ICES WGMIXFISH-METHODS REPORT 2018

ICES ADVISORY COMMITTEE

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Report of the Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS)

15-19 October 2018

Nantes, France

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

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Executive summary

The ICES Working Group on Mixed Fisheries Methods (WGMIXFISH-METHODS) (Chair: Youen Vermard (FR)) met at IFREMER, **Nantes, France**15–19 October 2018 to:

a) Increase the number of species included in the current Celtic Sea mixed fisheries considerations. Priority will be given to target species identified based on knowledge of identified mixed fisheries interactions in the Celtic Sea.
b) Assess the potential of developing mixed fisheries scenarios for pelagic fish in the Baltic.
c) Develop models for flatfish and roundfish fisheries in the North Sea.
d) Assess the model sensitivity and potential impact of using the actual quota by fleet/country (e.g FIDES database) rather than the last year observed share on the mixed fisheries scenarios results.
e) Develop models for mixed fisheries in the Bay of Biscay.
f) Increase the number of species in the Iberian Waters model.

Additionally, work started on transitioning WGMIXFISH code from GitLab to the ICES Transparent Assessment Framework.

1 Introduction

1.1 Background

The mixed fisheries methods working group (WGMIXFISH-METHODS) was formed in response to the need to further develop how ICES provides mixed fisheries advice and to progress application of methods to areas other than the North Sea, independent of the annual advisory meeting (WGMIXFISH-NS; ICES, 2015). WGMIXFISH-METHODS met in Nantes 15th – 19th October 2018 to consider the following terms of reference.

1.2 Terms of Reference

g) Increase the number of species included in the current Celtic Sea mixed fisheries considerations. Priority will be given to target species identified based on knowledge of identified mixed fisheries interactions in the Celtic Sea.
h) Assess the potential of developing mixed fisheries scenarios for pelagic fish in the Baltic.
i) Develop models for flatfish and roundfish fisheries in the North Sea.
j) Assess the model sensitivity and potential impact of using the actual quota by fleet/country (e.g FIDES database) rather than the last year observed share on the mixed fisheries scenarios results.
k) Develop models for mixed fisheries in the Bay of Biscay.
l) Increase the number of species in the Iberian Waters model.

1.3 Definitions

Two basic concepts are of primary importance when dealing with mixed-fisheries, the fleet (or fleet segment), and the métier. Their definition has evolved with time, but the most recent official definitions are those from the CEC's Data Collection Framework (DCF, Reg. (EC) No 949/2008), which we adopt here*:*

- ***A Fleet segment*** is a group of vessels with the same length class and predominant fishing gear during the year. Vessels may have different fishing activities during the reference period, but might be classified in only one fleet segment.
- ***A Métier*** is a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterized by a similar exploitation pattern.

In 2013, WGMIXFISH-METHODS requested data according to aggregations based on the definitions of the EU Data Collection Framework (DCF) and these terms are used consistently in this report.

1.4 Software

All analyses were conducted using the FLR framework (Kell *et al.* (2007); www.flr-project.org) running with R 3.5.1 (R Development Core Team, 2008). All forecasts were projected using the same stf() function in the Flash Package. The FCube method is developed as a stand-alone script using FLR objects as inputs and outputs.

The FCube model has been presented and described in Ulrich *et al.* (2008, 2011). 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.

2 ToR A - Increase the number of species included in the current Celtic Sea mixed fisheries considerations. Priority will be given to target species identified based on knowledge of identified mixed fisheries interactions in the Celtic Sea.

2.1 Basis

ICES was requested to assess the possibility of expanding the number of stocks included in the Celtic Sea mixed fisheries considerations, where priority should be given to target species of high economic interest, such as megrims and anglerfish. This request was further broken down by ACOM into three main tasks:

a) To describe and evaluate the species mixing in Celtic Sea demersal fisheries and identify the stocks for which information and data are sufficient to include in the mixed fisheries analysis for Celtic Sea. Review the current mixed fisheries scenarios provided for the Celtic Sea, evaluate if it is possible to include additional stocks in the mixed fishery and suggest possible process.
b) If required develop and issue a data call for data needed to incorporate the stocks identified under a) in the mixed fisheries analysis for Celtic Sea.
c) Expand the mixed fisheries model for Celtic Sea to include the species identified in a).

2.2 Identify the species to include

An analysis was conducted to identify candidate species for possible inclusion in Celtic Seas mixed fisheries considerations. Eleven species were considered: monkfish (MON, *Lophius piscatorius* and *Lophius budegasa*), cod (COD, *Gadus morhua*), haddock (HAD, *Melanogrammus aeglefinus*), hake (HKE, *Merluccius merluccius*), megrim (MEG, *Lepidorhombus whiffiagonis* and *Lepidorhombus boscii*), *Nephrops* (NEP, *Nephrops norvegicus*), plaice (PLE, *Pleuronectes platessa*), pollack (POL, *Pollachius pollachius*), sole (SOL, *Solea solea*) and whiting (WHG, *Merlangius merlangus*). The aims of the analysis were to determine:

1) the relative contributions of each species to the overall weight and value of landings in the Celtic Seas
2) to assess the level of mixing among these species within the fisheries executed within the area.
3) Are the single species stocks assessments for candidate species suitable for inclusion in FCube?

This analysis was conducted on retained catch data which was submitted to the WGMIXFISH accessions, focusing on an average of the last three years (2015–2017). Four Member States (MS) are responsible for the majority of the landings in this area and so were the focus of this analysis. Using a three year average the total landings (tonnes) for each of the species was plotted. The species which accounted for the largest landings were monkfish and hake (Fig 2.1). These species were mostly landed by the French fleet (Fig 2.2). Each member state exhibited differences in fishing behaviour, with French fleets targeting mainly monkfish and hake, English fleets targeting monkfish and megrim, and Irish fleets targeting whiting and *Nephrops*.

Fishing is an economic activity, therefore monetary value can be used as an indicator of fisher intent and targeting behaviour. Overall, the most valuable and targeted species in the Celtic Sea during this time period were monkfish, *Nephrops*, hake and megrim (Fig 2.3), although the highest price is for sole (Table 2.1). There is variation in how member states target these species (Fig 2.4) and in the price per kilogram for each species (Table 2.2)

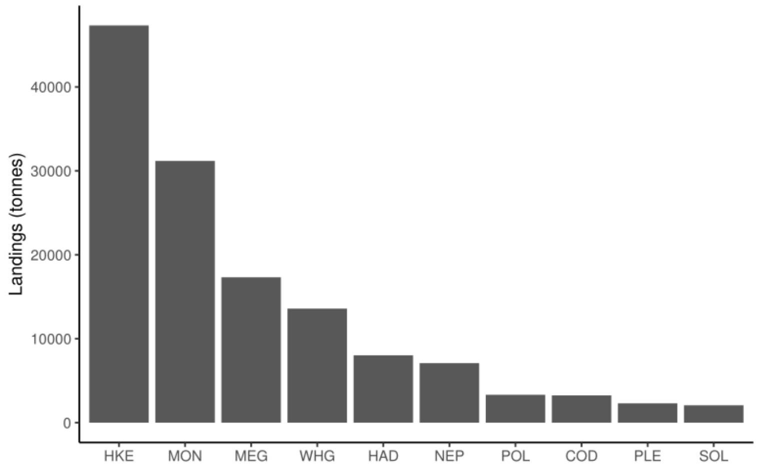


Figure 2.1 Distribution of landings weight per species using a three year average (2015–2017).

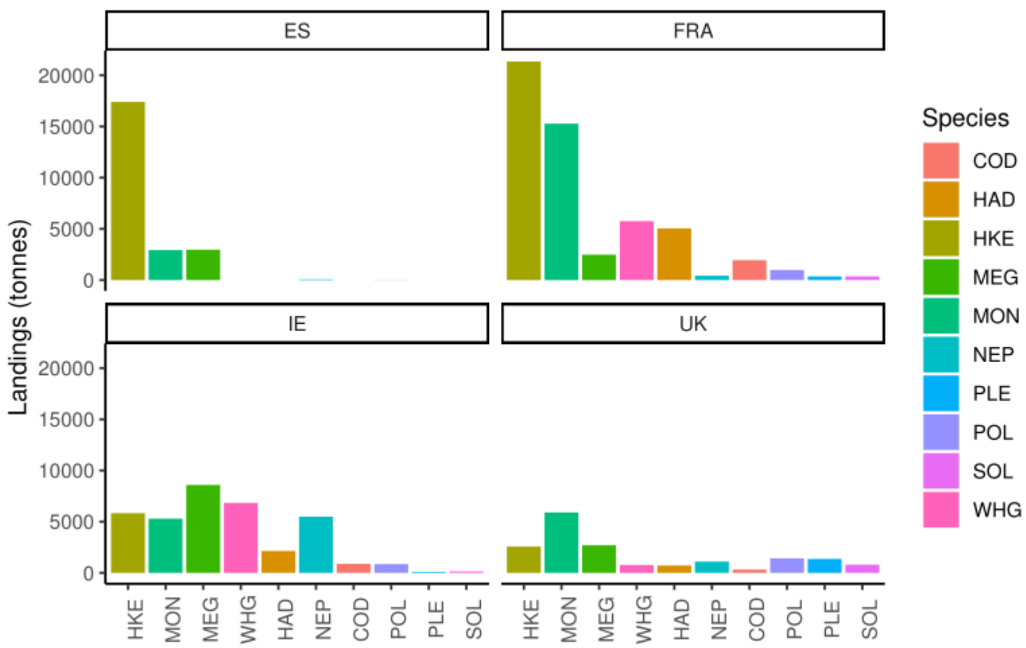


Figure 2.2 Distribution of landings weight per species using a three-year average (2015–2017), per country

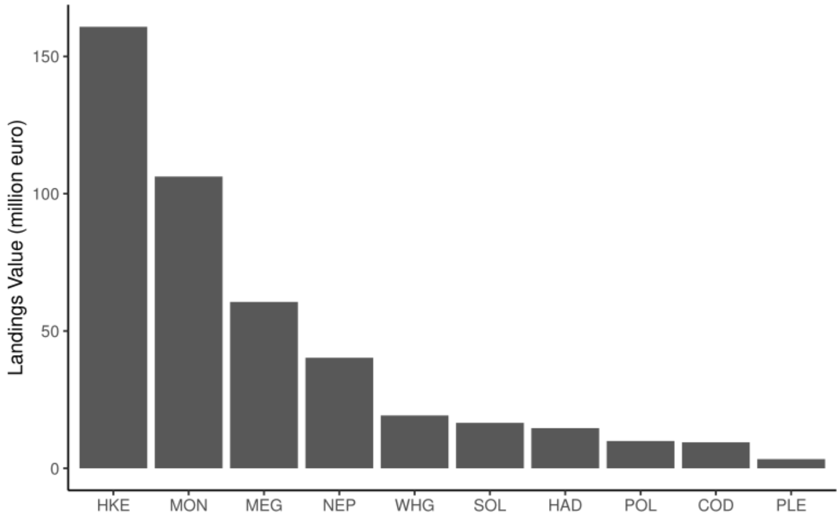


Figure 2.3 Average value Celtic Sea Landings from 2015 – 2017

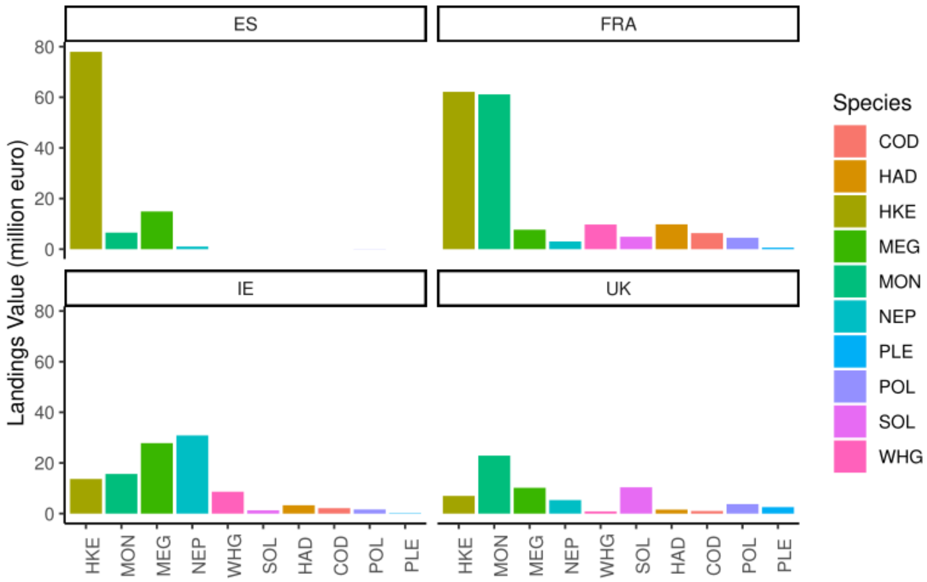


Figure 2.4 Average value Celtic Sea Landings from 2015 – 2017 for the four main member states operating in the Celtic Sea.

Table 2.1 Summary of the average price (Euro/kg) of species landed in the Celtic Sea from 2015–2017

Species	price_euro_kg
SOL	12.62
NEP	5.68
MEG	3.62
MON	3.61
HKE	3.41
POL	3.02
COD	3.01
HAD	1.85
PLE	1.83
WHG	1.44

Table 2.2 Summary of the average price (Euro/kg) of species landed in the Celtic Sea per member state from 2015–2016

Country	COD	HAD	HKE	MEG	MON	NEP	PLE	POL	SOL	WHG
ES	NA	2.01	4.48	5.02	2.24	14.89	NA	2.96	10.67	NA
FRA	3.26	1.94	2.91	3.10	4.00	7.07	1.67	4.55	13.53	1.69
IE	2.40	1.54	2.34	3.24	2.96	5.62	1.77	1.90	8.96	1.26
UK	3.14	2.16	2.72	3.78	3.88	4.85	1.88	2.62	12.86	1.13

Each of these 10 species were examined to determine the extent of mixing within the Celtic Sea. This species interaction in, terms of landings, was described using two plots and a summary table. Combined, these two plots allow us to make some inferences about the extent of mixed in relation to each of species included. The plot on the left-hand side shows the cumulative landings, ordered by the proportion of the species landed by each unique level 4 métier. This plot indicates to what extent a species is being targeted and whether or not they are part of a mixed fishery. A clean fishery will have all the points along the top of the plot, while a bycatch species will quickly drop down to a low proportion. The pie-chart on the right shows overall species composition of the métiers which landed relevant species. Finally, a summary table shows the proportion of the species of interest, per metier being executed in the Celtic Sea. A summary of these species interactions can be found in Table 3.

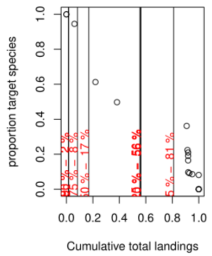
From this analysis it can be concluded that the priority species to include in the Celtic Sea FCube are monkfish, hake, megrim and *Nephrops*. These four species constitute the bulk of the weight (tonnage) and value (euros) of retained catch in the Celtic Sea (Figure 2.1 and 2.3). Additionally, these four species are caught as part of mixed fisheries executed by many of the Celtic Seas métiers, resulting in mixed fisheries interactions with each other, and interactions with the three species currently assessed by WGMIXFISH (cod, haddock and whiting) (Table 2.2).

Table 2.3 Summary species mixing in the Celtic Sea. (i) Cumulative landings, ordered by the proportion of the species landed by each unique level 4 métier, indicating to what extent a species is being targeted. (ii) Species composition, identifying the species with which this species is typically landed. (iii) Total proportions of the species, demonstrates to what extent a metier targets this species, and how clean the fishery is.

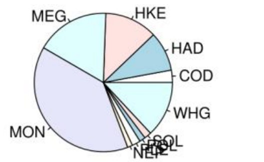
Species	(i) Cumulative Landings	(ii) Species Composition	(iii) Total proportions per métier	Summary

MON

(i) Cumulative Landings



(ii) Species Composition



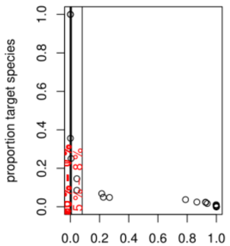
(iii) Total proportions per métier

	Métier (lvl 4)	MON Landings (tonnes)	Total Landings (tonnes)	Proportion of MON per métier %
3	GTR_DEF	1889.78	2042.74	93
4	OTT_DEF	4937.61	8369.40	59
5	TBB_DEF	5086.08	11894.82	43
6	OTB_DEF	16411.76	55758.22	29
7	OTT_CRU	196.39	888.41	22
10	MIS_MIS	150.17	1318.12	11
11	OTB_CRU	688.91	8211.08	8
12	GNS_DEF	1531.89	18988.83	8
13	OTM_DEF	19.64	263.78	7
14	SSC_DEF	259.07	4928.95	5

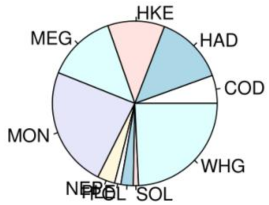
Summary: Monkfish is directly targeted by a number of métiers (GTR, OTT & TBB)(iii), with 40% of the of monkfish landings occurring from métiers where they comprise of >50% of total landings (i). Monkfish occurs in mixes with slope species (MEG) and gadoids (HKE, HAD, COD, WHG), and NEP(ii)

COD

(i) Cumulative Landings



(ii) Species Composition



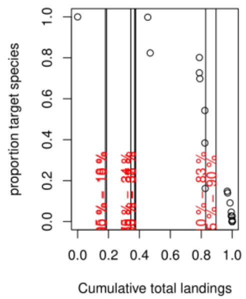
(iii) Total proportions per métier

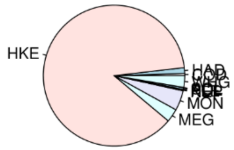
	Métier (lvl 5)	COD Landings (tonnes)	Total Landings (tonnes)	Proportion of COD per métier %
3	SDN_DEF	13.42	53.50	25
4	OTT_CRU	128.00	888.41	14
6	OTT_DEF	553.34	8369.40	7
7	OTB_DEF	1692.57	55758.22	3
8	SSC_DEF	137.32	4928.95	3
9	MIS_MIS	35.56	1318.12	3
10	OTB_CRU	192.41	8211.08	2
11	TBB_DEF	252.20	11894.82	2
13	GTR_DEF	34.01	2042.74	2
15	GNS_DEF	193.49	18988.83	1

Summary: Cod is not directly targeted by any métier in the Celtic Sea (iii), with almost 100% of the landings occurring in métiers where cod comprises of less than 20% of the landings (i). Cod is landed in mixes with slope species (MON & MEG), and other gadoids (HAD, HKE & WHG), and NEP(ii)

SPECIES	(I) CUMULATIVE LANDINGS	(II) SPECIES COMPOSITION	(III) TOTAL PROPORTIONS PER MÉTIER	SUMMARY

HKE

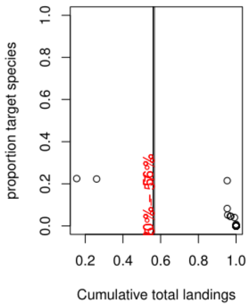


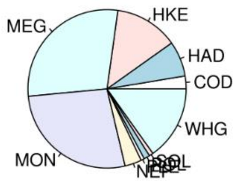


	Métier (lvl 5)	HKE Landings (tonnes)	Total Landings (tonnes)	Proportion of HKE per métier %
2	LLS_DEF	21479.19	21525.00	100
3	LLS_FIF	741.35	908.96	82
4	GNS_DEF	15054.00	18988.83	79
6	OTM_DEF	141.58	263.78	54
7	SSC_DEF	1535.05	4928.95	31
8	OTT_CRU	122.84	888.41	14
9	OTB_DEF	6732.11	55758.22	12
10	MIS_MIS	116.03	1318.12	9
11	OTT_DEF	736.12	8369.40	9
13	OTB_CRU	373.99	8211.08	5
14	TBB_DEF	272.44	11894.82	2
16	GTR_DEF	15.79	2042.74	1

Hake is directly targeted, with around 80% of landings occurring in métiers where hake comprises of >50% of the landings (i). Hake is targeted by a variety of gear types including long lines which demonstrate a clean fishery with a 100% HKE bring landed (ii). Small mixes of mixes of gadoids (COD, HAD, WHG), slope species (MON & MEG) , and NEP (ii).

MEG

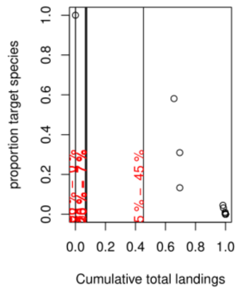


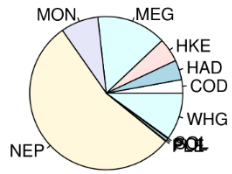


	Métier (lvl 4)	MEG Landings (tonnes)	Total Landings (tonnes)	Proportion of MEG per métier %
1	TBB_DEF	2676.70	11894.82	23
2	OTB_CRU	1831.94	8211.08	22
3	OTB_DEF	11993.72	55758.22	22
5	OTT_CRU	46.50	888.41	5
6	SSC_DEF	227.42	4928.95	5
7	MIS_MIS	59.94	1318.12	5
8	OTT_DEF	335.78	8369.40	4
9	GNS_DEF	142.12	18988.83	1

Megrim is not a targeted species, with 100% of landings occurring in métiers where Megrim comprises of <30% of the landings (i). Megrim is mostly landed by trawler (iii), in mixes with gadoids (HAD, HKE, COD & WHG), slope species (MON), and NEP (ii).

NEP



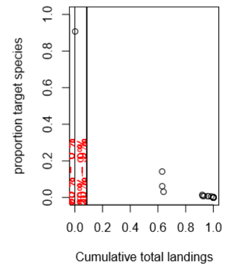


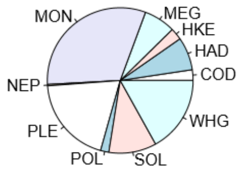
	Métier (lvl 5)	NEP Landings (tonnes)	Total Landings (tonnes)	Proportion of NEP per métier %
2	OTB_CRU	4655.21	8211.08	57
3	OTT_CRU	271.49	888.41	31
5	OTB_DEF	2039.13	55758.22	4
6	MIS_MIS	22.62	1318.12	2
7	OTT_DEF	79.51	8369.40	1
8	TBB_DEF	17.65	11894.82	0

Nephrops is a targeted species, >60% of landings occurring in métiers where *Nephrops* comprises of >60% of the landings (i). *Nephrops* are targeted by trawler (OTB & OTT)(iii), along with mixes of gadoids (HAD, HKE, COD & WHG) slope species (MON & MEG) (ii).

Species	(i) Cumulative Landings	(ii) Species Composition	(iii) Total proportions per métier	Summary

PLE

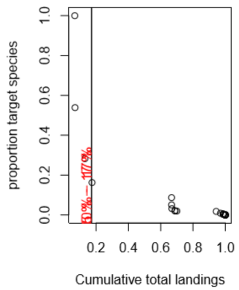


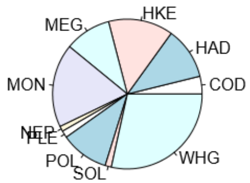


	Métier (lvl 5)	PLE Landings (tonnes)	Total Landings (tonnes)	Proportion of PLE per métier %
2	TBB_DEF	1447.53	11894.82	12
4	MIS_MIS	22.27	1318.12	2
5	OTB_DEF	643.96	55758.22	1
7	OTT_DEF	60.57	8369.40	1
8	GTR_DEF	13.34	2042.74	1
9	OTB_CRU	45.80	8211.08	1
10	SSC_DEF	22.70	4928.95	0
11	GNS_DEF	35.15	18988.83	0

Plaice are not a targeted, with just under 100% of landings occurring in métiers where Plaice comprise of <15% of the landings (i). Plaice is mostly landed by beam trawlers (iii), in mixes with gadoids (HAD, HKE, COD & WHG), slope species (MON, MEG), and NEP (ii).

POL

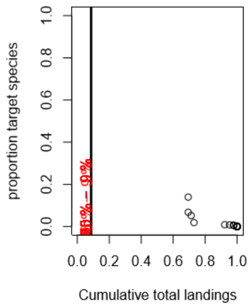


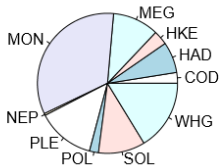


	Métier (lvl 5)	POL Landings (tonnes)	Total Landings (tonnes)	Proportion of POL per métier %
1	LHM_DEF	227.43	227.43	100
3	LLS_FIF	146.42	908.96	16
4	MIS_MIS	202.18	1318.12	15
5	GNS_DEF	1633.50	18988.83	9
7	GTR_DEF	39.31	2042.74	2
9	OTB_DEF	807.74	55758.22	1
10	SSC_DEF	61.83	4928.95	1
11	TBB_DEF	88.61	11894.82	1
12	OTT_DEF	52.10	8369.40	1
15	OTB_CRU	16.85	8211.08	0
16	LLS_DEF	28.19	21525.00	0

Pollack are targeted by hand and pole lines, which demonstrate a clean fishery (i, ii). The remaining landing occur in mixes with gadoids (HAD, HKE, COD, POL & WHG), slope species (MON, MEG), NEP, and SOL (ii).

SOL



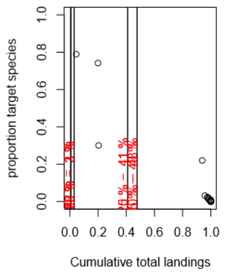


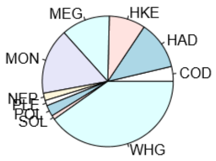
	Métier (lvl 5)	SOL Landings (tonnes)	Total Landings (tonnes)	Proportion of SOL per métier %
1	DRB_MOL	11.41	17.10	67
2	TBB_DEF	1425.94	11894.82	12
4	MIS_MIS	37.27	1318.12	3
5	GTR_DEF	37.24	2042.74	2
6	OTB_CRU	62.57	8211.08	1
7	OTB_DEF	398.62	55758.22	1
8	OTT_DEF	50.26	8369.40	1
10	GNS_DEF	42.35	18988.83	0

Sole mostly a non-target, with just under >80% of landings occurring in métiers where Sole comprise of <15% of the landings (i). Sole is mostly landed by beam trawlers (iii), in mixes with gadoids (HAD, HKE, COD & WHG), slope species (MON, MEG), PLE, and NEP (ii). One métier (DRB_MOL) appears to target sole (>50%)(iii), however this refers to very low tonnage and will not be considered for the purposes of this analysis.

SPECIES	(I) CUMULATIVE LANDINGS	(II) SPECIES COMPOSITION	(III) TOTAL PROPORTIONS PER MÉTIER	SUMMARY

WHG

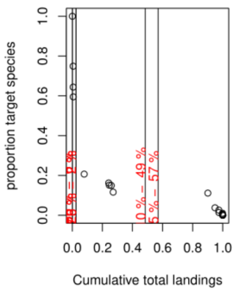


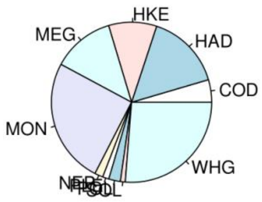


	Métier (lvl 5)	WHG Landings (tonnes)	Total Landings (tonnes)	Proportion of WHG per métier %
2	OTM_SPF	42.65	51.50	83
3	MIS_MIS	565.17	1318.12	43
4	SSC_DEF	2099.73	4928.95	43
5	OTM_DEF	60.95	263.78	23
6	OTB_DEF	9989.89	55758.22	18
7	OTT_DEF	256.77	8369.40	3
8	TBB_DEF	245.32	11894.82	2
10	OTB_CRU	137.02	8211.08	2
12	GNS_DEF	161.55	18988.83	1

Whiting are an increasingly targeted species in the Celtic Sea, with approximately 20% of landings occurring in métiers where whiting comprise of >80% of the landings (i). Whiting is mostly landed by beam trawlers (iii), in mixes with gadoids (HAD, HKE, COD & WHG), slope species (MON & MEG), flatfish (PLE & SOL), and NEP (ii). One métier (OTM_SPF) targets whiting (83%)(iii).

HAD





	Métier (lvl 5)	HAD Landings (tonnes)	Total Landings (tonnes)	Proportion of HAD per métier %
2	SDN_DEF	40.07	53.50	75
4	OTT_DEF	1307.34	8369.40	16
5	SSC_DEF	584.66	4928.95	12
6	OTM_DEF	30.62	263.78	12
7	OTT_CRU	101.80	888.41	11
9	OTB_DEF	5048.71	55758.22	9
10	MIS_MIS	106.92	1318.12	8
11	TBB_DEF	382.35	11894.82	3
12	OTB_CRU	206.39	8211.08	3
14	GNS_DEF	192.94	18988.83	1

Sole are not a targeted, with just under >80% of landings occurring in métiers where Sole comprise of <15% of the landings (i). Plaice is mostly landed by beam trawlers (iii), in mixes with gadoids (HAD, HKE, COD & WHG), slope species (MON & MEG), flatfish (PLE and SOL), and NEP (ii).

2.3 Impacts on the fleet characterisation

With the addition of new species, a number of challenges will arise in how the fleets targeting these species are conditioned. With the addition of new species comes the addition of new metiers and new fleets, thereby increasing the FCube model complexity. This complexity could impact the quality of the model which relies on accurate identification of the technical interactions between fleets, gears and the resulting composition of species in the retained catch. The spatiotemporal heterogeneity of the conditioned fleets needs to be considered. Recent work by this group (Moore *et al.* in press) demonstrates that a fairly simplistic structure of fishing units (country of provenance, fishing location, gear and target species) can effectively describe the complex mixed fisheries scenarios being executed within the Celtic Sea consistently across multiple years. It is recommended that during the next WGMIXFISH-METHODS meeting this group explores whether these findings hold true with the addition of new species.

2.4 Species suitability for inclusion in FCube

The 10 species considered for inclusion in the Celtic Sea FCube model can be further divided into 21 stocks, all of which vary in their suitability for inclusion in FCube. These stocks vary in their single species assessment model, framework, quality, and intermediate year assumptions (Table 2.4). It was decided that during this meeting, only category 1 stocks, with full quantitative assessments, would be tested in FCube, as there is currently no method for the inclusion of data poor stocks in FCube. Many of these category 3 flat fish stocks, which were initially considered for inclusions are due to be benchmarked by ICES in 2020, after which, if they progress to category 1 stocks, it will be easier to incorporate them into FCube.

Table 2.4 List of candidate stocks for inclusion, the details of their assessment availability, ICES assessment category describing available knowledge, model type, short term forecast availability.

Species	Stock	Assessment	Category	Model Type	STF
mon	**27.7b-k & 8a-b,k**	yes	1	a4a	yes
cod	**27.7ek**	yes	1	XSA	yes
had	**27.7bk**	yes	1	ASAP	yes
hke	**27.3a46-8abd**	yes	1	ss3	yes
meg	**27.7b-k8abd**	yes	1	Bayesian statistical catch-at-age	yes
ple	**27.7bc**	no	6	none	none
ple	**27.7e**	yes	3	XSA	yes
ple	**27.7fg**	yes	3	SPiCT	yes
ple	**27.7hk**	yes	3	XSA	yes
pol	**27.767**	yes	4	ss3	yes
sol	**27.7bc**	no	6	none	none
sol	**27.7e**	yes	1	XSA	yes
sol	**27.7fg**	yes	1	XSA	yes
sol	**27.7hk**	yes	3	XSA	yes
whg	**27.b-c &e-k**	yes	1	XSA	yes
nep	**16**	yes	1	Analytical model	yes
nep	**17**	yes	1	Analytical model	yes

Species	Stock	Assessment	Category	Model Type	STF
nep	**19**	yes	1	Analytical model	yes
nep	**2021**	yes	1	Analytical model	yes
nep	**22**	yes	1	Analytical model	yes
nep	**7OTH**	no	6	none	none

However, the principle challenge to the incorporation of new species into the Celtic Sea FCube is the alignment of single species stock assessment, with some stocks distributed across several TAC units, while for others (plaice and sole) there are several stocks within the Celtic Seas, which is further complicated by varying assumptions of species mixing within individual stocks. Although there is agreement between the TAC and assessment area of hake, megrim and anglerfish, all three stocks expand well beyond the boundaries of the Celtic Sea (Figure 2.5). This can be rectified by using proportions of catch, effort and TAC for the subset of the Celtic Sea but requires an assumption about the catch coming from other areas; this is handled in the model by assuming constant fishing effort/fishing mortality from areas not explicitly modelled for each scenario. This effectively neutralises the effect of the other areas on the overall stock F under the scenarios (allowing their side-by-side comparison of the effects in the modelled fleets), though care is required in interpreting the overall catches, as this assumption indirectly affects the catch by the modelled fleets due to the fact a constant F for other areas under a 'min' FCube scenario would reduce catches for the modelled fleets more than a constant F under the 'max' scenario under the Baranov catch forecast. Other spatial resolution issue arises with the incorporation of *Nephrops* which are assessed at the spatial resolution of Functional Unit (FU), and are based on ICES Statistical Rectangle boundaries. However, *Nephrops* management, specifically TAC allocation, is at the level of ICES area, with a TAC being provided for all of area 7 (except FU16), additionally only some of these FU's receive an abundance estimate (necessary to calculate a catchability).

It should be noted that the largest obstacle to the inclusion of *Nephrops* is the mismatch between the timing of mixed fisheries advice (WGMIXFISH-Advice, June) and the *Nephrops* single species advice (WGNEPS, October) which incorporates the latest underwater TV surveys. This group recommends that the WGMIXFISH-Advice be delayed until October to facilitate the incorporation of this valuable fishery.

Assumptions around species mixing pose an additional challenge. Both monkfish and megrim have designated TACs for groups of both species, however they are assessed as single species. Monkfish species, *Lophius piscatorius* and *Lophius budegassa*, mix within the Celtic Sea. Levels of mixing appear to be variable over the time, ranging annually from 10 – 30 % of *L. budegassa*. Both stocks were benchmarked in 2018. As a result, *L. piscatorius* now has an accepted category 1 analytical assessment, with reference points, and a short term forecast. *L. budegassa*, however, remains a category 3 assessment based on survey trends. Yet, the issue of species mixing within fisheries was not addressed at the benchmark. Instead, the benchmark recommended that this issue be reviewed in more detail with the intention of developing an appropriate species split for a future benchmark (ICES, 2018).

Megrim (*Lepidorhombus whiffiagonis*) and four-spot megrim (*Lepidorhombus boscii*) are two closely related flatfish species, which mix within the Celtic Sea. The TACs covers both megrim species, although there is s no catch advice for four-spot megrim, as it is considered to constitute less than 5% of total landings based on historical sampling of the Scottish and Irish megrim catch (ICES, 2016). However, to successfully incorporate this economically valuable species into FCube, WGMIXFISH would need clear guidelines from the single species assessment as to how species splits should be applied.

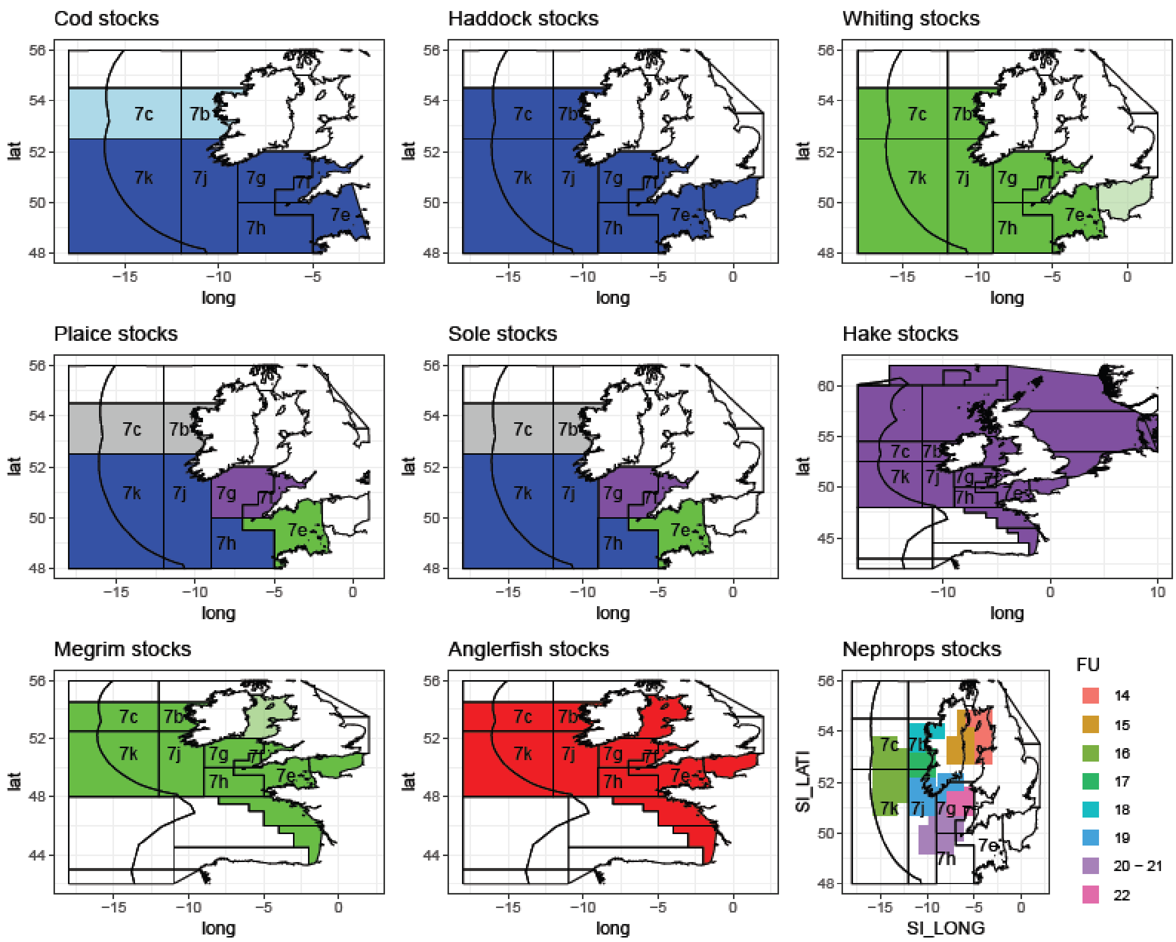


Figure 2.5: Stock and TAC boundary overlaps for the different species considered. For each panel (species) a different colour shading indicates a different stock unit, while only the area modelled has ICES division labels (the "Celtic Sea")

2.5 Improve data and workflow

If additional species are to be successfully incorporated into WGMIXFISH-Advice there needs to be a number of improvements to data sources and workflow, to ensure quality, transparency, and accessibility of an advice product. Currently three data sources are used to produce mixed fisheries advice for the Celtic Sea: ICES Accession, InterCatch, and single species FLR stock objects. A disproportionate amount of time is spent by WGMIXFISH-Advice in cleaning and matching these three data sources. This wastage of time has resulted in insufficient discussion on the quality and outcomes of the models. This working group have identified possible solutions to this problem, all of which would require intersessional work and support from ICES secretariat.

- **Datacall:** Data submitted through ICES Accession currently contains a high number of errors in naming terminology. ICES provides a prescriptive format for these naming systems, however some aspects of the datacall require clarification to reduce the chance of errors submission. This working group will supply ICES Secretariat with a list of datacall improvements.

- **Screening:** Data needs to be screened by ICES at the point of submission. A recommendation of this group is to intersessional work with ICES Secretariat to develop an R script which can check the individual country submission for quality and send a quality report back to the user. This will provide a QA process on the data submitted, such as that used for the VMS datacall - https://github.com/ices-eg/VMS-datacall. This screening process will improve our ability to merge the three data sources and estimate consistent parameters for métier catchability and effort used in the model.
- **Stock coordinators:** Expert input from the single species stock co-ordinators is required to improve the current procedure. This group will develop a short form to be completed by stock coordinators, this form will outline the information and data required by WGMIXFISH, therefore avoiding any issues version control of assessments or misinterpretation of data in reports and stock annexes. This form should also include a description of the InterCatch allocation system applied for the stock.
- **Transparent Assessment Framework (TAF):** Work has already begun on the transfer of the mixed fisheries code to reproducible R Markdown documents which are being moved to TAF.

2.6 Expand the mixed fisheries model

Finally, priority species which were identified as suitable for inclusion in the production of mixed fisheries advice were grouped into tiers, based on their data quality and priority (Table 2.5). These tiers were systematically tested for their performance in FCube and their interaction with each other. This framework is divided into three main stages:

i) Reproduce the single species advice
ii) Conditioning the fleet
iii) FCube forecast

The outcomes of these trial runs were then discussed in the context of what intersessional work should be to support next year's advice drafting process.

Table 2.5: A description of the tiers, the stocks and the logic behind their grouping.

Tier	Stock	Detail
Tier 1	**cod 7ek** **had 7bk** **whg 7b-c &e-k**	These are the stocks in the original analysis, all are category 1 assessments with deterministic short term forecasts which can be performed accurately in FLR.
Tier 2	**hke 3a46-8abd** **meg 7b-k8abd** **mon 7b-k & 8a-b,k**	These were identified as the first priority demersal stocks to include, but were also the most challenging due to the range of assessment and forecasting methods. The following summarises the issues encountered: Northern hake: The single stock assessment is a length-based SS3 model, where the output from the assessment is converted to an age-based approximation to allow a forecast in FLR. Similarly, to the forecasts performed for the Bay of Biscay model, we were able to forecast catches close to the single stock advice (< 2 % difference in 2018, ~ 5 % difference in 2019) but difference in SSB were very difference (~ 33 % higher in 2020). Megrim: The single stock assessment is an age-based Bayesian model where the median output from the assessment was used as input to deterministic forecasts in FLR. There was some difficulty reproducing close to the advice (a catch difference of 16 % in 2018)

TIER	STOCK	DETAIL
		which we could not explain. This is being further investigated with the stock coordinator as there is no clear reason why a large difference should be found (a small difference from a deterministic forecast of the median assessment outputs might be expected from the median of a stochastic forecast). Also, we are required to make an assumption concerning the split of the TAC that's belongs to each species based on the landings split, which is uncertain/unclear. Monkfish: The single stock assessment is a statistical catch-at-age model with forecasts undertaken in the FLR framework. There is no problem in recreating the forecasts.
Tier 3	**sol 7e** **sol 7fg**	While not considered immediate priority stocks for inclusion they are category 1 stocks with full analytical assessments and forecasts. As the assessments are XSA with deterministic short term forecasts we could replicate them perfectly with FLR.
Tier 4	**ple 7bc** **ple 7e** **ple 7fg** **ple 7hjk** **pol** **sol 7bc** **sol 7hjk**	These stocks do not have full analytical assessments and as such there iso currently accepted method for producing forecasts for inclusion in FCube. While approaches for including stocks with only trends based advice was discussed (Section 2.4), it was considered this required further testing before it could be used for advice. In addition, some stocks (ple 7hjk, sol 7hjk, ple 7fg) were due to be benchmarked in the coming year, where their inclusion in FCube could be reconsidered.
Nephrops **New**	**FU16** **FU17** **FU19** **FU2021** **FU22** **NEP7OTH**	In order to understand the impact of these different approaches we run two versions of the code, i) with the latest stock abundances, ii) with the data truncated to use the previous year abundance estimates (as if we were undertaking the advice process in May). Handing of the dead discards v live discards needs to be addressed.
Nephrops **Old**	**FU16** **FU17** **FU19** **FU2021** **FU22** **NEP7OTH**	The biggest challenges remain: The assumption that the share of the Area VII TAC in b-k is the same as observed in previous years (with only ~ 42% of the quota caught outside of VIIa, which is not included in the model). The timing of the advice for *Nephrops*, where because the surveys take place in the summer the advice is not released until October. This means that we have either to incorporate *Nephrops* using the previous year's abundance estimates (which will be inconsistent with the single stock advice) or cannot release the mixed fisheries advice until October/November.

2.6.1 Reproducing the advice

It was generally possible to reproduce the single species advice for all the additional stocks within a reasonable tolerance given the range of forecasting methods (≤5% difference in catches) except for megrim in the intermediate year, where the difference was much larger (~ 16%). In addition, for hake the SSB forecasts in the TAC year + 1 were very difference (~ 33%). Both these issues will need investigating going forward to try and reduce the inconsistencies when presented the mixed fisheries scenarios as advice.

Individual stock details are set out in the can be seen in Figure 2.6.

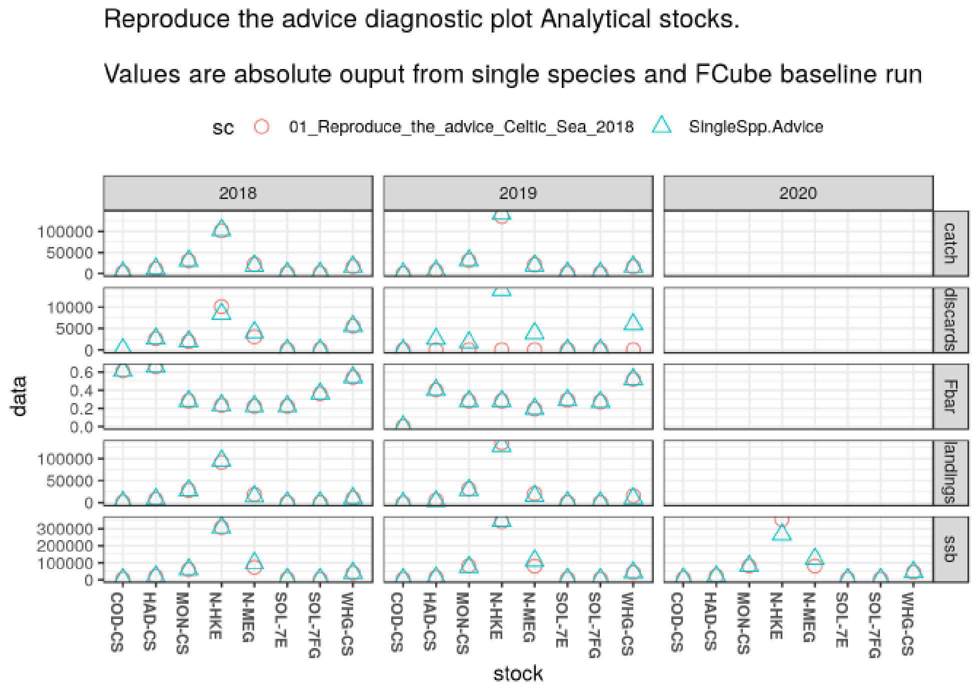


Figure 2.6 Difference between FCube baseline run and Single Species advice for finfish stocks, showing Fbar (2018–2019), catch, discards and landings (2018–2019) and SSB (2018–2020).

2.6.2 Conditioning the fleets

Conditioning the fleets is a vital component of this framework. This is the section of the assessment process where the most time is spent correcting the errors of data submissions, which is done to account for the various errors in coding when data are submitted, where all fleets and metiers are aggregated and filtered. Therefore, this process has to deal with all the issues related to the data submission through accession and InterCatch. The whole process takes a very long time despite the progressive implementation of smarter algorithms to partly correct and recode species name, country, areas, fleets, metiers. A major part of the script still requires manual recoding. This script has nearly 2000 lines of R code and this part represents nearly two third of the code.

No major issues were spotted regarding the inclusion of new stocks assuming a careful partitioning of areas and species for stocks where boundaries expand further than the Celtic sea itself. New species that were represented over several stocks (e.g sole and *Nephrops*) were recorded in all effort, landings and InterCatch file with a special code mixing FAO species code and stock boundaries (eg SOL-7FG) with names matching the assessment stock object. For *Nephrops*, Functional units needs to be converted back into ICES division. This is easily overcome if data submission follows the same rule, i.e. for example *Nephrops* in FU22 becomes NEP-FU22 and rather than providing FU22 as area, ICES division are provided so that the catches are naturally splitting for each FU as ICES division. This works needs to be done prior data submission. When data was missing, FU areas were converted in the ICES division within that FU with the highest proportion of catches.

While processing the data, it was unclear for monkfish and megrim, because of various FAO codes in the accession files, if the splits between species has already been done prior submission of data to accession. Comparing the landings and discards in accession with the available advice sheets led to assume the splitting was done before data were submitted to accession but this aspect is not documented at all in the data submission considering several FAO codes for those species and mixing of those species were found. Some coefficients were found in the latest ICES benchmark reports to allow some splitting of the catches between species. This option was implemented for megrim and monkfish but disabled for this exercise.

Apart from the recoding task, the allocation of discards rates based on InterCatch data showed, because of different sorting habits and on-board data collection, some local area exhibits relatively high discards quantities in comparison to nearby areas and somehow induce substantially higher estimates than actually reported. Some basis rules reject discards rates above 98% but depending on the behaviour of some fleets for some species, that threshold might need to be modulated at the stock or local level to take account of the possibility that discards above 98% might occasionally happen. It also appears that some stocks were not fully uploaded into InterCatch (monkfish, sole) therefore it is unknown of this affect the estimates of discard rates. Overall, the estimates and allocation of discards rates would probably benefit from an improved allocation of discard rates.

2.6.2 FCube runs

A trial run was undertaken with combinations of stocks as described above, in order to better understand any likely consequences on the dynamics of the mixed fisheries advice. Little time was available to evaluate these runs, as the complexities of including a large number of additional stocks meant work had to continue beyond the meeting. A summary of the outcome of these trial runs can be found in Table 2.6. Table 2.6 summaries the catch projections, and choke species for each of the combinations of stocks. Immediately it can be seen that the addition of any new species alter the perception of gadoid projection (Tier 1) in 2019. There are many complicated dynamics at play here, and much intersessional work needs to be done to describe and understand these dynamics.

For example, the inclusion of *Nephrops* alongside the Tier 1 stocks changes the dynamics for the 'max' scenario where NEP2021 becomes a significant driver of effort for the fleets. This was also the case for the NEP Old Tier 1 scenario (where we approximated the advice given the previous year's abundance estimates for *Nephrops* from the UWTV survey). The major difference here is the higher TAC for *Nephrops* and catches under the scenario than with the most recent UWTV surveys (which revised down significantly abundance estimates for some of the key FUs).

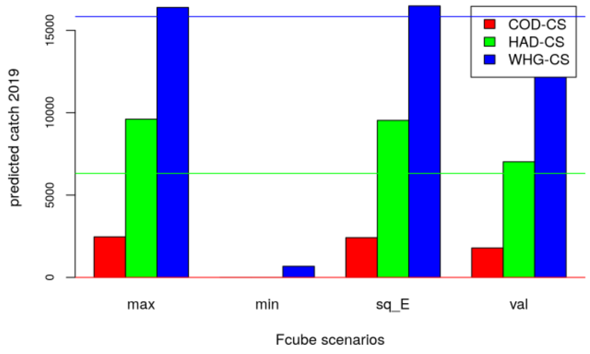
Including the Tier 2 stocks also resulted in changed dynamics, with monkfish and megrim both limiting effort of fleets under the 'min' scenario, and northern hake and monkfish being the least limiting stocks under the 'max' scenario. Further including sole 7e and sole7fg changed the dynamics again in that sole 7fg become limiting for 1 fleet, while sole 7e was least limiting for 17 stocks. In reality, sole 7fg would not limiting fleets catches of the other stocks due to the limited geographical bounds of the stock, where other stocks could be caught by fleets moving elsewhere when their sole7fg quota was exhausted. Similarly, its likely fleets could change their spatial effort distribution to change their proportion of sole7e in their catch, and it's important we consider the nature of these effort dynamics in including more geographically restricted stocks in the model.

Including all stocks together (Nep New Tier 123) led to a much more dynamic system, with more stocks being the limit for fleets under the 'min' scenario.

Table 2.6 : Summary of FCube runs with varying stock/tier combinations

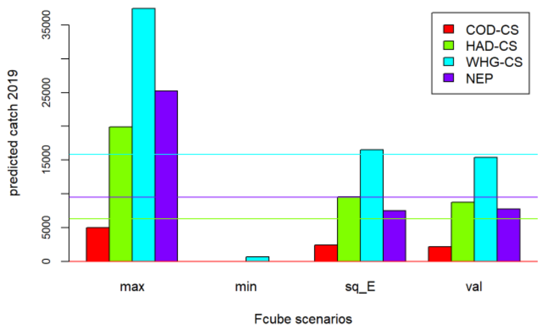
	FCUBE 2019 PROJECTION'S	CHOKE SPECIES

Tier 1



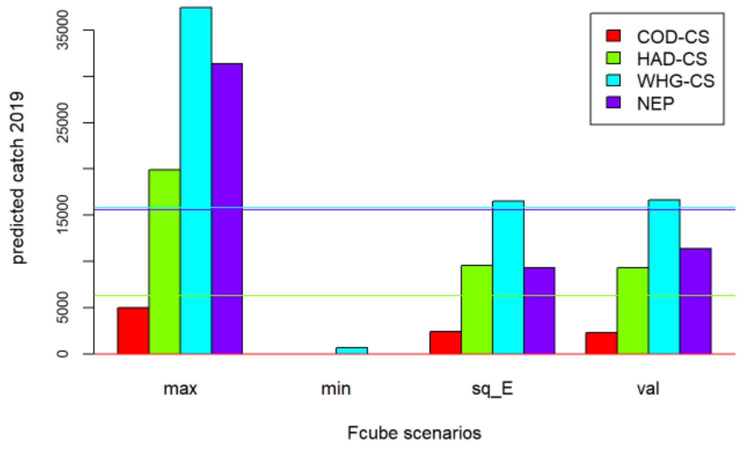
	CHOKE SPECIES		LEAST LIMITING SPECIES	
	% of 2017 effort limited by each spp in 2019	No. of Fleets	% of 2017 effort limited by each spp in 2019	No. of Fleets
COD-CS	0.801	10		
HAD-CS	0.162	1	0.039	2
WHG-CS	0.038	2	0.961	10

Tier 1
NEP New



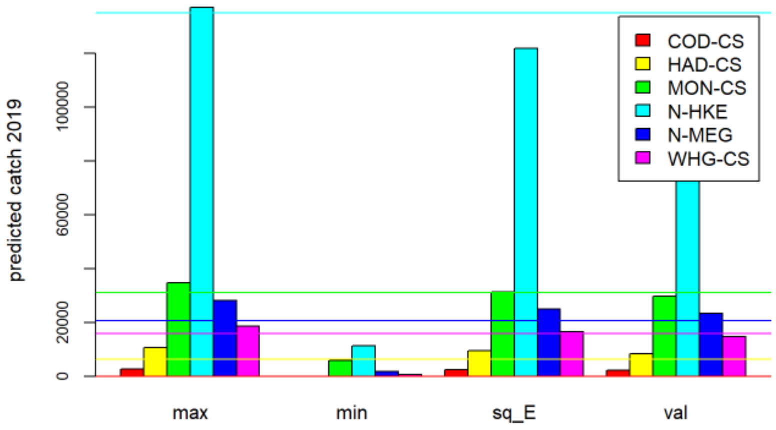
	CHOKE SPECIES		LEAST LIMITING SPECIES	
	% of 2017 effort limited by each spp in 2019	No. of Fleets	% of 2017 effort limited by each spp in 2019	No. of Fleets
COD-CS	0.858	11		
HAD-CS	0.114	1	0.173	2
NEP16	0.000	1		
NEP 17	0.000			
NEP 19	0.000			9
NEP 2021	0.552		0.552	
NEP 22	0.000			
NEP7OTH	0.000	2		3
WHG-CS	0.275		0.275	

Tier 1 NEP Old



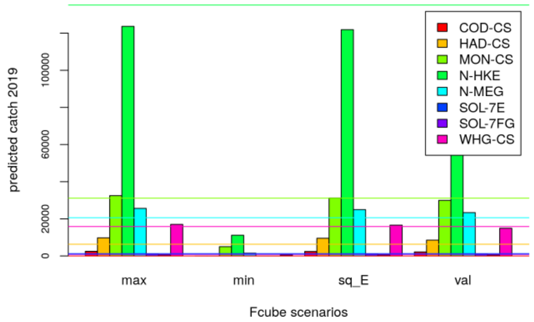
	Choke species		Least limiting species	
	% of 2017 effort limited by each spp in 2019	No. of Fleets	% of 2017 effort limited by each spp in 2019	No. of Fleets
COD-CS	0.858	11		
HAD-CS	0.114	1	0.173	1
NEP16	0.000	1		
NEP 17	0.000			
NEP 19	0.000			9
NEP 2021	0.000		0.552	
NEP 22	0.000			
NEP7OTH	0.000	2		3
WHG-CS	0.275		0.275	

Tier 1,2



	Choke species		Least limiting species	
	% of 2017 effort limited by each spp in 2019	No. of Fleets	% of 2017 effort limited by each spp in 2019	No. of Fleets
COD-CS	0.851	13	0	
HAD-CS	0.109	2	0	
MON-CS	0.011	1	0.290	3
N-HKE	0.000	0	0.509	10
N-MEG	0.025	1	0.000	
WHG-CS	0.004	1	0.201	4

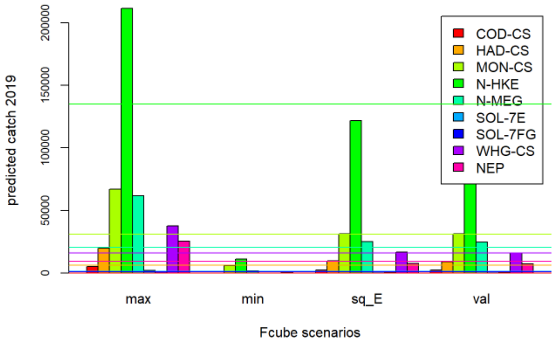
Tier 1, 2, 3



	CHOKE SPECIES		LEAST LIMITING SPECIES	
	% of 2017 effort limited by each spp in 2019	No. of Fleets	% of 2017 effort limited by each spp in 2019	No. of Fleets
COD-CS	0.928	17		
HAD-CS	0.034	2		
MON-CS	0.010	1		
N-HKE			0.014	2
N-MEG				
SOL-7E			0.842	17
SOL-7FG	0.024	1		
WHG-CS	0.004	1	0.144	2

Tier 1,2,3

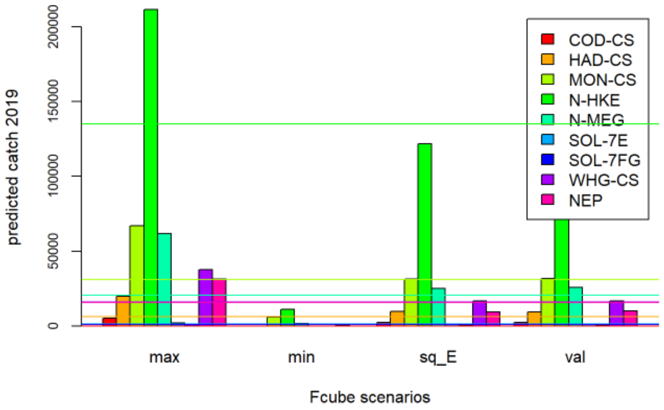
NEP New



	CHOKE SPECIES		LEAST LIMITING SPECIES	
	% of 2017 effort limited by each spp in 2019	No. of Fleets	% of 2017 effort limited by each spp in 2019	No. of Fleets
COD-CS	0.928	17		
HAD-CS	0.034	2		
MON-CS	0.004	2		
N-HKE	0.000		0.014	2
N-MEG	0.000			
SOL-7E	0.000		0.473	
SOL-7FG	0.024	1		
NEP16	0.000			10
NEP 17	0.010			
NEP 19	0.000			
NEP 2021	0.000		0.514	9
NEP 22	0.000	1		
NEP7OTH	0.000	1		
WHG-CS	0.000			

Tier 1,2,3

NEP Old



	Choke species		Least limiting species	
	% of 2017 effort limited by each spp in 2019	No. of Fleets	% of 2017 effort limited by each spp in 2019	No. of Fleets
COD-CS	0.928	17		
HAD-CS	0.034	2		
MON-CS	0.004	2		
N-HKE	0.000		0.014	2
N-MEG	0.000			
SOL-7E	0.000		0.473	
SOL-7FG	0.024	1		
NEP16	0.000			10
NEP 17	0.010			
NEP 19	0.000			
NEP 2021	0.000		0.514	9
NEP 22	0.000	1		
NEP7OTH	0.000	1		
WHG-CS	0.000			

2.7 Conclusion

This working group has identified 11 new stocks for inclusion in the Celtic Seas FCube. The challenges and possible pitfalls associated with their inclusion have been identified and tested. This working group would recommend the inclusion of *Nephrops* and all Tier 1 species (monkfish, hake, and megrim) in next year's advice drafting. However, there is much intersessional work that needs to be done to ensure that usable advice can be produced in a transparent manner. This group needs to consider some of the dynamics this induces (stock boundaries, different TAC areas), which should be a ToR for next year's WGMIXFISH-METHODS meeting which we recommend is held in May.

2.8 Recommendations

The recommendations of this working group are:

1) Request that ACOM swap the timing of WGMIXFISH-ADVICE meeting with the WGMIXFISH-METHODS meeting to allow for the incorporation of updated *Nephrops* advice.
2) Work with ICES Secretariat to clarify datacall.
3) Work with ICES Secretariat to create a screening system for data submission.
4) Provide single species stock coordinators (WGCSE, WGBIE and WGNSSK) with a form requesting clearly what WGMIXFISH requires.
5) Continue work to transfer code to TAF framework.
6) Analysis the outcomes of the FCube runs to determine the drives of the scenarios produced.

3 Terms of Reference B - This term of reference was to assess the potential of developing mixed fisheries scenarios for pelagic fish in the Baltic.

3.1 Degree of species mixing in the catches of Baltic Sea pelagic fisheries

The Baltic Fisheries Assessment Working Group (ICES, 2018) compiled the information available from the different Baltic Sea countries on their pelagic fleet, the species composition of their landings, and the existing monitoring programs.

At the scale of the Baltic Sea, the majority of the catches are taken by pelagic trawlers performing a directed fishery for either sprat or herring, in which bycatch of the other species occur. Most of the countries also have fisheries using fixed gears (gillnets or traps) which catch exclusively herring (accounting for up to 20% of the total national herring catches, depending on the country). Finally, part of the catches come from industrial fisheries using small mesh sizes and likely to catch both species but for which catches are often not sorted by species.

Catch statistics at the national level presented by WGBFAS, indicate that all countries catch both sprat and herring, but proportions vary across countries (from 90% herring in Finland to 76% sprat in Lithuania).

At the metier level (trawl fishery targeting herring or trawl fishery targeting sprat), all countries reported that bycatch occurred, but only part of the countries provided estimates of the bycatch percentages (based on log books and sale slips). Disparities are observed between countries: for instance, the bycatch of herring in the Polish sprat fishery in under 3% while Russia reports bycatch rates varying between 13 and 64%. Likewise, for herring, the directed herring fishery close to Bornholm in SD 23–25 is reported to have less sprat in the catches than further north in the Baltic (SD 27– 29). Mixing of herring and sprat in the directed herring trawl fishery is highest in SD 32, decreasing further north in SDs 30–31.

The catches species composition in these directed fisheries is also reported to vary on a seasonal scale with higher concentrations of sprat in the directed herring trawl fishery in the 1st and the 4th quarters (which correspond to the main fishing seasons), in particular in the northern Baltic Sea.

The information available mainly comes from logbooks and sales slips and therefore is collected at a scale that does not allow to assess the degree of actual mixing at the scale of a trawl haul. It is therefore not clear to WGMIXFISH if the two species actually occur in mixed catches in a given trawl haul (actual technical interaction), or if they occur through occasional hauls with rather clean catches of the bycatch species (taken intentionally or not).

There was some concern raised by the WGBFAS group about the accuracy of the landing species composition data. The fact that most countries consistently utilize their quota of sprat and herring almost to 100 %, even though the stock development for sprat and herring has changed dramatically, is taken by WGBFAS as an indication of potential species misreporting. In the different countries, information on catches species composition are also collected during control operations. The extent to which scientific institutes can access this data, and to which this data is used to correct for potential misreporting varies across countries. WGBFAS indicated that control data for all Baltic Sea countries could be requested to the European Fisheries Control Agency in order to get a better overview of the extend of misreporting. It is important to assess the magnitude of misreporting problems, and when possible correct the fisheries statistics, before using them as the basis for mixed fisheries models.

3.2 Applicability of the mixed fisheries models currently used in WGMIXFISH to the case of pelagic fisheries

- Effort measure

The models used in WGMIXFISH (FCube and FLBEIA) are based on the relationship between fishing mortality (based on stock assessment output) and the fishing effort (based on fisheries statistics), at the fleet level. For the demersal fisheries (dominated by bottom trawl), the nominal effort measured as number of kW.days (vessel power times sum of trips duration) is broadly accepted as a fair measure of the effective effort. For pelagic fisheries, it is less likely that a nominal effort in kW.days is an accurate measure of effective effort.

A fishing trip for a pelagic trawler is typically divided in a succession of activities (Vermard *et al.*, 2010), some focusing on targeting the fish (searching suitable fish aggregations using acoustic equipment, trawling) more than others (steaming to fishing grounds, pumping the fish out of the net and processing the catch). The proportion of time dedicated to these different activities depends on the characteristics of the spatial distribution of the resource and its degree of aggregation. For migratory stocks, the location of the fishing ground may depend on the time of the year, resulting in different proportion of the trip represented by steaming time in different months. The proportion of time spent fishing compared to searching is also higher for highly aggregated species (e.g. blue whiting) than for more scattered ones (e.g. horse mackerel, Fässler *et al.* 2016) . It is also not straightforward to which extend these different activities contribute to the effective fishing effort, depending on the degree of targeting of the species that they imply. Estimating a fishing effort can be further complicated in situations where vessels communicate their fishing positions, where some vessels can benefit from the searching time from others. Finally, vessel power is a poor descriptor of fishing power for pelagic trawlers (Reid *et al.* 2011) for which excess engine capacity can be used for other purposes than towing the net (seawater refrigeration, faster cruising, allowing for larger size and increased storage).

The link between nominal and effective effort in the Baltic Pelagic fisheries should be investigated to assess whether simple and easily available measures of effort – such as kW.days as used in demersal fisheries – can be used in a potential pelagic mixed fisheries model. Quantifying the proportion of the time actually dedicated to targeting the fish (based on analyses of vessel tracks for instance, combined with acoustic information), and describing how this proportion varies at different scales (trips, season, year), could help establish whether the trip duration is a good proxy for effective effort.

- Assumptions made on catchability

The catchability– expressed as the ratio between the partial fishing mortality of a given fishing fleet for a given stock and the effort of this fleet - is a central parameter in the mixed fisheries models used to provide advice on mixed fisheries. Catchability coefficients are calculated - for each of the stocks appearing in the catches of each of the fleets -based on the catch and effort data, and the stock assessment output for the most recent year in the data (usually the year prior to the current year). These coefficients are then assumed to be constant in the mixed fisheries short term projections, and are used to convert future quota shares of the different stocks for each fleet into a fishing effort. Different scenarios (“min”, “max”, ...) are then applied to define which effort will be deployed by each fleet, and catchabilities are used again to compute the corresponding partial fishing mortalities and landings. A central assumption in the mixed fisheries models is therefore that fleets have constant catchabilities for the different stocks over the period for which the projections are made (i.e. current year -1 to current year +1).

For pelagic species, the assumption of constant catchability is more likely to be challenged. First, pelagic species tend to remain aggregated in schools and fishermen are often very efficient at finding these aggregations (knowledge, use of acoustic equipment, sharing information). The catch per unit of effort can remain constant even if stock size is declining (described as hyperstability by Hilborn and Walters, 1992). It is therefore likely that catchability becomes higher as the stock size decreases. Another potential issue with pelagic fish is the dependency of their habitat to environmental conditions. Environmental variability can cause changes their distribution -extend of the distribution, vertical distribution, degree of aggregation and schools characteristics – which affect the catchability of the different fleet for these stocks. In case of strong environmental anomaly, the year-to –year change in catchability can be substantial (Maunder *et al.*, 2006). Although such effects can potentially happen for any species (e.g. Erisman *et al.* 2011), they are likely to be more pronounced for pelagic species, such that the assumption of constant catchability might not be realistic.

- Spatial and temporal issues

The models used in WGMIXFISH are not spatially or temporally explicit. This comes down to assuming that stock distribution (and overlap between stock) is constant, both at the seasonal and at the interannual scales. The differences in local abundances are implicitly accounted for in the difference in the catchability estimated for the fleets of different countries, exploiting the stocks in different areas.

Pelagic stocks have a more variable distribution than demersal stocks, and often undertake more extensive migrations. Their availability to a given fleet, and degree of spatial overlap between target and bycatch is therefore susceptible to vary between seasons and between years, which would hamper the application of the type of models used in WGMIXFISH and call for the use of spatial/temporal explicit models.

Analysis of spatial and temporal data on species distribution (surveys or fisheries data) could provide some insight in the variability in the distribution of herring and sprat, and on the extent of their overlap.

3.3 Conclusions and recommendations

The information presented by the WGBFAS indicates that there is a moderate degree of mixing in the catches of the Baltic Sea pelagic fisheries. There are also some indications from the control data that species misreporting may occur, which could be, if that is intentional, an indication that quotas of bycatch are potentially limiting. Therefore, there appears to be enough justification for developing a mixed fisheries model for these fisheries.

However, a number of conceptual questions have to be addressed to assess whether the tools currently used by WGMIXFISH can be applied in the case of these fisheries, or if alternative approaches should be envisaged instead.

The WGMIXFISH group recommends that a series of analyses should be carried out to better describe the quality of the data available, the extend of the species mixing in the landings and variability of the catchability of the different fleets. The following road map is suggested:

- Assess the reliability of the catch composition declared in the logbook using control data from the European control agency.
- Based on detailed logbook data, and possible observer data, describe in detail how the mixed fisheries interactions occur (in terms of geographical location, period of the year, and fleets involved). Data collected from acoustic surveys can also be used to inform on the degree of spatial overlap between herring and sprat, and the degree of mixing of the two species at the school (or group of schools) level.
- Make a mixed fisheries data call to assemble a landing and effort database for the pelagic fisheries in the Baltic Sea
- Based on catches and effort per fleet data, time series of catchabilities for herring and sprat could be calculated for the different fleets. Any large variation in the catchabilities (especially if not correlated between the two species) would indicate that the mixed fisheries models used at WGMIXFISH are not suitable to describe the Baltic Sea pelagic fisheries.

4 Terms of Reference C - Develop models for flatfish and roundfish

4.1 Introduction to the issue

In terms of single-stock assessments, the North Sea has always been considered as a single area (ICES Subarea 4), without further spatial division. This is different from most other areas, where stocks can be defined at the level of the subdivision (including for some of the Greater North Sea area, e.g. Divisions 7d, 3a20 and 6a). Additionally, the DCF does not consider the spatial structure of the North Sea either, and sampling strata and metiers definitions are defined over the entire Subarea 4. As a consequence, the mixed-fisheries model has also been accordingly designed considering area 4 as a unique area.

Nevertheless, this is a well-known fact that the fish populations are not homogeneously defined throughout the North Sea. And in particular, the main flatfish species (sole and plaice) are mainly caught in the southern part by the southern fisheries (from e.g. Netherlands and Belgium), and the main roundfish species (cod, haddock and saithe) are mainly caught in the northern part by the northern fisheries (from e.g. Scotland and Norway).

Since the fisheries are defined by country, differences in catch composition are nevertheless already accounted for to some extent in the model. However, not distinguishing between sub-areas or other spatial divisions can lead to assuming that different species can be caught together whether they are not. A second problem is that some fleets can be considered to be limited in the FCube “min” scenario (or, contrarily, not limited in the “max” scenario) by a given stock, whereas in reality this stock can represent only a very small portion of the catch.

The WGMIXFISH group was therefore requested to reflect on the potential need, added value and impact of splitting the current model setup into two sub-models, one flatfish- and one roundfish-oriented. To answer this WGMIXFISH investigated in some details the spatial distribution of the various species, and their occurrence in the various métiers of the various countries.

4.2 Spatial overlap and mixing of roundfish and flatfish landings

WGMIXFISH-ADVICE relies on INTERCATCH data as a source of stock landings and discards at various levels of disaggregation (e.g. country, area, métier, age). As the database does not contain information at finer spatial scales than ICES management areas, the STECF FDI database[1] was used to show spatial patterns in landings by ICES rectangle (0.5° x 1.0° resolution). Since that data is for landings only (i.e. excluding discards), it offers a more conservative perspective of the true overlap between flatfish and roundfish. Nevertheless, the data provides information on the general spatial extraction patterns of wanted catch, including the degree of mixing between flatfish and roundfish landings.

[1] https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter

- Data analysis

FDI data of landings from 2016, areas 3B1-3 (annex IIA), were included in the exploration. Countries and gears most important to North Sea demersal mixed fisheries were included, as well as the most important stocks. For a full list of data levels included, see Table 4.1.

Table 4.1. FDI landings data used in the analysis.

Category	*Levels included*
Years	2016
Areas	3B1 (=ICES area 3a20, Skagerrak), 3B2 (=ICES area 4, North Sea), 3B3 (=ICES area 7d, Eastern Channel)
Countries	BEL = Belgium, DEU = Germany, DNK = Denmark, ENG = England, FRA = France, NLD = Netherlands, SCO = Scotland, SWE = Sweden
Gears	BEAM = beam trawl, BT1 = beam trawl >=120 mm, BT2 = beam trawl 80–119 mm, GT1 = trammel nets-, GN1 = gill net, LL1 = long line, TR1 = otter trawl >= 100 mm, TR2 = otter trawl 70–99 mm
Roundfish stocks*	ANF = anglerfish, **COD** = cod, **HAD** = haddock, HKE = hake, **POK** = saithe, **WHG** = whiting
Flatfish stocks*	BLL = brill, DAB = dab, FLE = flounder, LEM = lemon sole, **PLE** = plaice, **SOL** = sole, TUR = turbot, WIT = witch sole

* Bold text indicates stocks, or their sub-stocks, that are presently included in North Sea WGMIXFISH-ADVICE

Maps were created to show the overall distribution of landings by stock, in addition landings by stock aggregates (roundfish and flatfish) were created that summarize both relative and absolute landings, and aided in illustrating the degree of overlap.

An index of mixing between roundfish and flatfish landings was calculated using the following approach. Pielou's evenness index was first calculated for each ICES rectangle:

$$J = H'/\log S\ ,$$

where H' is the Shannon-Weaver diversity index, $H' = \sum_i^S p_i \log p_i$, S is the total number of species (i.e. richness; S=2), and p_i is the proportion of individuals belonging to the ith species (*i.e.* flatfish or roundfish). Landings weight was used in place of abundance. For example, when a given area's landings are comprised entirely of roundfish or flatfish, the result is $J = 0$, while equal proportions result in $J = 1$. A single mixing index (J_w, i.e. 'weighted evenness') was calculated as the mean of all ICES rectangles, r, weighted by landings, L_r:

$$J_w = \frac{\sum_r^n J_r L_r}{\sum_r^n L_r}\ .$$

- Overall distribution patterns

Figure 4.1 shows the general spatial landings distribution across all gears and countries for the main roundfish (red hues) and flatfish (blue hues) stocks. The patterns show a majority of flatfish landings being derived from the shallower areas of the southern and eastern sections of the North Sea, while roundfish landings are more from the deeper areas to the northwest and along the Norwegian trench. There is nevertheless a degree of overlap, mainly around the Northwest of Denmark.

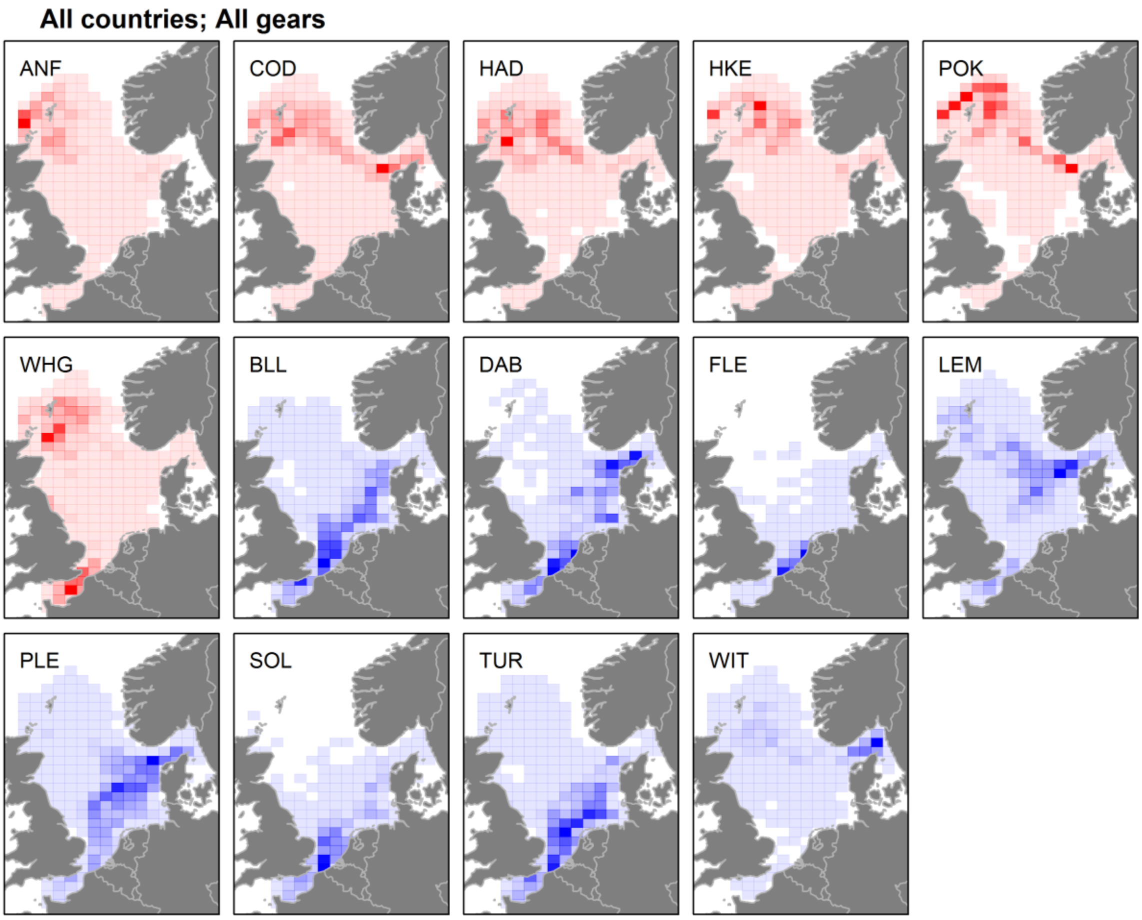


Figure 4.1: Landings by ICES rectangle and stock for 2016. Roundfish and flatfish stocks are coloured in red and blue, respectively. Darker colours indicate higher landings. ANF=Anglerfish, COD=Cod, HAD=Haddock, HKE=Hake, POK=Saithe, WHG=Whiting, BLL=Brill, DAB = Dab, FLE=Flounder, LEM=Lemon sole, PLE=Plaice, SOL=Sole, TUR=Turbot, WIT=Witch flounder.

The results of the overall landings patterns by stock aggregate is shown in Figure 4.2. Again, the separation of areas dominated by flatfish and roundfish landings patterns is observed, with most mixing occurring along the Norwegian trench, near the north-eastern boundary of ICES area 4b, and areas near the English Channel. The overall mixing index is $J_w = 0.36$.

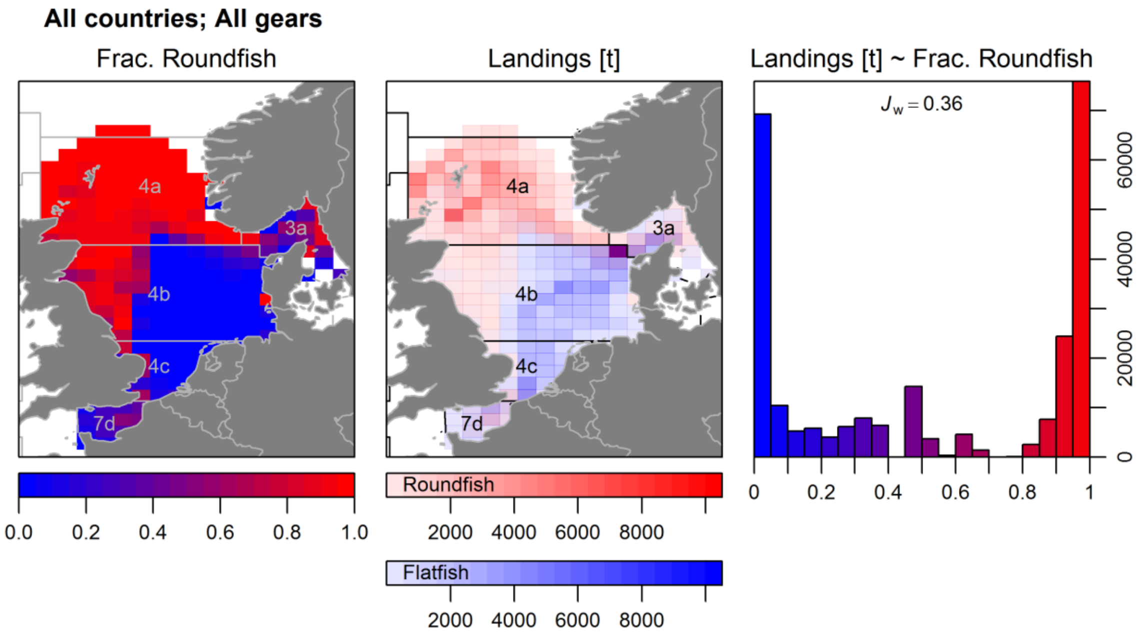


Figure 4.2. Landings by ICES rectangle and stock aggregates for 2016 across all countries and gears. The left panel shows the fraction of roundfish in landings by ICES rectangle. The middle panel scales colour transparency with landings to emphasize areas with highest values. Colour scale legend illustrate colour intensities for non-mixed landings, although purple hues would indicate mixing of roundfish and flatfish, as in the left panel. The right panel shows total landings by mixing category (i.e. fraction roundfish), with the overall mixing index (Jw) shown at the top.

Mixing indices by country can be seen in Figure 4.3, showing significant variation among countries. Countries with lower values (e.g. England, Germany and Netherlands) avoid areas of stronger mixing. Germany also shows less mixing in areas of the Norwegian trench than seen in other countries. Differences in gear or higher discard rates may be responsible for this deviation. The highest index was observed for Denmark, which shows much higher landings from the main mixing areas of the Norwegian trench. The higher index of Belgium is due to higher landings derived from the northeast extent of ICES area 4b and near the English Channel (areas 4c, 7d). Figures showing mixing of stock aggregates for each country can be seen in Annex 3 (Figures 4.3-10)

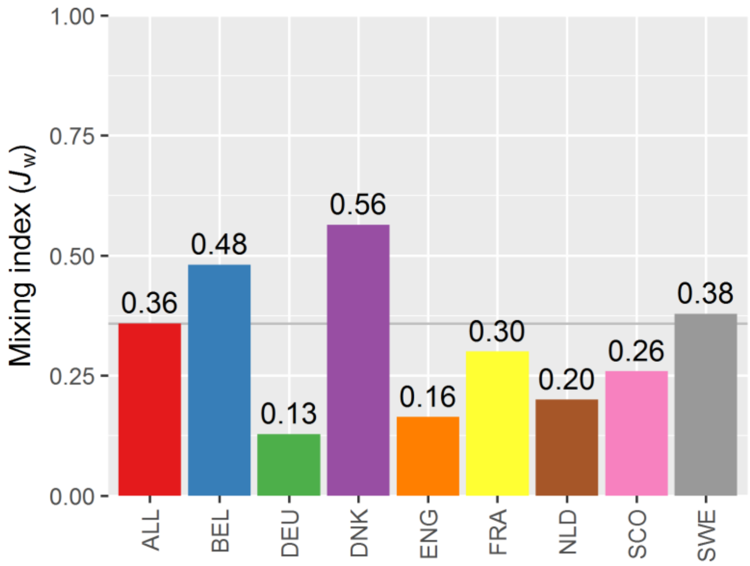


Figure 4.3. Mixing indices by country for all gears. Horizontal grey line references the overall mixing index. ALL=Overall, BEL=Belgium, DEU=Germany, DNK=Denmark, ENG=England, FRA=France, NLD=Netherlands, SCO=Scotland, SWE=Sweden.

- Distribution patterns of main trawl gears

Distribution patterns in landings from the main trawl gears alone were also explored in order to further identify degrees of mixing for the most mixed gears. These included gears "TR1" and "TR2" (categories of otter trawl or demersal seine), which are gears likely to have mixing of roundfish and flatfish catches. They differ in terms of their mesh size, with TR1 ≥ 100 mm and TR2 ≥ 70 mm and < 100 mm.

The patterns in landings derived from the larger mesh-sized TR1 gear (Figure 4.4) shows less mixing of roundfish and flatfish landings than the TR2 gear (Figure 4.5) (J_w of 0.31 vs 0.66, respectively). TR1 is more associated with roundfish landings derived from the more northern areas of North Sea (4a), while TR2 is more associated with mixed roundfish and flatfish landings from shallower depths of the eastern North Sea (4b), English Channel (7d) the Skagerrak (3a20). The pattern of higher mixing indices associated with the TR2 gear is observed for all countries (Figure 4.6).

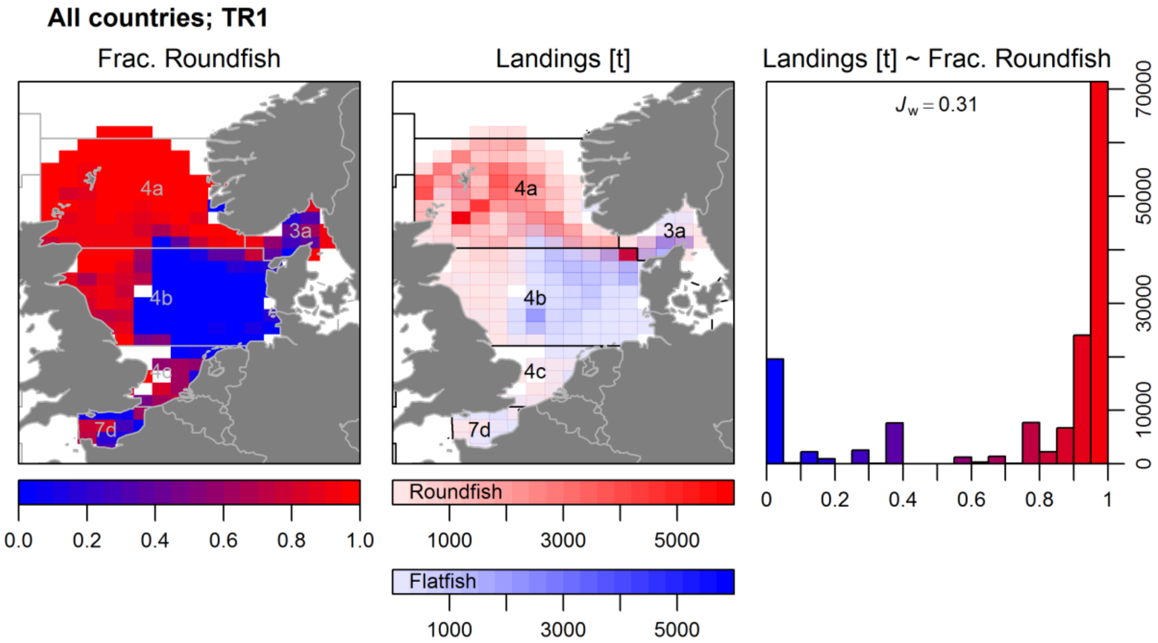


Figure 4.4. Landings for TR1 gear by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.

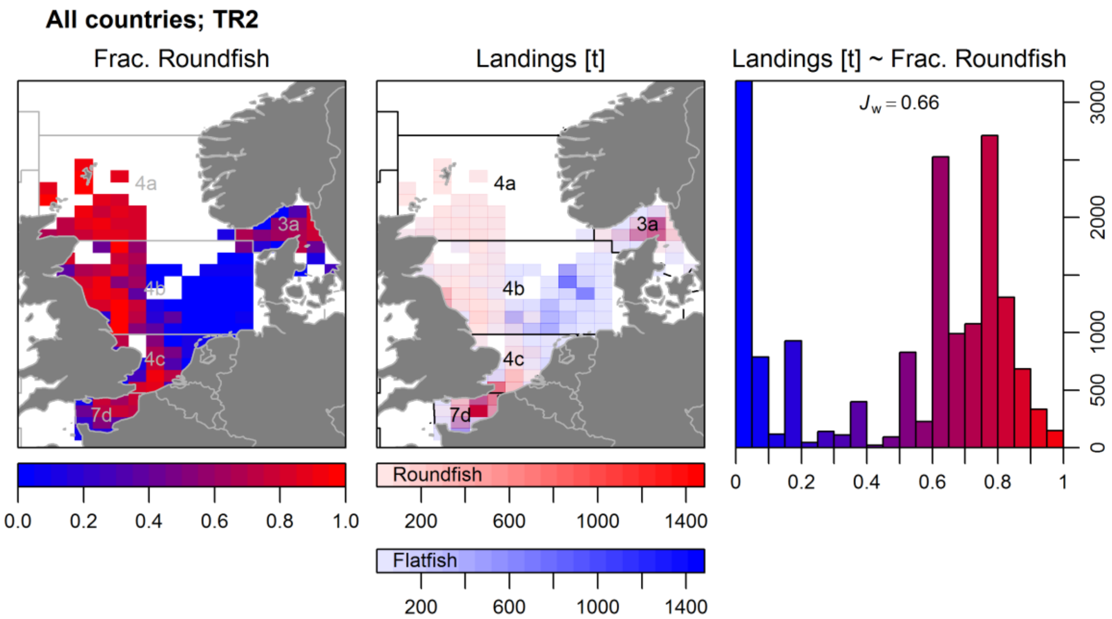


Figure 4.5. Landings for TR2 gear by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details

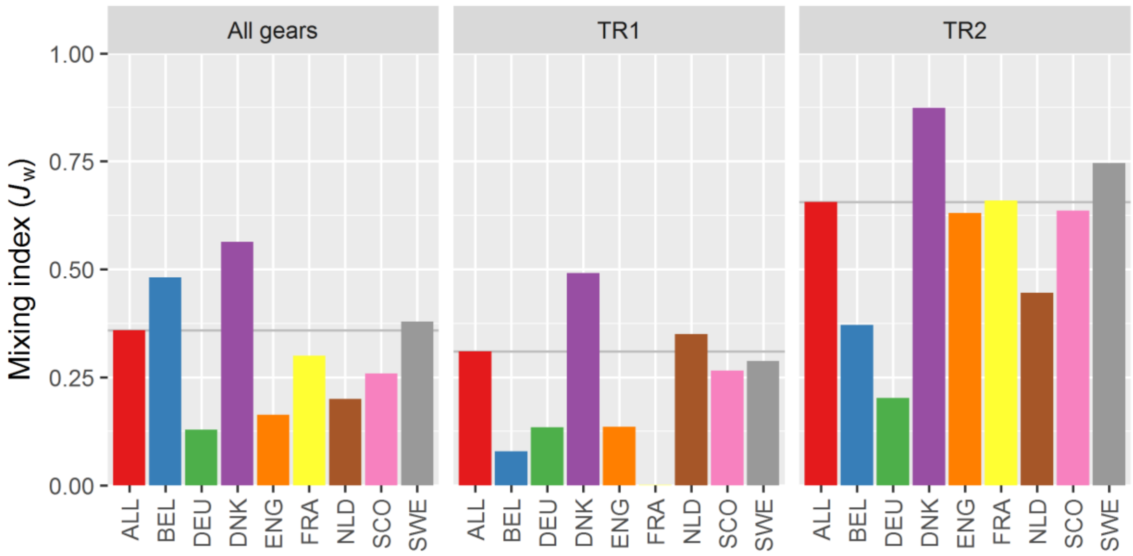


Figure 4.6. Mixing indices by country and gear. Horizontal grey line references the overall mixing index. ALL=Overall, BEL=Belgium, DEU=Germany, DNK=Denmark, ENG=England, FRA=France, NLD=Netherlands, SCO=Scotland, SWE=Sweden.

4.3 Are flatfish and roundfish exploited by different fleets?

The development of separate mixed fisheries models for roundfish and for flatfish would be justified if there was only little interaction between flatfish and roundfish species in most of the North Sea fleets. In order to investigate if this is the case, and to supplement the mapping by country above, the WGMIXFISH dataset was investigated in more details. The main fleets responsible for the majority of the catches were identified for a selection of stocks (2 roundfish: cod and whiting and 2 flatfish stocks: sole and plaice).

In the case of North Sea sole (Fig. 4.7), 80% of the 2017 landings are taken by 4 beam trawler fleets (Dutch and Belgian) and the fleet OTH (which is a grouping of smaller fleets+ Norwegian data). This stock therefore appears to be caught mainly by flatfish specialist fleets (the landings of these 4 beam trawler fleets are composed almost exclusively of plaice or sole).

North Sea plaice, on the other hand, is caught by a large number and a greater diversity of fleets (10 fleets are responsible for 80% of the landings, Figure 4.8). Some of these fleets are flatfish specialists, in which plaice and sole represent most of the landings (i.e. Dutch, English and Belgian beam trawlers), but for others (mainly Danish fleets) plaice is caught with a mix of gadoids, and in one instance (Scottish otter trawlers larger than 24 m), plaice represents only a minor part of the landings dominated by roundfish.

North Sea cod is also caught by a large number of fleets (9 fleets to reach 80% of the landings, Fig. 4.9). Most of these fleets have their landings dominated by roundfish (EN_FDF, Scottish otter trawls), but catch also flatfish (plaice) in small proportion. About 20% of cod landings are also taken by the Danish fleets, targeting both plaice and different gadoids.

Finally, the bulk of the whiting is landings is also taken by a small number of fleets (5, Figure 4.10). Whiting is the main target stock for one of them (French otter trawlers) which also catches Eastern channel plaice and sole in smaller proportion. However, the large majority of whiting landings are taken by fleets for which this stock represents only a small percentage.

This analysis shows that there is not a clear separation between flatfish and roundfish fisheries. While sole is indeed exclusively caught by beam trawlers, plaice is also targeted by Danish fleets which also targets roundfish. Plaice is also an abundant bycatch in roundfish fisheries. Roundfish stocks are mainly taken by fleets targeting those stocks, but potentially also with flatfish (e.g. French otter trawl for whiting, Danish fleets for cod). Furthermore, this analysis does not look into details of the stocks representing a smaller percentage of the landings; thus, there is probably additional overlap for stocks caught by flatfish and roundfish fisheries.

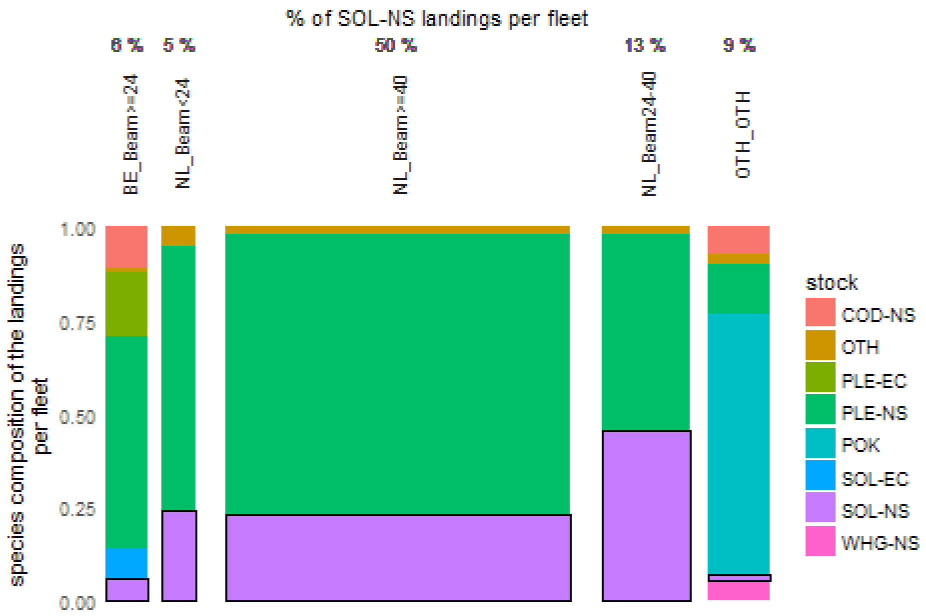


Figure 4.7: main fleets contributing to 80% for the landings for North Sea sole (bar width proportional to the percentage of the 2017 sole landings taken by each fleet) and landing composition of each of these fleets (colouring of the bar indicating the percentage of each stock in the 2017 landings for each fleet, with sole highlighted).

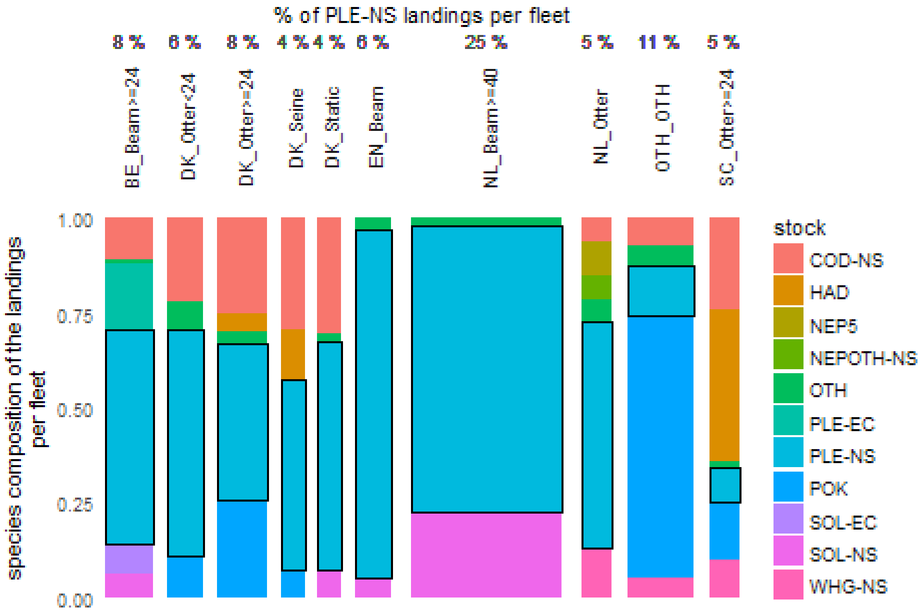


Figure 4.8. Main fleets contributing to 80% for the landings for North Sea plaice (bar width proportional to the percentage of the 2017 plaice landings taken by each fleet) and landing composition of each of these fleets (colouring of the bar indicating the percentage of each stock in the 2017 landings for each fleet, with plaice highlighted).

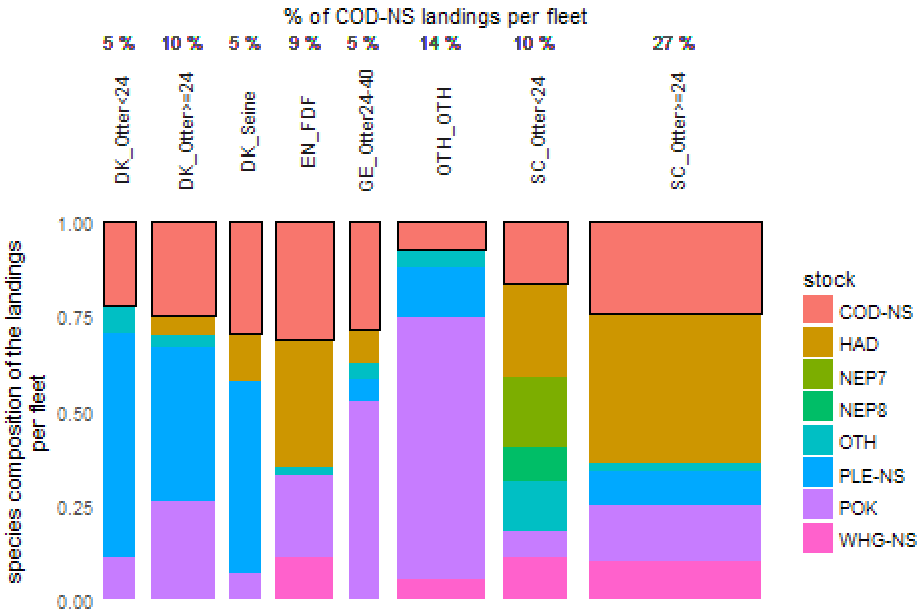


Figure 4.9: Main fleets contributing to 80% for the landings for North Sea cod (bar width proportional to the percentage of the 2017 cod landings taken by each fleet) and landing composition of each of these fleets (colouring of the bar indicating the percentage of each stock in the 2017 landings for each fleet, with cod highlighted).

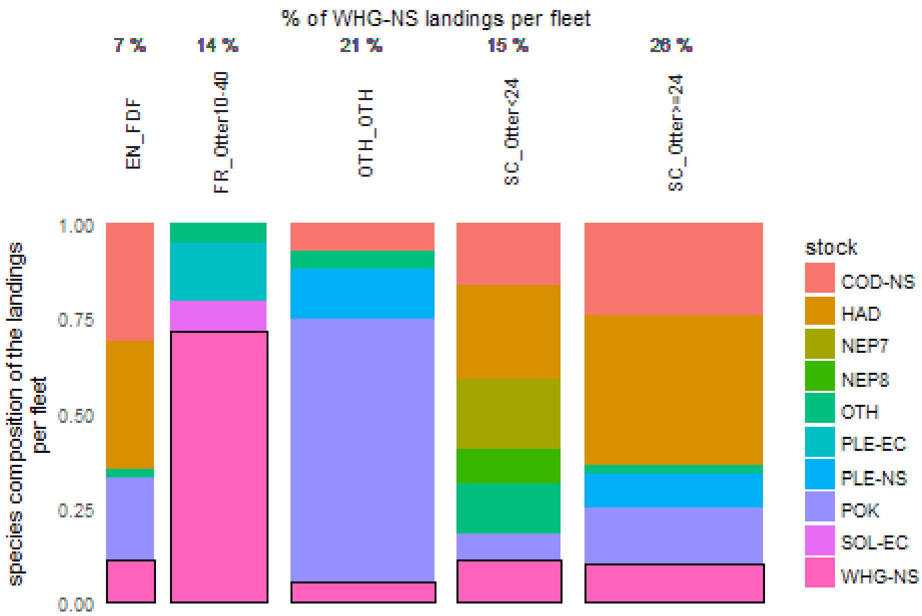


Figure 4.10. Main fleets contributing to 80% for the landings for North Sea whiting (bar width proportional to the percentage of the 2017 whiting landings taken by each fleet) and landing composition of each of these fleets (colouring of the bar indicating the percentage of each stock in the 2017 landings for each fleet, with whiting highlighted).

4.4 Potential choke effect of roundfish stocks in the flatfish targeting fisheries

The outcome of the latest North Sea mixed fisheries forecast (ICES WGMIXFISH-ADVICE 2018) can be used to investigate the importance of the roundfish stocks for fleets targeting flatfish. The case of the 4 Dutch fleets included in the model (3 beam trawl fleets and 1 otter trawl fleet, all catching mainly flatfish) is taken here as example.

The mixed fisheries forecast produces an estimate of the effort needed by each fleet to catch its quotas for the different stocks. Comparing these efforts indicates which stocks are the least limiting and most limiting stocks.

For these flatfish targeting fleets, the most limiting species will be whiting (in red on Figure 4.11). The effort needed to catch the whiting quota, especially for the beam trawlers, is very small compared to the effort corresponding to the quota of the main target species of these fleets (plaice and sole). This indicates that whiting is likely to be a choke species for the Dutch demersal fisheries in 2019. For these 4 fleets, the second most limiting stock is cod.

The current North Sea model therefore shows that these flatfish targeting fleets are likely to be limited by their limited roundfish quotas. This indicates that important constraints in the system would be completely eluded if the mixed fisheries advice was to be given based on separate models for flatfish and roundfish fisheries

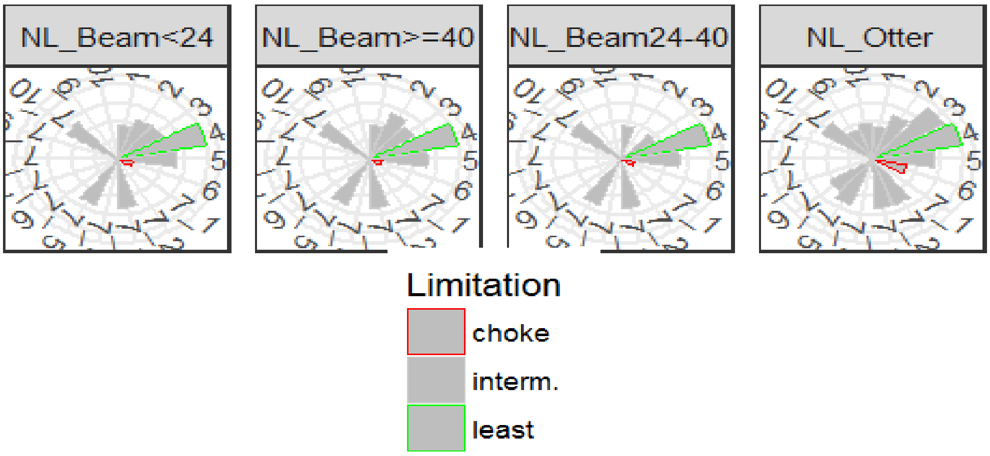


Figure 4.11. Estimates of effort by fleet needed to reach the single-stock advices. Red triangles highlight the most limiting species for that fleet in 2019 ("choke species"), whereas the green triangles highlight the least limiting species. (1: cod 27.47d20; 2: had 27.46a20; 3: Plaice 27.420; 4: pok 27.3a46; 5: sol 27.a; 6: whg 27.47d; 7_1: NEP10; 7_2: NEP32; 7_3: NEP33; 7_4: NEP34; 7_5: NEP35; 7_6: NEP6; 7_7: NEP7; 7_8: NEP8; 7_9: NEP9; 7_10: NEPOTH; 9: ple 27.7d; 10: sol 27.7d).

4.5 Economic aspects

The demersal mixed fishery model for the North Sea defines fleets by vessels with similar length class and predominant fishing gear, while further segmentation into métiers is based on fishing operations with a similar exploitation pattern (e.g. based on similar target species, gear, area). Presently, WGMIXFISH-ADVICE uses the FCube model (Ulrich *et al*., 2011) to provide advice on quota uptake under a variety of scenarios, helping to identify incompatibilities between single species advice (TACs) in a mixed fisheries context. The group has also been advancing towards supplementing this advice with additional economic information. Towards this goal, a parallel version of the North Sea model has been implemented in FLBEIA (Garcia *et al*., 2017, 2012), which allows for the integration of economic data (e.g. fixed and variable costs, price). A preliminary version of model has already been used in medium-term scenarios that address the economic consequences of strict Common Fishery Policy implementation (e.g. fishing at MSY levels, discard ban) (Taylor *et al*., 2018). Although some of the fleets are likely to primarily target a single stock aggregate, there are also fleets that show a more mixed pattern due to their métier allocations (e.g. see Section 4.4.). Disaggregating fleet capacity and fishing effort into separate roundfish and flatfish models would likely undermine the ability to address economic questions in a clear and realistic manner, since some economic variables (e.g. fixed costs) are more relevant at the fleet level.

4.6 Conclusions and ways forward

The analyses above have provided a very detailed picture of the level of mixing between roundfish and flatfish in the North Sea demersal fisheries.

While it is undeniable that a majority of the fisheries, in terms of overall tonnage, can be considered as displaying low levels of mixing between flat- and roundfish, the analyses presented here have also shown that the mixing is far from negligible. This is mainly true in some specific areas (e.g. Centre-East of the North Sea), some specific gears (e.g. TR2) and for some specific countries (e.g. Denmark). But ultimately, most fleets have a degree of mixing, and no country lands exclusively one of the two types of fish, not even the Netherlands or Scotland, All together, the WGMIXFISH considers that the separation of what would constitute a round- or a flatfish fishery is not clear and distinct enough to justify splitting the model. Splitting the model would raise a lot of questions and create a lot of difficulties regarding where to draw the border lines, and which gears and fleets to include in each sub-model. It would also lose the ability to account for the diverse sources of revenue and the recognition of the ability of the fleet to switch target species if one stock becomes in a poorer state. Such ongoing adaptation to e.g. targeting saithe to targeting plaice following quota availability has been documented for a Danish demersal trawler by Mortensen *et al.* (2018). Splitting the model would also go against the efforts made over the last few years to increase the number of stocks in the model, including several important bycatch stocks.

Instead, the WGMIXFISH considers more appropriate to improve the analysis of the actual quota limitations in the fishing fleets, to define whether a stock could be truly limiting in the "min" scenario". The first step of this was developed in ToR d) of the 2018 Working Group, where quota limitations within a country were investigated using the FIDES TAC database and the Choke Mitigation Tool (CMT) developed by the North Western Water Advisory Council (Rihan, 2018).

4.7 Future development

The North Sea MIXFISH model is continually being updated in response to the changing stock status as determined within WGNSSK. In addition, the involvement of group members in various EU projects with mixed fisheries components has resulted in adaptations in the model structure to allow for a more flexible framework. One such example is the incorporation of data-limited stocks for which only biomass dynamics are modelled (e.g. SPiCT model, Pedersen and Berg, 2017). With these adaptations in place, the working group is presently considering the inclusion of several stocks (Table 4.2), many of which are data-limited flatfish stocks (e.g. turbot, flounder, brill, which flounder, dab, lemon sole). It is of note that the FDI data shows that several of these stocks have substantial landings derived from areas of high mixing.

Turbot is likely to be recognized as a Category 1 stock starting next year, and will most certainly be included in future advice. Other likely candidates for inclusion are brill and witch founder, for which TAC advice is given and SPiCT models are accepted and used in defining MSY proxy reference points. While not currently used for advice, the addition of non-TAC stocks (e.g. flounder, grey gurnard, dab, etc.) is also of interest in addressing the effects of mixed fisheries on bycatch species, and the case study members are likely to address these aspects in ongoing projects.

Table 4.2. Prospective stocks for WGMIXFISH-ADVICE inclusion

Stock	Common name	Cat.	Benchmarks	Advice frequency (Next)	Remarks
tur.27.4	turbot	3 (1)	2017, 2018, 2020	Biennial (2019)	SAM assessment since 2015, with 2 over 3 HCR based on SSB output; Survey data and commercial LPUE indices are used; Likely moving to Cat. 1 in 2019; Combined TAC with brill.
fle.27.3a4	flounder	3	2018	None	No advice given from 2017 onwards; advice based on 2 over 3 HCR using survey trends. LBI and SPiCT assessment available for MSY proxy reference points. Combined TAC with dab until 2016; none since.
brill.27.3a47de	brill	3	2020	Biennial (2019)	Biennial advice is provided based on the LPUE trends of the Dutch beam trawl fleet. Length-based indicators and SPiCT model provide MSY proxies. Combined TAC with turbot.
wit.27.3a47d	witch flounder	3	2018	Biennial (2020)	SAM and SPiCT assessment, but SAM is used for stock status; IBTS CPUE indices used; biennial advice; Currently, lemon sole and witch flounder are managed under a combined species TAC
gug.27.3a47d	grey gurnard	3	None	None	2 over 3 rule; Length based methods were tested in order to define MSY proxy reference points for this stock; Given that the catch data are highly uncertain and only available for a short time period, the SPiCT model was not considered as an option for MSY proxies. Grey gurnard in Subarea 4, Divisions 7.d and 3.a is a non-target stock with no TAC. ICES has not been requested to provide advice on fishing opportunities for this stock
dab.27.3a4	dab	3	2016	None	2 over 3 rule based on SSB from IBTS–Q1 ; SURBAR used to derive evaluate stock status; SPiCT used for MSY proxy reference points - showing reference FMSY proxy and the relative biomass is above the reference BMSY proxy; non-target species with no TAC
ang.27.3a46	anglerfish	3	2018	Annual	SPiCT assessment exists, but not used. 2 over 3 rule used for advice (based on survey index).
lem.27.3a47d	lemon sole	3	2018	Biennial (2020)	SPiCT assessment for this stock was rejected; Age-structured survey indices with deltaGAM; advice based on the 2 over 3 rule, applied to relative SSB estimates from SURBAR; Stock status in relation to Fmsy proxies was to be evaluated using a suite of length-based indicators (LBIs); biennial advice

5 Terms of Reference D - Assess the model sensitivity and potential impact of using the actual quota by fleet/country (e.g FIDES data base) rather than the last year observed share on the mixed fisheries scenarios results.

5.1 Background

The objective of this study is to investigate the assumptions made in the mixed-fisheries advice "min" scenario, and in particular whether some fleets can actually be potentially choked by some stocks.

FCube calculations assume a sharing of future fishing opportunities across the various fleets. In the real life, there is no such thing as a relative stability by fleet, since the TACs are initially shared across Member States, which each have different procedures to allocate the national quota to the various fishers. Additionally, Member States swap quotas throughout the year, so the final quota share is often not the same as the initial relative stability share.

The current procedure in FCube is thus to estimate a kind of "relative stability proxy", allocating future opportunities by fleet (e.g. Target partial F in 2019) based on their proportion in landings of a given stock in 2017.

The issue with this assumption is that a fleet can end up in a choke situation in the model, even if in reality that fleet has access to quota in the country but is not catching it. For example, a given French fleet has low catches of haddock in 2017, which gives a low proportion of the total F for that stock. If haddock advice decreases this gives a low target partial F 2019 for that fleet. At equal catchability, this means that there requires fewer days to reach that target F. Haddock can thus become a choke species for that fleet in the FCube model, even though in reality there might be a lot of unused haddock quota in France.

The idea of that ToR is thus to explore how to include information on Member States' quota in the FCube model.

5.2 Levels of choke issues

An important milestone in the understanding of the problem has been **the need to identify the various types of possible choke situations**, and to **characterise their causes and responsibility**. It has been recognized that choke issues can potentially occur at various levels, depending whether the shortage of quota is due to a poor status of a stock or a poor distribution of fishing rights. The Advisory Councils (NSAC, 2017[2]) have developed a system for categorizing choke problems as follows:

- **Category 1**: Sufficient quota at Member State level—choke is due to distribution within the Member State such that a region, a fleet segment or an individual vessel does not have enough but this can be resolved by the Member State itself.
- **Category 2**: Sufficient quota at EU level, but insufficient quota at MS level—choke is due to a mis-match of catches and the distribution of quotas between Member States and can theoretically be resolved between themselves in a regional context.

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[2] NSAC. 2017a. NSAC Advice Ref. 14-1617. Managing Fisheries within the Landing Obligation. http://nsrac.org/wp-content/uploads/2016/12/14-1617-Managing-theFisheries-within-the-Landing-Obligation-1.pdf.

- **Category 3**: Insufficient quota at EU level—choke is due to insufficient quota within the relevant sea basin to cover present catches or catch levels that can be realistically reduced, resulting in a total stop of fishing for a Member State or Member States.
- **Category 4**: Economic choking may occur at the vessel level when there is a considerable bycatch of a low value species and the boat is filled with fish that will not deliver a profit.

The (NSAC, 2017) did also acknowledge that that all parties, from the deck and wheelhouse of each fishing vessel, to the Commission, Member States and the co-legislators, the European parliament and the Council, can contribute to prevent choke situations (Figure 5.1).

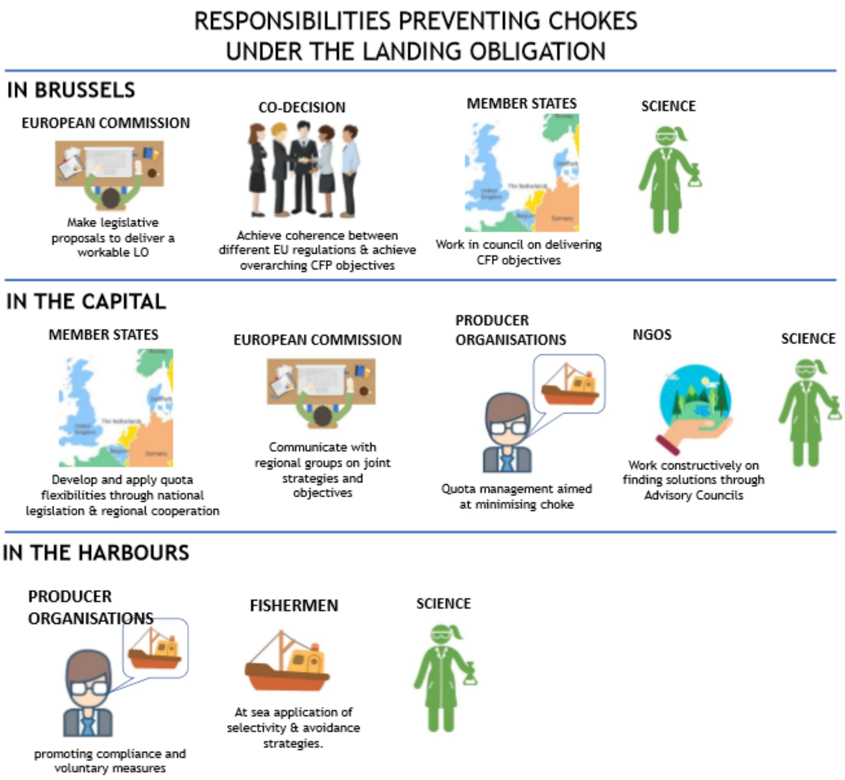

Figure 5.1 Responsibilities preventing choke under the landing obligation

5.3 The Choke Mitigation Tool

The Choke Mitigation Tool (CMT) relates to analyses initiated by the NWW Advisory Council (NWWAC 2016[3], Rihan, 2018[4]) to compare the catches (including discards) of each Member State with its quota, both initial and final after swaps, and considering the quota uplift corresponding to discards

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[3] http://www.nwwac.org/publications/north-western-waters-choke-species-analysis-2016.2448.html

[4] [4] http://www.europarl.europa.eu/RegData/etudes/STUD/2018/617472/IPOL_STU(2018)617472_EN.pdf

The calculations of the CMT for 2017 are based on the Union TAC with estimated full uplift (both uplift already included in TAC and additional discards estimates not yet included in the Union TAC – see below). Then for each Member State:

- Initial Quota share = Initial quota / Union TAC (without estimated uplift)
- Initial quota + full uplift = Union TAC with full uplift * initial quota share
- Reported landings (from WGMIXFISH database)
- Estimated discards (from WGMIXFISH database)
- Estimated total catches = reported landings plus estimated discards
- Discard rate (estimated discards/estimated catch)
- Reported Landings / Initial quota
- Reported landings / final quota
- Estimated catches / initial quota
- Estimated catches / final quota
- Estimated catches / initial quota + full uplift (in proportion)
- Estimated catches - initial quota + full uplift (in tonnage)

Accordingly, the Choke Mitigation Tool calculations were implemented in R and applied for 2017 using the WGMIXFISH dataset and the TAC and quotas 2017 data obtained from the EU FIDES database, which records the initial and final (after swaps) quota by member state.

A few data handling /assumptions were made to achieve consistency between the different datasets:

- All English and Scottish WGMIXFISH data were summed together as "UK"
- All *Nephrops* data excluding FU 32 in Norwegian zones were summed
- TAC and quotas by areas were summed up at the stock level (e.g. Cod in North Sea, Skagerrak and Eastern Channel)
- The Eastern Channel plaice WGMIXFISH data is compared with the TAC and quotas for the entire Channel (East + West), which is thus an underestimation of the potential choke effect as Western Channel catch data are not in the WGMIXFISH data
- Conversely, the whiting stock covers the Eastern Channel as well, but is compared only to the North Sea TAC and quotas, which gives an overestimation of the choke effect as the Eastern Channel catches belongs to the larger TAC in Area VII.

The Scheveningen Group in collaboration with the NSAC has implemented a gradual implementation by stock and fishery of the landing obligation in the North Sea (Table 5.1), where the simplest cases were implemented earliest.

Table 5.1 Gradual phasing-in of the landing obligation in the North Sea demersal fisheries

Fishery	Cod	Haddock	Saithe	Whiting	N. lobster	Sole	Plaice	N. prawn	Hake
TR1	2017	2016	2016 /2018	2017	2017	2017	2016	2016	2019
TR2	2018	2016	2018	2018	2016	2016	2019	2016	2019
GN/GT	2017	2017	2018	2017	2017	2016	2019	2016	2019
LL	2017	2017	2018	2017	2017	2017	2019	2016	2016
BT1	2018	2017	2018	2017	2017	2017	2017	2016	2019
BT2	2018	2017	2018	2018	2017	2016	2019	2016	2019
TRAPS	2018	2017	2018	2017	2016	2017	2019	2016	2019
Trawl 32–69 mm	2018	2017	2018	2017	2017	2017	2019	2016	2019

In the Eastern Channel, the landing obligation including uplift applied for whiting and sole in 2017.

For the stocks and fisheries already included in the LO in 2017 according to the table above, the uplift is already included in the 2017 TAC. MIXFISH discards estimates for the corresponding metiers were summed, and deduced from the estimated Union TAC plus uplift.

The initial and final (after swaps) quotas by stock and Member State are compared to the landings (Figure 5.2), both in absolute value (top) and as proportion (share of the Union TAC vs. share of the total landings for that stock).

The figure illustrates where the quotas are well utilised, where swaps have been necessary, and where they are unutilised.

The resulting CMT calculation of Tonnage Difference between the 2017 estimated catches and the potential (initial quota + full uplift) by stock and Member State is displayed figure 5.3. The countries with a negative difference can be expected to experience choke situation in 2019 if the Landing Obligation is fully implemented and enforced.

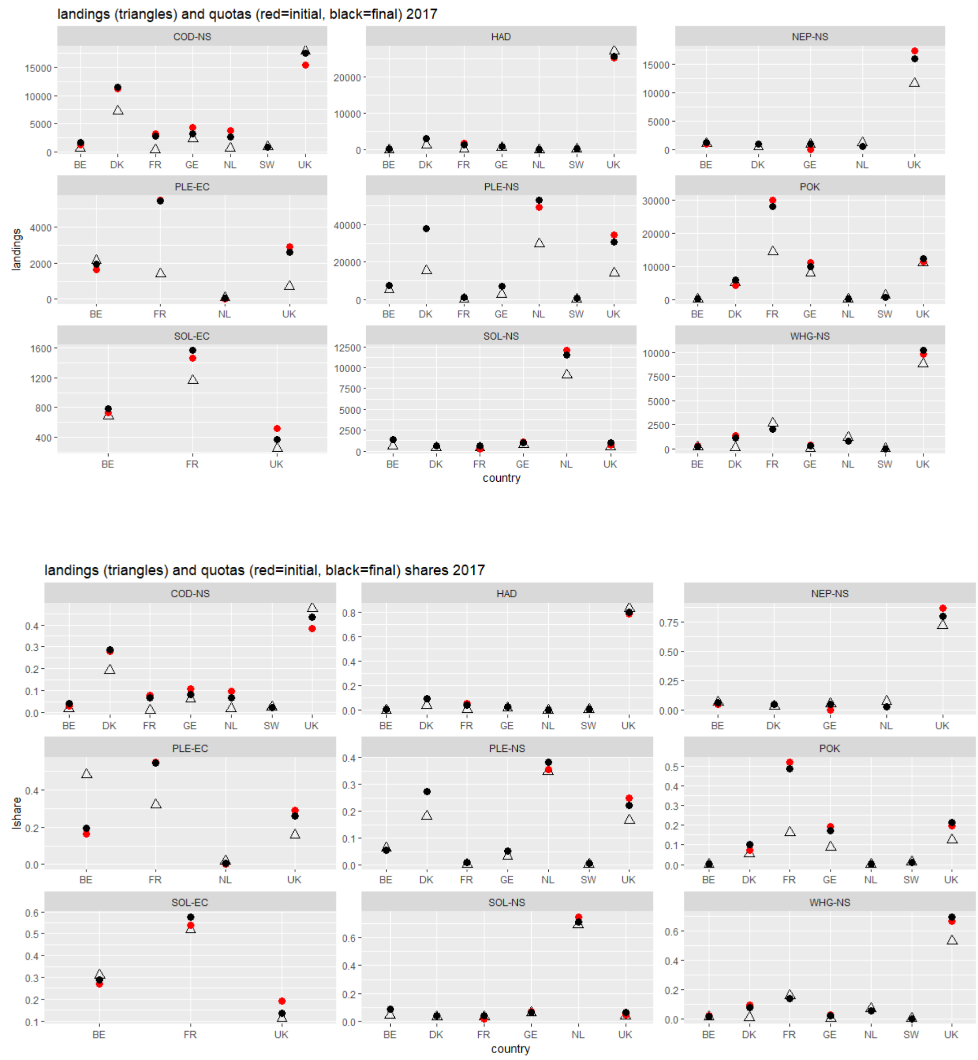


Figure 5.2. Landings and quotas 2017.

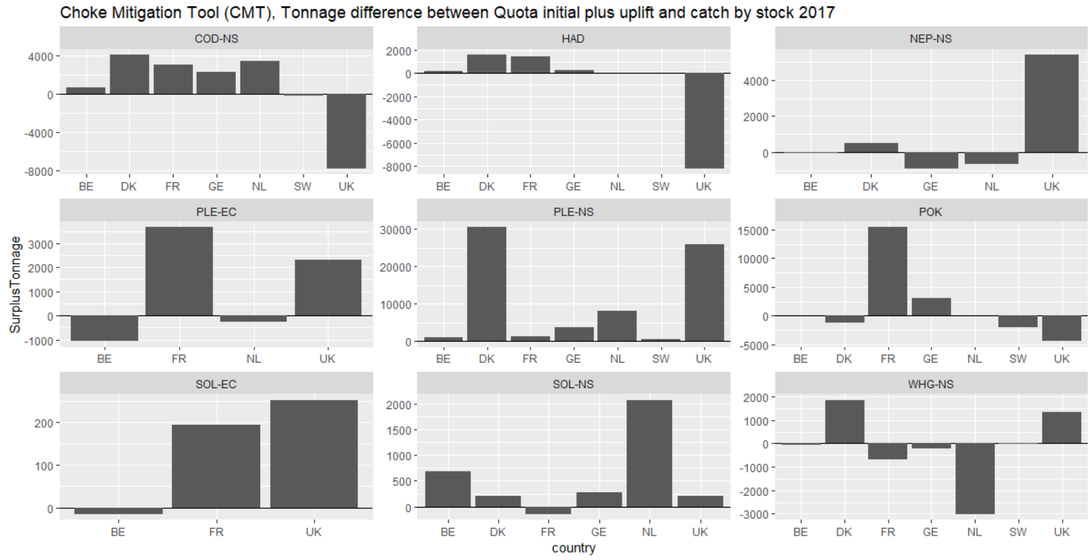


Figure 5.3. Choke mitigation tool (CMT). Tonnage difference between quota initial plus uplift and catch by stock in 2017.

5.4 Inclusion of CMT approach in FCube projections

If a Member State has a lot of unused quota for a stock, that stock shall not be estimated to be a choke species for the fleets of that Member State. This addresses the ChokeCategory 1. The possible imperfect allocation between fleets within a Member State are not included here.

If a stock cannot be a choke, this means that it shall not be able to limit the estimated fishing effort of the fleet in the "min" scenario. The procedure included in FCube is as follows:

- Estimation of Partial F by country in 2019 (Target F * initial quota share [relative stability]
- Calculation of Potential F by country at status quo: Sum of 2017 effort*catchability by fleet of the country
- If Partial F by country in 2019 > Potential F by country at status quo then the stock does not enter the "min" scenario for the fleets of that country

The first exploratory run achieved during WGMIXFISH meeting gave results displayed in Figure 5.4. As expected, the "Min" scenario becomes less restrictive for a number of fleets.

This ToR could not be fully finalised and investigated further during the course of meeting week, and will be completed before or during the next MIXFISH Working Group in 2019.

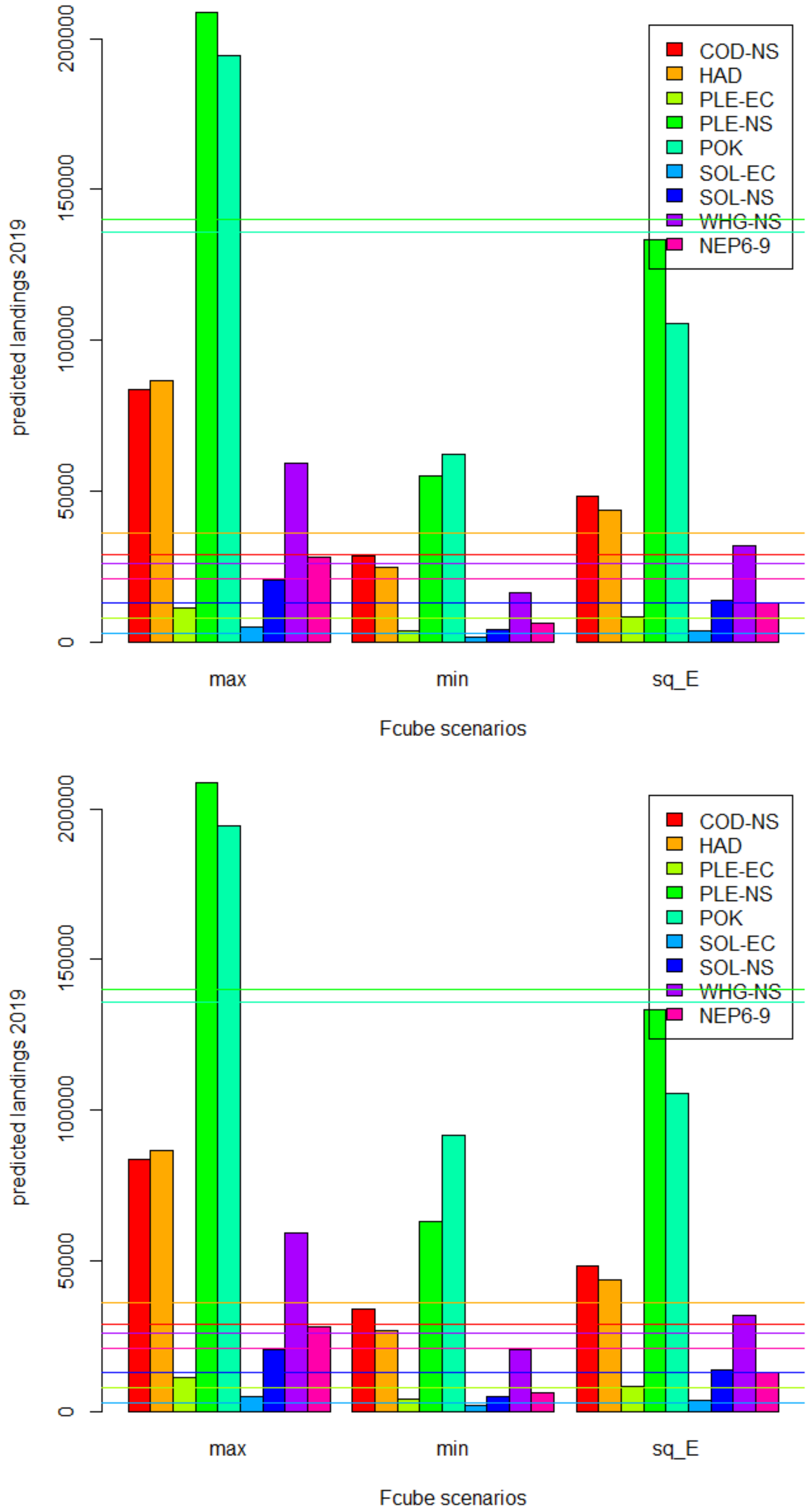


Figure 5.4. First exploratory run without (Top) and with (bottom) the CMT correction in the "min" scenario.

6 Terms of Reference E - Develop models for mixed fisheries in the Bay of Biscay

6.1 Application of the Fleet and Fishery Forecasting method “FCube” to the Bay of Biscay

Annual mixed fishery advices are currently given for the North Sea and the Celtic Sea eco-regions and the Iberian Waters (ICES, 2018a). Such advices are required to meet the needs under the new Common Fisheries Policy to account for both technical and biological interactions between fisheries and stocks. In the past, the lack of métier-disaggregated catch and effort data has limited the development of mixed fisheries approaches in the Bay of Biscay but the use of the ICES InterCatch for the transmission and processing of biological and catch data to assessment working groups, and the joint WGBIE-WGMIXFISH data call, with métier-disaggregated catch and effort data, allow to make available the data needed to develop advisory methods to this eco-region.

As a first step towards mixed fisheries advice for the Bay of Biscay (part of the Bay of Biscay and Iberian coast eco-region), an application of the Fleet and Fishery Forecasting method “FCube” methodology (Ulrich *et al.*, 2011) has been developed over the past two years. At this stage, the objective of the analysis was mainly to demonstrate the feasibility of the approach and only two stocks (in a preliminary attempt) and then three stocks with analytical assessments (Hake, *Merluccius merluccius*) in Division 3.a, subareas 4, 6 and 7 and divisions 8.a,b,d (Northern stock), Bay of Biscay sole (*Solea solea*) and Megrim (*Lepidorhombus whiffiagonis*) in divisions 7b-k and 8a,b,d), considered as the most suitable initial candidates, were included. As more stocks from the Bay of Biscay are now assessed analytically, this approach could be developed and extended to further stocks for which important biological and technical interactions are taking place in the Bay of Biscay; good candidates are Bay of Biscay *Nephrops*, Bay of Biscay sea bass (*Dicentrarchus labrax*) and anglerfish (*Lophius piscatorius*) in Subarea 7 and divisions 8.a,b,d.

It is also important to highlight that various mixed fishery approaches are being developed for this area, using either the FLBEIA (Garcia *et al.*, 2012) or IAM (Merzereaud *et al.*, 2011) framework and that such approaches could be a complement to the FCube methodology. Future work may therefore include comparison of the different available approaches to identify the suitability of the methods for meeting different advisory objectives (i.e. short term advice, long-term management strategy evaluation etc…), as part of the general development of mixed fisheries advice.

6.2 Fisheries

The Bay of Biscay covers ICES divisions 8a,b,d. Fisheries are targeting a large range of species with different gears. Trawl fisheries (using otter, beam and pelagic trawl) take place for *Nephrops*, hake, anglerfishes, megrims, sole, sea bass as well as cephalopods (cuttlefish and squid). Net fisheries target sole, hake, pollack, seabass, anglerfishes as well as some crustacean species while a longline fishery targets hake. The fisheries are mainly carried out by French and Spanish vessels though some Belgian beam trawl vessels target sole.

Fishing operation (and the associated fleets) catching hake in ICES Division 3a and subareas 4, 6 and 7 and megrim in Subarea 7 are also included in the current analysis to account for the whole fishing mortality on that species. Fishing operation in those areas are carried out mainly by vessels from Spain, France, Ireland and UK.

6.3 Data

6.3.1 Stock input data

The assessment data for the three stocks were taken from WGBIE (ICES, 2018b). Stock input data are not currently available as FLRStock objects. For sole, the assessment being carried out with XSA, the conversion of the data to FLRStock object was straightforward. For hake and megrim however, the assessment is carried out using differente software which makes the conversion into a FLRStock object more cumbersome. For hake, the assessment, implemented in Stock Synthesis (Methot and Wetzel, 2013) is carried out using a quarterly step stock dynamics and quarterly cohorts (called "morph"). The quarterly population dynamics parameters (numbers at age, fishing mortality at age) estimated by Stock Synthesis were thus converted into yearly quantities so they could be directly included into FCube FLR.

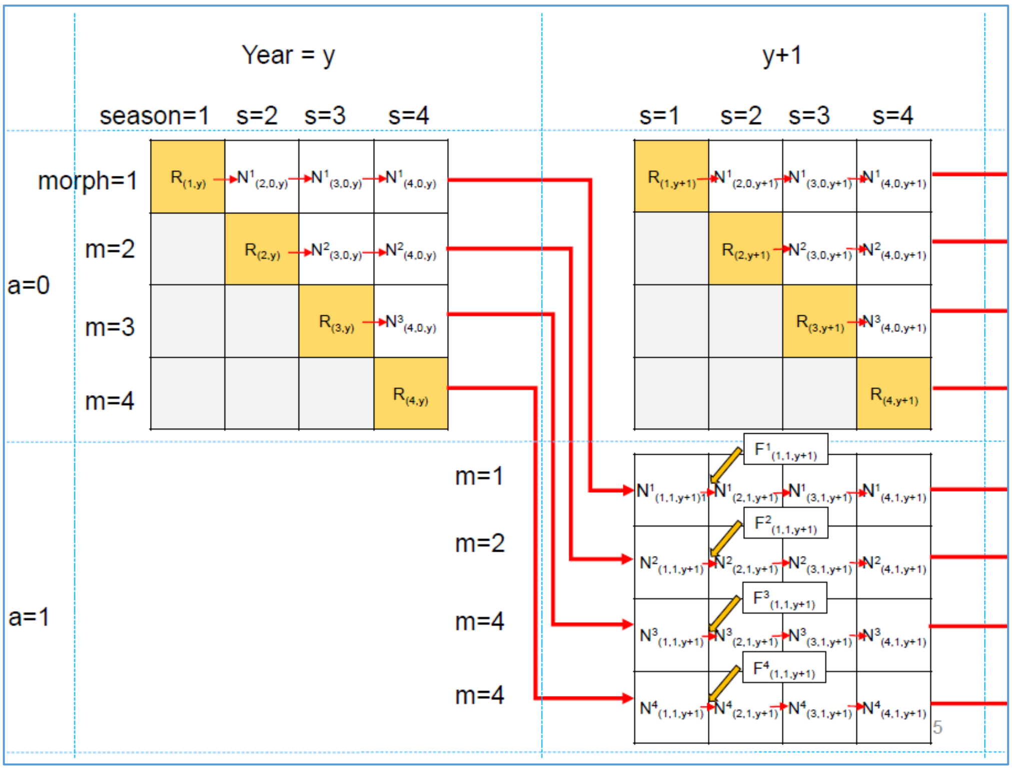


Figure 6.1 presents a simplified version of the quarterly stock dynamics as currently implemented in Stock Synthesis for hake. Each year is divided into 4 seasons (corresponding to 4 quarters) and the fate of 4 cohorts (or morphs) by age class are followed along the quarterly time steps. Each cohort recruits in a different quarter. For each year, age group and trimester, a morph dependent fishing mortality is applied to each morph $F^{m}_{s,a,y}$.

The numbers at age in the population (input to the FLR stock object) were calculated by summing up the number of survivors of each morph at the start of the year (quarter 1):

$$N_{a,y} = \sum_{m=1}^{nmorphs} N_{1,,a,y}^{m}$$

F at age by season were computed as a weighted sum of the morph dependent fishing mortalities:

$$F_{s,a,y} = \sum_{m=1}^{nmorphs} \left(N_{s,a,y}^{m} \Big/ \sum_{m=1}^{nmorphs} N_{s,a,y}^{m} \right) * F_{s,a,y}^{m}$$

They were then averaged over the 4 quarters to compute the annual F at age:

$$F_{a,y} = \frac{\sum_{s=1}^{nseas} F_{s,a,y}}{nseas}$$

For megrim, the assessment is carried out using a Bayesian catch-at-age statistical model and the median of the population dynamics parameters provided by WGBIE were used as input to FCube.

6.3.2 Catch and effort input data

We used métier-based landing and effort files requested by the WGMIXFISH data call from 2018. The procedure to define the fleets and métier in the model were similar to those applied in the North Sea or the Celtic Sea. In summary:

- 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 an "others" ("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 areas (either "Bay of Biscay" or "Other areas" (Celtic Sea, West of Scotland and North Sea).

The final data used contained 35 national fleets from four countries (Table 6.1), covering landing and effort for the years 2015, 2016 and 2017. These fleets engage in one to eight different métiers each, among a total of 13 métiers. Several fleets still represent a small amount of catches and could be combined in order to reduce the total number of fleets. This will be carried out in further analyses.

Table 6.1. Fleets used in the Bay of Biscay analysis and corresponding total landings by year and stock

	2015	2016	2017

Fleets	HKE	MEG	SOL	HKE	MEG	SOL	HKE	MEG	SOL
ESP_Gillnet_<10 m							12	0	1
ESP_Gillnet_10<24 m	19	0		9	0		13		0
ESP_Gillnet_24<40 m	271	0		298	1		362	0	
ESP_Gillnet_all	1965	2	0	2378	5	0	1622		0
ESP_Longline_10<24 m	48			45			108		0
ESP_Longline_24<40 m	1751			3267			3009		
ESP_Longline_all	21283			24009			15469		
ESP_Trawl_>=40 m	131	46		126	53		233	47	2
ESP_Trawl_24<40 m	7747	3697	6	8553	3743	4	5869	3120	4
FR_Gillnet_all	21750		2561	20412		2257	20508	5	2161
FR_Longline_all	8782			10422			11014		
FR_Other_all	322	52	23	267	29	20	74	102	17
FR_Trawl_<10 m	8	0		10	0		7	0	
FR_Trawl_>=40 m	1986	0		2851	0		2668	0	
FR_Trawl_10<24 m	1037	2600		1252	2760		1520	477	
FR_Trawl_24<40 m	2305	413		2608	349		2333	2351	
FR_Trawl_all	6475		907	6774		822	6417	2170	797
IE_Gillnet_10<24 m	581	47		776	68		826	56	
IE_Gillnet_24<40 m	87			111	1		111	0	
IE_Trawl_10<24 m	1061	1732		1363	2092		1427	1878	
IE_Trawl_24<40 m	961	1276		1138	1398		1003	1379	
OT_Gillnet_10<24 m	207			122			160		
OT_Other_<10 m	6			17			28		
OT_Other_10<24 m	497			781	0		85		
OT_Other_24<40 m	12	0		17			2543	0	
OT_Trawl_10<24 m	736	0		456	0		326	0	
OT_Trawl_24<40 m	5040	495		5818	597		3608	733	
UK_Gillnet_all	1278	4	0	1239	5		1427	5	
UK_Longline_all	4379			5124	0		4210		
UK_Other_all	855	3		1431	3		736	2	
UK_Trawl_<10 m	2	13		2	11		1	18	
UK_Trawl_>=40 m	180			162			162		
UK_Trawl_10<24 m	947	260		604	258		939	240	
UK_Trawl_24<40 m	3661	2544		4785	2458		5257	2262	
UK_Trawl_all	8	1		2	0		8	1	
Total	**96378**	**13187**	**3497**	**107230**	**13831**	**3103**	**94099**	**14848**	**2983**

The balance of landings of the stocks across gear categories is shown in Figure 6.1. As a large proportion of hake and megrim landings are caught in area outside the Bay of Biscay, technical interaction with the Bay of Biscay sole stock is limited to few métiers. In order to get a more relevant interaction analysis for the Bay of Biscay, this stresses the need to expend this work to other stocks and/or métiers where potential interactions are important (sea bass, *Nephrops* and anglerfish for example).

As indicated by Table 6.2, a "limited" number of fleets are sharing their fishing effort between métiers carried out inside and outside the Bay of Biscay. It may thus be useful, for the different FCube scenarios, to consider alternative hypothesis of effort levels for the métiers carried out outside the Bay of Biscay. These could be kept constant instead of varying, as this is the currently the case, in proportion of the overall fishing effort of the fleet. This analysis may also be considered, for consistency of the advice, in relation with the analysis carried out for the other areas part of the WGMIXFISH advice and which share common stocks and fisheries (Celtic sea and North Sea).

Table 6.2. Effort share by métier (in %) for each fleet included in the FCube analysis

	Metiers													
Fleets	GNS_DEF_Biscay	GNS_DEF_Other	LLS_DEF_Biscay	LLS_DEF_Other	MIS_MIS_Biscay	MIS_MIS_Other	OTB_CRU_Biscay	OTB_CRU_Other	OTB_DEF_Biscay	OTB_DEF_Other	OTH	PTB_DEF_Biscay	SSC_DEF_Biscay	SSC_DEF_Other
ESP_Gillnet_<10m	100	0	0	0	0	0	0	0	0	0	0	0	0	0
ESP_Gillnet_10<24m	100	0	0	0	0	0	0	0	0	0	0	0	0	0
ESP_Gillnet_24<40m	29	71	0	0	0	0	0	0	0	0	0	0	0	0
ESP_Gillnet_all	80	20	0	0	0	0	0	0	0	0	0	0	0	0
ESP_Longline_10<24	0	0	100	0	0	0	0	0	0	0	0	0	0	0
ESP_Longline_24<40	0	0	9	91	0	0	0	0	0	0	0	0	0	0
ESP_Longline_all	0	0	19	81	0	0	0	0	0	0	0	0	0	0
ESP_Trawl_>=40m	0	0	0	0	0	0	0	0	100	0	0	0	0	0
ESP_Trawl_24<40m	0	0	0	0	0	0	0	0	23	68	0	9	0	0
FR_Gillnet_all	69	31	0	0	0	0	0	0	0	0	0	0	0	0
FR_Longline_all	0	0	45	55	0	0	0	0	0	0	0	0	0	0
FR_Other_all	0	0	0	0	21	79	0	0	0	0	0	0	0	0
FR_Trawl_<10m	0	0	0	0	0	0	5	0	34	62	0	0	0	0
FR_Trawl_>=40m	0	0	0	0	0	0	0	0	0	100	0	0	0	0
FR_Trawl_10<24m	0	0	0	0	0	0	0	0	36	64	0	0	0	0
FR_Trawl_24<40m	0	0	0	0	0	0	0	0	3	96	0	0	0	0
FR_Trawl_all	0	0	0	0	0	0	9	2	48	34	0	0	3	3
IE_Gillnet_10<24m	0	100	0	0	0	0	0	0	0	0	0	0	0	0
IE_Gillnet_24<40m	0	100	0	0	0	0	0	0	0	0	0	0	0	0
IE_Trawl_10<24m	0	0	0	0	0	0	0	31	0	63	0	0	0	6
IE_Trawl_24<40m	0	0	0	0	0	0	0	27	0	69	0	0	0	4
OT_Gillnet_10<24m	0	100	0	0	0	0	0	0	0	0	0	0	0	0
OT_Other_<10m	0	0	0	0	0	100	0	0	0	0	0	0	0	0
OT_Other_10<24m	0	0	0	0	0	100	0	0	0	0	0	0	0	0
OT_Other_24<40m	0	0	0	0	0	100	0	0	0	0	0	0	0	0
OT_Trawl_10<24m	0	0	0	0	0	0	0	91	0	9	0	0	0	0
OT_Trawl_24<40m	0	0	0	0	0	0	0	13	2	80	0	0	0	6
OTHER_fleets	0	0	0	0	0	0	0	0	0	0	100	0	0	0
UK_Gillnet_all	1	99	0	0	0	0	0	0	0	0	0	0	0	0
UK_Longline_all	0	0	0	100	0	0	0	0	0	0	0	0	0	0
UK_Other_all	0	0	0	0	0	100	0	0	0	0	0	0	0	0
UK_Trawl_<10m	0	0	0	0	0	0	0	76	0	24	0	0	0	0
UK_Trawl_>=40m	0	0	0	0	0	0	0	0	0	100	0	0	0	0
UK_Trawl_10<24m	0	0	0	0	0	0	0	42	0	58	0	0	0	0
UK_Trawl_24<40m	0	0	0	0	0	0	0	1	0	99	0	0	0	0
UK_Trawl_all	0	0	0	0	0	0	0	0	0	0	0	0	0	100

All the analysis was performed on catches (landings and discards) except for sole for which discards are limited and not included in the current assessments.

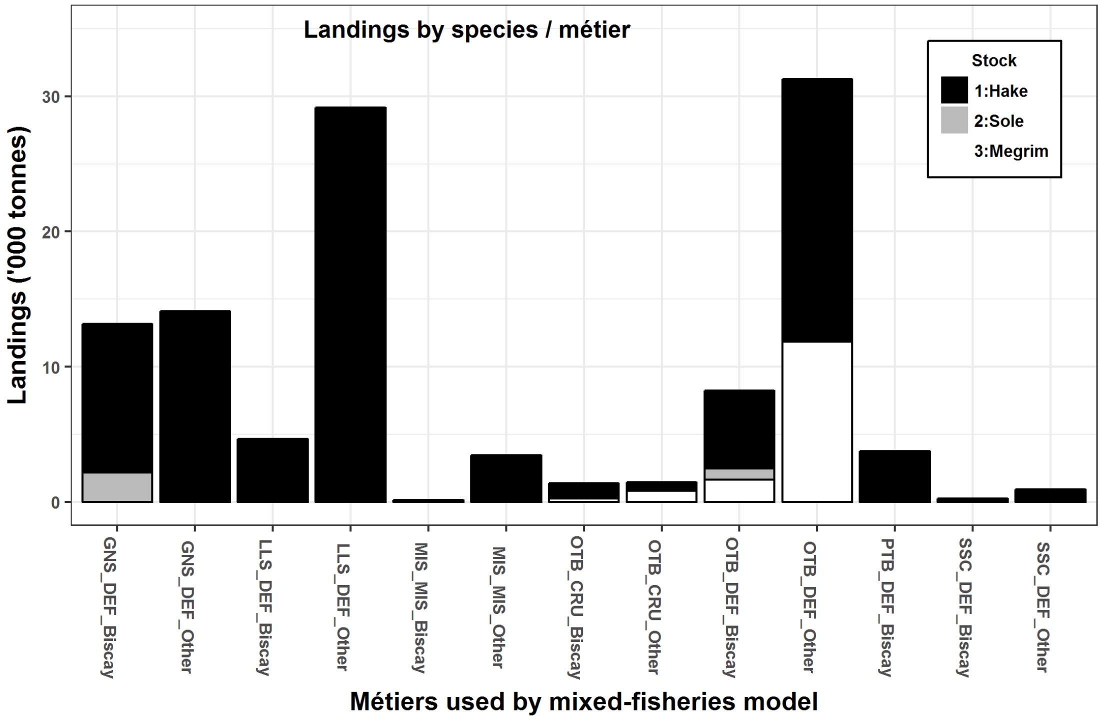


Figure 6.1. Landing distribution of species by métier.

As a cross check of the data, the total landings across all fleets was compared to the values estimated from the single species stock assessments (Table 6.3). It must be noted that the column labelled "WG landings estimated by FCube" correspond to the landings estimated within FCube from the assessment parameter (F, N and weight-at-age). As shown in table 6.3 they are different from the landings used by the working group for hake and megrim. This is because the population dynamics models are slightly different for those two species (see above). Furthermore, for megrim, the population dynamics parameters were only available for the last year of the assessment (2017) and have been used (repeated) for 2015 and 2016. On overall, there is some discrepancy in landings coverage for the three stocks. This discrepancy needs to be investigated further for hake and megrim. For sole, the discrepancy is mainly due to the lack of data from Belgium which will need to be addressed in the next WGMIXfish datacall.

Table 6.3. Proportion of the stocks total landings (from WGBIE) covered by the MIXFISH fleets. A ratio > 1 means that the catch information in WGMIXFISH is higher than the information used by WGBIE.

year	stock	WG landings estimated by FCube	ratio	MIX-fish datacall landings	diff.	WG landings from Intercatch and WG report
2015	HKE	88575	0.92	96378	7803	95023
2016	HKE	104056	0.97	107230	3175	107530
2017	HKE	101982	1.08	94099	-7884	104670
2015	MEG	14283	1.08	13187	-1096	11569
2016	MEG	14283	1.03	13831	-452	11548
2017	MEG	14283	0.96	14848	565	13784
2015	SOL	3638	1.04	3497	-141	3644
2016	SOL	3234	1.04	3103	-131	3232
2017	SOL	3245	1.09	2983	-263	3249

6.4 Results

Results are only presented here to illustrate the feasibility of mixed-fishery short-term forecasts for the Bay of Biscay.

6.4.1 Baseline runs.

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

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

The results from these baseline runs are compared with the results from the corresponding ICES runs in Table 6.4 The replicated forecast for the hake and sole stocks were almost identical to the single stocks advices, even if in the hake case FCube is using a different software and stock dynamic model for short term projections. For megrim however, large discrepancies are observed for the intermediate year (2018) which need to be investigated further intersessionally.

Table 6.4. Comparison between baseline run and ICES advice for the three stocks.

		HKE	SOL	MEG
2018	Landings Baseline	101436	3621	21634
	Landings ICES	103238	3621	18528
	% difference	-2%	0%	17%
2019	Landings Baseline	135135	3872	20603
	Landings ICES	142240	3872	18976
	% difference	-5%	0%	9%

6.4.2 Mixed fisheries runs.

Mixed fishery forecasts were performed based on the scenarios used in the North Sea, the Celtic Sea and the Iberian Waters advice, these scenarios are:

min: Fishing stops when the catch for any one of the stocks considered meets the single-stock advice. This option is the most precautionary option, causing under-utilisation of the single-stock advice possibilities of other stocks.

max: Fishing stops when all stocks considered have been caught up to the ICES single-stock advice. This option causes overfishing of the single-stock advice possibilities of most stocks.

hake: All fleets set their effort corresponding to that required to land their quota share of the hake, regardless of other catches.

megrim: All fleets set their effort corresponding to that required to land their quota share of the megrim, regardless of other catches

sole: All fleets set their effort corresponding to that required to land their quota share of the sole, regardless of other catches.

status quo effort (sq_E): The effort is set equal to the effort in the most recently recorded year for which landings and discard data are available.

Figure 6.2 presents the level of effort required by each fleet to catch their quota share of the single stock TAC advice.

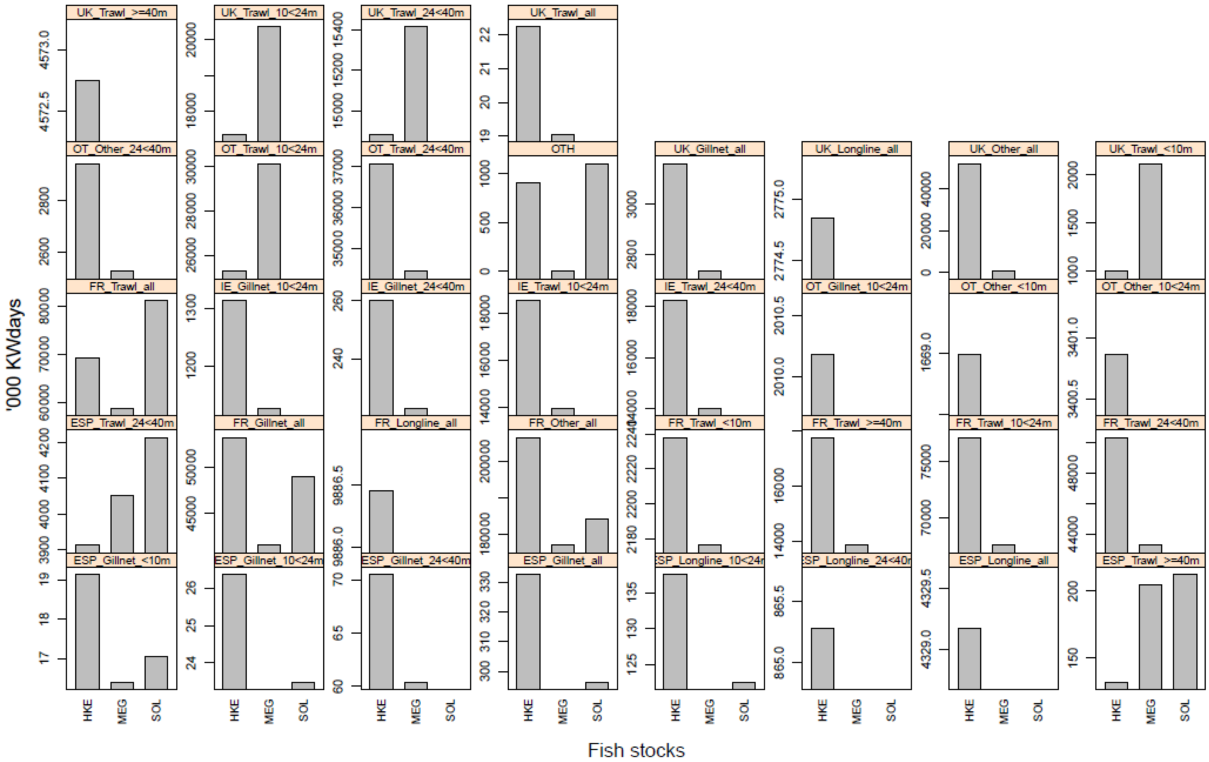


Figure 6.2. Fcube estimates of effort by fleet corresponding to the individual "quota share" by stock in 2017.

The TAC year landings under the mixed fisheries scenarios are summarized in Figure 6.3, with the forecast fishing effort by fleet in Figure 6.4.

The « hake » and « max » are driven by the level of single stock hake fishing effort. They result in over-quota landings for sole and megrim.

The « meg » scenario is driven by the level of single stock megrim fishing effort. For the fleets landing megrim, the fishing effort is reduced to the level of fishing effort required to fulfil the megrim quota for 2019 while for the other fleets, the fishing effort is kept constant. This scenario (together with the min scenario) lead to underutilization of catching opportunity for hake and sole although for sole, the impact is very limited.

The sq_E scenario results in overshoots for megrim while there is an under-shoot of the hake TAC.

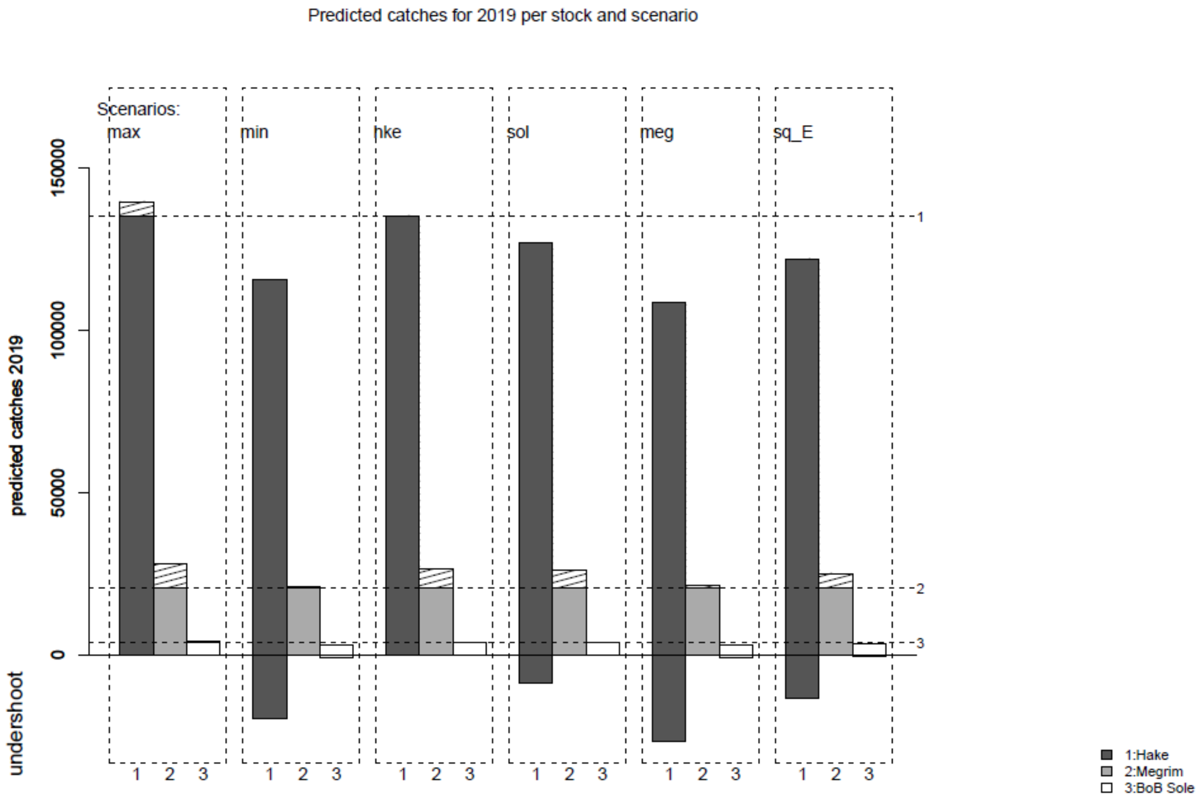


Figure 6.3. TAC year results (2017). Fcube estimates of potential landings by stock after applying the status quo effort scenario to all stocks in the intermediate year followed by the Fcube scenarios. Horizontal lines correspond to the TAC set by the single-stock advice. Bars below the value of zero show the scale of undershoot (compared to the single species TAC) in cases where landings are predicted to be lower when applying the scenario.

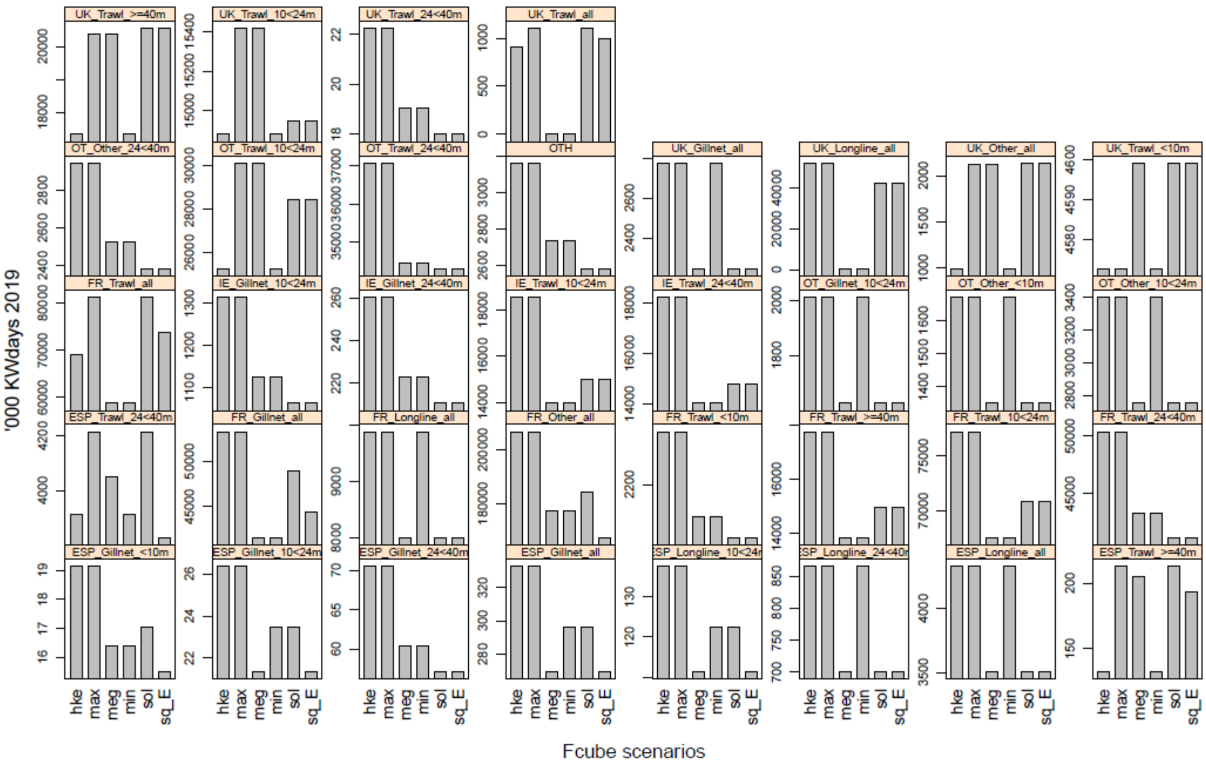


Figure 6.4. Fcube estimates of effort by fleet and by scenario for 2017.

6.5 Conclusions

This analysis shows that it is currently possible to generate Bay of Biscay mixed fisheries considerations based on current available data and the Fcube method. However, one limitation of the present implementation is the somewhat "limited" level of interaction between fleets and métier for the three stocks considered as a large part of the fishing activity on hake and megrim is taking place outside the Bay of Biscay. Further work is needed to take into account other important species that are caught simultaneously with hake and sole. This could include at short term *Nephrops*, sea bass and anglerfish for which analytical assessments are available.

One of the objectives of the analysis was also to test the possibility to parameterize Fcube with stocks assessed with models (Stock Synthesis, Bayesian statistical catch at age) based on a slightly different population dynamics configuration (quarterly time steps and cohorts for Stock Synthesis) than the one implemented in FCube. The results obtained show that for short-term forecast, results obtained for hake are very similar. However, some additional work is still needed for the megrim stock.

6.6 Conditioning of FLBEIA in Bay of Biscay and Iberian Waters

The FLBEIA model was conditioned using the InterCatch data for Bay of Biscay and Celtic Sea. The stocks included were Black and White Anglerfishes, Hake and Megrim.

The fleets were defined as a combination of country, gear and area in the case of Spanish trawlers, because the vessels do not change area. However, in the case for the rest the fleet was defined as a combination of country and gear. Hence, in the case of Spanish trawlers the métiers indicate only the mesh size and target species, and in the rest of the fleets they also indicate the area. The hake catches in the North Sea were aggregated in a single fleet (HKE_NS). Furthermore, the catches of Hake and White Anglerfish of countries different to Belgium, France, Ireland, UK, and Spain in ICES subareas 6, 7, and 8 were aggregated in stock specific fleets, HKE_CS and MON_CS, France. The resulting number of métiers was that high that it was decided to aggregate all the métiers that contribute in a less that a 1% to the total catch of the stocks in a MIS métier specific to each country. This criterion resulted in a manageable number of fleets and métiers but it could have drawbacks. In the existing Fcube-Bay of Biscay the métiers have been collapsed removing the mesh size attribute and collapsing similar gear (for example OTT and OTB). The final fleets and métiers using this criterion are listed in Table 6.1.

6.6.1 Testing of different HCR

This FLBEIA configuration was used to test different harvest control rules (HCR), the HCR used by ICES in the MSY framework for stocks in category 1 and a multi-stock HCR that uses fishing mortality ranges to give consistent TAC advice (Garcia *et. al*, 2016). Black anglerfish was not included in these simulations because it is in DLS category 3. The HCR were tested under two different scenarios, the actual scenario where landing obligation (LO) is not implemented (BaU, Business as usual) and an scenario where LO is fully implemented and the fleets do not change their fishing strategy (LO). The multi-stock HCR was tested using three different settings, 'max', 'mean' or 'min', the less precautionary is the 'max' setting followed by 'mean' and the most precautionary in the 'min' option. Independently of the setting the HCR always produces TAC advices corresponding to fishing mortalities within the fishing mortality ranges.

6.6.2 Spawning Stock Biomass

The SSB was always above Blim for Hake and Megrim. However, the probability of the SSB of Monkfish falling below Blim was slightly higher that 0 with the ICES HCR and the multistock HCR and 'max' option and BaU scenario (Figure 6.11).

6.6.3 Fishing Mortality

Under actual management scenario the ICES-HCR is hardly able to bring fishing mortality within ranges for monkfish and megrim (Figure 6.12). The performance of the multi-stock HCR is even worst for monkfish and its fishing mortality situated above the upper range for the whole simulation. The 'mean' option produced fishing mortalities between Fmsy and upper range for megrim and monkfish and between Fmsy and lower for hake. The multi-stock HCR with the 'min' option resulted in fishing mortalities according to Fmsy for megrim and monkfish but below the lower range for Hake (Figure 6.12). Under landing obligation were well below the fishing mortality target (Fmsy) for all the stocks in the whole simulation period. The fishing mortalities obtained with the 'min' setting in the Multi-stock HCR were even lower. The 'max' option produced fishing mortalities between Fmsy and Fupp for megrim and monkfish and between Flow and Fmsy for hake. The 'mean' option resulted in fishing mortalities equal or lower than Fmsy.

6.6.4 Ratio between catch and TAC (Quota Uptake)

In actual management scenario the less restrictive stock is Hake. Hence, the quota uptake of this stock is equal to 1 for all the HCR and there is an overshoot of the TAC for the rest of the stocks (Figure 6.13). With the ICES-HCR the over-shoot of megrim and monkfish was between 30% and 50% in the whole projection. With the MultiStock-HCR, independently of the setting, in the medium term the quota uptake stablished around 1. In the case of LO, the quota uptake of Hake was below 80% in ICES-HCR scenario and increased slightly ~85% in the Multi-Stock HCR scenarios. For monkfish there were not significant differences among scenarios and for megrim the quota uptake was closer to 1 with ICES-HCR scenario.

This result contrast with the case where there is only one fleet in the mixed-fishery. In this case the quota uptake was almost 1 for almost all the stocks and all the scenarios (Garcia, 2018). The problem in this implementation is that the relative exploitation pattern by stock at fleet level differs from the overall selection pattern of the fishery. Hence, what is consistent in terms of overall fleet it is not consistent at fleet level. Figure 6.14 shows what happens with quota uptake in 2025 for two different fleets, Spanish trawlers in Subarea 7 and Spanish trawlers in Subarea 8. Under current management scenario the quota uptake of Spanish trawlers in Division 8 worsens with the multi-stock HCR and improves slightly under LO. However, the performance of the multi-stock HCR for Spanish trawlers in Division 7 under current management is almost perfect (quota uptake ~ 1) and improves significantly with LO.

Table 6.6.1 List of fleet and métiers in FLBEIA conditioning for Bay of Biscay and Celtic Sea

Country	Fleet	Metier
BE	MIS_BE	MIS
	TBB_BE	TBB_DEF_70-99_8
		TBB_DEF_70-99_7
FR	GNS_FR	GNS_DEF_8
		GNS_DEF_7
	LLS_FR	LLS_DEF_8
		LLS_DEF_6
		LLS_DEF_7
	MIS_FR	MIS
	OTB_FR	OTB_CRU_>=70_7
		OTB_DEF_100-119_7
		OTB_DEF_70-99_8
		OTB_CRU_>=70_8
		OTB_DEF_70-99_7
		OTB_DEF_>=120_6
	OTM_FR	OTM_DEF_70-99_8
	OTT_FR	OTT_CRU_>=70_8
		OTT_DEF_>=70_8
		OTT_DEF_100-119_7
		OTT_CRU_>=70_7
IR	MIS_IR	MIS
	OTB_IR	OTB_CRU_100-119_7
		OTB_CRU_70-99_7
		OTB_DEF_100-119_7
		OTB_DEF_70-99_7
	SSC_IR	SSC_DEF_100-119_7
	TBB_IR	TBB_DEF_70-99_7
SP	GNS_SP	GNS_DEF_7
		GNS_DEF_8
	LLS_SP	LLS_DEF_6
		LLS_DEF_7
		LLS_DEF_8
	MIS_SP	MIS
	OT6_SP	OTB_DEF_100-119_6
		OTB_DEF_70-99_6
	OT7_SP	OTB_DEF_100-119_7
		OTB_DEF_70-99_7
	OT8_SP	OTB_DEF_>=70_8
		OTB_MCF_>=70_8
		OTB_MPD_>=70_8
	PTB_SP	PTB_DEF_>=70_8
UK	GNS_UK	GNS_DEF_7
	LLS_UK	LLS_DEF_6
		LLS_DEF_7
	MIS_UK	MIS
	OTB_UK	OTB_DEF_>=120_7
		OTB_DEF_70-99_7
	TBB_UK	TBB_DEF_70-99_7
Others	HKE_BC	MIS
	HKE_NS	MIS
	MON_CE	MIS

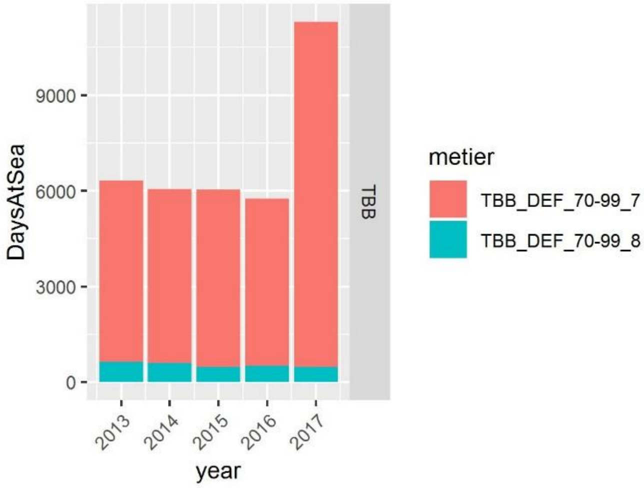


Figure 6.1. Belgium effort by métier and fleet.

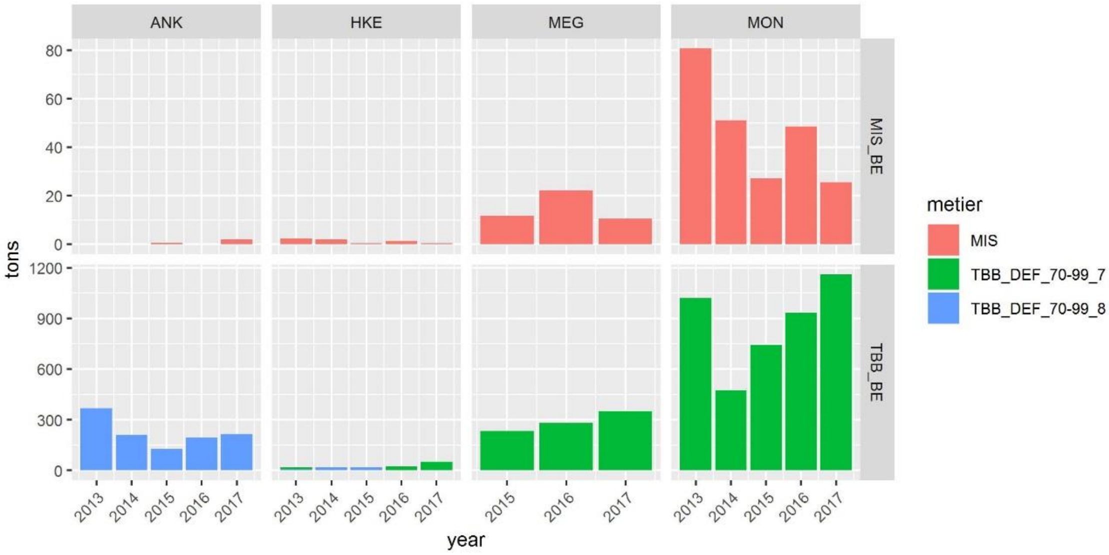


Figure 6.2 Belgium catches by stock, métier and fleet.

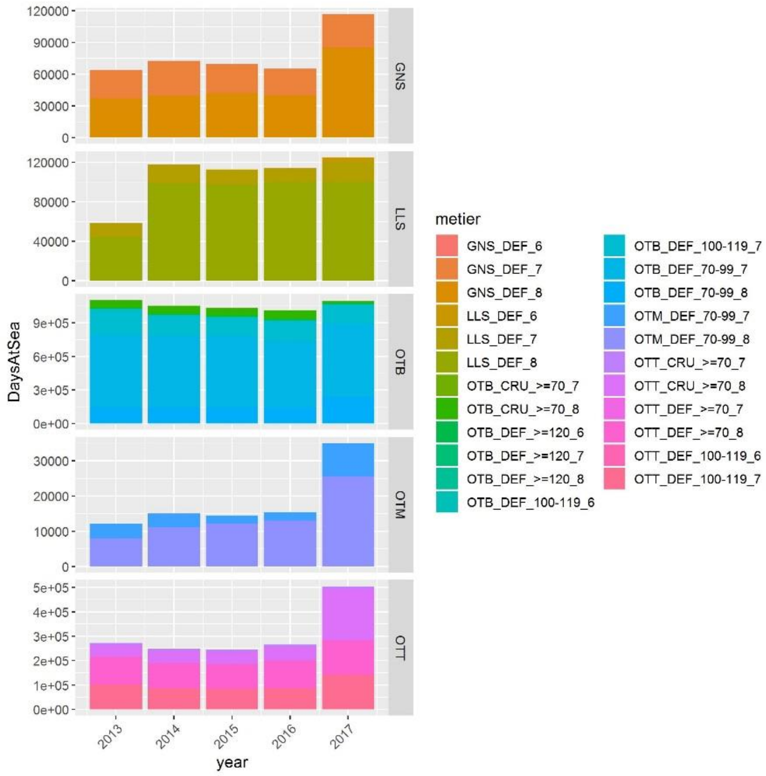


Figure 6.3 French effort by métier and fleet.

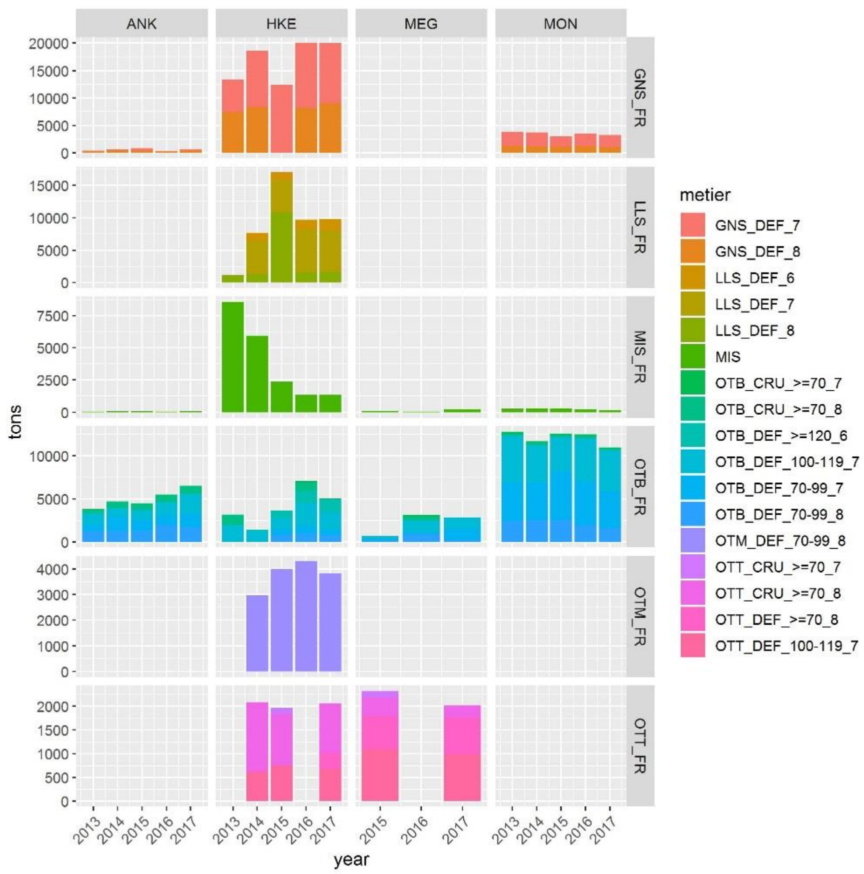


Figure 6.6.4 French catches by stock, métier and fleet.

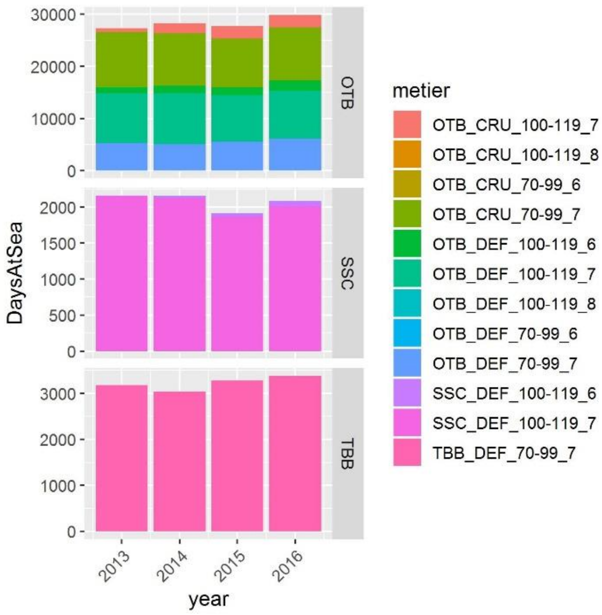


Figure 6.6.5 Irish effort by métier and fleet.

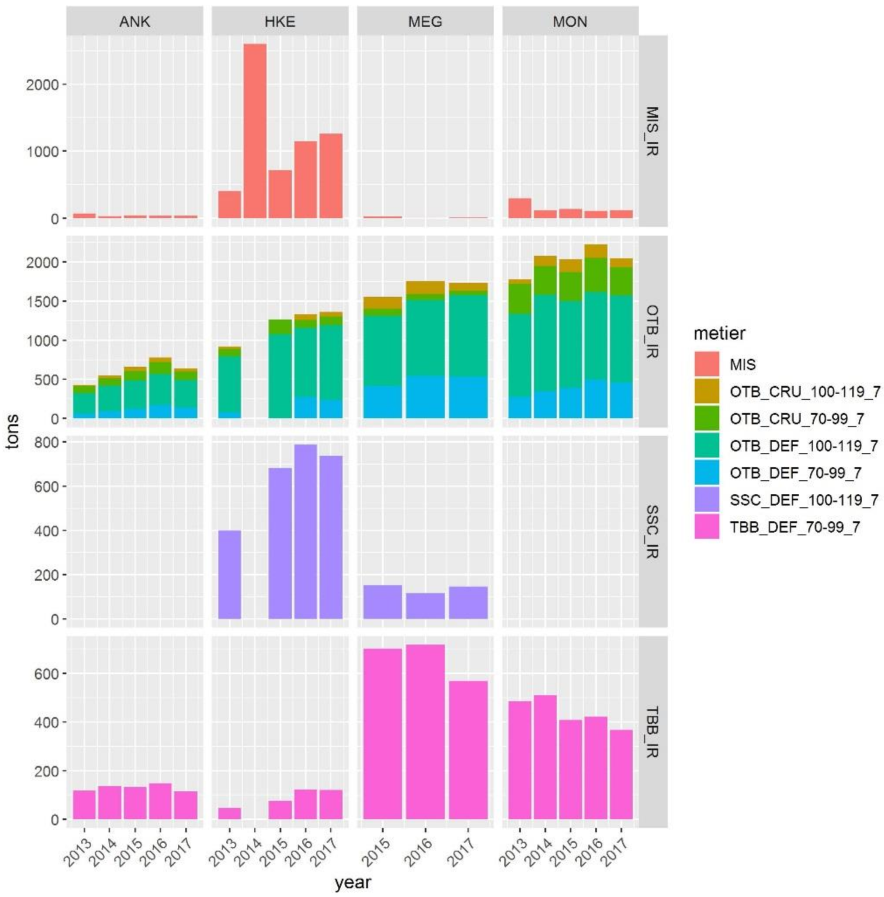


Figure 6.6.6 Irish catches by stock, métier and fleet.

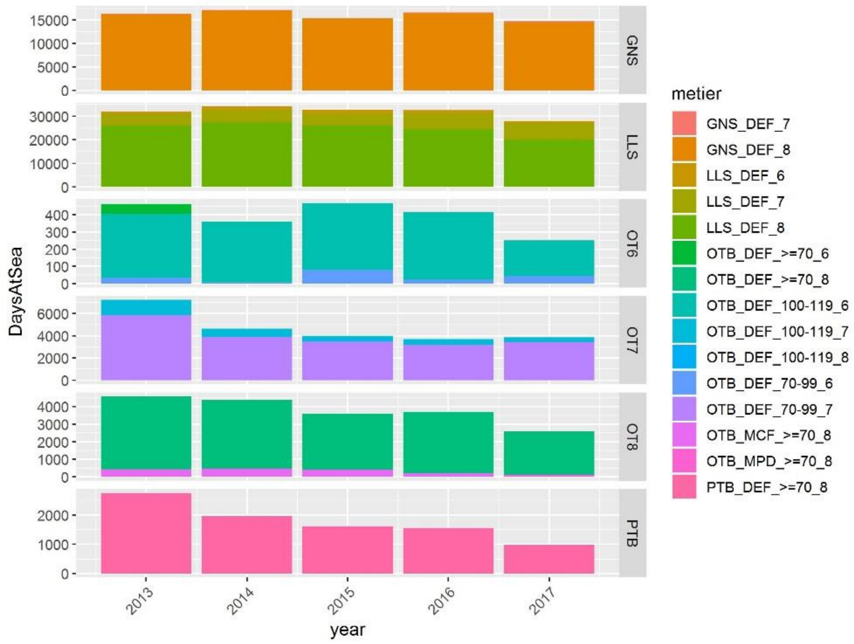


Figure 6.6.7 Spanish effort by métier and fleet.

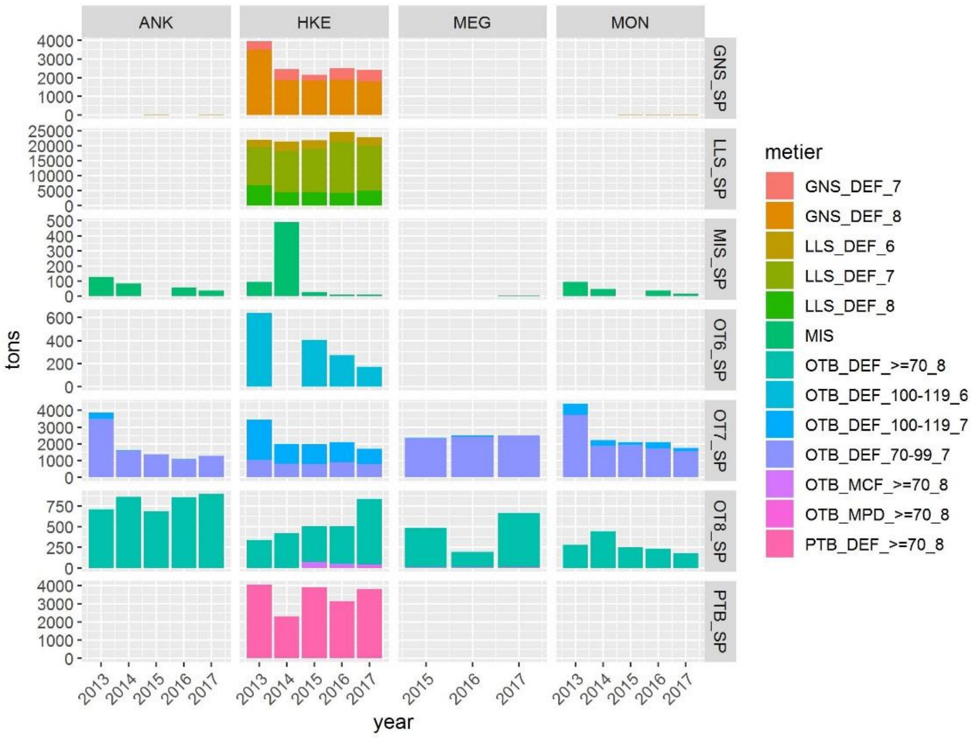


Figure 6.6.8 Spanish catches by stock, métier and fleet.

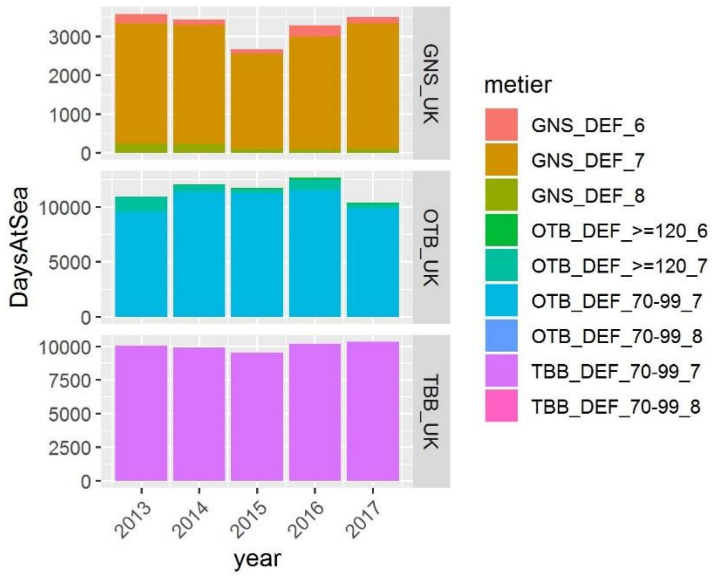


Figure 6.6.9 UK effort by métier and fleet.

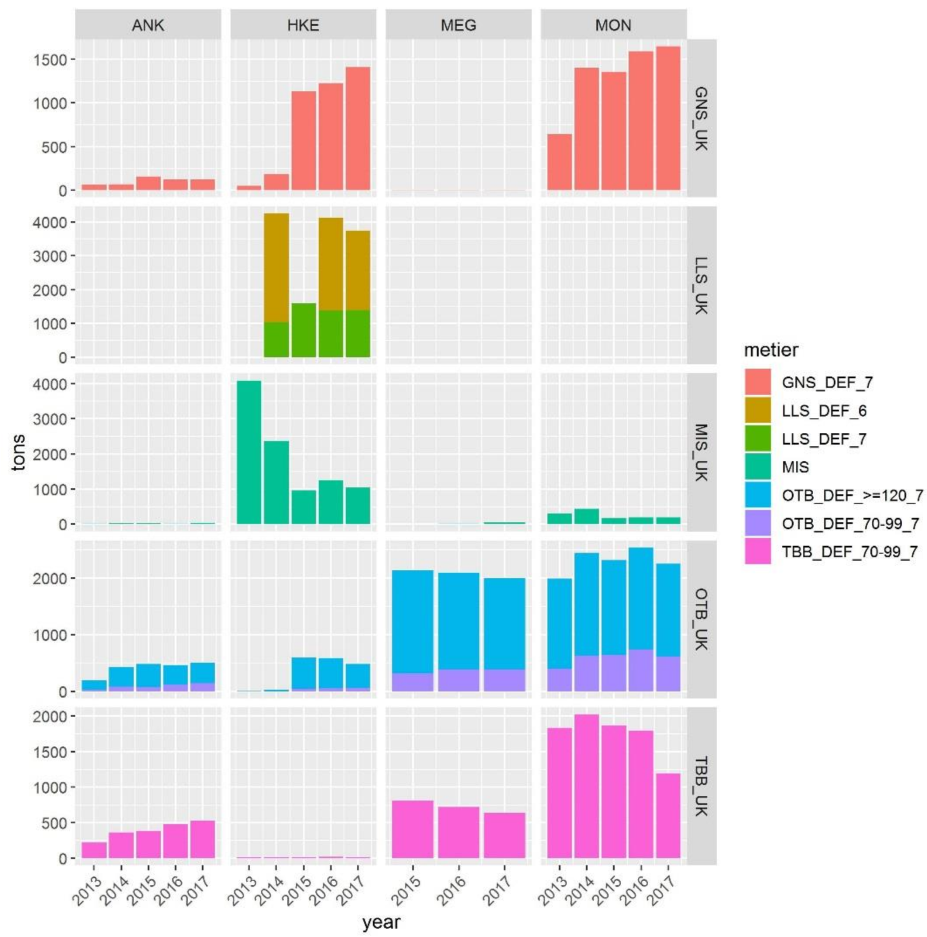


Figure 6.6.10 UK catches by stock, métier and fleet.

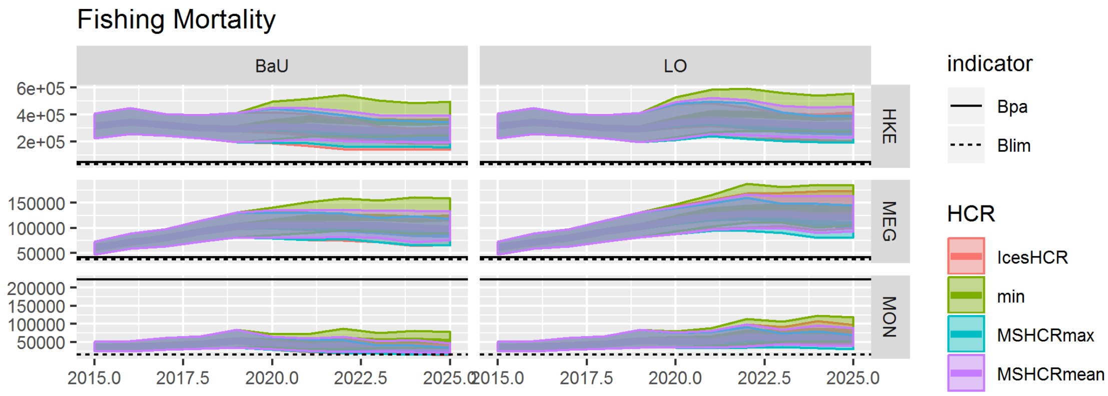


Figure 6.6.11 Spawning biomass obtained in each scenario. Shaded area corresponds with 95% confidence interval and the lines with the median. Horizontal lines correspond with Blim and Bpa.

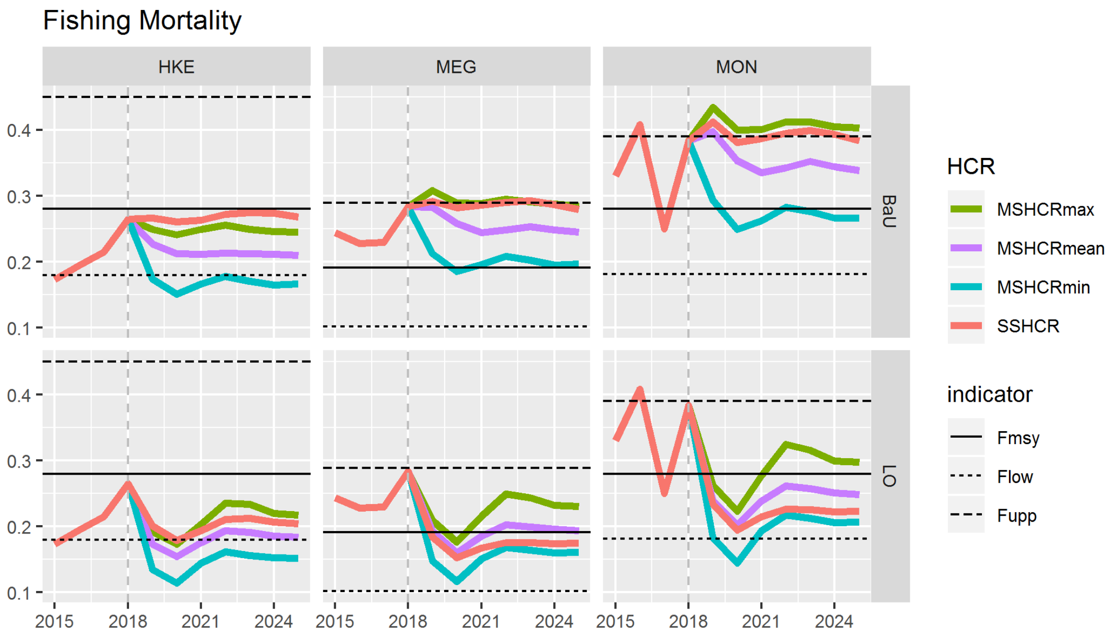


Figure 6.6.12 Fishing mortality obtained in each scenario. Horizontal lines correspond with Fmsy, and the fishing mortality ranges (Flow and Fupp)

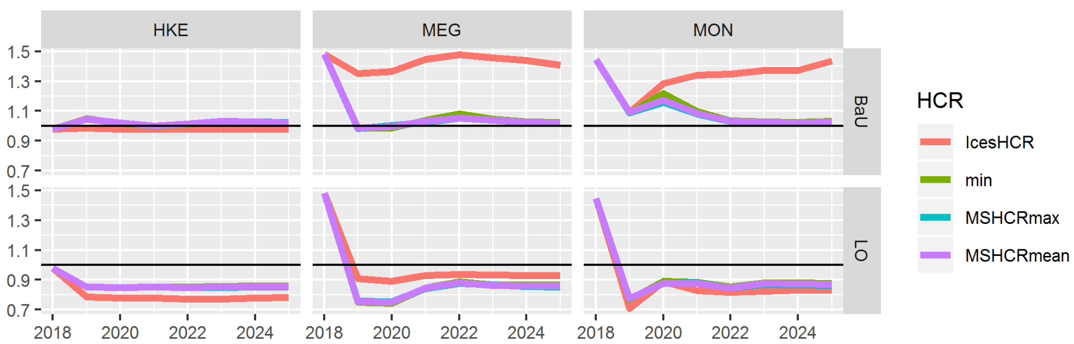


Figure 6.6.13 Quota uptake (ratio between catch and TAC) along years for each scenario. Horizontal line corresponds with the case where the catch is equal to the TAC.

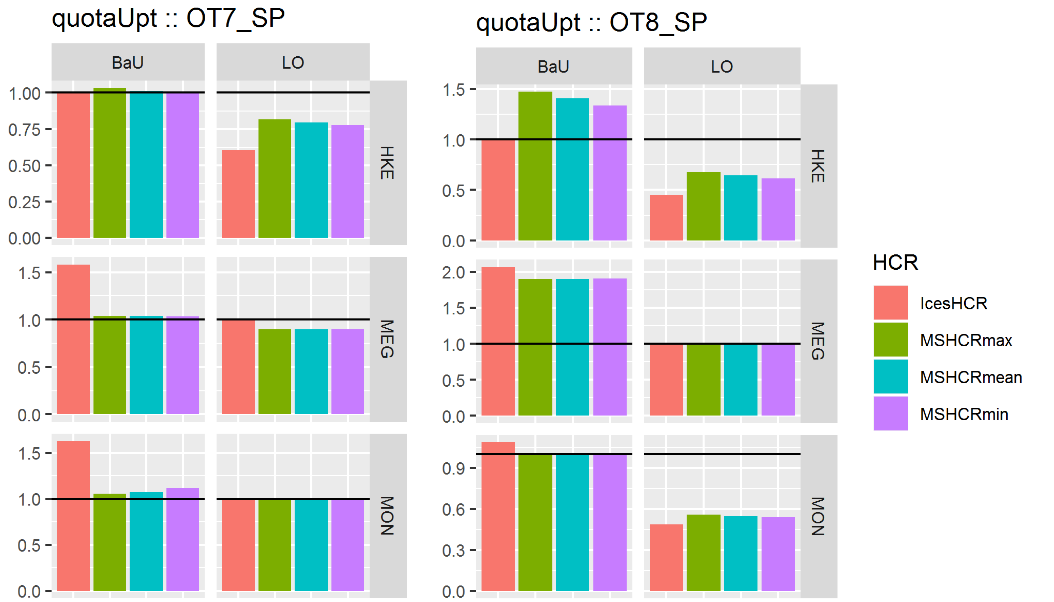


Figure 6.6.14 Quota uptake (ratio between catch and TAC) in 2025 for Spanish trawlers in ICSE Subarea 7 (left) and in division 8 (right) in each scenario. Horizontal line corresponds with the case where the catch is equal to the quota share.

7 Terms of Reference F - Increase the number of species in the Iberian Waters model.

7.1 Analysis of catch composition of Spanish demersal fleet in Iberian Waters

The possibility of including additional stocks in the mixed fishery was analyzed for the Iberian Waters (IW) area. The current FLBEIA model, used to provide the advice for IW, considers 4 stocks: hke.27.8c9a, ldb.27.8c9a, meg.27.8c9a and mon.27.8c9a. The inclusion of key stocks in FLBEIA model would improve the mixed fisheries considerations in this area.

The analysis was conducted considering the official landings data submitted by Spain to the present Working Group. This data set consists of data of retained catches by year, métier and ICES subdivision, from 2015 to 2017. A more precise analysis of the IW fisheries would need the inclusion of data from Portugal data that they were not available during the WG. The data were processed to focus on main commercial species. Species with very low catches and species without advice and TAC were aggregated as OTHERS. A prioritized list of stocks for IW was created based on the following factors: the relevance of a species in terms of being a target species, technical interactions and the risk of being a choke species. Also, the suitability of the stocks for its inclusion in FLBEIA was another issue considered to create the list.

Table 7.1. Main species/taxon in Spanish demersal métiers. The importance in terms of landings and ICES data category are indicated.

Species	Landings (t)	%	ICES Data Category	WGMIXFISH2018
Micromesistius poutassou	26676	36.71	cat1	
Others	16111	22.17		
Scomber scombrus	9792	13.47	cat1	
Trachurus trachurus	9761	13.43	cat1	
Merluccius merluccius	7152	9.84	cat1	included
Lophius piscatorius/budegassa	1780	2.45	cat1, cat3	included (mon.8c9a)
Lepidorhombus boscci/whiffiagonis	861	1.18	cat1, cat1	included (ldb.8c9a, meg.8c9a)
Pollachius pollachius	253	0.35	cat5	
Solea spp	177	0.24	cat5	
Nephrops norvegicus	65	0.09	cat3, cat4	
Raja montagui	30	0.04	cat3	
Leucoraja naevus	16	0.02	cat3	

The main target species for the groundfish fleets in the Iberian Waters are hake (HKE), anglerfishes (ANK, MON), megrims (LDB, MEG), *Nephrops* (NEP), horse mackerel (HOM), mackerel (MAC) and blue whiting (WHB). Other target species are pollack (POL) and sole (SOL) (Table 7.1). Three pelagic/semi-pelagic species (blue whiting, mackerel and horse mackerel) are responsible of the 64% of the total landings in these demersal métiers.

Nine Spanish demersal métiers were analyzed (Table 7.2). The gillnet métier target to anglerfish (ES_GNS_DEF_>=100_0_0) is responsible of only 1% of landings while the Pair Trawl targeting pelagic and demersal species (ES_PTB_MPD_>=55_0_0) contributes with 37% of landings. Landings from other two gillnet métiers (ES_GNS_DEF_60-79_0_0 and ES_GNS_DEF_80-99_0_0) represent 3% each one. The OTB métiers (ES_OTB_MCD_>=55_0_0, ES_OTB_DEF_>=55_0_0, ES_OTB_MPD_>=55_0_0) have pelagic and demersal species as target and catch the 34% of landings. Trammel nets and long-liners métiers (ES_LLS_DEF_0_0_0, ES_GTR_DEF_60-79_0_0) have multiple target species, being the group of Others the most caught, other important species are anglerfishes, hake, pollack and sole.

Table 7.2. Species composition for the Spanish demersal métiers. The relative importance of each métier is shown.

Metier (% Total Landings)	Species	Landings (t)	%
ES_GNS_DEF_>=100_0_0 (1%)	Lophius piscatorius/budegassa	630	84.7
	OTHERS	45	6.1
	Merluccius merluccius	36	4.9
	Scomber scombrus	23	3.1
	Lepidorhombus boscci/whiffiagonis	4	0.6
	Trachurus trachurus	2	0.2
	Micromesistius poutassou	1	0.2
	Raja montagui	1	0.1
	Leucoraja naevus	1	0.1
	Solea spp	0	0.1
	Pollachius pollachius	0	0.1
ES_GNS_DEF_60-79_0_0 (3.3%)	OTHERS	1198	50.1
	Merluccius merluccius	500	20.9
	Trachurus trachurus	439	18.4
	Scomber scombrus	170	7.1
	Pollachius pollachius	37	1.6
	Lophius piscatorius/budegassa	23	1.0
	Solea spp	18	0.8
	Lepidorhombus boscci/whiffiagonis	2	0.1
	Raja montagui	1	0.0
	Micromesistius poutassou	1	0.0
	Leucoraja naevus	0	0.0
ES_GNS_DEF_80-99_0_0 (3.3%)	Merluccius merluccius	1423	58.9
	OTHERS	589	24.4
	Trachurus trachurus	272	11.3
	Scomber scombrus	71	3.0
	Micromesistius poutassou	21	0.9
	Pollachius pollachius	18	0.7
	Lepidorhombus boscci/whiffiagonis	16	0.7
	Lophius piscatorius/budegassa	5	0.2
	Solea spp	0	0.0
	Raja montagui	0	0.0
	Leucoraja naevus	0	0.0
ES_GTR_DEF_60-79_0_0 (4.2%)	OTHERS	2229	72.5
	Lophius piscatorius/budegassa	402	13.1
	Merluccius merluccius	142	4.6
	Solea spp	105	3.4
	Trachurus trachurus	67	2.2
	Scomber scombrus	62	2.0
	Pollachius pollachius	41	1.3
	Raja montagui	17	0.6
	Lepidorhombus boscci/whiffiagonis	4	0.1
	Leucoraja naevus	1	0.1
	Micromesistius poutassou	1	0.0
	Nephrops norvegicus	0	0.0
ES_LLS_DEF_0_0_0 (6.8 %)	OTHERS	3227	65.5
	Merluccius merluccius	1411	28.6
	Pollachius pollachius	147	3.0
	Scomber scombrus	71	1.5
	Trachurus trachurus	41	0.8
	Micromesistius poutassou	31	0.6
	Lophius piscatorius/budegassa	1	0.0
	Solea spp	1	0.0
	Raja montagui	1	0.0
	Leucoraja naevus	0	0.0
	Lepidorhombus boscci/whiffiagonis	0	0.0

Metier (% Total Landings)	Species	Landings (t)	%
ES_OTB_DEF_>=55_0_0 (16.1%)	OTHERS	3931	33.2
	Micromesistius poutassou	3907	33.0
	Trachurus trachurus	1076	9.1
	Merluccius merluccius	994	8.4
	Lepidorhombus boscci/whiffiagonis	727	6.2
	Lophius piscatorius/budegassa	572	4.8
	Scomber scombrus	550	4.7
	Solea spp	33	0.3
	Nephrops norvegicus	13	0.1
	Leucoraja naevus	10	0.1
	Pollachius pollachius	8	0.1
	Raja montagui	8	0.1
ES_OTB_MCD_>=55_0_0 (7.6%)	OTHERS	3532	64.3
	Micromesistius poutassou	1289	23.5
	Merluccius merluccius	358	6.5
	Trachurus trachurus	176	3.2
	Lophius piscatorius/budegassa	54	1.0
	Nephrops norvegicus	52	1.0
	Solea spp	16	0.3
	Lepidorhombus boscci/whiffiagonis	7	0.1
	Scomber scombrus	5	0.1
	Leucoraja naevus	1	0.0
	Raja montagui	0	0.0
ES_OTB_MPD_>=55_0_0 (20.9%)	Trachurus trachurus	7197	47.3
	Scomber scombrus	6504	42.7
	OTHERS	835	5.5
	Micromesistius poutassou	258	1.7
	Merluccius merluccius	246	1.6
	Lepidorhombus boscci/whiffiagonis	98	0.6
	Lophius piscatorius/budegassa	79	0.5
	Raja naevus	2	0.0
	Leucoraja naevus	1	0.0
	Raja montagui	2	0.0
	Solea spp	2	0.0
	Nephrops norvegicus	0	0.0
ES_PTB_MPD_>=55_0_0 (36.6%)	Micromesistius poutassou	21168	79.6
	Scomber scombrus	2337	8.8
	Merluccius merluccius	2042	7.7
	OTHERS	524	2.0
	Trachurus trachurus	491	1.9
	Lophius piscatorius/budegassa	14	0.1
	Lepidorhombus boscci/whiffiagonis	3	0.0
	Leucoraja naevus	0	0.0
	Solea spp	1	0.0

Figure 7.1 shows the species composition for each métier. Hake is caught in all the métiers and it is the main target species for LLS_DEF_0_0_0, GNS_DEF_80_99 and GNS_DEF_70_99. Megrims are caught in almost all métiers. White and black anglerfish are the main target species for GNS_DEF_>= 100_0_0 and GTR_DEF_60_79_0_0.

Nephrops is only caught in 2 trawl métiers (OTB_DEF>=55_0_0 and OTB_MCD_>=55_0_0) but, due to the economic relevance of the species and to the tiny quotas available in the whole IW area, the five Functional Units of *Nephrops* are proposed to be included in the FLBEIA model.

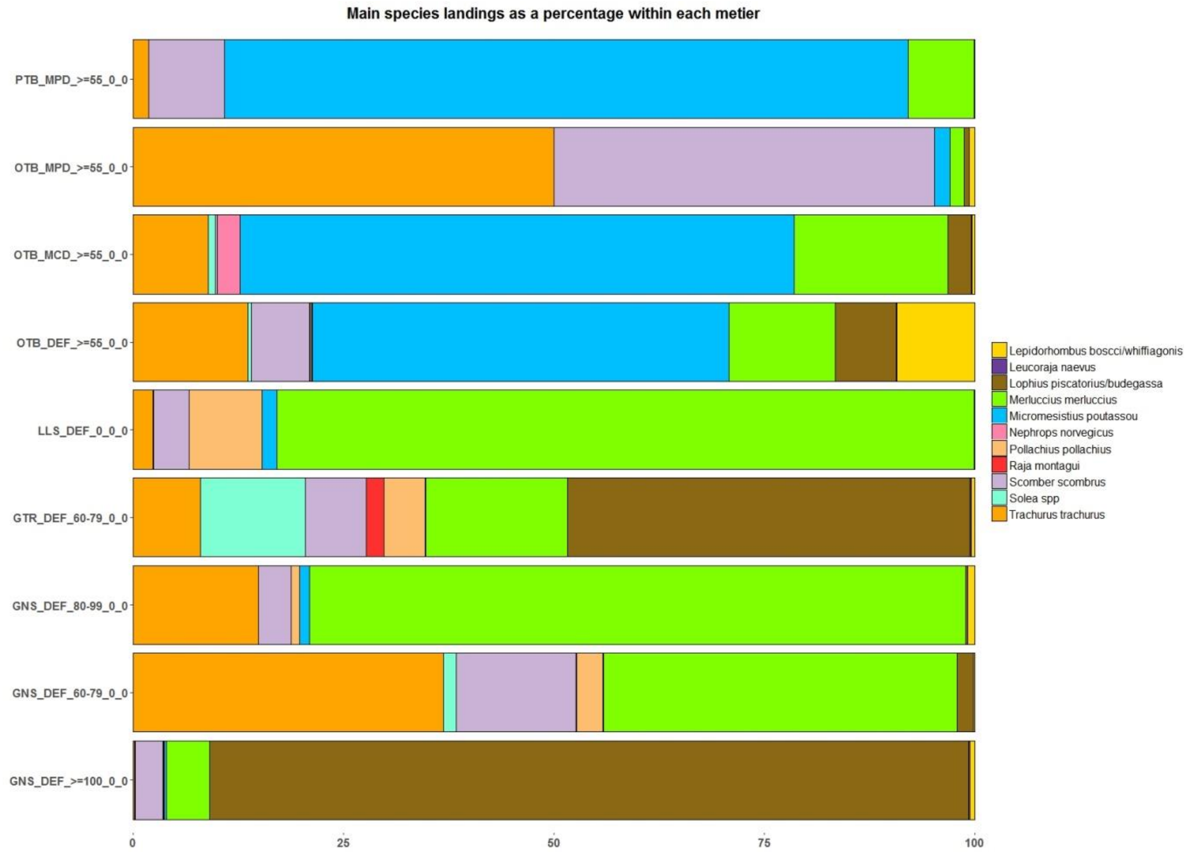


Figure 7.1. Main species landings as a percentage within each Spanish demersal métier.

Blue whiting is present in all métiers, except in GNS_DEF>=100_0_0, and it is the main target species for 3: PTB_MPD_>=55_0_0, OTB_DEF_>=55_0_0 and OTB_MCD_>=55_0_0. The blue whiting stock should be incorporated in the FLBEIA model. Horse mackerel is present in all métiers, except in GNS_DEF>=100_0_0, and it is the main target species in OTB_MPD_>=55_0_0. Two stocks of horse mackerel are defined in IW area, both are key stocks to mixed fisheries considerations in IW area. Mackerel is together with horse mackerel the main species of OTB_MPD_>=55_0_0 and is also caught with other pelagic and demersal species in 8 métiers.

Trammel net métier (GTR_DEF_60_79_0_0) catches a great variety of demersal species, being pollack and sole the species with the highest economic importance.

Raja montagui and *Leucoraja naevus* are caught in GTR_DEF_60_79 and in OTB_DEF_>=55_0_0. However, being difficult to avoid their capture and due to the low quota available for these species the risk of being a choke species is high.

Table 7.3. Prioritized list of stocks to include in the IW mixed fisheries model. √: already included; √: included in WGMIXFISH-METHODS 2018; √: to be included.

Stocks	Included	ICES Data Category	TAC at species levels
hke.27.8c9a	√	cat1	yes
meg.27.8c9a	√	cat1	no
ldb.27.8c9a	√	cat1	no
mon.27.8c9a	√	cat1	no
ank.27.8c9a	√	cat3	no
Nephrops FU30	√	cat4	no
Nephrops FU28-29	√	cat3	no
Nephrops FU26-27	√	cat3	no
Nephrops FU25	√	cat3	no
Nephrops FU31	√	cat3	no
whb.27.1-91214	√	cat1	yes
hom.27.9a	√	cat1	yes
hom.27.2-8	√	cat1	yes
mac.27.nea	√	cat1	yes
pol.27.89a	√	cat5	yes
sol.27.8c9a	√	cat5	yes
rjm.27.9a	√	cat5	no
rjn.27.9a	√	cat5	no

Based on the results of the previous analysis, a prioritized list of stocks that should be considered in the mixed fisheries model for IW area was created (Table 7.3). The first four stocks are already included in the FLBEIA model. As part of the work of this WG, the FLBEIA model was modified to include black anglerfish stock (ank.27.8c9a). The next stocks to be included are the *Nephrops* Functional Units, WBH stock, the two horse mackerel stocks, mackerel stock, pollack, sole and rajidae. Eight of these stocks are ICES category 1 with quantitative assessment and forecast available, but the other 10 stocks are in ICES category 3 or higher. For the stocks in category 3 or higher, a new approach to include them in the mixed fisheries models was proposed (Section 8.a).

7.2 Inclusion of anglerfish (*Lophius budegassa*) in to the mixed-fisheries advice framework

Black-bellied anglerfish was benchmarked in 2018 (ICES, 2018a) and the assessment model was changed from ASPIC (Prager, 1994) to SPiCT (Pedersen, 2017). The assessment model was accepted as an analytic assessment by the benchmark and WGBIE participants (ICES, 2018b). However, it was later rejected as analytical assessment by the Advisory Drafting working group and accepted only to be used as abundance index in the ICES category 3.

We used the catch from InterCatch and effort data provided by Spain and Portugal to the WGMIXFISH-ADVICE working group to condition the fleets and metiers used to provide mixed-fisheries advice using FLBEIA (ICES, 2018c). Furthermore, some bugs were detected and corrected on the conditioning of the already included stocks. The mixed-fisheries advice did not change in relative terms but the absolute values for the 'mon' scenario were different.

The population dynamic model was first conditioned using SPiCT's dynamics which were replicated in R. however, as the advice was provided using DLS category 3 formula, the method proposed in Section (Section 8.a).was used to calculate the catch of black-bellied anglerfish produced by a given effort and the other way around.

7.3 Conditioning of fleets and métiers

The catch from InterCatch used to condition the model was almost equal to the data used by the assessment working group (Table 7.5).

The percentage of the catch of each stock considered is shown in Figure 7.2 . Black anglerfish is the third in terms of its contribution to the total catch after the white anglerfish. The distribution of the catch by metier is provided in Figure 7.3. Black anglerfish is mainly caught by DEF_>=65_0_0 metier.

7.3.1 Trends

Analyses of trends by fleet were carried out on 2015–2017 data. Several overview graphs were produced to aid quality checking of the data once compiled into the final fleets object for catches, effort and catchability. In order not to extend the report with repetitive graphics, only the catchability plots by stock, fleet and métier for Spain (Figure 7.4.a) and Portugal (Figure 7.4.b) are included in this report. With only three years of data it is not possible to ensure that there is any trend in the data. In general, more than trends it seems that there is variability in the data. However, without an assessment of the impact of this variability on the results it is not possible to anticipate the possible impact of this variability. In some specific cases, like hake in Spanish otter trawlers or megrim in Portuguese otter trawlers, the catchability has decreased since 2015 which points out a possible decreasing trend that should be confirmed when more data is available. In the case of black anglerfish, as biomass estimate is not available for this stock, instead of catchability we these plots show the catch per unit of effort, i.e, $q \cdot B$. In the case of Portuguese fleets the catchability and CPUE of white and black anglerfishes respectively show similar trends for all the métiers except for 'DEF_>=65_0_0' métier. In the case of Spanish métiers there was no relationship, in general, between both quantities.

Discrepancies were found between the FLBEIA baseline runs and the single stock forecasts. The discrepancies were reduced in comparison with the May analysis due to an improvement in the input data. These discrepancies are attributed to methodological differences between the length-based, seasonal and statistical assessment models used by WGBIE and the age-based annual forecast used by WGMIXFISH. There was no difference in the SSB of megrim and the difference in the SSB of the four-spot megrim was lower than 4%. However, the differences in the fishing mortality was around 4% and 8%. In the case of hake the differences in fishing mortality were around 2% and in biomass were lower than 7%. Finally, in the case of white anglerfish the differences in both, fishing mortality and SSB, were lower than 5%. Black anglerfish is in category 3 stock so comparison of short-term forecast was carried out for this stock.

7.3.2 Description of scenarios

7.3.2.1 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.

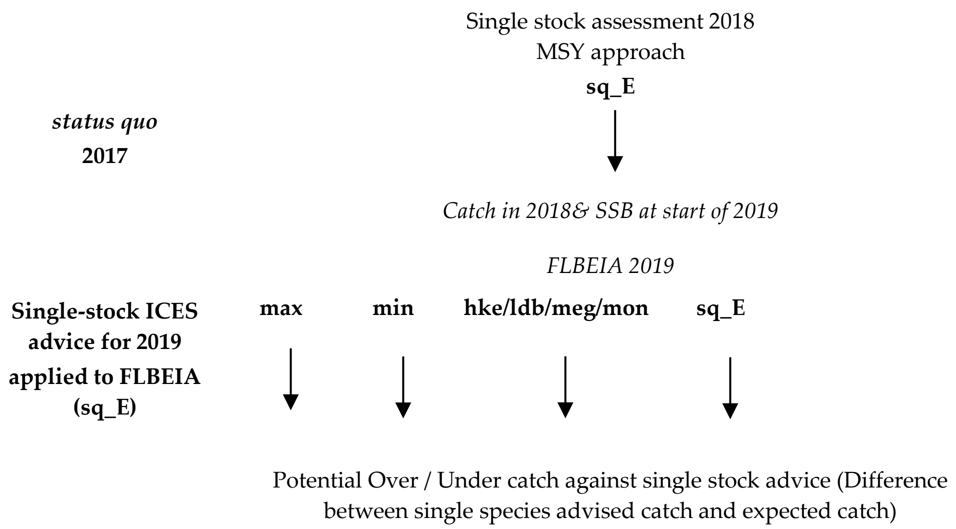
The various single-stock forecasts presented by WGBIE are performed using different software and setups (see 7.3.1 above). However, for the purpose of the mixed-fisheries analyses, it is necessary to gather all forecasts into a single unified framework, which builds on the 'FLBEIA library (Garcia *et 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).

7.3.2.2 Mixed fisheries runs

The mixed fishery analysis used a status quo effort assumption for the intermediate year (2018), with the FLBEIA scenarios used for the TAC year (2018). 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:



7.3.3 Results of Fcube runs

7.3.3.1 Baseline run

The rationale behind the single species baseline runs is given in Section 4.3.1.2. The ICES single-stock advice for these stocks in 2018 (ICES, 2018b) is based on the maximum sustainable yield (MSY) approach. The issues and problems encountered in replicating the single species advice for each species are given below. The results from these baseline runs are compared with the results from the corresponding ICES runs in Tables 7.6.a and 7.6.b.

There are some differences between the single-stock catch and SSB values, and the values obtained from the mixed-fisheries scenarios that consider all fleets set their effort corresponding to their quota shares for each given species. For catch the difference is around 7% for megrim and around 9% for hake. For hake and four-spot megrim the difference was lower that 2%. In SSB the difference for monkfish was around 15% and for the rest of the stocks it was lower than 2%. For hake and anglerfish, differences are to be expected because the length-based seasonal models used in the stock assessments are approximated with annual age-based models in the mixed-fisheries analysis. The reason for the discrepancy is unknown in the case of the megrims. This issue could not be investigated in depth at this time.

Hake

Discrepancies lower than 7% were obtained for hake in both SSB and fishing mortality. This stock is assessed by the GADGET model (Frøysa *et al.*, 2002; Begley and Howell, 2004), a stochastic assessment model which is difficult to simulate in a mixed-fisheries deterministic forecast. GADGET is a forward simulation model that can be structured in both age and length; therefore requiring direct modelling of growth within the model. In the case of southern stock of hake, the model is length based and F multipliers do not apply linearly.

Four-spot megrim

There were no differences in biomass but there were differences in fishing mortality (~8%). This stock is assessed by applying the XSA model. In 2014, a benchmark (WKSOUTH) was undertaken in order to include discards on the assessment (ICES, 2014).

Megrim

Discrepancies in biomass were low (<3%) but here were bigger differences in fishing mortality (~6%). This stock is assessed by applying the XSA model. In 2014, a benchmark (WKSOUTH) was undertaken in order to include discards on the assessment (ICES, 2014).

White anglerfish

Discrepancies of 6% in SSB and of 5% for fishing mortality were obtained for white anglerfish. The assessment of this stock is performed by applying the SS3 model (Methot, 2000) disaggregated by length. This methodology is applied to this stock since it was accepted in the WKFLAT benchmark in 2012 (ICES, 2012) to replace the previous assessment method (ASPIC; Prager, 1994). In 2018 the stock was benchmarked (ICES, 2018a) and some of the model setting were changed.

The initial WG purpose of investigating in depth the reasons for potential discrepancies was not possible to fulfil with the time available during the WG meeting. However, the results were considered still illustrative regarding the modelling of the technical interactions between stocks and fleets.

7.3.3.2 Black anglerfish

The '**ank**' scenario results in effort and catch levels similar to '**mon**' scenario. These two stocks are caught together and have a join TAC. Something similar happen for the two megrims. The results are sensible and support the approach for data limited stocks presented in (Section 8a).

7.3.3.3 Mixed fisheries analyses

The full overview of the FLBEIA projections to 2019 is presented in Table 7.7 and Figures 7.5.a to 7.5.b The results for 2019 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.

The "**max**" scenario shows the upper bound of potential fleet effort and stock catches and the stock which, to reach its Fmsy target, needs the maximum increase in effort is, according to the current analysis, white anglerfish. However, through assuming that all fleets continue fishing until all their stock shares are exhausted irrespective of the economic viability of such actions, this scenario is generally considered with low plausibility.

ICES single-stock advice provides TACs expected to meet single stock FMSY. 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 would stop fishing when their first stock share is exhausted, regardless of the actual importance of this stock share for the fleet. While this can be considered an unlikely scenario as long as discarding is allowed, this scenario reflects the constraints that result from a strictly implemented discard ban. Fishing effort should be reduced more than 60% of its 2018 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.

Within the scenarios based on each of the stocks, the "**hke**" scenario gives almost the same result as the "min" scenario, showing hake as the choke species. This scenario reflects the target fishing mortality as set for the hake MSY approach; however, the results present loss of fishing opportunities for anglerfishes and, in a lesser extent, for megrims. The "**ldb**" and "**meg**" scenarios provide a very similar perspective, almost doubling 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 metiers. The "**mon**" and "**ank**" scenario maintain the single-stock advice for anglerfishes, but almost triple the single-stock advice for the other stocks.

The "**sq_E**" scenario provides is almost in the middle of "hke" and "mon" scenarios.

7.3.3.3.1 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 landing share by fleet and stock in 2017. 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 7.6).

Table 7.4. Iberian waters: Summary of the 2018 landings and target Fs, resulting from the Advice Approaches considered by ICES. TACs make reference to total catches, as they are used in the assessment model, except for white anglerfish which represent only landings.

Stocks	TAC 2019	F 2019	SSB 2020	Rational
Black anglerfish VIIIc-IXa	2062 t	NA	NA	MSY approack
Hake VIIIc-IXa	8561 t	0.25	38286 t	MSY approach
Four-spot megrim VIIIc-IXa	1399 t	0.19	8078 t	MSY approach
Megrim VIIIc-IXa	292 t	0.19	1519 t	MSY approach
White anglerfish VIIIc-IXa	2197 t	0.31	7452 t	MSY approach

Table 7.5. 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
2017	ANK	860	861	1	1.00
2017	HKE	10847	10624	223	0.98
2017	LDB	1172	1200	28	1.02
2017	MEG	288	283	5	0.98
2017	MON	1446	1445	1	1.00

Table 7.6.a. Iberian waters: Baseline run outputs from the FLBEIA FLR package.

Management plan		ANK	HKE	LDB	MEG	MON
2018	**Fbar**	NA	0.6	0.28	0.29	0.143
	FmultVsF17	NA	1.36	1.58	1.79	1.13
	Landings	833	13653	1577	578	1556
	SSB	0	24115	8821	2504	11128
2019	**Fbar**	NA	0.25	0.19	0.19	0.24
	FmultVsF18	NA	0.42	0.69	0.66	1.68
	Landings	2062	6801	1252	361	2153
	SSB	0	24250	8808	2258	11104
2020	**SSB**	0	33443	9256	2197	10036

Table 7.6.b. Iberian waters: Comparison between baseline run and ICES advice. Figures for 2018 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.

	Management plan	ANK	HKE	LDB	MEG	MON
2018	Landings Baseline	833	13653	1577	578	1556
	Landings ICES	NA	14483	1585	612	1556
	% difference	NA	0.94	0.99	0.94	1
2019	Landings Baseline	2062	6801	1252	361	2153
	Landings ICES	2062	7220	1270	417	2153
	% difference	1	0.94	0.99	0.87	1

Table 7.7. Results of running FLBEIA scenarios on the TAC year (2019). Comparison of the singe-stock ICES advice and potential landings in the various FLBEIA scenarios.

	Single-stock catches advice 2019		Catches per mixed-fisheries scenario 2019 relative to the single-stock catch advice							
Stock	WGBIE	WGMIXFISH	“Max”	“Min”	“Hke”	“Ldb”	"Meg"	"Mon"	“Ef_Mgt”	"Val"
ank.27.8c9a	2062	2062	1.01	0.28	1	0.28	0.45	0.42	0.8	0.49
hke.27.8c9a	8281	8281	2.7	1	2.8	1	1.59	1.79	2.7	1.73
ldb.27.8c9a	1633	1633	2.1	0.62	2.1	0.62	1	0.93	1.74	1.26
meg.27.8c9a	399	399	1.84	0.66	1.84	0.66	1.06	1	1.6	1.33
mon.27.8c9a	2153	2153	1.28	0.35	1.27	0.35	0.54	0.49	1	0.62

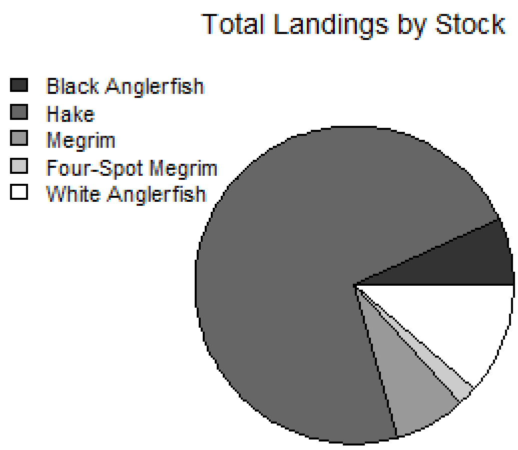


Figure 7.2. Iberian waters: Distribution of landings of the stocks included in the mixed fisheries projections.

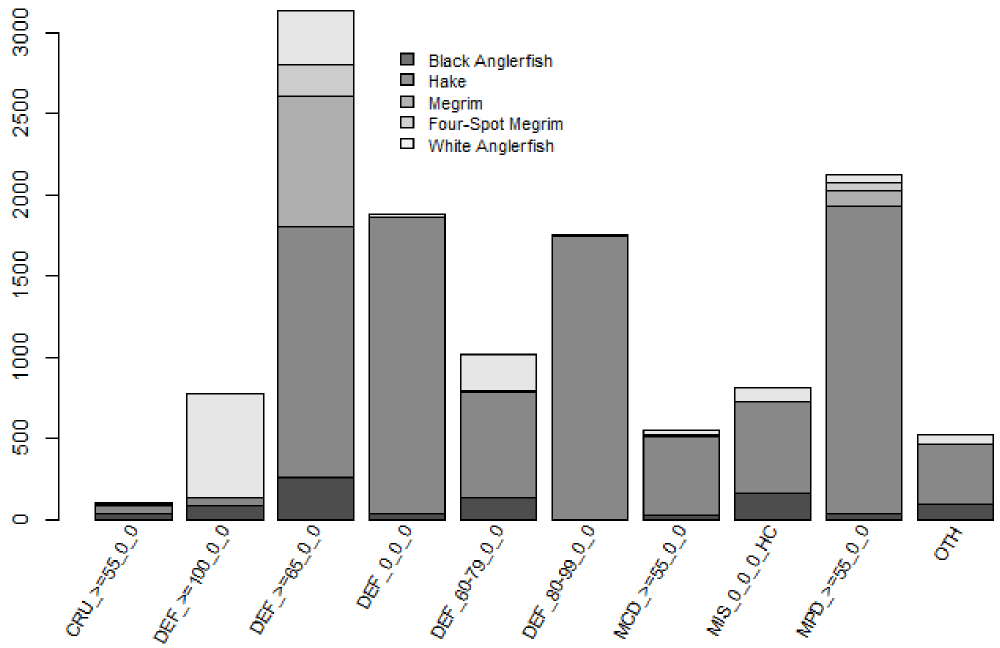


Figure 7.3. Iberian waters: Landings distribution of species by métier.

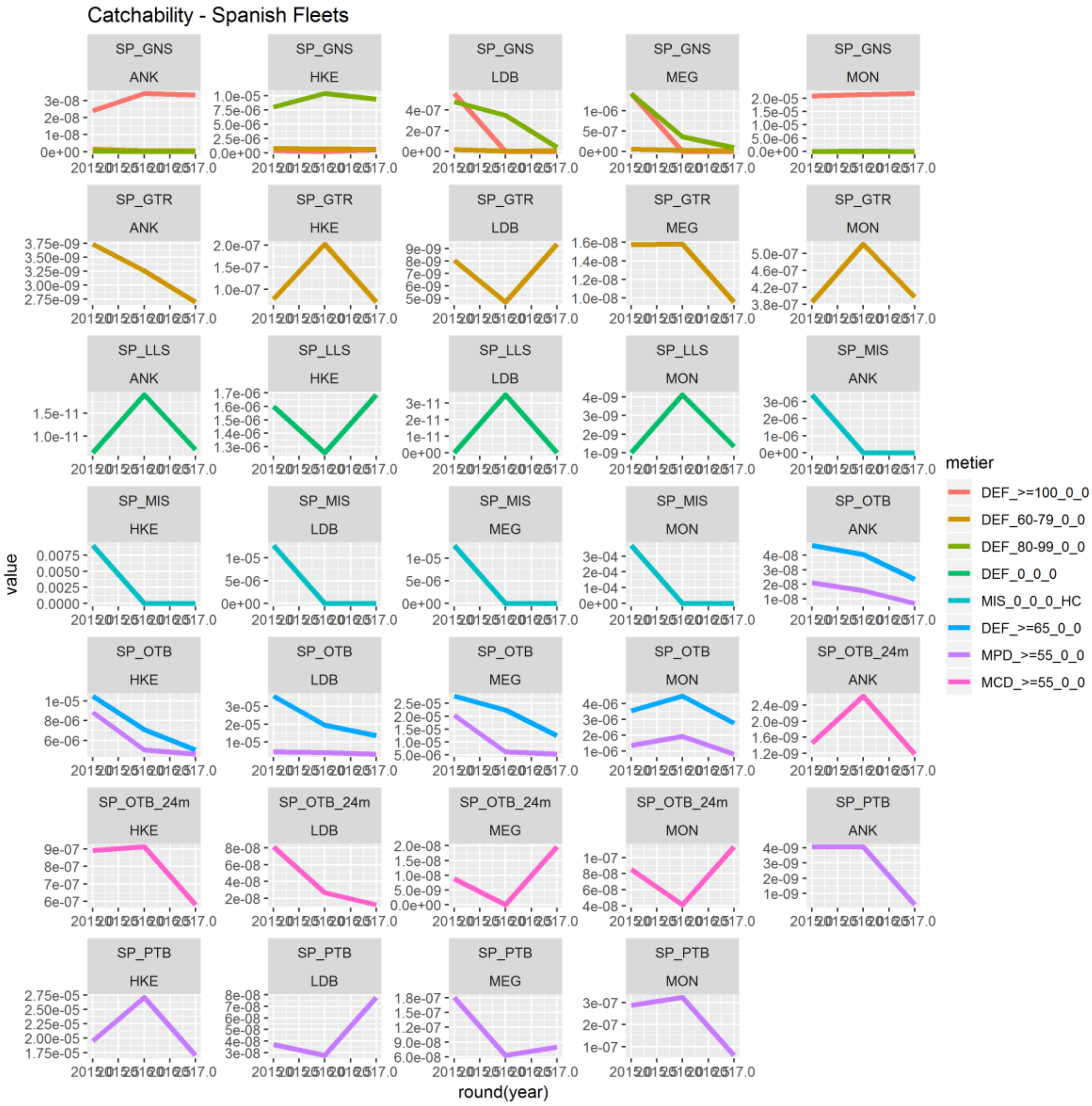


Figure 7.4.a. Iberian waters: trends of Spanish catchability by stock, fleet and métier.

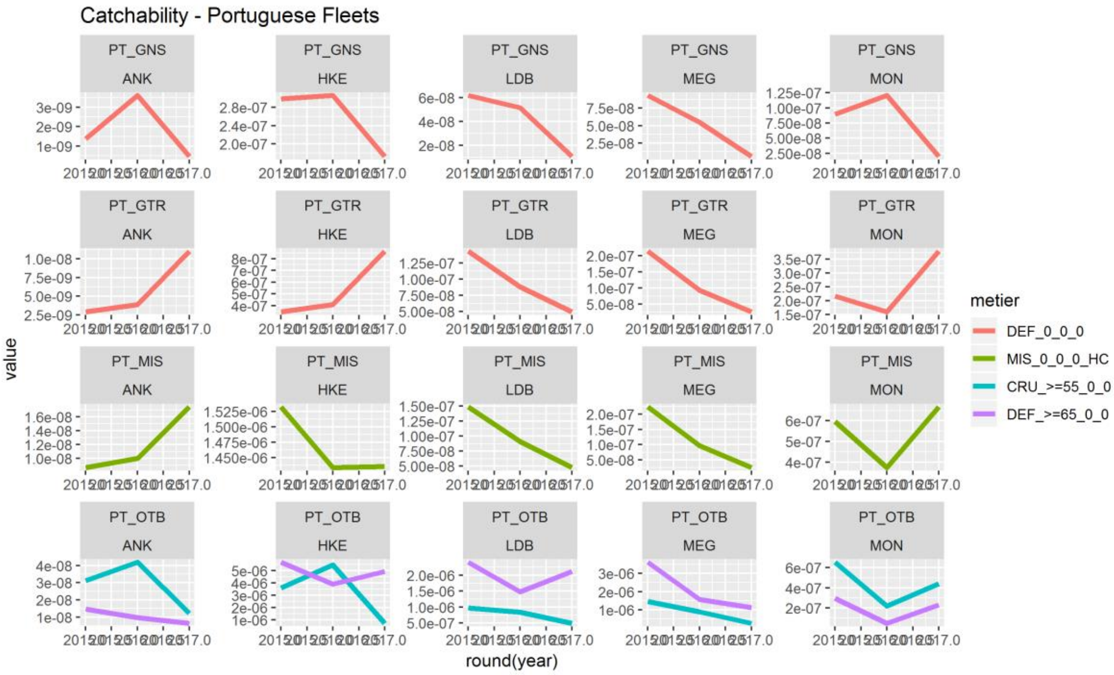


Figure 7.4.b. Iberian waters: trends of Portuguese catchability by stock, fleet and métier.

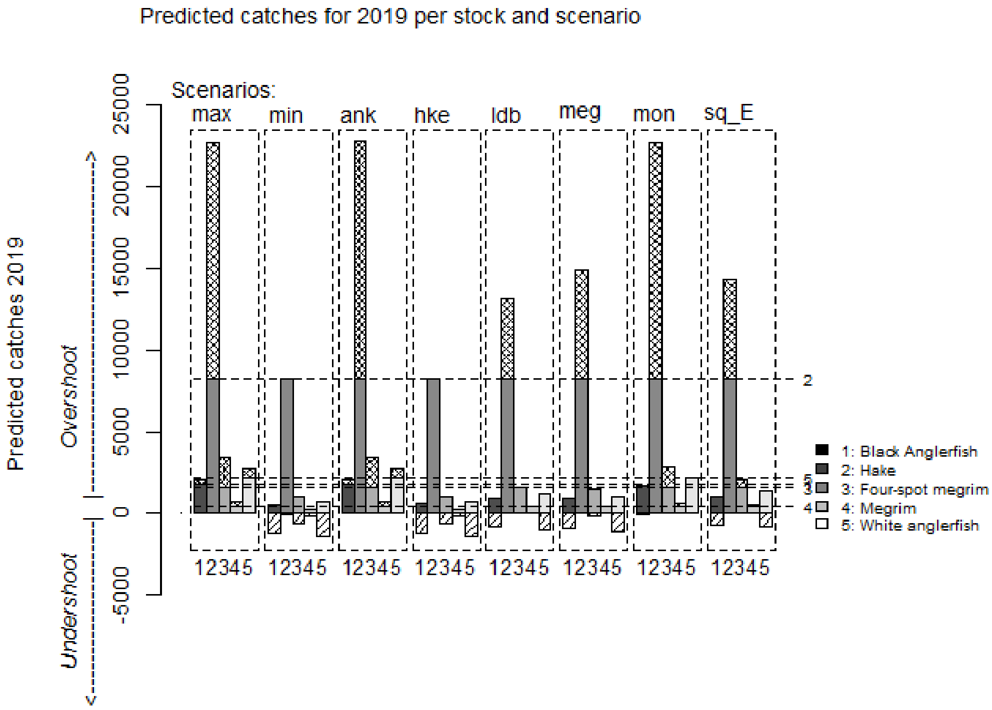


Figure 7.5.a. Iberian waters mixed-fisheries forecasts: TAC year results (2018) including a stock in DLS category 3 (ANL, L. budegassa). Fcube estimates of potential catches by stock after applying the status quo effort scenario to all stocks in the intermediate year followed by the Fcube scenarios. Horizontal lines correspond to the 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. The part of the bar with simple shaded lines indicates the part of the TAC that has not been consumed (undershoot). The double shaded lines indicate an overshoot of the TAC.

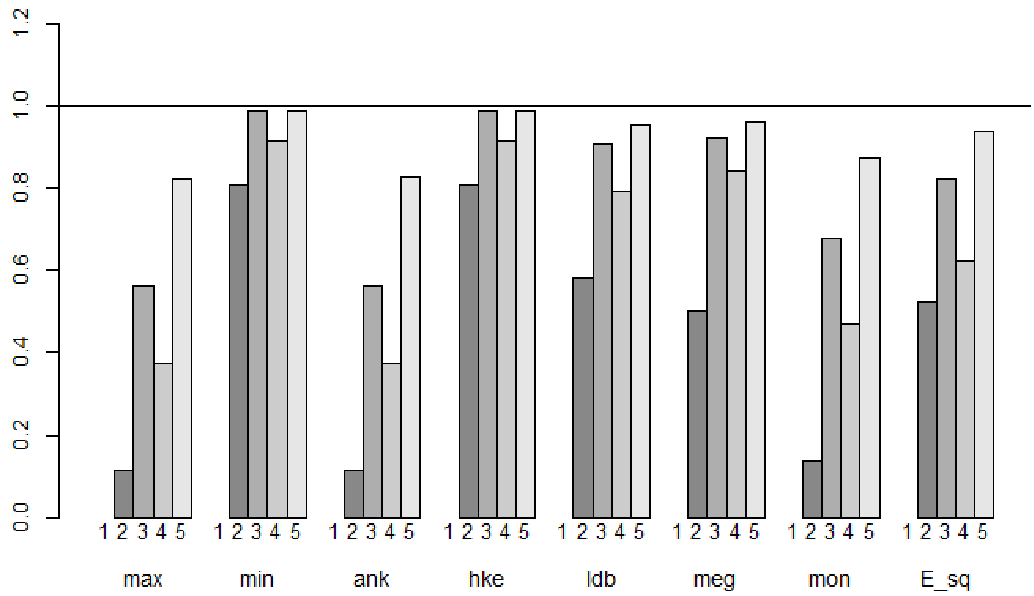


Figure 7.5.b. Iberian waters mixed-fisheries forecasts: Estimates of potential SSB at the start of 2019 by stock after applying the mixed fisheries scenarios, expressed as a ratio to the single species advice forecast. Horizontal line corresponds to the SSB resulting from the single-stock advice (at the start of 2019).

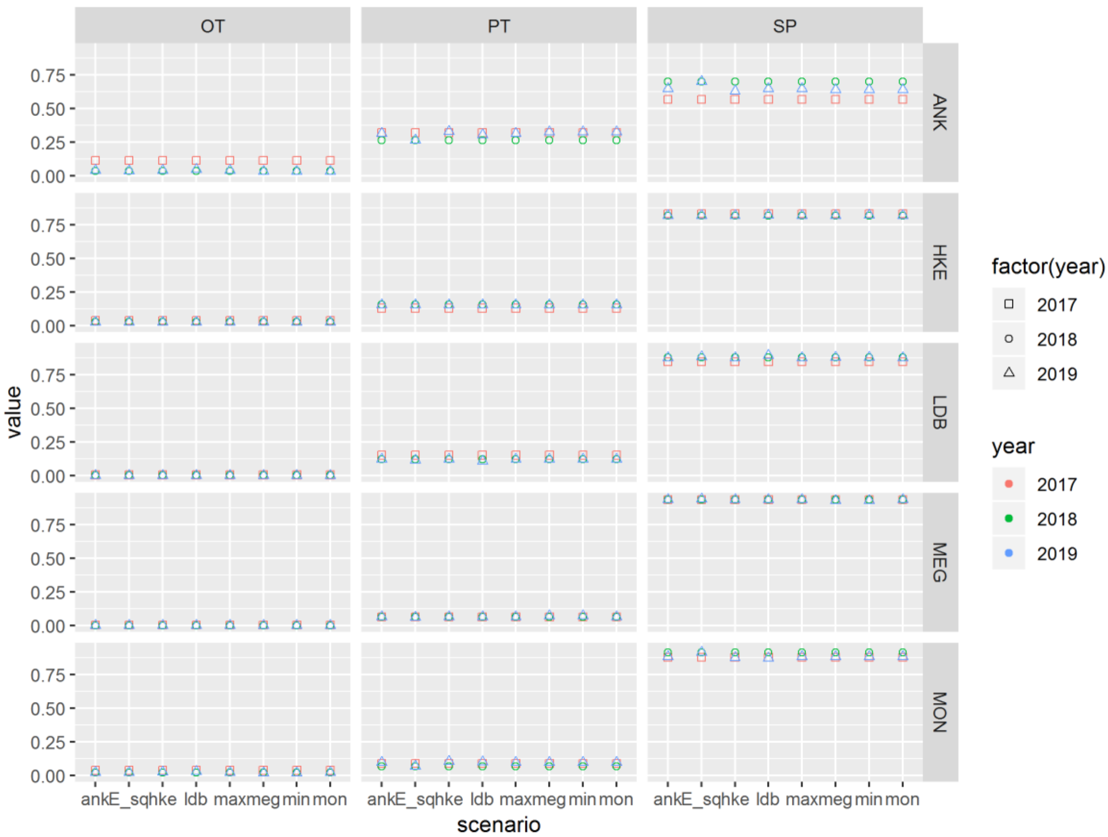


Figure 7.6. Iberian waters mixed-fisheries forecasts: Test for relative stability. Changes of relative share of landings by country in 2018 and 2019 compared to the 2017 share for 7 Fcube scenarios.

8 Presentations

Details of additional presentations given during the meeting.

8.1 Forecasting catch and effort for stocks in category 3 and beyond

(Dorleta Garcia)

To analyze the impact of single stock TACs in mixed-fisheries framework, essentially what it is needed, is to forecast the catch corresponding to a certain effort level and the other way around. In this section we present a procedure to do this forecast without the necessity of knowing the biomass of the stock.

In the forecast of data-rich stocks it is normally assumed that the recruitment in the intermediate and advice years is constant and equal to the mean (or geometric mean) of a certain period in the historical time series. In data limited stocks we can think in biomass, instead of age structure, because the last is usually not known. Hence, analogously we can assume that the biomass is constant, i.e:

$$B_y = B_{y+1} = B$$

If there are time-series of catch and effort available ant métier (m) level, $C_{m,1}, \dots, C_{m,y-1}$ and $E_{m,1}, \dots, E_{m,y-1}$, we can assume that the catch production is described as the product of catchability q_m, biomass and effort E:

$$C_{m,y} = q_m \cdot B_y \cdot E_{m,y}$$

As effort and catch are known, for the historical time-series we can calculate the product between catchability and biomass, α:

$$\alpha_{m,y} = q_m \cdot B_y$$

Using an abundance index or expert knowledge, we can define/identify a period were biomass has been fairly constant to approximate the constan$\alpha_m = q_m \cdot B$ as:

$$\hat{\alpha}_{m,y} = \widehat{q_m \cdot B} = \text{mean}(q_m \cdot B_y)_{y=y_0}^{y_1}$$

In a previous study carried out by WGMIXFISH members (REF) it was concluded that the best predictor of the CPUE is the CPUE of previous year. Hence, assuming that the biomass and the CPUE are linearly related, the best estimate of B would be B_{y-1} and the best estimate of α would be:

$$\hat{\alpha}_m = q_m \cdot B_{y-1} = \frac{C_{m,y-1}}{E_{m,y-1}}$$

Then in the projection we can use $\hat{\alpha}$ to calculate:

- The catch corresponding to a given effort as: $C_E = \hat{\alpha} \cdot \mathrm{E}$
- Or the effort corresponding to the TAC as: $E_{TAC} = \frac{\mathrm{TAC}}{\hat{\alpha}}$

The procedure can be applied at fleet/métier level using the corresponding catch, effort and quota share data. The procedure could be generalized to other stock production functions like the Cobb-Douglas that includes elasticity parameters in biomass and effort. The only restriction is that the biomass and other parameters can be distinguished from effort and catch.

8.2 Fishers behaviour in response to catch shares

(Peter Kuriyama)

Catch shares were implemented in 2011 in the US West Coast Groundfish fishery. The risk of exceeding overfished species quotas is high, and fishing effort may concentrate in areas with known species mixes. Additionally, communication and collaboration among fishers may increase. We measured shifts in fishing effort in each of the two years before and four years after catch share implementation and fit random utility models to these data to measure port-specific behavioral changes. Fishing effort declined and concentrated in areas closer to the coast. Fine-scale individual vessel habits (within five kilometer radii), distance from port and the previous tow, and revenues were significant predictors of fishing locations ($p < 0.05$) in all ports in all years. There was also evidence that in Astoria and Newport, the two biggest ports, fishers were hesitant to fish in areas unfished recently by members of the fleet. Bycatch expectations, accounted for as the coast of purchasing quota for each species, did not affect location choices. Thus, somewhat to our surprise, fishing locations were better explained by habits, distance, and revenue than by avoidance costs associated with fishing in areas with the highest quota prices.

8.3 Defining choice sets of fleets dynamic models

(Peter Kuriyama)

A central component of any discrete choice analysis is the selection of alternatives that determine a decision agent's choice set. Failure to properly specify an agent's choice set will generate biased parameter estimates resulting in inaccurate behavioral predictions as well as biased estimates of policy relevant metrics (e.g. elasticities and welfare measures). The development of more behaviorally realistic choice sets is integral to our ability to predict agent behavior and inform public policy. We propose two methods of constructing choice sets by sampling from a set of specific points in space that can be used to model agent behavior when choice alternatives are unknown to the researcher, potentially infinite, and differ according to spatial and temporal factors. We consider an approach that samples only from observed choice locations and one that samples from all locations on a fine scale grid. Using Monte Carlo analysis we compare the performance of these point-based sampling methods to commonly used methods that simplify the geospatial complexity of an agent's choice set by spatially aggregating choice alternatives over pre-defined discrete areas. We then apply these alternative approaches to modelling location choices made in the Pacific groundfish trawl fishery that has a complex spatial choice structure. Both the Monte Carlo and application results provide considerable support for the efficacy of approaches that create choice sets by sampling from a set of specific locations rather than from discrete areas that aggregate potential choice alternatives over space.

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Annex 2: Proposed ToR for 2019 WGMIXFISH Meetings

2019/X/ACOMXX The Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METHODS), chaired by Claire Moore, Ireland, will meet in Nantes, France 10-14 June, 2019 to:

a) Document the complete workflow of WGMIXFISH-ADVICE, from data submission to advice production, in order to improve the workflow and increase understanding of the process, both within and outside the working group.
b) Develop a road map for future WGMIXFISH development and advice.
c) Update and develop datacall for WGMIXFISH-ADVICE, identifying possible areas of improvements, expansion, and cohesion across ecoregions.
d) Continued exploration of the impacts of additional species to the Celtic Sea FCube model.
e) Assess the fleet/métier definition in Bay of Biscay.
f) Development of Irish Sea FCube.
g) Continued development of the combined implementation of FCube and FLBEIA in conjugation with STECF/WGECON economists.
h) Presentation of results of WKTarget workshop and future collaborations with WGMIXFISH.

WGMIXFISH-METHODS will report by 15 July 2019 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.

Annex 3: Landings plots for roundfish and flatfish

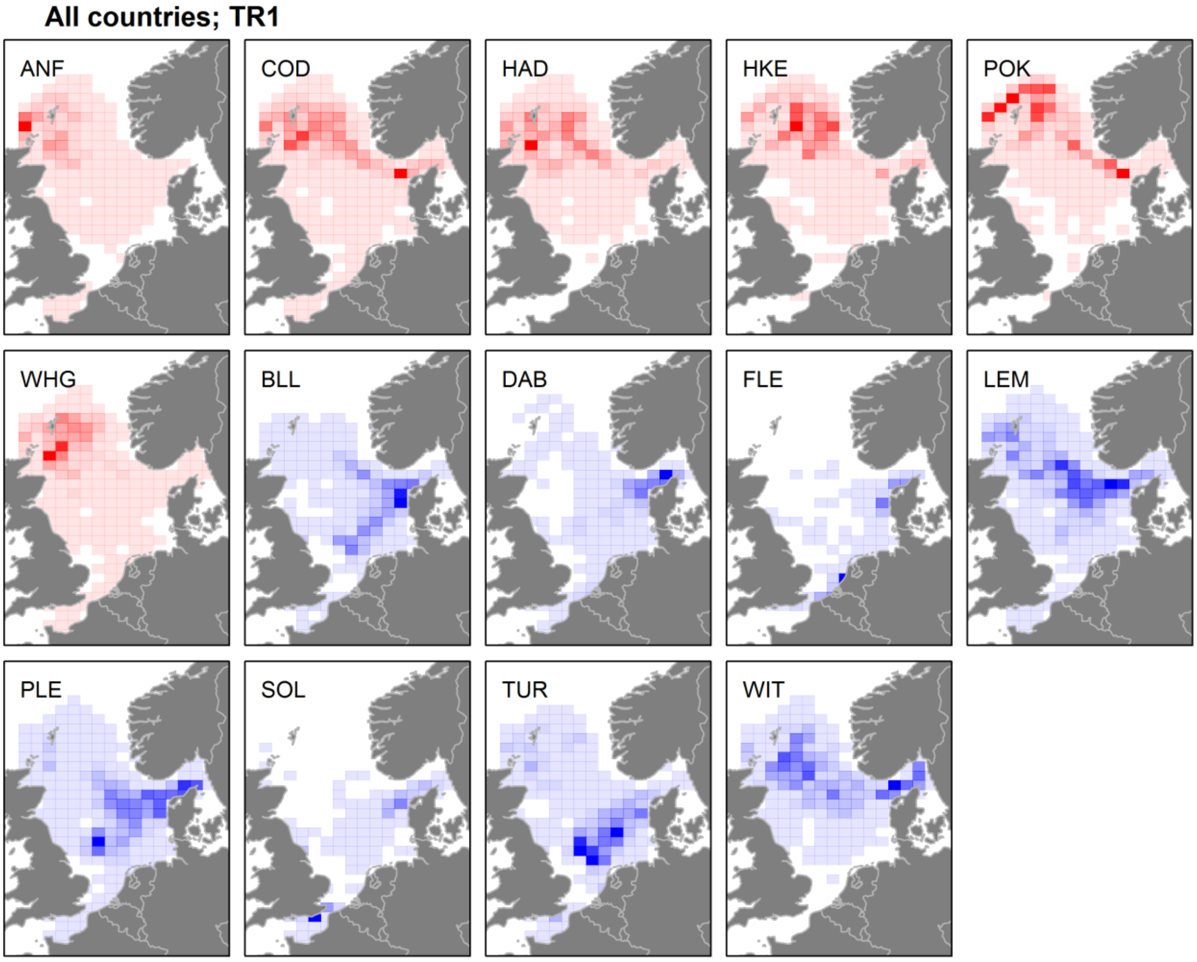

Figure A3.1. Total landings for TR1 gear by ICES rectangle and stock for 2016. Roundfish and flatfish stocks are coloured in red and blue, respectively. Darker colours indicate higher landings. See Table 4.1 for stock code definitions.

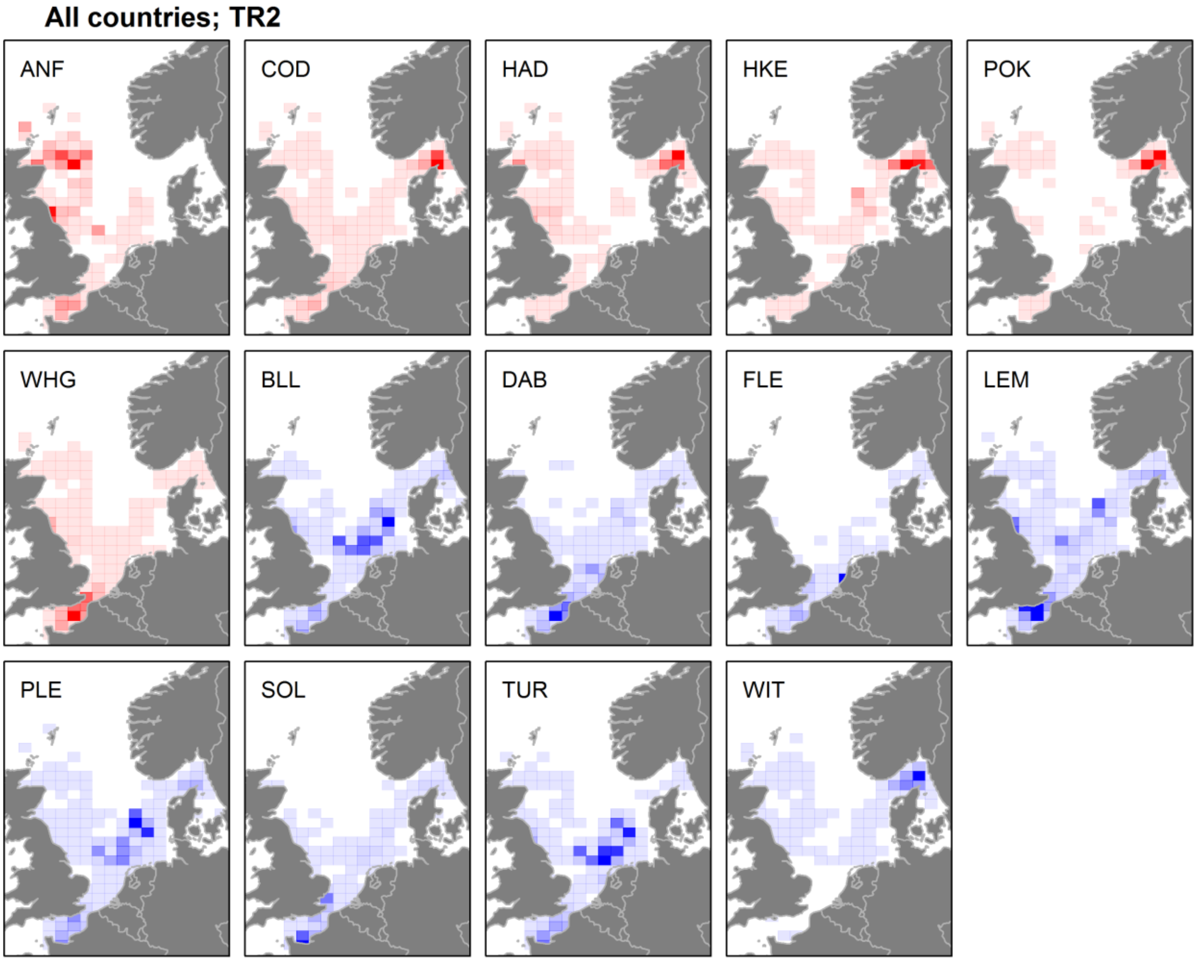

Figure A3.2. Total landings for TR2 gear by ICES rectangle and stock for 2016. Roundfish and flatfish stocks are coloured in red and blue, respectively. Darker colours indicate higher landings. See Table 4.1 for stock code definitions.

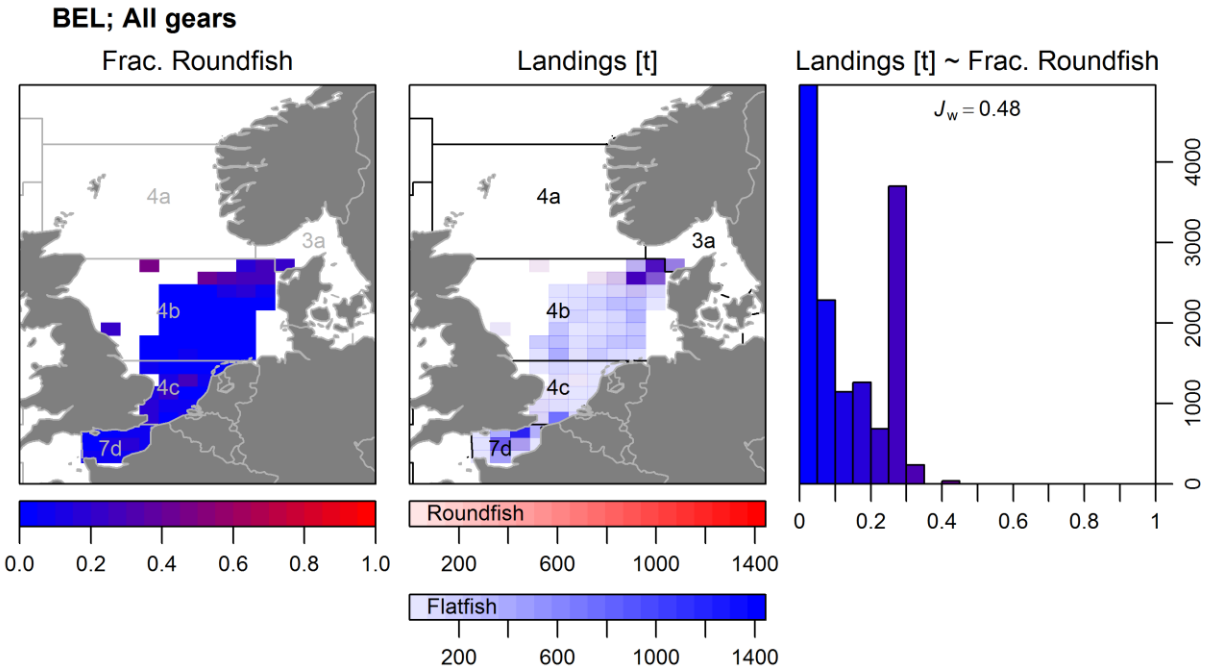

Figure A3.3. Landings for Belgium by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.

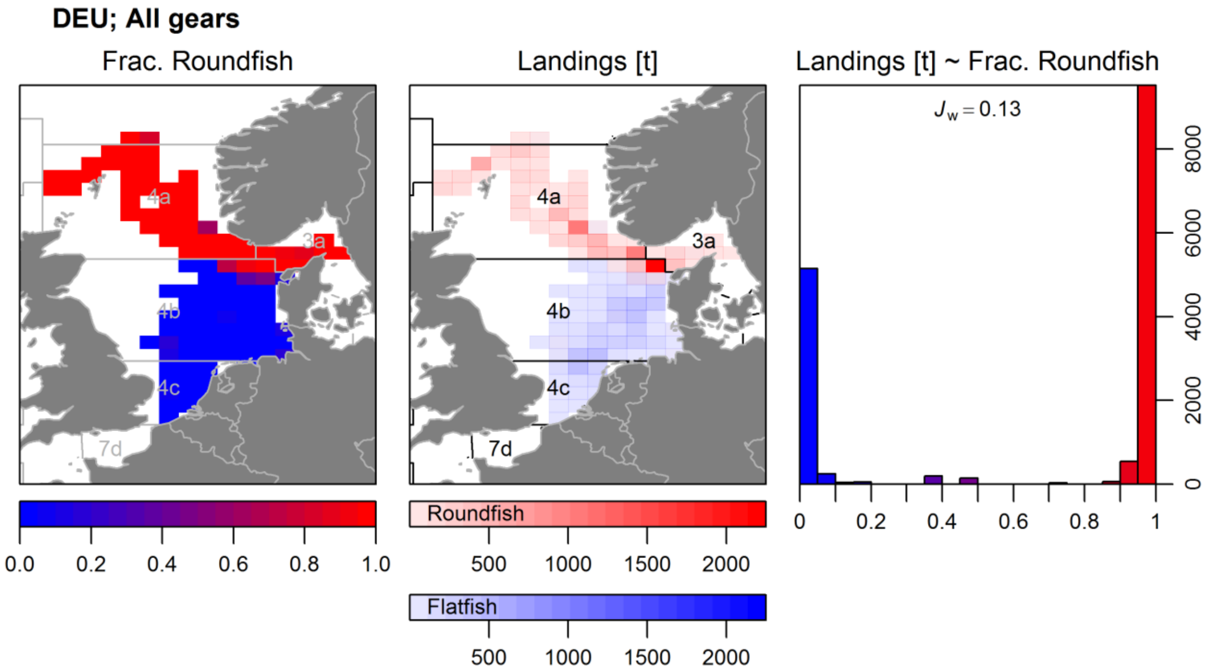

Figure A3.4. Landings for Germany by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.

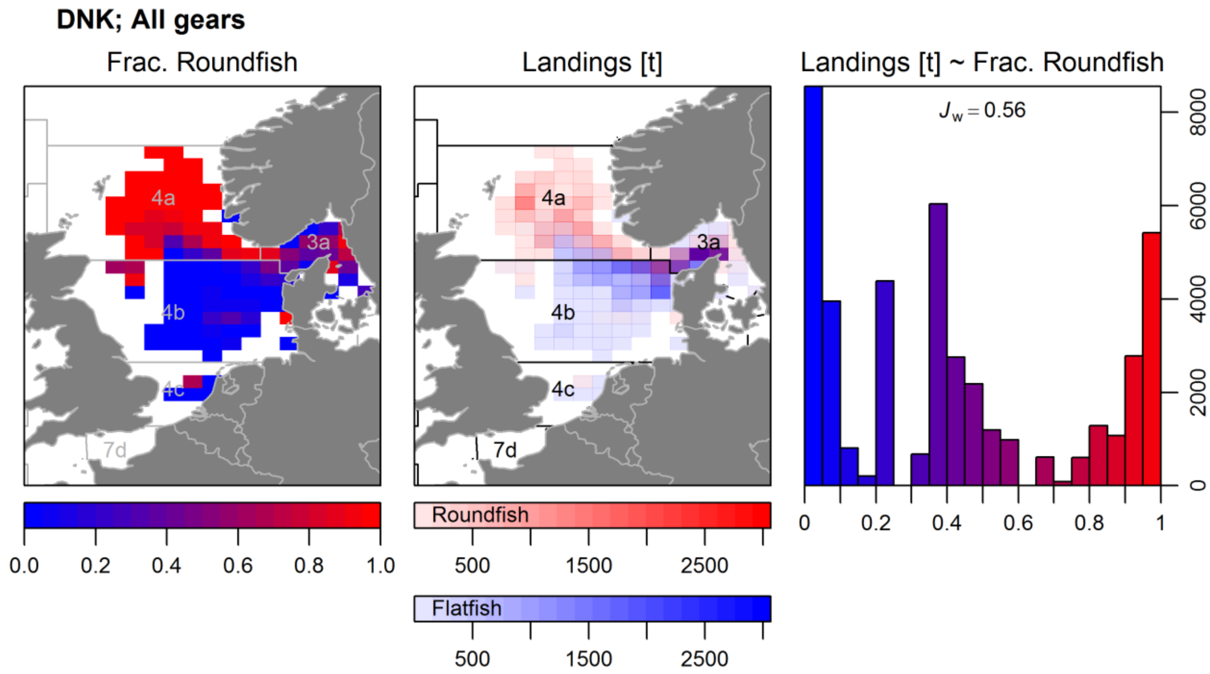

Figure A3.5. Landings for Denmark by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.

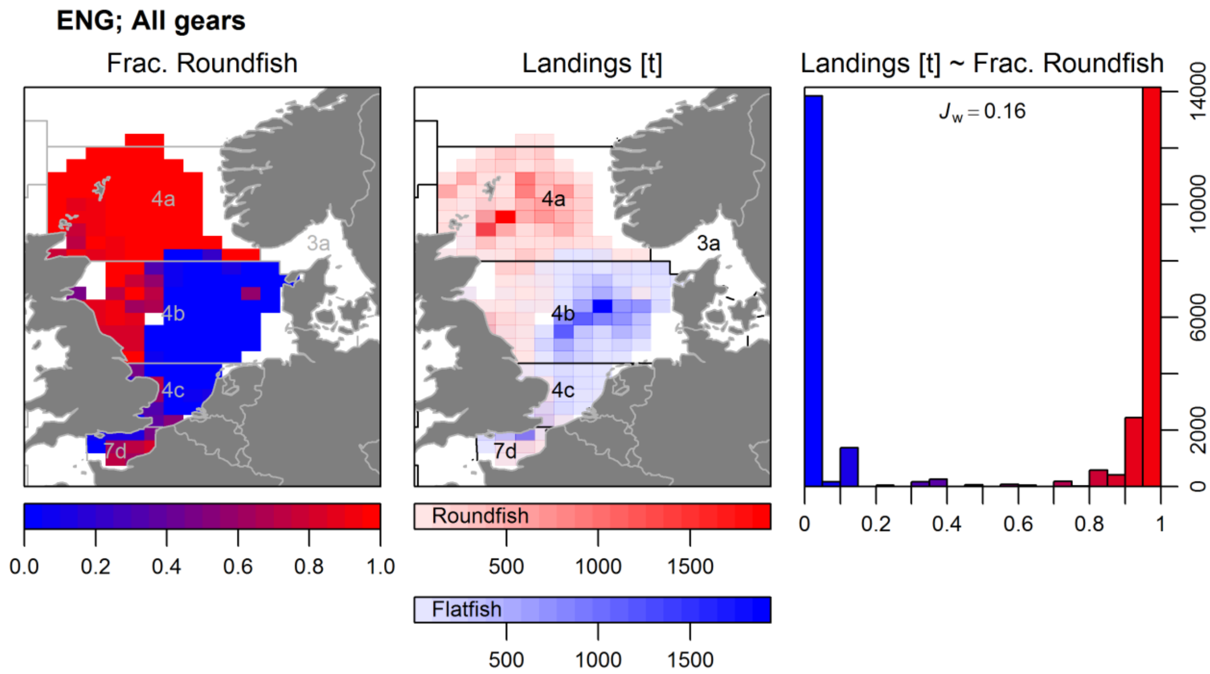

Figure A3.6. Landings for England by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.

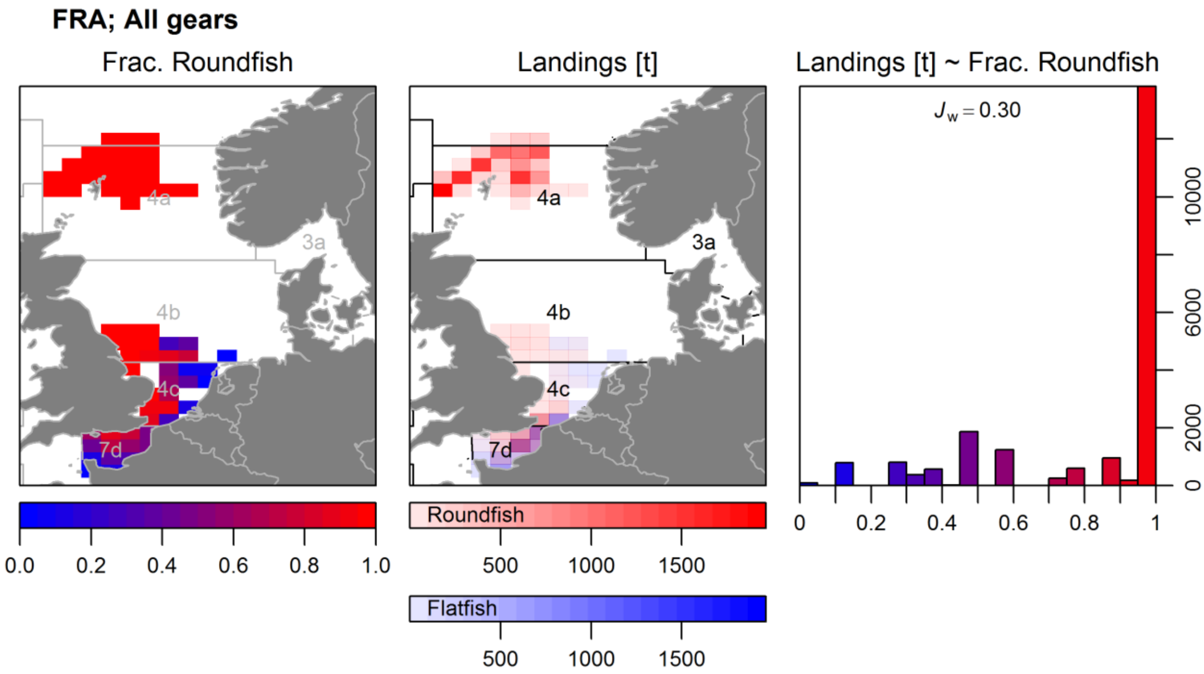

Figure A3.7. Landings for France by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.

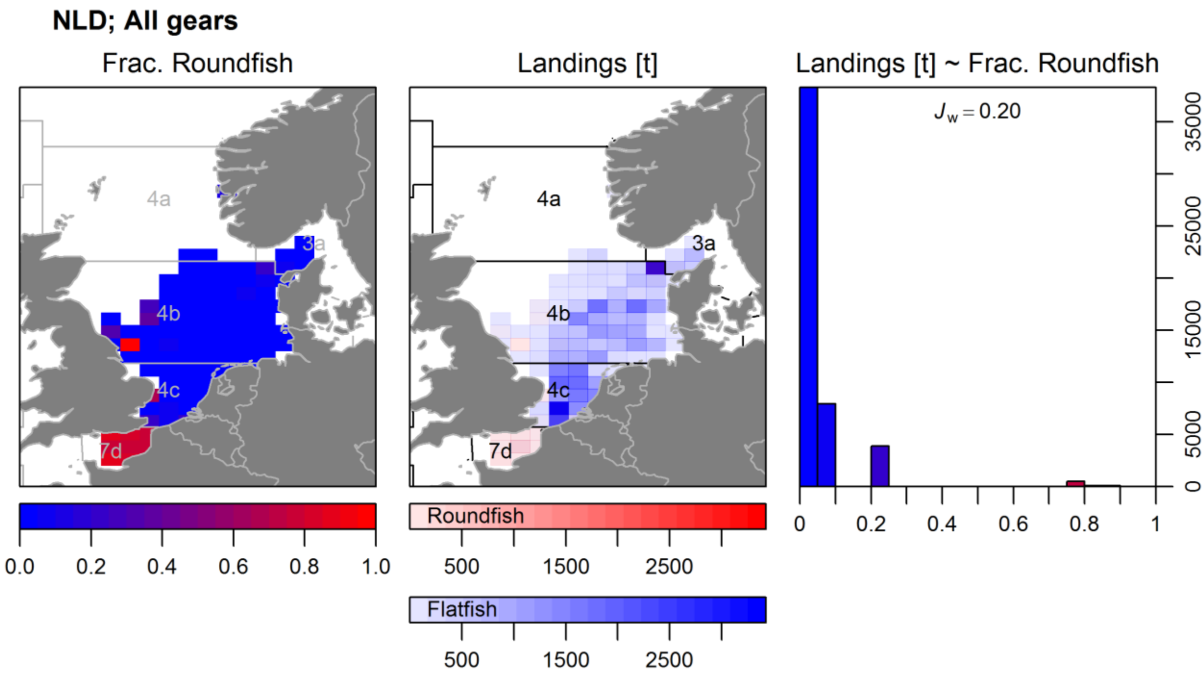

Figure A3.8. Landings for Netherlands by ICES rectangle and stock aggregates for 2016. See Fig. 3.2 for details.

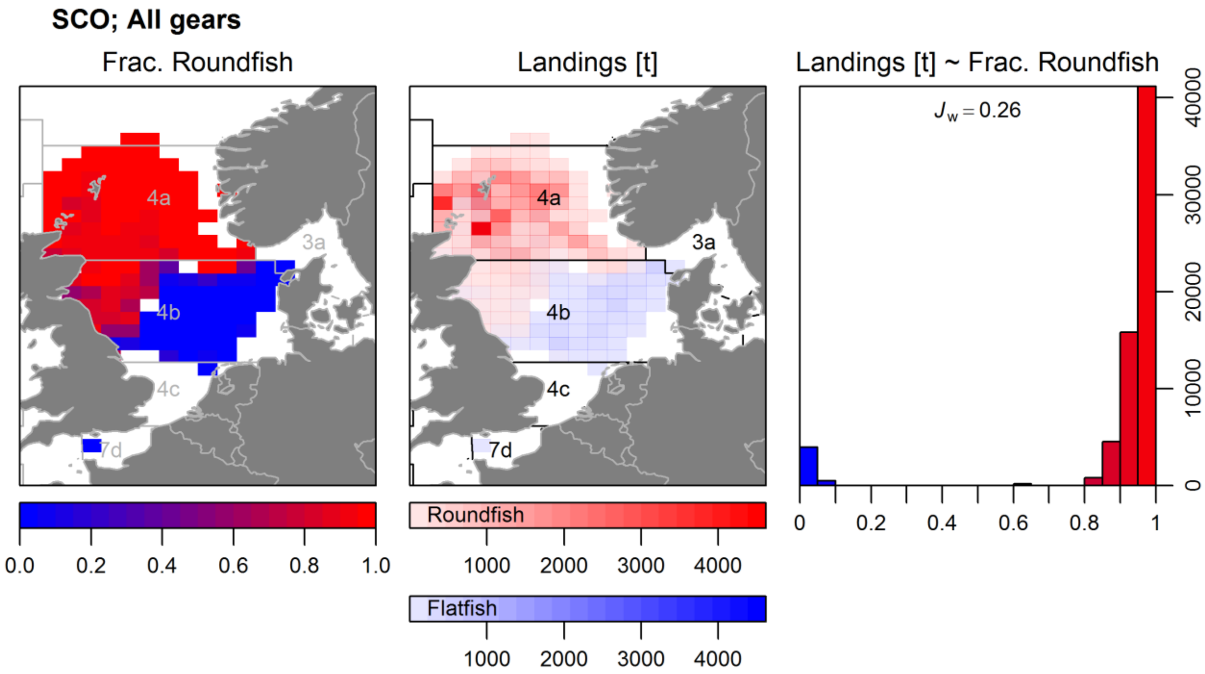

Figure A3.9. Landings for Scotland by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.

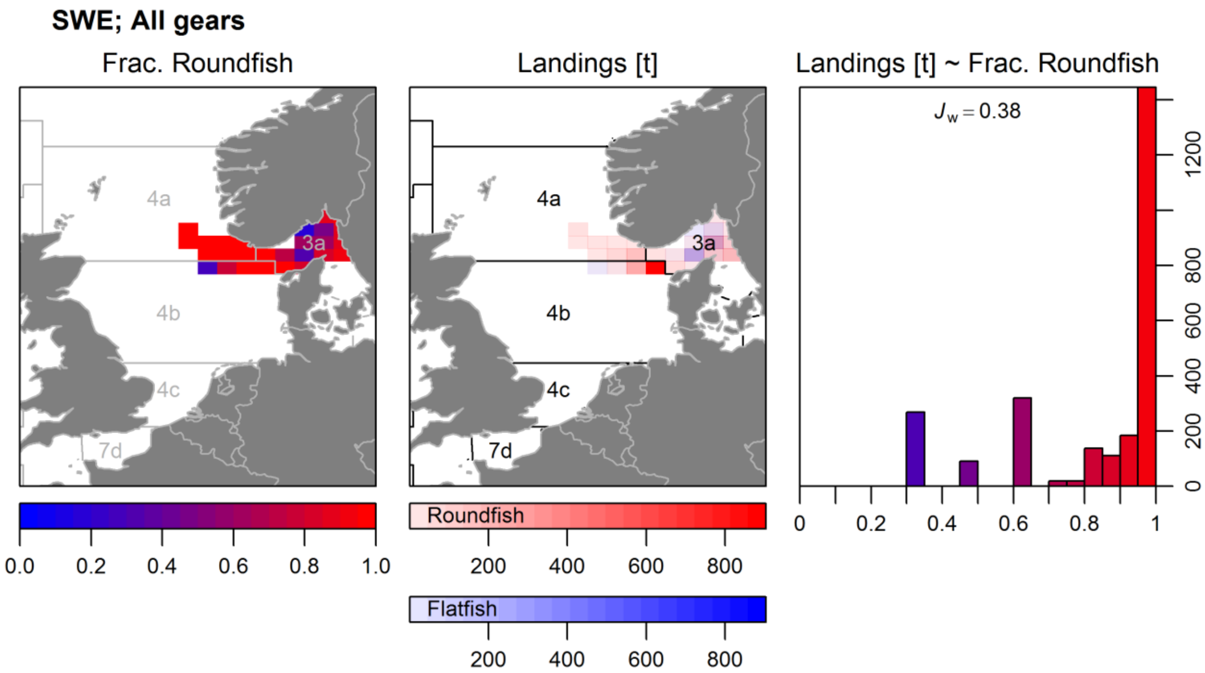

Figure A3.10. Landings for Sweden by ICES rectangle and stock aggregates for 2016. See Fig. 4.2 for details.