Stock annex for Blue ling in Division Vb, and Subareas VI, VII

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Blue ling (*Molva dypterygia*) in ICES Division Vb and Sub areas VI and VII; **bli-5b67**
Working Group	WGDEEP
Date	February 2014
Revised by	WKDEEP 2014/ P. Lorance.

A. General

A.1. Stock definition

Based upon biological investigations in the early 1980s it was suggested that at least two adult stock components were found in the Northeast Atlantic, a northern stock in Subarea XIV and Division Va with a small component in Vb, and a southern stock in Subarea VI and adjacent waters in Division Vb. This was considered supported by differences in length and age structures between areas as well as in growth and maturity (Magnússon and Magnússon, 1995). Egg and larval data from early studies also suggested the existence of many spawning grounds in ICES Division Va, Vb and Subarea VI and elsewhere and were considered suggesting further stock separation. However, in most areas, except Icelandic waters, small blue ling below 60 cm do not occur and fish appear in surveys and commercial catches at 60–80 cm suggesting scale large spatial migrations and therefore limited population structuring. There was also reported differences in length-at-age but these may have come from different interpretations of growth rings in otoliths and the slower growth in Icelandic waters compared to the Faroes and Shetland areas is challenged by the comparison of recent length-at-age of blue ling from Areas Vb, VI and VII and mean length-at-age in Icelandic waters estimated in the 1980s (Figure 1).

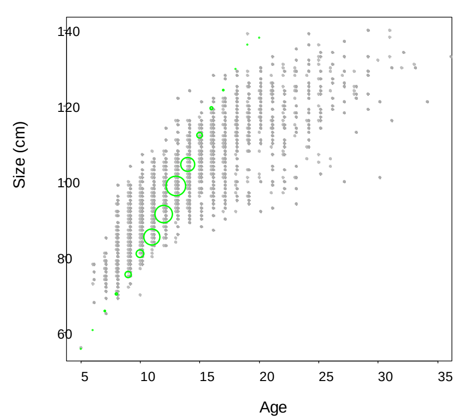

Figure 1. Age–length-key from French age estimates (years 2009–2013 combined, n=2222), compared to mean-length-at –age estimated in Icelandic waters in the early 1980s (green circles, the diameter of circle in proportion to the number of fish, n=994, redrawn from Magnússon and Magnússon (1995).

The assessment unit was defined as ICES Division Vb and Subareas VI and VII. In Subareas VI and VII, only adults fish occur, juveniles are not caught to any significant level in. The situation is slightly different in Division Vb where some small fish occur in small numbers. These could be used for age and growth estimation purposes (Magnussen, 2007). However numbers caught in Faroese trawl surveys do not seem significant to the size of the exploited adult stock. Further, unlike in Icelandic waters where small blue ling caught in shallow (100 m or less) waters and blue ling of less than 60 cm caught along the upper slope make in some years more than half the total number caught in trawl surveys, blue ling is almost not caught shallower than 200 m in Faroese waters (Figure 2).

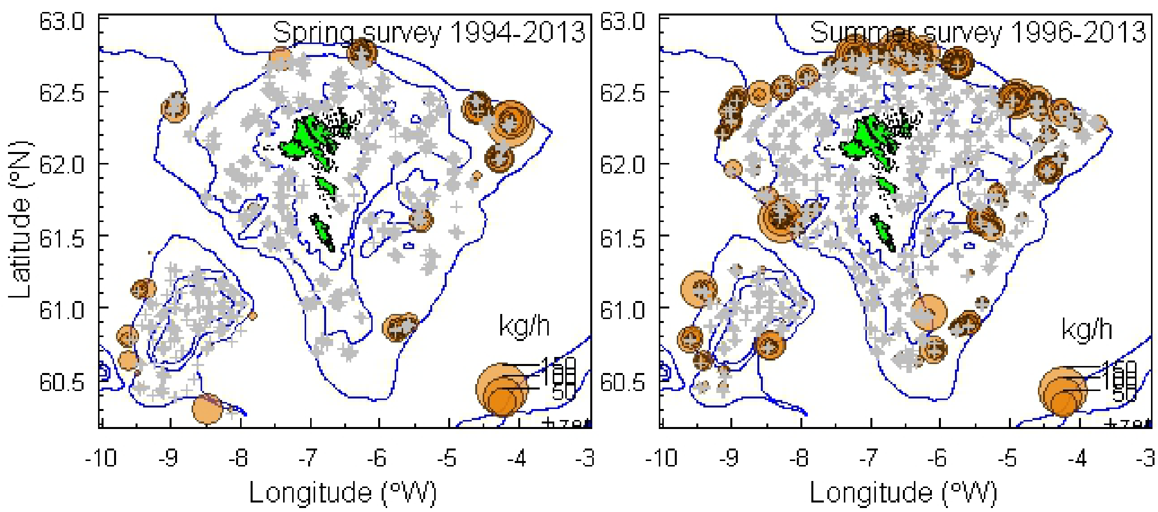

Figure 2. Spatial distribution of blue ling caught in the Faroese spring and summer surveys, depth contours are 100, 200 and 500 m.

Similarly, in the neighbouring ICES Division XIIb, from where landings are currently a few hundred tonnes per year but have been higher in the past, only adult fish are known to be caught and as the western Hatton Bank in XIIb is the continuation to the west of the Bank located in VIb, ICES Division XIIb should be considered as the same stock as blue ling in Vb, VI and VII. This will only impact marginally the assessment results as catch in recent years in XXIb have been small compare to catch in VB, VI and VII. Higher catch were caught is the past and this would results in slightly higher estimates of the initial biomass in the SRA (see below).

Spawning areas

Blue ling spawning occurs (i) in Vb, on the southern and southwestern margins of Lousy Bank;(ii) in VIa along the continental slope northwest of Scotland and close to of Rosemary Bank; (iii) in VIb on the margins of Hatton Bank (Figure 3) and is considered to take place at depths of 730–1100 m between March and May inclusive in Vb and VIa, and during March and April in VIb. From 1970 to 1990, the bulk of the fishery for blue ling was seasonal fisheries targeting these aggregations. To prevent depletion of adult populations, temporal closures were introduced by the EC in 2009 within ICES Division VIa.

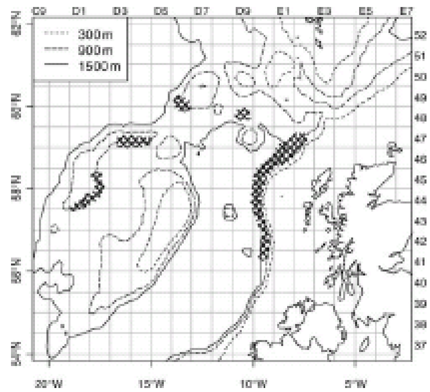

Figure 3. Known spawning areas of blue ling to the West of Scotland (from Large *et al*., 2010).

A.2. Fishery

The main fisheries are those by Faroese trawlers in Vb and French trawlers in VI, mostly VIa, and, to a lesser extent, Vb. Total international landings from Subarea VII are small bycatch in other fisheries. In Subarea Vb and Division VI, other fisheries landings blue ling are the Norwegian longline fishery for ling and tusk where blue ling is a bycatch and Scottish trawlers. Landings from these fleets have been small since the 2000s. Scottish trawlers landed the species mainly from the mid-1990s to early 2000s when their landings exceeded 1000 t/year. German vessels fished 1000 to 7000 t/year from the late 1960s to early 1980s. Norwegian landings were also up to 4000 t in 1973 but have decreased to less than 100 tonnes after 2000.

Landings from Subareas VIII and IX previously reported as blue ling are now ascribed to the closely related Spanish ling (*Molva macrophthalma*) and blue ling is not known to occur to any significant level in these subareas. The area of distribution of the stock is limited to somewhere between 50 and 55°N along the Porcupine Bank slope (Bridger, 1978; Ehrich, 1983, Lorance *et al*., 2009).

Landings by Faroese trawlers are mostly taken in the spawning season. Historically, this was also the case for French trawlers fishing in Vb and VI. However, in recent years blue ling has been taken mainly in a mixed French trawl fishery for roundnose grenadier, black scabbardfish and blue ling. This fishery is further mixed with fishing for shelf species such as saithe, hake, monkfish and megrim.

The rapid increase in the size of this fishery in the early 1970s is considered to be related to the expansion of national fisheries limits to 200 nautical miles and the resultant displacement of fishing effort and the associated development of markets.

A.3. Ecosystem aspects

B. Data

B.1. Commercial catch

B. 1.1. Landings and discards

In 2008, the landings time-series from the southern blue ling stock was extended back to 1966 based on North Western Working Group reports from 1989–1991 and data in Moguedet (1988). Landings data in the 1980s for French freezer trawlers may be underestimated in some years but were included in 2011 for years 1988–2000.

Large French catches were reported as ling at the start of the fishery in 1973–1975. In order to derive a best estimate of blue ling landings, the average ling landings in the years preceding the start of the French blue ling fishery were subtracted from estimates of blue ling and ling combined.

Landings data by ICES statistical rectangles have been provided by France, (UK) Scotland, UK (England and Wales), Spain (Basque country fleet fishing along the continental slope to the West of the British Isles) and Ireland and have been aggregated by quarter and plotted to display the geographical distribution of the fishery by year starting from 2005.

Blue ling is not discarded to any significant level because no small blue ling are caught in the fishery.

B.2. Biological

Available growth parameter in length and weight for blue ling are summarized in Tables 1 and 2 and maturity parameters in Table 3.

Table 1. Growth parameters of blue ling.

L_∞ (cm)	K (year^{-1})	T_0	Number of fish	Age range	Sex	Maximum observed size	Area	Reference
160	0.11	N/A	79	3-17	Combined		Faroe Bank	Magnussen, 2007
165.8	0.084	-0.138	N/A	? - 20	Female	147 (1)	ICES VIa	Moguedet, (1985, 1988)
112.2	0.158	0.318	N/A	? - 19	Male	110	ICES VIa	(1)
125	0.152	1.559	2619	5-25 (2,3)	Combined	136 (3)	Vb VIa,b	
145.2	0.155	1.281	1412		Female		Vb VIa,b	Ehrich and Reinsch, 1985
109.7	0.199	1.833	1391		Males		Vb VIa,b	(4)
116.25	0.17	0.57	590	5-20+	Female	130	Faroe Islands (5)	
104.2	0.197	0.57	331	5-20+	Male	107	Faroe Islands (5)	
137.37	0.13	0.46	117	6-18+	Female	139	Shetland Islands (5)	Thomas, 1987
108.31	0.185	0.57	227	5-20+	Male	109	Shetland Islands (5)	
			563	20 +	Female	138.5 (7)	Icelandic slope	
			431	17	Male	115 (7)	Icelandic slope	
			1492	20+ (6)	Combined	137.86 (7)	Icelandic slope	
			?	?	Combined	145-150 (8)	Iceland and RR (9)	Magnússon and Magnússon, 1995
			?	?	Female	140	Spawning aggreg. RR (9)	
			?	?	Male	124	Spawning aggreg. RR (9)	
			1399		Combined	130-135 (10)	West of the British Isles	Bridger, 1978
					Female	ca 145 (11)	West of the British Isles	Ehrich, 1983
					Males	ca 112 (11)	West of the British Isles	
			240 (♂+♀)		Female	150-155 (12)	West of the British Isles	Gordon and Hunter, 1994
			240 (♂+♀)		Male	110-115 (12)	West of the British Isles	Gordon and Hunter, 1994
			197		Combined	140	Norwegian Deep	Bergstad, 1991

(1) from sampling in 1984-85; Female>= 130cm were 3% of total female numbers; (2) the bulk in age groups 7–20;(3) from length distribution of German landings 1980 and 1982; (4) estimates based upon length and age data from sampling of German blue ling landings (Ehrich and Reinsch, 1985). (5) based upon sampling in 1977 and 1979 (Shetland Islands) and 1977 and 1978 (Faroe Islands); areas are defined according to Figure 1 (Thomas, 1987). (6) Magnússon and Magnússon (1995) reported mean length by age for the years 1978–1982. In their sample (n=1492), there was seven fish of the age group 20+ . (7) From age estimation sample; mean length of the oldest age group: six individuals for females, one for males, seven combined; (8) visually from length distribution plots; few fish above 130 cm; (9) RR: Reykjanes Ridge; (10) from a plot of length distribution by 5 cm length classes. Largest length class was 130–135 cm. It included 1–2% of total number of fish measured, they modal size class was 95–99 cm; (11) from plot, modal size by 120 cm for females and 95 cm for males. (12) From SAMS surveys (unpublished data), from histogram by 5 cm size classes. Modal sizes of 95–100 cm for males and 105–110 for females, n=240 (sex combined).

Table 2. Growth parameters in weight.

W∞ (g)	K	T_0	Number of fish aged	Length range (TL, cm)	Age range (y)	Sex	Reference	Area
19 688	0.094		79	NA	3 - 17	Combined	Magnussen, 2007	Faroe Islands
5191						Male	Ehrich and Reinsch, 1985	
13 166						Female	Ehrich and Reinsch, 1985	

Table 2. Maturity parameters, A50: age at 50% maturity; m: rate at which the population attains maturity (Magnussen, 2007); L50 length at 50% maturity; M50 weight at 50% maturity.

Sex	Area	A50	m	L50 (cm)	M50 (g)	Reference
Combined	Faroe Bank	6.2	1.66	79	1696	Magnussen, 2007
Female	Iceland	11	N/A	88	N/A	Magnússon and Magnússon, 1995
Male	Iceland	9	N/A	75	N/A	Magnússon and Magnússon, 1995
Female	Faroe Islands	8.1	N/A	N/A	N/A	Thomas, 1987 (1)
Male	Faroe Islands	6.4	N/A	N/A	N/A	Thomas, 1987 (1)
Female	South and West of the Faroe Islands	7	N/A	85		Magnússon et al., 1997
Male	South and West of the Faroe Islands	6	N/A	80		Magnússon et al., 1997
Combined	ICES IIa	N/A	M/A	75		Joenes, 1961

(1) The author specified that not too much significance should be given do the result because very few immature fish were caught and stated "it might be sufficient to know that the fish mature at an age between 6 and 8 years".

Table 3. Coefficient a and b of weight–length relationship $W=a*L^b$ for blue ling.

Area	Sex	a	b	Number of fish	size range (cm)	Weight range (g)	Reference
ICES VI	Combined	0.00191	3.14882	280	62 - 142		Dorel, 1986
ICES VI	Males	0.002	3.02	NA	69 - 109	715 - 2900	Moguedet 1988
	Females	0.0023	3.00	NA	74 - 142	1150 - 8600	

B.2.1. Length composition

Length composition of the landings have been available from Faroese trawlers in Division Vb since 1996 and French trawlers in Division VIa since 1984. Mean length of blue ling from the Norwegian reference fleet in Divisions Vb, VIa, VIb are also provided. Age estimation of blue ling was carried out in the past and was disrupted because consistency between readers was considered poor. Nevertheless, there is a general agreement that blue ling recruits to this stock at a size of 70–80 cm have an age of 6–8 years. Age estimation of blue ling sampled from French landings were resumed in 2009 in application of DCF. Reading scheme for estimating the age of blue ling does not significantly differ for that of most gadoid species although the number of growth increments to count is higher (Figure 4). Nevertheless, age estimation for this species are unvalidated.

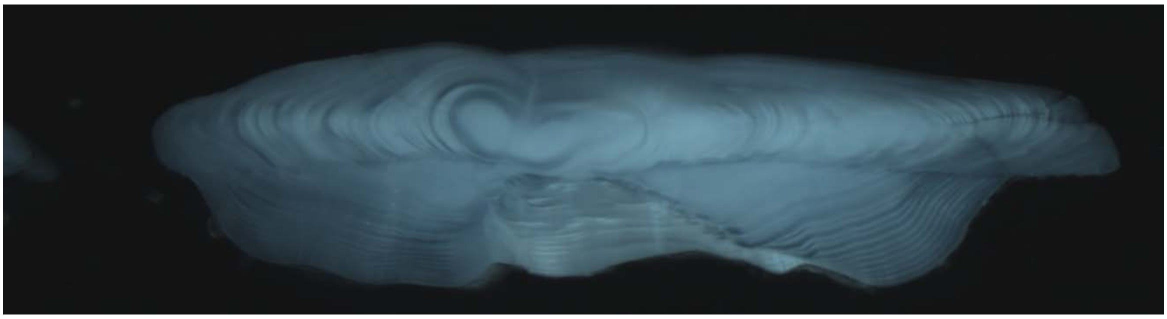

Figure 4. Thin sections of blue ling otolith.

B.2.2 Weight-at-age

No time-series but overall weight-at-age are derived from age–length keys and length–weight relationships.

B.2.3. Maturity and natural mortality

Natural mortality (M) was estimated using the relationship (Annala, J. H., Sullivan, K. J. (1996):

M = ln(100)/maximum age

In this relationship, the maximum age should be set at the age where 1% of a year class is still alive. Based on Faroese and French age readings and considering a maximum age for blue ling at 30 years M has been presumed in the order of 0.15. In a compilation of published age data as part of the EU DEEPFIHSMAN project more than 4000 individual age data were found, none exceeded 25 years. Based on this the maximum age was refine as 25. As a consequence, *M* estimated from the relationship from Hoenig (Hoenig, 1983; Hewitt and Hoenig, 2005) and from was maximum age relationship above has been refined to 0.18. The empirical relationship from Pauly (1980) applied by WKLIFE) with growth parameters K=0.152 and L_{∞}.= 125 for both sex combined (Ehrich and Reinsch, 1985) returns a similar *M* of 0.19.

Juvenile blue ling are not known to occur on the fishing nor in Subareas Vb, VI and VII to any significant level. Fish recruit to this area and to the spawning stock at an age of 6 to 8 years. All blue ling occurring in Vb, VI and VI can be considered as mature fish.

B.3. Surveys

Weight and number per hour trawling in the Faroese spring survey since 1994 have been provided. Number have been provided for small (<80 cm) and large (>80 cm) fish. However, it was stressed that these surveys are limited to depth shallower than 500 m. These data may provide useful information on recruitment.

An index of abundance in number per hour was available from a Scottish deep-water survey to the west of Scotland for years 1998–2011. The fish community of the continental shelf slope to the northwest of Scotland has been surveyed by Marine Scotland-Science since 1996, with strictly comparable data available between 1998 and 2008. This has focused on a core area between 55–59°N, with trawling undertaken at depths ranging from 300 to 1900 m with most of the hauls being conducted at fixed stations, at depths of around 500 m, 1000 m, 1500 m and 1800 m. Further hauls have been made on seamounts in the area, and on the slope around Rockall Bank, but these are exploratory, irregular and are not taken into account in the index of abundance. This survey was conducted biennially, in September, until 2004, and annually in 2004–2009. Locations of trawl sites between depths of 500–1500 m are shown in Figure 5. From 1998 to 2008 the bottom trawl was rigged with 21" rock-hopper groundgear, however in 2009, a switch was made to lighter groundgear, with 16" bobbins.

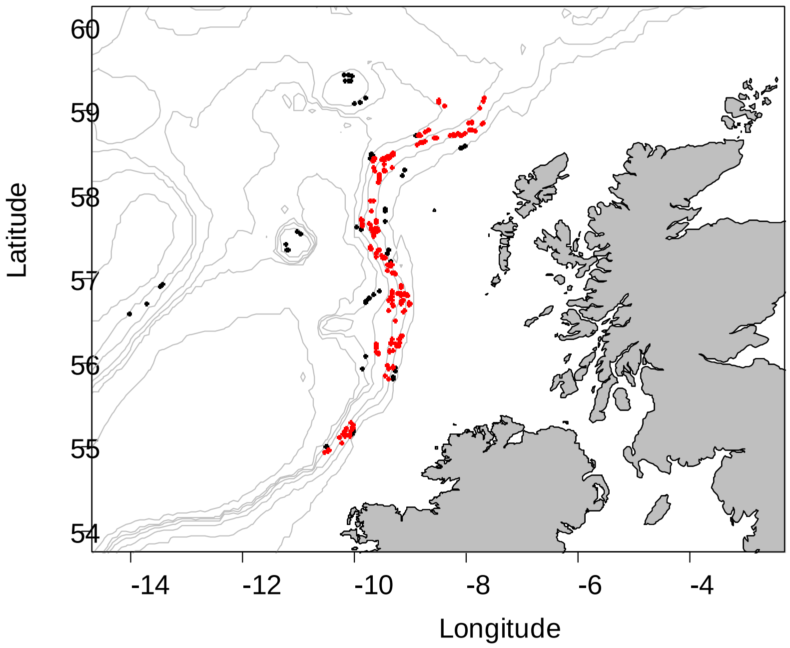

Figure 5. Sites of valid hauls in the 500–1500 m depth band in the Scottish Deep-water Survey dataset, 1998–2009 (in red). Valid hauls at other depths are shown in black.

An index of abundance was available from an Irish deep-water trawl survey of the fish community of the continental shelf slope to west and northwest of Ireland carried out from 2006 to 2009. The sampling protocol of this survey was standardised in accordance with the Scottish deep-water survey with trawling at fixed stations around 500 m, 1000 m, 1500 m and 1800 m. The gear used throughout the surveys series was the same as that used by Scotland in 2009. To be consistent across the years the haul data used for the index calculation only includes the areas that are covered in all four years and the depth bands (500–1500 m) that are covered in all four years. In total, the dataset comprised 42 valid hauls.

B.4. Commercial cpue

A French deep-water tallybook database (based on fishers' own records) developed by the French industry is used to compute Landings per Unite of Effort (lpue) indices starting from year 2000 (Lorance *et al.*, 2010). The database includes more years back to 1992 with landings of blue ling back to 1993. However, there is not enough data one blue ling before 2000 because of different components of deep-water vessels being included and small catch of blue ling from vessel contributing to the data in 1993–1999. The abundance index is standardized using a GAM model.

To represent the spatial aspect in the model, five small areas where the fleet has caught blue ling were defined as cluster of ICES rectangles (Figure 3). Fishing area definition was based on a working paper presented at WGDEEP 2006 on an analysis of logbook data. In this working document fishing grounds, exploited since the 1990s were denoted ref5 (for reference 5), edge6 (for edge of continental slope) and other6 (for other fishing grounds in VI. New fishing grounds, i.e. not fished by French trawlers for fresh fish before 2000 in ICES Division Vb and Subareas VI were denoted new5 and new6 respectively (Figure 6).

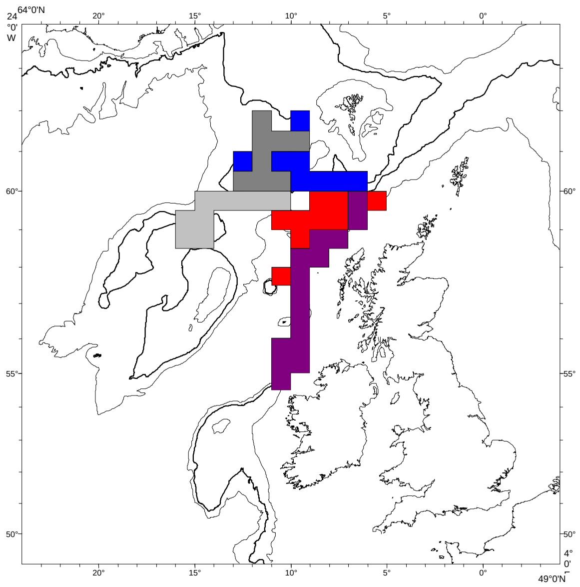

Figure 6. Areas (clusters of statistical rectangles) used to calculate French lpue for blue ling. Dark grey, new grounds in ICES Division Vb (new5); light grey, new grounds in Subarea VI (new6); red, others in Subarea VI (other6); purple, edge in VI (edge6); blue, reference in Division Vb (ref5).

The GAM models used to standardize the haul-by-haul catch data has the form:

log(E[landings]) = s(haul duration) + s(depth) + month + vessel.id+ rectangle + year:Area

where E[] denotes expected value, s() indicates a smooth nonlinear function (cubic regression spline), vessel.id the vessel identity and year:area an interaction term. The dependent variable is landings and not lpue, which allows including haul duration as explanatory variable and have a non-proportional relationship between landings and fishing time. The fit was done assuming a Tweedie distribution of the dependent variable with a log-link function using the mgcv package in R (Wood, 2006).

The Tweedie distribution has mean μ and variance $\phi\mu^p$, where ϕ is a dispersion parameter and p is called the index. As a Poisson-Gamma compound distribution was used, $1<p<2$, the index p could not be estimated simultaneously with the model parameters. In 2010, a detailed study was carried out and p=1.3 provided the best fit (Lorance *et al.*, 2010).

In 2009, the model fit was restricted to haul durations from 60 to 300 minutes and depth 200–1100 m covering the species depth range and excluding too short and long hauls for which there are a few data. This lpue standardisation method allowed estimating lpue time-trends for the five small areas. The model provided lpue time-trends for the five areas. To derive standardized estimates for the whole study zone, lpue values are predicted for January, for all rectangles in each area (using the average haul depth in each rectangle), a 5-h haul duration, and a vessel that operated during the whole period as prediction variables. Predictions for the entire study zone were then derived as the weighted average of the five area (rectangle average) estimates, with the weights being the number of rectangles in each area (Lorance *et al.*, 2010). Some changes occurred in the fishery: protection areas for bleu ling spawning were introduced in 2009. As these limited the possibility for fishing for blue ling in these areas, hauls carried out throughout the time-series were excluded. The small areas new5 and new6 were not fished in 2011 by vessels contributing to the tallybooks. As a result, the index for based upon the catch in three areas only. The depth and haul duration range was adjusted to reduce the confidence limits of the estimated. Depth range of 500–1200 m and duration of 120–480 minutes were used. The change in these selections impacts little the estimates but reduce the confidence limits.

B.5. Other relevant data

No other relevant.

C. Assessment: data and method

Two assessment methods are used for this stock. A model call multiyear catch curve (MYCC) which is a random effects population dynamics model based on proportion-at-age and removal is used to estimate the total mortality and an age-structured Stock Reduction Analysis (SRA) is used to assess the trajectory in the population biomass over the catch history starting from 1966. International landings were small before the early 1970s so that biomass in the 1960s can be considered at of close to unexploited levels.

Multiyear catch curve

The multiyear catch curve model was carried out to estimate total annual mortality Zt taking account of interannual variations in recruitment. The data used are proportions-at-age in numbers by year and total catch (landings) in numbers by year.

The population dynamics in numbers are modelled as:

$$N_{a,t} = N_{a-1,t-1}e^{-Z_{t-1}} \qquad a_r \le a \le A_+ \qquad t = 1........T \tag{1}$$

$$N_{A_+,t} = (N_{A_+-1,t-1} + N_{A_+,t-1})e^{-Z_{t-1}} \tag{2}$$

where $N_{a,t}$ are population numbers-at-age *a* in year *t*, A_+ is an age plus group and Z_t are annual total ~mortality rates. Recruitment-at-age a_r is assumed to vary randomly over time following a lognormal distribution

$$N_{1,t} = R_t \qquad R_t \sim \mathrm{logN}(\mu_R, \sigma_R) \qquad t = 1\ldots T \tag{3}$$

where μ_R is the mean recruitment and σ_R the standard deviation. For ease of interpretation the coefficient of variation (CV_R) instead of σ_R was calculated making use of the fact that *var(ln(x)) ≈ ln(CV(x)²+1)*. Recruitment is treated as a random effect in model fitting.

Annual total mortality Zt is modelled by a random effect using a random walk over time:

$$Z_t = Z_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim \mathrm{N}(0,\sigma_{\mathrm{Z}}) \qquad t = 1\ldots\ldots T \tag{4}$$

The initial state vector at the beginning of year t=1 is calculated assuming constant historic total mortality $Z_0 = M + F_0$

$$N_{a,1} = e^{(a_r - a)Z_0} R_{a_r+1-a} \qquad a_r < a \le A_+ \tag{5}$$

where F_0 is constant historic fishing mortality.

The initial numbers in the plus group $N_{A+,1}$ are estimated by an infinite sum over previous years.

The observation model has two parts, the first one for population numbers-at-age $Y_{a,t}$ and the second for total catch in numbers. Numbers-at-age, assumed to follow a multinomial distribution.

$$Y_{a,t} \sim \mathrm{Multinom}(\mathrm{p}_{a,t}, m_t) \qquad a_r \le a \le A_+ \qquad t = 1\ldots\ldots T \tag{6}$$

where $p_{a,t}$ are proportions-at-age and m_t is the effective sample size in year t. Due to the clustered nature of individuals, the sample size in trawl surveys or harbour sampling programs does not correspond to the number of individuals measured but is rather much smaller (Pennington and Vølstad, 1994). As a result the observed variability is much larger than would be expected given the number of measurements. Therefore the effective sample size was estimated from the sampling data using a Dirichlet-multinomial distribution and the dirmult package in R by Twedebrin272 k, Twedebrink (2009).

The second observation model for the total catch (in numbers) which is assumed to follow a Gamma distribution with parameters α and β.

$$Ct \sim \mathrm{Gamma}(\alpha,\beta) \tag{7}$$

$$E[C_t] = \left(\frac{Z_t - M}{Z_t}\right)(1 - e^{-Z_t}) \sum N_{a,t} \tag{8}$$

The coefficient of variation (CV_c) of the Gamma distribution is related to the α parameter as CVc=1/sqrt(α) and $\beta = \alpha / E[Ct]$. The model is parameterised in terms of CVc.

Not all model parameters **θ**={Z_0,..., Z_t, M, F_0, μ_R, σ_R, $NA_{+,1}$, CV_R, CVc} can be estimated and some need to be fixed. The fixed parameters where set as follows:

- natural mortality M=0.18
- coefficient of variation of landings or catch (CVc=0.05) to allow for some misreporting

Estimation of free model parameters **θ** **i**s carried out by maximum likelihood based on the observation vector $\boldsymbol{y} = (C_1,..., C_T, Y_{ar,T},,..., Y_{A+,T})$ which has conditional density f_θ (**y** | **u,v**) where $\boldsymbol{u}$ = ($R1$,..., Rn) is the vector of the latent random recruitment variable with marginal density $h(\boldsymbol{u}$) $\boldsymbol{v}$=(Z_1,………,Z_{T-1}) is the total mortality random effect variable with marginal density $g(\boldsymbol{v})$. The marginal likelihood function is obtained by integrating out $\boldsymbol{u}$ **and** $\boldsymbol{v}$ from the joint density $\mathcal{L}$

$$\mathcal{L}(\theta) = \iint f_\theta(y|u,v) h_\theta(u) g_\theta(v) y(u) y(v) \tag{9}$$

The double integral in (9) is evaluated using the Laplace approximation as implemented in the random effects module of AD Model builder and described in Skaug and Fournier (2006). AD Model builder automatically calculates standard deviations of estimates based on the observed Fisher Information matrix.

For the analysis the data are restricted to the fully recruited age classes, 9 and over, a plus group is set at-age 19, called 19+.

Stock Reduction Analysis: SRA

Stock reduction analysis (SRA) is a developed form of delay-difference model (Quinn and Deriso, 1999). The method uses biological parameters and information for time delays due to growth and recruitment to predict the basic biomass dynamics of age structured populations without requiring information on age structure.. A description of the general approach can be found in Kimura and Tagart (1982), Kimura *et al.* (1984) and Kimura (1985 and 1988).

The aim of stock reduction analysis is to estimate past and present biomass for a fishery. Three types of input data are required: biological parameters, abundance indices, and a complete catch history.

SRA is an iterative process, which operates with the following steps:

- A biomass *B0* of the stock at the beginning of the catch history (initial biomass) is chosen;
- The stock biomass over the time-series is calculated by forward projection using, at each time-step the stock–recruitment relationship (derived from the input steepness), the natural mortality and removal to calculate number-at-age at the start of the next time interval;
- The catchability q of each time-series of biomass index and the coefficient of variation c of the index are calculated;
- The likelihood of the value of B_0 and q is calculated.

These four steps are repeated for a range of B_0 and the B_0 that maximises the likelihood of observed abundance indices is retained.

Implicit assumptions of this age-structured SRA include that (i) there is no density-dependence in growth and natural mortality, (ii) the stock–recruitment relationship is of the Beverton and Holt type.

Software used: *FLaspm*

FLaspm is a package for the statistical computing environment R (R Development Core Team, 2010). The package is open source and is currently hosted at GoogleCode (the source code is freely available at http://code.google.com/p/deepfishman/. *FLaspm* is part of the FLR project (Kell *et al.*, 2007) and requires that the package *FLCore* is also installed (v >2.3). The stock reduction model used in this analysis implements the model described in Francis (1992) and is capable of fitting multiple indices simultaneously. Up to four time-series of indices are used for blue ling, namely the Landings Per Unit of Effort (lpue) from French haul-by-haul catch and effort, the Irish bottom-trawl survey from 2006 to 2009; the Scottish bottom-trawl survey starting from 1998, with missing years (no survey) in 1999, 2001, 2003 and 2010 and an index from the Faroese survey. The two (spring and summer) Faroese surveys are combined in one single mean index. Trials have been conducted with one time-series and results were similar, as the time-series are actually similar. Conversely, the two Faroese survey should not be included in the model because they only cover a restricted range of the stock area and in included as two series they would overweight the Scottish survey which cover areas from which there is as much or more catch.

In some case the fit does not converge, the reasons for this have not been identified and this was already reported in a working document in 2011 (Scott *et al.*, 2011). Only minor change in the data (e.g. replacing the length–weight relationship by another one producing similar weights-at-age may allow the model to converge or not. This suggests that the problem lies in the minimisation routine. The method requires time-series data of annual catches, one or more abundance index and a range of biological parameters. The effect of these biological parameters on results is investigated using sensitivity analysis. A Beverton and Holt stock–recruitment relationship with a steepness of 0.75 is used throughout.

Input data:

Total international landings from 1966 should be used for this assessment. Three tuning indices were available: French abundance index derived from skipper tallybook data, Marine Scotland’s FRV SCOTIA deep-water survey and Irish (2006 to 2009).

Other stock indicators

A time-series of mean length in French landings is used as a further stock indicator and the consistency of this indicator with models outputs should be check in order to detect any possible deviations from models assumptions. For example, estimated increased proportion of older fish in the MYCC should be reflected in increasing mean length in the landings or large recruitment estimates should be reflected by decrease in mean length. Length indicators from the Faroese and Scottish trawl surveys should be used in the same way.

Model Options chosen:

Input data types and characteristics:

Parameter	Symbol	Value
Maximum age	A_{max}	30
Natural mortality	M	0.15
Steepness of Beverton–Holt stock recruitment relationship	h	0.75
Age of first selectivity	A_{sel}	7
Age of maturity	A_{mat}	7
von Bertalanffy growth parameters	L_∞	125 cm
	k	0.152
	t_0	1.552
Length–weight parameters	a	2e-6
	b	3.15

D. Short-Term Projection

No short-term prediction are carried out for this stock.

E. Medium-Term Projections

None.

F. Long-Term Projections

None.

G. Biological Reference Points

No biological reference points defined.

H. Other Issues

The stock identity is an issue for blue ling. The only area were juvenile are known to occur in high number in the Icelandic shelf. No juvenile are known to occur in Subareas VI and VII and number observed in the Faroese survey (about one fish smaller than 80 cm per hour) do not seem sufficient to supply the abundance for adult blue ling.

H.1. Historical overview of previous assessment methods

Exploratory assessment carried out far are summarised below (synthesis carried out as part of the DEEPFISHMAN project).

Year	Assessment type[3]	Method	Assessment package/ program used	Used for advice?	If not, what was latest scientific advice based on?
1998	Exploratory	Schaefer& DeLury depletion model	CEDA (1)	No	French OTB and Faroese longline lpue
2000	Exploratory	Schaefer& DeLury depletion model	CEDA (1)	No	French OTB unstandardised lpue
2004	Exploratory	Schaefer, Pella-Tomlinson and Fox production models & DeLury depletion model	CEDA (1)	No	Trend in French commercial otter trawl lpue
	Exploratory	Stock reduction	PMOD	No	Trend in French commercial otter trawl lpue
2006	Exploratory	Catch Survey analysis	CSA (Mesnil, 2003)	No	Trend in French commercial otter trawl lpue

(1) MRAG (UK) software.

[3] Exploratory, Benchmark (to identify best practise), Update (repeat of previous years' assessment using same method and settings but with the addition of data for another year).

Summary of data ranges used in recent assessments:

Data	2007 assessment	2008 assessment	2009 assessment	2010 assessment
Landings	Years: 1988–2006	Years: 1988–2007	Years: 1966-2008	Years: 1966–2009
Quarterly length dist. of French landings	Years: 1989–2006	Years: 1984–2007	Years: 1984–2008	Years: 1984–2010
Quarterly length dist. of Faroese landings	Years: 1995–2006	Years: 1995–2007	Years: 1995–2008	Years: 1995–2009
Quartely age dist.				Year: 2009
Survey: Scottish deep-water			Years: 1998-2008 N° per hour	Years: 1998–2009 N° per hour
Survey: Irish				Years: 2006–2009 N° per hour
Survey: spring and autumn Faroese				Years: 1994–2009 N° per hour Size
Haul-by-haul lpues from French trawlers	Not used	Not used	Years: 2000-2008	Years: 2000–2009
Aggregated unstandardised French lpue	Years: 1989–2006	Years: 1989–2007	Years: 1989–2008	Not used

I. References

Annala, J. H., and Sullivan, K. J. 1996. Report from the Fishery assessment plenary, April-May 1996: stock assessments and yield estimates. 308 pp.

Bridger, J. P. 1978. New deep-water trawling grounds to the West of Britain. Laboratory Leaflet, Ministry of Agriculture Fisheries and Food (MAFF), Directorate of Fisheries Research, Lowestoft, United Kingdom.

Dorel, D. 1986. Poissons de l'Atlantique Nord-Est. Relations Taille-Poids. DRV-86-001/RH/NANTES, 183 pp. (available at http://Archimer.ifremer.fr).

Ehrich, S. 1983. On the occurrence of some fish species at the slopes of the Rockall Trough. Archiv für Fischereiwissenschaft, 33: 105–150.

Hewitt, D. A., and Hoenig, J. M. 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fishery Bulletin, 103: 433–437.

Hilborn, R., and Walters, C.J. 1992. Quantitative Fisheries Stock Assessment – Choice, Dynamics and Uncertainty. New York & London. Chapman & Hall.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82:898–903.

Kell, L. T., Mosqueira,I,. Grosjean, P., Fromentin, J., Garcia, Hillary, R., Jardim, E., Mardle, S., Pastoors, M. A., Poos, J. J., Scott, F. and Scott, R. D., 2007, *FLR: An open-source framework for the evaluation and development of management strategies,* ICES Journal of Marine Science, 64(4), 640–646.

Kimura, D.K., and Tagart, J.V. 1982. Stock reduction analysis, another solution to the catch equations. Canadian Journal of Fisheries and Aquatic Sciences, vol. 3 no. 11, pp 1467–1472.

Kimura, D.K., Balsiger, J.W., Ito, D.H. 1984. Generalised stock reduction analysis. Canadian Journal of Fisheries and Aquatic Sciences, vol. 41, no. 9, pp 1325–1333.

Kimura, D.K. 1985. Changes to stock reduction analysis indicated by Schnute's general theory. Canadian Journal of Fisheries and Aquatic Sciences, vol. 42, no. 12, pp 2059–2060.

Kimura, D.K. Stock–recruitment curves as used in the stock reduction analysis model. 1988. J. CONS. CIEM., vol. 44, no. 3, pp 253–258.

Large, P.A. 2002. The use of stock reduction analysis to assess deep-water species in the ICES area – an initial investigation (WD to ICES WGEEP, 2002).

Large, P. A., Diez, G., Drewery, J., Laurans, M., Pilling, G. M., Reid, D. G., Reinert, J., South, A. B., and Vinnichenko, V. I. 2010. Spatial and temporal distribution of spawning aggregations of blue ling (*Molva dypterygia*) west and northwest of the British Isles. ICES Journal of Marine Science, 67: 494–501.

Lorance, P., Pawlowski, L., and Trenkel, V. M. 2009. Deriving blue ling abundance indices from industry haul by haul data. ICES Annual Science Conference, Berlin, 21–25 September 2009, ICES CM 2009/L:12, 25 pp.

Lorance, P., Pawlowski, L., and Trenkel, V. M. 2010. Standardizing blue ling landings per unit effort from industry haul-by-haul data using generalized additive models. ICES Journal of Marine Science, 67: 1650–1658.

Lorance, P., Agnarsson, S., Damalas, D., des Clers, S., Figueiredo, I., Gil, J., and Trenkel, V. M. 2011. Using qualitative and quantitative stakeholder knowledge: examples from European deep-water fisheries. ICES Journal of Marine Science, 68: 1815–1824. Lorance, P., Agnarsson, S., Damalas, D., des Clers, S., Figueiredo, I., Gil, J., and Trenkel, V. M. 2011. Using qualitative and quantitative stakeholder knowledge: examples from European deep-water fisheries. ICES Journal of Marine Science, 68: 1815–1824.

Magnussen, E. 2007. Interpopulation comparison of growth patterns of 14 fish species on Faroe Bank: are all fishes on the bank fast-growing? Journal of Fish Biology, 71: 453–475.

Magnússon, J. V., and Magnússon, J. 1995. The distribution, relative abundance, and biology of the deep-sea fishes of the Icelandic slope and Reykjanes Ridge. *In:* Hopper, A. G., Deep-water fisheries of the North Atlantic oceanic slope. Kluwer Academic Publishers, Dordrecht/Boston/London, 161–199.

Mesnil, B. 2003. The Catch-Survey Analysis (CSA) method of fish stock assessment: an evaluation using simulated data. Fisheries Research (Amsterdam), 63: 193–212.

Moguedet, P. 1988. Approche de la dynamique de stocks accessoires : Le cas des lingues (*Molva* spp.) exploitées par la flottille industrielle Lorientaise. Université des Sciences et Techniques de Lille Flandre Artois, Lille, 301.

Ofstad, L.H. 2013. Info about length distributions and cpue from groundfish surveys and commercial catches for blue ling in Faroese waters (Vb), Faroe Marine Research Institute, WD to WGDEEP 2013, 8pp.

Quinn T.J. and Deriso R.B. 1999. *Quantitative Fish Dynamics*. Oxford University Press. New York. 1999. 542p.

R Development Core Team. 2010. *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria.

Scott, F. Lorance, P. and Large, P. 2011. Exploratory assessment using stock reduction analysis to assess blue ling (*Molva dypterygia*) in Vb, VI, VII. (WD submitted to ICES WGEEP, 2011).

Wood, S. N. 2006. Generalized additive models. An introduction with R. Chapman & Hall/CRC, Boca Raton.