Celtic Sea mixed-fisheries considerations

Mixed-fisheries considerations for divisions 7.b–c and 7.e–k (Celtic Sea)

Mixed-fisheries considerations are presented for cod (cod.27.7e-k), haddock (had.27.7b-k), whiting (whg.27.7b-ce-k), Norway lobster (functional units [FUs] 16, 17, 19, 20–21, 22, and 27.7 outside FUs), sole (sol.27.7fg), white anglerfish (mon.27.78abd), and megrim (meg.27.7b-k8abd) in the Celtic Sea.

Based on mixed-fisheries considerations and single-stock catch advice, cod is the most limiting stock for Celtic Sea demersal fisheries. This is due to the zero-catch advice for cod and because almost all fisheries operating with demersal gears catch cod. Six fishing scenarios are presented (Figure 1, descriptions in Table 1) to illustrate trade-offs in catches, fishing mortality and SSB for different mixed fisheries scenarios.

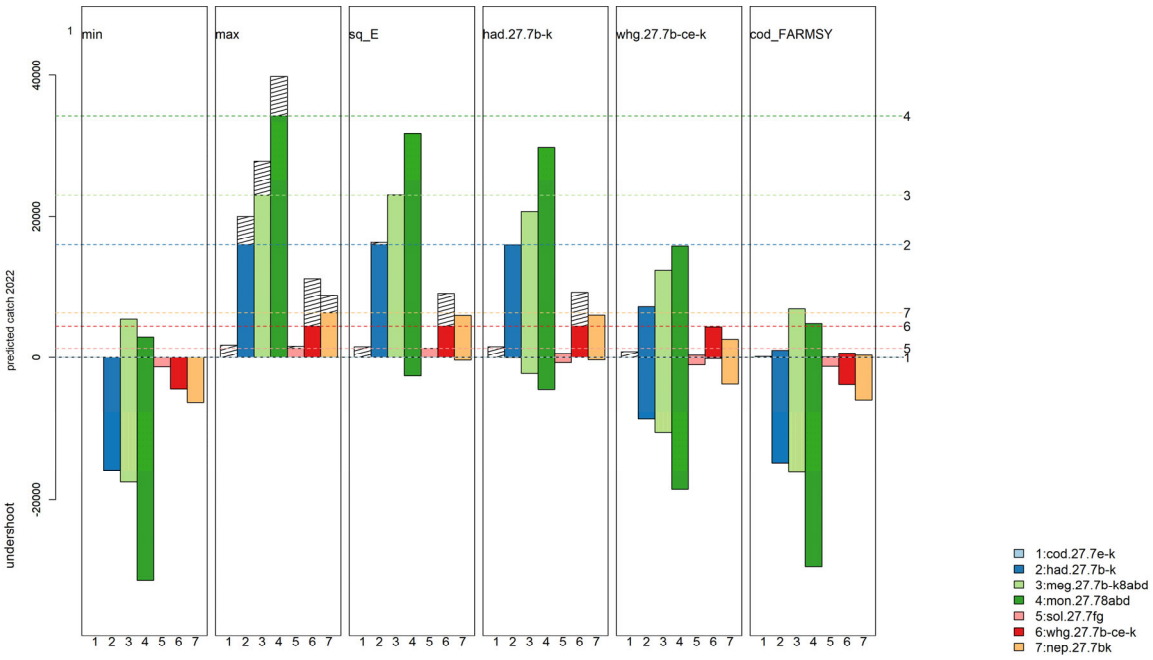

Figure 1 Mixed fisheries for the Celtic Sea. Mixed-fisheries projections. Estimates of potential catches (in tonnes) by stock and by scenario (Table 1). The horizontal lines correspond to the single-stock catch advice for 2022. The bars below the value of zero show undershoots (compared to single-stock advice) where catches are predicted to be lower when applying the scenario. Hatched bars represent catches that overshoot the single-stock advice.

An alternative analysis estimates the fishing mortality (F) by stock which, if used for setting single-stock fishing opportunities for 2022, may reduce the gap between the most and the least restrictive advised catch, thus reducing the potential for catch advice overshoot and undershoot. This approach is only used for demersal stocks that have the F_{MSY} range available (Figure 2). This "range" scenario suggests that the fishing mortality rates for cod and whiting are at the upper end of the F_{MSY} range, with all other stocks being at or close to the lowest bound of their respective F_{MSY} ranges (Figure 2). Norway lobster is not included in this "range" scenario.

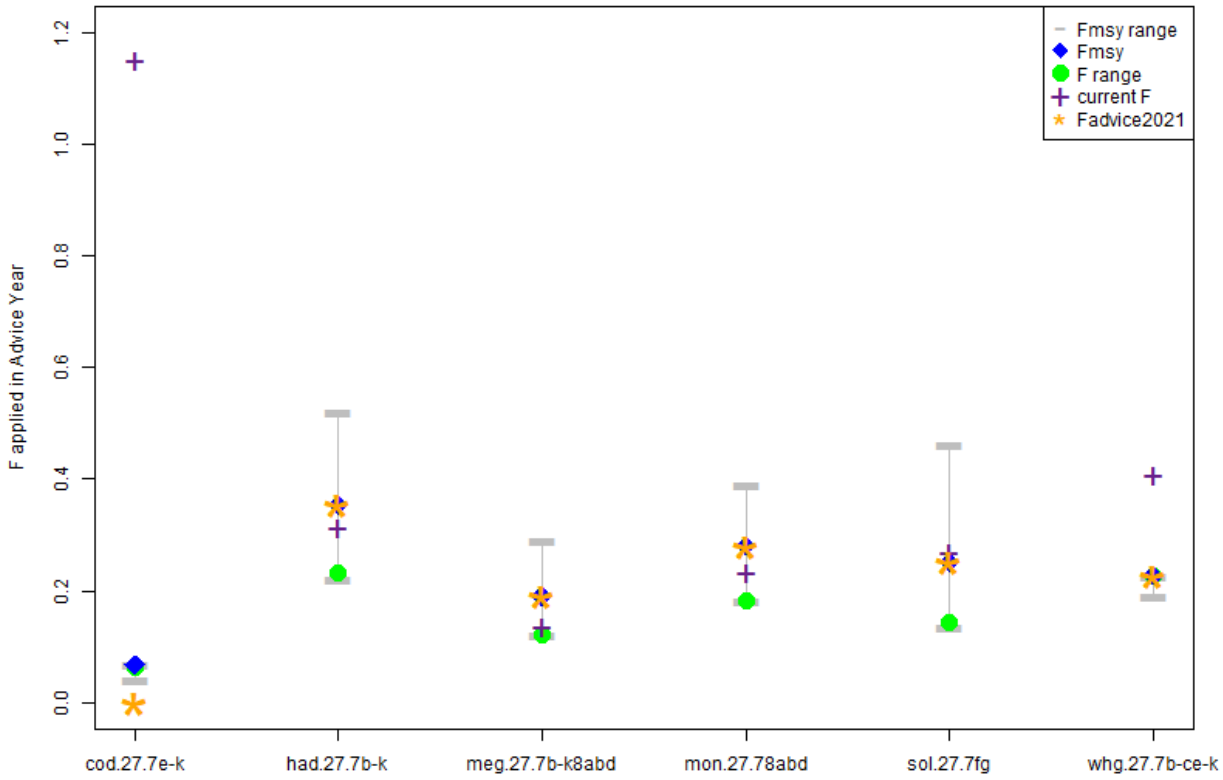

Figure 2 Mixed fisheries for the Celtic Sea. The fishing mortality applied in 2022 for the "F range" scenario using the reduced F_{MSY} ranges for cod and whiting. The "F range" scenario uses fishing mortality rates for each stock that reduce the mismatch between opportunities for the six stocks. The current fishing mortality (2020), the fishing mortality corresponding to the single-stock advice, and the F_{MSY} and the F_{MSY} ranges are shown for comparison.

Table 1 Mixed fisheries for the Celtic Sea. Mixed-fisheries scenarios considered for the Celtic Sea demersal fisheries.

Scenario codes	Scenarios
max	**"Maximum":** For each fleet, fishing stops when all stocks have been caught up to the fleet's stock shares*. This option causes overfishing of the single-stock advice possibilities of all stocks.
min	**"Minimum":** For each fleet, fishing stops when the catch for any one of the stocks meets the fleet's stock share. This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks.
sq_E	**"*Status quo* effort":** The effort of each fleet in the catch advice year (2022) is set equal to the average effort in the most recent three years (2018–2020) for which catch and effort data are available.
had.27.7b–k	**"Haddock MSY approach":** All fleets set their effort corresponding to that required to catch their haddock stock share, regardless of other catches.
whg.27.7b–ce–k	**"Whiting MSY approach":** All fleets set their effort corresponding to that required to catch their whiting stock share, regardless of other catches.
cod_F_{AR}MSY	**"Reduced cod F_{MSY}":** All fleets set their effort corresponding to that required to catch their cod stock share, where the cod advice is set according to reduced F_{MSY} ($F = 0.068 = F_{MSY} \times SSB_{2022}/MSY\ B_{trigger}$), regardless of other catches.

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

Catch scenarios

Mixed-fisheries advice considers the implications of mixed fisheries operating under single-stock catch advice regimes based on the fishing patterns of the various fleets in recent years (2018–2020). Scenario assumptions for the intermediate

year (2021) and forecast year (2022) are listed in Table 2. These assumptions may differ from those used in the single stock forecasts.

Table 2 Mixed fisheries for the Celtic Sea. Assumptions made for the intermediate year (2021) and in the forecast year (2022).

Variable	Value
Effort per fleet (2021)	kWdays: average (2018–2020)
Fishing patterns (2021-2022)	Catchability by stock and métier: average (2018–2020) Effort-share by métier: average (2018–2020)
Quota allocations (2022)	Landings shares for fleets: average (2018–2020)
Catches outside of the Celtic Sea (2022)	Full uptake of quota. This relates to area 27.8abd catches of anglerfish and megrim.

A total of six scenarios are presented, corresponding to different fleet behaviours for 2022 (Table 1). The forecasted scenarios are presented in terms of catch and the potential for quota over- and undershoot, which is driven by the most and the least restrictive single-stock advice (Figure 1). Scenarios that result in under- or overutilization are useful in identifying imbalance between the fishing opportunities of the various stocks. They indicate the direction in which fleets may have to adapt to more fully utilize their catch opportunities without collectively exceeding single-stock fishing opportunities. The scenarios presented here do not assume either any quota balancing in the forecast through changes in targeting behaviour in 2022 or any change in the selection pattern of the fleets.

The "min" scenario is consistent with a full implementation of the EU landing obligation given the individual single-stock advice. In 2022, the "min" scenario shows that cod limits 22 of the 24 fleets due to the zero-catch advice for cod and that almost all fleets catch cod to a greater or lesser extent. The two remaining fleets had no cod landings and one of these was limited by whiting (Figure 3). The "max" scenario demonstrates the upper bound of potential fleet effort and stock catches (Table 3, Figure 1), in that it assumes all fleets continue fishing until all their stock shares for all stocks are exhausted. Clearly, the assumption that all fleets continue fishing until all their stock shares are exhausted irrespective of economic viability, legality, or fleet capacity, does not make it a plausible scenario. Its purpose is mainly to illustrate inconsistencies in single-stock catch advice. In 2022, the "max" scenario indicated that fleets have different least limiting stocks, which results in over-quota catches of all stocks (Figure 3). Megrim (six fleets), white anglerfish (three fleets), Norway lobster (12 fleets over four different functional units [FUs]), and haddock (two fleets) are the least limiting stocks.

Almost all fleets in the Celtic Sea catch cod, which is the most limiting stock in this area. The 2022 forecast with the cod catch advice at zero implies that catches of the other Celtic Sea stocks would also be zero (the "min" scenario), there would be some catch of anglerfish and megrim in the Bay of Biscay (area 27.8abd). To provide a scenario with non-zero catch, a reduced cod F_{MSY} scenario is presented ("cod_F_{AR}MSY"), based on ICES advice rule, which gives an F value of 0.068 for cod and results in undershoots for all other stocks, as fishing is stopped when the cod quota is reached. Under this scenario fleets would be required to reduce their effort (2022) by 94%. The "max" scenario assumes that all fleets catch all their quotas irrespective of the economic viability of doing so and is intended to represent the maximum potential catch; this scenario leads to an overshoot for all stocks, as individual fleets are least limited by different stocks.

The *status quo* effort scenario ("sq_E") results in full utilization of most stocks, a small overshoot of haddock, a large overshoot of cod and whiting, and a small undershoot of white anglerfish and Norway lobster.

Mixed-fisheries catch scenarios can take specific management priorities into account, and these results indicate that it is not possible to achieve all single-species management objectives simultaneously. ICES single-stock advice for demersal stocks considered here is based on the EU multiannual plan (MAP) for demersal stocks in the western waters (EU, 2019), except for nep.27.7outFU (which is based on the precautionary approach). ICES provides zero-catch advice for cod in 2022, based on precautionary considerations. The "max", "sq_E", and "had.27.7b–k" scenarios all result in cod being fished above F_{lim} (1.130) in 2022. All demersal fish stocks are fished above F_{MSY} under the "max" scenario, while all but white anglerfish and sole are fished above F_{MSY} under the "sq_E" scenario (Table 4).

A "range" scenario as described in Ulrich *et al*. (2017) searches for the minimum sum of differences between potential catches by stock under the "min" and "max" scenarios within the F_{MSY} ranges. It estimates fishing mortality by stock which, if used for setting single-stock fishing opportunities for 2022, may reduce the gap between the most and least restrictive TACs, thus reducing the potential quota over- and undershoot. This scenario was run using reduced F_{MSY} ranges when stock

size is below MSY $B_{trigger}$ for cod (F_{MSY} range 0.040–0.068) and whiting (F_{MSY} range 0.191–0.228) and the full range for the other stocks. Norway lobster is not included in this "range" scenario. The outcomes of this scenario (Figure 2) are driven by the restrictive nature of the whiting and cod advice. Fishing mortality rates for cod and whiting are at the upper end of the F_{MSY} range, with all other stocks being at or close to the lowest bound of their respective F_{MSY} ranges. The results are presented as outcomes of single-stock forecasts using the identified range of fishing mortalities and do not take account of the technical interactions as for the mixed-fisheries scenarios. This implies that the catches forecasted within the "range" scenario could only be achieved with substantial changes in fishing patterns.

Table 3 Mixed fisheries for the Celtic Sea. Catch per mixed-fisheries scenario 2022, in tonnes.

Stock	Single-stock catch advice (2022)^	Catch per mixed-fisheries scenario (2022)						Range*
		max	min	sq_E	cod_F_{AR}MSY	had.27.7b–k	whg.27.7b–ce–k	
cod.27.7e-k	0	1775	0	1536	132	1543	834	126
had.27.7b-k	15946	19996	0	16281	1040	15899	7195	11058
meg.27.7b-k8abd	22964^	27832	5446	23015	6882	20691	12341	15608
mon.27.78abd	34275	39775	2905	31701	4812	29742	15746	23125
sol.27.7fg	1337	1615	0	1332	71	601	314	809
whg.27.7b-ce-k	4452	11187	0	9104	635	9240	4310	4452
nep.fu.16	2804	3443	0	2113	116	2172	880	n/a
nep.fu.17	360	291	0	190	10	194	83	n/a
nep.fu.19	407	307	0	225	11	233	104	n/a
nep.fu.2021	1978	2639	0	1958	108	1880	870	n/a
nep.fu.22	1257	1967	0	1340	72	1361	586	n/a
nep.27.7outFU	150	210	0	141	8	142	61	n/a

n/a: stocks for which ranges of F_{MSY} are either not available or not yet included in the scenario.
* The results of the "range" scenario are bounded by the single-stock MSY ranges (or reduced ranges) and do not directly account for any technical interactions. These catches could only be achieved with substantial changes in fishing patterns.
^ Advised catches of no more than the indicated value.

Table 4 Mixed fisheries for the Celtic Sea. Fishing mortality (F) or harvest ratio (for Norway lobster) resulting from single-stock advice and different mixed-fisheries scenarios. The colour gradients of the legend show the forecast fishing mortality under each scenario in relation to reference points detailed in the legend.

Stock	Single-stock F advice (2022)	F(2022) resulting from mixed-fisheries scenarios						Range**
		max	min	sq_E	cod_F_{AR}MSY	had.27.7b–k	whg.27.7b–ce–k	
cod.27.7e-k	0	1.616	0	1.232	0.068	1.243	0.511	0.064
had.27.7b-k	0.353	0.493	0	0.385	0.021	0.374	0.154	0.232
meg.27.7b-k8abd	0.191	0.23	0.041	0.186	0.052	0.166	0.096	0.12
mon.27.78abd	0.280	0.335	0.021	0.258	0.035	0.24	0.12	0.18
sol.27.7fg	0.251	0.311	0	0.249	0.012	0.105	0.053	0.145
whg.27.7b-ce-k	0.228	0.749	0	0.571	0.032	0.582	0.236	0.228
nep.fu.16*	0.062	0.076	0	0.047	0.003	0.048	0.019	n/a
nep.fu.17*	0.052	0.044	0	0.029	0.002	0.029	0.012	n/a
nep.fu.19*	0.058	0.05	0	0.036	0.002	0.038	0.017	n/a
nep.fu.2021*	0.060	0.085	0	0.063	0.003	0.06	0.028	n/a
nep.fu.22*	0.085	0.141	0	0.096	0.005	0.097	0.042	n/a

Legend

$F_{2022} \leq F_{MSY}$
$F_{2022} > F_{MSY}$, $< F_{pa}$
$F_{2022} > F_{pa}$, $< F_{lim}$
$F_{2022} > F_{lim}$

*Norway lobster stocks have no F_{pa} or F_{lim} limits, and so colours relate to above (black) or below (white) F_{MSY} harvest ratios.
**Single-stock advice is based on F ranges in accordance with the EU MAP for demersal stocks in the western waters (EU, 2019).

Table 5 Mixed fisheries for the Celtic Sea. Spawning-stock biomass (SSB) results in 2023 from single-stock advice and different mixed-fisheries scenarios (Figure 2). Weights in tonnes. The colour gradients of the legend show the forecast SSB under each scenario in relation to reference points detailed in the legend.

Stock	Single-stock advice	SSB (2023) resulting from mixed-fisheries scenarios						Range
		max	min	sq_E	cod_F_{AR}MSY	had.27.7b–k	whg.27.7b–ce–k	
cod.27.7e-k	3449	880	3446	1200	3246	1189	2199	3258
had.27.7b-k	56747	49606	71727	53528	70578	53919	63522	62173
meg.27.7b-k8abd	138512	139749	163365	144816	161845	147262	156072	152543
mon.27.78abd	82203	77983	103726	83561	102379	84919	94684	89884
sol.27.7fg	5719	5455	7160	5750	7086	6521	6828	6277
whg.27.7b-ce-k	37372	31007	40420	32676	39837	32565	36684	37372

Legend

$SSB_{2023} > B_{pa}$ or MSY $B_{trigger}$
$SSB_{2023} > B_{lim}$, no B_{pa} defined
$SSB_{2023} > B_{lim}$, $< B_{pa}$ or MSY $B_{trigger}$
$SSB_{2023} < B_{lim}$

Figure 3 Mixed fisheries for the Celtic Sea. Estimates of effort by fleet needed to reach each single-stock advice. The stocks are coded by colour, with the bar for the most limiting stock ("choke species") for each fleet in 2022 highlighted with a red border and the bar for the least limiting species highlighted with a green border. Fleet names are given by country, main gear, and vessel length (m).

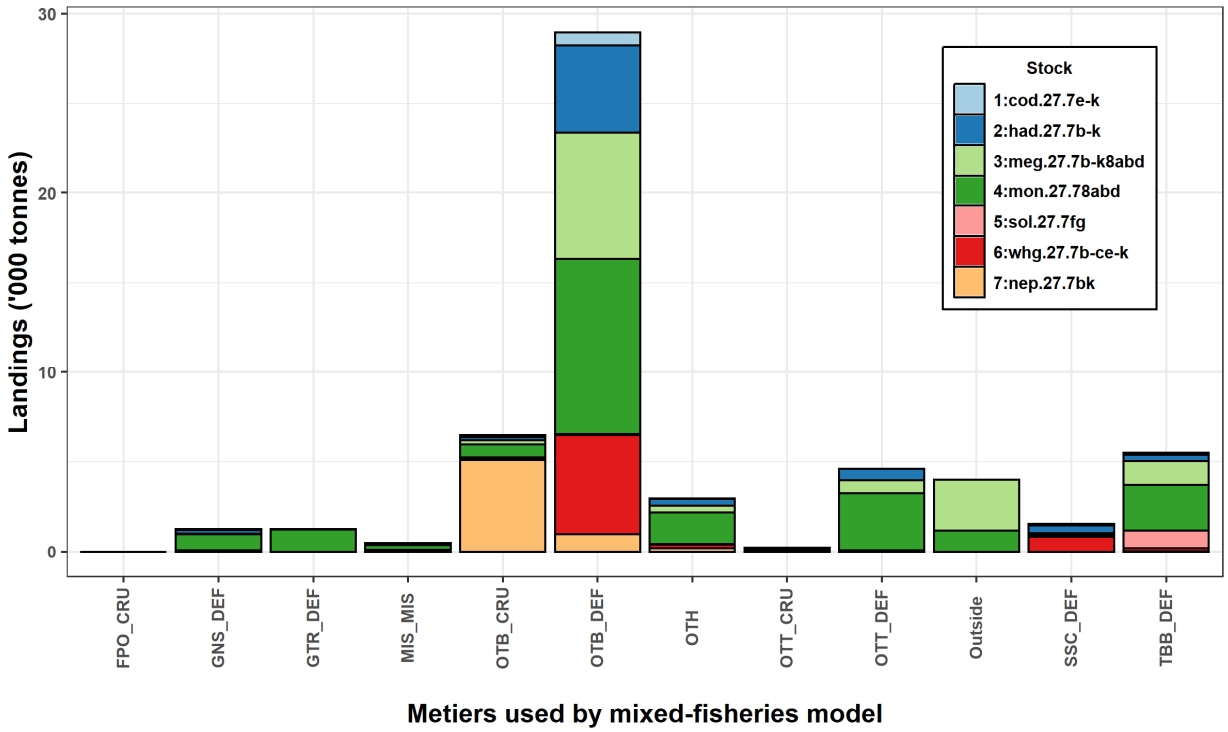

Figure 4 Mixed fisheries for the Celtic Sea. Landings distribution of species by métier with landings consisting of ≥ 1% of any of the stocks (Table 6) average from 2018 to 2020 (list of métiers available in Table 6). Note: the "other" (OTH) displayed here is a mixed category consisting of (i) landings without corresponding effort and (ii) landings of any combination of fleet and métier with landings < 1% of any of the stocks (Table 4) average from 2018 to 2020.

Table 6 Mixed fisheries for the Celtic Sea. Métier categories used in the mixed-fisheries analysis.

Mixed-fisheries métiers	Gear	Target species
OTB_DEF	Otter trawls	Demersal fish
OTT_DEF	Twin otter trawls	Demersal fish
OTB_CRU	Otter trawls	Crustaceans
OTT_CRU	Twin otter trawls	Crustaceans
OTM_DEF	Midwater trawls	Demersal fish
OTM_SPF	Midwater trawls	Small pelagic fish
GNS_DEF	Gillnets	Demersal fish
GTR_DEF	Trammel nets	Demersal fish
SSC_DEF	Scottish seines	Demersal fish
TBB_DEF	Beam trawls	Demersal fish
FPO_CRU	Static pots	Crustaceans
OTH	Other gears	Any
MIS_MIS	Miscellaneous	Any
Outside	All gears	Any

Quality considerations

Mixed-fisheries projections for the Celtic Seas ecoregion are based on full analytical single-stock assessments. Single-stock forecasts are also reproduced independently as part of the mixed-fisheries analyses, allowing additional quality control of both processes. The quality of the individual forecasts of the single-stocks will affect the quality of the mixed-fisheries scenarios. For the mixed-fisheries advice, the intermediate year assumption used was *status quo* fishing effort (average 2018–2020).

It has not yet been possible to include hake, which is also important in the mixed fisheries, due to technical difficulties.

Methods and data

Mixed-fisheries considerations are based on single-stock assessments combined with knowledge on species composition in catches in the Celtic Seas fisheries (Moore *et al.*, 2020) and using the F_{cube} method (Ulrich *et al.*, 2011, 2017). Mixed-fisheries scenarios are based on central assumptions that fishing patterns and catchability in the TAC year are the same as those in recent years (2018–2020). The year range used as a recent mean (2018–2020) covers the period during which the EU landing obligation was introduced, so the data reflect changes in fishing patterns over this period. It has not been possible to predict further changes in fishing patterns over the projection period.

The mixed-fisheries forecasts include full analytical single-stock assessments for the following stocks: cod, haddock, whiting, megrim, white anglerfish, and sole; as well as five Norway lobster FUs with underwater TV (UWTV) surveys for absolute estimates of abundance (Table 6).

The TACs for anglerfish and megrims cover two species (for anglerfish: *L. piscatorius* and *L. budegassa*; for megrims: *L. whiffiagonis* and *L. boscii*) but only the first of these two species in each case have full analytical assessments and are included in the mixed-fisheries catch advice. For anglerfish this is considered to be 78% of catches in Subarea 7 (ICES, 2020a) and for megrims 95% of catches from each area, so the majority of the TAC derived from these stocks are included.

For Norway lobster only part of the TAC area (Subarea 7) is covered by the advice. For the mixed-fisheries projections it was assumed that 47.9% of the landings come from divisions 7.b–k (average proportion from 2000 to 2020).

Table 7 Mixed-fisheries advice for the Celtic Sea**.** Advice and management area for the stocks considered

Species	ICES single-stock advice area	Management area
Cod	Divisions 7.e–k	EU TAC divisions 7.b–c, 7.e–k and subareas 8–10; EU waters of CECAF 34.1
Haddock	Divisions 7.b–k	EU TAC divisions 7.b–k and subareas 8–10; EU waters of CECAF 34.1.1
Whiting	Divisions 7.b–c and 7.e–k	EU TAC divisions 7.b–k
Megrims	Divisions 7.b–k, 8.a, 8.b, and 8.d	EU TAC divisions 7.b–k and 8.abd
Anglerfishes	Subarea 7 and divisions 8.a, 8.b, and 8.bd	EU TAC divisions 7 and 8abd
Sole	Divisions 7.f and 7.g	EU TAC division 7.fg
Norway lobster	5 FUs and 1 outside FU	EU TAC division 7, and Functional Unit 16

The mixed-fisheries scenarios and forecasts are produced using data requested as part of an ICES data call, issued formally under EU Data Collection Framework (DCF) regulations. This provides consistency in catch and effort totals. Additionally, separate data files containing total weight of landings and effort in kWdays by fleet and métier are requested. Fleet and métier categories used in the mixed-fisheries analysis are based on DCF level 4 and 5 categories, respectively. Grouping across categories has been performed to aggregate over 'small' métiers (defined as métiers with less than 1.0% landed in 2019 for each of the stocks considered).

Average total landings (2018–2020) of all species considered in the mixed-fisheries advice were 58 017 tonnes. The breakdown by stock is shown in Figure 5 and percentages by gear are:

- 72% landed by otter trawls and seines.
- 9% landed by beam trawls.
- 4% by gillnets, trammel nets and pots.
- 8% by other gears.
- 7% caught outside of study area.

Total discards (not shown in the plot) were 10 742 tonnes (16% by weight of total catch).

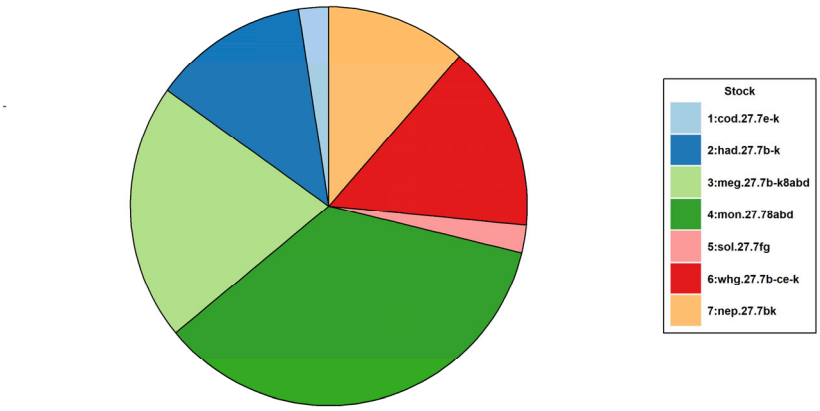

Figure 5 Mixed fisheries for the Celtic Sea. Landings distribution by stock.

Table 8 Mixed fisheries for the Celtic Sea. The basis of the assessment.

ICES stock data category	1 and 5 (ICES, 2021a)
Assessment type	F_{cube} (FLR [Ulrich *et al*., 2011])
Input data	Assessments of the relevant stocks in the Celtic Seas ecoregion working group (WGCSE; ICES, 2021b) and Bay of Biscay and Iberian ecoregion working group (WGBIE; ICES, 2021c); catch and effort by fleet and métiers
Discards and bycatch	Included as in the single-stock assessments
Indicators	None
Other information	None
Working groups	WGCSE (ICES, 2021b), WGBIE (ICES, 2021c), and the Working Group on Mixed-fisheries Advice (WGMIXFISH-ADVICE; ICES, 2021d).

Issues relevant for the advice

The model includes two stocks (mon.27.78abd and meg.27.7b–k8abd) that are also included in the -mixed fisheries advice for the Bay of Biscay ecoregion. Catches of these stocks outside of the Celtic Sea are included in the model as separate fleets, and full uptake of quota for these fleets is assumed. The outcomes for mon.27.78abd and meg.27.7b–k8abd can only be considered representative in the context of Celtic Sea demersal fisheries. There may be inconsistencies between the catch forecasts in scenarios in the Celtic Sea and Bay of Biscay mixed-fisheries advice; in future years, consideration will be given to splitting the presented catch advice between the respective areas. Differences in stock distributions mean that spatial decoupling of catches of cod, haddock, and whiting from those of megrims, anglerfishes, and sole could be achieved (Dolder *et al.,* 2018).

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