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## 10 Megrim (*Lepidorhombus* ssp.) in divisions 4.a and 6.a (northern North Sea, West of Scotland)

### Type of assessment in 2022

Update of 2021 assessment with new landings and survey data. The model used to carry out the assessment is the Schaefer Surplus production process model in R and Winbugs.

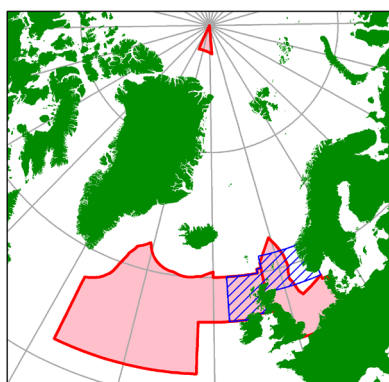
### ICES advice applicable to 2023

ICES advise that when the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied, catches in 2023 that correspond to the F ranges in the plan are between 5550 tonnes and 7200 tonnes.

### 10.1 General

#### Stock description and management units

Megrim stock structure is uncertain and historically the Working Group has considered megrim populations in 6.a and 6.b as separate stocks. The review group questioned the basis for this in 2004. Data collected during an EC study contract (98/096) on the 'Distribution and biology of anglerfish and megrim in the waters to the West of Scotland' showed significantly different growth parameters and significant population structure difference between megrim sampled in 6.a and 6.b (Anon, 2001). Spawning fish occur in both areas but whether these populations are reproductively isolated is not clear. As noted by WGNDS (2008), megrim in 4.a has historically not been considered by ICES. Since 2009 data from 4 and 2.a are included in this report, but international catch and weight-at-age data for 4, prior 2006 were not available to the working group. Given that there is little evidence to suggest that megrim in 6.a and 4.a are separate stocks, based on a visual inspection of the spatial distribution of commercial landings and fishery-independent survey data, WKFLAT (2011) concluded that megrim in 6.a and 4.a should be considered as a single stock. This has subsequently been supported through recent genetic studies (MacDonald and Prieto, 2012) indicating that there is one stock consisting of divisions 4.a (northern North Sea) and 6.a (West of Scotland) and another separate stock in Division 6.b (Rockall).



■ TAC/Management area  
▨ Assessment area

Management area (red boxes) and assessment area (blue hatched boxes).

Species:	Megrim <i>Lepidorhombus</i> spp.	Zone:	United Kingdom and Union waters of 4; United Kingdom waters of 2a (LEZ/2AC4-C)
Belgium	8 <sup>(4)</sup>	Analytical TAC	
Denmark	7 <sup>(4)</sup>	Article 8(2) of this Regulation applies	
Germany	7 <sup>(4)</sup>		
France	45 <sup>(4)</sup>		
Netherlands	36 <sup>(4)</sup>		
Union	103 <sup>(4)</sup>		
United Kingdom	2 660 <sup>(4)</sup>		
TAC	2 763		

<sup>(4)</sup> Special condition: of which up to 20 % may be fished in United Kingdom, Union and international waters of 6a north of 58° 30' N (LEZ/\*6AN58).

Species:	Megrim <i>Lepidorhombus</i> spp.	Zone:	6; United Kingdom and international waters of 5b; international waters of 12 and 14 (LEZ/56-14)
Spain	550 <sup>(4)</sup>	Analytical TAC	
France	2 146 <sup>(4)</sup>	Article 8(2) of this Regulation applies	
Ireland	627 <sup>(4)</sup>		
Union	3 323 <sup>(4)</sup>		
United Kingdom	2 258 <sup>(4)</sup>		
TAC	5 581		

<sup>(4)</sup> Special condition: of which up to 25 % may be fished in United Kingdom and Union waters of 2a and 4 (LEZ/\*2AC4C).

2022 TAC for 6, EC waters of 5.b and International waters of 12 and 14 (lower) and TAC for 4 and 2.a (upper).

The uptake of the 2020 TAC for ICES Division 6 and EU waters of 5.b was 36.7%. The small uptake was mainly due to poor utilisation of quota by France and the UK, managing only 5.8 and 37.4% respectively. In Area 4 and 2.a, uptake of the TAC was 78.4%. The majority of available TAC (96.2%) is allocated to the UK, who take 86.1% of it.

## Fishery in 2021

### Landings

Catches of megrim comprise two species, *Lepidorhombus whiffiagonis* and *L. boscii*. Information available to the Working Group indicates that *L. boscii*, are a negligible proportion of the Scottish and Irish megrim catch (Kunzlik *et al.*, 1995; Anon, 2001).

Commercial catches are dominated by female megrim, typically 90% of the total catch. The InterCatch catch estimate is 3803 tonnes, and the ICES landings estimate for 6.a and 4.a. is 3603 tonnes. The total ICES landings are well below the total TAC covering the fished areas of 4.a–6.a.

Official landings data for each country together with Working Group best estimates of landings from 6.a are shown in Table 10.2 and for 4.a in Table 10.3. To estimate ICES landings, we take InterCatch estimates and, if unavailable, we use official estimates. There are often minor differences between official data and InterCatch for most countries.

### Discards

Discard data were made available by Ireland, Scotland and France and total discards were estimated to be 200 tonnes or 5.6% by weight for the stock area in 2021. Total discard estimates have been reasonably consistent around 5–10% over the last nine years, although there have been some changes in rates within countries.

A linear decline in discards from 30 to 15% over time between 1985 and 2012 is assumed in the stock assessment. From 2013 onwards discard data have taken from InterCatch, there is no deviation from the agreed stock annex.

### Catch

A breakdown of 2021 catch by main gear type in InterCatch is given below:

Catch	Landings			Discards		
	Finfish trawls	<i>Nephrops</i> trawls	Other Gears	Finfish trawls	<i>Nephrops</i> trawls	Other Gears
3803 tonnes	98%	<1%	1.6%	34%	66%	<1%
	3603 tonnes			200 tonnes		

### Surveys

Indices from six fishery-independent surveys are used in the assessment. The surveys are outlined in Table 10.1 below and details can be viewed in the stock annex.

**Table 10.1. Summary indices used for surplus production model.**

NUMBER	SURVEY	NATIONALITY	AREA	TIME-SERIES	DEPTH RANGE (M)
1	Sco-IBTS-Q3 (G2829)	SCOTLAND	4.A	1987–PRESENT	<400 M
2	Sco-IBTS-Q1 (G1022)	SCOTLAND	4.A	1987–PRESENT	<400 M
3	ScoGFS-WIBTS-Q1 (G1179)	SCOTLAND	6.A	1986–2010	40–400
4	ScoGFS-WIBTS-Q4 (G4299)	SCOTLAND	6.A	1986–2010	50–300
5	SIAMISS-Q2 (G3745)	SCOTLAND	6.A*/4.A	2005–PRESENT	50–1050
6	SIAMISS-Q2 (G1794)	IRELAND	6.A*	2005–PRESENT	50–850

Figures 10.1 to 10.5 present the megrim biomass maps for the SIAMISS and IBTS surveys. The SIAMISS bubble plots show an increasing abundance over time throughout the area over the time-series. Figures 10.2. (Sco-IBTS-Q3 (G2829) 4.a) and 13.3 (Sco-IBTS-Q1(G1022) 4.a) show the large increase in biomass over time in the northern North Sea. Biomass in the southern North Sea remains quite low.

Figures 10.4 (ScoGFS-WIBTS-Q1(G1179) 6.a) and 10.5 (ScoGFS-WIBTS-Q4(G4299) 6.a) also show an increase in biomass over the time-series and are shown until the survey design and ground gear changed in 2010. Data were truncated from the time-series going into the assessment.

## 10.2 Estimation of survey cpue indices

### Cpue trends of survey data

The data from the IBTS surveys exhibit a relatively large proportion of zeros, therefore the delta method of Stefánsson (1996) was used to generate indices. This method (delta-gamma model) comprises fitting two generalized linear models. The first model (binomial GLM) is used to obtain the proportion of non-zero tows, and is fit to the data coded as 1 or 0, if the tow contained a positive or zero CPUE, respectively. The second model is fit to the positive only CPUE data using a gamma or lognormal GLM.

The biomass trend for the SIAMISS survey is shown in Figure 10.6. There is a weakly increasing trend over time with year effects evident in 6.a in 2013 and 2017. The biomass trends for the four IBTS surveys are shown in Figure 10.7.

## 10.3 Stock assessment

The input data for the stock assessment are given in Table 10.4 this comprises of a time-series from all survey indices, and ICES catch estimates for this stock.

## 2022 Final run

The Pearson residual diagnostic plots for the final assessment are shown in Figure 10.8. The residuals for the two 6.a surveys and the SIAMISS survey are fairly randomly dispersed around zero. A trend in the residuals is evident for the two 4.a surveys, with increasing positive residuals in the last decade.

The prior and posterior distributions for the parameters in the final model fit, are shown in Figure 10.9. The priors are given in Table 10.5. The posterior distributions are similar to previous year's assessments. The posterior parameter estimates for the final assessment model are given in Table 10.6. These are similar to recent assessments.

Figure 10.10 shows the final model fits to the CPUE series and the estimates of total biomass and harvest ratio. The fits to the 6.a and SIAMISS surveys are reasonable. The fits to the 4.a surveys show that the model is not fitting well to those surveys in recent years. This issue needs to be examined further in the next benchmark.

The time-series of  $B/B_{MSY}$  and  $F/F_{MSY}$  landings and discards used in the final assessment are given in Table 10.7.

## Comparison with previous assessments

Figure 10.11 compares the final assessment with those conducted by WGCSE at previous meetings. The 2022 assessment assesses the biomass estimate to be stable at the 2021 levels; prior to being revised down in recent years. Estimates of fishing mortality continue on an upward trend. There are also some deviations in the historic estimates of  $F$  and Biomass around 2000. These are linked to the use of the 6.a surveys to derive the delta-gamma CPUEs truncated in 2010.

To evaluate evidence of possible bias in the assessment population metrics, a Mohn's Rho analysis resulted in values of -0.045 for  $F_{bar}$  and 0.044 for biomass. ICES considers a value greater than 0.20 to be unacceptably high.

## State of the stock

The state of the stock has not changed since last year. Fishing mortality has been below  $F_{MSY}$  for almost the full time-series and has an overall declining trend since the late 1990s. Biomass has consistently been above  $MSY B_{trigger}$  and shows an increasing trend since 2005. The stock in 2022 is estimated to be 1.44 times  $B_{MSY}$  and the fishing mortality in 2021 is estimated to be have been 52% of  $F_{MSY}$ .

## 10.4 Short-term projections

Short-term projections have been updated according to the method set out in the stock annex. The basis for the catch options is given in Table 10.8.

The management option table is given in Table 10.9. Fishing at  $F_{MSY}$  in 2023 is projected to result in total catches of 7200 t (landings of 6798 t and discards of 402 t) and a Biomass of 1.32 times  $B_{MSY}$  in 2024.

## 10.5 Biological reference points

### Precautionary approach reference points

$F_{MSY}$ ,  $B_{MSY}$  and the yield at MSY are all directly estimated in the model. It should be noted that these will vary when new survey and catch information is added.  $B_{pa}$  and  $B_{lim}$  are defined as  $50\%B_{MSY}$  and  $30\%B_{MSY}$  respectively.  $F_{lim}$  is defined as  $1.7 F_{MSY}$  and is the  $F$  that drives the stock to  $B_{lim}$  assuming  $B_{lim}=30\%B_{MSY}$ . The derivation is given below:

$$P=rB(1-B/K)$$

*The surplus productivity associated with  $B_{lim}$  is:*

$$P_{lim}=rB_{lim}(1-B_{lim}/K)$$

*The corresponding  $F$  is:*

$$F_{lim}=rB_{lim}(1-B_{lim}/K)/B_{lim} = r(1-B_{lim}/K)$$

$$B_{lim}=0.3B_{MSY} = 0.3K/2$$

$$F_{lim} = r(1-0.3K/(2K)) = r(1-0.3/2) = 0.85r$$

$F_{MSY}=r/2$ , let  $x$  denote the proportionality between  $F_{MSY}$  and  $F_{lim}$

$$xF_{MSY}=F_{lim}$$

$$x(r/2)=0.85r$$

$$x=2*0.85$$

$$x=1.7$$

### MSY reference points

In 2015 ICES provided precautionary  $F_{MSY}$  ranges that are derived to deliver no more than a 5% reduction in long-term yield compared with MSY. Details of this analysis are given in WKM-SYREF3 (ICES, 2015) and the derivations are given below.

	MSY Flower <sup>b)</sup>	$F_{MSY}$ <sup>b)</sup>	MSY $F_{upper}^{b)}$ with AR	MSY $B^{trigger}$
Megrim in divisions 4.a and 6.a	$0.39 \times r$ <sup>d)</sup>	$r/2$ <sup>d)</sup>	$r/2$ <sup>d)</sup>	$K$ <sup>d)</sup>

The stock has been fished below  $F_{MSY}$  for more than ten years, therefore, the WG considered it appropriate to set the MSY  $B^{trigger} = B_{MSY}$  according to the ICES guidelines (ICES, 2017).

### Uncertainties and bias in assessment and forecast

The model estimates of  $B$  and  $F$  do have large uncertainty. Despite this, there is a low probability that SSB is below MSY  $B^{Trigger}$  and a high probability that  $F$  is below  $F_{MSY}$ .

The reference points are re-estimated within the assessment. The change between 2022 and 2021 reference points are consistent with previous years and results in a rescaling of relative stock status. However, in absolute terms, stock trends are consistent with those of previous years.

The biomass time-series from surveys has increasing uncertainty boundaries as the index increases. This results in uncertainty bounds in the model estimates; shows a contraction from the 2021 assessment.

Owing to incomplete discard data, historical discard rates (1985–2012) are assumed to have declined, from 30% at the beginning of the time-series, to an estimate of 15% in 2012. The evaluation

of current stock status is robust to this assumption. Estimates since 2013 are based on observed discards.

## Recommendation for next benchmark

This stock was subject to an inter-benchmark in 2012 (IBP-MEG, 2012). Due to incomplete age data, particularly for 4.a, a Bayesian state-space surplus production model was chosen as the final assessment model. Subsequent update assessments have highlighted a problem fitting to the 4.a surveys which needs to be examined in a future benchmark.

WGCSE recommends the following explorations:

- The SIAMISS survey should be merged into one continuous index. The length data for the index should also be examined.
- The ScoGFS-WIBTS-Q1/Q4 2011+: the ScoGFS-WIBTS-Q1/Q4 survey time-series should also be examined for re-introduction into the assessment as a new time-series. There may also be scope to integrate the IGFS.
- Available length and age-structured data should be compiled for this stock.
- Length or age-structured assessment models could be explored.

Once sufficient progress has been made on the points above, WGCSE will suggest a benchmark schedule.

## Management considerations

Megrim is a bycatch species in the mixed demersal trawl in divisions 6.a and 4.a. Management measures for other species have constrained the fishery and reduced effort and fishing mortality on megrim. The general increase in mesh size in 6 and 4 since 2010 has also benefited the stock.

The TAC in 6 has not been fully utilised. However, the uptake rate is country-specific, with some Member States reporting landings above their quota in the North Sea. Partial quota uptake by individual Member States may be linked to reduction in effort rather than reflective of a reduction in biomass. The TAC and assessment area are incompatible. There are two separate TAC areas covering ICES areas 6 and 4, whereas the assessment covers ICES divisions 6.a and 4.a combined. Due consideration of the inconsistency between management and assessment area is required when setting fishing opportunities for this stock and the separate 6.b Rockall stock. ICES (2013) have advised the EC that the TAC areas should be consistent with the assessment area and that ICES has no basis on how to split the catch advice so that it is consistent with the TAC areas.

## 10.6 References

- ICES. 2015. Report of the Joint ICES-MYFISH Workshop to consider the basis for  $F_{MSY}$  ranges for all stocks (WKMSYREF3), 17–21 November 2014, Charlottenlund, Denmark. ICES CM 2014/ACOM:64. 156 pp.
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- Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. *ICES Journal of Marine Science*, 53, 577–588.

**Table 10.2. Megrim in Subarea 6.a. Nominal catch (t) of Megrim West of Scotland, as officially reported to ICES and WG best estimates of landings. The shaded cells show updates in official data compared with last year.**

Year	Belgium	France	Ireland	Netherlands	Spain	UK – Eng, Wales & N.Irl.	UK – Scotland	UK	Official Total	ICES landings
1990	0	398	317	0	91	25	1093	-	1924	2210
1991	1	455	260	0	48	167	1223	-	2154	2432
1992	0	504	317	0	25	392	887	-	2125	2549
1993	0	517	329	0	7	298	896	-	2047	2721
1994	1	408	304	0	1	327	866	-	1907	2693
1995	0	618	535	0	24	322	952	-	2451	3498
1996	0	462	460	0	22	156	944	-	2044	4054
1997	0	192	438	1	87	123	954	-	1795	3272
1998	0	172	433	0	111	65	841	-	1622	2705
1999	0	0	438	0	83	42	831	-	1394	2648
2000	0	135	417	0	98	20	754	-	1424	2247
2001	0	252	509	0	92	7	770	-	1630	2473
2002	0	79	280	0	89	14	643	-	1105	1828
2003	0	92	344	0	98	13	558	-	1105	1642
2004	0	50	278	0	45	17	469	-	859	1328
2005	0	48	156	0	69	10	269	-	552	561
2006	0	53	221	0	52			346	672	875
2007	0	104	191	0	5			667	967	1301
2008	0	92	172	0	149			874	1287	1545
2009	0	174	188	0	112			953	1427	1387
2010	0	271	318	0	288			822	1699	1698
2011	0	153	227	0	217			715	1312	1297
2012	0	140	214	0	142			590	1086	1132
2013	0	105	203	0	213			470	991	949
2014	0	126	246	0	57			465	894	948
2015	0	140	311	0	140			520	1110	1110

Year	Belgium	France	Ireland	Netherlands	Spain	UK – Eng, Wales & N.Irl.	UK – Scotland	UK	Official Total	ICES landings
2016	0	189	408	0	146			694	1437	1437
2017	0	132	336	0	313			579	1359	1359
2018	0	117	301	0	273			680	1370	1392
2019	0	122	271	0	368			844	1606	1611
2020*	0	119	250	0	302			710	1381	1380
2021*	0	123	378	0	335			633	1468	1464

\* Preliminary official landings.

**Table 10.3. Megrim in Subarea 4 and 2.a. Nominal catch (t) of Megrim North Sea, as officially reported to ICES and WG best estimates of landings.**

Country	Belgium	Denmark	France	Germany	Germany, Fed. Rep. of	Ireland	Netherlands	Norway	Spain	Sweden	UK – Eng, Wales & N.Irl.	UK – England & Wales	UK- N. Ire- land	UK – Scotland	UK	Official total	ICES landings
1990	4	2	-	-	3	-	24	-	-	-	17	-	-	1126	-	1176	837
1991	3	1	-	6	-	-	28	-	-	-	9	-	-	1169	-	1216	878
1992	2	4	36	3	-	-	27	-	-	-	47	-	-	1372	-	1491	1025
1993	7	6	25	4	-	-	30	-	-	-	8	-	-	1736	-	1816	1081
1994	2	1	27	1	-	-	28	-	-	-	19	-	-	2000	-	2078	1207
1995	7	2	24	2	-	-	26	-	-	-	44	-	-	2193	-	2298	1172
1996	5	7	14	1	-	-	9	-	-	-	4	-	-	3221	-	3261	1199
1997	3	5	16	2	-	-	20	-	-	-	3	-	-	3091	-	3140	1584
1998	5	18	14	4	-	-	30	-	-	-	5	-	-	2628	-	2704	1548
1999	4	21	.	1	-	-	26	-	-	-	4	-	-	2121	-	2177	1111
2000	10	29	7	3	-	-	20	-	-	-	2	-	-	2044	-	2115	1247
2001	2	52	5	1	-	-	11	-	-	-	2	-	-	1854	-	1927	1098

Country	Belgium	Denmark	France	Germany	Germany, Fed. Rep. of	Ireland	Netherlands	Norway	Spain	Sweden	UK – Eng, Wales & N.Irl.	UK – England & Wales	UK- N. Ire-land	UK – Scotland	UK	Official total	ICES landings
2002	5	8	6	-	-	-	9	-	-	-	3	-	-	1675	-	1706	975
2003	3	11	11	2	-	1	7	<0.5	-	-	1	-	-	1235	-	1271	727
2004	-	7	9	2	-	-	11	<0.5	-	-	1	-	-	1130	-	1160	739
2005	-	1	3	4	-	-	19	<0.5	-	-	1	-	-	958	-	986	n/a
2006	0	3	4	1		0	6	1	0	0					1342	1357	1179
2007	0	11	18	4		0	1	1	0	0					1437	1472	1047
2008	0	31	20	1		0	1	4	0	0					1524	1581	1349
2009	0	54	9	0		0	0	6	0	0					1474	1543	1484
2010	0	22	1	0		0	1	2	0	0					1440	1466	1499
2011	0	23	10	3		0	0	1	0	0					1394	1431	1421
2012	0	35	5	3		0	0	1	0	0					1397	1441	1458
2013	0	48	7	3		0	0	17	0	0					1690	1765	1788
2014	0	35	7	1		0	0	12	0	0					1475	1530	1551

Country	Belgium	Denmark	France	Germany	Germany, Fed. Rep. of	Ireland	Netherlands	Norway	Spain	Sweden	UK – Eng, Wales & N.Irl.	UK – England & Wales	UK- N. Ire- land	UK – Scotland	UK	Official total	ICES landings
2015	0	26	1437	0		0	0	8	0	0					1175	1217	1230
2016	0	46	13	2		0	2	21	0	0					1278	1362	1361
2017	0	60	36	3		0	< 0.5	29	0	0					1199	1327	1235
2018	0	61	67	1		0	1	34	0	0					1543	1706	1611
2019	0	63	103	4		0	1	46	0	0					1340	1557	1585
2020*	< 0.5	40	80	3		0	4	48	0	< 0.5					1768	1943	1935
2021*	0	73	74	9		0	1	49	0	< 0.5					1944	2150	2139

\* Preliminary official landings.

**Table 10.4. Time-series of megrim survey indices in ICES Area 6.a and Division 4 as used in the surplus production model.**

year	sco.6.a.q1	sco.6.a.q4	sco.4.a.q1	sco.4.a.q3	monk.6.a	monk.4.a
1985	2.587	NA	NA	NA	NA	NA
1986	1.688	NA	1.288	NA	NA	NA
1987	1.371	NA	1.525	NA	NA	NA
1988	2.009	NA	1.721	NA	NA	NA
1989	1.162	NA	1.345	NA	NA	NA
1990	1.073	1.589	0.771	NA	NA	NA
1991	0.793	1.274	0.509	0.331	NA	NA
1992	0.958	1.885	0.654	0.319	NA	NA
1993	1.013	2.058	1.106	0.306	NA	NA
1994	1.589	3.246	0.270	0.381	NA	NA
1995	1.556	1.863	0.000	0.391	NA	NA
1996	1.940	1.946	0.516	0.605	NA	NA
1997	1.100	1.081	0.433	0.430	NA	NA
1998	1.094	1.893	0.836	0.224	NA	NA
1999	1.322	1.360	1.005	0.237	NA	NA
2000	1.140	1.186	0.869	0.249	NA	NA
2001	0.998	0.968	0.297	0.092	NA	NA
2002	0.760	1.857	1.269	0.352	NA	NA
2003	1.272	1.205	0.519	0.316	NA	NA
2004	1.244	1.064	0.283	0.460	NA	NA
2005	0.690	1.013	0.590	0.809	1660.379	4753.223
2006	0.917	1.121	0.790	0.927	2688.942	3344.997
2007	0.907	1.199	0.868	1.389	3380.351	6347.544
2008	1.253	0.957	1.607	1.195	2467.080	7754.168
2009	1.573	1.397	1.949	1.100	3830.668	5946.946
2010	1.171	NA	1.769	1.726	3312.129	5394.946
2011	NA	NA	1.983	1.638	2501.990	4683.594

year	sco.6.a.q1	sco.6.a.q4	sco.4.a.q1	sco.4.a.q3	monk.6.a	monk.4.a
2012	NA	NA	2.609	1.523	3450.807	4839.468
2013	NA	NA	2.669	1.477	6174.864	6460.015
2014	NA	NA	2.202	1.277	3033.072	11970.300
2015	NA	NA	3.014	1.297	2563.105	4986.899
2016	NA	NA	1.440	1.274	3027.648	8207.787
2017	NA	NA	1.830	1.013	6508.563	10238.937
2018	NA	NA	1.414	1.073	3364.165	7154.307
2019	NA	NA	0.657	0.963	2143.573	7982.271
2020	NA	NA	1.362	0.866	NA	NA
2021	NA	NA	1.154	0.736	3268.490	6897.872

**Table 10.5.** *Lepidorhombus whiffiagonis* in ICES areas 6.a and 4.a. Prior distributions on parameters.

Parameter	Symbol	Prior distribution	Notes
Intrinsic rate of population growth	$r$	$\text{Uniform}(0.001, 2.0)$	
Carrying capacity	$K$	$\text{Uniform}(\ln(\max(C)), \ln(10 \times \sum_{t=1985}^{2010} C_t))$	From the maximum catch to ten times the cumulative catch across all years assuming uniform distribution on the logarithmic scale
Catchabilities	$\log(q_j)$	$\text{Uniform}(-11.0, 0.0)$	Uniformly distributed on log-scale. See catchability sensitivity in Section 2.2.3.1
Process error variance	$\frac{1}{\sigma_u^2}$	$\text{Gamma}(\text{shape} = 0.001, \text{rate} = 0.001)$	Gamma distributed on inverse variance (precision) scale
Measurement error variances	$\frac{1}{\sigma_{\varepsilon,j}^2}$	$\text{Gamma}(\text{shape} = 0.001, \text{rate} = 0.001)$	Gamma distributed on inverse variance (precision) scale
Proportion of $K$ in 1985	$a$	$\text{Uniform}(0.01, 2.0)$	

**Table 10.6. Parameter estimates for final assessment outputs.**

Parameter	Estimates 2014	Estimates 2015	Estimates 2016	Estimates 2017	Estimates 2018	Estimates 2019	Estimates 2020	Estimates 2021	Estimates 2022
r.hat	0.55	0.51	0.51	0.51	0.47	0.50	0.51	0.52	0.52
K.hat	43134	47216	46840	42681	55129	44116	42625	41634	40573
MSY	5660	5612	5362	5072	5362	5123	5101	5020	4978
F <sub>MSY</sub>	0.28	0.26	0.26	0.25	0.23	0.25	0.26	0.26	0.26
B <sub>MSY</sub>	21567	23608	23420	21340	27565	22058	21313	20817	20287
B	4109	42416	42356	37610	38057	37062	32660	32408	31632
F	0.08	0.07	0.07	0.07	0.08	0.08	0.1	0.1	0.12
B <sub>lim</sub>	6470	7082	7026	6402	8269	6617	6394	6245	6086
B <sub>trig</sub>	10783	11804	11710	10670	13782	11029	10656	10408	10143

**Table 10.7. Time-series of  $B/B_{MSY}$  and  $F/F_{MSY}$  estimates and landings and discards in tonnes for the final assessment.**

Year	$B/B_{MSY}$			Landings	Discards*	$F/F_{MSY}$		
	Low	Value	High			Low	Value	High
1985	1.20	2.33	3.54	4499	1928	0.38	0.68	1.16
1986	1.08	1.64	2.25	2858	1193	0.33	0.53	0.77
1987	1.07	1.54	2.05	4614	1874	0.58	0.93	1.31
1988	1.02	1.43	2.04	5212	2061	0.65	1.15	1.66
1989	0.80	1.15	1.56	3451	1327	0.50	0.88	1.27
1990	0.74	1.05	1.43	3047	1140	0.47	0.82	1.22
1991	0.70	0.99	1.30	3310	1204	0.59	0.95	1.40
1992	0.72	1.04	1.38	3574	1263	0.58	0.98	1.46
1993	0.79	1.12	1.51	3802	1305	0.57	0.97	1.42
1994	0.81	1.21	1.70	3900	1300	0.53	0.93	1.32
1995	0.86	1.24	1.75	4670	1511	0.59	1.10	1.57
1996	0.82	1.19	1.71	5253	1649	0.68	1.31	1.91
1997	0.72	1.00	1.37	4856	1478	0.78	1.40	2.01
1998	0.66	0.95	1.37	4253	1254	0.67	1.26	1.86
1999	0.62	0.92	1.36	3759	1074	0.59	1.13	1.70
2000	0.57	0.86	1.24	3494	966	0.56	1.10	1.64
2001	0.55	0.80	1.11	3571	956	0.65	1.20	1.80
2002	0.55	0.82	1.18	2803	725	0.47	0.88	1.32
2003	0.58	0.86	1.21	2369	592	0.37	0.70	1.06
2004	0.59	0.87	1.22	2067	499	0.32	0.58	0.88
2005	0.63	0.89	1.16	1527	356	0.24	0.41	0.61
2006	0.72	1.01	1.31	2054	461	0.30	0.49	0.73
2007	0.82	1.15	1.47	2348	508	0.31	0.50	0.73
2008	0.91	1.28	1.66	2894	602	0.34	0.56	0.83
2009	1.01	1.40	1.84	2871	574	0.30	0.51	0.72
2010	1.03	1.41	1.85	3197	614	0.36	0.56	0.84
2011	1.03	1.45	1.91	3257	600	0.29	0.47	0.68

Year	B/B <sub>MSY</sub>			Landings	Discards*	F/F <sub>MSY</sub>		
	Low	Value	High			Low	Value	High
2012	1.16	1.58	2.08	2545	449	0.26	0.42	0.60
2013	1.27	1.77	2.43	2737	327	0.22	0.37	0.53
2014	1.33	1.79	2.36	2500	309	0.20	0.33	0.48
2015	1.21	1.67	2.17	2471	152	0.21	0.31	0.44
2016	1.28	1.75	2.26	2792	167	0.23	0.36	0.51
2017	1.37	1.88	2.62	2594	193	0.19	0.32	0.45
2018	1.25	1.69	2.16	3003	255	0.26	0.41	0.56
2019	1.12	1.55	1.96	3197	184	0.29	0.45	0.65
2020	1.13	1.56	2.07	3316	214	0.30	0.47	0.68
2021	1.14	1.53	1.99	3603	200	0.34	0.52	0.74
2022	0.95	1.44	2.01					

\* Discard estimates prior to 2013 are approximated, based on limited sampling information.

**Table 10.8. Basis for the catch options.**

Variable	Value	Notes
$F_{2022}/F_{MSY}$	0.52	<i>Status quo</i> : $F_{sq}$ = relative F (2021)
$B_{2023}/B_{MSY}$	1.53	Fishing at $F_{sq}$
Catch (2022)	3580	Fishing at $F_{sq}$ ; in tonnes
Projected landings (2022)	3380	Assuming average landings ratio (2019–2021); in tonnes
Projected discards (2022)	200	Assuming average discard ratio (2019–2021); in tonnes

Table 10.9. The management option table.

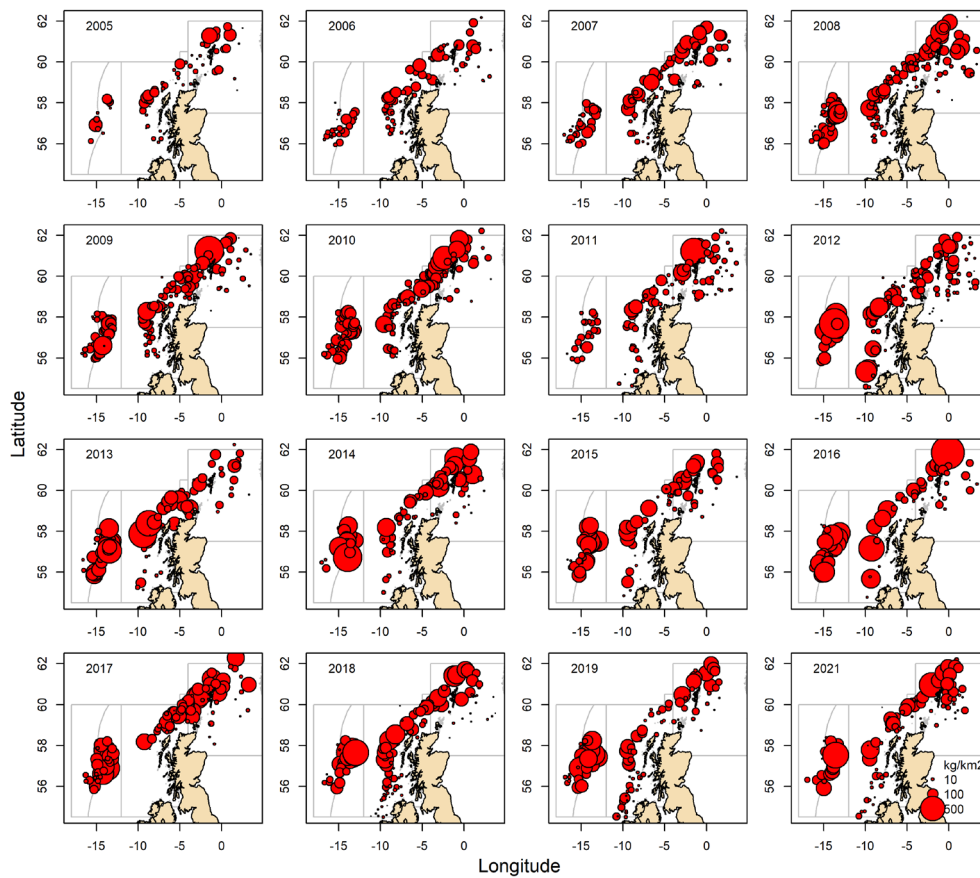
Basis	Total catch (2023)	Projected landings (2023)	Projected discards (2023)	Fishing mortality $F_{2023}/F_{MSY}$	Stock size $B_{2024}/B_{MSY}$	% B change*	% TAC change^	% advice change^^
ICES advice basis								
MSY approach = $F_{MSY}$	7200	6798	402	1	1.32	-13.1	-13.7	-2.0
EU MAP^^^: $F_{MSY}$	7200	6798	402	1	1.32	-13.1	-13.7	-2.0
$F = MAP^{^^^} F_{MSY lower}$	5550	5240	310	0.76	1.41	-7.1	-33	-24
$F = MAP^{^^^} F_{MSY upper}$	7200	6798	402	1	1.32	-13.1	-13.7	-2.0
$F = 0$	0	0	0	0	1.71	11.7	-100	-100
$B_{2024} = B_{lim}$	26800	25302	1498	3.70	0.33	-79	221	264
$B_{2024} = B_{pa} = MSY B_{trigger}$	13000	12273	727	1.80	1.01	-33	56	77
$B_{2024} = B_{2023}$	3500	3304	196	0.48	1.52	0	-58	-52

\* Biomass 2024 relative to biomass 2023.

^ Total catch in 2023 relative to TAC 2022 (8344 tonnes).

^^ Advice value for 2023 relative to the advice value for 2022 (7350 tonnes).

^^^ EU multiannual plan (MAP) for the Western Waters (EU, 2019).



**Figure 10.1.** Maps of the northern continental shelf around the British Isles showing the biomass of megrim during the Scottish Irish Anglerfish and Megrim Industry Science Survey (SIAMISS) survey 2005–2021. There was no survey in 2020 due to COVID.

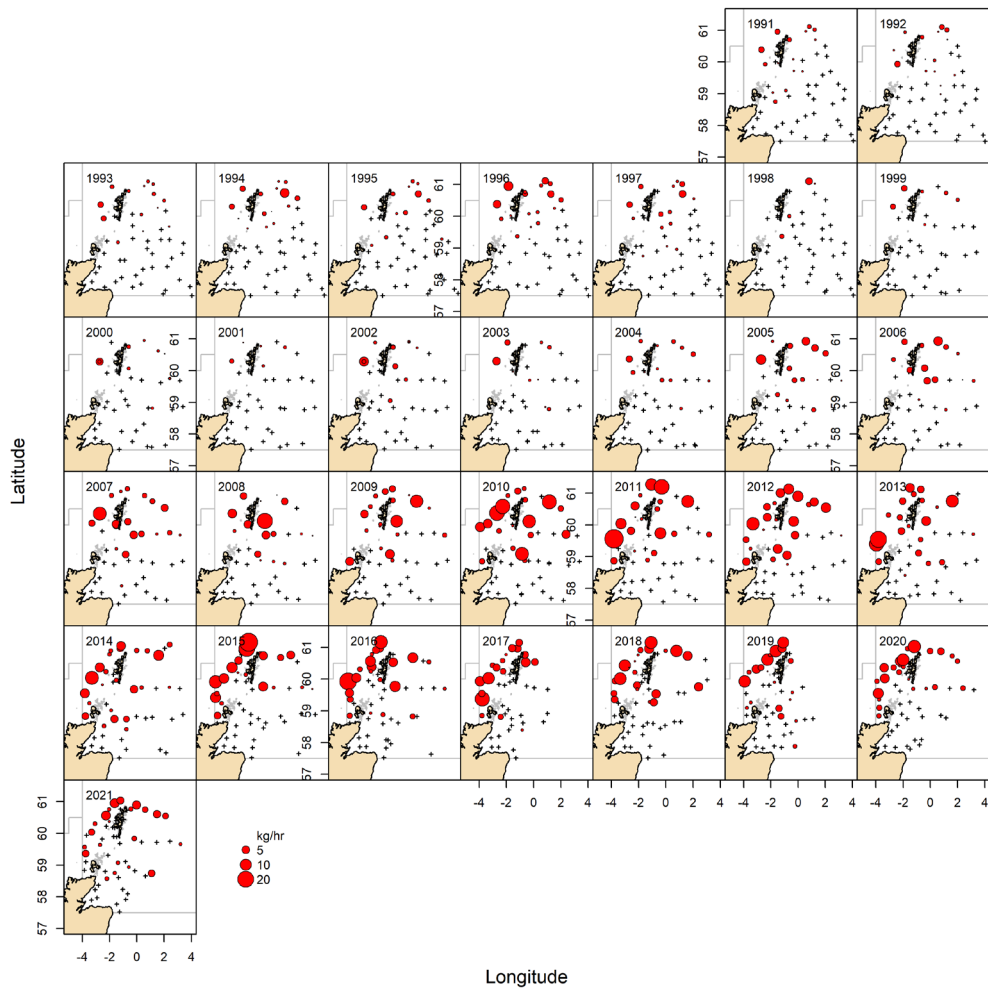


Figure 10.2. Sco-IBTS Q3 4.a 1991–present megrim biomass maps.

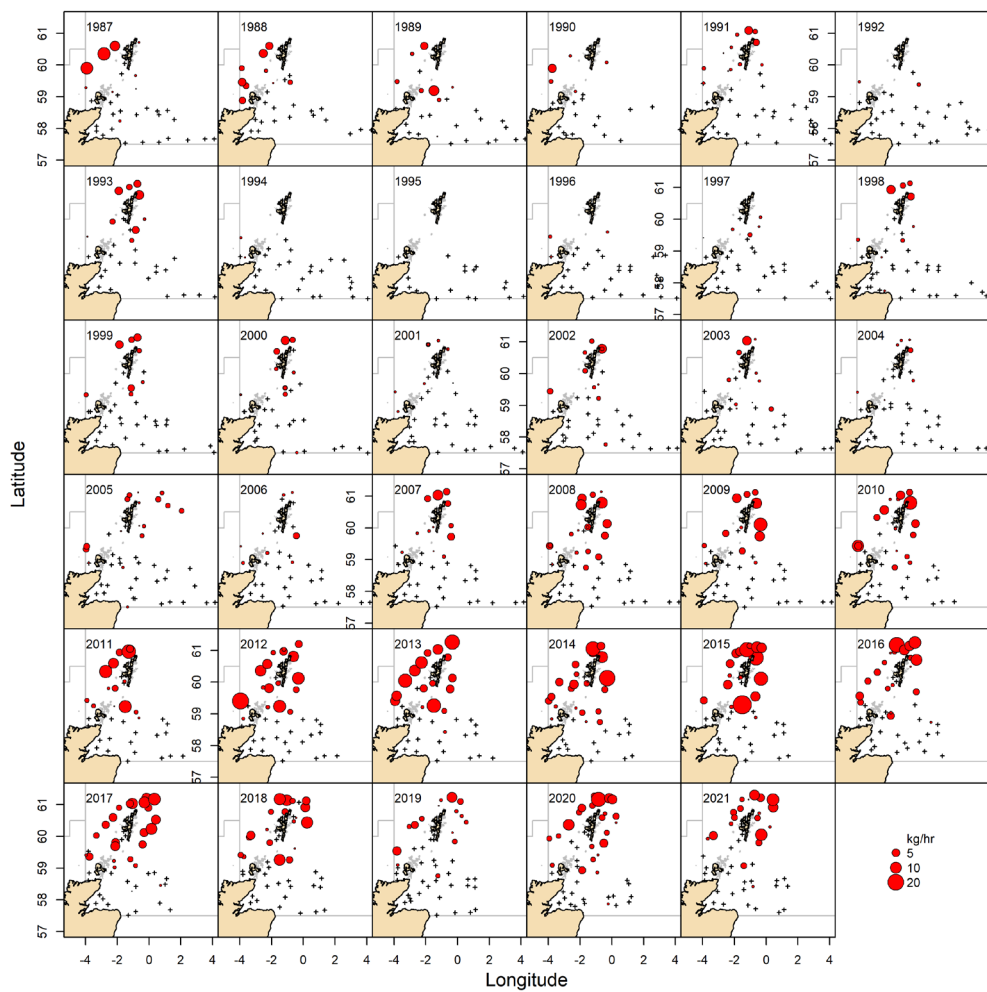


Figure 10.3. ScolBTS Q1 4.a 1986–present megrim biomass maps.

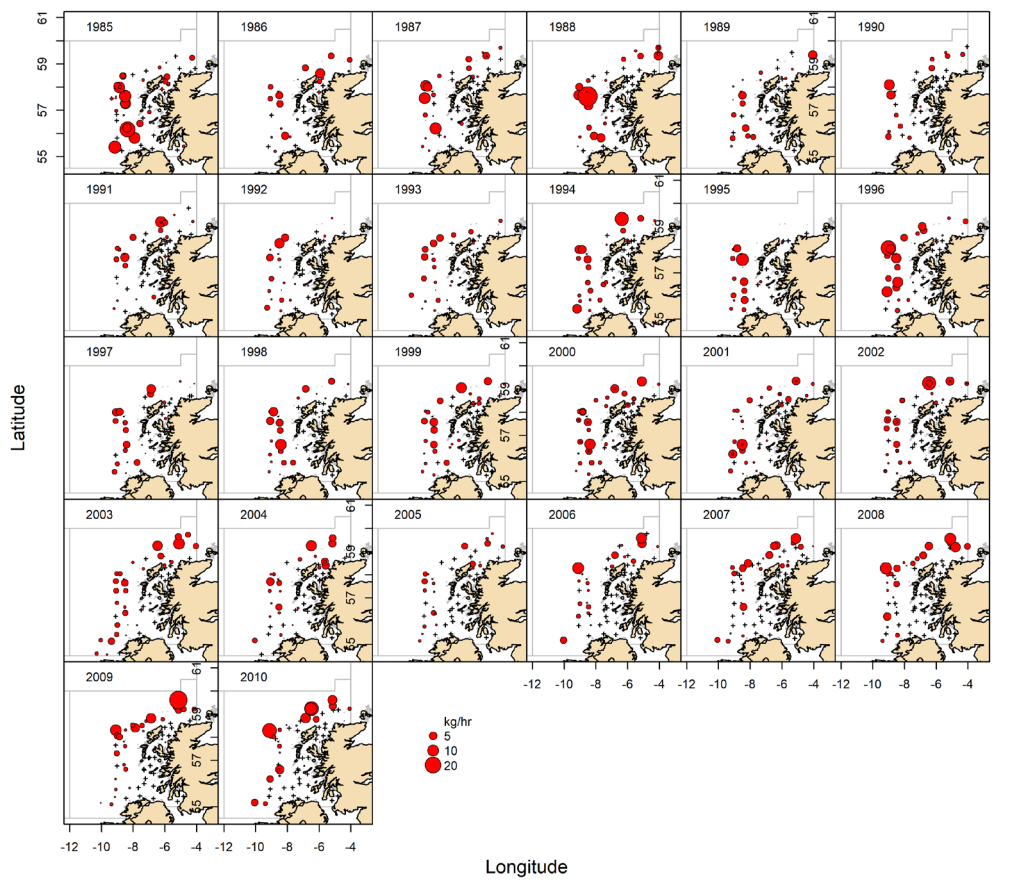


Figure 10.4. ScoGFS-WIBTS Q1 6.a megrim biomass maps.

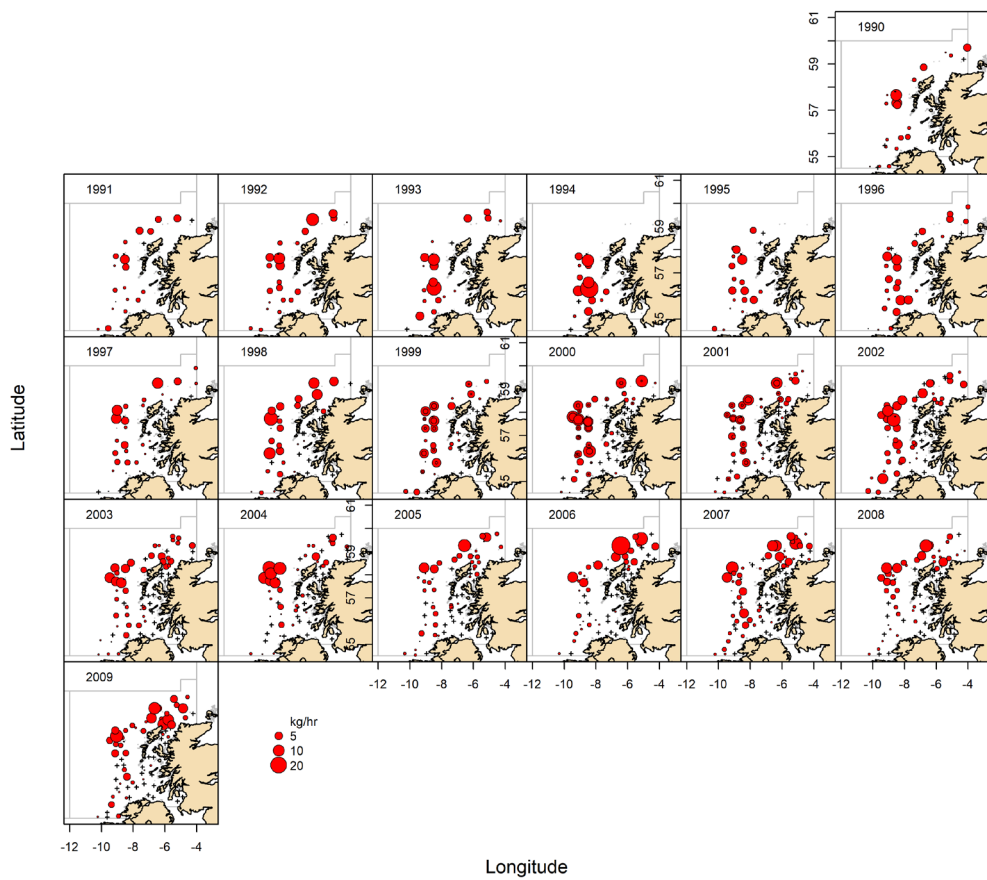
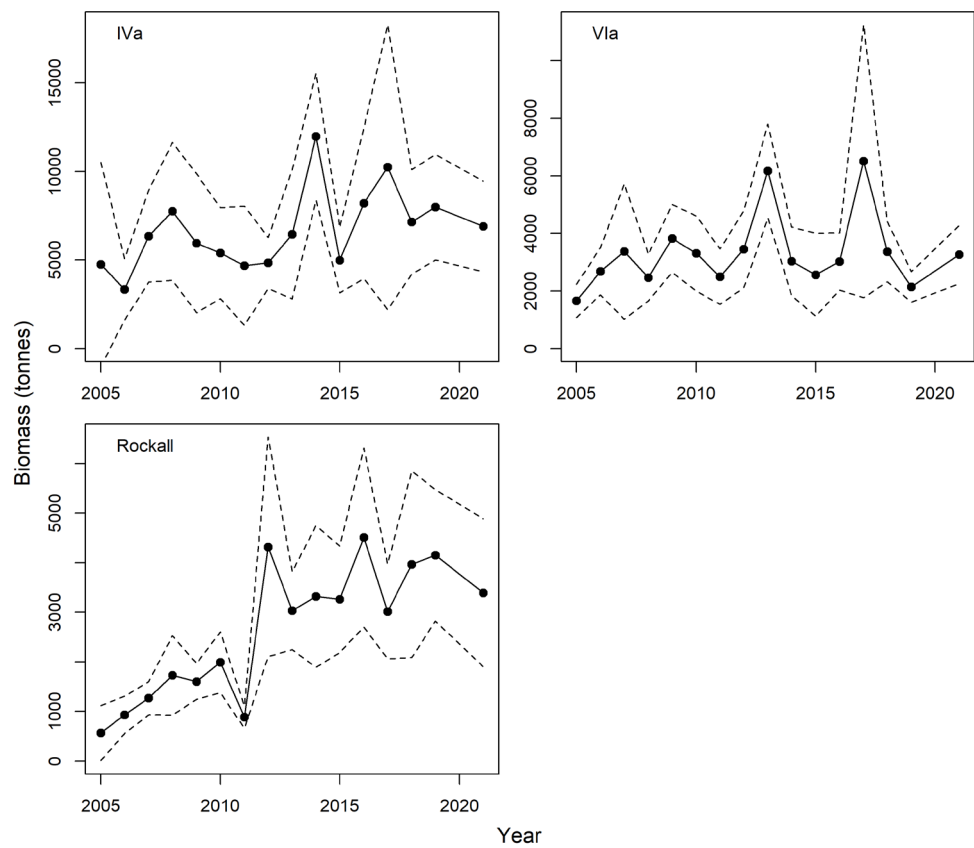


Figure 10.5. ScoGFS-WIBTS Q4 6.a megrim biomass maps.



**Figure 10.6. Megrim biomass estimates in ICES divisions 4, 6.a and 6.b from Scottish Irish Anglerfish and Megrim Industry Science Survey (SIAMISS) survey with 95%cls.**

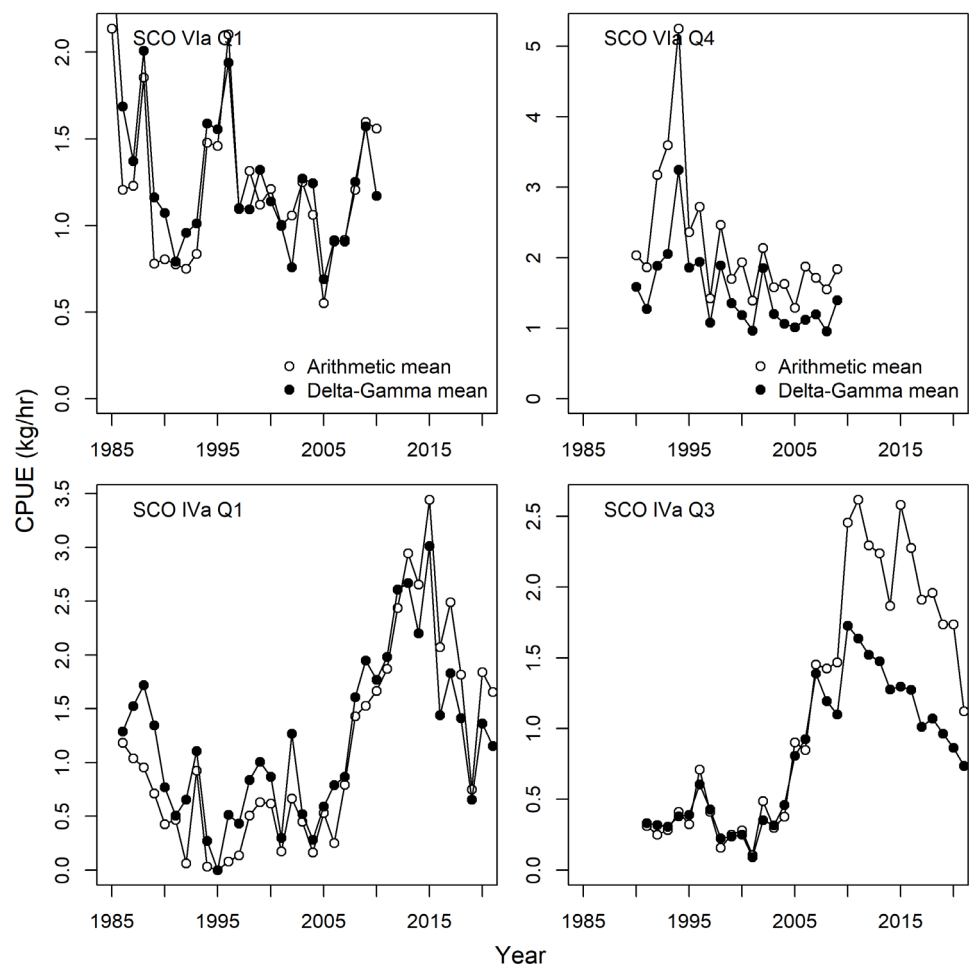


Figure 10.7. Megrim CPUE estimates in ICES Division 6.a Q1 top left panel and 6.a Q4.

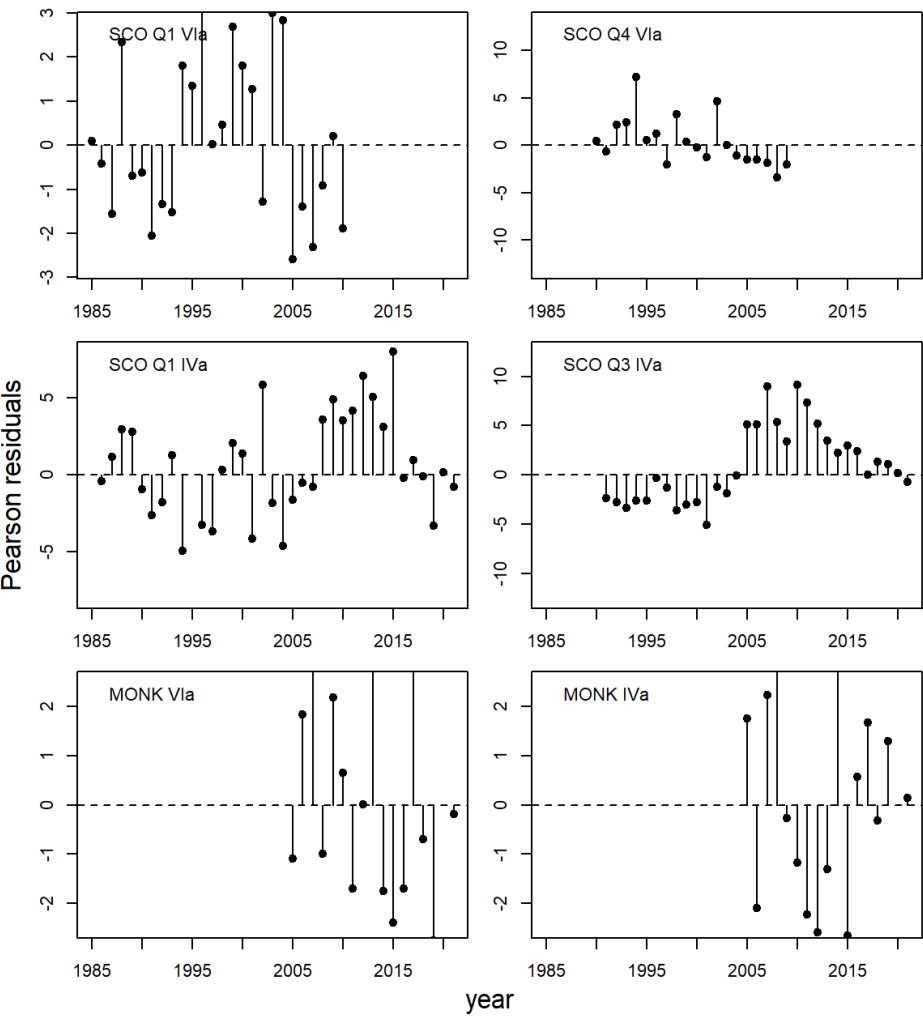


Figure 10.8. Pearson residuals for the six survey indices.

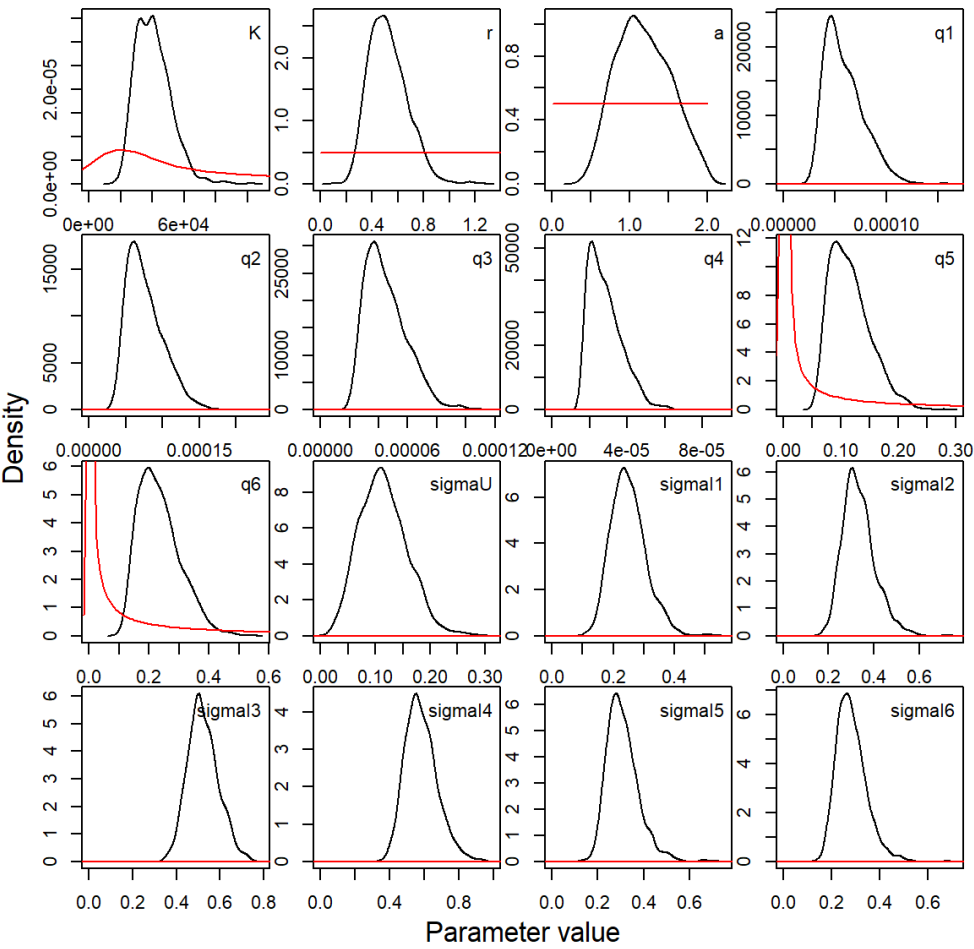


Figure 10.9. Prior (red line) and posterior distributions (black line) for the parameters in the model.

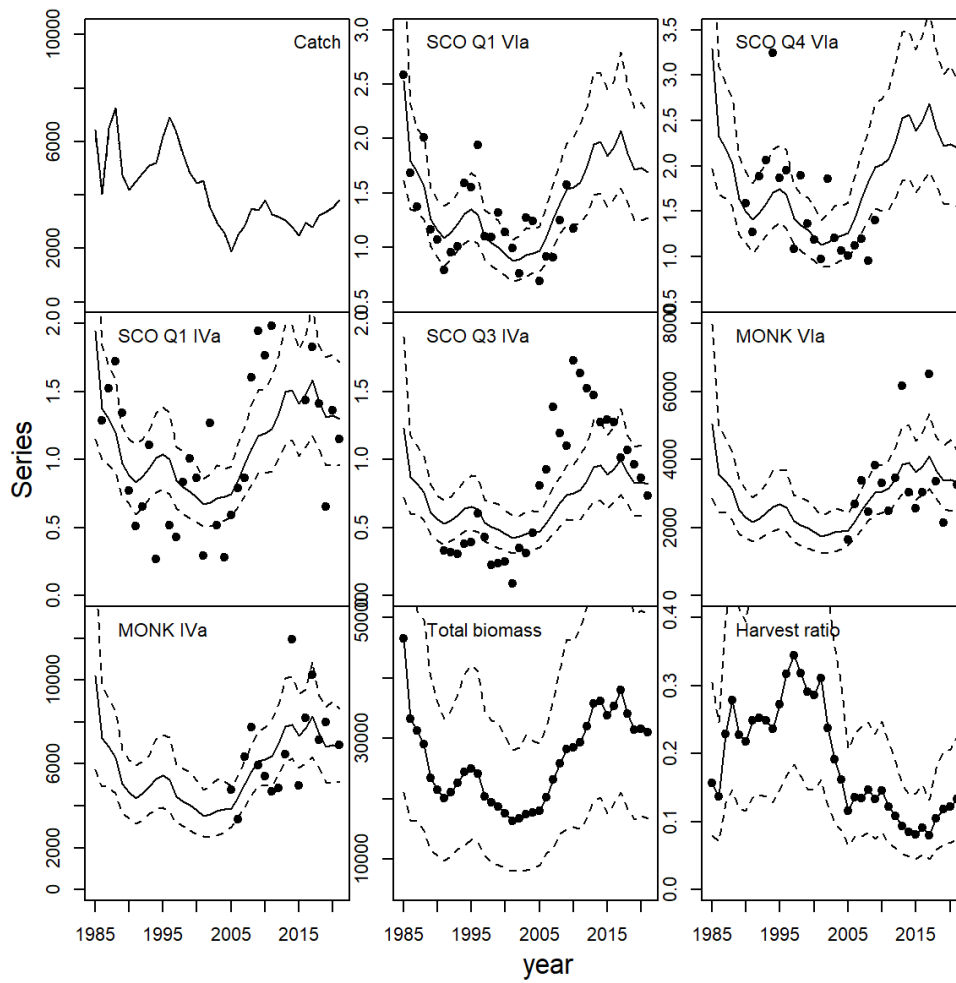


Figure 10.10. Time-series of catch and model estimates of total biomass and exploitation rate (median values are shown as solid lines and 95% confidence intervals shown as broken lines). The model fits to the various CPUE series is also shown (observations dots, median fit solid line and 95% confidence intervals shown as broken lines).

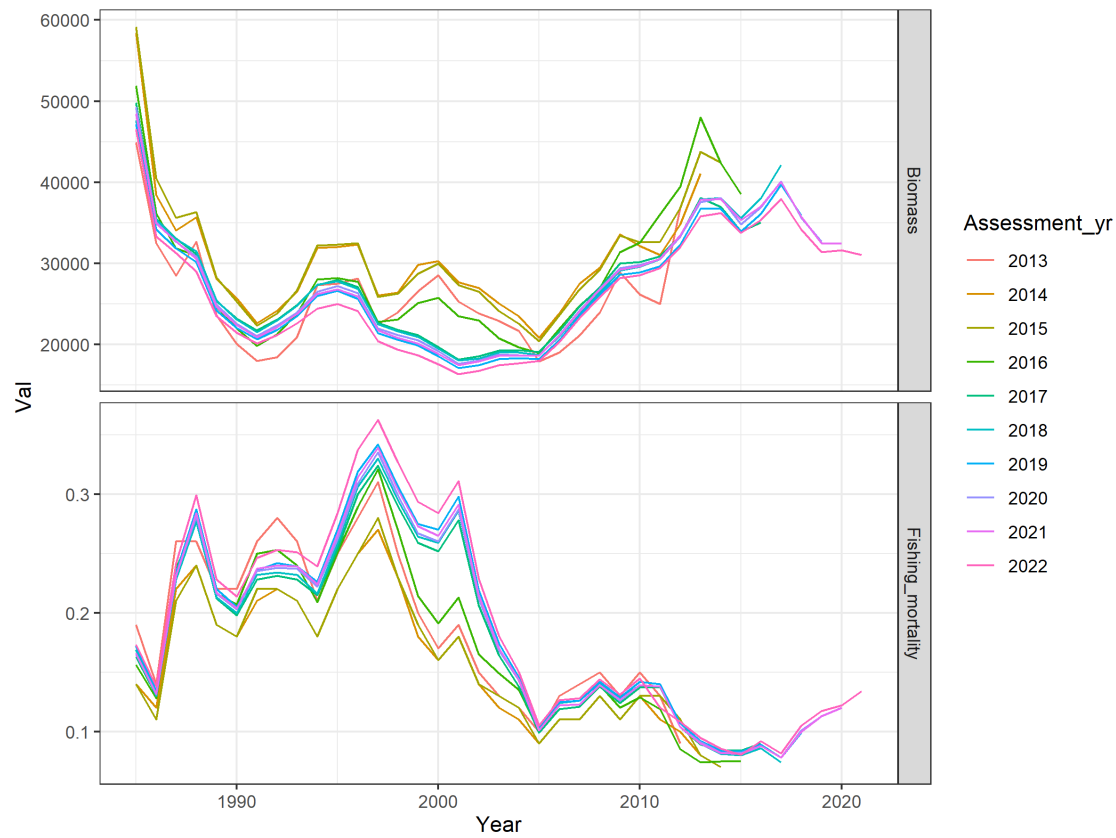


Figure 10.11. Comparison with previous assessments.

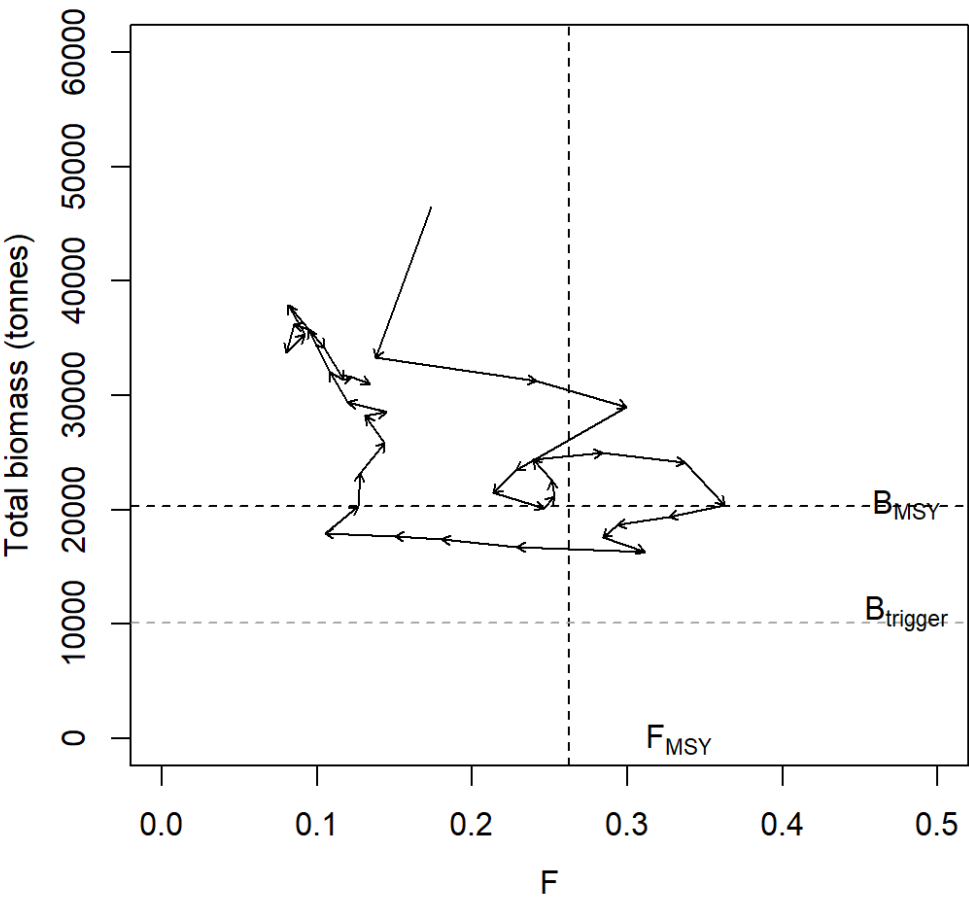


Figure 10.12. Kobe plot of stock status.