

## EU request to ICES to provide plausible and updated $F_{MSY}$ ranges for the stocks of species inhabiting western EU waters

### Advice summary

ICES indicates that for many stocks of species inhabiting western EU waters,  $F_{MSY}$  ranges are not available. For a number of other stocks, the  $F_{MSY}$  ranges have been provided in previous advice and are up to date. A summary is provided.

ICES provides precautionary  $F_{MSY}$  ranges that are intended to deliver no more than a 5% reduction in long-term yield compared with MSY for stocks not previously covered, including cod, haddock and plaice\* in Division 7.a (Irish Sea) and Norway lobster in FU 20-21.

### Request

#### Background:

The Commission is preparing long term management plans for western EU waters (ICES subareas 5 to 10). According to Art. 10 of Regulation (EU) No 1380/2013 on the Common Fisheries Policy a multiannual plan shall include quantifiable targets, a time frame to reach the targets and safeguards to ensure that the quantifiable targets are met.

The first set of  $F_{MSY}$  ranges for the stocks to be covered by western EU waters multiannual plan was provided by ICES in 2016 (ICES Special Request Advice Northeast Atlantic Ecoregion, Version 4 of 11 July 2016)

#### Request:

ICES is requested to provide plausible and updated values around  $F_{MSY}$  (range for  $F_{MSY}$ ) for the stocks of the following species inhabiting western EU waters (including those straddling western EU waters and adjacent waters)

Black scabbardfish in subareas 1, 2, 4–8, 10, and 14, and divisions 3.a, 5.a–b, 9.a, and 12.b

Alfonsinos in subareas 1-10, 12 and 14 (the Northeast Atlantic and adjacent waters)

Roundnose grenadier in Division 5.b, subareas 6 and 7

Sea bass in divisions 4.b, 4.c, 7.a, and 7.d–h

Sea bass in Division 8.ab\*

Cod in Division 7.a

Cod in divisions 7.e–k

Cod in Subarea 4 and divisions 7.d and Subdivision 20

Megrim in divisions 4.a and 6.a

Megrim in divisions 7.b–k, 8.a–b, and 8.d

Four-spot megrim in divisions 8.c and 9.a

Megrim in divisions 8.c and 9.a

Anglerfish in divisions 7.b–k, 8.ab, and 8.d

Anglerfish in divisions 8.c and 9.a

Haddock in Division 6.b

Haddock in Division 7.a

Haddock in Division 7.b–k

Whiting in divisions 7.b, 7.c and 7.e–k

Whiting in Subarea 8 and Division 9.a

Hake in subareas 4, 6 and 7, divisions 3.a, 8.a–b and 8.d

Hake in divisions 8.c and 9.a

Blue ling in Division 5.b, subareas 6 and 7

Red seabream in Subarea 9

Red seabream in Subarea 10

Plaice in Division 7.a\*

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\* Version 2: Added to the request after the initial advice was published on 15 March 2018. Sea bass in Division 8.ab was requested on the 15 May 2018. Plaice and sole in Division 7.a, Norway lobster in divisions 8.a and 8.b (FU 2 –24) and Northern shrimp in divisions 3.a and 4.a East was requested on 22 May 2018.

*Plaice in divisions 7.d and 7.e*  
*Pollack in Subarea 7*  
*Common sole in Division 7.a\**  
*Common sole in divisions 7.b and 7.c*  
*Common sole in Division 7.d*  
*Common sole in Division 7.e*  
*Common sole in divisions 7.f and 7.g*  
*Common sole in divisions 7.h, 7.j and 7.k*  
*Common sole in divisions 8.a and 8.b*  
*Common sole in divisions 8.c and 9.a*  
*Common sole in Division 6; Union and international waters of 5.b; international waters of 12 and 14*  
*Norway lobster in Division 6.a, (FU11)*  
*Norway lobster in Division 6.a, (FU12)*  
*Norway lobster in Division 6.a, (FU13 - Firth of Clyde).*  
*Norway lobster in Division 6.a, (FU13 – Strait of Jura)*  
*Norway lobster in Division 7.a, (FU14)*  
*Norway lobster in Division 7.a, (FU15)*  
*Norway lobster in Division 7.b,c,j,k, (FU16)*  
*Norway lobster in Division 7.b, (FU17)*  
*Norway lobster in Subarea 7 and rectangles outside the functional units (Southern Celtic Seas, Southwest of Ireland) (FU18)*  
*Norway lobster in Division 7.a, g, j (FU19)-Irish Sea, Celtic Sea, Eastern Southwest of Ireland*  
*Norway lobster in Division 7.g, h- (FU20-21)- Celtic Sea*  
*Norway lobster in divisions 7.g, 7.f (FU22)- Celtic Sea & Bristol Channel*  
*Norway lobster in divisions 8.a and 8.b (FU 2 -24)\**  
*Norway lobster Division 8.c (FU25)-southern Bay of Biscay and northern Galicia*  
*Norway lobster in Division 9.a, functional units 26–27 (Atlantic Iberian waters, East western Galicia, and northern Portugal (FU26-27)*  
*Norway lobster in Division 9.a, Atlantic Iberian waters, East and southwestern and southern Portugal (FU 28-29)*  
*Norway lobster in Division 9.a, Atlantic Iberian waters East and Gulf of Cadiz (FU 30)*  
*Northern shrimp in divisions 3.a and 4.a East\**

### Elaboration on the advice

The  $F_{MSY}$  ranges [ $F_{lower}$ ,  $F_{upper}$ ] are intended to deliver no more than a 5% reduction in long-term yield compared with the maximum sustainable yield (MSY). This choice is subjective, but a justification is provided in the Basis of the Advice section below. This approach has already been applied in the ICES advice for MSY ranges for stocks in the Baltic Sea and North Sea (ICES, 2015) and selected stocks in subareas 5–10 (ICES, 2016a).

To be consistent with the ICES precautionary approach,  $F_{upper}$  is capped, so that the probability of spawning-stock biomass (SSB) <  $B_{lim}$  is no more than 5%. To derive the value of the cap on  $F_{MSY}$  upper, the ICES MSY advice rule (AR) is used, which requires a linear reduction of  $F$  towards zero when SSB is below  $MSY B_{trigger}$ .

The evaluations are based on average long-term yield and are adequate to estimate  $F_{MSY}$  under the prevailing conditions of growth, maturity, recruitment, and natural mortality. As the environment changes and species adapt, the values may need to be revised to reflect changing conditions. It should be noted that: (1) yield will fluctuate around an average, (2) the estimated average yield is based on single-species considerations and may not hold in an ecosystem context, and (3) yield is conditional on existing fisheries management (including technical measures). Yield is considered to be all landed catch plus discarded catch above the minimum conservation reference size (MCRS). Age related proxies for MCRSs are used to partition discards.

\* Version 2: Added to the request after the initial advice was published on 15 March 2018. Sea bass in Division 8.ab was requested on the 15 May 2018. Plaice and sole in Division 7.a, Norway lobster in divisions 8.a and 8.b (FU 2 -24) and Northern shrimp in divisions 3.a and 4.a East was requested on 22 May 2018.

For many of the stocks contained in this request, the  $F_{MSY}$  ranges are not available, as methods for calculating  $F_{MSY}$  ranges for category 3–6 stocks are not developed. For many category 1 and 2 stocks,  $F_{MSY}$  ranges have already been provided in previous advice. It is noted that many of the requested TAC areas do not match the stock assessment units. Table 1 provides a summary for each of the stocks in the request. Reference points and  $F_{MSY}$  ranges were required to be recalculated for cod in Division 7.a and haddock in Division 7.a, and the resulting ranges are provided below the table.  $F_{MSY}$  ranges were also calculated for Norway lobster in FU 20-21. Information for some stocks that became available after benchmarks were held in 2018 is included in this version.\*

**Table 1** List of the stocks for which plausible and updated  $F_{MSY}$  ranges were requested, the current TAC areas, and the type of advice that has been provided by ICES (MSY or precautionary approach) as well as comments regarding these ranges. The reference indicated in the comments for stocks that have an up-to-date  $F_{MSY}$  range is the document where the range can be found at the time when this advice was released on March 15, 2018.

N°	Species	Stock area	N°	Corresponding TAC area in EU western waters	MSY or precautionary advice	ICES category	Comments
1	Black scabbardfish	Subareas 1, 2, 4, 6–8, 10, and 14, and divisions 3.a, 5.a–b, 9.a, and 12.b	1	CECAF 34.1.2	Precautionary approach	3	$F_{MSY}$ ranges calculation not currently possible
			2	8, 9, 10	Precautionary approach	3	$F_{MSY}$ ranges calculation not currently possible
2	Alfonsinos	Northeast Atlantic	3	3-10, 12, 14	Precautionary approach	5	$F_{MSY}$ ranges calculation not currently possible
3	Roundnose grenadier	Division 5.b, subareas 6 and 7	4	5b, 6, 7	Precautionary approach*	3*	$F_{MSY}$ ranges calculation not currently possible*
4	Seabass	Divisions 4.b, 4.c, 7.a, and 7d–h	5	4bc,7, 7d–7h	MSY	1	$F_{MSY}$ ranges up to date for the stock in divisions 4.b, 4.c, 7.a, and 7d–h ( <a href="#">ICES, 2018a</a> )*
5	Cod	Division 7.a	6	7a	MSY	1	$F_{MSY}$ ranges provided in Table 2
6	Cod	Divisions 7e–k	7	7bce-k,8,9,10	MSY	1	$F_{MSY}$ ranges up to date for the stock in divisions 7e–k ( <a href="#">ICES, 2016a</a> )
6a	Cod	Subarea 4, Division 7.d and Subdivision 20 (to match with 7.d)	8	7d	MSY	1	ICES provides advice for cod in Subarea 4, Division 7.d, and Subdivision 20. $F_{MSY}$ ranges up to date ( <a href="#">ICES, 2017b</a> )
7	Megrim	Divisions 4.a and 6.a	9	5b,6,12,14	MSY	1	$F_{MSY}$ ranges for the stock in divisions 4.a and 6.a up to date ( <a href="#">ICES, 2015</a> )
8	Megrim	Divisions 7.b–k, 8.a–b, and 8.d	10	7	MSY	Four-spotted megrim (cat 5) Megrim (cat 1)	ICES provides advice for two megrim advice in this area. $F_{MSY}$ ranges calculation for four-spotted megrim is not currently possible. For megrim, $F_{MSY}$ ranges up to date for divisions 7b–k, 8a–b, and 8d ( <a href="#">ICES, 2016a</a> )

\* Version 2: for roundnose grenadier the stock was assessed as category 3 (ICES, 2018a); for seabass the information was updated following the completion of a benchmark in 2018.

N°	Species	Stock area	N°	Corresponding TAC area in EU western waters	MSY or precautionary advice	ICES category	Comments
			11	8abde	MSY		See line above
9	Four-spot megrim	Divisions 8.c and 9.a	12	8c,9,10	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 8.c and 9.a ( <a href="#">ICES, 2016a</a> )
10	Megrim	Divisions 8.c and 9.a				1	F <sub>MSY</sub> ranges up to date for the stock in divisions 8.c and 9.a ( <a href="#">ICES, 2016a</a> )
11	Anglerfish^	Divisions 7.b–k, 8.a–b, and 8.d	13	7	Precautionary approach	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 7.b–k, 8.a–b, and 8.d ( <a href="#">ICES, 2018b</a> )*
			14	8adbde	Precautionary approach	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 7.b–k, 8.a–b, and 8.d ( <a href="#">ICES, 2018b</a> )*
12	Anglerfish^	Divisions 8.c and 9.a	15	8c,9,10	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 8.c and 9.a ( <a href="#">ICES, 2018b</a> )*
13	Haddock	Division 6.b	16	6b,12,14	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in Division 6.b ( <a href="#">ICES, 2016a</a> )
14	Haddock	Division 7a	17	7a	Precautionary approach	1	F <sub>MSY</sub> ranges provided in table 2
15	Haddock	Division 7.b–k	18	7b-k, 8,9,10	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 7.b–k ( <a href="#">ICES, 2016a</a> )
16	Whiting	Divisions 7.b, 7.c, and 7e–k	19	7b-k	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 7.b–c and 7.e–k ( <a href="#">ICES, 2016a</a> )
17	Whiting	Subarea 8 and Division 9.a	20	8	Precautionary approach	5	F <sub>MSY</sub> ranges calculation not currently possible
18	Hake	Subareas 4, 6, and 7, divisions 3.a, 8.a–b, and 8.d	21	6,7,5b, 12,14	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in subareas 4, 6, and 7, divisions 3.a, 8.a–b, and 8.d ( <a href="#">ICES, 2016a</a> )
19			22	8abde	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in subareas 4, 6, and 7, divisions 3.a, 8.a–b, and 8.d ( <a href="#">ICES, 2016a</a> )

\* Version 2: information updated following the completion of a benchmark in 2018

N°	Species	Stock area	N°	Corresponding TAC area in EU western waters	MSY or precautionary advice	ICES category	Comments
	Hake	Divisions 8.c and 9.a	23	8c,9,10	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 8.c and 9.a ( <a href="#">ICES, 2016a</a> )
20	Blue ling	Division 5.b, subareas 6 and 7	24	5b, 6,7	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in Division 5.b, subareas 6 and 7 ( <a href="#">ICES, 2016a</a> )
21	Red seabream	Subarea 9	25	9	Precautionary approach	3	F <sub>MSY</sub> ranges calculation not currently possible
22	Red seabream	Subarea 10	26	10	Precautionary approach	5	F <sub>MSY</sub> ranges calculation not currently possible
23	Plaice	Divisions 7.d and 7.e	27	7de	MSY / precautionary approach	Plaice 7d(cat 1); Plaice 7e (cat 3)	ICES provides advice for plaice in 7.d and 7.e separately. Plaice in 7.d has up-to-date F <sub>MSY</sub> ranges ( <a href="#">ICES, 2015</a> ). F <sub>MSY</sub> ranges calculation for plaice in 7.e not currently possible
24	Pollack	Subarea 7	28	7	Precautionary approach	4	F <sub>MSY</sub> ranges calculation not currently possible
25	Common sole	Divisions 7.b and 7.c	29	7bc	Precautionary approach	6	F <sub>MSY</sub> ranges calculation not currently possible
26	Common sole	Division 7.d	30	7d	MSY	1	ICES provides advice for sole in Division 7.d. F <sub>MSY</sub> ranges up to date ( <a href="#">ICES, 2017c</a> ).
27	Common sole	Division 7.e	31	7e	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in Division 7.e ( <a href="#">ICES, 2016a</a> )
28	Common sole	Divisions 7.f and 7.g	32	7fg	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 7.f and 7.g ( <a href="#">ICES, 2016a</a> )
29	Common sole	Divisions 7.h, 7.j and 7.k	33	7hjk	Precautionary approach	3	F <sub>MSY</sub> ranges calculation not currently possible
30	Common sole	Divisions 8.a and 8.b	34	8ab	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in divisions 8.a and 8.b ( <a href="#">ICES, 2016a</a> )
31	Common sole	Divisions 8.c and 9.a	35	8cde,9,10	Precautionary approach	5	F <sub>MSY</sub> ranges calculation not currently possible
32	Common sole	Division 6; Union and international waters of 5.b; international waters of 12 and 14	36	5,6b,12, 14	Precautionary approach		ICES does not have a stock for sole in this area.
33	Norway lobster	Division 6.a, (FU11)	37	6,5b,12,14	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in (FU11) ( <a href="#">ICES, 2016a</a> )

N°	Species	Stock area	N°	Corresponding TAC area in EU western waters	MSY or precautionary advice	ICES category	Comments
34	Norway lobster	Division 6.a, (FU12)				1	F <sub>MSY</sub> ranges up to date for the stock in (FU12) ( <a href="#">ICES, 2016a</a> )
35	Norway lobster	Division 6.a, (FU13fc)				1	F <sub>MSY</sub> ranges up to date for the stock in (FU13fc) ( <a href="#">ICES, 2016a</a> )
36	Norway lobster	Division 6.a, (FU13sj)				1	F <sub>MSY</sub> ranges up to date for the stock in (FU13sj) ( <a href="#">ICES, 2016a</a> )
37	Norway lobster	Division 7.a, (FU14)	38	7	MSY	1	F <sub>MSY</sub> ranges up to date for the stock in (FU14) ( <a href="#">ICES, 2016a</a> )
38	Norway lobster	Division 7.a, (FU15)				1	F <sub>MSY</sub> ranges up to date for the stock in (FU15) ( <a href="#">ICES, 2016a</a> )
39	Norway lobster	Divisions 7.b –c, j –k (FU16)				1	F <sub>MSY</sub> ranges up to date for the stock in (FU16) ( <a href="#">ICES, 2016a</a> )
40	Norway lobster	Division 7.b, (FU17)				1	F <sub>MSY</sub> ranges up to date for the stock in (FU17) ( <a href="#">ICES, 2016a</a> )
41	Norway lobster	Subarea 7 and rectangles outside the functional units (Southern Celtic Seas, southwest of Ireland) (FU18)				5	F <sub>MSY</sub> ranges calculation not currently possible
42	Norway lobster	Division 7.a, 7.g, and 7.j (FU19)-Irish Sea, Celtic Sea, eastern southwest of Ireland				1	F <sub>MSY</sub> ranges up to date for the stock in (FU19) ( <a href="#">ICES, 2016a</a> )
43	Norway lobster	Division 7.g and 7.h (FU20–21)- Celtic Sea				1	F <sub>MSY</sub> ranges up to date for the stock in (FU19) ( <a href="#">ICES, 2016c</a> )
44	Norway lobster	FU21					FU21 advice is given in conjunction with FU20 (line above)
45	Norway lobster	Divisions 7.g and 7.f (FU22)- Celtic Sea & Bristol Channel	1	F <sub>MSY</sub> ranges up to date the for the stock in (FU22) ( <a href="#">ICES, 2016a</a> )			
46	Norway lobster	Division 8.c -southern Bay of Biscay and northern Galicia) (FU25)	39	8abde	MSY	3	F <sub>MSY</sub> ranges calculation not currently possible. Note that there are two FUs in Division 8.c (FU25 and FU31) TAC area does not match the stock area.
47	Norway lobster	Division 9.a, functional units 26–27 (Atlantic Iberian waters, East, western Galicia, and northern Portugal (FU26–27)	40	9,10	Precautionary approach	3	F <sub>MSY</sub> ranges calculation not currently possible

N°	Species	Stock area	N°	Corresponding TAC area in EU western waters	MSY or precautionary advice	ICES category	Comments
48	Norway lobster	Division 9.a, Atlantic Iberian waters, East and southwestern and southern Portugal (FU 28–29)				3	F <sub>MSY</sub> ranges calculation not currently possible
49	Norway lobster	Division 9.a, Atlantic Iberian waters East and Gulf of Cadiz (FU 30)				4	F <sub>MSY</sub> ranges calculation not currently possible
50*	Sea bass	Division 8.ab (northern and central Bay of Biscay)			MSY	1	F <sub>MSY</sub> ranges up to date for the stock in 8.ab ( <a href="#">ICES, 2018c</a> )
51*	Plaice	Plaice in Division 7.a (Irish sea)			MSY	1	F <sub>MSY</sub> ranges provided in Table 2
52*	Common sole	Division 7.a (Irish sea)			MSY	1	F <sub>MSY</sub> ranges up to date for the stock in Division 7.a ( <a href="#">ICES, 2016a</a> )*
53*	Norway lobster	divisions 8.a and 8.b (FU 22 -24)			MSY	1	F <sub>MSY</sub> ranges calculation not currently possible.
54*	Northern shrimp	in divisions 3.a and 4.a East			MSY	1	F <sub>MSY</sub> ranges up to date for the stock in 3.a and 4.a ( <a href="#">Cardinale, M. et al., 2017</a> ; page 102, with historic recruitment)

^ Anglerfish stocks in divisions 7.b–k, 8.a–b, and 8.d and anglerfish in divisions 8.c and 9.a are assessed by species: white anglerfish (*Lophius piscatorius*) and black belly anglerfish (*Lophius budegassa*)

Calculation of reference points for cod and haddock in Division 7.a was undertaken at the Working Group for the Celtic Seas Ecoregion (WGCSE) (ICES, 2017a). These reference points did not include the F<sub>MSY</sub> range, and the range calculation was performed in response to the current request. In the process of defining the F<sub>MSY</sub> ranges, several refinements were suggested that caused the reference points to differ from those calculated previously (ICES, 2017a), and so for consistency all of the reference points have been updated. The MSY reference points are summarized in Table 2. In addition, the F<sub>MSY</sub> range for Norway lobster in FUs 20–21, which had been previously estimated by the WGCSE (ICES, 2016c), was reviewed and is also provided.

The estimation procedure requires some choices of the input to use and associated assumptions, and this introduces additional uncertainty. The results for cod are believed to be particularly influenced by a dome-shaped age selection pattern, which is associated with cod being taken as bycatch in most recent years. If the selection pattern changes when fishing practices target cod, it could be expected that the F<sub>MSY</sub> and associated range currently estimated would represent an overestimate and a revision of F<sub>MSY</sub> reference points would be needed.

The derived F<sub>MSY</sub> range for the four stocks is presented in Table 2.

\* Version 2: Information inserted for sea bass in Division 8ab, plaice and common sole in Division 7a, Norway lobster FU22-24 and northern shrimp in divisions 3.a and 4.a

**Table 2**  $F_{MSY}$  ranges for cod, haddock and plaice in the Irish Sea [ $F_{lower}$ ,  $F_{upper}$ ] and for Norway lobster in FUs 20–21, intended to deliver no more than 5% reduction in long-term yield compared with  $F_{MSY}$ .

Stock code	Stock name	$F_{MSY\ lower}$	$F_{MSY}$	$F_{MSY\ upper}$
had.27.7a	Haddock ( <i>Melanogrammus aeglefinus</i> ) in Division 7.a (Irish Sea)	0.20	0.28	0.35
cod.27.7a	Cod ( <i>Gadus morhua</i> ) in Division 7.a (Irish Sea)	0.36	0.44	0.44
nep.fu.2021 *	Norway lobster ( <i>Nephrops norvegicus</i> ) in the FU 20 (Labadie) and FU 21 (Jones and Cockburn)	5.9%	6%	6%
ple.27.7a *	Plaice ( <i>Pleuronectes platessa</i> ) in Division 7.a (Irish Sea)	0.133	0.196	0.293

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\* Version 2:  $F_{MSY\ lower}$  value corrected and information inserted for plaice in Division 7.a.



## Basis of the advice

### Background

For stocks where ICES advice is given based on the MSY approach, ICES has developed an advice rule (AR) based on the  $F_{MSY}$  fishing mortality reference point that provides the exploitation rate used to give catch advice and a biomass reference point,  $MSY B_{trigger}$ . With the ICES advice rule, if the SSB in the TAC year is predicted to be lower than  $MSY B_{trigger}$ , then the  $F$  is reduced linearly (ICES, 2016b). The ICES MSY AR is evaluated to check if the  $F_{MSY}$  and  $MSY B_{trigger}$  combination results in maximum long-term yield subject to precautionary considerations; i.e. in the long term the annual probability of  $SSB < B_{lim}$  should be no more than 5%. This probability is denoted as  $F_{P.05}$ .

To develop suitable  $F_{MSY}$  ranges, ICES has used the following criteria:

- 1) MSY is interpreted as the maximum long-term average yield from a stock exploited sustainably. This implies variable catch from year to year from a stock above precautionary limits.
- 2)  $F$  refers to total  $F$  for catch (landings plus discards).
- 3)  $F_{MSY}$  and the ranges  $F_{upper}$  and  $F_{lower}$  are calculated based on maximizing long-term average yield, where yield is taken to be the catch of fish at lengths above the minimum conservation reference size (MCRS).
- 4) The  $F_{MSY}$  ranges are derived based on yields within 95% of yields at  $F_{MSY}$ . The choice of 95% of yield is somewhat arbitrary, but is in line with a “pretty good” yield concept (e.g. Hilborn, 2010) and delivers less than 5% reduction in long-term yield compared with MSY.
- 5) The estimated values for  $F_{MSY}$  and associated ranges are based on recent stock biology, fishery characteristics, and environmental conditions. ICES has generally applied current growth, maturation, and natural mortality typically based on values from the last ten years used in the stock assessments.
- 6) For simulated recruitment the full time-series was used, unless there was evidence of change having occurred.
- 7) The ICES catch advice at  $F_{MSY}$  and at  $F_{upper}$  and  $F_{lower}$  will follow an advice rule based on  $F$  reduction when SSB in the TAC year is predicted to be below  $MSY B_{trigger}$  (ICES advice rule). This advice rule conforms to the current ICES MSY approach. ICES considers that to be in accordance with the precautionary approach and does not consider that  $F$  should be maintained at  $F_{MSY}$  when stock biomasses are below  $MSY B_{trigger}$ .
- 8) In order to be consistent with the ICES approach for estimating  $F_{MSY}$ , and taking into account advice error, as well as biological and fishery variability, the values of  $F_{upper}$  and  $F_{MSY}$  are capped so that the probability of  $SSB < B_{lim}$  is no more than 5%. If the stock has no available precautionary criteria (i.e. when the estimation of  $F_{MSY}$  is based on a deterministic calculation and there is no  $B_{lim}$  or no evaluation of the probability of  $SSB < B_{lim}$ ), the  $F_{MSY}$  range is constrained to a maximum of  $F_{MSY}$  and a minimum of  $F_{lower}$ .

The range was thus defined as follows (where  $F_{P.05}$  is the value of  $F$  that corresponds to 5% probability of  $SSB < B_{lim}$ ):

Case	Final $F_{MSY}$	$F_{MSY}$ range
$F_{upper} < F_{P.05}$	$F_{MSY}$	$F_{lower} - F_{upper}$
$F_{MSY} < F_{P.05} < F_{upper}$	$F_{MSY}$	$F_{lower} - F_{P.05}$
$F_{P.05} < F_{MSY} < F_{upper}$	$F_{P.05}$	$F_{lower} - F_{P.05}$
$F_{P.05}$ cannot be defined	$F_{MSY}$	$F_{lower} - F_{MSY}$

### Results and conclusions

The results are summarized in Table 3. This table gives the values of  $F_{MSY}$  and the  $F_{MSY}$  upper and lower ranges based on 5% reduction in yield. The table also shows the  $F$  values that give a 5% probability ( $F_{P.05}$ ) of SSB falling below  $B_{lim}$ . This is provided both with and without ICES advice rule applied. For cod, the values of  $F_{MSY}$  and  $F_{MSY}$  upper are modified based on the precautionary considerations detailed in the text table above.

**Table 3** Estimates of  $B_{lim}$ ,  $B_{pa}$ ,  $F_{MSY}$ , and  $F$  at 95% of MSY above and below  $F_{MSY}$ ,  $F_{P.05}$  with and without the ICES advice rule (AR),  $F_{pa}$  and  $F_{lim}$ . All options are considered based on an upper bound on 95% MSY, constrained to be at or below  $F_{P.05}$  with the AR.

Stock code	Stock	$B_{lim}$	$B_{pa}$	$F_{pa}$	$F_{lim}$	MSY $B_{trigger}$ (t)	Precautionary F, $F_{MSY}$ , and F intervals estimated without Advice Rule (AR)				With AR $F_{P.05AR}$	Options for upper bound, all limited by PA considerations $F < F_{P.05}$	
							$F_{P.05}$	$F_{MSY}$	95% below	95% above		95% yield, no AR	95% yield, with AR
had.27.7a	Division 7.a	2994	4160	0.38	0.53	4280	0.35	0.28	0.20	0.35	0.41	0.35	0.37
cod.27.7a	Division 7.a	6000	8616	0.58	0.81	8616	0.44	0.44	0.36	0.44	0.44	0.44	0.44
nep.fu.2021	FU20–21	-	-	-	-	-	-	6%	5.9%*	6%	-	-	-
ple.27.7a*	Division 7.a	3958	5294	0.35 5	0.49 5	8757	0.40 3	0.196	0.133	0.293	0.802	0.432	0.938

**Methods**

An EqSim analysis was conducted for Irish Sea cod and haddock following the same protocol set up by WKMSYREF4 (ICES, 2016b). Data used in the EqSim analysis were from the 2017 assessment (ICES, 2017). Settings are provided in Table 4.

**Table 4** Settings for cod, haddock and plaice in the Irish Sea used in the calculation of reference points and  $F_{MSY}$  range. Estimation assumed no autocorrelation in recruitment.

Data and parameters	Cod		Haddock		Plaice*	
	Setting	Comments	Setting	Comments	Setting	Comments
SSB-recruitment data	Series 1992–2016		Full data series (1992 to 2016)		Full data series (year classes 1981–2017)	
Stock–recruit model	Fitted segmented regression		Model averaged		Fitted segmented regression	
Exclusion of extreme values (option extreme.trim)	Yes	5 <sup>th</sup> and 95 <sup>th</sup> percentiles	Yes	5 <sup>th</sup> and 95 <sup>th</sup> percentiles	No	
Trimming of R values	Yes	-3,+3 standard deviations	Yes	-3,+3 standard deviations	Yes	-3, +3 Standard deviations
Mean weights and proportion mature; natural mortality	2007–2016	Inspected and no trend in last ten years observed	2007–2016	Inspected and no trend in last ten years observed	2008–2017	Inspected and no trend in last 10 years observed
Exploitation pattern	2007–2016	Inspected and no trend in last ten years observed	2007–2016	Inspected and no trend in last ten years observed	2008–2017	Inspected and no trend in last 10 years observed
Assessment error in the advisory year. CV of F	0.212	Default value calculated from five stocks in WKMSYREF4 (ICES, 2016b)	0.212	Default value calculated from five stocks in WKMSYREF4 (ICES, 2016b)	0.201	Calculated from update assessment WGCSE 2018
Autocorrelation in assessment error in the advisory year	0.423	Default value calculated from five stocks in WKMSYREF4 (ICE,S 2016b)	0.423	Default value calculated from five stocks in WKMSYREF4 (ICES, 2016b)	0.423	Default value calculated from 5 stocks in WKMSYREF3

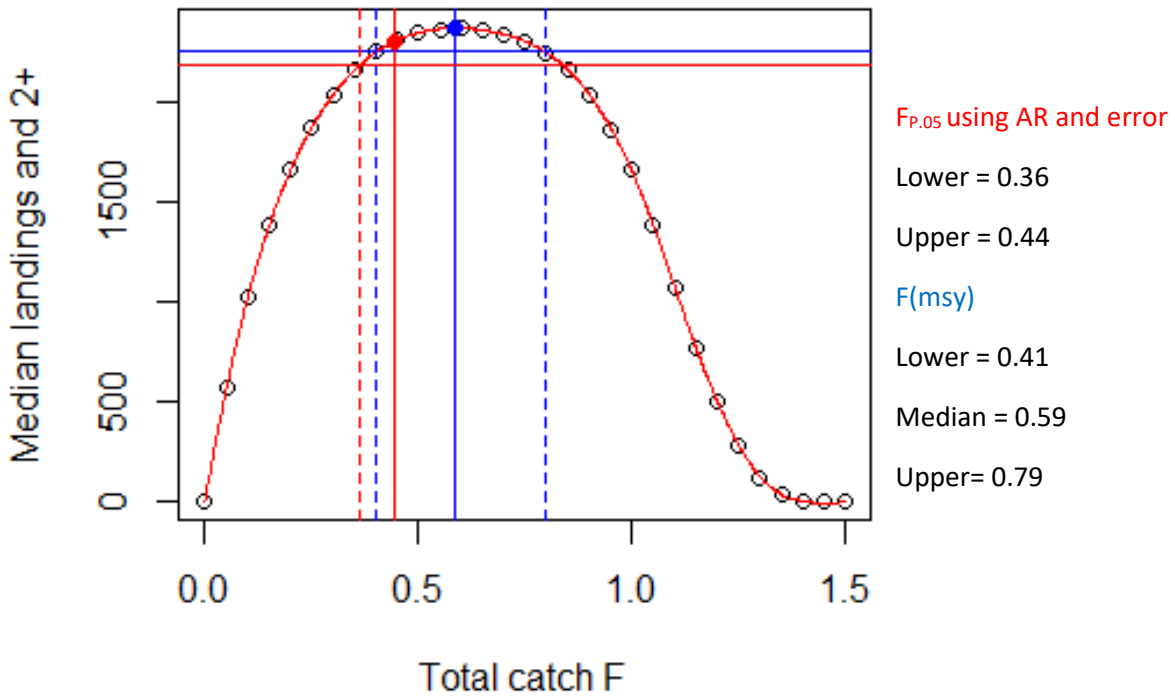
\* Version 2: In table 3,  $F_{MSY}$  lower value corrected and information inserted for plaice in Division 7.a. In table 4, information inserted for plaice in Division 7.a.

**Table 5** Basis for the reference points for cod, haddock and plaice in Division 7.a and Norway lobster in functional units (FU) 20–21

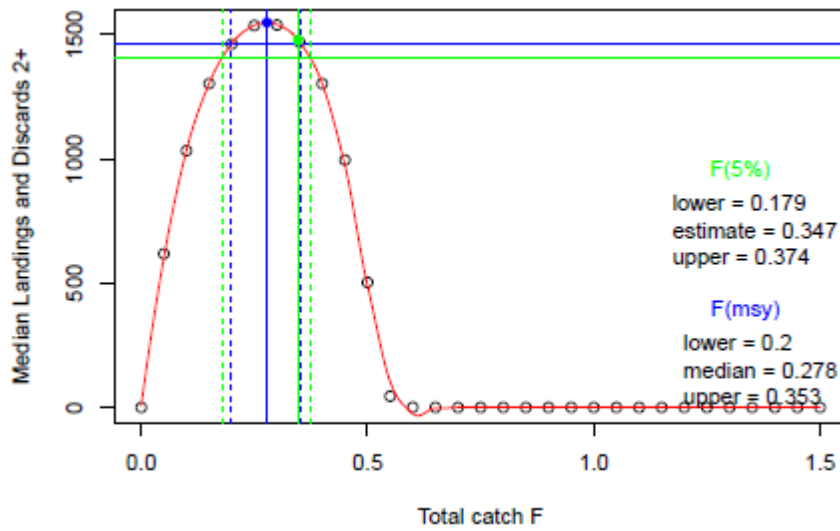
Cod	
$B_{lim}$	Visual interpretation of SSB-recruitment relationship over the full time-series. $B_{lim}$ set to 6000 t, which corresponds to the break in the SR relationship.
$B_{pa}$	$B_{lim}$ combined with the assessment error; $B_{lim} \times \exp(1.645 \times \sigma)$ ; $\sigma = 0.2$
$F_{lim}$	F with 50% probability of $SSB < B_{lim}$
$F_{pa}$	$F_{lim}$ combined with the assessment error; $F_{lim} \times \exp(-1.645 \times \sigma)$ ; $\sigma = 0.2$
$MSY_{Btrigger}$	$B_{pa}$ ; Irish Sea cod has been fished at, or below $F_{MSY}$ for < five years.
Haddock	
$B_{lim}$	The lowest SBB at which above recruitment in the upper quartile has been observed
$B_{pa}$	$B_{lim}$ combined with the assessment error; $B_{lim} \times \exp(1.645 \times \sigma)$ ; $\sigma = 0.2$
$F_{lim}$	F with 50% probability of $SSB < B_{lim}$
$F_{pa}$	$F_{lim}$ combined with the assessment error; $F_{lim} \times \exp(-1.645 \times \sigma)$ ; $\sigma = 0.2$
$MSY_{Btrigger}$	5 <sup>th</sup> percentile of $B_{FMSY}$ ; Irish Sea haddock has been fished at, or below $F_{MSY}$ for > five years.
Plaice*	
$B_{lim}$	$B_{loss}$ = Minimum SSB observed
$B_{pa}$	$B_{lim}$ combined with the assessment error; $B_{lim} \times \exp(1.645 \times \sigma)$ ; $\sigma = 0.177$
$F_{lim}$	F with 50% probability of $SSB < B_{lim}$
$F_{pa}$	$F_{lim}$ combined with the assessment error; $F_{lim} \times \exp(-1.645 \times \sigma)$ ; $\sigma = 0.201$
$MSY_{Btrigger}$	Lower 5%ile of $B_{FMSY}$
Norway lobster Fu 20-21	
$F_{MSY}$	$F_{MSY}$ proxy, equivalent to $F_{0.1}$ for combined sexes, derived from length-based per recruit analysis.

For cod in the Irish Sea,  $F_{MSY}$  is higher than  $F_{P.05}$ , therefore,  $F_{MSY}$  is set to  $F_p$   $F_{P.05.05} = 0.441$ . Since  $F_{MSY}$  is set to  $F_{P.05}$ , following the advice rule we set  $F_{MSYUpper} = F_{MSY}$ . To calculate  $F_{MSYLower}$  the F at which 95% of the long term median yield achieved at  $F_{MSY}$  is used (Figure 1).

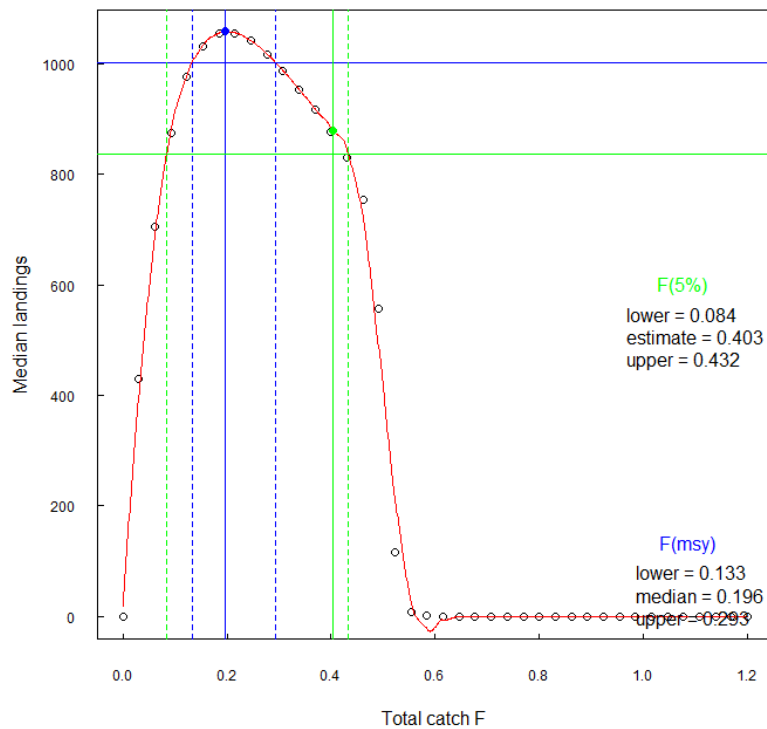
\* Version 2: Table with the basis for reference points inserted for plaice in Division 7.a



**Figure 1** Yield curve and  $F_{MSY}$  upper and lower ranges (vertical blue lines) and  $F_{P,05}$  upper and lower ranges (vertical red lines) after setting  $F_{MSY}$  to  $F_{P,05}$  for Irish Sea cod.  $F_{MSY}$  median point estimates and upper and lower bound are given.



**Figure 2** Yield curve and  $F_{MSY}$  upper and lower ranges (vertical blue lines) and  $F_{lim}$  upper and lower ranges (vertical green lines) for Irish Sea haddock.  $F_{MSY}$  median point estimates and upper and lower bound are given (bottom right). Ages 2+ are used as a proxy for fish above MCRS. Note that F(5%) indicates  $F_{P,05}$ .



**Figure 3\*** Yield curve and  $F_{MSY}$  upper and lower ranges (vertical blue lines) and  $F_{lim}$  upper and lower ranges (vertical green lines) for Irish Sea plaice.  $F_{MSY}$  median point estimates and upper and lower bound are given (bottom right).

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\* Version 2: Reference inserted