

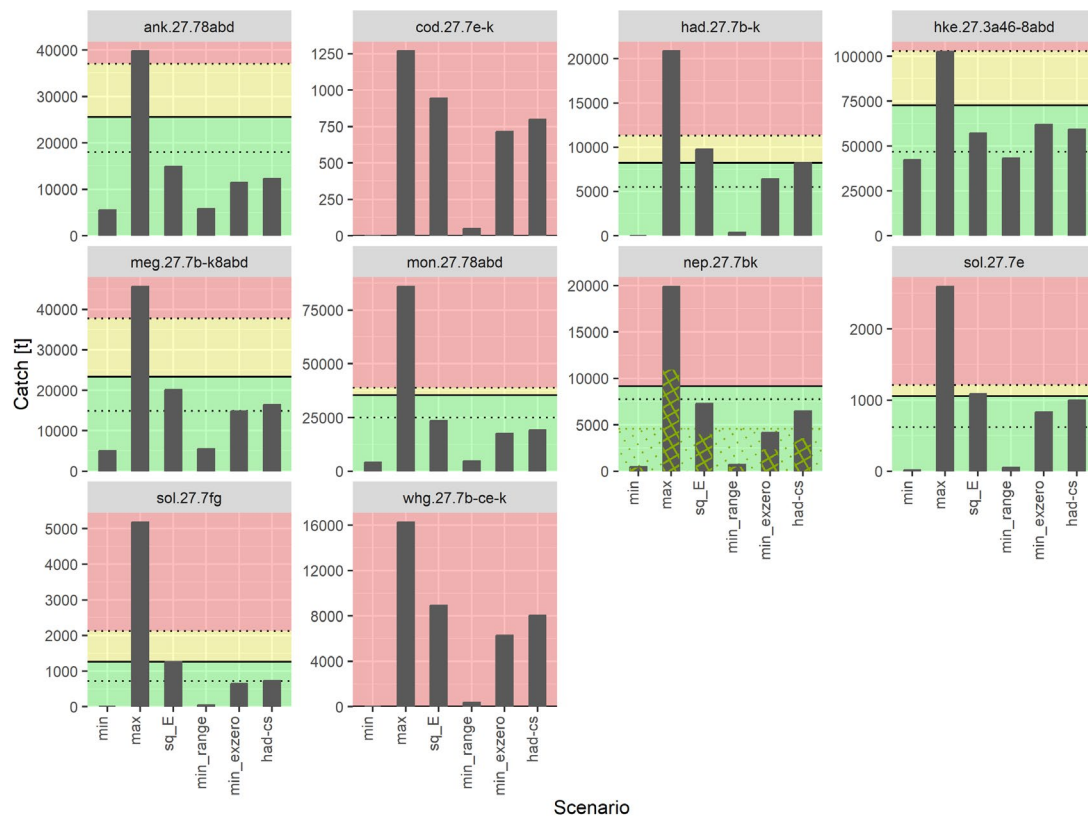
## Celtic Sea mixed-fisheries considerations

### Mixed-fisheries considerations

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), two sole stocks (western English channel, sol.27.7e and Celtic Sea, sol.27.7fg), white and black-bellied anglerfish (mon.27.78abd and ank.27.78abd), megrim (meg.27.7b-k8abd), and hake (hke.27.3a46–8abd) in the Celtic Sea.

Given the single-stock catch advice for 2024, the most limiting stocks for demersal fisheries in the Celtic Sea are cod and whiting, with 27 of 35 defined fleets reaching their cod and whiting quotas with a lower effort than for the other stocks, and three further fleets reaching their cod quote with a lower effort than for other stocks. This is due to the zero-catch advice for cod and whiting and the fact that almost all fisheries operating with demersal gears catch these stocks. The least limiting stock is Norway lobster in FU 20-21 (18 fleets) followed by black-bellied anglerfish (16 fleets). It is assumed that fleet fishing patterns in the forecast years are the same as observed in the recent past.

Mixed fisheries projections are conducted for six scenarios corresponding to different assumptions on the future effort deployment by the fleets (Table 1). The trade-offs in catches and any potential for overshoot and undershoot of the single-stock advice associated with each scenario are shown (Figure 1).



**Figure 1**

Mixed fisheries for the Celtic Sea. Mixed-fisheries projections. Estimates of potential 2024 catches (in tonnes) by stock and scenario. The horizontal solid line corresponds to the single-stock catch advice. For those stocks with fishing mortality ranges defined, the lower dotted lines illustrate the catches corresponding to  $F_{MSY\ lower}$  or reduced  $F_{MSY\ lower}$  for stocks with  $SSB < MSY\ B_{trigger}$ . The upper dotted lines illustrate the catches corresponding to  $F_{MSY\ upper}$  for stocks with defined ranges and with  $SSB \geq MSY\ B_{trigger}$ . The hashed bars in nep.27.7bk indicate the proportion of catches of Norway lobster caught in FU 16, and the dotted area indicates the catch limit which applies in this FU.

**Table 1** Mixed fisheries for the Celtic Sea. Mixed-fisheries scenarios.

Scenario code	Mixed-fisheries effort assumption	Basis for catch target 2024
Minimum (min)	For each fleet, fishing in 2024 stops when its first stock share* has been caught. This scenario is the most precautionary option and can highlight some potential “choke species” issues.	ICES catch advice
Maximum (max)	For each fleet, fishing in 2024 continues until all its stock shares* have been caught. This option illustrates the degree of overfishing of the single-stock advice if fishing is not restricted by the fleet stock shares*.	
Status quo effort (sq_E)	The effort of each fleet in 2024 is set equal to the average effort in the most recent three years (2020–2022) for which landings and discard data are available	
Minimum including ranges (min_range)	Same as “min” scenario	Catches corresponding to $F_{MSY\ upper}$ for stocks in good status ( $SSB \geq MSY\ B_{trigger}$ ) and scaled $F_{MSY}$ advice levels ( $F_{MSY} \times SSB/MSY\ B_{trigger}$ ) for the other stocks (including zero-catch advice stocks). Applies only to stocks with ranges defined.
Minimum excluding zero-catch advice stocks (min_exzero)	For each fleet, fishing in 2024 stops when the catch for any one of the stocks meets its stock share*, ignoring cod and whiting where there is zero-catch advice. This scenario illustrates the effect of fishing on the next nearest non-zero-catch advice stock.	ICES catch advice
Haddock single-stock advice (had-cs)	For each fleet, fishing in 2024 stops when the catch of haddock meets its stock share* for haddock, regardless of other catches. Fleets which do not catch haddock follow a <i>status quo</i> effort assumption (as described for the “sq_E” scenario).	

\* Throughout this document, the term “stock share” or “fleet stock share” is used to describe the share of the fishing opportunities for each particular fleet. These are calculated based on the single-stock advice for 2024 and the historical proportion of the stock landings taken by the fleet (2020–2022).

## Catch scenarios

Mixed-fisheries analyses consider the implications of mixed fisheries operating under single-stock catch advice regimes given that there are no changes in the quota shares of the fleets for the different stocks, in the proportion of effort per métiers for each fleet, in discard rates or catchability in the métiers during the forecast period compared to the most recent data years (2020–2022). Scenario assumptions for the intermediate year (2023) and forecast year (2024) 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 (2023) and in the forecast year (2024).

Variable	Notes
Effort per fleet (2023)	kWdays: average (2020–2022)
Fishing patterns (2023–2024)	Catchability by stock and métier: average (2020–2022) Effort-share by métier: average (2020–2022)
Quota allocations (2024)	Landings shares for fleets: average (2020–2022)
Catches outside of the Celtic Sea (2024)	Associated with a single additional fleet per stock, it is assumed that they catch their full fleet stock share. This relates to area 27.8abd catches of anglerfish (white and black-bellied) and megrim and area 27.3a46–8abd hake.

A total of six scenarios are presented, corresponding to different effort constraints for 2024 (Table 1). The forecasted scenarios are presented in terms of catch and the potential for catch advice over- and undershoot, which is driven by the most and the least restrictive single-stock advice (Figure 1 and Table 3). Scenario results for fishing mortality (F) in 2024 and spawning-stock biomass in 2025 are presented in Tables 4 and 5, respectively.

Scenarios that result in under- or overshoot are useful in identifying the main mismatches between the fishing opportunities of the various stocks, where limiting catch advice can create potential “choke species” effects at fleet level. They indicate the direction in which fleets may have to adapt their fishing behaviour to more fully utilize their catch opportunities without collectively exceeding single-stock fishing opportunities. Estimates of effort required by each fleet segment to reach its “share” of each single-stock advice are shown in Figure 2.

The “min” scenario is consistent with a full implementation of a landing obligation (without any exemptions) given the individual single-stock advice (Table 3, Figure 1). In 2024, the “min” scenario shows that cod limits 30 of the 35 fleets; 27 of these fleets will also choke on whiting. This is due to the zero-catch advice for cod and whiting and that almost all fleets catch cod and whiting to a greater or lesser extent. The five remaining fleets had no cod or whiting landings and so were limited by white anglerfish (two fleets), haddock, Celtic Sea sole, and Norway lobster outside of functional units respectively (Figure 2).

The “max” scenario shows 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 irrespective of economic viability, legality, or fleet capacity. In 2024, the “max” scenario indicated that fleets have different least limiting stocks, which results in over-quota catches of all stocks (Figure 2). Norway lobster FU 20-21 (18 fleets), black-bellied anglerfish (16 fleets), and western English Channel sole (one fleet) are the least limiting stocks.

The *status quo* effort “sq\_E” scenario sets the effort of each fleet in the forecast years equal to the average of the effort in the most recent three years for which data are available (2020–2022). This scenario investigates the mixed-fisheries outcomes if the situation remains the same in terms of total effort and effort allocation among métiers. For 2024, this scenario results in large catch overshoots above the single-stock advice of cod and whiting, a small overshoot of haddock and western English Channel sole, small undershoots of white and black-bellied anglerfish, hake, megrim, and Norway lobster, and full uptake of Celtic Sea sole (Table 3, Figure 1).

The “min\_range” scenario explores how the higher catch options associated with the  $F_{MSY\ upper}$  or scaled  $F_{MSY}$  reference points (for stocks where ranges are defined) may reduce choking behaviour in mixed fisheries and increase overall quota uptake. In this scenario, the choke species per fleet are the same as for the “min” scenario. Catches for all stocks in 2024 are slightly increased above the “min” scenario as a result of the increase in catch opportunity provided by the scaled  $F_{MSY}$  advice rule (Table 3, Figure 1).

The “min\_exzero” scenario is consistent with a full implementation of a landing obligation given the individual single-stock advice for all stocks except cod and whiting. In this scenario cod and whiting were not included as effort-restricting stocks. In 2024, haddock becomes the most limiting stock constraining 11 out of 35 fleet segments for this scenario. The remaining fleets are constrained by Norway lobster (eight fleets across three functional units), hake (five fleets), Celtic Sea sole and western English Channel sole (four fleets for each), white anglerfish (two fleets) and megrim (one fleet; Figure 2).

In addition, a “had-cs” scenario is presented because of the strong technical interaction between haddock and the two zero-catch advice cod and whiting stocks. This scenario assumes that effort is set according to the single-stock catch advice for haddock for all fleets (based on ICES MSY approach) and presents catches for other stocks in a mixed-fisheries context. Under this scenario, the haddock catch advice is fully utilized, while the cod and whiting catch advice are exceeded. All other stock catch advice is underutilized (Table 3, Figure 1).

ICES single-stock advice for demersal stocks considered here is based on its MSY approach, except for Norway lobster outside of FUs, which is based on ICES precautionary approach. ICES provides zero-catch advice for cod and whiting in 2024, based on the MSY approach with precautionary considerations. Scenario results show that it is not possible to achieve all advised single-stock catches simultaneously under current fishing patterns. Additionally, there is no scenario which can achieve SSB above  $B_{lim}$  for cod or whiting in 2025 (Table 5).

**Table 3** Mixed fisheries for the Celtic Sea. Catches in 2024 (tonnes) resulting from single-stock advice and different mixed-fisheries scenarios for demersal fish species.

Stock	Single-stock advice	Catch per mixed-fisheries scenario (2024)					
	Catch (2024)*	min	max	sq_E	min_range	min_exzero	had-cs
ank.27.78abd	25579	5513	39753	14884	5787	11434	12311
cod.27.7e-k	0	0	1267	944	47	714	799
had.27.7b-k	8252	4	20858	9763	363	6398	8217
hke.27.3a46-8abd	72839	42269	102604	57131	43107	61906	59301
meg.27.7b-k8abd	23303	5006	45587	20119	5517	14845	16423
mon.27.78abd	35502	4098	85844	23380	4702	17400	19048
sol.27.7e	1057	14	2593	1085	55	826	998
sol.27.7fg	1267	2	5179	1262	46	646	730
whg.27.7b-ce-k	0	0	16265	8912	370	6266	8033
nep.fu.16	4560	367	10912	3980	480	2336	3519
nep.fu.17	454	0	1236	452	15	241	403
nep.fu.19	248	5	762	278	14	150	245
nep.fu.20-21	1865	77	1672	609	95	392	586
nep.fu.22	1912	1	4348	1597	54	858	1405
nep.out.7^	120	6	266	97	9	56	87

\* Advised catches of no more than the indicated value.

^ Landings only

**Table 4** Mixed fisheries for the Celtic Sea. Fishing mortality (F) or harvest rate (for Norway lobster) in 2024 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 advice	F (2024) resulting from mixed-fisheries scenarios					
	F (2024)	min	max	sq_E	min-range	min_exzero	had-cs
ank.27.78abd*	0.163	0.033	0.27	0.092	0.035	0.070	0.075
cod.27.7ek	0	0.000	2.0	1.12	0.036	0.73	0.86
had.27.7b-k	0.353	0.000	1.34	0.45	0.0140	0.27	0.36
hke.27.3a46-8abd	0.24	0.131	0.36	0.182	0.134	0.199	0.190
meg.27.7b-k8abd	0.233	0.044	0.52	0.194	0.049	0.139	0.155
mon.27.78abd*	0.192	0.020	0.55	0.122	0.023	0.089	0.098
sol.27.7e	0.29	0.003	0.87	0.28	0.012	0.206	0.25
sol.27.7fg	0.251	0.000	2.0	0.25	0.0080	0.119	0.135
whg.27.7b-ce-k	0	0.000	2.0	0.75	0.023	0.47	0.65
nep.fu.16**	0.062	0.005	0.148	0.054	0.0065	0.032	0.048
nep.fu.17**	0.059	0.000	0.21	0.077	0.0025	0.041	0.068
nep.fu.19**	0.048	0.002	0.24	0.088	0.0045	0.048	0.078
nep.fu.20-21**	0.060	0.003	0.060	0.022	0.0034	0.0141	0.021
nep.fu.22**	0.10	0.000	0.27	0.100	0.0034	0.053	0.088

\* ank.27.78abd and mon.27.78abd have no  $F_{lim}$ .

\*\* Norway lobster stocks have no  $F_{pa}$  or  $F_{lim}$  limits, and so colours relate to above (black) or below (white)  $F_{MSY}$  harvest rates.

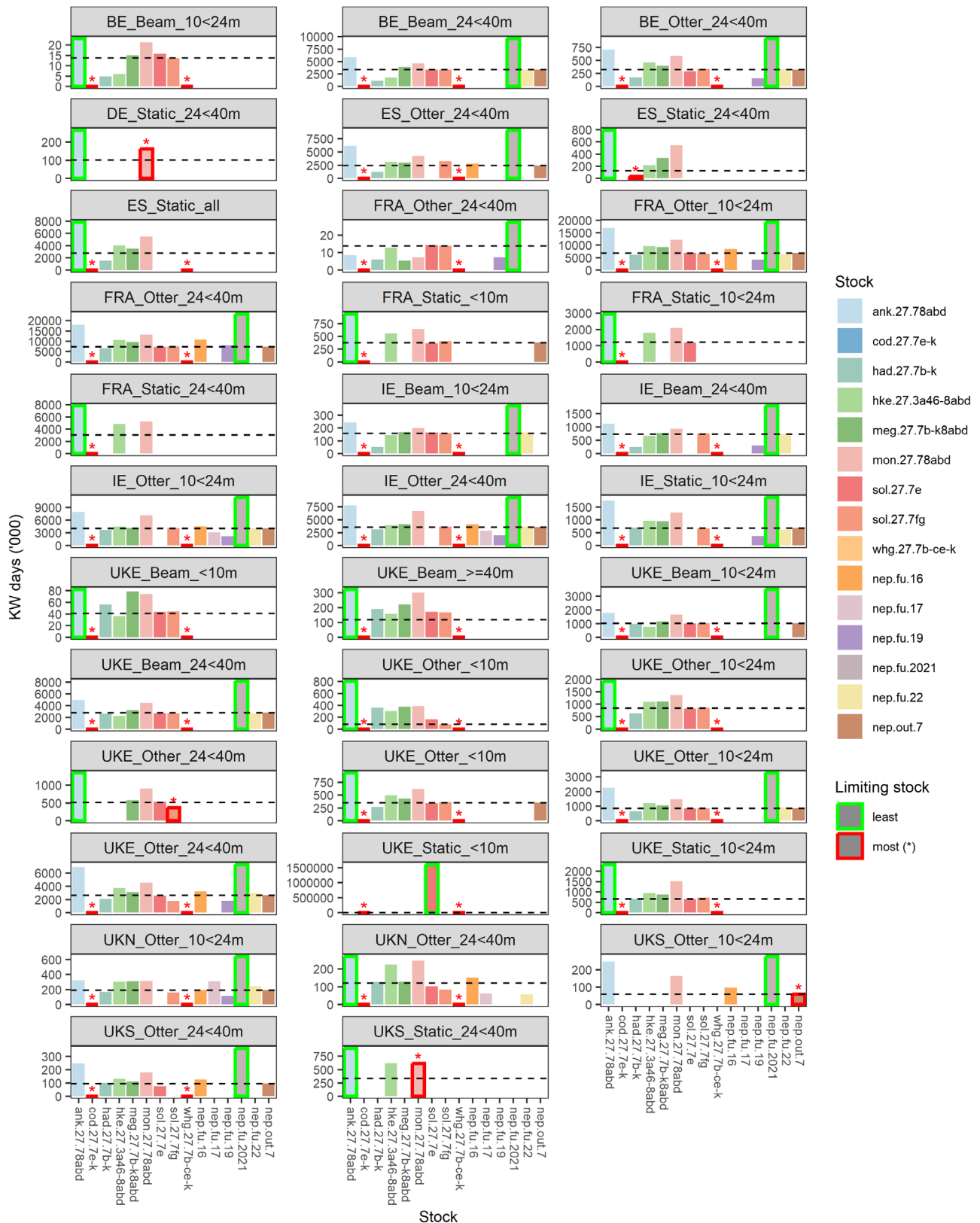
Legend:	Fish stocks	Norway lobster FUs
	$F_{2024} \leq F_{MSY}$	$F_{2024} \leq F_{MSY}$
	$F_{MSY} < F_{2024} \leq F_{pa}$	-
	$F_{pa} < F_{2024} \leq F_{lim}$	-
	$F_{pa} < F_{2024}$ , no $F_{lim}$ defined	-
	$F_{2024} > F_{lim}$	$F_{2024} > F_{MSY}$

**Table 5** Mixed fisheries for the Celtic Sea. Spawning-stock biomass (SSB) results in 2025 from single-stock advice and different mixed-fisheries scenarios. Results are not presented for Norway lobster. All weights are in tonnes. The colour gradients of the legend show the forecast SSB under each scenario in relation to reference points detailed in the legend.

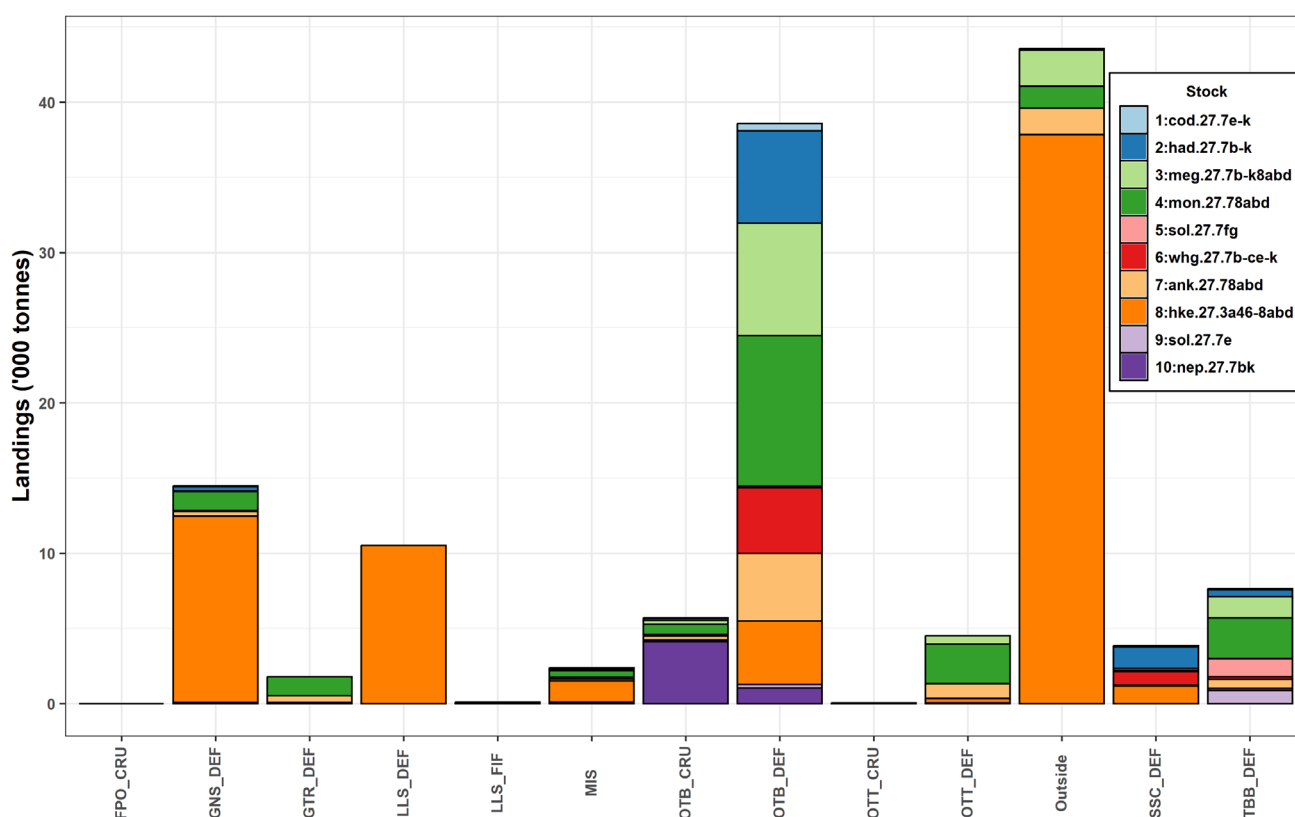
Stock	Single-stock advice	SSB (2025) resulting from mixed-fisheries scenarios					
	SSB (2025)	min	max	sq_E	min_range	min_exzero	had-cs
ank.27.78abd	60186	68614	54383	64697	68499	66137	65771
cod.27.7e-k	2265	2237	387	817	2164	1147	1024
had.27.7b-k	30295	38390	17664	28524	38031	31883	30062
hke.27.3a46-8abd*	129326	144809	114432	137270	144383	134855	136172
meg.27.7b-k8abd	89889	109212	67200	93429	108675	98922	97276
mon.27.78abd	64669	77634	44513	69782	77387	72216	71545
sol.27.7e	3500	4745	2251	3700	4705	3952	3785
sol.27.7fg	5659	7063	1684	5756	7016	6389	6299
whg.27.7b-ce-k	33995	33516	19524	25580	33181	27888	26336

\*Female SSB

Legend:	
	$SSB_{2025} \geq B_{pa}$ or $MSY B_{trigger}$
	$SSB_{2025} \geq B_{lim}$ ; no $B_{pa}$ defined
	$B_{lim} \leq SSB_{2025} < B_{pa}$
	$SSB_{2025} < B_{lim}$



**Figure 2** Mixed fisheries for the Celtic Sea. Estimates of effort needed by fleet to reach the catch advice for each single stock. Stocks are coded by colour, with the bars for two most limiting stock (“choke species”) for each fleet in 2024 highlighted with a red border and asterisk and the bars for the least limiting species highlighted with a green border. Fleet names are given by country, main gear, and vessel length (m). The *status quo* effort for each fleet (average 2020–2022) is shown as a dashed line for reference.



**Figure 3** Mixed fisheries for the Celtic Sea. Distribution of stocks landed by métier (average 2020–2022). A list of métier definitions is available in Table 6 and described in the ‘Methods and data’ section.

**Table 6** Mixed fisheries for the Celtic Sea. Métiers used in the mixed-fisheries analysis.

Métier	Gear	Target species
LLS_DEF	Longline trawls	Demersal fish
LLS_FIF	Longline trawls	Finfish
OTB_DEF	Otter trawls	Demersal fish
OTT_DEF	Twin otter trawls	Demersal fish
OTB_CRU	Otter trawls	Crustaceans
OTT_CRU	Twin otter trawls	Crustaceans
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
MIS	Other miscellaneous gears	Any
Outside (of 7bc,e–k)	All gears	Any

### Quality considerations

The single-stock assessments form the basis of the mixed-fisheries scenarios, and the single-stock forecasts are reproduced as part of the mixed-fisheries analyses, allowing for additional quality control of both processes. Some discrepancies are to be expected between the single-stock forecasts and the reproduction of the advice in the mixed-fisheries forecast. Despite the methodological differences between single-stock forecasts and mixed-fisheries forecasts, the differences observed this year were small (< 3%) for all stocks, and the mixed-fisheries forecast was considered close enough to the single-stock advice to be used as a basis for the mixed-fisheries scenarios. The quality of the individual forecasts of the single-stocks will affect the quality of the mixed-fisheries scenarios.

Two new scenarios have been added this year: a “min\_range” scenario and a “min\_exzero” scenario (Table 1).

**Table 7** Mixed fisheries for the Celtic Sea. The basis of the assessment.

Assessment type	FCube (FLR; Ulrich <i>et al.</i> , 2011)
Input data	Assessments of the relevant stocks in the Celtic Seas ecoregion working group (WGCSE; ICES, 2023a) and Bay of Biscay and Iberian ecoregion working group (WGBIE; ICES, 2023b); catch and effort by fleet and métier
Discards and bycatch	Included as in the single-stock assessments
Indicators	None
Other information	Benchmarked in 2021 (ICES, 2021)
Working groups	<a href="#">WGCSE</a> (ICES, 2023a), <a href="#">WGBIE</a> (ICES, 2023b), and the Working Group on Mixed-fisheries Advice ( <a href="#">WGMIXFISH-ADVICE</a> ; ICES, 2023c).

### Issues relevant for the advice

Mixed-fisheries scenarios are based on the central assumptions that fishing patterns of fleets (quota shares per stock, effort allocation to different métiers) and catchability in 2023 and 2024 are the same as those in recent years (2020–2022). In reality, fishing patterns may change over time, particularly in response to significant changes in policy.

The model includes four stocks (ank.27.78abd, hke.27.3a46-8abd, 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 stock shares for these fleets is assumed. The outcomes for ank.27.78abd, hke.27.3a46-8abd, 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 considerations.

Megrim and anglerfishes are mainly abundant in different locations to cod, haddock, and whiting. This implies that there is potential for fleets to more selectively fish on these groups (Dolder *et al.*, 2018). This flexibility is not captured in the mixed-fisheries forecasts because of the assumption of a static distribution of fishing effort among a given fleet's métiers.

Each of the TACs for anglerfish and megrim includes advice for two species (for anglerfish, *Lophius piscatorius* and *L. budegassa*; for megrim, *Lepidorhombus whiffiagonis* and *L. boscii*). *Lepidorhombus boscii* (which accounts for < 5% of megrim catches from each area) is not yet included in the mixed-fisheries analysis; however, the model includes the majority of the megrim stock catches.

Norway lobster fisheries are managed under one TAC for Subarea 7, while ICES advises on the basis of FUs. Similarly, anglerfish and megrim are managed with combined-species TACs. The mixed-fisheries analysis is based on ICES catch advice for the individual FUs and stocks. As a consequence, the extent of effort limitation may differ if based on TAC unit rather than on individual FU/stock.

The present analysis includes nine demersal fish stocks and six Norway lobster stocks. Other species are caught in these fisheries and could influence fishing activity. For Norway lobster, only part of the TAC area (Subarea 7) is covered by this case study, but the TAC is a combination of all FUs of Norway lobster in Subarea 7. This includes a restriction on how much can be taken from FU 16 (a so-called 'of which' provision).

The "min\_range" scenario makes use of the multiannual plan (MAP)  $F_{MSY}$  ranges defined for demersal stocks under the EU MAP for the western waters (EU, 2019). There is no agreement with UK regarding this plan, and it is not used as the basis of the advice for these shared stocks.

### 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.*, 2019); this is done using the FCube method (Ulrich *et al.*, 2011, 2017). The forecasts are presented in terms of total catches. All stocks have been under a landing obligation since 2019, and all catches for these species are assumed to count against the fleet stock shares each year. Note that the FCube method restricts effort using an F target and therefore may slightly deviate from target catch advice.



Fleets used in the mixed-fisheries analysis are defined by their country, predominant gear type, and vessel length. Fleets landing less than 1% of each stock (2020–2022) are aggregated to the “MIS\_MIS” fleet. Fleets that have catches but lack corresponding effort data are included in the mixed-fisheries model to account for all sources of fishing mortality for the stocks included. The “OTH” fleets (one per stock) account for differences in total catch between the fleet data and observed catches from the single-stock assessments. Out-of-area catches for stocks where they occur are also accounted for in the stock-specific fleets. The “OTH” and “MIS\_MIS” fleets are not included in Figure 2.

Table 6 describes the métiers used, and Figure 3 illustrates the landings by métier and stock. Métiers are based on gear type and target assemblage. Within a fleet, métiers that do not land more than 10% of any stock (2020–2022) are aggregated under the “MIS” métier.

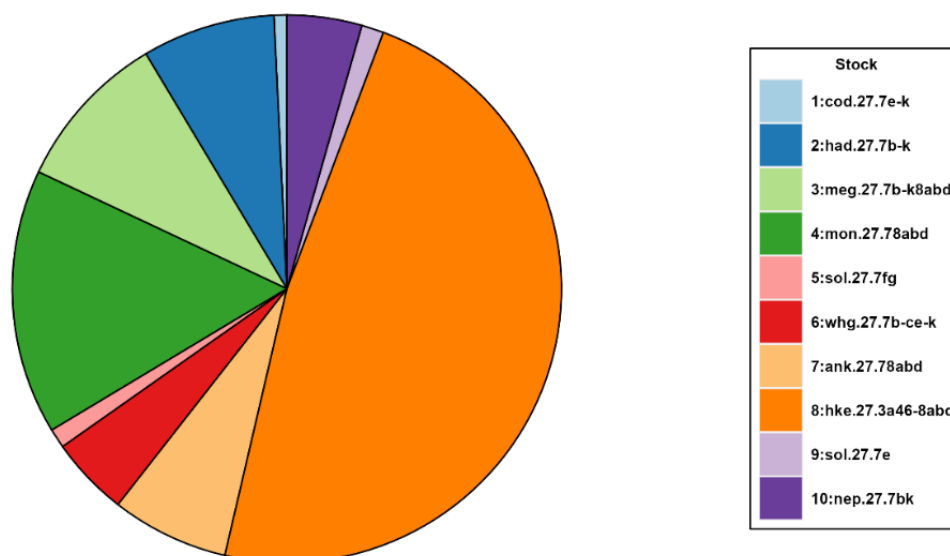
The mixed-fisheries forecasts include full analytical single-stock assessments for the following stocks: cod, haddock, whiting, megrim, white and black-bellied anglerfish, hake, and sole (in the Celtic Sea and in the western English channel), as well as five Norway lobster FUs with underwater TV (UWTV) surveys for absolute estimates of abundance. There are differences between stock areas, management areas, and management rules (ICES MSY approach or precautionary approach) for the stocks considered here. Table 8 summarizes the advice area and management areas for the main stocks.

For Norway lobster, only part of the TAC area (Subarea 7) is covered by this case study, although a single TAC covers all FUs of Norway lobster in Subarea 7. As there is a restriction on how much can be taken from FU 16 (a so-called ‘of which’ provision), this FU is treated separately. First, these landings are assumed to come from FU 16 (full uptake of its ‘of which’ provision) and then from the rest of Subarea 7. The rest of the Subarea 7 landings are assumed to come from the Celtic Sea (41.3%) and from the Irish Sea (58.7%; average landing proportions 2000–2022).

Average total landings (2020–2022, Figure 4) of all species considered in the mixed-fisheries considerations were 92 400 tonnes, with:

- 37% landed by otter trawls and seines;
- 6% by gillnets, trammel nets and pots;
- 12% by beam trawls;
- 8% by longlines;
- 4% by unknown gears;
- 32% by fleets outside the area.

Total discards (not shown in Figure 4) were 11 030 tonnes (11% by weight of total catch).



**Figure 4** Mixed fisheries for the Celtic Sea. Landings distribution by stock (average 2020–2022).

**Table 8** Mixed-fisheries considerations for the Celtic Sea. Advice and management area for the stocks considered.

Species	ICES single-stock advice area	Management area
Anglerfishes	Subarea 7 and divisions 8.a, 8.b, and 8.bd. Category 1 stock.	Separate TACs for subarea 7 and division 8abde
Cod	Divisions 7.e–k. Category 1 stock.	TAC divisions 7.b–c, 7.e–k and subareas 8–10; EU
Haddock	Divisions 7.b–k. Category 1 stock.	TAC divisions 7.b–k and subareas 8–10; EU waters of
Whiting	Divisions 7.b–c and 7.e–k. Category 1 stock.	TAC divisions 7.b–k
Megrim	Divisions 7.b–k, 8.a, 8.b, and 8.d. Category 1 stock.	Separate TACs for subarea 7 and division 8abde
Hake	Divisions 3.a, 4, 6, 7, and 8.abd. Category 1 stock.	Separate TACs for divisions 3.a; 4 and 2.a; 6, 7, 5.b, 12 and 14; 8.abde
Sole	Divisions 7.e. Category 1 stock.	TAC divisions 7.e
Sole	Divisions 7.f and 7.g. Category 1 stock.	TAC divisions 7.fg
Norway lobster	Five FUs (Category 1 stocks) and one outside FU (Category 5 stock).	TAC Subarea 7; and Functional Unit 16

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