**: Fishing pressure on the stock is below F_{MSY}, and stock size is above MSY $B_{trigger}$.	ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 2062 tonnes. To ensure that the stock in Functional Unit (FU) 9 is exploited sustainably, management should be implemented at the functional unit level. ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level.
Nephrops	Noup (FU 10)	Underwater TV (UWTV) surveys in Functional Unit (FU) 10 have been conducted sporadically and indicated that the density is relatively low (0.13 *Nephrops* m^2). Landings are at a historical minimum.	ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should not exceed 46 tonnes. In order to ensure the stock in this FU is exploited sustainably, management should be implemented at the functional unit level.
Nephrops	Norwegian Deep (FU 32)	The state of this stock is unknown. Harvest rates are thought to be low for this stock even if a low density is assumed (e.g. the lowest observed density in the North Sea is in Functional Unit (FU) 7, Fladen Ground). Catches have been decreasing since 2006. Discarding has been low in the last 4 years.	ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should be no more than 381 tonnes. If this stock is not under the Norwegian discard ban in 2021 and 2022 and discard rates do not change from the average, this implies landings of no more than 379 tonnes.
Nephrops	Horns Reef (FU 33)	**Summary:** The state of this stock is unknown. Landings have been relatively stable since 2004, fluctuating without trend at around 1000 tonnes. The mean density of Norway lobster decreased by 43% from 2017 to 2018.	ICES advises that when the precautionary approach (PA) is applied, wanted landings in each of the years 2021 and 2022 should not exceed 956 tonnes. ICES cannot quantify the corresponding total catches. To ensure that the stock in Functional Unit (FU) 33 is exploited sustainably, management should

Species	Area	Stock status	Advice 2020 and 2021
			be implemented at the functional unit level.
Nephrops	Devils Hole (FU 34)	The state of the stock is unknown. The mean survey density indicates the stock has declined from 2009 to 2017.	ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should not exceed 566 tonnes. In order to ensure the stock in this functional unit (FU) is exploited sustainably, management should be implemented at the functional unit level.

6.4 Fleets and métiers

6.4.1 Catch and effort data

Prior to 2012, catch (landings and discards) and effort data were submitted to WGMIXFISH as comma separated files structured around the distinction of gear, mesh size and vessel length categories (based to a large extent on the format used by the STECF for the evaluation of effort management). From 2012 to 2014 a joint WGNSSK/WGMIXFISH data call has been issued, with age and discards data by métier (consistent with the DCF definition of métiers) to be submitted to InterCatch, and landings and effort data by métier and vessel length class to be submitted as .csv files. Since 2015, ICES generalised the data call to most stocks and regions. The process and the quality of data have thus continuously improved over time.

Noticeably, although the data collation process is smoother, it remains a very tedious and time-demanding work. The processes developed to automate the various steps of merging different data sets from different countries and different data sources together have increased the amount of checks and graphical visualization of the data. Starting from 2019, data submissions have been evaluated with the aid of newly developed quality control routines, which summarized in a report. This process has aided both data submitters and participants of WGMIXFISH in terms of identifying problematics entries and has greatly eased the model conditioning process.

The relative size of landings of the stocks incorporated in the mixed fisheries projections is shown in Figure 6.1.

Despite the data now being available according to DCF categorization, WGMIXFISH was of the opinion to continue using the categorization following the EU Cod management plan as used in previous years, both in order to maintain the consistency of the MIXFISH time-series and in order to continue addressing management-oriented scenarios and issues. WGMIXFISH métiers are thus defined as combinations of gear, mesh size and area (North Sea (Area 4), Skagerrak (Area 3.a) or Eastern Channel (Area 7.d), see Table 6.1 and Figure 6.2.

The consistency between DCF and EU Cod plan categories had been investigated by WGMIXFISH 2011 and during the pilot data call performed in autumn 2011. It was determined that most DCF métiers as sampled by individual nations could automatically be allocated to a corresponding EU Cod plan métier, with two exceptions: the TBB_DEF_70-99_0_0 métier in the

North Sea (as the corresponding BT2 métier is only defined for the mesh sizes 80–99) and the OTB_DEF (or CRU)_90-119_0_0 métier in the Skagerrak, which straddles over the TR1 (>=100 mm) and TR2 (70–99 mm) categories. As in previous years, the TBB_DEF_70-99_0_0 métier was assumed equivalent to BT2, and the Skagerrak 90-119_0_0 was assumed as TR2, to maintain consistency with previous data. Since 2012 the Swedish *Nephrops* fishery with an escapement grid, OTB_CRU_70-89_2_35 has been kept distinct from the other DCF métiers.

The final dataset extracted from InterCatch for use by WGNSSK includes discards estimates (either imported or raised) for all stocks and métiers. These InterCatch estimates have been used to estimate a discard ratio for each métier/stock combination, which allows allocating discards for all WGMIXFISH fleets and métiers with matching names, such that:

$$d^* = \left(\frac{D}{L}\right) l$$

Where d* is the discard value for the métier used by FLBEIA, l is the weight of landings for the métier used by FLBEIA and L and D are the weight of landings and discards entered for the (vessel length aggregated by métier in InterCatch). For age-based stocks, discard rates are estimated for each age class.

6.4.2 Definitions of fleets and métiers

The procedure for defining fleets and métiers was not revised in 2021, and has therefore been the same since 2012. Nevertheless, as the procedure is applied to the last data year, the number of fleets and métiers can vary slightly from one WGMIXFISH report to the next.

In summary, the procedure follows a number of steps:

Matching DCF métiers with definitions used in the cod long-term management plan

Establishing fleets by country, gear type and, when deemed necessary, vessel length group

Matching consistency between effort and catch data files. Métiers without catch of any of the modelled stocks in the last data year (now 2020) are not retained.

Aggregating "small" métiers to reduce the number of units in the modelling. A métier failing to catch at least 1.0% of at least one of the stocks considered in the most recent data year is classified as small. Within each fleet, all these small métiers are then aggregated by fleet in one "Other" métier (OTH). Further, all small fleets (i.e. containing only the "OTH" métier), are aggregated into one single "OTH" fleet.

This year, fleets are conditioned as age-disaggregated fleets, this means that catchability at age is considered for each metier rather than having catchability at the fleet level (see Stock Annex).

In 2020, the final data used contained 40 national fleets (including the OTH fleet). These fleets engage in 1 to 8 different métiers each, resulting in 141 combinations of country*fleet*métier*area catching fish and *Nephrops* stocks considered this year (Table 6.1). The balance of landings of the stocks across gear categories is shown in Figure 6.2.

As a cross check of the data, the total landings and discards across all fleets was compared to the values estimated from the single-species stock assessments. Some landings may not be allocated to fleets, due to for example missing countries or areas (e.g. Area 6.a for saithe and haddock) or national landings with missing logbook information that cannot be allocated to a fleet. To address the remaining small inconsistencies between fleet data used by WGMIXFISH and stock data, the differences between them were pooled into the "OTH" fleet (both landings and discards).

This year, new diagnostics were produced to check the fleet conditioning in FLBEIA. The fishing mortality at age and averaged as well as age-disaggregated and total catch, landings and discards across all fleets was compared to the values estimated from the single-species stock assessments (Figure 6.3 to Figure 6.6 and

Table 6.2 to Table 6.5). Some discrepancies exist, for example for catch and landings at age for haddock. This is due to the fact that weight at age for each stock is now given at the fleet level rather than the stock. For haddock, this induces some differences in mean weight at age in landings between the InterCatch data and the ones used in the single species assessment.

6.4.3   Trends

A number of overview graphs (using the Lattice and ggplot package in R) were produced to aid quality checking of the data once compiled into the final fleets object. Some are useful to show the relative importance of the fleets chosen and trends in their effort and catches. Effort by fleet in absolute levels (Figure 6.7) and relative trends (Figure 6.8), and landings by fleet and stock (Figure 6.9) are included in this report.

6.5   Mixed fisheries forecasts

6.5.1   Description of scenarios

Baseline run
The objectives of the single-species stock baseline run are to reproduce, as closely as possible the single-species advice produced by ACOM with the mixed-fisheries model, and act as the reference scenario for subsequent mixed fisheries analyses.

The various single-stock forecasts presented by WGNSSK are performed using different software and setups (see Section 6.2.1). For the purpose of the mixed fisheries analyses, it is necessary to gather all stock assessment output and forecasts settings into a single unified framework in FLR, which builds on the "FLBEIA" package (García *et al.*, 2017). The same forecast settings as in WGNSSK are used for each stock regarding weight-at-age, selectivity and recruitment, as well as the assumptions made for the intermediate year (2021) and the basis for advice (ICES MSY advice rule). Using these settings, and not introducing any mixed-fisheries interactions, short-term forecasts are carried out at WGMIXFISH. This baseline run is then compared to the estimates provided in the ICES advice sheets.

For a number of stocks, it is not expected that the single-stock advice can be exactly reproduced using the mixed-fisheries model. There are data and model related differences between the framework used at WGMIXFISH and the different single-stock forecasts conducted at WGNSSK:

- Although assumption used for conditioning the forecast are the same, in FLBEIA, future assumptions regarding biology and exploitation pattern are derived from fleet-disaggregated data, while at WGNSSK they are derived from stock-level assessment input and output
- The catch process is modelled using a different equation (Baranov equation for single stock advice and for Cobb Douglas equation in FLBEIA)
- For a number of stocks assessed using SAM (cod, saithe, sole 7d and witch), the single-stock advice is based on stochastic forecasts (in which the forecast result is the median of a number of iterations, carried out with different starting conditions and process variance realisation), while FLBEIA is deterministic.

- For haddock and whiting, the single stock forecast is a multi-fleet forecast conducted using the Multi Fleet Deterministic Projection (MFDP) forecast software with a fleet specification that is different from FLBEIA (human consumption and industrial fleets).

In order to check that the mixed-fisheries model, in absence of mixed-fisheries interactions, is able to reproduce the single stock advice with only minimal discrepancies, three sets for forecasts are compared:

- The single-stock advice forecast from WGNSSK
- An FLR forecast using the fwd() function that uses exactly the same input (starting abundances, future biology and selectivity) and the same production function (Baranov)
- The FLBEIA baseline run (with mean weight, discard rate and selectivity at age based on the mixed-fisheries data, and using the Cobb Douglas production function).

Mixed fisheries runs

Prior to 2013, projections were run applying the mixed fisheries scenarios two years in a row, i.e. both for the intermediate year and the TAC year. This allowed WGMIXFISH to analyse why management plans often did not deliver their expected results and why some short-term forecasts had been over-optimistic in the past (Kraak *et al.*, 2013), by evaluating the impact of the assumptions in the intermediate year.

However, since 2013, the working group adopted a forecast approach for the intermediate year on the basis of s*tatus quo* effort (Table 6.6). The *status quo* effort assumption is considered a plausible assumption and is more in line with the standard single-stock short-term forecasting approach (which apply a *status quo* F, unless a TAC constraint is used).

An important change to the projections was implemented in 2015, to account for the landings obligation. Historically, the mixed fisheries projections have been presented in terms of landings and overshoots or undershoots of the retained portion of the catch, assuming fishing fleets would discard as observed in past years and that only the landings counted against the fleets' stock shares.

This year, the projections were run assuming a full and perfect implementation of the discard ban (i.e. all quota species caught must be landed, with no exemptions, *de minimis* or inter-species flexibilities) for species under landing obligation, i.e. all catches are assumed to be landed and to count against the quota.

While WGMIXFISH is aware that the landings obligation may not be enforced for all stocks in 2022, and that discards will not disappear overnight, it was considered that this option would bring new insights to where the choke effects will lie. The main implication of this change in the results would be that stocks for which some fleets had high discards in the past may become more limiting for those fleets, due to the mismatch between their catches (which now all count against the fleets' stock shares) and their stock shares based on historical landings.

In summary, the FLBEIA runs followed the scheme below:

Single-stock assessment 2021

Management Plan/ MSY approach

Status quo
2021

sq_E

Catch in 2021 and SSB at start of 2022

Single-stock Management
Plans applied to FLBEIA (*status quo*) re-
sults

FLBEIA 2022

min   max   cod   val   range   sq_E

Potential Over / Under catch against single-stock advice
(Difference between single-species advised catch and expected catch)
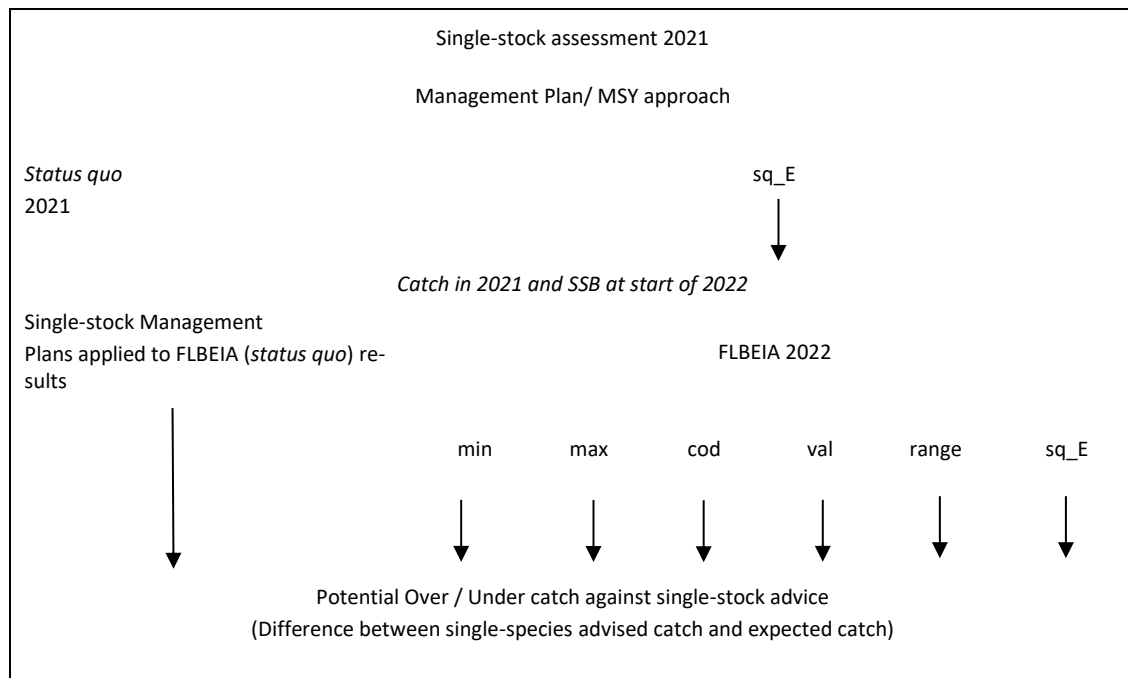
6.5.2   Results of FCube runs

Baseline run

The Figure 6.10 summarises the trends in single-stocks advice between the last data year (2020) and the two forecast years (2021 and 2022). For the COD-NS stock, the assumed F_{bar} in 2021 is lower than in 2020 and the F_{bar} for 2022 resulting from the ICES MSY advice rule will decrease sharply compared to 2021 (as SSB is forecasted to be close to 50% of MSY $B_{trigger}$). The corresponding landings in 2021 are at a similar level as in 2020, and the landings corresponding to the 2022 advice are about than half of the landings reported for 2020. Given this strong reduction in F_{bar}, North Sea cod is likely to be the most limiting stock in the mixed fisheries projections. The fishing mortality for the advice year is also decreasing compared to current level for saithe (POK) and witch (WIT), corresponding to a decrease in the landings corresponding to the advice in 2022 for a similar magnitude as for cod. On the other hand, the advice catch for haddock (HAD) and whiting (WHG-NS) strongly increase in 2022 (+86% for HAD due to two consecutive good year-classes entering the fishery in 2022, and +236% for WHG-NS due to a combination of an upwards revision of F_{MSY} and good recent recruitments).

The comparison between the FRL baseline run and the ICES single-species advice is summarised in Table 6.7 for the *Nephrops* stocks and in Figure 6.11 for the fish stocks. The issues encountered in replicating the single-species advice in FLR are detailed below.

Cod: The North Sea cod forecast is a stochastic projection, and is produced internally in SAM by generating 1000 replications within the confidence interval of the F-at-age, N-at-age and catch multiplier estimates. The short-term forecast conducted at WGMIXFISH does not use SAM, but a simple deterministic forecast.

Some small differences were observed (-0.01% for the F_{bar} value for 2021, -2.2% in the estimated catches in 2022 but up to 7.5% difference in SSB in 2023). Nevertheless, the FLR forecast was considered sufficiently close to the single stock advice that it could be used as a satisfactory basis for the mixed fisheries projection.

Haddock: In 2021, the haddock was assessed using a TSA (time-series analysis, Fryer, 2002) assessment model and MFDP programme as the forecasting software. The method developed in WGNSSK to parameterise future selectivity and weight-at-age for haddock are sometimes quite specific and do not always follow common standards (e.g. weights-at-age in the forecasted period produced by a growth model instead of the commonly used assumption of constant weights equal to the average over the recent years). Those specific values could not be reproduced in the forecasting procedure of FLR and were therefore entered manually.

Some small discrepancies were also observed for this stock (8.5% for the F_{bar} value for 2021, -- 5.2% in the estimated catches in 2022 but up to 0.8% difference in SSB in 2023). The FLR forecast was considered sufficiently close for use in the mixed fisheries projection.

It was not possible to fully understand the reason for these small differences. The MFDP uses two distinct fleets (human consumption and industrial), with distinct selectivity, which is not the case for the FLR forecast which does not include the industrial bycatch. Although this fishery represents only a small percentage (less than 1% in 2021) of the total catch, this difference in method could potentially explain the small discrepancies in the forecast.

Whiting: Although whiting is assessed using SAM, the WGNSSK forecast is deterministic, conducted using MFDP. The WGNSSK forecast treats the industrial bycatch separately from the landings for human consumption, with specific future weights-at-age and selectivity and assumes an F value independent from the value of target F for the human consumption fishery. The FLR forecast used at WGMIXFISH did not allow for multiple fleets and therefore the industrial bycatch is included in the landings component. The future landings selectivity and weights-at-age were recalculated as the weighted means of the values in the landings for human consumption and industrial bycatch.

This difference in forecast procedure resulted in small discrepancies in the output with differences in catches of -0.3% and 3.3% for 2021 and 2022 respectively, and of 0.9% in 2023 for the SSB.

Saithe: As for cod, the 2021 saithe assessment and forecast were carried out using the SAM assessment model. The difference in forecast procedure compared to WGMIXFISH resulted in differences in the output of -2.0% in the 2021 SSB and -5.2% in the 2022 catches and -6.7% in 2023 for SSB. The FLR forecast was considered sufficiently close for use in the mixed fisheries projection.

North Sea Plaice: Straightforward, no problems encountered. The 0.7% difference in the 2022 catch is explained by the fact that the expected catch of North Sea plaice taking place in Division 7.d have been removed after calculation from the single-stock advice, while this is taken into account at a later stage in the WKMIXFISH analyses.

English Channel Plaice: Significant migrations of plaice occur between the North Sea, Eastern Channel and Western Channel. As a result, only a proportion of the plaice TAC defined in Subdivision 7.d corresponds to the Eastern Channel plaice. The forecast takes account of the expected quantity of plaice caught in the eastern channel adjusting for these migrations.

The results from the FLR forecast were close to the single-species forecast, with differences in the output of 1.5% and -0.1% for the catches in 2021 and 2022 and -0.3% in 2023 for SSB.

North Sea Sole: The results from the FCube forecast were nearly identical to those of the single-species forecast.

English Channel Sole: The 2021 English Channel Sole assessment and forecast were carried out using the SAM assessment model. As for the other stocks with a SAM stochastic forecast, some small differences were observed between the single-stock and the FLR forecasts (2.1% for the F_{bar} value for 2021, -3.7% in the estimated catches in 2022 and -4.5% difference in SSB in 2023).

Turbot: The turbot assessment is conducted with SAM, but the WGNSSK forecast procedure is deterministic using the FLR package. These results were reproduced identically at WGMIXFISH.

The turbot assessment does not include discard information (for lack of accurate discard-at-age data), and therefore the landings (in the assessment and in the short-term projections) are equal to the catches. WGNSSK applies a correction of the projected landings to take into account the 8.8% discard rate in weight. This has not been reproduced in the WGMIXFISH baseline run - since mixed fisheries projections are based on landing values - and explains the 8.8% difference in the 2021 and 2022 catch between the single-stock advice and the WGMIXFISH baseline run.

Witch: As for other stock where SAM is used to run a stochastic forecast, small differences with the single species advice were encountered, of 0.3 % and -2.0% for the catches in 2021 and 2022, and -1.4% and -10.2% for SSB in 2022 and 2023.

*Nephrops***:** The forecasts applied the recommended harvest rates to the most recent abundance estimates available for the relevant FUs (FU 6, 7 8 and 9). The ICES advice for 2022 is given assuming that the landing obligation is applied in 2021 for all FUs, with an exemption of high survival for catches with pots (FPO), and for catches with bottom trawls (OTB, TBN) with a mesh size of at least 80 mm equipped with a netgrid selectivity device. The WGNSSK procedure was reproduced as closely as possible in FCube and the differences in the forecasted 2022 landings were in all cases under 1%.

The forecast conducted using FLBEIA without mixed-fisheries interactions, is compared to the single-stock advice and the FLR/fwd() forecast on Figure 6.12. The conditioning in FLBEIA is done based on catches. To create the baseline run, the catches in 2021 and 2022 from the single-stock advice were used as constraints. This differs from the method applied for the single-stock advice and the FLR / fwd() forecast, for which the constraint in the intermediate year can be either a F_{bar} or a catch constraint (depending on the stocks) and the calculation in the advice year is based on a F_{bar} value. As a result, the forecasted catches for 2021 and 2022 in the FLBEIA baseline run are the same as the advice (black line on Figure 6.12), and small differences with the FLR/fwd() forecast are observed (as detailed above). Differences are observed for the catches for 2020, the last data year. The 2020 catches in FLBEIA are the sum across métiers of the landings and discards-at-age multiplied by the corresponding weight-at-age which are obtained by WGMIXHFISH from the InterCatch data combined with the accession data while the catch for the single-stock advice and FLR/fwd() forecast are computed at WGNSSK from the InterCatch data only.

In the case of Eastern Channel plaice and sole, the difference in the 2020 catch is very large (50% higher in the WGMIXFISH data). Although these discrepancies are likely due to the differences in methodologies used at WGNSSK and WGMIXFISH to treat the InterCatch data, the exact reason for this discrepancy could not be explained. The catches in 2020 are the reference to compute the catchabilities of the fleets for the different stocks. In FLBEIA, catchabilities are calculated based on catches-at-age and effort per fleet (whereas FCube used partial fishing mortality and effort). The higher catches in 2020 in the FLBEIA model for the two eastern English Channel flatfish stocks result in catchability values that are high (compared to the value that would have resulted from using the WGNSSK catches). This somehow influenced the corresponding F_{bar} estimated by FLBEIA are, for these two stocks, between 50% and 100% higher than in the single stock advice and FLR/fwd() forecasts. However, since stock dynamics do not rely on fishing mortality in FLBEIA, but rather catch, the forecasted SSB are in line with the FLR/fwd(), and differences with the single-stock advice are minimal.

For the other stocks, the FLBEIA forecast generally reproduced the single-stock forecasts well for the SSB, landings and catches (meaning that the abundances-at-age and therefore the catch process are modelled accurately). Some differences are observed for the fishing mortality, but since

the model is based on the Cobb-Douglas equation, fishing mortality is not directly affecting the calculation and is rather a quantity that is post-calculated from the efforts and the catchabilities.

Mixed fisheries analyses

The full overview of the FLBEIA projections are presented in Table 6.8 and in Figure 6.13 to Figure 6.16. Figure 6.13 displays the catch by scenario for each of the species. Potential over-shoot/undershoot on this figure are calculated by comparing the single-species catch advice for 2021 with the mixed fisheries catch estimates. As ple.27.7d, tur.27.4, and wit.27.3a.47d have low landings compared to other stocks, the results for these stocks are also presented in detail in Figure 6.14. The anticipated SSBs in 2023 of the mixed fisheries scenarios compared to the base-line are shown in Figure 6.15, and Figure 6.16 shows the effort needed to reach the single-stock advice and highlights the most and least limiting stock per fleet. A new figure that illustrates similar results than Figure 6.16 but in terms of quota uptake instead of absolute effort is pre-sented in Figure 6.17. A summary of catches by scenario, including the single-stock advice values for reference, is presented in Table 6.9. Finally, Figure 6.18 summarises all the mixed fisheries projections and compares them to the single-species advice projections.

The outcomes of the "min" and "max" scenarios are driven by the stocks that will be most and least limiting for each individual fleet. Cod was estimated to be the most limiting stock in the "min" scenario. The "min" scenario assumes that fleets would stop fishing when their first quota share is exhausted, regardless of the actual importance of this quota share, thus leading to a distorted perception of plausible fleet behaviour. While this can be considered an unlikely sce-nario as long as discarding is allowed, this scenario reflects the constraints that result from a strictly implemented discard ban. Assuming a strictly implemented landings obligation (i.e. a discard ban where all catches of quota species must be counted against quota, with no flexibilities such as exemptions, *de minimis* allowed discards or inter-species flexibility, as the "min" scenario represents), cod would be the most limiting stock, constraining 37 of the 40 fleet segments (Figure 6.16 and Figure 6.17). Sole in the Eastern Channel constrains two fleet segments and witch limits one fleet. This would result on undershooting the catch quota for all stocks except cod in 2022 (Figure 6.13 and Figure 6.14).

Conversely, in the "max" scenario, North Sea whiting would be the least limiting stock for 25 out of 40 fleets. This is due to the fact that its catch advice for 2022 was increased by 236% com-pared to the previous year. If Norway lobster were managed by separate TACs, Norway lobster in FU7 would be least limiting for 6 fleets, while North Sea plaice and sole would be least limiting for 2 fleets. Finally, North Sea haddock, Norway lobster in FU8 and FU9, Eastern Channel plaice and North Sea turbot would be the least limiting for 1 fleet segment (Figure 6.16 and Figure 6.17). Under the "max" scenario all stocks are overshot (Figure 6.13 and Figure 6.14). The overshoot for North Sea haddock is particularly large this year. This is a consequence of the large increase in catch advice for whiting, given that they are caught together as well as the 86% increase in its own catch advice, which makes it getting closer to the catch advice for North Sea plaice, which has been the largest for several consecutive years (Figure 6.13).

The "cod_ns" scenario reflects the fishing mortality corresponding to the single-species advice for cod.27.47d20 (based on the ICES MSY approach), and the results present fishing opportuni-ties for other stocks in a mixed fisheries context. According to the single-stock advice, a reduction of about 50% in fishing mortality and catch is required for North Sea cod between 2021 and 2022. It is assumed that effort reductions in fleets (to achieve new partial Fs) apply equally to all fleets with any cod catch, including those where it represents a small bycatch component. Similar sce-narios based on the single-stock advice for the other finfish stocks could be provided by ICES, but the "cod_ns" scenario is considered here because cod is the most limiting species. For this reason, the "min" and "cod_ns" scenarios produced very similar results in terms of catches and ssb in the short forecast period.

In the "val" scenario fishing opportunities by stock and their potential market value are taking into consideration. For 2022, this scenario estimates effort levels close to the *status quo*. Historically this scenario has been observed to predict effort levels closer to the realized effort than the other scenarios (Ulrich *et al.*, 2011). In this scenario, some overshoot of cod, haddock, saithe, North Sea sole, turbot and witch, and undershoot of whiting, North Sea and Eastern Channel plaice and Norway lobster (FUs 6-9) are predicted.

Mixed fisheries results for Norway lobster are displayed after combining functional units 6-9 (FUs 6-9) in one plot, but stock status and fishing opportunities differ widely across FUs. In particular, FU7 (Fladen Ground) is exploited well below the MSY target, and acts as a least limiting stock for 6 fleets. In order to ensure Norway lobster stocks are exploited sustainably in the different FUs, management should therefore be implemented at the FU level. Potential undershoot of catch opportunities for FU7 should not be transferred to other FUs.

Optimised range option

The results of the "range" scenario are presented (Figure 6.19 and Figure 6.20), where the potential quota mismatch in 2022 are minimized by setting target fishing levels within the FMSY ranges. This scenario returns a fishing mortality by stock which, if used for setting single-stock fishing opportunities for 2022, may reduce the gap between the most and the least restrictive TACs, thus reducing the potential for quota over- and undershoot. This "range" scenario suggests that the potential for mixed-fisheries mismatch would be lowered with a 2022 catch advice in the lower part of the F_{MSY} range for haddock, saithe, and whiting, and near the highest possible value for cod and witch, in accordance with the maximum sustainable yield (MSY) approach and the MAP (EU multiannual plan). For the rest of the stocks the F_{bar} should be very close to FMSY. Norway lobster is not included in the "range" scenario.

Table 6.1. Final fleet and métier categories used in the mixed fishery analysis. 4, 3AN and 7D refer to ICES area. Effort is in kWdays and catch is in tonnes, and both figures are for the year 2020.

Fleet	Metier	Effort	Catch	Fleet	Metier	Effort	Catch
BE_Beam<24	beam_oth.4	507	70	FR_Otter>=40	TR1.4	3012	9072
BE_Beam<24	BT2.4	130	229	FR_Otter>=40	TR1.6A	1608	1177
BE_Beam<24	BT2.7D	202	1008	FR_Otter10-40	OTH	146	29
BE_Beam>=24	BT1.4	1037	2907	FR_Otter10-40	TR1.6A	509	18
BE_Beam>=24	BT2.4	276	972	FR_Otter10-40	TR1.7D	39	3
BE_Beam>=24	BT2.7D	1359	1676	FR_Otter10-40	TR2.4	579	1799
BE_DSeine	OTH	314	365	FR_Otter10-40	TR2.7D	4103	3651
BE_DSeine	TR2.7D	74	44	GE_Beam<24	beam_oth.4	3829	347
BE_Otter	OTH	170	67	GE_Beam<24	BT2.4	357	435
BE_Otter	TR1.4	326	787	GE_Beam<24	OTH	2	4
BE_Otter	TR2.4	291	2278	GE_Beam>=24	BT2.4	3390	2268
DK_Otter<24	OTH	233	56	GE_Otter<24	OTH	82	79
DK_Otter<24	TR1.3AN	246	299	GE_Otter<24	TR1.4	299	439
DK_Otter<24	TR1.4	472	702	GE_Otter<24	TR2.4	280	851
DK_Otter<24	TR2.3AN	2014	1545	GE_Otter>=40	OTB32-69.4	2863	402
DK_Otter<24	TR2.4	29	51	GE_Otter>=40	TR1.4	411	795
DK_Otter>=24	OTB32-69.4	3187	17	GE_Otter>=40	TR3.4	501	150
DK_Otter>=24	OTB32-69.6A	625	5	GE_Otter24-40	OTH	47	75
DK_Otter>=24	OTH	1114	165	GE_Otter24-40	TR1.4	3959	7446
DK_Otter>=24	TR1.3AN	296	269	GE_Otter24-40	TR2.4	502	1154
DK_Otter>=24	TR1.4	2946	4440	GE_Static	GN1.3AN	21	32
DK_Otter>=24	TR2.3AN	627	406	GE_Static	GN1.4	215	75
DK_Otter>=24	TR2.4	181	313	GE_Static	OTH	40	0
DK_Seine	TR1.3AN	377	1486	NL_Beam<24	beam_oth.4	3247	148
DK_Seine	TR1.4	893	1274	NL_Beam<24	BT1.3AN	25	476
DK_Static	GN1.3AN	564	1554	NL_Beam<24	BT1.4	15	826
DK_Static	GN1.4	906	2619	NL_Beam<24	BT2.4	241	3985
DK_Static	OTH	18	17	NL_Beam>=40	BT1.3AN	797	2850

Fleet	Metier	Effort	Catch	Fleet	Metier	Effort	Catch
EN_<10	GN1.4	144	40	NL_Beam>=40	BT1.4	2936	6287
EN_<10	GN1.7D	80	264	NL_Beam>=40	BT2.4	15344	58761
EN_<10	GT1.7D	113	87	NL_Beam>=40	OTH	88	303
EN_<10	OTH	441	74	NL_Beam24-40	beam_oth.4	501	37
EN_<10	pots.4	1432	110	NL_Beam24-40	BT1.3AN	62	205
EN_<10	pots.7D	782	0	NL_Beam24-40	BT1.4	283	673
EN_<10	TR2.4	314	594	NL_Beam24-40	BT2.4	2374	11305
EN_<10	TR2.7D	112	210	NL_Otter	OTH	28	18
EN_Beam	BT1.4	406	852	NL_Otter	otter_oth.4	403	950
EN_Beam	BT2.4	1373	3149	NL_Otter	TR1.3AN	33	95
EN_Beam	BT2.7D	103	189	NL_Otter	TR1.4	929	4009
EN_FDF	OTH	36	204	NL_Otter	TR2.4	1295	4203
EN_FDF	TR1.4	235	1000	NL_Otter	TR2.7D	976	1033
EN_FDF	TR2.4	64	230	NL_Pelagic	pelagic.4	2649	156
EN_Otter<24	OTH	62	60	NL_Pelagic	pelagic.6A	2262	23
EN_Otter<24	TR1.4	236	1384	NL_Pelagic	pelagic.7D	824	0
EN_Otter<24	TR2.4	608	1430	OTH_OTH	OTH	25534	2502
EN_Otter<24	TR2.7D	115	57	SC_Beam	BT1.6A	2	5
EN_Otter>=40	OTB32-69.4	971	28	SC_Beam	OTH	391	995
EN_Otter>=40	OTB32-69.6A	353	1	SC_Otter<10	OTH	12	12
EN_Otter>=40	OTB32-69.7D	241	3	SC_Otter<10	TR2.4	195	514
EN_Otter>=40	OTH	253	271	SC_Otter<24	OTH	1	0
EN_Otter24-40	OTH	11	12	SC_Otter<24	TR1.4	5737	19106
EN_Otter24-40	otter_oth.4	686	285	SC_Otter<24	TR1.6A	931	635
EN_Otter24-40	otter_oth.7D	615	243	SC_Otter<24	TR2.4	1277	7327
EN_Otter24-40	TR1.4	560	1359	SC_Otter<24	TR2.6A	2086	169
EN_Static	GN1.7D	12	11	SC_Otter>=24	OTH	147	302
EN_Static	OTH	37	5	SC_Otter>=24	TR1.4	7651	46352
EN_Static	pots.4	2006	7	SC_Otter>=24	TR1.6A	1458	4020

Fleet	Metier	Effort	Catch	Fleet	Metier	Effort	Catch
EN_Static	pots.7D	417	0	SC_Otter>=24	TR2.7D	151	227
FR_<10	GN1.7D	51	1	SC_Static	GN1.4	445	15
FR_<10	GT1.7D	247	54	SC_Static	LL1.4	1152	162
FR_<10	OTH	1244	45	SC_Static	LL1.6A	493	5
FR_<10	TR2.7D	73	87	SC_Static	OTH	24	0
FR_Beam	BT2.7D	121	140	SC_Static	pots.4	3537	14
FR_Beam	OTH	21	2	SC_Static	pots.6A	3507	0
FR_Nets	GT1.7D	614	434	SW_Otter	OTH	1793	281
FR_Nets	OTH	172	49	SW_Otter	TR1.4	642	1330
FR_OTH	OTH	6226	1780	SW_Otter	TR2.3AN	810	966
FR_OTH	pelagic.4	1009	45	SW_Otter	TR2_grid.3AN	803	537
FR_OTH	pelagic.7D	675	82	SW_Static	OTH	78	26
FR_OTH	TR2.7D	490	811	SW_Static	pots.3AN	826	296
FR_Otter>=40	OTH	1	0				

Table 6.2. Average fishing mortality (Fbar) in 2020 between the single stock assessment (SSA) and FLBEIA

	SSA	FLBEIA	Diff_FLBEIA/SSA
COD-NS	0.448	0.412	-0.081
HAD	0.194	0.203	0.044
PLE-EC	0.217	0.255	0.178
PLE-NS	0.149	0.160	0.075
POK	0.453	0.484	0.069
SOL-EC	0.336	0.373	0.112
SOL-NS	0.233	0.230	-0.011
TUR	0.350	0.344	-0.018
WHG-NS	0.185	0.192	0.034
WIT	0.279	0.306	0.097

Table 6.3. Total catch in 2020 between the single stock assessment (SSA) and FLBEIA.

	SSA	FLBEIA	Diff_FLBEIA/SSA
COD-NS	24074.604	25197.242	0.047
HAD	39510.681	46652.113	0.181
PLE-EC	4850.329	5354.164	0.104
PLE-NS	82933.599	91435.266	0.103
POK	76819.823	80792.874	0.052
SOL-EC	3032.303	3166.556	0.044
SOL-NS	11375.518	11056.387	-0.028
TUR	3104.000	3251.934	0.048
WHG-NS	35119.189	34316.213	-0.023
WIT	2142.332	2222.403	0.037

Table 6.4. Total landings in 2020 between the single stock assessment (SSA) and FLBEIA

	SSA	FLBEIA	Diff_FLBEIA/SSA
COD-NS	19371.915	19947.186	0.030
HAD	31476.235	37511.525	0.192
PLE-EC	2092.831	2275.638	0.087
PLE-NS	44068.052	47901.290	0.087
POK	73790.988	77087.239	0.045
SOL-EC	2370.934	2481.063	0.046
SOL-NS	9376.151	8714.981	-0.071
TUR	3104.000	3251.934	0.048
WHG-NS	19756.056	19185.567	-0.029
WIT	1979.665	2037.493	0.029

Table 6.5. Total discards in 2020 between the single stock assessment (SSA) and FLBEIA

	SSA	FLBEIA	Diff_FLBEIA/SSA
COD-NS	4696.766	5250.056	0.118
HAD	9111.630	9140.588	0.003
PLE-EC	2757.498	3078.527	0.116
PLE-NS	38865.547	43533.977	0.120
POK	3028.861	3705.635	0.223
SOL-EC	661.369	685.493	0.036
SOL-NS	1935.504	2341.405	0.210
TUR	0.000	0.000	0.000
WHG-NS	15342.101	15130.646	-0.014
WIT	184.072	184.911	0.005

Table 6.6. Intermediate year assumption in the baseline and mixed fisheries projections.

	Fbar in 2021	Landings in 2021	Discards in 2021	Catches in 2021	SSB in 2022
cod.27.47d20	0.456	20033	10181	30214	49172
had.27.46a20	0.277	33257	61411	94668	502896
ple.27.7d	0.316	1558	3506	5063	35612
ple.27.420	0.173	41127	55520	96647	1081623
pok.27.3a46	0.481	60634	4244	64878	117668
sol.27.7d	0.483	2108	1362	3471	12716
sol.27.4	0.253	12096	2924	15019	57842
tur.27.4	0.343	3307	126	3433	9823
whg.27.47d	0.200	18834	24250	43084	255997
wit.27.3a47d	0.307	1873	253	2126	4332
nep.fu.5	0.004	474	296	770	7700
nep.fu.6	0.005	1674	565	2240	23427
nep.fu.7	0.001	5491	86	5576	161266
nep.fu.8	0.003	1671	322	1993	30279
nep.fu.9	0.005	927	230	1157	13243
nep.fu.10	0.003	11	0	11	110

	Fbar in 2021	Landings in 2021	Discards in 2021	Catches in 2021	SSB in 2022
nep.fu.32	0.001	177	3	180	1800
nep.fu.33	0.002	1612	0	1612	16120
nep.fu.34	0.006	2167	0	2167	9800
nep.27.4outFU	0.003	531	123	654	6462

	Fbar in 2021	Landings in 2021	Discards in 2021	Catches in 2021	SSB in 2022

Table 6.7. Comparison between baseline run and ICES advice for *Nephrops** in the TAC year. The values for *Nephrops* FUs that do not receive an absolute ICES abundance estimate are set according to the ICES approach for data-limited *Nephrops* stocks. No 'ICES advice' values are given for *Nephrops* in the intermediate year because the baseline run uses values based on recorded landings in the previous year which can vary significantly from the advice for each FU.

year	value	scenario	NEP5	NEP6	NEP7	NEP8	NEP9	NEP10	NEP32	NEP33	NEP34	NEPOTH-NS
2022	landings	ICES_advice	1031	1731	14664	3154.0	2042	46	379	956	530	301
2022	landings	MIXFISH_baseline	1031	1731	14666	2968.0	2043	46	379	956	530	301
2022	landings	difference (%)	0	0	0	-5.9	0	0	0	0	0	0

*These numbers are landings values; ICES advice does not provide total catch.

Table 6.8. Results of Final FLBEIA runs.

scenario	year	indicator	COD-NS	HAD	PLE-EC	PLE-NS	POK	SOL-EC	SOL-NS	TUR	WHG-NS	WIT	NEP10	NEP32	NEP33	NEP34	NEP5	NEP6	NEP7	NEP8	NEP9	NEPOTH-NS
baseline	2021	landings	21498	36618	2856	51458	60648	2709	14825	3349	21166	2158	15	243	2188	1330	733	2595	7522	2425	1307	721
baseline	2022	landings	11707	100056	3257	83067	44247	1951	14202	3321	51430	1115	46	379	956	530	1031	1731	14666	2968	2043	301
baseline	2021	catch	27183	51031	6260	97598	63927	3248	17046	3349	37170	2315										
baseline	2022	catch	13957	122052	6361	143514	47048	2292	15220	3321	85494	1182	46	381	956	566	1570	1940	14804	3217	2063	301
baseline	2021	Fbar	0.37	0.127	0.22	0.149	0.453	0.29	0.233	0.36	0.185	0.279	0.144	0.137	0.136	0.141	0.152	0.126	0.039	0.14	0.076	0.156
baseline	2022	Fbar	0.142	0.194	0.25	0.21	0.309	0.191	0.207	0.361	0.371	0.12						0.081	0.075	0.163	0.118	
baseline	2021	ssb	37872	236322	39308	1002918	134735	14155	64793	8951	225375	3498										
baseline	2022	ssb	54620	572970	36990	1093696	121801	14434	58617	9420	262152	4084										
baseline	2023	ssb	81163	729482	31309	1112676	142930	15713	60352	9081	240850	4631										
min	2021	Fbar	0.456	0.277	0.316	0.173	0.481	0.483	0.253	0.343	0.2	0.307	0.003	0.001	0.002	0.006	0.004	0.005	0.001	0.003	0.005	0.003
min	2022	Fbar	0.163	0.087	0.121	0.065	0.18	0.169	0.093	0.122	0.078	0.116	0.001	0	0.001	0.004	0.002	0.002	0	0.001	0.002	0.001
min	2023	Fbar	0.098	0.051	0.072	0.044	0.106	0.101	0.065	0.081	0.047	0.072	0.001	0	0.001	0.002	0.001	0.001	0	0.001	0.001	0.001
min	2021	ssb	38156	234000	39157	1001508	132322	14103	64282	9154	222767	4009	110	1800	16120	9800	7700	23426	161265	30278	13243	6462

sce-nario	year	indi-cator	COD-NS	HAD	PLE-EC	PLE-NS	POK	SOL-EC	SOL-NS	TUR	WHG-NS	WIT	NEP10	NEP32	NEP33	NEP34	NEP5	NEP6	NEP7	NEP8	NEP9	NEPOTH-NS
min	2022	ssb	49172	502896	35612	1081623	117668	12716	57842	9823	255997	4332	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
min	2023	ssb	72221	741445	34695	1193154	155404	14647	67549	11609	281230	5474	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
min	2021	catch	30214	94668	5063	96647	64878	3471	15019	3433	43084	2126	11	180	1612	2167	770	2240	5576	1993	1157	654
min	2022	catch	14273	61824	1971	43212	29151	1339	6234	1283	23047	987	5	76	695	946	333	1039	2617	897	477	287
min	2023	catch	11867	40479	1169	32129	23340	970	4896	975	15863	826	3	48	435	602	207	674	1569	558	309	180
min	2021	land-ings	20033	33257	1558	41127	60634	2108	12096	3307	18834	1873	11	177	1612	2167	474	1674	5491	1671	927	531
min	2022	land-ings	11166	45668	669	20045	27246	901	5321	1283	12676	871	5	75	695	566	205	782	2579	799	451	235
min	2023	land-ings	9726	33455	436	15989	21869	653	4199	975	9402	750	3	47	435	565	126	507	1547	497	291	149
min	2021	dis-cards	10181	61411	3506	55520	4244	1362	2924	126	24250	253	0	3	0	0	296	565	86	322	230	123
min	2022	dis-cards	3107	16156	1302	23167	1905	438	913	0	10372	116	0	1	0	380	128	257	38	98	27	52
min	2023	dis-cards	2141	7024	733	16139	1471	317	697	0	6461	76	0	1	0	37	81	167	23	61	18	31
max	2021	Fbar	0.456	0.277	0.316	0.173	0.481	0.483	0.253	0.343	0.2	0.307	0.003	0.001	0.002	0.006	0.004	0.005	0.001	0.003	0.005	0.003
max	2022	Fbar	1.65	1.132	0.778	0.41	1.924	1.974	0.864	0.783	0.604	1.338	0.008	0.004	0.012	0.028	0.01	0.017	0.003	0.01	0.012	0.006
max	2023	Fbar	1.699	1.037	1.138	0.535	1.955	2.075	1.143	1.179	0.637	1.414	0.008	0.004	0.013	0.032	0.011	0.018	0.003	0.01	0.012	0.007
max	2021	ssb	38156	234000	39157	1001508	132322	14103	64282	9154	222767	4009	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
max	2022	ssb	49172	502896	35612	1081623	117668	12716	57842	9823	255997	4332	110	1800	16120	9800	7700	23427	161266	30279	13243	6462

sce-nario	year	indi-cator	COD-NS	HAD	PLE-EC	PLE-NS	POK	SOL-EC	SOL-NS	TUR	WHG-NS	WIT	NEP10	NEP32	NEP33	NEP34	NEP5	NEP6	NEP7	NEP8	NEP9	NEPOTH-NS
max	2023	ssb	14578	317899	20141	992959	44241	5200	31931	6828	207045	2543	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
max	2021	catch	30214	94668	5063	96647	64878	3471	15019	3433	43084	2126	11	180	1612	2167	770	2240	5576	1993	1157	654
max	2022	catch	64648	358303	8880	209543	141642	5524	27434	5823	121077	4382	29	475	3900	4359	1866	5408	14803	4982	2600	1570
max	2023	catch	35606	209036	6399	206834	88895	2569	19440	4989	111572	3435	30	478	4274	4988	2032	5697	15087	5090	2646	1707
max	2021	land-ings	20033	33257	1558	41127	60634	2108	12096	3307	18834	1873	11	177	1612	2167	474	1674	5491	1671	927	531
max	2022	land-ings	8705	94144	2178	66027	41960	1428	12902	3291	45363	838	29	373	956	566	943	1461	14589	2865	1951	247
max	2023	land-ings	6198	78640	1248	65299	38976	545	10634	3362	49456	1060	30	374	956	566	966	1461	14589	2865	1951	247
max	2021	dis-cards	10181	61411	3506	55520	4244	1362	2924	126	24250	253	0	3	0	0	296	565	86	322	230	123
max	2022	dis-cards	55944	264158	6702	143516	99682	4096	14532	2532	75713	3544	0	102	2944	3793	923	3948	214	2117	649	1322
max	2023	dis-cards	29408	130395	5150	141534	49919	2024	8807	1627	62116	2375	0	103	3318	4422	1066	4236	498	2225	695	1459
sq_E	2021	Fbar	0.456	0.277	0.316	0.173	0.481	0.483	0.253	0.343	0.2	0.307	0.003	0.001	0.002	0.006	0.004	0.005	0.001	0.003	0.005	0.003
sq_E	2022	Fbar	0.566	0.217	0.316	0.172	0.524	0.563	0.259	0.343	0.191	0.489	0.003	0.001	0.004	0.013	0.004	0.005	0.001	0.003	0.004	0.003
sq_E	2023	Fbar	0.581	0.243	0.319	0.172	0.542	0.751	0.272	0.342	0.191	0.465	0.003	0.001	0.004	0.013	0.004	0.005	0.001	0.003	0.004	0.003
sq_E	2021	ssb	38156	234000	39157	1001508	132322	14103	64282	9154	222767	4009	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
sq_E	2022	ssb	49172	502896	35612	1081623	117668	12716	57842	9823	255997	4332	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
sq_E	2023	ssb	48175	655543	29346	1124389	117173	11171	56787	9636	260126	4257	110	1800	16120	9800	7700	23427	161266	30279	13243	6462

sce-nario	year	indi-cator	COD-NS	HAD	PLE-EC	PLE-NS	POK	SOL-EC	SOL-NS	TUR	WHG-NS	WIT	NEP10	NEP32	NEP33	NEP34	NEP5	NEP6	NEP7	NEP8	NEP9	NEPOTH-NS
sq_E	2021	catch	30214	94668	5063	96647	64878	3471	15019	3433	43084	2126	11	180	1612	2167	770	2240	5576	1993	1157	654
sq_E	2022	catch	33236	137790	4649	107730	67594	3138	15503	3239	53698	2315	11	180	1612	2167	770	2240	5576	1993	1157	654
sq_E	2023	catch	32881	136996	3906	107177	72396	2806	14598	3045	55614	2411	11	180	1612	2167	770	2240	5576	1993	1157	654
sq_E	2021	land-ings	20033	33257	1558	41127	60634	2108	12096	3307	18834	1873	11	177	1612	2167	474	1674	5491	1671	927	531
sq_E	2022	land-ings	11168	93840	1531	50077	46609	1595	12811	3098	28473	1066	11	177	956	566	474	1461	5496	1758	1084	247
sq_E	2023	land-ings	9235	84588	1303	53133	42720	721	11263	2982	32180	1235	11	177	956	566	474	1461	5496	1758	1084	247
sq_E	2021	dis-cards	10181	61411	3506	55520	4244	1362	2924	126	24250	253	0	3	0	0	296	565	86	322	230	123
sq_E	2022	dis-cards	22068	43950	3118	57653	20985	1543	2692	140	25226	1250	0	3	656	1601	296	779	80	236	73	407
sq_E	2023	dis-cards	23646	52408	2603	54044	29676	2085	3335	63	23434	1176	0	3	656	1601	296	779	80	236	73	407
cod-ns	2021	Fbar	0.456	0.277	0.316	0.173	0.481	0.483	0.253	0.343	0.2	0.307	0.003	0.001	0.002	0.006	0.004	0.005	0.001	0.003	0.005	0.003
cod-ns	2022	Fbar	0.163	0.087	0.135	0.066	0.18	0.185	0.094	0.125	0.079	0.116	0.001	0	0.001	0.004	0.002	0.002	0	0.001	0.002	0.001
cod-ns	2023	Fbar	0.098	0.051	0.09	0.045	0.106	0.124	0.066	0.084	0.047	0.072	0.001	0	0.001	0.002	0.001	0.001	0	0.001	0.001	0.001
cod-ns	2021	ssb	38156	234000	39157	1001508	132322	14103	64282	9154	222767	4009	110	1800	16120	9800	7700	23427	161266	30279	13243	6462

scenario	year	indicator	COD-NS	HAD	PLE-EC	PLE-NS	POK	SOL-EC	SOL-NS	TUR	WHG-NS	WIT	NEP10	NEP32	NEP33	NEP34	NEP5	NEP6	NEP7	NEP8	NEP9	NEPOTH-NS
cod-ns	2022	ssb	49172	502896	35612	1081623	117668	12716	57842	9823	255997	4332	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
cod-ns	2023	ssb	72218	741441	34303	1192373	155404	14486	67443	11580	281001	5474	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
cod-ns	2021	catch	30214	94668	5063	96647	64878	3471	15019	3433	43084	2126	11	180	1612	2167	770	2240	5576	1993	1157	654
cod-ns	2022	catch	14276	61827	2150	43856	29151	1411	6338	1311	23341	987	5	76	695	946	333	1039	2617	897	477	287
cod-ns	2023	catch	11924	40509	1389	32950	23341	1079	5012	1007	15884	827	3	48	435	602	207	674	1569	558	309	180
cod-ns	2021	landings	20033	33257	1558	41127	60634	2108	12096	3307	18834	1873	11	177	1612	2167	474	1674	5491	1671	927	531
cod-ns	2022	landings	11168	45671	710	20301	27246	913	5410	1311	12751	871	5	75	695	566	205	782	2579	799	451	235
cod-ns	2023	landings	9775	33462	473	16368	21870	648	4296	1007	9409	751	3	47	435	565	126	507	1547	497	291	149
cod-ns	2021	discards	10181	61411	3506	55520	4244	1362	2924	126	24250	253	0	3	0	0	296	565	86	322	230	123
cod-ns	2022	discards	3108	16157	1440	23555	1905	498	927	0	10590	116	0	1	0	380	128	257	38	98	27	52
cod-ns	2023	discards	2150	7046	915	16583	1471	431	716	0	6475	76	0	1	0	37	81	167	23	61	18	31
val	2021	Fbar	0.456	0.277	0.316	0.173	0.481	0.483	0.253	0.343	0.2	0.307	0.003	0.001	0.002	0.006	0.004	0.005	0.001	0.003	0.005	0.003
val	2022	Fbar	0.497	0.212	0.331	0.187	0.445	0.553	0.321	0.389	0.213	0.423	0.004	0.001	0.004	0.009	0.004	0.006	0.001	0.003	0.004	0.003

sce-nario	year	indi-cator	COD-NS	HAD	PLE-EC	PLE-NS	POK	SOL-EC	SOL-NS	TUR	WHG-NS	WIT	NEP10	NEP32	NEP33	NEP34	NEP5	NEP6	NEP7	NEP8	NEP9	NEPOTH-NS
val	2023	Fbar	0.514	0.237	0.343	0.187	0.465	0.737	0.321	0.387	0.213	0.409	0.004	0.001	0.004	0.009	0.004	0.006	0.001	0.003	0.004	0.003
val	2021	ssb	38156	234000	39157	1001508	132322	14103	64282	9154	222767	4009	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
val	2022	ssb	49172	502896	35612	1081623	117668	12716	57842	9823	255997	4332	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
val	2023	ssb	51645	656704	28967	1115925	125714	11167	53371	9287	255499	4351	110	1800	16120	9800	7700	23427	161266	30279	13243	6462
val	2021	catch	30214	94668	5063	96647	64878	3471	15019	3433	43084	2126	11	180	1612	2167	770	2240	5576	1993	1157	654
val	2022	catch	31213	136389	4862	114778	60644	3148	17077	3577	59850	2218	13	162	1623	1611	771	2519	6495	2334	1251	687
val	2023	catch	32631	135274	4038	112587	68099	2819	15161	3241	60418	2362	13	162	1623	1611	771	2519	6495	2334	1251	687
val	2021	land-ings	20033	33257	1558	41127	60634	2108	12096	3307	18834	1873	11	177	1612	2167	474	1674	5491	1671	927	531
val	2022	land-ings	11166	92497	1615	52326	46257	1595	12804	3247	29914	1057	13	159	956	566	495	1460	6402	2079	1180	247
val	2023	land-ings	9340	84447	1271	54623	42547	723	11105	3086	32995	1225	13	159	956	566	495	1460	6402	2079	1180	247
val	2021	dis-cards	10181	61411	3506	55520	4244	1362	2924	126	24250	253	0	3	0	0	296	565	86	322	230	123
val	2022	dis-cards	20047	43891	3246	62452	14387	1553	4273	329	29936	1161	0	3	667	1045	276	1060	93	255	71	440
val	2023	dis-cards	23292	50827	2767	57964	25552	2096	4056	155	27422	1137	0	3	667	1045	276	1060	93	255	71	440

Table 6.9. Mixed fisheries for the North Sea. Catch per mixed-fisheries scenario 2022, in absolute values.

Stock	Single-stock catch advice (2022) *	Catch per mixed fisheries scenario (2022)					
		max	min	cod-ns	sq_E	val	range
cod.27.47d20	14276	64648	14273	14276	33236	31213	13780
had.27.46a20	128708	358303	61824	61827	137790	136389	112251
ple.27.7d	6365**	8880	1971	2150	4649	4862	6418
ple.27.420	142508	209543	43212	43856	107730	114778	142085
pok.27.3a46	49614	141642	29151	29151	67594	60644	35142
sol.27.7d	2380	5524	1339	1411	3138	3148	2009
sol.27.4	15330**	27434	6234	6338	15503	17077	13999
tur.27.4	3609	5823	1283	1311	3239	3577	3083
whg.27.47d	88426	121077	23047	23341	53698	59850	73087
wit.27.3a47d	1206	4382	987	987	2315	2218	1105
nep.fu.5	1570	1866	333	333	770	771	NA
nep.fu.6	1940**	5408	1039	1039	2240	2519	NA
nep.fu.7	14803**	14803	2617	2617	5576	6495	NA
nep.fu.8	3216**	4982	897	897	1993	2334	NA
nep.fu.9	2062**	2600	477	477	1157	1251	NA
nep.fu.10	46	29	5	5	11	13	NA
nep.fu.32	381	475	76	76	180	162	NA
nep.fu.33	956	3900	695	695	1612	1623	NA
nep.fu.34	566	4359	946	946	2167	1611	NA
nep.27.4outFU	301	1570	287	287	654	687	NA

NA: stocks for which ranges of F_{MSY} are either not available or not yet included in the scenario.

* Advised catches no more than the indicated value.

** Single-stock advice is based on ranges in accordance with the EU MAP for demersal stocks in the North Sea (EU, 2019). The value presented here is for catches corresponding to F_{MSY}.

Total Landings by Stock
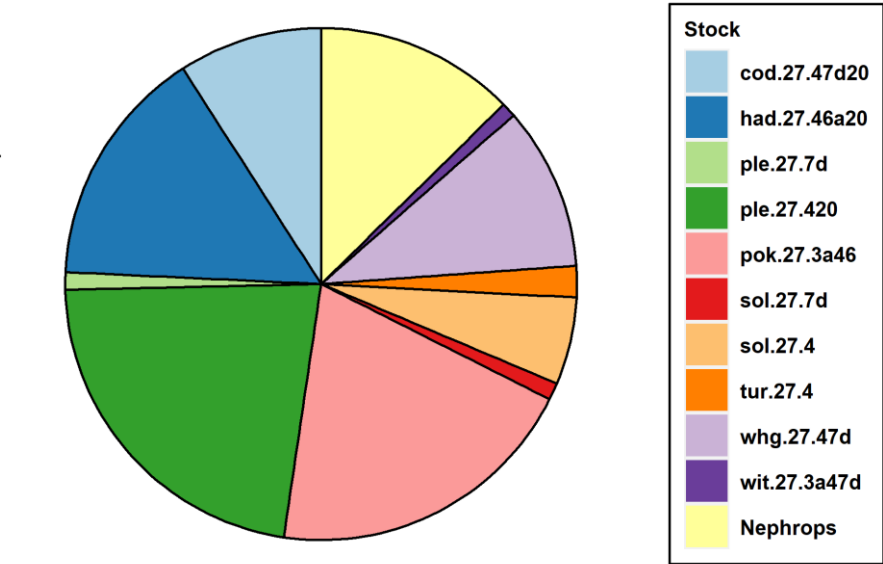
Figure 6.1. Distribution of 2020 landings of those stocks included in the mixed fisheries projections.

Total Landings by gear-groupings
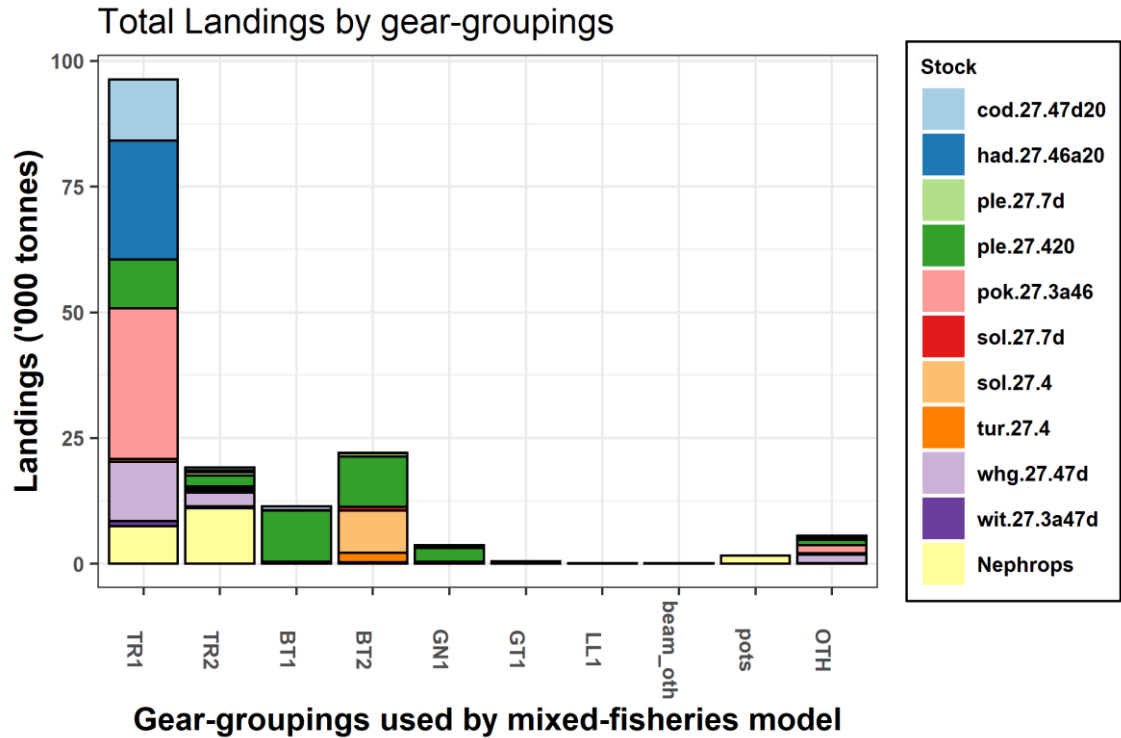
Figure 6.2. 2020 landings distribution of species by métier with landings consisting of ≥1% of any of the stocks. Note: The "other" (OTH) displayed here is a mixed category consisting of (i) landings without corresponding effort and (ii) landings of any combination of fleet and métier with landings <1% of any of the stocks.
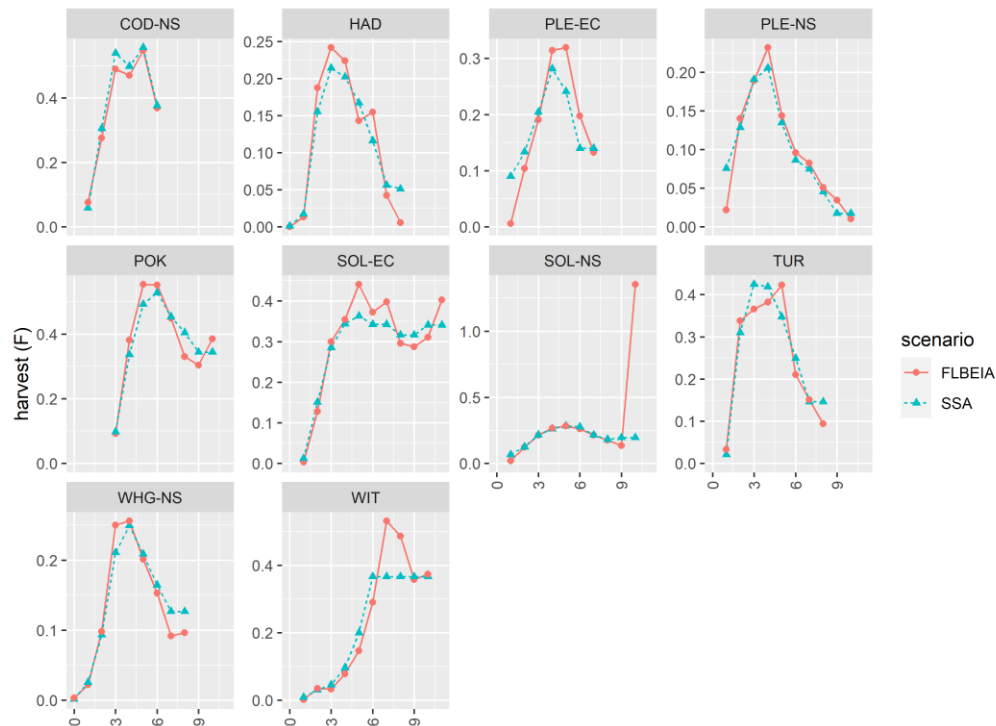
Figure 6.3. Fishing mortality at age in the last assessment year (2020).
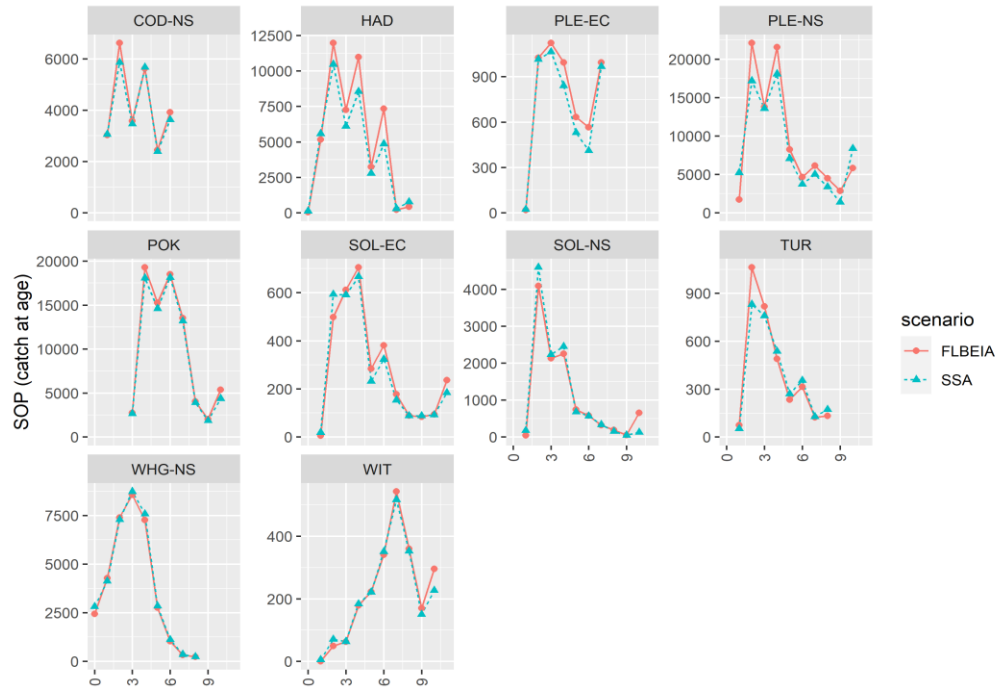
Figure 6.4. Sum of product (numbers*weight) catches in the last assessment year (2020).
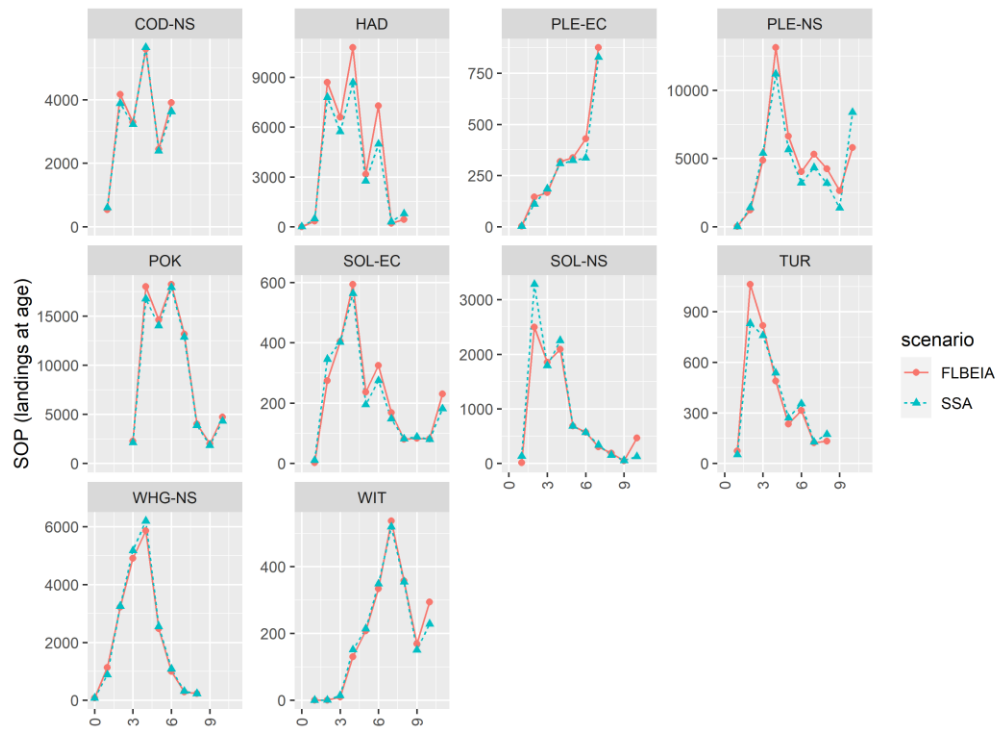
Figure 6.5. Sum of product (numbers*weight) landings in the last assessment year (2020).
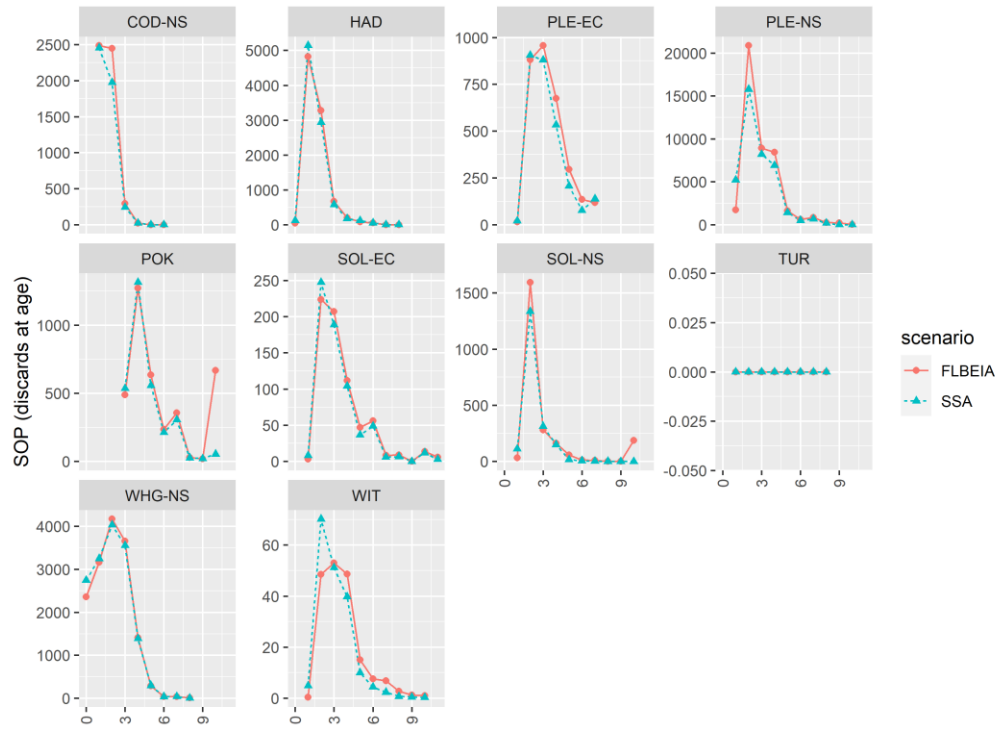
Figure 6.6. Sum of product (numbers*weight) discards in the last assessment year (2020).
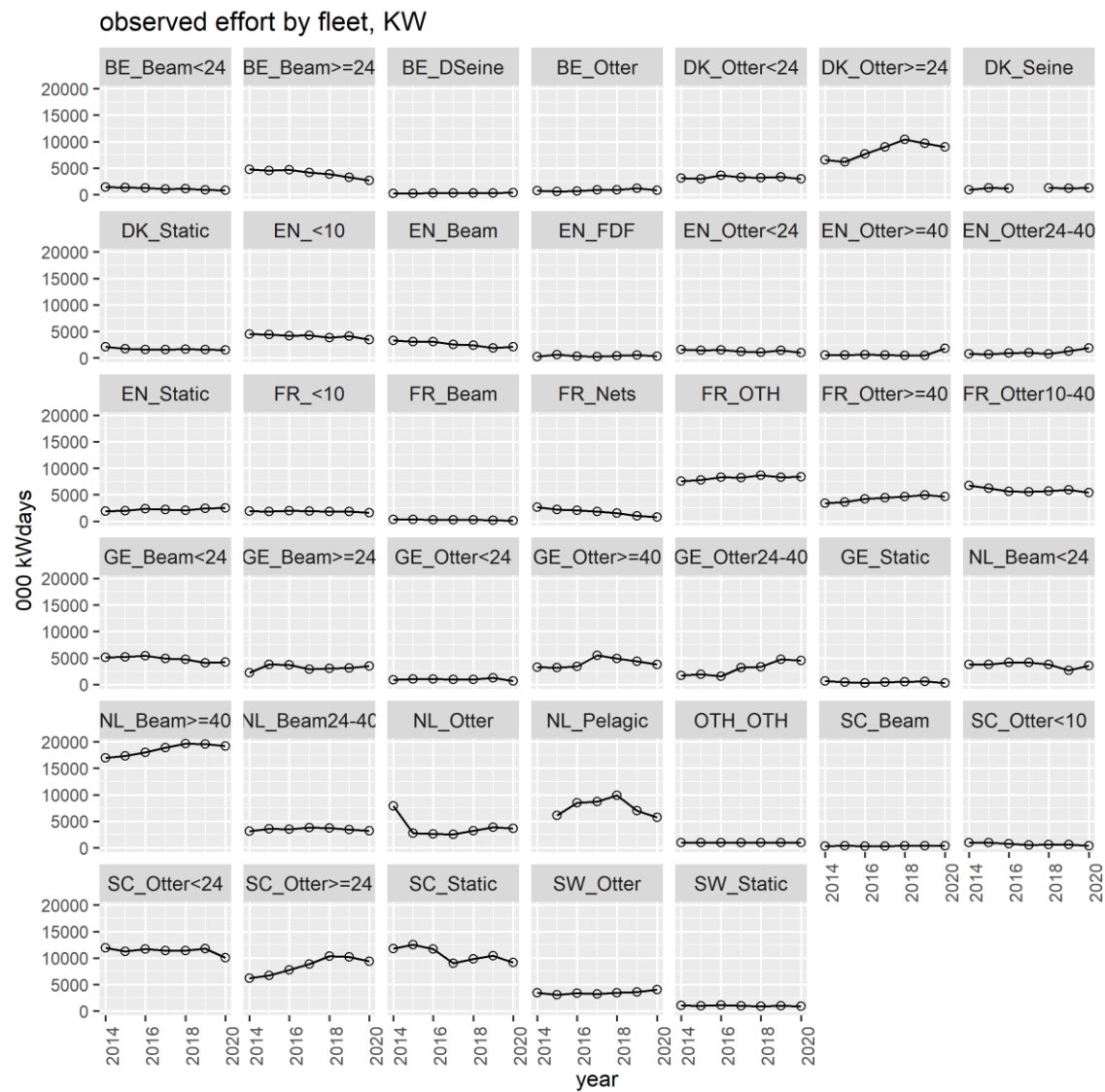
Figure 6.7. Effort by fleet and year for the North Sea demersal fleets, in '000 KWdays.
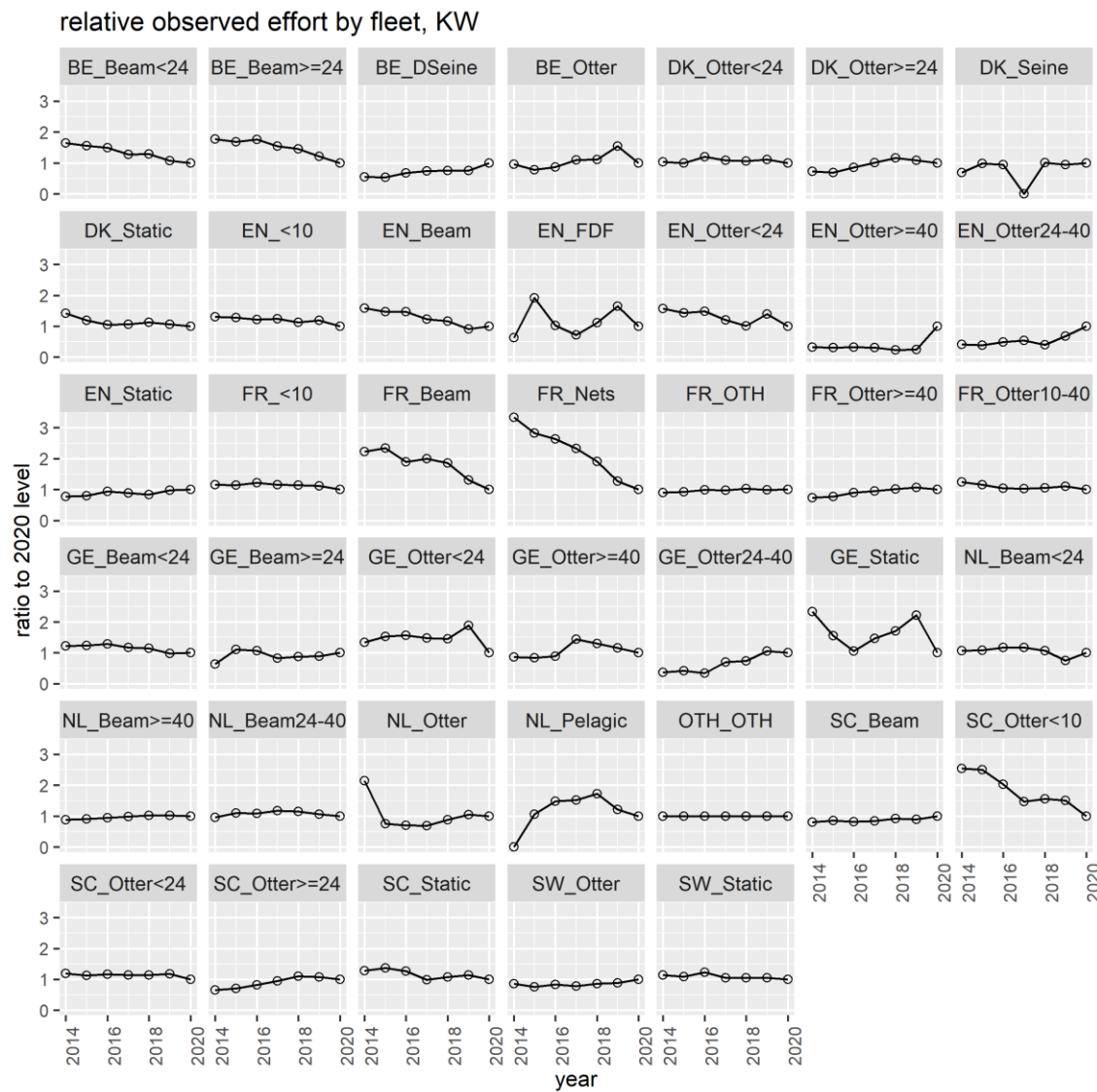
Figure 6.8. Relative trends (compared to the 2020 value) in effort (KW Days) by fleet and year for the North Sea demersal fleets.
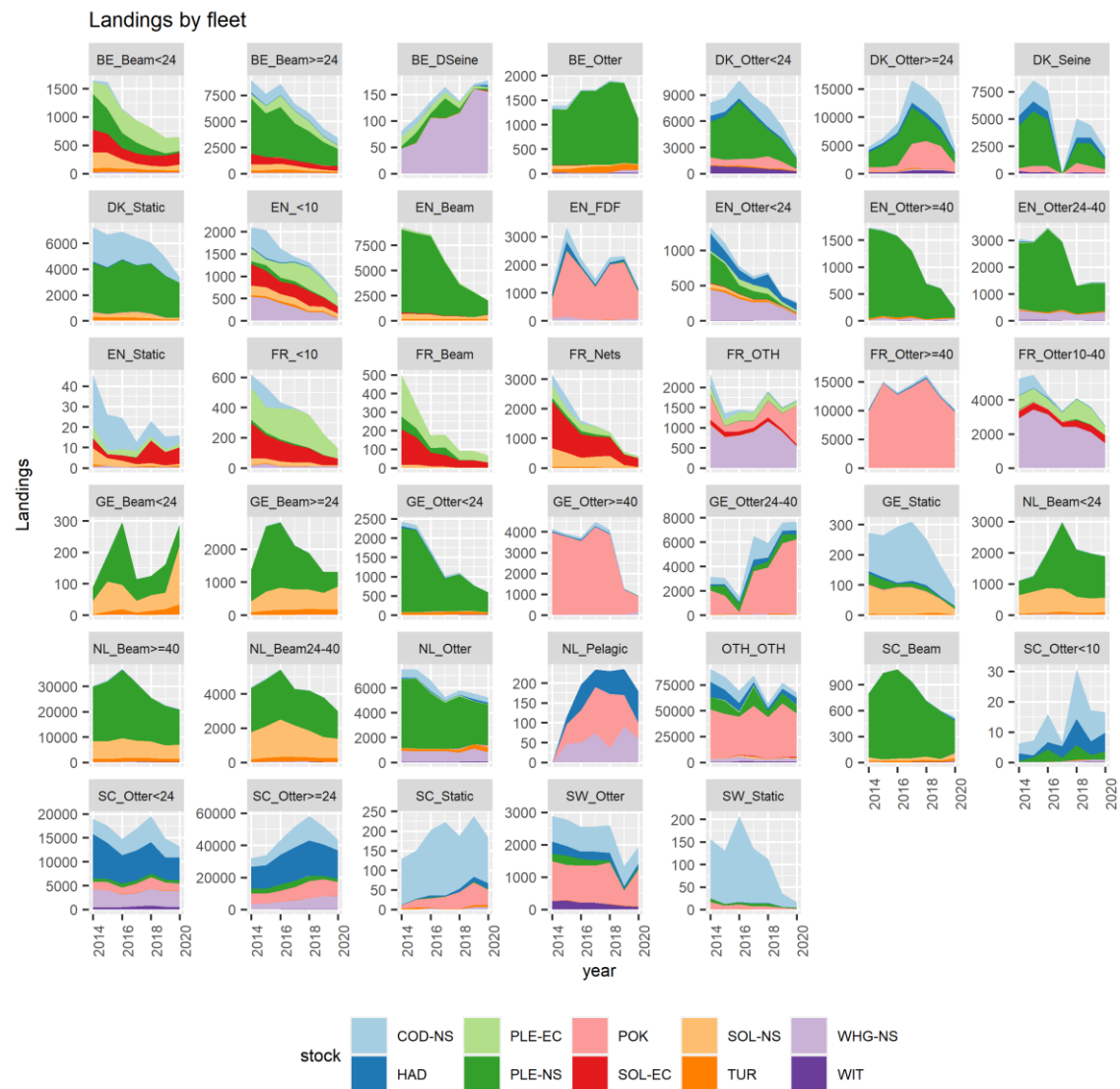
Figure 6.9. Landings by fleet, stock and year.
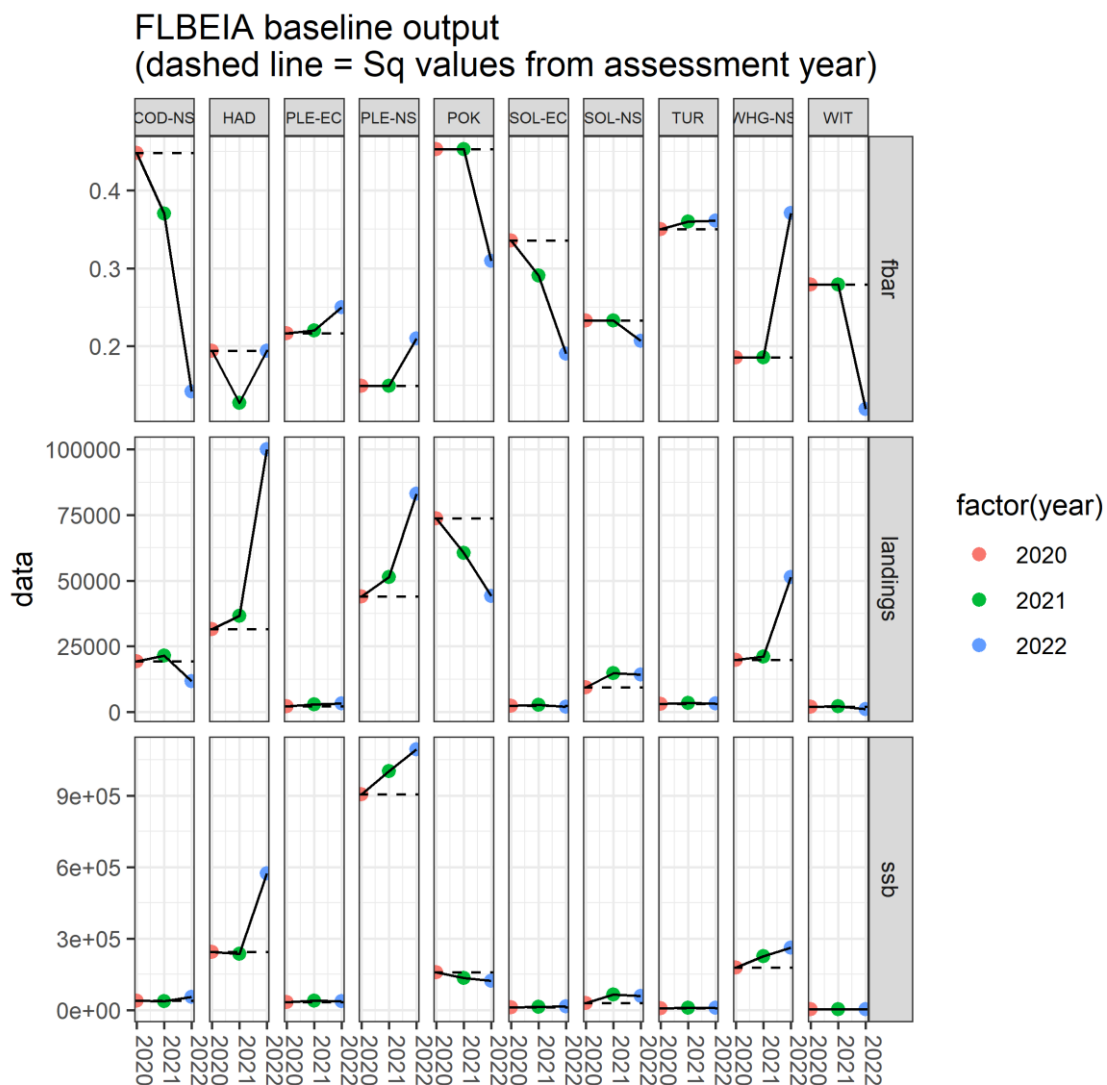
Figure 6.10. Summary of the relative changes in the single-stock advice for 2021 and 2022 compared to the situation in 2020.
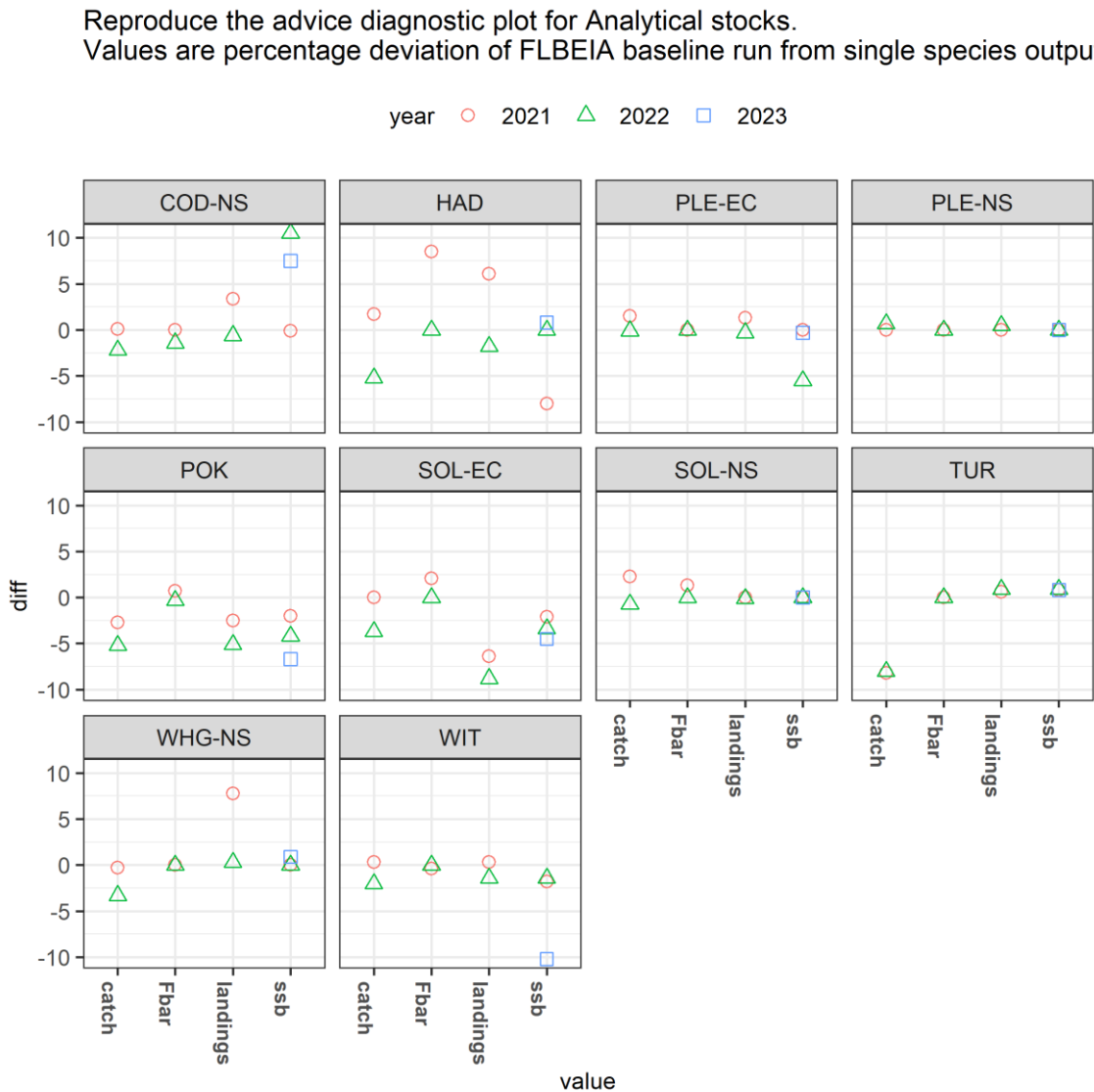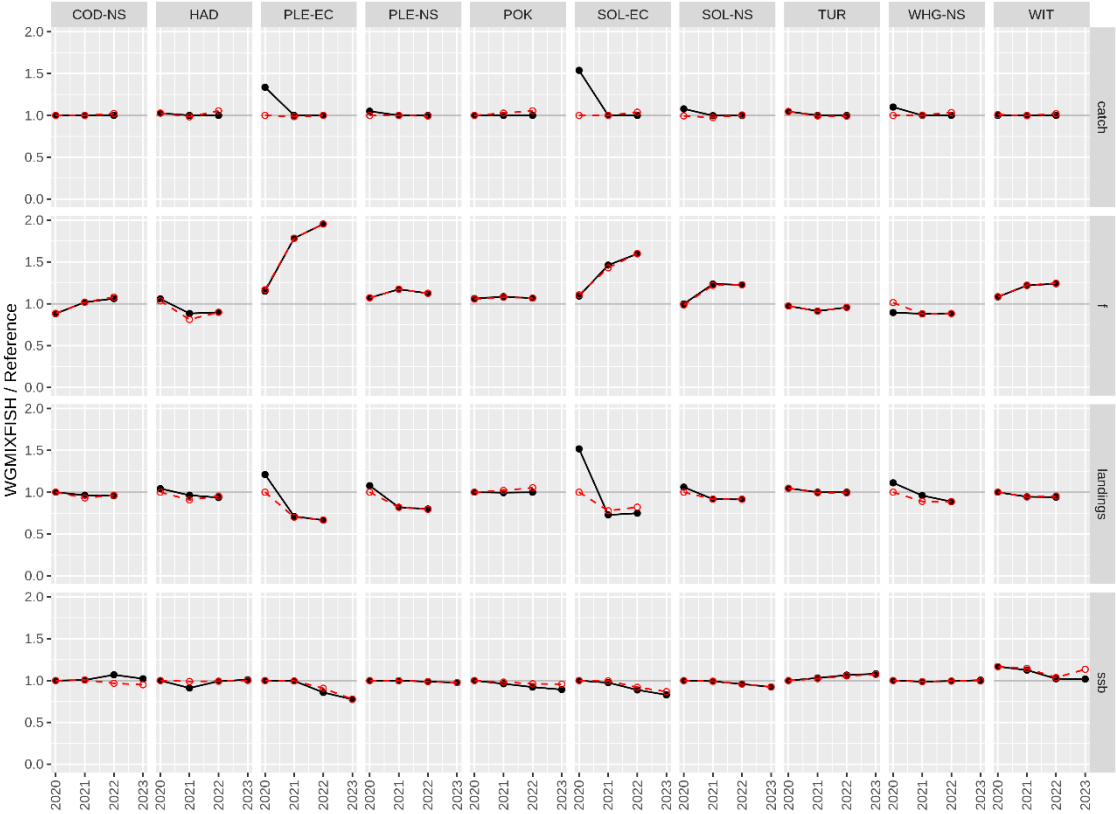
Figure 6.11. Difference between FLBEIA baseline run and Single-species advice for finfish stocks, showing Fbar (2021—2022), landings (2021—2022) and SSB (2021—2023).

Figure 6.12. Reproduce the advice summary statistics for WGMIXFISH forecasts using single-stock advice catch restrictions. Displayed are the indicator ratios of the WGMIXFISH forecast values versus those of the single stock advice (black) and baseline (red). A WGMIXFISH forecast was conducted for each stock separately, whereby the yearly catch values assumed by the single stock advice are used to restrict each fleet's fishing effort.
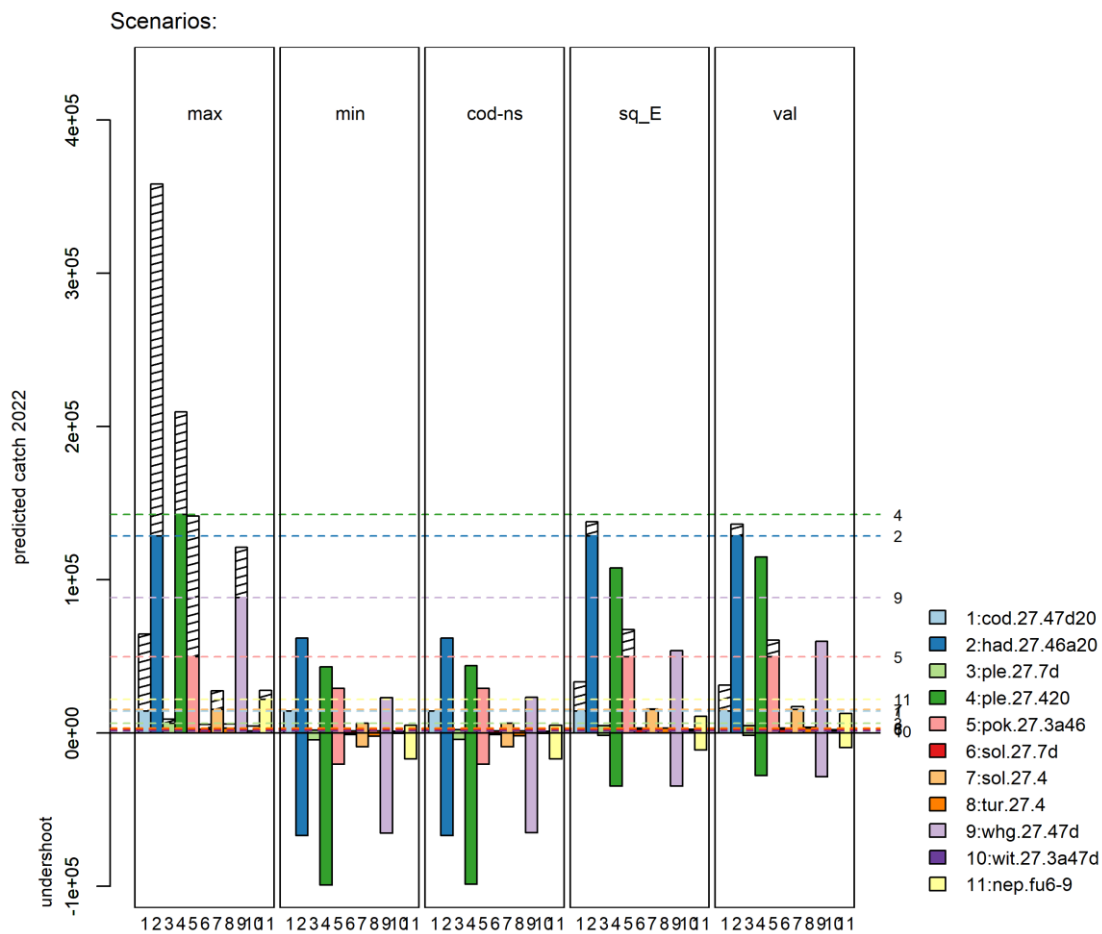
Figure 6.13. Mixed-fisheries projections. Estimates of potential catches (in tonnes) by stock and by scenario. Horizontal lines correspond to the single-stock catch advice for 2022. Bars below the value of zero show undershoot (compared to single-stock advice) where catches are predicted to be lower when applying the scenario. Hatched columns represent catches that overshoot the single-stock advice.
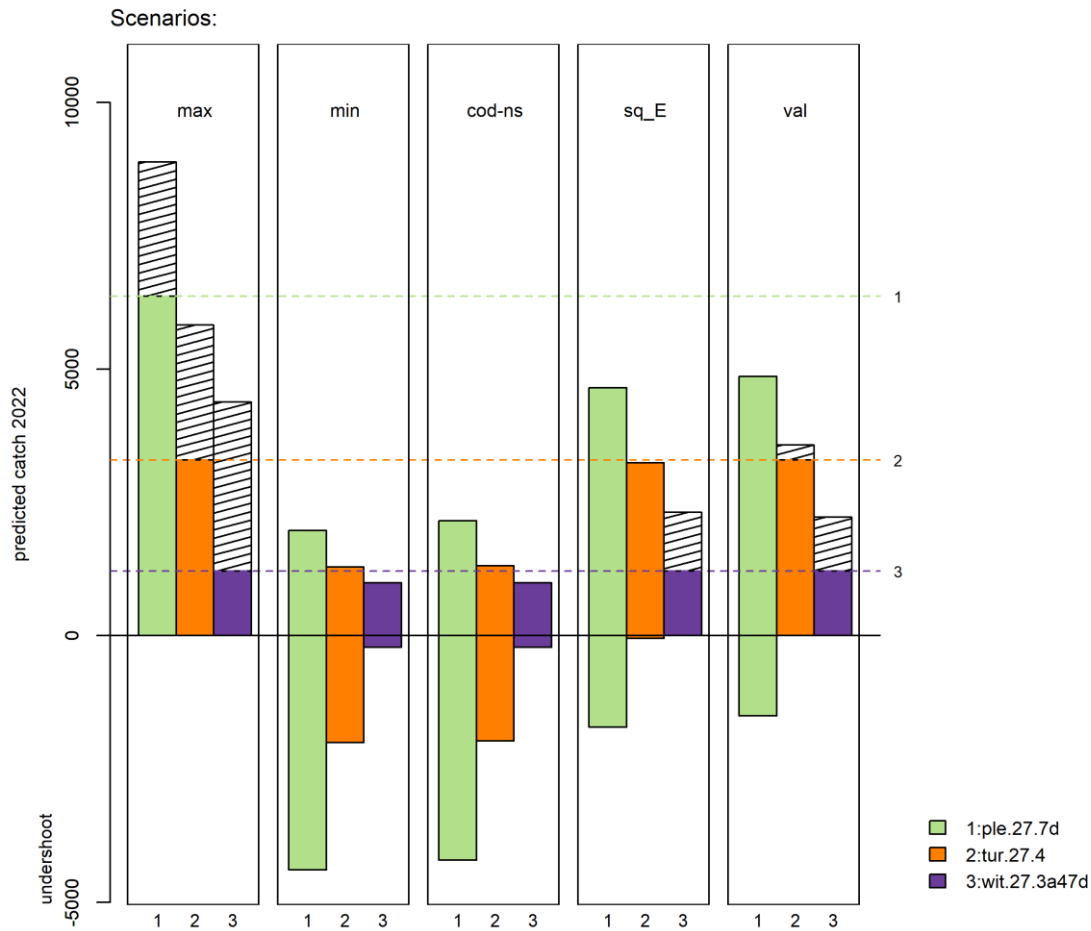
Figure 6.14. Mixed fisheries projections results for the stocks subject to lower landings (detail from Figure 6.13). Estimates of potential catches (in tonnes) by stock and by scenario. Horizontal lines correspond to the single-stock catch advice for 2022. Bars below the value of zero show undershoot (compared to single-stock advice) where catches are predicted to be lower when applying the scenario. Hatched columns represent catches that overshoot the single-stock advice.
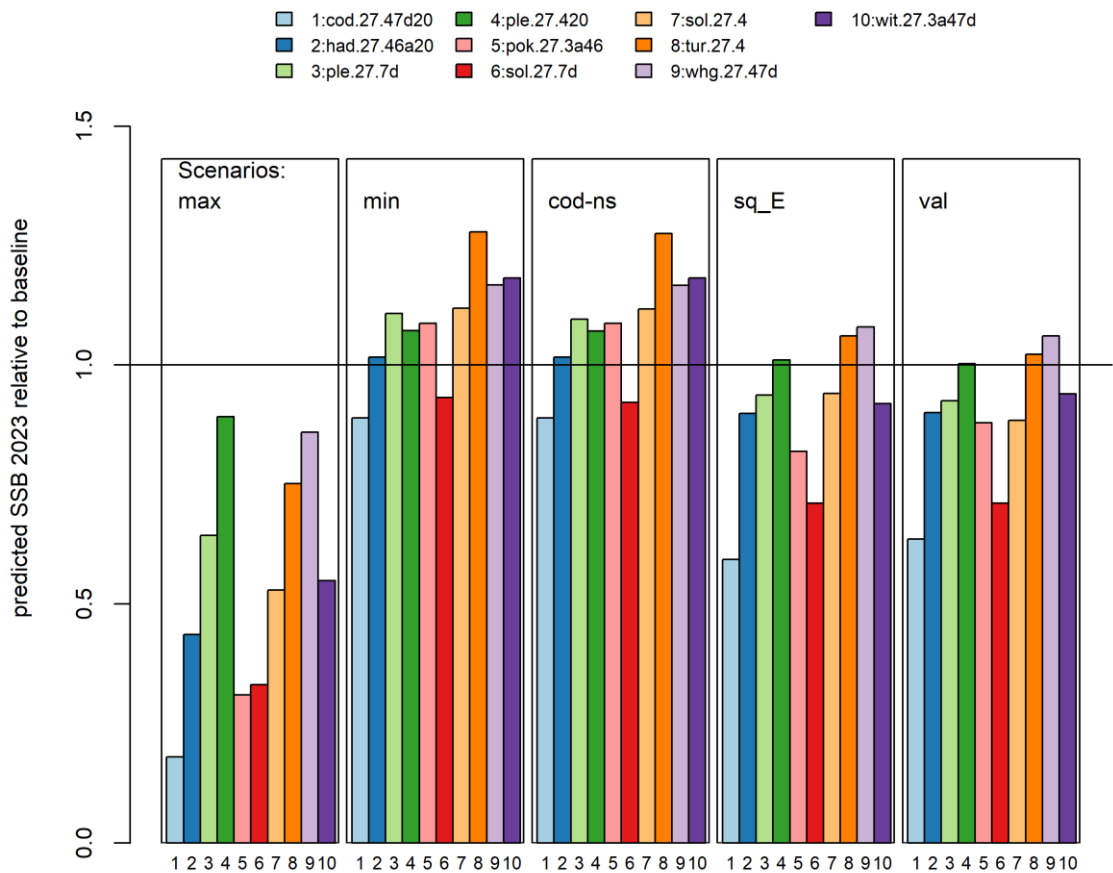
Figure 6.15. Mixed fisheries for the North Sea. Estimated SSB at the start of 2023 by stock after applying the mixed-fisheries scenarios, expressed as a ratio to the single-stock advice forecast. The horizontal line corresponds to the SSB resulting from the single-stock advice. Norway lobster are not included as the abundance was not forecasted in the mixed-fisheries model.

Figure 6.16. Mixed fisheries for the North Sea. Estimates of effort by fleet needed to reach each single-stock advice. Red triangles highlight the most limiting species for that fleet in 2022 ("choke species"), whereas the green triangles highlight the least limiting species. Fleet names are given by country (BE = Belgium, DK = Denmark, EN = England, FR = France, GE = Germany, IE = Ireland, NI = Northern Ireland, NL = the Netherlands, SC = Scot-land, SW = Sweden, OTH = Others) and by meaningful combinations of main gear and vessel size differing across countries and based on homogeneous average fishing pat-terns. FDF = Fully Documented Fisheries vessels. Vessels in the various fleet segments can engage in several fisheries (métiers) over the year.
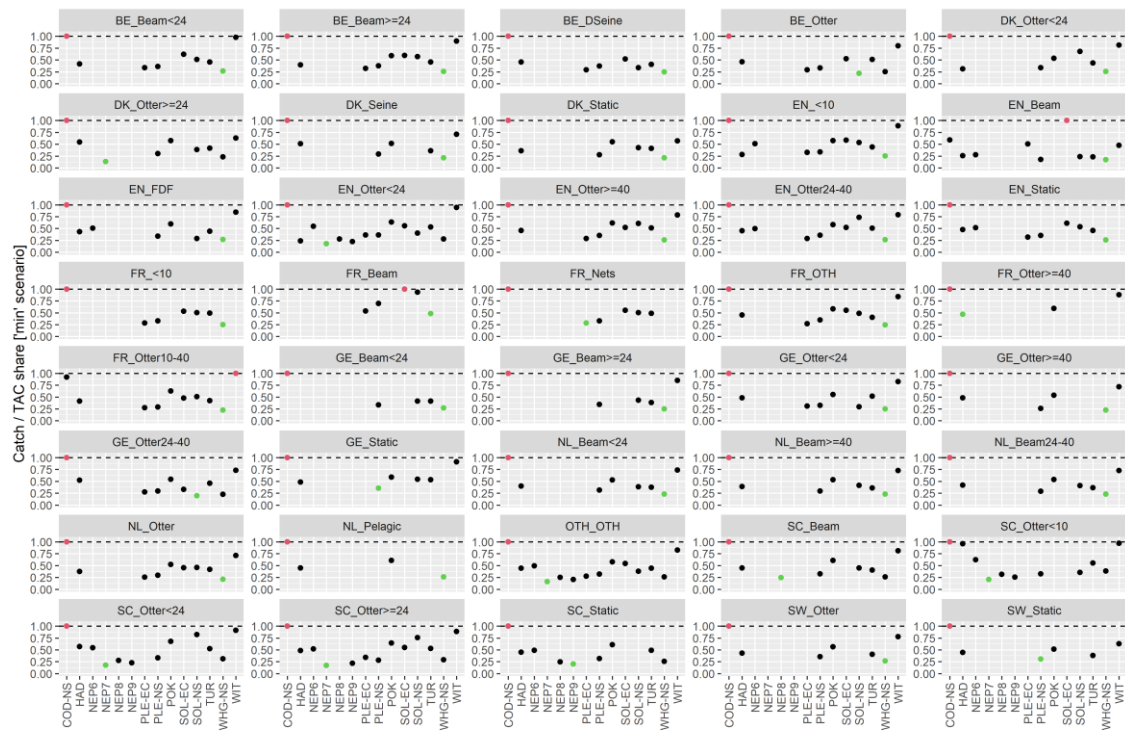
Figure 6.17. Quota uptake in 2022 in the min scenario. Red dots highlight the most limiting species for that fleet ("choke species"), whereas the green dots highlight the least limiting species.
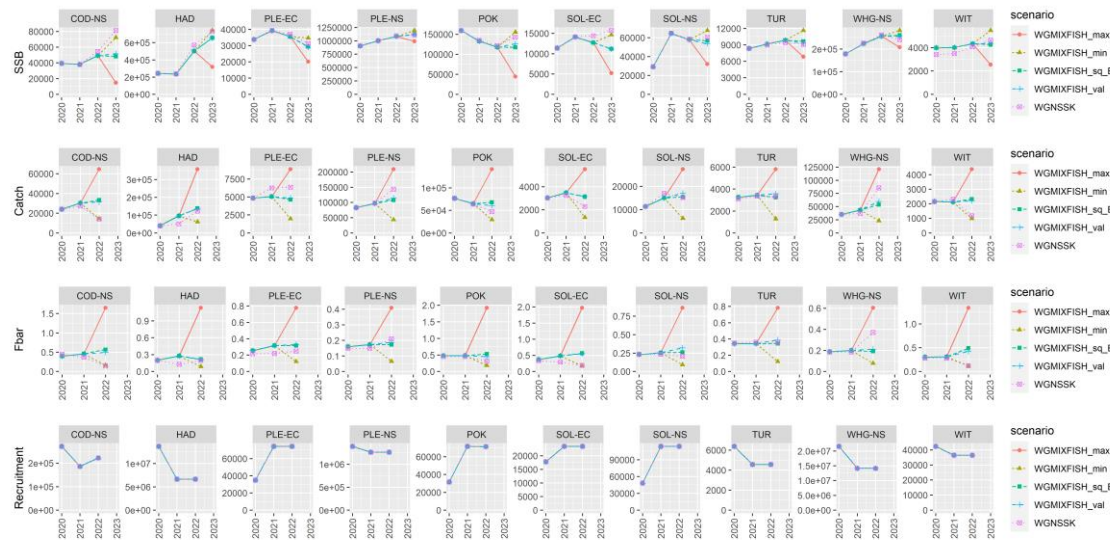

Figure 6.18. Comparison of the mixed fisheries projections in all the scenarios (WGMIXFISH) with the single-species advice projections (WGNSSK).
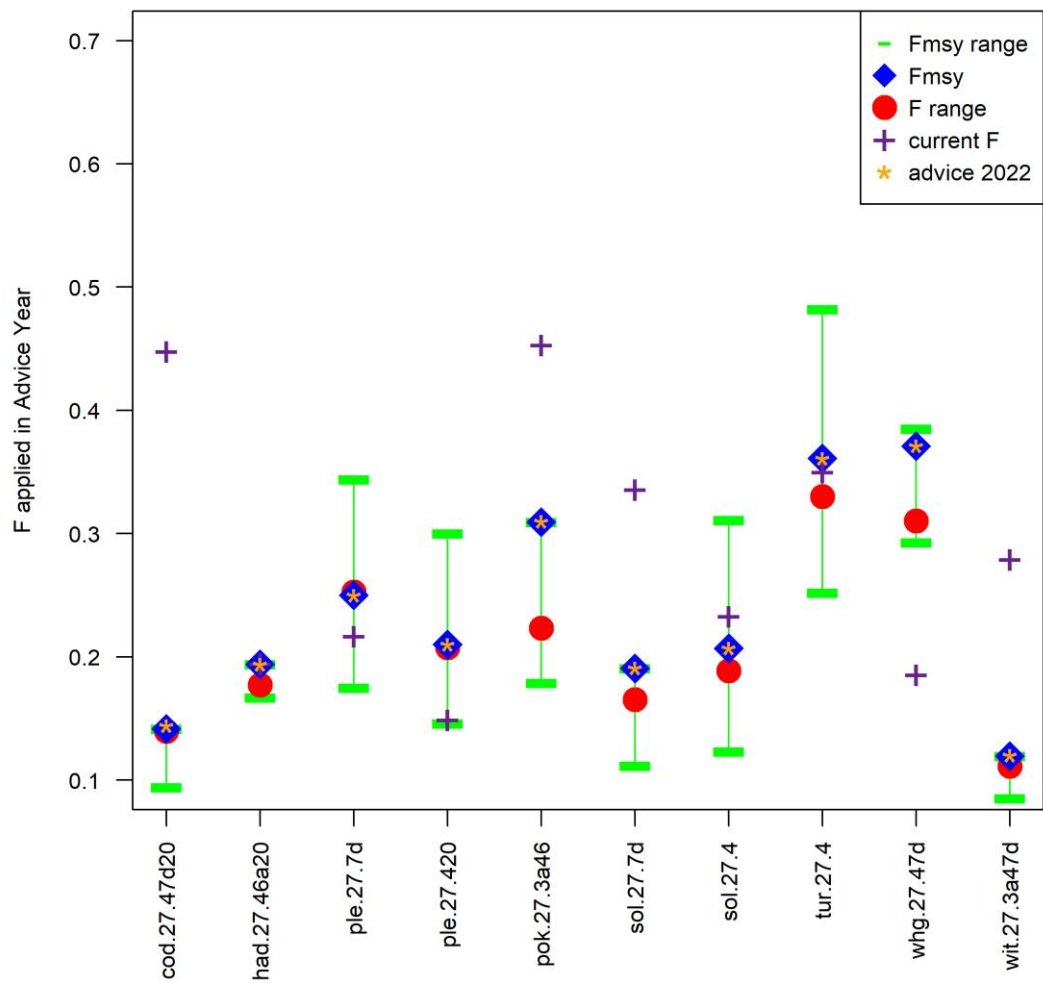
Figure 6.19. North Sea mixed-fisheries 2022 "range" fishing mortality within the F_{MSY} range, compared with F_{MSY}, the current F (F in 2020), and F in the single-stock advice for 2022. The "range" F is the one giving the lowest difference in tonnage between the "max" and the "min" scenario across all stocks and fleets. For cod in the North Sea, F_{MSY} ranges are limited in accordance with the MSY approach and the MAP when below $MSYB_{trigger}$.
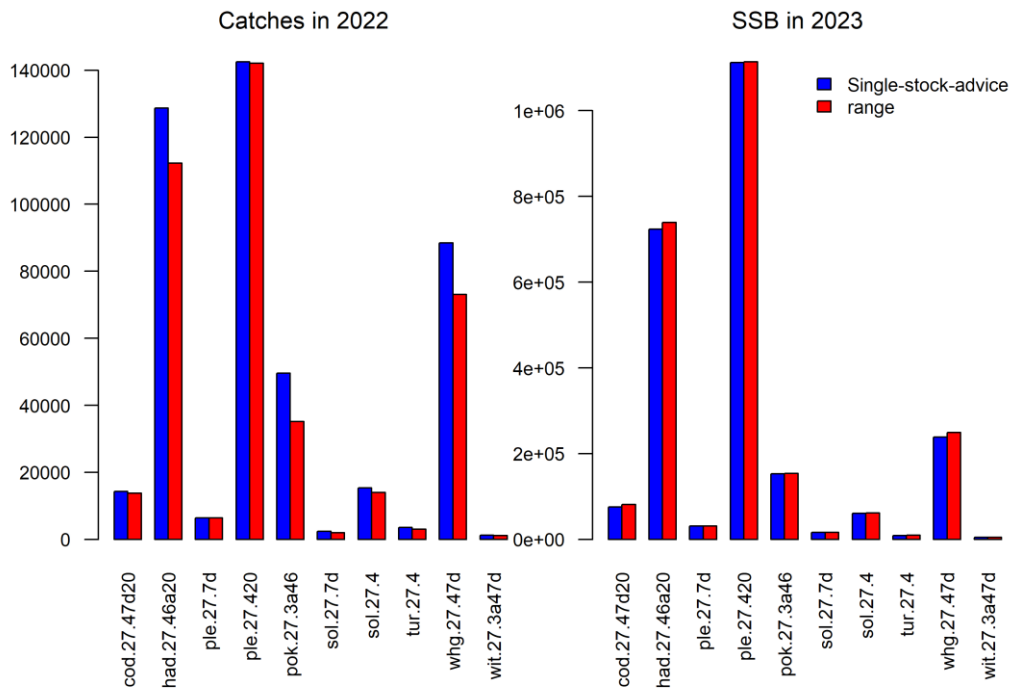
Figure 6.20. Comparison of the outcomes in terms of total catches in 2022 (left) and SSB in 2023 (right) between the F_{MSY}-based single-stock advice and the F_{range}-based forecast.

7 WGMIXFISH-METHODS planning

7.1 Bay of Biscay

There are several issues in the modelling process to provide mixed fisheries advice for Bay of Biscay that need to be addressed in future meetings.

- Investigate the differences obtained in the short term forecast between that carried out for mixed fisheries advice and that of the assessment working grouops, specially for seabass, mackerel and blue whiting.
- Improve fleet structure based on this year fleet configuration, e.g. consider removing some of them with low contribution to the catch, remove stocks that are only caught ocassionally or where only caught in the past. Documenting and justifiying the procedure.
- Analyse reported data for rays and decide on how to make assigments to the different species, given official catch data and information from surveys. Documenting and justifiying the assumptions made.
- Analyse statibility of main model parameters, i.e. catchability, total effort, effort share and quota share. Based on the analysis consider the best way of conditioning the model at fleet/metier level, recent years average or last year value.
- Adapt the currently available code in the ICES-taf repository (https://github.com/ices-taf) to follow the principles of TAF.
- Analyse the option of including fleet-dependent age structure in the conditioning of the model for some stocks.
- Analyse the relevance of existing scenarios and identify new relevant ones.

7.2 Celtic Sea

The following topics have been identified for future work in the North Sea case study:

- Inclusion of hake (and any other stocks)
- Continued implementation of FLBEIA model.
- Streamlining code, repository and results tables and figures.

7.3 Iberian Waters

- Continued implementation of the FLBEIA model
  - Improve gear grouping of fleets used in mixed-fisheries scenarios in order to best reflect the technical interactions in the region.
  - Include hake as category 1
- Continued implementation of code, results, tables and figures in TAF
- Continued discussion for the inclusion of other stocks, although there are very few stocks in ICES category 1 exploited in the area by mixed fisheries.

7.4 North Sea

The following topics have been identified for future work in the North Sea case study:

- TAF – The current repository is working with the TAF framework but the structure could be further improved to be more in-line with the TAF philosophy. Improvements could include:
  - Improved organization or removal of created subdirectories (created within the standard data/, model/, output/, and report/ directories).
  - Improved separation of model and output routines. Model routines would be more focused on the actual model runs, while output routines would extract those results (e.g. as summary data objects).
  - Full documentation of all required package versions within SOFTWARE.bib. TAF coordinators have provided somewhat conflicting information here, which needs to be resolved; e.g. commonly used packages (e.g. FLCore, ggplot) are assumed to be on the TAF server and need not be included. This can still, however, be an issue if the advice has relied on an older, specific package version.
- Diagnostics
  - Revision and expansion of diagnostic tables and figures to evaluate the model conditioning and outcomes. Further figures illustrating the mixed fisheries intermediate year assumptions would be help (e.g. comparison of SSB at the beginning of the advice year versus the single species advice)
- Data
  - The stock objects for *Nephrops* FUs have historically been created and maintained by WGMIXFISH by extracting annual values from the advice documents. This procedure is inefficient and prone to errors. We suggest asking WGNSSK *Nephrops* stock coordinators to provide FLStock objects directly.

  - Methodology
    - FIDES – The current advice year has elucidated some possible issues with how we use FIDES data to update the choking behaviour of fleets; specifically, the removal of choking stocks for countries who did not fully utilize their TAC is the last data year resulted in unrealistic forecasts with too few restrictions to fishing effort. A review of this process should be done to explore other possible adaptions to the procedure. The group agrees that the FIDES data is still a valuable data source for create more realistic short-term forecasts.
    - Intermediate year assumptions – This is a discussion that should be had across case studies. Also, should the same intermediate year assumptions be used among all scenarios (including "range").
- Report & 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.
- 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 in preparation for a transition to FLBEIA.

7.5   Irish Sea

The following areas would be useful to address in order to improve the mixed fisheries assessment methods in the Irish Sea

- Methods for the inclusion of stochastic assessment methods (e.g. SAM) into the FLR FCube framework. Improvements for the inclusion of SAM assessment methods have been demonstrated by the North Seas and Celtics Seas subgroups in 2020. The Irish Sea subgroup aims to implement such methods in the mixed fisheries assessment of Plaice and Sole in Division 7a
- Methods for the inclusion of category 3 and other data poor stocks. The Irish Sea sub-group are developing code for the replication of the currently Irish Sea Cod single-species assessment in their mixed fisheries model. This species is assessed using a trends based assessment which uses a biomass index derived from the NI-GFS scientific survey.
- Potential improvements to the methods for the inclusion of *Nephrops* stocks in the mixed fisheries assessments. For example, whether the spatial aspects of *Nephrops* fisheries can be better accounted for (e.g. via fleet objects), and the potential merits of dividing TACs within regions based on single-species advice rather than recent landings.
- The use of FIDES information on quota uptake by member states to inform 'min' and 'range scenarios
- Improvements to fleet and metier structures to best reflect Irish Sea fisheries practices and technical interactions

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Annex 1:   Recommendations

No recommendations

Annex 2:   List of participants

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Annex 3:   Audit reports

Audit of the Mixed-fisheries advice for the Bay of Biscay

Date: 17/11/2021

Auditor: Harriet Cole

Summary of the advice

1.   **Assessment type:** FLBEIA mixed fisheries assessment
2.   **Single stock Assessments used as basis** (stock/assessment model/EG forecast method)

Species	Assessment	Forecast
WHITE ANGLERFISH 7, 8.a–b and 8.d	a4a	FLR-STF
HAKE 3.a, 4, 6, 7 and 8.a,b,d	SS3	SS3 (ad hoc R code)
SOLE 8.a-b	FLR-XSA	FLR STF
MEGRIM 7.b-k and 8.a-b,d	Bayesian statistical catch at age model	ad hoc R code
NORWAY LOBSTER 8.a-b	UWTV survey	Ad-hoc (excel sheet)
HORSE MACKEREL in the Northeast Atlantic	SS3	FLR-STF
MACKEREL in the Northeast Atlantic and adjacent waters	SAM	FLR-STF
BLACK-BELLIED ANGLERFISH 7, 8.a-b,d	Survey trend (Category 3)	No
POLLACK 8 and 9.a	None (Category 5)	No
SMOOTH-HOUND in the Northeast Atlantic and adjacent waters	Survey trend (Category 3)	Ad-hoc (excel sheet)
BLUE WHITING in the Northeast Atlantic and adjacent waters	SAM	SAM
WHITING 8 and 9.a	None (Category 5)	No

3.   **Framework used for mixed fisheries forecasts:**
      The FLBEIA model coded in R, using the FLR framework (www.flr-project.org).
4.   **Data issues:**
      The 2020 accessions submission from France resulted in a large increase in the amount of landings allocated to the FR_MIS metier and a corresponding reduction in other metiers compared to last year. Gillnetters appear to be particularly affected with their catch and effort being allocated to FR_MIS. The metier allocations will be reviewed and revised at the next METHODS meeting.

      The sea bass single stock advice results could not be replicated by WGMIXFISH. This is probably due to the way recreational catches are included in the signal stock assessment

model however, these details have not been passed on to WGMIXFISH and the stock coordinator was unavailable during the week of the meeting. The decision was taken to remove this stock from the Bay of Biscay scenarios.

The French accessions data for 2020 did not appear to record any catch of thornback and cuckoo ray and only reported catches for undulate rays. Whereas, the accessions data from Spain include thornback and cuckoo ray catches but did not include undulate ray catches. Skates and rays are prone to mislabelling in the reporting of catches. These stocks were removed from the model as this issue would need more time to investigate in coordination with the relevant national data submitters.

Some discrepancies between the single stock advice and the Baseline run to reproduce the advice were found for mackerel and blue whiting. These are noted in te report section as needing further investigation.

5.   Consistency:

Sea bass, undulate ray, thornback ray and cuckoo ray have been removed from the mixed fisheries scenarios (see data issues).

Blue whiting and Pollock have been added as stocks for this year however, an explanation is not given in the report. I think this would be helpful especially since Pollack is the most limiting stock this year.

There have been some changes to the scenarios presented in the advice and the stocks for which projected catches are presented under the scenarios (see Figure 1 in the advice sheet). This change has occurred to present the most relevant stocks in both the projected catches and the scenarios presented.

There have been some changes to the names of the defined fleets used in the mixed fisheries model, specifically the French fleets, due to a change in the metier definitions used in the accessions fleet data submission from France for 2020.

4.   Mixed fisheries situation:

Pollock (pol.27.89a) is most limiting stock (15 of 22 fleets). This is because thecatch advice for this stock has had sharp reduction in 2022 (39%). The least limiting stock is black bellied anglerfish (ank.27.78abd) (11 of 22 fleets).

5.   Management Plan:

A multi-annual plan exists and covers some stocks in Western Waters and adjacent waters however, for some of these stocks, this MAP is currently not recognised by Norway or the UK. In those cases, ICES advice is given on the ICES MSY approach.

General comments

Advice sheet: Well written and adheres to the generic format agreed for all mixed fisheries advice sheets. Data issues affecting the advice were explained within the text.

TAF: Generally well documented and easy to follow. Results were fully reproducible. There were no issues to get the code running once I'd worked out the correct package versions needed.
Report section: Very well written and easy to follow. All data issues were documented and described.

Stock annex: Well written with a clear structure. Good use of linking to information procided in other ICES documents (e.g. Fisheries Overviews). Avoiding repetition of this information keeps the document short and to the point.

Technical comments

All technical comments for documents have been added to the documents as a tracked change or comment balloon.

Advice sheet: The discussion on the reporting of the skate/ray stocks assign the stocks to the countries (France and Spain) the wrong way round. France reported only undulate rays; Spain reported cuckoo and thornback rays but did not report undulate rays.

TAF: The repository does not include a bootstrap folder and all datasets, both raw (input) and processed (outputs) are uploaded to the repository. Best practice would be to provide only the input data (in the bootstrap folder) so that after running the taf.bootstrap() function the user can generate all output products. This saves on space in the TAF repositories. Additionally, the bootstrap process requires two bibliographies (DATA.bib and SOFTWARE.bib) which provide metadata on the input datasets and document the software and R packages and the versions used which would be helpful.

Report section: A few small typos.

Stock annex: A few minor comments and typos.

Conclusions

The assessment has been carried out appropriately and is fully reproducible. There are some minor deviations from previous years due to issues in the data or lack of information on single stock assessment methods and so these changes are justified. Some restructuring to the TAF repository would be beneficial.

Audit of the Mixed-fisheries advice for the Celtic Seas ecoregion

Date: 05/11/2021

Auditor: Gianfranco Anastasi

Summary of the advice
1. **Assessment type**: FCube mixed fisheries assessment
2. **Single stock Assessments used as basis** (stock/assessment model/EG forecast method)

Stock	Assessment	Forecast
cod.27.7.e–k	Age-based stochastic analytical assessment (SAM)	SAM
had.27.7.bc,e–k	Age-based stochastic analytical assessment (SAM)	SAM
whg.27.7.bc,e–k	Age-based stochastic analytical assessment (SAM)	SAM
meg.27.7b-k8abd	Bayesian statistical catch at age using catches in the model and forecast	Stochastic
mon.27.78abd	a4a	FLR STF
sol.27.7fg	Age-based stochastic analytical assessment (SAM)	SAM
nep.fu.16	Underwater TV survey	NA
nep.fu.17	Underwater TV survey	NA
nep.fu.19	Underwater TV survey	NA
nep.fu.2021	Underwater TV survey	NA
nep.fu.22	Underwater TV survey	NA
nep.out.7	Precautionary approach	NA

3. **Framework used for mixed fisheries forecasts:**
    The FCube model coded in R, using the FLR framework (www.flr-project.org).
4. **Data issues:**
    A new data call for WGMixedFish is in place from this year, which changed the format in which the data was requested. The new structure of the data call greatly increased the quality and consistency of data provided, however there were still a number of member state specific issues which were not fixed in time for the advice meeting. These issues were dealt with input from expert knowledge during the WGMixedFish.
5. **Consistency:**
    The assessment process had two minor deviations from 2021 mixed fisheries scenarios, which were discussed by WGMixedFish and are described in the WG report.
6. **Mixed fisheries scenarios for 2022:**

    1. An effort based intermediate year assumption (average effort 2018-2020) was used, instead of the single stock advice assumption.

    2. A fishing mortality consistent with the catch advice in the TAC year was used to drive the mixed fisheries scenarios, instead of the fishing mortality consistent with the single stock catch advice.

7. **Mixed fisheries situation:**
   Cod is the most limiting stock for Celtic Sea demersal fisheries ("min" scenario shows that cod limits 22 of the 23 fleets). It is caught by almost all fisheries operating with demersal gears producing an inability to separate cod from other stocks caught in the fisheries. The assessment of cod has indicated that when the MSY approach and precautionary considerations are applied, there should be zero catch in 2022.

8. **Management Plan:**
   A multiannual management plan (MAP) for Western and adjacent waters has been adopted by the EU for stocks covered by this advice (Council Regulation (EC) 2019/472) which ICES considers to be precautionary. However, there is no agreed shared management plan with UK for this stock. There are two species specific management plans in this region; a recovery plan for hake (Council Regulation (EC) No 811/2004) which implements a Total Allowable Catch (TAC) annually based on a defined Harvest Control Rule (HCR) and a management plan with both a HCR and effort management element for sole in the Western channel (7.e; Council Regulation (EC) No 509/2007). There are also a number of effort, technical and area closure measures in place for the area.

General comments

Report, advice and stock annex are generally clear and well-written, and have been made available on the ICES sharepoint. The code, data and R packages are available on the ICES Transparent Assessment Framework (TAF) and can be reproduced from this repository.

There are two deviations from the 2020 advice process (described above), these were discussed at the WGMixedFish 2021 advice meeting, and are detailed in the report.

Technical comments

Advice sheet

Advice sheet should be double checked for consistency of the terminology used throughout the document (e.g. advice/considerations).

Code and reproducibility

The code runs reproduces the assessment process based on the data supplied on the ICES TAF repository. It would benefit from some explanations on the contents of the repository, which files to use and the order they need to be run (e.g. a Readme file to guide the user). The code requires specific versions of the libraries. Therefore, essential and specific versions of the libraries needed (e.g. Stockassessment) should ideally be added to the repository for a quick user access.

Stock Annex

Generally well-written and clear (Last updated: October 2021).

Conclusions

The assessment has been carried out appropriately, and is reproducible. I would suggest pay some attention to the structure of the repository to make the code more accessible to the user.

Audit of the Mixed-fisheries advice for the Iberian Waters

Date: 17/11/2021

Auditor: Marieke Desender

Summary of the advice
1. **Assessment type:** All forecasts were projected using the FLBEIA Package (v1.15.5) (García *et al.,* 2017).
2. **Single stock Assessments used as basis** (stock/assessment model/EG forecast method)
3.

Stocks	Assessment	Forecast
BLACK ANGLERFISH 8c9	SPiCT	NA
HAKE 8c9ac	Cat 3 (index based)	NA
FOUR-SPOT MEGRIM 8c9a	XSA	MFDP
MEGRIM 8c9a9a	XSA	MFDP
WHITE ANGLERFISH 8c9a	SS3	SS3 (ad hoc R code)

4. **Framework used for mixed fisheries forecasts:**
    FLBEIA model using the FLR framework (www.flr-project.org). All analysis run in R.
5. **Data issues:**
    Some country specific data had to be corrected during the working group.

    The estimates at the start of the advice year were all consistent with the single-stock forecasts with negligible differences. The largest observed difference was 7% for F in 2021 for white anglerfish. These are to be expected mainly because of the difference between the length-based model used for this stock and the age-based model applied in the mixed-fisheries analysis.

6. **Consistency:**
    The advice seems consistent and similar to last years mixed fisheries trends.

7. **Mixed fisheries situation:**
    hake is the most limiting stock for all fleets in Iberian waters demersal fisheries. Conversely, both anglerfish stocks are the least limiting stocks. If fleets set their efforts at the anglerfish stocks, overshoot and reduction of SSB is more noticeable in the four-spot megrim stock, possible due to an increased technical interaction between this species and the anglerfish stocks.

8. **Management Plan**:
    The MAP (multiannual management plan) for the Western Waters applies to all demersal stocks included in the mixed fisheries advice.

General comments

The advice sheet is well written and reads fluently. Also the report and stock annex are well structured. There are some discrepancies between stock annex and report such as forecast procedure in the table above (NA?).

Scripts are well organized however the code blocks at several points.

Technical comments:

Updating the readme file on github with directions how to go through the code, or how to get started (also include TAF and bootstrap etc when you run for the first time).

Care has to be taken when the same code is rerun twice in case it blocks or gives an error. Depending on where the working directory is set some folders or files might be copied over twice. Suggestion, make paths relative, check if the path already exists and define working directory at beginning of code?

Not sure if accessing the data via url is a better idea than having it all available after pulling once from github in the bootstrap. I personally struggled trying to access the data via a github url probably because of a password manager or internet security issues at work.

In the second r code "02_MixFish21_IW_FLR_Objs0", trouble with loading "MON2020.Rdata". Fixed with copying the file over from ICES SharePoint, the rest of the script runs well.

Script 5 "05_MixFish21_IW_Sims". Something goes wrong with NA's? in the FLBEIA scenario runs.

Maybe pushing intermediate outputs as well to github might help getting through the code in later stages?

Audit of the Mixed-fisheries advice for the Greater North Seas Ecoregion

Date: 05/11/2021

Auditor: Matthew Pace

Summary of the advice

1. **Assessment type:** FLBEIA mixed fisheries assessment
2. **Single stock Assessments used as basis** (stock/assessment model/EG forecast method)

Species	Assessment	Forecast
COD 4, 3.a and 7.d	SAM	SAM
HADDOCK 4, 3.a and 7.d	TSA	MFDP
PLAICE 4	AAP	FLR 2.3, FLSTF
SAITHE 4, 3.a and 6	SAM	SAM
SOLE 4	AAP	FLR 2.3, FLSTF
WHITING 4 and 7.d	SAM	MFDP
PLAICE 7.d	AAP	FLR 2.x, FLSTF
SOLE 7.d*	SAM	SAM
TURBOT 4	SAM	FLR (fwd-routines)
WITCH 4, 3.a and 7.d	SAM	SAM
Nephrops FU's 5–10, 32, 33, 34 & other in Sub area 4	UWTV - analytical and non-analytical depending on FU	UWTV- analytical and non-analytical depending on FU

3. **Framework used for mixed fisheries forecasts**:
   FLBEIA model using the FLR framework (www.flr-project.org). All analysis run in R.
4. **Data issues:**
   None reported
5. **Consistency:**
   The 2021 mixed fisheries assessment uses the FLBEIA simulation framework following the 2021 WGMIXFISH methods meeting and Inter-Benchmark (IBPMIXFISH). This is major departure from the FCube framework used in previous mixed fisheries assessments, and concordance in forecasted stock trajectories and fleet behaviour under the two model frameworks was the subject of Inter-Benchmark work. Conditioning the North Sea FLBEIA model is extensively discussed in the 2021 WGMIXFISH-METHODS report, the Stock Annex and report. Checks of model behaviour and changes to the conditioning approaches are well-documented in these reports.
   Sole in 7d was reincluded in the mixed fisheries analysis in 2021 after being upgraded to Category 1.
6. **Mixed fisheries situation:**

   Cod is estimated to be the most limiting-stock in the Greater North Sea mixed-fisheries model (for 37 of 40 fleets), whereas whiting is the least-limiting (25 of 40 fleets). To reach

single stock advice, cod-limited fleets would need to reduce effort in 2022 by 50%, on-average, relative to 2020 levels.

7.   **Management Plan:**

Demersal fisheries in the North Sea region are managed under a multi-annual plan for the North Seas region (Regulation (EU) 2018/973)

General comments

The stock annex, report and advice are well-written, informative and are available on the ICES sharepoint. The stock annex provides a clear and concise summary of the advice areas, major fisheries and technical measures for each stock, and an overview of the data and methods used to generate the mixed fisheries advice. The report provides further details on the software and simulation scenarios evaluated. The advice sheet presents mixed fisheries considerations based on simulations for the Greater North Seas ecoregion and has been restructured based on formatting guidelines discussed during the WG advice meetings.

Technical comments

Code and reproducibility

The code repository is well-structured with a clear and helpful 'read me' that provides a brief outline and description of the key scripts in the analysis. Individual scripts are overall well-organised, with annotated chunks of code and the generation of useful diagnostic plots and tables, but frequently contain redundant code, ad hoc fixes and hard-coding of variables (e.g. biological reference points). Future iterations of the analysis would benefit from the removal of obsolete code, better documentation of fixes and the associated assumptions and uncertainties, higher-level commenting of code to outline the logical flow of the analysis within each script, and avoidance of hard-coding in favour of reading-in external data. This will increase the transparency and generalizability of the work.

Minor issues that may be addressed are updating the repository 'read me' to: (i) refer to 'data_00_Standardising_FLStocks_FLBEIA.R', (ii) add a description for 'model_00_settings.R', and (iii) refer to extant markdown scripts for the generation of report figure and tables. It may also be helpful specify the required package versions at the outset.

Stock Annex

References to FCube on pg 7 should be updated to FLBEIA. Equations on pgs 9 and 10 should be referenced consistently and there are two different equations presented as Eq 2.

Report

It is unclear what asterisks in Table 1 and section 1.3.2 are referring to.

Conclusions

The assessment is fully reproducible and well-reported. The use of FLBEIA is a major methodological shift from the FCube and this has been extensively evaluated and documented in multiple WG reports.

Annex 4: List of stock annexes

The table below provides an overview of the WGMIXFISH Stock Annexes. Stock Annexes for other stocks are available on the ICES website Library under the Publication

Type "Stock Annexes".

Stock ID	Stock name	Last updated	Link
mix.bob	Bay of Biscay Mixed Fisheries Annex	October 2021	mix.bob_SA
mix.cs	Celtic Sea Mixed Fisheries Annex	October 2021	mix.cs_SA
mix.ns	North Sea Mixed Fisheries Annex	November 2021	mix.ns_SA

Annex 5: Next meetings resolution (draft)

The **Working Group on Mixed Fisheries Advice** (WGMIXFISH-ADVICE), chaired by Marc Taylor* (Germany) and Harriet Cole* (Scotland), will meet Copenhagen (possible hybrid), on 3–7 October 2022 to:

a) Carry out mixed fisheries projections for the Bay of Biscay taking into account the single species advice and the management measures in place for 2022 for anglerfish, megrim, sea bass, hake, sole, Norway lobster, whiting and pollack that is produced by WGBIE in May 2022; for mackerel, horse mackerel, and blue whiting produced by WGWIDE in September 2022 and rays and smooth hound produced by WGEF in October 2022.

b) Carry out mixed demersal fisheries projections for the Celtic Sea taking into account the single species advice and the management measures in place for 2022 for cod, haddock, whiting, hake, megrim, monkfish, and *Nephrops norvegicus* that is produced by WGCSE and WGBIE in 2022.

c) Carry out mixed fisheries projections for Iberian waters taking into account the single species advice and the management measures in place for 2022 for hake, four-spot megrim, megrim and white anglerfish that is produced by WGBIE in May 2022, and further develop mixed fisheries analyses for the region.

d) Carry out mixed demersal fisheries projections for the Irish Sea (27.7.a) taking into account the single species advice for cod, haddock, whiting, plaice, sole, and *Nephrops norvegicus* that is produced by WGCSE in 2022.

e) Carry out mixed demersal fisheries projections for the North Sea taking into account the single species advice and the management measures in place for 2022 for cod, haddock, whiting, saithe, plaice, sole, turbot, *Nephrops norvegicus*, sole 7.d and plaice 7.d that is produced by WGNSSK in May 2022;

f) Produce draft mixed-fisheries sections for the ICES advisory report 2022 that includes a dissemination of the fleet and fisheries data and forecasts for the North Sea, Celtic Sea, Bay of Biscay, and Iberian waters.

WGMIXFISH-Advice will report by 30 November 2022 for the attention of ACOM.