ICES CM 2012/N:04

Title: Preliminary spatially disaggregated stock assessment of northern hake, a widely distributed stock of the north-east Atlantic.

Authors: Michel Bertignac, Carmen Fernández and Richard Methot

Abstract

European hake (*Merluccius merluccius*) is widely distributed over the north-east Atlantic shelf, from Norway to Mauritania. Despite its large distribution (covering ICES Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d, from Norway to the Bay of Biscay) and a complex population structure, the so-called northern stock of hake is currently assessed as a single unit, using a spatially aggregated implementation of the Stock Synthesis assessment model. In this study, a preliminary spatially explicit implementation of Stock Synthesis is developed, which accounts for the distribution of the hake population during its life cycle (nurseries and spawning areas) and the distribution of the fleets (trawlers, gillnetters and long-liners) exploiting the stock at various life stages. By explicitly incorporating spatial structure, the model can make consistent use of survey indices that only cover part of the stock distribution area. The model is fitted to commercial fishing data (landings, discards and quarterly size composition) and survey indices corresponding to the geographical areas defined in the model. Parameter estimation is carried out using the maximum likelihood estimation approach. Little information is currently available on exchange rates between main distribution areas and population structuring, so several hypotheses are tested. Implications in terms of stock assessment and management are discussed.

Key words: Northern hake, spatial dynamics, population structure, spatial stock assessment.

Michel Bertignac, STH, Ifremer Centre de Brest, BP 70, 29280 Plouzané, France [email: michel.bertignac@ifremer.fr]
Carmen Fernández, International Council for the Exploration of the Sea [email: cferllxx@gmail.com]
Richard Methot, National Marine Fisheries Service 2725 Montlake Blvd., Seattle WA 98112, United States [email: richard.methot@noaa.gov]

Introduction

European hake (*Merluccius merluccius*) is widely distributed over the North-east Atlantic shelf, from Norway to Mauritania, with a larger density from the British Islands to the south of Spain (Casey and Pereiro 1995). For several decades, this species has been a very important resource for many demersal fisheries of the region. Since the end of the 1970s, the International Council for the Exploration of the Sea (ICES) considers two stocks units for assessment: the so-called northern stock, in ICES Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d, and the southern stock, in Divisions VIIIc and IXa, along the Spanish and Portuguese coasts. International catch data are available by stock since 1961. For the northern stock, total landings declined from 100 000 tonnes in the early ninety sixties to 60 000 tonnes in the ninety seventies and eighties. They further declined during the nineties, to reach their lowest value over the period in 1998 (35 000t). Since then, landings have been increasing and reached 73 000t in 2010 (ICES 2011).

Following concerns in the late 1990s about the low stock biomass and the possibility of recruitment failure (ICES, 2000) a range of technical measures were introduced (Council Regulations N°1162/2001, 2602/2001 and 494/2002) in order to improve the selection pattern and protect juveniles, and a recovery plan was subsequently adopted (Council regulation EC Reg. No 811/2004). As targets set in the recovery plan have been reached (ICES, 2008), a management plan needs to be developed and is still pending. According to the CFP reform proposal, single-species management shall be replaced with multi-stock management plans (STECF, 2012) and, in this context, it is foreseen to develop area-based management. Northern hake crosses several management areas (STECF, 2012) and spatial distribution and movement will be important elements to account for in the development of a management plan for the fishery catching this stock.

Notwithstanding difficulties to interpret hake otoliths for ageing, an internationally agreed ageing method was developed (Lucio et al., 2000; Pineiro and Sainza, 2003) and used for several years by ICES to derive estimates of catch-at-age for stock assessment. Results of recent tagging studies carried out in the Bay of Biscay (de Pontual et al., 2003, 2006) showed that the agreed age determination methods overestimate age. This was found to have important consequences for the perception of the historical development of the stock and its fishery and for medium-term forecasts and estimates of long-term sustainable yields (Bertignac and de Pontual, 2007). As validated data are currently insufficient to develop any alternative robust age estimation method (de Pontual et al., 2006), an age-based stock assessment model could no longer be used, and a benchmark workshop carried out by ICES in 2010 (ICES, 2010) led to a change in the assessment model. Previously assessed with an age-based cohort analysis (XSA, Darby and Flatman, 1994), the northern hake stock is now assessed using the size/age-structured version of the Stock Synthesis assessment model (Methot, 2005). This is a flexible model which allows using length-structured data (available for hake), while it is not necessary to incorporate age-structured data.

Despite its large distribution and a complex population structure, the northern hake stock is still assessed as a single unit, using a spatially aggregated implementation of Stock Synthesis. In this study, a preliminary spatially explicit implementation of Stock Synthesis is developed, which accounts for the distribution of the hake population during its life cycle and the distribution of the fleets (trawlers, gillnetters and long-liners) exploiting the stock at various life stages. By explicitly incorporating spatial structure, the model can make consistent use of survey indices that only cover part of the stock distribution area. Furthermore, results from such a model could provide useful information for the development of an area-based management for the fisheries catching northern hake, such as recruitment and population distribution, movement rates between areas and their evolutions over time.

Material and methods

Data

Landings data are compiled by ICES (2011), based on auction hall sales notes and logbooks. Length frequency distributions of the landings are mainly sampled at auction halls. The majority of discards data have been collected by observers under the EU Data Collection Regulation implemented in 2003, and consist of estimates of length distributions and discard rates. Some pre-2003 discard data are also available for some fleets.

We define fleets on the basis of fishing methods and geographical regions. Two regions are specified, each including one of the two main nursery areas, which are located on the "*Grande Vasière*" in the Bay of Biscay and on the shelf of the Celtic sea. Accordingly, the two areas used in the model are the Bay of Biscay (ICES Divisions VIIIa,b,d) and a larger one including the Celtic sea (Subarea VII) and the northern part of the stock distribution (Division IIIa and Subareas IV and VI). The northern part of the stock distribution was initially defined as a separate area in the model, but due to the low contrast in the data available for this area, it was later decided to merge it with the Celtic sea area. Although the geographical extension of the two areas is quite different (Fig.1), their contributions to the total landings are of similar magnitude (Fig.2). The fishery landings, discards, and size compositions were organized into 6 fishing fleet categories (GL7, GL8, TR7, TR8, NEP8, NORTH; see Table 1 for a description), where each fleet operates in only one of the model areas (a requirement in Stock Synthesis). This choice of “fleets” was driven by the need to account for distinct selection patterns, while limiting the number of fleet categories to a manageable value. All fleets using trawl gears in a model area are merged into a single category, except for *Nephrops* trawlers fishing in the Bay of Biscay, which have a clearly distinct selection pattern and large discarding of immature hake. Fleets using long-line and gillnet are also merged into a single category, combining the two gears, for each region. The last fleet category includes miscellaneous gears fishing in the northern part of the stock distribution. Landing data are available on a yearly basis from 1978 to 1989 and on a quarterly basis from 1990 to present. In both model areas, landings were similar until the end of the nineties (Fig. 2), at which point they diverge, becoming lower in the Bay of Biscay. In recent years, landings have increased substantially in both areas.

Four surveys provide relative indices of hake abundance over time (Table 2). The French EVHOE groundfish survey, which has been conducted since 1987 on the shelf of the Bay of Biscay and since 1997 on the shelf of the Celtic Sea, occurs in autumn. It has been split by area (EVHOE7 and EVHOE8). The French RESSGASC groundfish survey provides indices for the Bay of Biscay for 1987-2001. Indices are available for the four quarters of the year until 1997 and for the second and fourth quarters afterwards. The Spanish Porcupine groundfish survey (PORCUPINE) started in 2001. It is carried out in September every year, covering the Porcupine bank, at depths between 180 and 800 m. The Irish Groundfish Survey (IGFS) started in 2003. This survey is conducted in autumn in the west of Ireland and Celtic sea. As shown in Figure 3 for the EVHOE surveys, it is apparent that inter-annual variations in abundance are different between the two model areas.

Population model: settings, constraints and model assumptions.

The Stock Synthesis model is an age-structured population model widely used to estimate abundance and mortality of exploited marine populations (Methot 1989, 2000). The model and its user manual are available from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov). The strength of Stock Synthesis lies in its flexibility for modelling how fisheries affect populations. Of particular interest for hake is its ability to extract information on population characteristics from length-only composition data (*i.e.* without age data), using a length-age version of the model. Stock synthesis simulates abundance and mortality of a harvested population and its dynamics over time. Comparisons are made between expected values estimated by the model and observations obtained from surveys and fishery sampling programmes. The goodness of fit is quantified through a log-likelihood function equal to the weighted sum of log-likelihood components of each data set (landings and discards in weight, survey abundance indices, length frequency distributions of landings, discards and surveys).

The population dynamics model developed in Stock Synthesis for Northern hake works on a seasonal basis, with the season corresponding to the 4 quarters of the year. Fish can recruit in any area and season (although in the hake model presented here, recruitment occurs only in quarters 2 and 3) and are assumed to be born at the start of the season. All fish advance to the next age on January 1st, irrespective of their birth season. Hence, not all fish aged a have the same real age from birth, as this depends on their birth season. Fish ages (in years) considered are $a = 0, 1, \ldots, A$, with A being an accumulator age (A=15 in the hake application). Length intervals used for hake cover from 4 to 130 cm, and are 1 cm wide from 4 to 40 cm, 2 cm wide from 40 to 100 cm, and 10 cm wide above 100 cm of length. The intervals are labelled $l = 1, 2, \ldots, L_{last}$.

For each model area z, the population at the start of a time step (consisting of a season s and year y combination) is structured as a set of n_M vectors of numbers at age a: $N_m(z, s, y, a)$, where the subscript $m = 1, \ldots, n_M$ represents the birth season of the fish in that vector (called a *morph* in Stock Synthesis). Since fish are kept in different vectors of numbers-at-age depending on their birth season, their real age from birth can be calculated at any time point. In the current application, only two *morphs* are considered (hence n_M =2), since birth occurs only in quarters 2 and 3. Having two instead of four birth seasons, allows speeding up considerably the estimation process without altering significantly the result of the analysis.

The processes acting on the population are recruitment, natural and fishing mortality, and movement of fish between areas. In the northern hake assessment, natural mortality is assumed constant: $M = 0.4$ per year. The fishing mortality caused by each fleet is calculated as a combination of time-specific (fishing intensity by quarter and year) and size (fishing selectivity) components. Each fleet acts only on the population vectors corresponding to the model area to which the fleet is allocated. The selectivity of each of the six fishing fleets is assumed to be length-based, with $S_{y,l,fl}$ denoting the selectivity of fleet fl in year y for length interval indexed by l. Selectivity is normalised so that $\max_l S_{y,l,fl} = 1$, for all years and fleets. A retention ogive gives the proportion of fish retained among those caught of length l (for each year and fleet). In Stock Synthesis, selectivity functions and retention ogives are allowed to change between years. Two types of selectivity at length are used: a double normal function, which uses 6 parameters to calculate two half-normal curves and an end-value on either side of a plateau, and a 2 parameter logistic function. The use of a logistic selectivity (which precludes dome-shapes) for the "North" fleet was necessary to produce a stable behaviour during parameter estimation. For all fleets, selectivity-at-length was assumed to be constant over all years. In the current model, only three fleets are assumed to produce discards (TR7, TR8 and NEP8). Retention in these fisheries is modelled as a logistic function of fish length, with asymptotic retention equal to 1 and unknown L_{50} and slope. For fleets TR7 and TR8, two different patterns of retention over time are assumed, one for years 1990–1997 and another one from 1998 onwards.

Since fishing selectivity is length-based but the population model is structured by age, a way to relate ages and lengths is required. This is done through the proportion of fish of age a (where, for each season and morph, a corresponds to real age from birth at the mid-time point of the season) that belong to length interval l, computed as the probability that a Normal random variable with mean L_a and coefficient of variation CV_a is in length interval l. Mean length at age a (L_a) is defined as a linear function going from the lowest end-point of the first length interval at age 0 (birth time) to $L_{\min}$ at age $a_{\min}$ (an age that must be selected and fixed). Above $a_{\min}$, mean length at age follows a Von Bertalanffy growth model with annual growth rate K, asymptotic length L_∞, and parameterised to go through $L_{\min}$ at age $a_{\min}$. The coefficient of variation of length at age (CV_a) is equal to some values CV_{young} and CV_{old} for ages below $a_{\min}$ and above A, respectively, and interpolates between these two ends using a linear function of mean length-at-age. In the northern hake assessment, $a_{\min}$ is chosen as 0.75, L_∞ is fixed at 130 cm, and K and $L_{\min}$ are treated as unknown parameters. The values of CV_{young} and CV_{old} are fixed at 0.2 and 0.1, respectively. All these parameters are assumed to be constant throughout the entire assessment period (years 1978-2010).

Total annual recruitment in year y, R_y, is given by a log-normal distribution, where the mean value is defined by the Beverton and Holt stock recruitment relationship, parameterised in terms of steepness h and equilibrium recruitment under no fishing R_0. In the northern hake assessment, steepness is fixed at h = 0.999, essentially implying no stock-recruitment relationship, and the coefficient of variation of the log-normal distribution is fixed at $\sigma_R = 0.4$.

Total annual recruitment R_y is apportioned to the areas z and seasons s in which recruitment is allowed to take place according to

$$R_{z,s,y} = R_y \frac{\exp(\rho_{z,y} + \rho_{s,y})}{\sum_{z,s} \exp(\rho_{z,y} + \rho_{s,y})}$$

where the sum in the denominator is over the areas and seasons in which recruitment is allowed. For northern hake, recruitment is allowed in the two areas in quarters 2 and 3, and the recruitment allocation parameters are defined such that the proportion of recruitment between the two areas and the two quarters is allowed to vary between years.,

Movement is modelled as the proportion of the population in an area moving to another area and, in the current hake model, is assumed to take place annually at the start of the year. There are two movement parameters per area pair. The first parameter defines movement for fish below some age (*min_age*) and the second parameter does the same for fish above some age (*max_age*), with values for intermediate ages calculated by linear interpolation. In the northern hake application, *min_age* and *max_age* are set, respectively, at ages 1 and 3, and it is assumed that there is no movement below age 1, whereas the movement parameter for *max_age* is estimated. We thus assume that hakes remain in their recruitment area until they mature (which takes place around age 3-4) and that they have the possibility to move to another area afterwards.

In the present analysis, we tested the following alternative models structures:

- Fit 1 : a combined area model in which each fleet has its own selectivity.
- Fit 2 : a two-area model without movement between areas and where each fishing fleet has its own selectivity (acting on the corresponding model area).
- Fit 3 : a two-area model without movement between areas and assuming the same selectivity for fishing fleets using the same gears (trawl) or group of gears (gillnet and longline) in different areas (*i.e.* same selectivity for TR7 and TR8, and for GL7 and GL8).
- Fit 4 : a two-area model with movement between areas and selectivities as in Fit 3 above.

Results

Selectivity curves and F at fully selected lengths

Estimated selectivity curves roughly reflect differences in length composition of the catch among fishing fleets and surveys (Figures 4 and 5). None of the fleets for which the double normal selectivity has been used displays asymptotic selectivity, even though the double-normal function allows this. Asymptotic selectivity has been imposed on the fleet that catches the larger fish (“North”). This is important as it means that the model has little information on the distribution of larger fish, given that the larger fish are not seen by the surveys or most of the fishing fleets. Comparing the 4 fits, selectivity for GL7, GL8 and NEP8 fleets is relatively stable from one fit to the other. This is different for the trawl fleets TR7 (Celtic sea) and TR8 (Bay of Biscay): when separate selectivities are allowed for the two of them (Fits 1 and 2), TR7 displays higher selectivity on larger fish than TR8 (the same happens for fleets GL7 and GL8, although the effect is less strong). The fleet "North" shows similar selectivity for Fits 1 to 3. For Fit 4, however, the only fit that allows movement between areas, a higher selectivity is estimated on small fish. For the surveys, there is little difference in selectivity between fits in general, except for the PORCUPINE survey.

Clearly, the estimated selectivity curves are not independent for different fleets. For example, the selectivity of a fleet with a higher proportion of large fish in its catch will be expected to be higher on those large lengths of fish than the selectivity of a fleet with a lower proportion of large fish in its catch (assuming that both fleets operate in the same model area, as population age-structure can also differ between areas and is also correlated with the resulting selectivity estimates). Population age-structure by area is also related to recruitment allocation between areas and movement of fish later in life (displayed in Figures 8 and 9). All this leads to complex correlation structures between recruitment allocation to areas, fishing pressure and selectivity in each area, and movement of fish between them, which are not easy to unravel.

Quarterly time series of F at fully selected lengths are presented in Figure 6, for each fishing fleet. It must be noted that F for each fleet applies only to the part of the population that is in the area in which the fleet operates and not to the entire stock. For fleets GL8 and TR8, higher F values are estimated for the fits with two areas and no movement (Fits 2 and 3), which could be related to the fact that older fish are not seen in the Bay of Biscay and, if the model does not allow them to migrate out of the area, then they must be disappear via higher fishing mortalities. For the TR7 fleet, higher F values are estimated for Fit 4, the fit that allows movement between areas. It is difficult to give a direct interpretation to these results for F, given that F here corresponds to fully selected lengths (*i.e.* is a scalar factor to be applied to the selectivity curve) and the selectivity curves estimated for the fleets vary across fits (Figure 4).

Growth parameters and catch composition

Estimated growth parameters (L_{min} and K) are very similar for all fits (Table 3). There is a good correspondence between estimated mean length-at-age and apparent modes in the length frequency distributions. Some examples of fits to length distribution data from Fit 4 are given in Figure 7.

Recruitment, stock distribution and movement in the spatially disaggregated fits.

Figure 8 presents the estimated recruitment and total biomass share between the two areas for the fits with spatial structure (Fits 2, 3 and 4), and Figure 9 presents estimated movement rates for Fit 4, which is the only one in which movement between areas is allowed. As a general feature for all fits (including several model configurations not shown here), the model estimates larger recruitment in the Bay of Biscay than in the Celtic Sea & North area. When movement is allowed between areas, the recruitment proportion in the Celtic Sea & North area becomes much smaller, ranging from 5% to 30%, depending on the year. Estimates of total biomass distribution by area differ to some extent between fits with and without movement. Estimates from Fit 2 and Fit 3 indicate that the stock is located mainly in the Celtic Sea & North area, while for Fit 4 (the fit that allows movement) the distribution of biomass between areas is much more even. When movement is allowed, net movement rates of hake are estimated to occur from south (Bay of Biscay) to north (Celtic Sea & North), as can be deduced from Figure 9.

Population trends

Trends in total recruitment, annual fishing mortality on the stock (calculated as an average over ages 1 to 4) and spawning stock biomass are presented in Figure 10. Overall trends are similar for all fits. Recruitment fluctuations appear to be without substantial trend over the whole series, with some good recruitments in the last years. SSB has decreased steadily from the start of the series until the end of the 1990s, which a sharp increase in recent years. Values of F increased from around 0.3-0.4 in the late 1970s and early 1980s, to around 1.0 during the 1990s. F declined sharply afterwards, to around 0.2-0.3 in 2010. The increasing biomass trend in recent years is driven by some good recruitments in combination with low values of F. For Fit 4, in which movement is allowed, the stock is estimated to be much larger.

Discussion

Some generic features were found in all the estimations carried out to date. One of them is that the model tends to estimate more recruitment in the Bay of Biscay area than in the "Celtic Sea & North" area. When movement is allowed, the model then transfers a substantial proportion of fish from the southern to the northern area at older ages, consistent with the fact that fewer larger fish are observed in the catches of fleets fishing in the south compared with those fishing in the north. When no movement is permitted, the model deals with the fact that fewer larger fish are seen in the south area by increasing the fishing mortality rates of the GL8 and TR8 fleets (killing the fish at shorter lengths). These results suggest that better overall fits are obtained when there is more younger fish in the southern area and more older fish in the northern area, as shown in Figure 11, which is consistent with the length frequency distributions seen in catches. Depending on model configuration, the estimates of different model parameters (recruitment allocations, movement, fishing mortalities and selectivities by fleet) will interact with each other to reach this overall situation. Some preliminary sensitivity analysis carried out showed that the more movement is allowed from south to north, the more recruitment is allocated to the south.

The results of the northern hake analysis are still very preliminary and must be taken with caution. They illustrate how difficult estimating stock spatial distribution and movement rates can be without actual movement data (tags) or without several selectivities that can reasonably be assumed to be asymptotic. The current model configuration is based on several strong hypotheses and constraints that need to be investigated further. This investigation should include alternative choices of fleet selectivities, with more constraints on some of them, alternative movement parameterisations by age, further exploration of seasonal allocation of recruitment by area, including season-area interactions, and alternative spatial structures in the model.

References

Belloc, G., 1935. "Etude monographique du merlu Merluccius merluccius L., 3ème partie." Revue des Travaux de l'Office des Pêches maritimes 8: 145-202.

Bertignac, M. and de Pontual, H. 2007. Consequences of bias in age estimation on assessment of the northern stock of European hake (Merluccius merluccius) and on management advice. ICES Journal of Marine Science. 64 (5): 981–988.

Casey, J. and J. A. Pereiro, 1995. European hake (M. merluccius) in the North-east Atlantic. Hake: fisheries and markets. J. Alheit and T. J. Pitcher. London, Chapman & Hall: 125-147.

Darby, C. D. and S. Flatman, 1994. "Virtual Population Analysis: Version 3.1 Windows/Dos User Guide." MAFF Information Technology Series, 1. Directorate of Fisheries, Lowestoft.

de Pontual, H., Bertignac, M., Battaglia, A., Bavouzet, G., Moguedet, P., Groison, A.L., 2003. A pilot tagging experiment on European hake (*Merluccius merluccius*): methodology and preliminary results. ICES Journal of Marine Science, 60: 1318-1327.

de Pontual, H., Groison, A. L., Pineiro, C., and Bertignac, M. 2006. Evidence of underestimation of European hake growth in the Bay of Biscay, and its relationship with bias in the agreed method of age estimation. ICES Journal of Marine Science, 63: 1674–1681.

ICES. 2010. Report of the Benchmark Workshop on Roundfish (WKROUND), 9–16 February 2010, Copenhagen, Denmark. ICES CM 2010/ACOM:36. 183 pp.

ICES. 2011. "Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim." ICES CM 2011/ACOM:11: 625p.

Lucio, P., Murua, H., and Santurtun, M. 2000. Growth and reproduction of hake (*Merluccius merluccius*) in the Bay of Biscay during the period 1996–1997. Ozeanografika, 3: 325–354

Methot, R. D. 2005. Technical Description of the Stock Synthesis II Assessment Program Version 1.17, March 2005. Fisheries, N. O. A. A.

Pineiro C., and Sainza M. 2003. Age estimation, growth and maturity of the European hake (Merluccius merluccius (Linnaeus, 1758)) from Iberian Atlantic waters. – ICES Journal of Marine Science, 60: 1086–1102.

STECF. 2012. Scientific, Technical and Economic Committee for Fisheries: Management plans part 2 - developing area based management plans (STECF-12-14). EUR – Scientific and Technical Research series – ISSN 1831-9424 (online), ISSN 1018-5593 (print). 72pp.

Figures

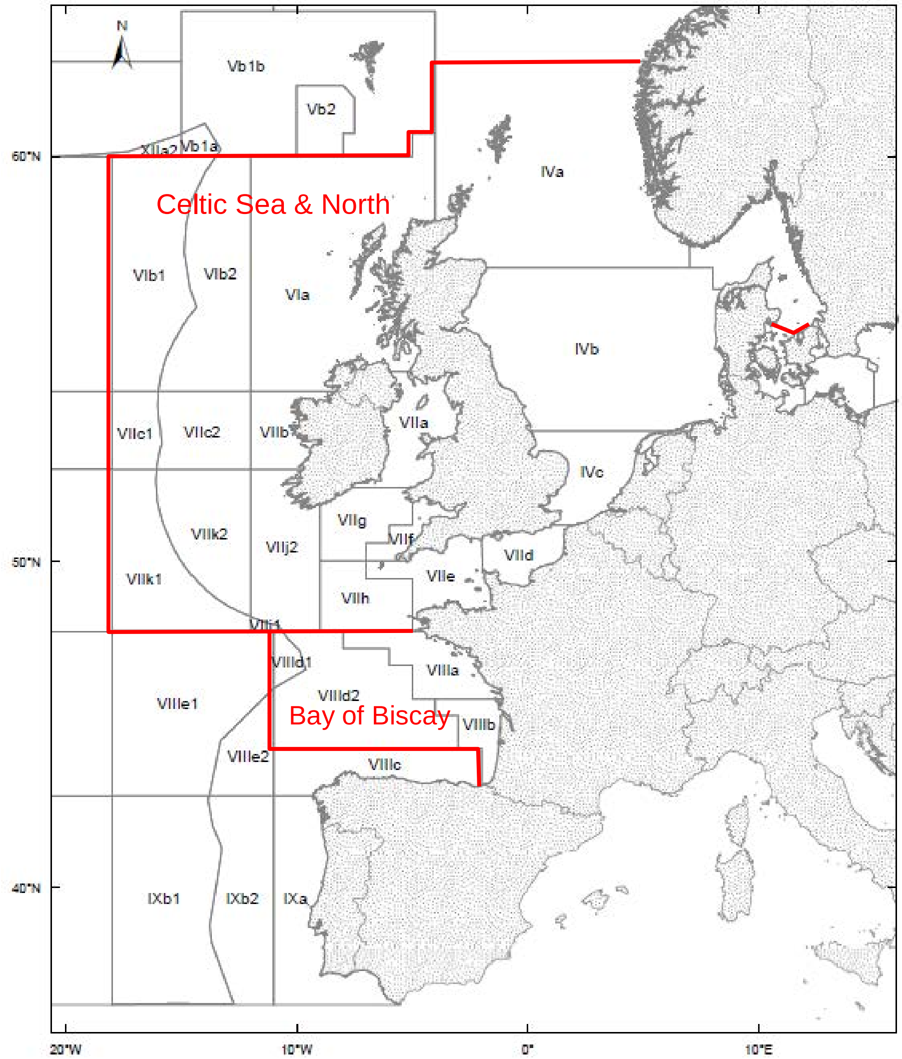

Figure 1. Regions defined for the spatial stratification of the model

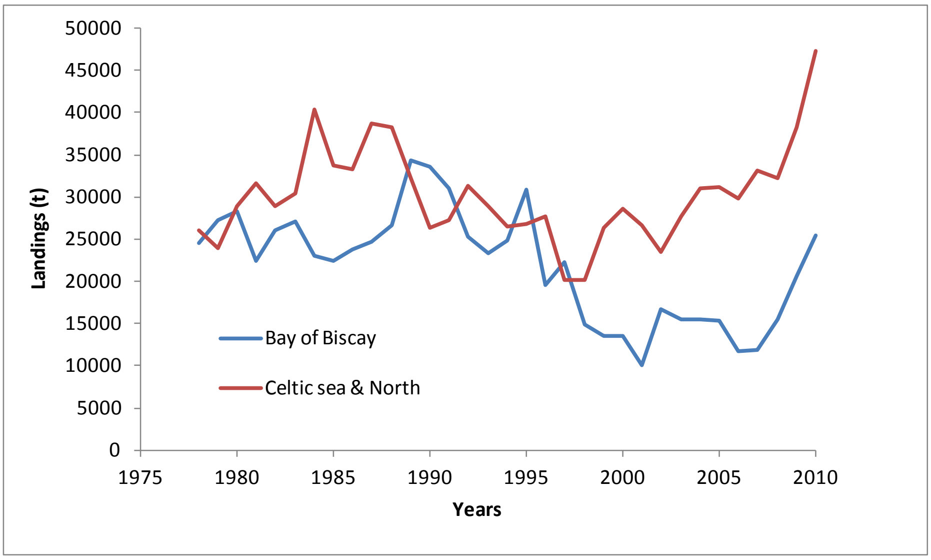

Figure 2. Trends in landings by area defined in the assessment model.

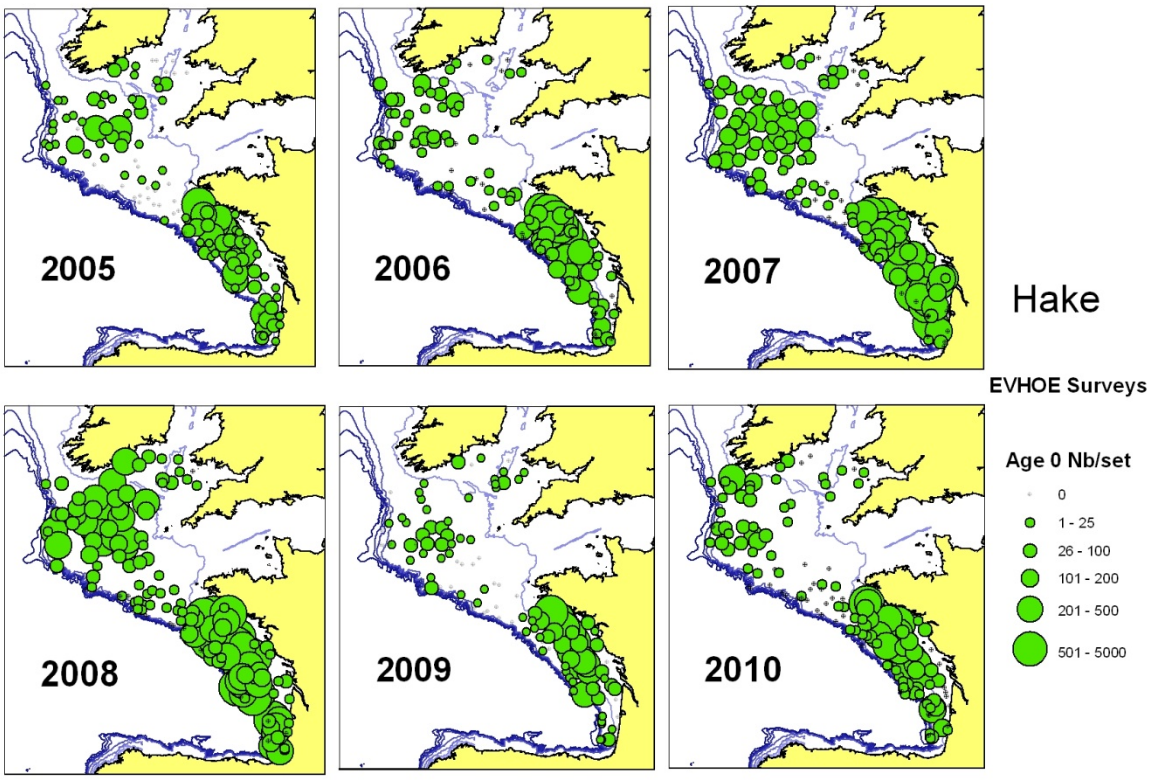

Figure 3. Spatial distribution of hake (0-20 cm) indices from EVHOE survey from 2005 to 2010.

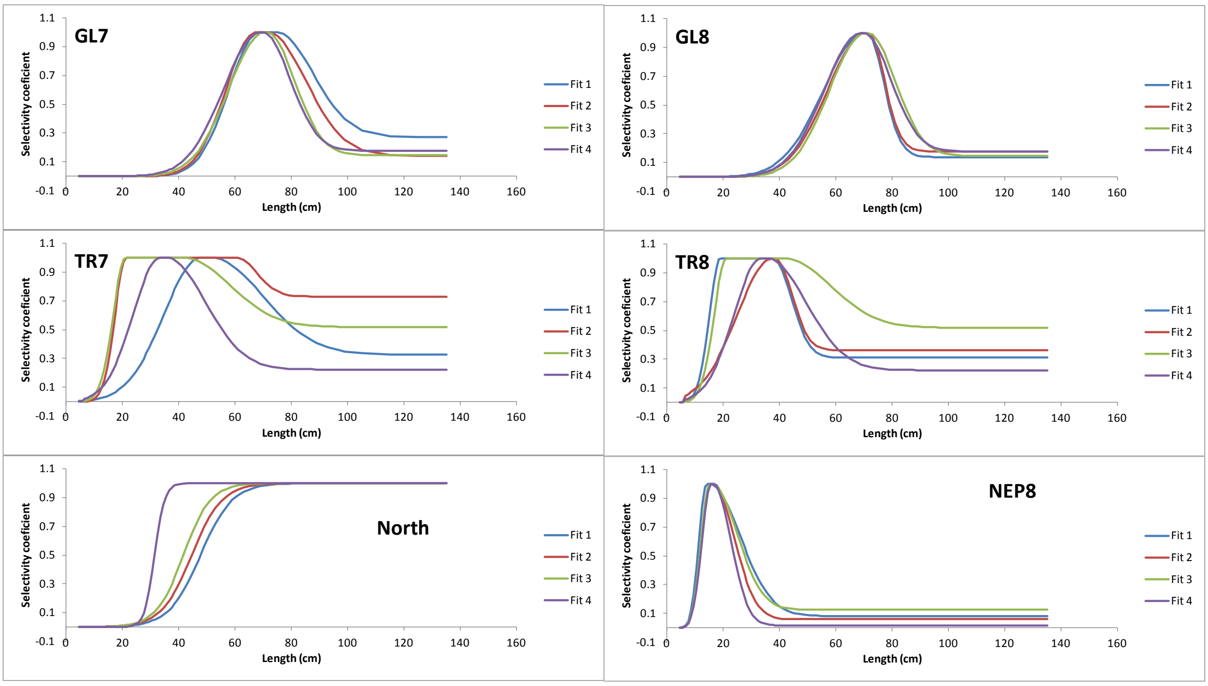

Figure 4. Estimated northern hake selectivity coefficients by commercial fleets for the 4 fits (see text for fit settings).

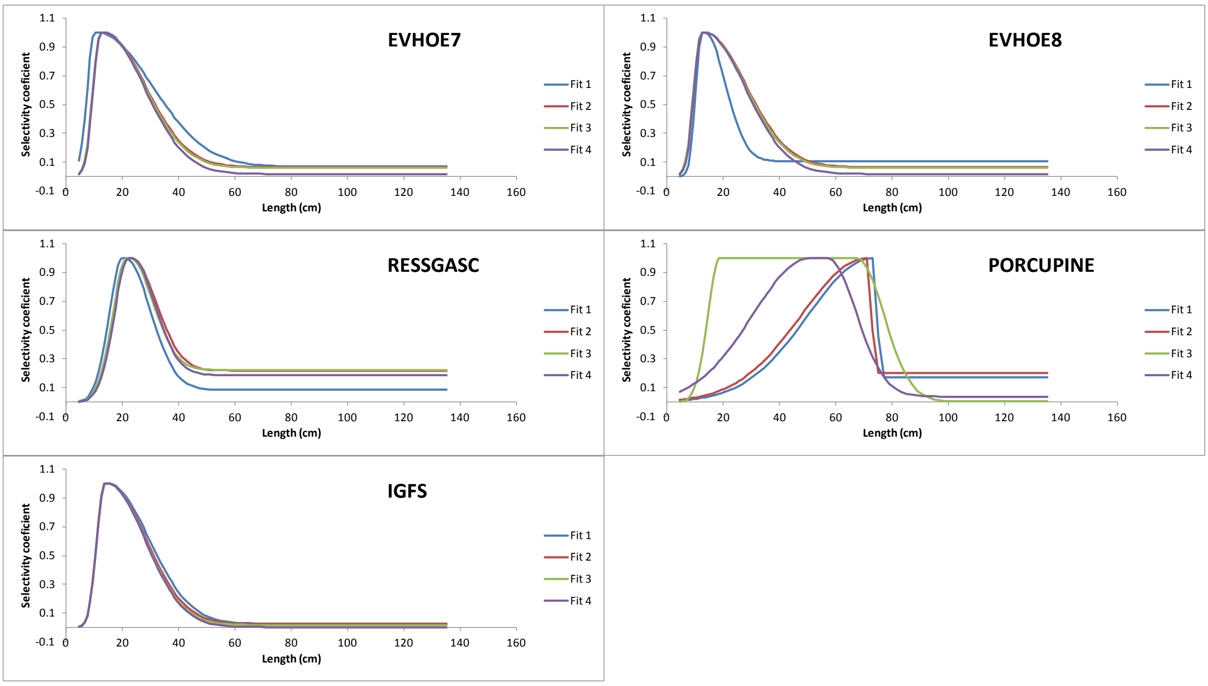

Figure 5. Estimated northern hake selectivity coefficients by suveys for the 4 fits (see text for fit settings)

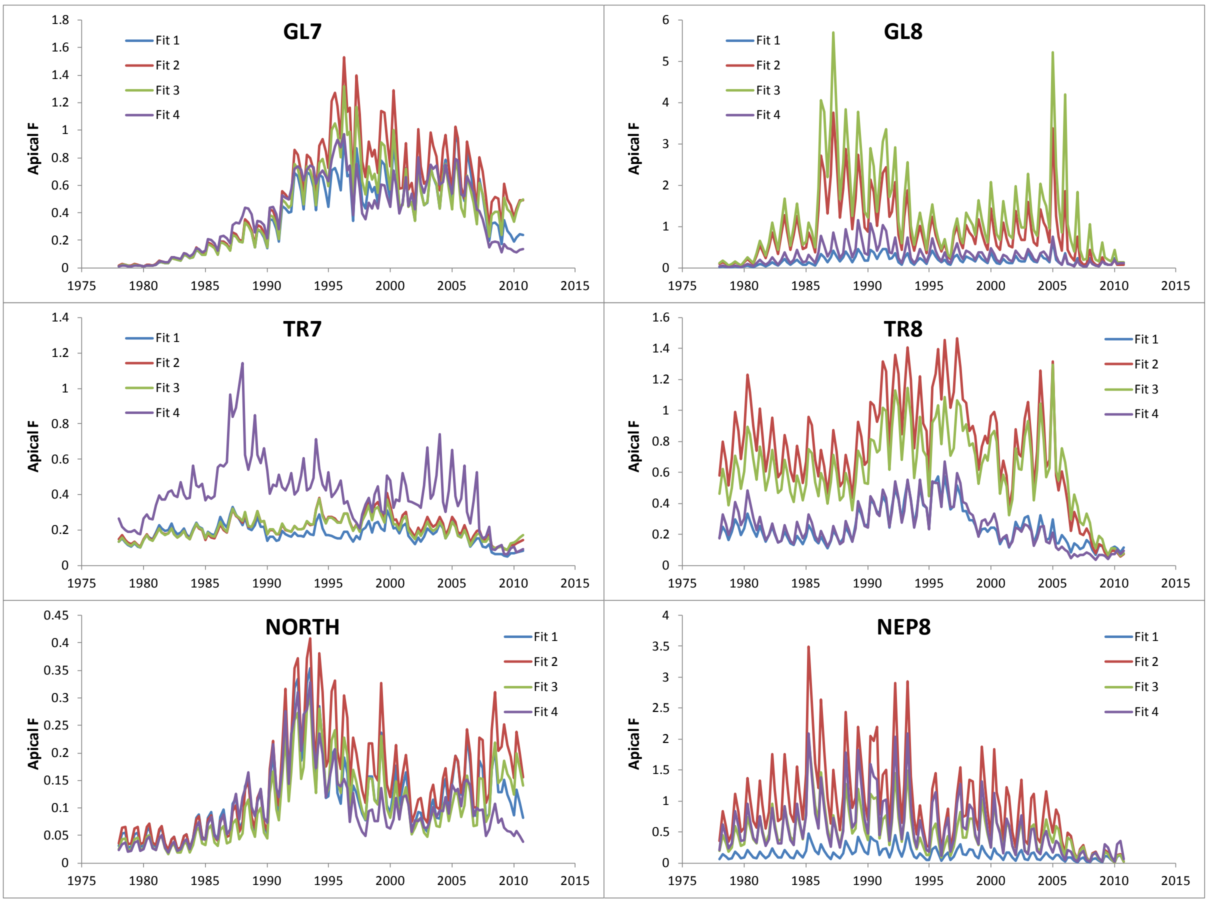

Figure 6. Estimated northern hake apical F by fleet for each fit (see text for fit settings).

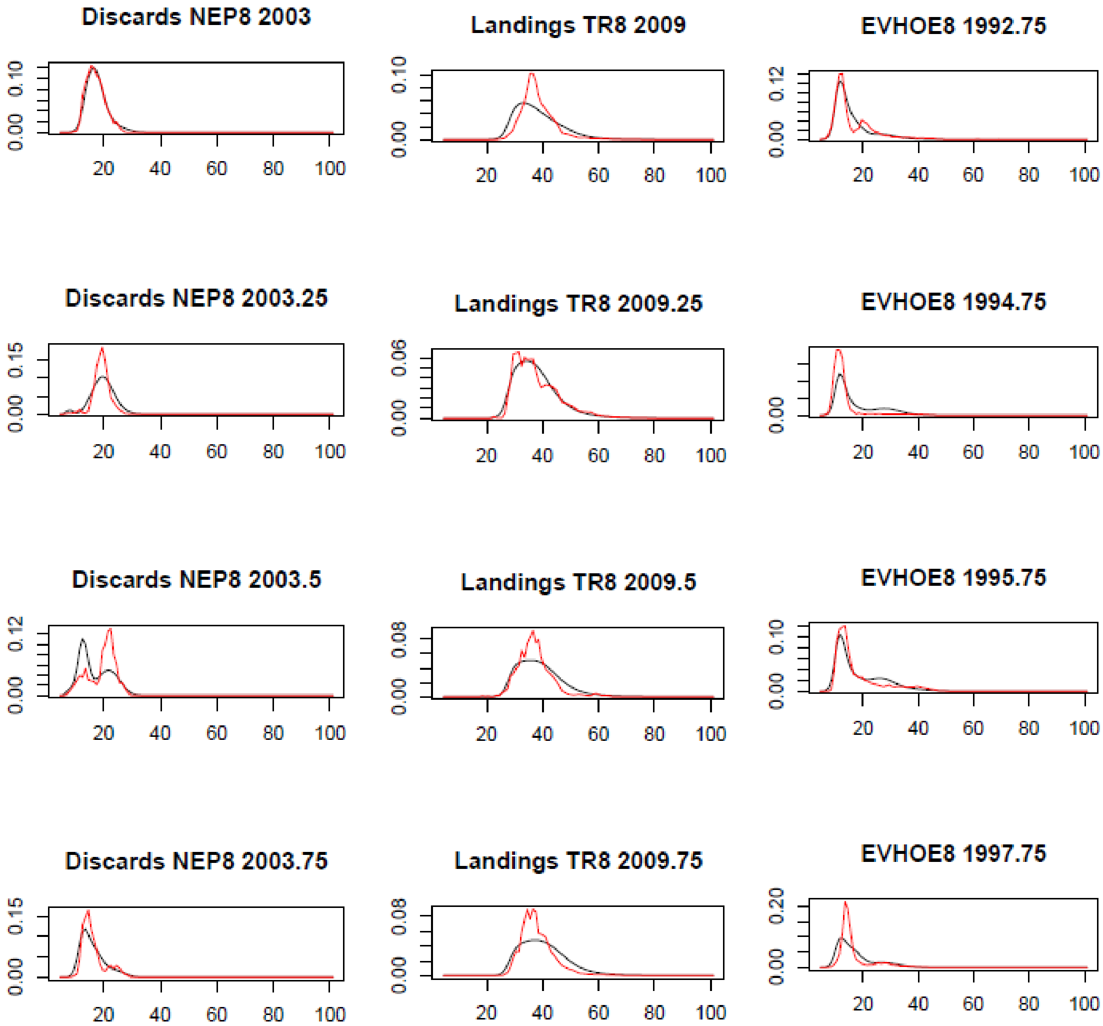

Figure 7. Examples of fits to quarterly length frequency distributions (Fit 4) of discards from the NEP8 fleet in 2003 (left), landings of the TR8 fleet in 2009 (center) and survey EVHOE8 in 1997 (right).

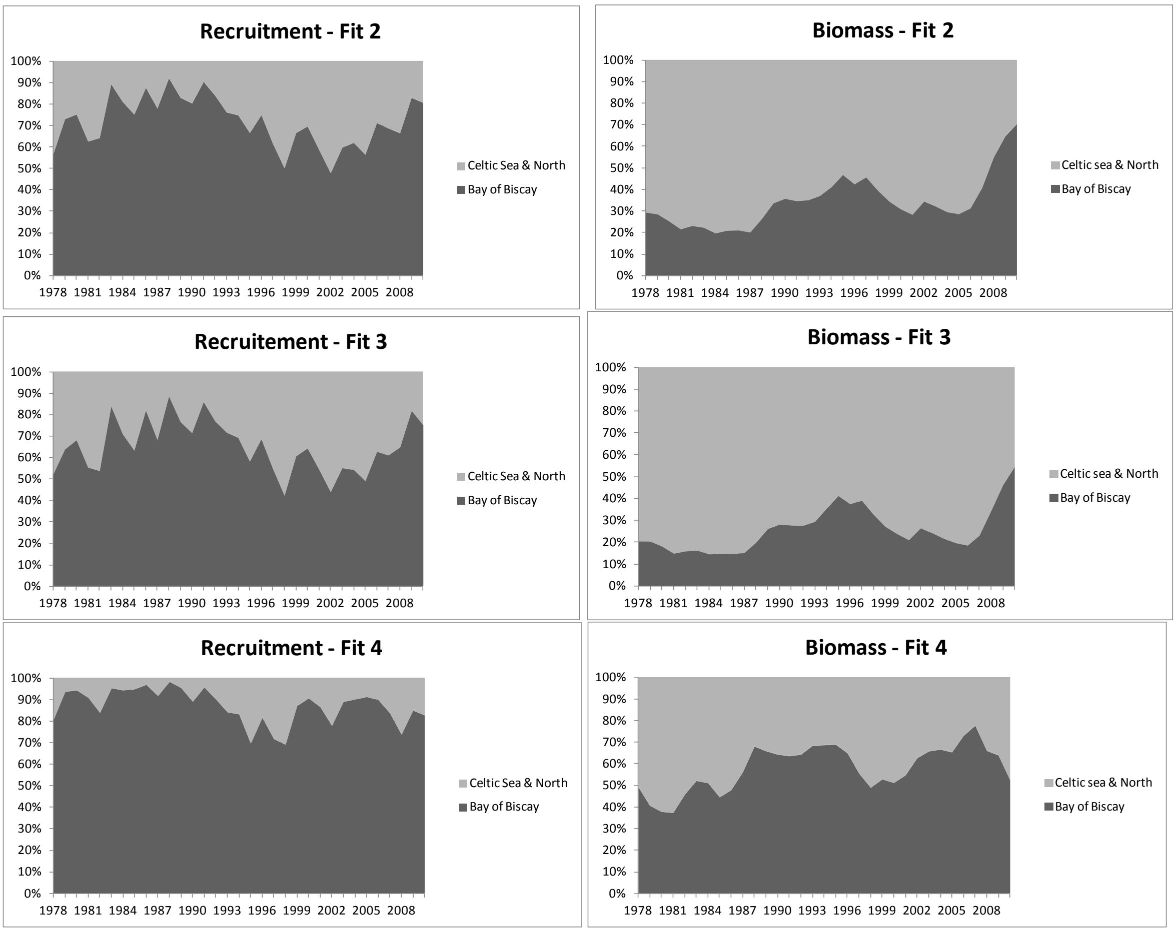

Figure 8. Recruitment (left) and total biomass (Right) allocation by area estimated for northern hake in the fits with spatial structure.

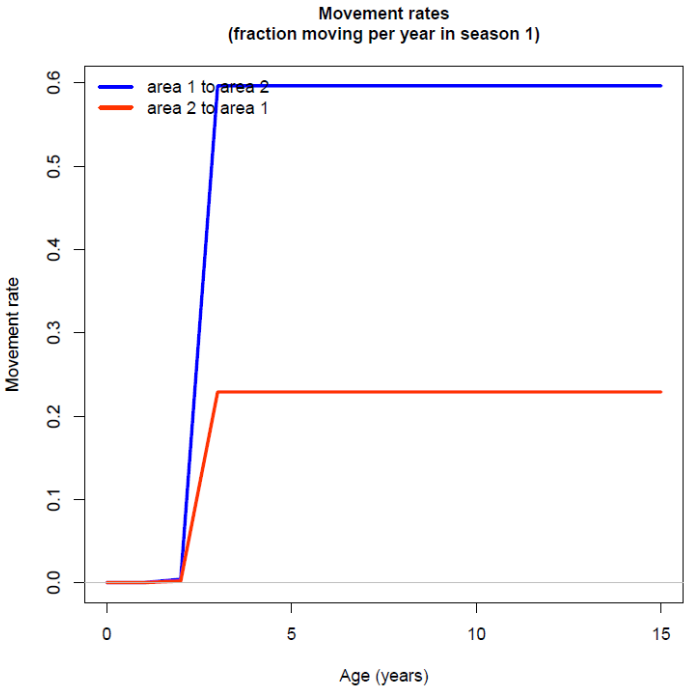

Figure 9. Movement rates estimated for northern hake in Fit 4

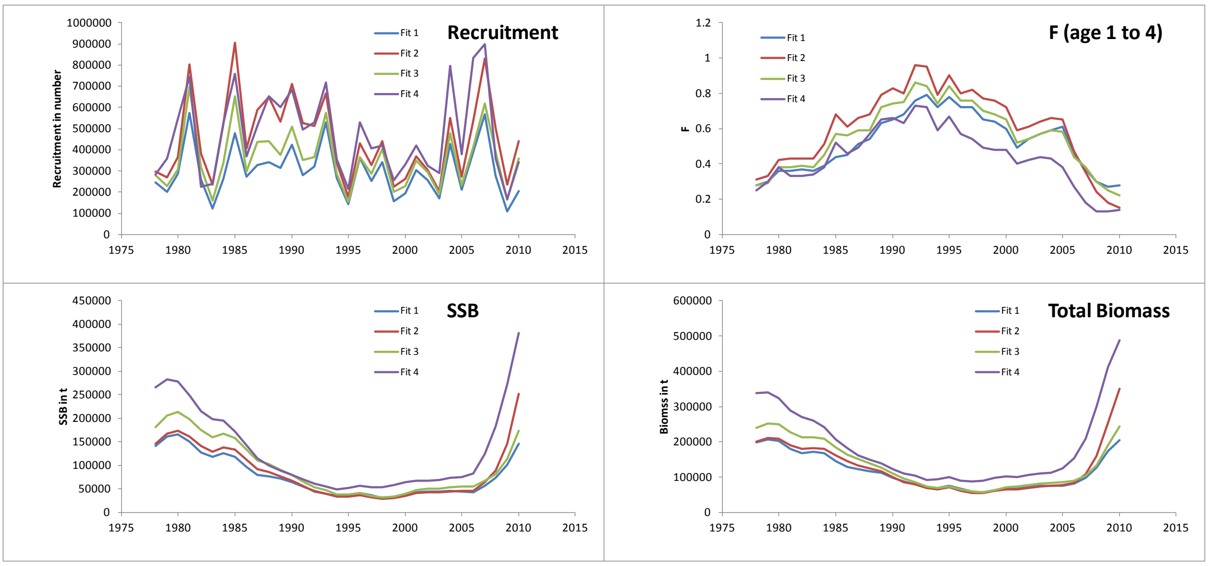

Figure 10. Historical trends in Recruitment, $F_{1\text{-}4}$ and SSB estimated for northern hake

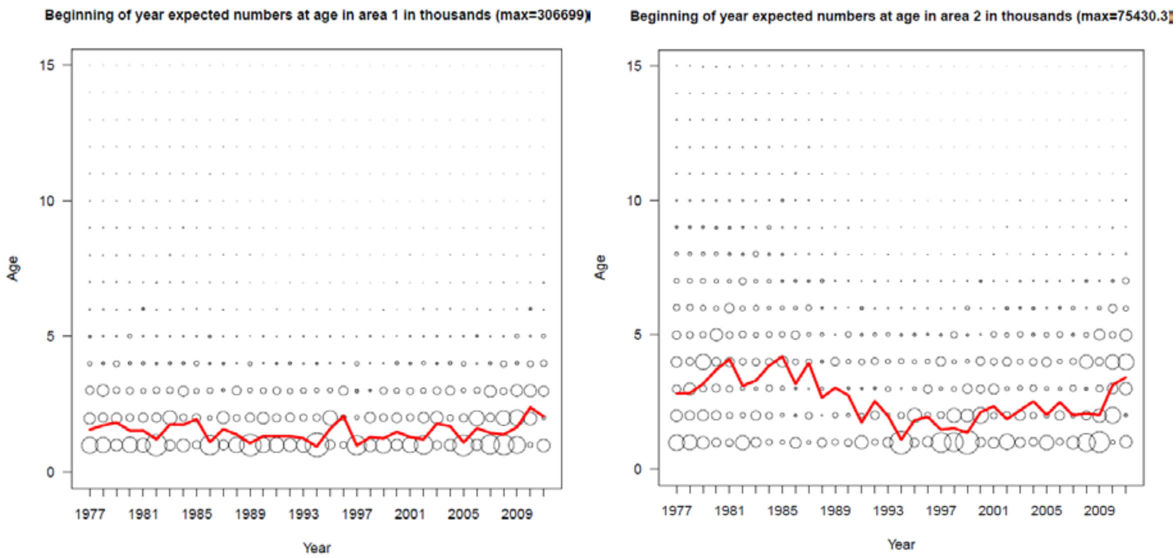

Figure 11. Estimated number at age by area for northern hake and Fit 4: area 1 is the Bay of Biscay and area 2 is the "Celtic Sea & North" area.

Tables

Table 1. Fleets characteristics and data available (Length Frequency distribution (LFD) and weight of landings and discards (W))

FLEETS	DESCRIPTION	LANDINGS	DISCARDS
GL7	Gillnet and Longline in VII	Yearly : 1978-1989 (LFD+W) Quarterly: 1990-2010 (LFD+W)	
TR7	Trawl in VII	Yearly : 1978-1989 (LFD+W) Quarterly: 1990-2010 (LFD+W)	1994, 1999, 2000, 2003–2008 (LFD + W)
GL8	Gillnet and Longline in VIII	Yearly : 1978-1989 (LFD+W) Quarterly: 1990-2010 (LFD+W)	
TR8	Trawl in VIII	Yearly : 1978-1989 (LFD+W) Quarterly: 1990-2010 (LFD+W)	2005–2008 (LFD + W)
NEP8	French trawl targeting *Nephrops* in VIII	Yearly : 1978-1989 (W) Yearly : 1985-1989 (LFD) Quarterly : 1990-2010 (LFD+W) Missing LFD for 1992 and 2000	2003–2008 (LFD + W)
NORTH	Miscelaneous gears, Division IIIa, Subareas IVand VI	Yearly : 1978-1989 (LFD+W) Quarterly: 1990-2010 (LFD+W) Missing LFD for 1992	

Table 2. Surveys characteristics and data available

SURVEYS	AREA	YEARS	QUARTER
EVHOE7	Celtic sea	1997–2010	4
EVHOE8	Bay of Biscay	1987–2010	4
RESSGASC	Bay of Biscay	1987–1997 1998–2001	1, 2 ,3 and 4 2 and 4
PORCUPINE	Porcupine Bank	2001–2010	3
IGFS	North, West and South of Ireland	2003–2010	4

Table 3. Growth parameters estimated for northern hake for the 4 fits

	L_{min}	K
Fit 1	18.326	0.136
Fit 2	18.062	0.144
Fit 3	18.495	0.144
Fit 4	18.580	0.128