Stock Annex for Megrim in Divisions VIa and IVa

Stock	Megrim in Divisions VIa and IVa
Working Group	WGCSE
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Revised by	IBP-MEG/2012; Norman Graham

A. General

A.1. Stock definition

Since the end of the 1970s ICES has assumed three different stocks for assessment and management purposes: megrim in ICES Subarea VI, megrim in Divisions VIIb–k and VIIIa,b,d and megrim in Divisions VIIIc and IXa. Megrim stock structure is uncertain and historically the Working Group has considered megrim populations in VIa and VIb 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' demonstrated significantly different growth parameters and significant population structure difference between megrim sampled in VIa and VIb (Anon, 2001). Spawning fish occur in both areas but whether these populations are reproductively isolated is not clear.

As noted by WGNSDS 2008, megrim in IVa has historically not been considered by ICES and WGNSDS 2008 recommended that VIa megrim should be considered by WGCSE. Landings data from IV and IIa are now included in this Report and work is underway to collect international catch and weight-at-age data for IV as well as VI. However, the availability of aggregated and age-disaggregated is sporadic.

Data from both the commercial fishery (using VMS and catches by statistical rectangle) and from fishery-independent surveys provide little evidence to support the view that megrim in VIa and IVa are indeed separate stocks. Based on the recommendations from WKFLAT (2011), megrim in VIa and IVa are considered a single unit stock and assessed accordingly. Megrim in VIb is considered a separate stock unit for assessment purposes.

A.2. Fishery

Megrim are predominately taken in otter trawl and to a lesser extent by Scottish seine. Analysis of VMS data indicates that megrim is taken in spatially discrete shelf fisheries and also in trawl fisheries conducted along the 200 m shelf break. Historically, ICES has assumed that megrim catches are closely linked to those of monkfish. Area misreporting of monkfish from VIa into IVa as a result of restrictive TACs in VIa is known to have occurred historically and catches have been redistributed into VIa using an algorithm developed by the Marine Science Scotland (see stock annex for Monkfish). Due to the assumed linkage between megrim and monkfish, megrim caught in VIa are also considered to have been area misreported and therefore the Working Group has historically applied the same redistribution method as used for monkfish. It remains unclear whether this pattern has continued in recent years, in 2009 the Working Group did not redistribute megrim catches in

VIa as the historic pattern, higher catches in the statistical rectangles immediately east of the 4° line, was not observed in 2009, indeed the 2009 pattern may indicate a reversal of the process due to a more restrictive TAC in IVa. However, treating megrim in VIa and IVa as a single unit stock has mitigated this problem.

The introduction of the Cod Long-Term Management Plan (EC Regulation 1342/2008) and additional emergency measures applicable to VIa in 2009 (EC Regulation 43/2009, annex III 6) has impacted on the amount of effort deployed and increased the gear selectivity pattern of the main otter-trawl fleets. Additionally, EC regulation 43/2009 has effectively prohibited the use of mesh sizes <120 mm for vessels targeting fish, which had been used particularly by the Irish fleet up to that point. Effort associated with the French fleet has continued to decline while the decline in both the Irish and Scottish TR1 fleets (120 mm mesh) appears to have stabilized. The increase in mesh size (from 100 to 120 mm) has also impacted on the retention length of megrim, increasing L50 from 28 cm to 42 cm, an increase of almost 50%.

Fishing effort in IV for the main Scottish otter fleet (TR1) have stabilized since the large effort reductions observed in previous years, effort levels associated with this mesh band have fallen by 64% since 2000. Following the increases in Irish effort in Subdivision VIb from 2004–2008, effort in 2009 has declined significantly. These reductions in effort in Scotland and Ireland are considered to have contributed to the decline of landings in Subarea VI. Landings in VI are well below the TAC. Uptake by France, who account for 44% of the TAC, is very low (~11%). Official landings in Subarea IV and Division IIa in recent years are close to the TAC.

There is anecdotal information from the Scottish industry that since the introduction of the Conservation Credits Scheme in Area IV, those vessels have responded with increasing focus on anglerfish and megrim in both IVa and VIa. Based on landings data presented to the Working Group, only 53% of the overall TAC for VI, EC waters of Vb and international waters of XII and XIV was used. The TAC in IV was fully utilized.

Commercial catches are dominated by female megrim, typically 90% of the total catch. Analysis of Irish logbook data by Anon (2002) showed that cpue trends varied throughout the year, showing a maximum in late spring/early summer following the spawning period and at their lowest in late autumn.

A.3. Ecosystem aspects

None considered.

B. Data

B.1. Commercial catch

Commercial landings by country are available since 1990. The UK accounts for ~80% of the total landings. Over 50% of the landings are taken in the North Sea (IVa) with the remainder taken in VIa (~40%) and VIb, there are also landing reported from other areas (IVb and IVc), but these are negligible.

International landings-at-age data based on quarterly market sampling are available from 1990 for V.I. Note that up until 2000, catch-at-age data from VIa and VIb was aggregated, only partial landings-at-age are available for VIb (post 2000). Landings numbers-at-age are available for IVa (post 2005), depending on year and country.

Ireland provides landings numbers-at-age by quarter, age disaggregated discard numbers-at-age by annum for both VIa and VIb. Scotland provides annual catch numbers-at-age by Divisions VI and VI and discards estimates by weight and number with associated length distribution. Since 2011, France has provided landings and effort (hours fished) by statistical rectangle with quarterly length distributions of landings and discards with associated sampling effort (hours fished).

The general paucity of both landings and discard data covering the assessment area has prevented the construction of a full-time and spatial series for megrim separately in VIa, VIb and IVa. The available data are not separated by sex. Females make up approximately 90% of the landings, but survey data show that the relative proportion of males increases with depth.

The quality of the available landings data (unknown area misreporting), discard information, lack of effort data and cpue data for the main fleet in the fishery, and disaggregated landings-at-age data at an appropriate area level severely hampers the ability of ICES to carry out an assessment for this stock.

Prior to 2000, discard data for VIa were combined together with data from VIb and no data fom IVa are available prior to 2005. The available data shows that discarding is variable and given the increases in mesh sizes introduced in 2000 (North Sea) and 2009 (West of Scotland) it is expected that discard rates have declined. Laurenson and MacDonlad (2008) note that while discarding of megrim below minimum landing size is low (<1%), discarding of legal sized fish was much higher at 22%. This is attributed to low market price for small grades and bruised fish, resulting in high grading of catches on length/quality reasons to maximise the value of a restrictive quota.

B.2. Biological

Megrim exhibit a strong negative growth relationship with increasing depth. Fish found in deep water (>200 m) are commonly the same size as fish one year younger found in shallower areas (Gerritsen *et al*., 2010). Analysis of age-at-length data shows a wide length distribution within ages and that age precision deteriorates when sampling levels fall below ~500 per annum. Poor age precision in recent years prevents the development of an age based assessment.

C. Assessment: data and method

The assessment method: Bayesian state–space biomass dynamic model.

C.1. Input data

C.1.1. Catch

International landings data collated by the ICES Working Group on the Celtic Seas Ecoregion (WGCSE) is used as an estimate of catch. However, it is recognised that discarding is a feature of the fishery but note that discard data are not available for the entire time-series and the availability or raised discard data is highly variable across fleets and areas therefore if catch data is to be used, then some assumptions regarding the historic discard pattern must be made.

To assess the sensitivity of the model outputs to this assumption, two alternative model runs with (i) a fixed 20% discard proportion over the full landings time-series and (ii) a linear decline in proportion from 30% at the start of the time-series to 10% at the end. It is probable that the proportion of megrim discarded in IVa has declined since 2000 and in VIa since 2009 the mesh size in the North Sea increased from 100 to 110 mm and was further increased to 120 mm in 2001, while in Division VIa, the mesh size was increased from 100 to 120 mm in 2009. It is therefore likely that the discarding profiles have probably changed significantly in line with these mesh size increases and this option is used for the final run. For catch data from 2011 onwards, discard estimates provided to the working group are used.

C.1.2. Survey indices

Indices from six fishery-independent surveys are used (Table 1.2.1.) for the assessment, four associated with the International Bottom Trawl Survey (IBTS) and two associated with the relatively recent (2005) dedicated anglerfish survey. Survey trends in cpue are shown in Figure 1.2.1 and tabulated in Table 1.2.2.

Table 1.2.1. Survey indices used for surplus production model.

NUMBER	SURVEY	NATIONALITY	AREA	TIME-SERIES
1	Sco-IBTS-Q3	Scotland	IVa	1987–2011
2	Sco-IBTS-Q1	Scotland	IVa	1987–2011
3	ScoGFS-WIBTS-Q1	Scotland	VIa	1986–2010
4	ScoGFS-WIBTS-Q4	Scotland	VIa	1986–2010
5	SAMISS-Q2	Scotland	VIa*/IVa	2005–2011
6	IAMISS-Q2	Ireland	VIa*	2005–2011

***VIa data from IAMISS-Q2 and SAMISS-Q2 combined into a single cpue estimate with variance.**

Table 1.2.2. Input parameters, individual survey cpue indices, landings and modelled discards for the final assessment run.

Year	Sco-WIBTS-Q1	Sco-WIBTS-Q4	Sco-IBTS-Q1	Sco-IBTS-Q3	SAMISS-Q2	SAMISS-Q2/ IAMISS-Q2	Landings (t)	Discards (t)
1985	NA	NA	NA	NA	NA	NA	4499	1928
1986	2.022041	NA	NA	NA	NA	NA	2858	1191
1987	1.438229	NA	0.15231	0.538613	NA	NA	4614	1871
1988	2.433792	NA	0.85134	0.352888	NA	NA	5212	2054
1989	1.372235	NA	1.349909	0.478759	NA	NA	3451	1322
1990	1.172838	1.421119	0.321947	0.241552	NA	NA	3047	1134
1991	0.993033	0.816731	0.489991	0.390778	NA	NA	3310	1196
1992	0.86039	1.872102	0.513651	0.27403	NA	NA	3574	1253
1993	1.091872	1.529652	0.879519	0.317033	NA	NA	3802	1293
1994	1.633247	5.962035	0.00751	0.267762	NA	NA	3900	1287
1995	1.626724	2.06466	0	0.386454	NA	NA	4670	1493
1996	1.994012	1.589756	0.174242	0.559735	NA	NA	5253	1628
1997	1.236186	1.08362	0.366326	0.438556	NA	NA	4856	1457
1998	1.257126	2.50406	0.585829	0.480087	NA	NA	4253	1235
1999	1.572227	2.486679	0.685998	0.35149	NA	NA	3759	1055
2000	1.774741	2.746517	0.782337	0.387239	NA	NA	3494	948
2001	1.571553	2.001607	0.167189	0.135261	NA	NA	3571	936
2002	1.32686	1.882926	0.943994	0.695834	NA	NA	2803	709
2003	1.365124	1.534736	0.417331	0.428694	NA	NA	2369	578
2004	1.396114	1.436756	0.144181	0.432644	NA	NA	2067	486
2005	0.768293	1.24548	0.345727	0.861051	2847.751	4612.849	1527	346
2006	0.946288	1.429524	0.415692	1.144823	3049.429	3464.123	2054	447
2007	0.952731	1.496073	0.751438	1.393703	3304.689	6940.738	2348	491
2008	1.281508	1.235648	1.264974	1.396733	3653.99	8023.604	2894	581
2009	1.956423	1.689299	1.813651	0.985541	4560.281	6297.433	2759	532
2010	1.233817	NA	1.212913	1.568344	4115.859	7502.313	2909	537
2011	NA	NA	1.400436	1.594589	NA	NA	NA	432

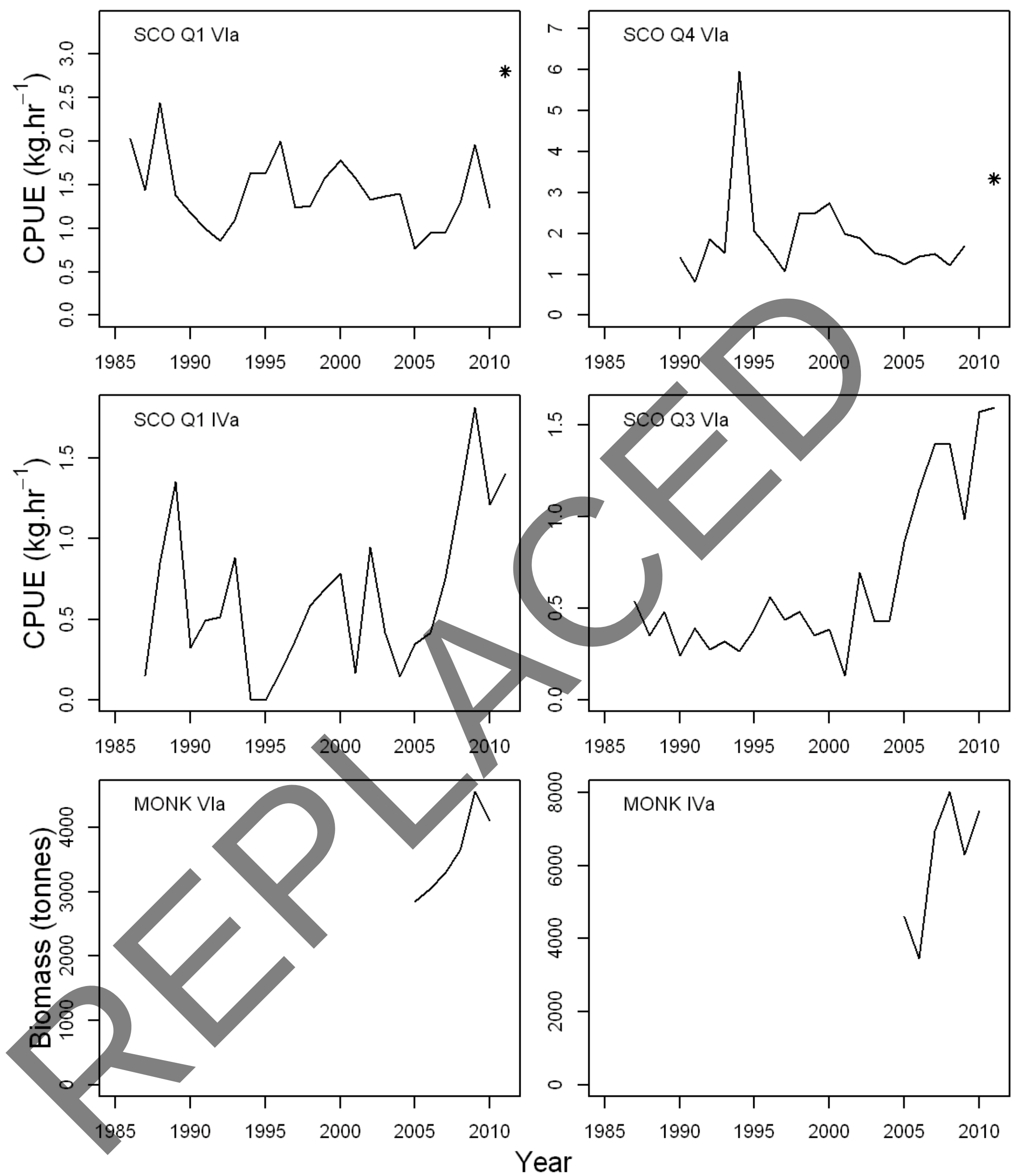

Figure 1.2.1. Trends in survey cpue indices used in the assessment of megrim in VIa and IVa. The asterix shown in Sco-WIBTS Q1 and Sco-WIBTS Q4 relates to the survey cpue in 2011/2012 but is not used due to changes in survey gear and design.

C.1.2.1. IBTS survey indices

IBTS survey data from Scottish groundfish survey data (Surveys 1–4, Table 2.2.1) are available for quarters 1 and 4 in ICES Area VIa and quarters 1 and 3 in ICES Area IVa north. The survey design is based on ICES statistical rectangles. One tow is selected per rectangle based on a library of clean tows. The tow location is largely the same every year and as such the design may be considered fixed station although minor changes to tow locations can occur. In 2010 both the groundgear and the survey design associated with the ScoGFS-WIBTS Q1 and Q4 surveys were changed. Rather than relying on fixed trawling locations moved to a new random-stratified survey design with trawl locations randomly distributed within ten *a priori* sampling strata. While there were rationale reasons for these changes, it has resulted in a breach in the time-series and it will not be possible to use these indices until a reasonable time-series, ca. five years, has been built up.

Catch weights are not routinely collected on all IBTS surveys so the length data were converted to weight using the length–weight relationship.

$$W = 0.0047L^{3.13} \qquad [1]$$

where W is the weight in grams and L is the length in centimeters. This relationship was estimated using all available megrim length–weight measurements from the dedicated monkfish survey. The weights were then raised by the numbers-at-length per tow and summed to provide a catch in kilograms per tow. This was divided by the duration of the tow in decimal hours to provide a cpue measured in units of $kg.hr^{-1}$.

The data from all four surveys exhibit a relatively large proportion of zeroes; therefore the delta method of Stefánsson (1996) was used to extract indices. The uncertainty surrounding each survey index (observation error) can be estimated within the assessment model or estimated externally and entered into the assessment model as a fixed quantity. For the present analysis we used the mean delta-gamma cpue estimates (for the IBTS surveys only) and allowed the model to estimate the measurement error of each survey.

C.1.2.2. Anglerfish survey indices

Scottish (SAMISS) and Irish (IAMISS) dedicated anglerfish surveys (Surveys 5–6, Table 1.2.1) have been undertaken in VIa and IVa (SAMISS only) since 2005. The survey design is stratified based on expected densities of anglerfish (not megrim), within each strata, the location of individual tows are randomly selected. The modelling approach of Stefánsson (1996) is mainly applicable to a fixed station design and therefore for the anglerfish indices we used the weighted cpue estimates and allow the observation error to be estimated within the model. The anglerfish survey provides absolute estimates of abundance and biomass. The average fish density at age *a* in stratum *s*, ρ_{as} , is estimated from the weighted mean of fish densities corrected for the catchability of each trawl, as follows:

$$\hat{\rho}_{as} = \sum_{i \in s} w_i \left\{ \sum_{l \in a} \frac{n_{lai}}{v_{1i}\hat{Q}_{li}} \right\} = \sum_{i \in s} w_i \left\{ \sum_{l \in a} \frac{n_{lai}}{\hat{e}_l (v_{1i} + v_{2i}\hat{h})} \right\}$$

where:

n_{lai} is the number of fish of age *a* and length *l* caught in trawl *i*,

$$w_i = \frac{v_{1i} + v_{2i}}{\sum_i (v_{1i} + v_{2i})},$$

v_{1i} is the area swept by gear in trawl *i* (the area swept by the wing),

v_{2i} is the sweep area of gear in trawl i i.e. the area swept by the door minus that swept by the wing,

$\hat{Q}_{li} = \hat{e}_l + \hat{e}_l \hat{h} \frac{v_{2i}}{v_{1i}}$ is the catchability estimate for a fish of length l in trawl i , following the definition by Somerton *et al*. (2007),

$\hat{e}_l$ is the estimated footrope selectivity-at-length l, is the proportion of fish of length l originally in the area swept by the wing which are caught by the net and do not escape under the footrope,

$\hat{h}$ is the estimated herding coefficient. ($\hat{h}$=0.017).

It should be noted that the methods outlined above were specifically designed for anglerfish. The most significant issue for megrim is that as there is no estimates of footrope selectivity, $\hat{e}_l$ is assumed to be 1. While this is not an issue when the survey indices are treated in a relative sense as presented here for megrim, Fernandes (2010) does use this approach to provide a raised absolute biomass based but notes that due to the full retention assumption for ground gear selectivity, the estimates are considered as a minimum estimate.

C.2. Method

Surplus production methods (Schaefer, 1954; Pella Tomlisson, 1969) offers a potential modelling approach in the absence of reliable catch-at-age data. Surplus production pools the overall positive contributory effects (growth and recruitment) with removals due to mortality into a single production function, thus the stock is considered solely in terms of biomass without regard for differences in age, size of sex structure. Surplus production models are commonly used when only relative biomass indices, either from survey or from commercial fisheries, and landings data are available. For computational simplicity, earlier methods assumed that the yield from the fishery is in equilibrium, where each year’s catch and effort data represent an equilibrium (steady-state) situation where the catch is assumed to equal the surplus production. This can result in overly optimistic estimates of MSY, particularly problematic when a stock is in decline. Process error methods also use catch and effort data, but do not make the assumption that the population is in equilibrium. Process error methods make the assumption that the measurement of catch and effort are measured without error. Conversely, observation error methods assume that the biomass response is correct and that all error is associated with measurement error. Polacheck *et al*. (1993) compared the performance of all three approaches and found that observation methods performed best, with the process method proving very imprecise. However, it would be preferable to consider both process error associated with the inherent population dynamics and observation error which describes the inherent variance in catch and effort observations. The development of state-space models has the ability to separately model and incorporate both process and observation error (Meyer and Millar, 1999).

Due to ageing issues with megrim in VIa and IVa associated with low sampling size and depth dependent growth issues, a surplus production process model is used (Schaefer, 1954) to describe the current exploitation of megrim relative to F_{MSY} and stock biomass relative to B_{MSY}. The biomass dynamics are given by a difference form of a Schaefer biomass dynamic model:

$$B_t = B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}$$

where B_t is the biomass at time t, r is the intrinsic rate of population growth, K is the carrying capacity, and C_t is the catch, assumed known exactly. To assist the estimation the biomass is scaled by the carrying capacity, denoting the scaled biomass $P_t = B_t/K$. Log-normal error structure is assumed giving the scaled biomass dynamics (process) model:

$$P_t = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K}\right)e^{u_t}$$

where the logarithm of process deviations are assumed normal $u_t \sim N(0, \sigma_u^2)$; σ_u^2 is the process error variance.

The starting year biomass is given by $B_{1985} = aK$, where a is the proportion of the carrying capacity in 1980.The biomass dynamics process is related to the observations on the indices through the measurement error equation:

$$I_{j,t} = q_j P_t K e^{\varepsilon_{j,t}}$$

where $I_{j,t}$ is the value of abundance index j in year t, q_j is index-specific catchability, $B_t = P_t K$, and the measurement errors are assumed log-normally distributed with $\varepsilon_t \sim N(0, \sigma_{\varepsilon,j}^2)$; $\sigma_{\varepsilon,j}^2$ is the index-specific measurement error variance.

C.2.1. Estimation-prior distributions

Estimation is undertaken in a Bayesian framework with Markov Chain Monte Carlo (MCMC) sampling using WinBUGS (Spiegelhalter *et al*., 1999). Prior distributions are given in Table 2.1.1. Note that prior distribution assumptions are important. In these preliminary runs we have assumed largely uninformative priors to see what information is present in the data to update these priors.

Sensitivities to K, assuming uniform normal or log-normal, distributions have been tested and although the fitted and posterior parameters are quite similar. The major difference being in the parameter *K*, which has an extremely long tail when a uniform prior is assumed. Most of the density of *K* is similarly distributed (good overlap when the distributions are overlayed). As the uniform prior distribution on the logarithm of *K* avoided long tails (which may have a very large effect on the mean), this was chosen in subsequent runs (e.g. retrospective and final).

Catchability sensitivity

Assigning a prior distribution that is uniform on the logarithmic scale is recommended for catchability in biomass dynamics models (Punt and Hilborn, 1997). A corresponding fit allowing for catchability to range over $[0, \infty]$ resulted in a poorly converged model with unrealistic estimated absolute abundances (order of 500 thousand tonnes). The range of the catchability parameter was thus scaled to have a lower limit of -11 on the logarithmic scale, this corresponds to a lower limit on *q* of exp(-11)= 1.67e-05, which allowed for biomass to range over 100 thousand tonnes from each series.

Table 2.1.1. ***Lepidorhombus whiffiagonis*** **in ICES Areas VIa and IVa. 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	$1/\sigma_u^2$	$\text{Gamma}(\text{shape} = 0.001, \text{rate} = 0.001)$	Gamma distributed on inverse variance (precision) scale
Measurement error variances	$1/\sigma_{\varepsilon,j}^2$	$\text{Gamma}(\text{shape} = 0.001, \text{rate} = 0.001)$	Gamma distributed on inverse variance (precision) scale
Proportion of K in 1985	a	$\text{Uniform}(0.01, 2.0)$	

D. Short-term projection

Model used: Risk based forecast

Software used: R

The lack of recruitment data and age data precludes the provision of a short-term forecast based on spawning–stock and recruitment relationships. Instead, using the historic dynamics of the stock, the likelihood of the stock exceeding F_{MSY} under a range of catch options is presented. Advice is based on maintaining the risk of F_{MSY} exceeding 5%.

E. Medium-term projection

Not presented.

F. Long-term projection

Not presented.

G. Biological reference points

	Type	Value	Technical basis
MSY	$B_{trigger}$	9633	50% of B_{MSY}
Approach	F_{MSY}	0.31	Estimated from model
Precautionary Approach	B_{lim}	5780	30% of B_{MSY}
	B_{pa}	Not defined	
	F_{lim}	1.7 F_{MSY}.	Fishing mortality that drives the stock to B_{lim}
	F_{pa}	Not defined	

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