Stock Annex: Hake (*Merluccius merluccius*) in divisions 8.c and 9.a, Southern stock (Cantabrian Sea and Atlantic Iberian waters)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Hake
Working Group	Working Group for the Bay of Biscay and the Iberic waters Ecoregion (WGBIE)
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A. General

A.1. Stock definition

Southern hake stock comprises the Atlantic coast of Iberian Peninsula corresponding to the ICES divisions 8.c and 9.a. The Northern limit is in the Spanish – French boundary and the Southern one in Gibraltar Strait. These boundaries were defined based on management considerations without biological basis.

Atlantic and Mediterranean European hake are usually considered as different stocks due to the differences in biology (i.e. growth rate or spawning season) of the populations in both areas. In the North-eastern Atlantic, there is no clear evidence of the existence of multiple hake populations, although Roldán *et al.* (1998) based on genetic studies states that "*the data (…) indicate that the population structure within the Atlantic is more complex than the discreete northern and southern stocks proposed by ICES*". It is likely that there is a degree of transfer between the Southern and Northern hake stocks, and recent studies on population genetics support that (Balado *et al*., 2003; Pita *et al*., 2010; Pita *et al.*, 2011), however there is at present a lack of data to quantify the amount of migrations between stocks.

A.2. Fishery

Hake in divisions 8.c and 9.a is caught in a mixed fishery by the Spanish and Portuguese fleets (trawls, gillnetters, longliners and artisanal fleets).

The Spanish trawl fleet is quite homogeneous and uses mainly two gears, pair trawl and bottom trawl. The percentage of hake present in the landings is small as there are other important target species (i.e. anglerfish, megrims, Norway lobster, blue whiting, horse mackerel and mackerel). During recent years there has been an increase in Spanish trawlers using a new High Vertical Opening gear towed by single vessels and targeting the pelagic species listed above. In contrast, the artisanal fleet is very heterogeneous and uses a wide variety of gears; traps, large and small gillnet, longlines, etc. The trawl fleet landings length composition, since the implementation of the minimum landing size in 1991, has a mode around 29–31 cm depending on the year. Artisanal fleets target different components of the stock depending on the gear used. Small gillnets catch smaller fish than gillnets and longlines, which target mainly large fish and have length composition with a mode above 50 cm. Hake is an important component of the catch for these fleets mainly due to the high prices that reaches in the Iberian markets.

Hake is caught by the Portuguese fleet in the trawl and artisanal mixed fisheries together with other fish and crustacean species. These include horse mackerel, anglerfish, megrim, mackerel, Spanish mackerel, blue whiting, red shrimp (*Aristeusantennatus*), rose shrimp (P*arapenaeuslongirostris*) and Norway lobster. The trawl fleet comprises two distinct components - the trawl fleet catching demersal fish (70 mm mesh size) and the trawl fleet targeting crustaceans (55 mm mesh size). The fleet targeting fish species operates along the entire Portuguese coast at depths between 100 and 200 m. The trawl fleet targeting crustaceans operates mainly in the southwest and south in deeper waters, from 100–750 m. The most important fishing harbours from Northern Portugal are: Matosinhos, Aveiro and FigueiraFoz, from Central Portugal are: Nazaré, Lisboa and Sines and Southern Portugal are: Portimão and Vila Real Santo António. The artisanal fleet lands hake mainly in the fishing harbours of the Centre. The main fishing harbours are Póvoa do Varzim (North), Sesimbra (Centre) and Olhão (South). Landings recorded by month show that the majority of the hake landings occur from May until October for both fleets.

A.3. Ecosystem aspects

European hake presents indeterminate fecundity and asynchronous development of the oocytes (Andreu, 1956; Murua *et al*., 1998; Domínguez-Petit, 2007). It is a serial or batch spawner (Murua *et al*., 1996). Duration of spawning season at the population level may differ between areas (Pérez and Pereiro, 1985; Alheit and Pitcher, 1995; Ungaro *et al*., 2001; Domínguez-Petit, 2007); but a latitudinal gradient exists such that the latest peaks of spawning occur in higher latitudes. In general, adults breed when water temperatures reach 10º or 12ºC, changing their bathymetric distribution depending on the region they are in and the local current pattern, releasing eggs at depths from 50 to 150m (Murua *et al*., 1996; 1998; Alheit and Pitcher, 1995). In general males mature earlier than females. Size at maturity is determined by density-dependent factors like abundance or age/length population structure and density independent factors like environmental conditions or fishing pressure (Domínguez *et al*., 2008). L50 varies between areas; in the Atlantic populations is between 40-47 cm (Lucio *et al*., 2002; Piñeiro and Saínza, 2003; Domínguez-Petit, 2007). Besides, temporal fluctuations in size at maturity within the population have been also observed what could reflect changes in growth rate (Domínguez *et al*., 2008). Changes in maturity parameters affect stock reproductive potential, because smaller and younger females have different reproductive attributes than larger and older individuals (Trippel *et al*., 1997; Mehault *et al.*, 2010). Maternal physiological status, spawning experience (recruit or repeat spawners) or food rations during gametogenesis are all known to alter fecundity, egg and larval quality, as well as duration of the spawning season (Hislop *et al*., 1978; Kjesbu *et al*., 1991; Trippel, 1999; Marteinsdottir and Begg, 2002). Change in stock structure entails a compensatory response of age/size at maturity because depletion of large fish can be compensated by increased egg production by young fish (Trippel, 1995).

Hake recruitment indices have been related to environmental factors (Sanchez and Gil, 2000). High recruitments occur during intermediate oceanographic scenarios and decreasing recruitment is observed in extreme situations. In Galicia and the Cantabrian Sea, generally moderate environmental factors such as weak Poleward Currents, moderate upwelling and good mesoscale activity close to the shelf lead to strong recruitments. Hake recruitment leads to well-defined patches of juveniles, found in localized areas of the continental shelf. These concentrations vary in density according to the strength of the year class, although they remain generally stable in size and spatial location. These authors have related the year-on-year repetition of the spatial patterns to environmental conditions. In the eastern, progressively narrowing, shelf of the Cantabrian Sea, years during which there is massive inflow of the eastward shelf edge current produce low recruitment indices, due to larvae and prerecruits being transported away from spawning areas to the open ocean.

In Portuguese continental waters the abundance of small individuals is higher between autumn and early spring. In the Southwest main concentrations occur at 200-300 m depth, while in the South they are mainly distributed at coastal waters. In the North of Portugal recruits are more abundant between 100-200 m water depths. These different depth-areas associations may be related with the feeding habits of the recruits, since the zooplankton biomass is relatively higher at those areas.

Hake is a highly *ichthyophagous* species with *euphausiids* although decapod prawns are an important part of its diet for smaller hake (>20 cm). In Galicia and the Cantabrian Sea hake is one of the apex predators in the demersal community, occupying together with anglerfish one of the highest trophic levels (Velasco *et al*., 2003). Its diet at >30 cm is mainly composed of blue whiting, while other species such as horse mackerel and clupeids are only important in shallow waters and in smaller individuals that also feed on other small fish. Along the Portuguese coast the diet of hake is mainly composed of crustaceans (particularly decapods) and fish. The main food items include blue whiting, sardine, snipefish, decapods and mysids. Cannibalism in the diet of hake is highly variable depending on predator size, alternative prey abundance, year or season. Cannibalism in stomach content observations ranged from 0 to 30% of total volume, with mean values about 5%; this produces a high natural mortality in younger ages.

B. Data

B.1. Commercial catch

Landings

The landings data used in the Southern Hake assessment are based on: (i) Portuguese sales notes compiled by the National Fisheries and Aquaculture Directorate; (ii) Spanish sales notes and owners associations data compiled by IEO; and (iii) Basque Country sales notes and Ship Owners data compiled by AZTI. Since 2011 Spanish landings are submitted by the national authority, which is a different procedure from the past scientific estimations. Scientific landings estimates are presented as UNALLOCATED

From 1982 to 1993 only annual landings for Spain were available. The length distributions of landings were computed by quarter after 1994. Raising procedures are performed at the national labs before submitting the data. For the period before 1994, it was assumed that the existing annual length distribution was caught in the middle of the year.

Discards

A Spanish Discard Sampling Programme is being carried out in Divisions 8.c and 9.a North since 1993. The series provides information on discarded catch in weight and number and length distributions for Southern hake. Spanish sampling was carried out in 1994, 1997, 1999-2000 and from 2003 onwards. The number of trips sampled by the Spanish program was distributed by three trawl fleets: Baca otter trawl, Pair trawl and

HVO (High Vertical Opening) trawl. Total discards were estimated raising sampling with effort. This series was revised and computed by quarter from 2004 onwards.

The Portuguese Discard Sampling Programme started in 2003 (second semester) and is based on a quasi-random sampling of co-operative commercial vessels. Two trawl fleets are sampled in this programme: Crustacean Trawl and Fish Trawl fleets. The discards estimation method was revised to take into account fishing hours as auxiliary variable and include outlier analysis.

Both series of discarded weights were rebuilt back to 1992 based on the relationships between discards and surveys, and discards and landings (ICES, 2010), with the aim of integrating them in assessment models.

B.2. Biological

A full revision of hake ecology was performed by Murua (2010). The sampling of commercial landings is carried out by the Fisheries Institutes involved in the fishery assessment (AZTI, IEO and IPMA) since 1982, except in the Gulf of Cadiz where length distributions are available only since 1994. The length composition sampling design follows a multistage stratified random scheme by quarter, harbour and gear.

After 2010, the gear sampling was substituted by a métier sampling. Raising procedure in every sampled vessel is performed by weight category and then extended to total catch in every month, harbour and gear (or métier after 2010). If there was any gap in the sampling procedure this was covered with the available information from the same quarter. Previous to 1994, only annual length distributions were available.

An international length-weight relationship for combined sexes for the whole period has been used since 1999 (a=0.00000659, b=3.01721).

Age information (otoliths) are collected by IEO, AZTI and IPMA. However, due to doubts on growth patterns and unstable ageing criteria, a von Bertalanffy growth model with t0=0, L_{inf}=130 cm and k~0.16 (where k is re-estimated by the stock assessment model every year) is used. The L_{inf} parameter value was chosen based on tagging data collected for the northern stock on the French coast and k estimates by the assessment models carried out during the Benchmark (ICES, 2010)

Natural mortality was assumed to be 0.4 year-1, instead of the past 0.2. The rationale is that if hake grows about two times faster, the hake longevity is reduced around half (from age ~20 to ~10). Hewit and Hoening (2005) estimate a relationship among longevity and M that produces a figure around 0.4. This value was set equal for all ages and years.

Maturity proportions-at-length was estimated with sexes combined from IEO sampling. Data available from IPMA and AZTI since 2004 were not considered due to inconsistencies with the IEO data. Maturity at length used to estimate population mature biomass was estimated with a logistic function (outside GADGET model) for all the years.

Hake is a dimorphic species where males mature at smaller size than females and also attain smaller asymptotic size (Cerviño, 2014, Murua, 2010).

B.3. Surveys

The Spanish October groundfish (spGFS-WIBTS-Q4) survey uses a stratified random sampling design with half hour hauls and covers the northwest area of Spain from Portugal to France during September/October since 1983 (except 1987).

Two groundfish surveys are carried out annually in the Gulf of Cadiz - in March, from 1994, and in November (spGFS-caut-WIBTS-Q4), from 1997. A stratified random sampling design with 5 bathymetric strata, covering depths between 15 and 700 m, is used in this area, with one hour hauls. Hake otoliths have been collected since 2000.

The Portuguese October groundfish (ptGFS-WIBTS-Q4) survey has been carried out in Portuguese continental waters since 1979 on board the RV "Noruega" and RV "Capricórnio". Work on calibration of these vessels showed a higher catchability of Capricórnio, in particular at lower sizes, as a consequence these years were calibrated. The main objective of this survey is to estimate hake's abundance indices to be used in stock assessment (Anon., 2008). A stratified sampling design was used from 1989 until 2004. In2005 a new hybrid random-systematic sampling design was introduced, composed by a regular grid with a set of additional random locations (Jardim and Ribeiro Jr., 2007; Jardim and Ribeiro Jr., 2008). The tow duration was 60 minutes until 2001 and reduced to 30 minutes for subsequent years, based on results of an experiment showing no significant differences in the mean abundance and length distribution between the two tow durations (Cardador personal communication, 2007).

B.4. Commercial cpue

Effort series are collected from Portuguese logbooks and compiled by IPMA, and from Spanish sales notes and Owners Associations data and compiled by IEO.

Landings, LPUE and effort are available for A Coruña trawl (SP-CORUTR) and Portuguese trawl (P-TR) fleets.

The cpue series (1989-present) of Portuguese trawlers is standardized using a GLM model with Gamma residuals, a "log" link function and explanatory variables year, zone, engine power, métier, percentage of hake in the catch, level of total catch and level of fishing effort.

Tuning data table (Table 1) shows details about these surveys and LPUEs as well as their use in the assessment model.

C. Historical Stock Development

Until 2008 this stock was assessed with XSA models based on ages estimated from ALK. In 2009 a Bayesian VPA was introduced. Since 2010, based on the decisions of the Benchmark a length based model with GADGETwas introduced.

C.1. Description of gadget

Gadget is an acronym for the "Globally applicable Area Disaggregated General Ecosystem Toolbox", which is a statistical model of marine ecosystems. Gadget was previously known as BORMICON and Fleksibest. Gadget is an age–length structured forward-simulation model, coupled with an extensive set of data comparison and optimization routines. Processes are generally modelled as dependent on length, but age is tracked in the models, and data can be compared on either a length and/or age scale. The model is designed as a multi-area, multifleet model, capable of including predation and mixed fisheries issues; however, it can also be used on a single species basis. Gadget models can be both very data- and computationally intensive, with optimization in particular taking a large amount of time. Worked examples, a detailed manual and further information on Gadget can be found on www.hafro.is/gadget. In addition, the structure of the model is described in Begley and Howell (2004), and a formal mathematical description is given in Frøysa *et al.* (2002).

Gadget is distinguished from many stock assessment models used within ICES (such as XSA) in that Gadget is a forward simulation model, and is structured by both age and length. It therefore requires direct modelling of growth within the model. An important consequence of using a forward simulation model is that the plus groups (in both age and length) should be chosen to be large enough that they contain few fish, and the exact choice of plus group does not have a significant impact on the model.

Setup of a gadget run

There is a separation of model and data within Gadget. The simulation model runs with defined functional forms and parameter values, and produces a modelled population, with modelled surveys and catches. These surveys and catches are compared against the available data to produce a weighted likelihood score. Optimization routines then attempt to find the best set of parameter values. Growth is modelled by calculating the mean growth for fish in each length group for each time-step, using a parametric growth function. In the hake model a Von Bertanlanffy function has been employed to calculate this mean growth. The actual growth of fish in a given length cell is then modelled by imposing a beta-binomial distribution around this mean growth. This allows for the fish to grow by varying amounts, while preserving the calculated mean. The beta-binomial is described in Stefansson (2001). The beta-binomial distribution is constrained by the mean (which comes from the calculated mean growth), the maximum number of length cells a fish can grow in a given time-step (which is set based on expert judgement about the maximum plausible growth), and a parameter β, which is estimated within the model. In addition to the spread of growth from the beta-binomial distribution, there is a minimum to this spread due by discretization of the length distribution.

Catches

All catches within the model are calculated on length, with the fleets having size-based catchability. This imposes a size-based mortality, which can affect mean weight and length-at-age in the population (Kvamme 2005). A fleet (or other predictor) is modelled so that either the total catch in each area and time interval is specified, or this catch per time-step is estimated. In the hake assessment described here the commercial catch and the discards are set (in kg per quarter), and the surveys are modelled as fleets with small total landings. The total catch for each fleet for each quarter is then allocated among the different length categories of the stock according to their abundance and the catchability of that size class in that fleet.

Likelihood Data

A significant advantage of using an age–length structured model is that the modelled output can be compared directly against a wide variety of different data sources. It is not necessary to convert length into age data before comparisons. Gadget can use various types of data that can be included in the objective function. Length distributions, age length keys, survey indices by length or age, cpue data, mean length and/or weight at age, tagging data and stomach content data can all be used. Importantly, this ability to handle length date directly means that the model can be used for stocks such as hake, where age data are sparse or considered unreliable. Length data can be used directly for model comparison. The model is able to combine a wide selection of the available data by using a maximum likelihood approach to find the best fit to a weighted sum of the datasets.

Optimization

The model has two alternative optimizing algorithms linked to it, a wide area search simulated annealing (Corona *et al.*, 1987) and a local search Hooke and Jeeves algorithm (Hooke&Jeeves, 1961). Simulated annealing is more robust than Hooke and Jeeves and can find a global optimum where there are multiple optima, but needs about 2-3 times the order of magnitude number of iterations than the Hooke and Jeeves algorithm. The model is able to use both in a single run optimization, attempting to utilize the strengths of both. Simulated annealing is used first to attempt to reach the general area of a solution, followed by Hooke and Jeeves to rapidly home in on the local solution. This procedure is repeated several times to attempt to avoid converging to a local optimum. The algorithms are not gradient-based, and there is therefore no requirement on the likelihood surface being smooth. Consequently, neither of the two algorithms returns estimates of the Hessian.

Likelihood weighing

The total objective function to be minimized is a weighed sum of the different components. Selection of the weights is based on expert knowledge of the quality of the data, the space-time coverage of each dataset, and the internal variance of the dataset. An internal weight based on individual adjustments of the model (var) is used to reflect the variability of the dataset. This was done by optimizing the model to each dataset in turn, and inverting the resulting objective score to use as a weight for that dataset. This has the effect of assigning high weights to low variance datasets, and low weights to high variance ones. It also normalizes the weighted contribution of the different datasets. These weights were then adjusted to account for the length of the dataseries, the spatial coverage of the area inhabited by the stock, and an expert judgement about the relative quality of the different datasets. The final column (% weight) in the table below gives the final weighted contribution of each dataset to the optimized objective function.

Finding these weights is a lengthy procedure, but it does not generally need to be repeated for each assessment. Rather, the current weights can be used for several years. The weighed contribution of the datasets in a new assessment should be computed, and compared against the previous year. Provided the relative contributions are similar, then the model results should be comparable between years.

C.2. Settings for the hake assessment

The population is defined by 1cm length groups, from 1-130 cm and the year is divided into four quarters. The age range is 0 to 15 years, with the oldest age treated as a plus group. Recruitment happens in the first and second quarter. The length at recruitment is estimated and mean growth is assumed to follow the von Bertalanffy growth function with L_{inf}=130 and k estimated by the model.

An international length-weight relationship for the whole period has been used since 1999 (a=0.00000659, b=3.01721).

Natural mortality was assumed to be 0.4 year-1

The commercial landings are modelled as two different fleets (1982-93 and 1994-present) with a selection pattern described by a logistic function. Cadiz data are modelled as an independent fleet from 1982-04 (Andersen function, see gadget manual for more information) and it was added to the landings fleet from 2005-08. Discards from 1992-

present follow an Andersen function. The same function was used for the Spanish survey, Cádiz survey and Portuguese survey. The surveys, on the other hand are modelled as fleets with constant effort and a nonparametric selection pattern that is estimated for three 15 cm length groups.

Table 1. Data used for the assessment are described below:

Description	Period	Area	Likelihood component
Landings -Length distribution	1994–lastYear	Iberia	Land1.ldist
Landings - Length distribution	1982–1993	Iberia	Land.ldist
Landings – Cadiz Length distribution	1994–lastYear	Gulf of Cadiz	cdLand.ldist
Spanish GFS- Length distribution	1982–lastYear	North Spain	SpDem.ldist
Port. GFS - Length distribution	1989–lastYear	Portugal	PtDem.ldist
Cadiz GFS- Length distribution	1990–lastYear	Gulf of Cadiz	CdAut.ldist
Discards - Length distribution	1994,1998,1999, 2004–lastYear	Iberia	Disc.ldist
Spanish GFS Abund. index:4-19cm	1982–lastYear	North Spain	SpIndex15cm.1
Spanish GFS Abund. index: 20-35cm	1982–lastYear	North Spain	SpIndex15cm.2
Spanish GFS Abund. index:36-51cm	1982–lastYear	North Spain	SpIndex15cm.3
Port. GFS Abund.index: 4-19 cm	1989–lastYear	Portugal	PtIndex15cm.1
Port. GFS Abund. index:20-35cm	1989–lastYear	Portugal	PtIndex15cm.2
Port. GFS Abund. index:36-51cm	1989–lastYear	Portugal	PtIndex15cm.3
A Coruña Abund. Index: 25-39 cm	1994–2012	North Spain	Spcpue15cm.1
A Coruña Abund. Index:40-54cm	1994–2012	North Spain	Spcpue15cm.2
A Coruña Abund. Index: 55-70cm	1994–2012	North Spain	Spcpue15cm.3
Port. Stand.Abundace index:25-39cm	1989–lastYear	Portugal	Ptcpue15cm.1
Port. Stand.Abundace index:40-54cm	1989–lastY	Portugal	Ptcpue15cm.2
Port. Stand.Abundace index:55-70cm	1989–lastY	Portugal	Ptcpue15cm.3

Table 2. Description of the likelihood components weighing procedure and relative contribution to the final total likelihood (Note that relative contribution may change from year to year depending on the new data used to fit the model):

Likelihood component	VAR	Quarters	Quality	Area	Multiplicative Weight
Land1.ldist	0.66	44	2	1	133.2
Land.ldist	0.91	72	3	0.9	213.9
cdLand.ldist	2.5	52	2	0.1	4.2
SpDem.ldist	0.87	27	4	0.5	62.3
PtDem.ldist	0.39	24	4	0.4	99
CdAut.ldist	0.38	10	4	0.1	10.4
Disc.ldist	1.04	36	1	0.9	31.2
SpIndex15cm.1	4.84	9	4	0.5	3.7
SpIndex15cm.2	0.98	9	4	0.5	18.3
SpIndex15cm.3	1.2	9	4	0.5	15
PtIndex15cm.1	3.75	8	4	0.4	3.4
PtIndex15cm.2	1.34	8	4	0.4	9.5
PtIndex15cm.3	0.52	8	4	0.4	24.5
Spcpue15cm.1	2.37	5	2	0.5	2.1
Spcpue15cm.2	0.23	5	2	0.5	21.5
Spcpue15cm.3	1.55	5	2	0.5	3.2
Ptcpue15cm.1	0.46	6.67	2	0.4	11.6
Ptcpue15cm.2	1.39	6.67	2	0.4	3.8
Ptcpue15cm.3	0.76	6.67	2	0.4	7

The parameters estimated are:

- The number of fish by age when simulation starts (ages 1 to 8).
- Recruitment each year (1982 to present).
- The growth rate (k) of the von Bertalanffy growth model.
- Parameter β of the beta-binomial distribution.
- The selection pattern of:
    - Commercial catches (1982-93). 2 params
    - Landings (1994-present). 2 params
    - Cadiz landings (1982-2004). 3 params
    - Discards (1992-present). 3 params
    - Spanish Survey. 3 params
    - Portuguese Survey. 3 params
    - Cadiz autumn Survey. 3 params

- Catchability of:
  - Spanish Survey (3 groups from 4 cm by 15 cm).3 params
  - Portuguese Survey. (3 groups from 4 cm by 15 cm).3 params
  - Spanish cpue (3 groups from 25 cm by 15 cm).3 params
  - Portuguese cpue (3 groups from 25 cm by 15 cm).3 params

The estimation can be difficult because of correlation between parameters or groups of parameters, and therefore the possibility of multiple optima cannot be excluded. The optimization was started with simulated annealing to make the results less sensitive to the initial (starting) values and then the optimization was changed to Hooke and Jeeves when the 'optimum' was approached. Multiple optimization cycles were conducted to ensure that the model had converged to an optimum, and to provide opportunities to escape convergence to a local optimum.

The model fits were analysed with the following diagnostics:

- Profiled likelihood plots. To analyse convergence in problematic parameters.
- Plot comparing observed and modelled length proportions in fleets (catches, landings or discards). To analyse how estimated population abundance and exploitation pattern fit observed proportions.
- Plot of residuals in catchability models. To analyse precision and bias in abundance trends.

D. Short-Term Projection

Model used: Age–length forward projection

Software used: GADGET (script: model/hke.predict.st.sh)

Initial stock size: estimates at the end of the assessment period estimated by the gadget model, with recruitment replaced by geometric mean (1989-Y-1), if last year recruitment estimate is rejected by the group.

Maturity: arithmetic mean of last 3 years

F and M before spawning: NA

Weight-at-age in the stock: modelled in GADGET with VB parameters and length-weight relationship

Weight-at-age in the catch: modelled in GADGET with VB parameters and length-weight relationship

Exploitation pattern:

GADGET is a length-age-based forward projection model, structured by quarter for southern hake. Two different "fleets" are used for projections, landings fleet with a logistic selection pattern, and discards fleet with an Andersen selection pattern. Although each fleet has a constant selection pattern function, the level of exploitation can be distinct by quarter. 8 F multipliers are required for projections (2 "fleets" (landings and discards) * 4 quarters), which are computed by averaging the last 3 years by quarter and fleet.

Intermediate year assumptions: If there is a trend in mean F for the last 3 years the multipliers are scaled to last year's F bar (ages 1-3), so that a single scaling factor is applied to all quarters. Otherwise, the multipliers are not scaled (script: /scripts/scripts.prj/multF.r).

Stock recruitment model used: geometric mean of years 89 to last year minus one.

Procedures used for splitting projected catches: driven by the selection patterns estimated by Gadget for each "fleet" (landings and discards).

E. Medium-Term Projections

F. Long-Term Projections

F multipliers are set in the way described for short-term projections.

Model used: Age–length forward projection until 2050

Software used: GADGET (script: model/hke.predict.lt.sh)

Maturity: arithmetic mean of last 3 years

F and M before spawning: NA

Weight-at-age in the stock: modelled in GADGET with VB parameters and length-weight relationship

Weight-at-age in the catch: modelled in GADGET with VB parameters and length weight relationship

Exploitation pattern:

Landings: logistic selection parameters estimated by GADGET.

Discards: Andersen (asymmetric) selection parameters estimated by GADGET.

Stock recruitment model used: geometric mean of years 89 to last year minus one.

Procedures used for splitting projected catches: driven by different selection functions (logistic for landings, Andersen for discards) and provided by GADGET.

G. Biological Reference Points

PA Reference points	Value	Rational
B_{lim}	7 956	Hockey stick breakpoint
B_{pa}	11 100	Blim * 1.4
Fl_{im}	1.05	F corresponding to the slope of the hockey stick SSB-Rec relationship
F_{pa}	0.75	Flim / 1.4
MSY Reference points		
F_{MSY}	0.25	
F_{MSY} lower	0.17	
F_{MSY} upper	0.36	
B_{MSY}	73 330	
MSY	18 139	
MSY $B_{trigger}$	11 100	

Reference points were estimated by WKMSYRef4 (ICES, 2016). F_{MSY}, Fl_{ower}, F_{upper} and MSY $B_{trigger}$ were rounded by ACOM who also set MSY $B_{trigger}$ as B_{pa}.

H. Other Issues and further work

It should be noted that a new assessment model has been developed to avoid the reliance on age-based data. This new model is considered to be an improvement on the previous method given the problems related to age data described previously. The latest benchmark panel (WKSOUTH, 2014) considered that ICES should be flexible in allowing model improvements during the Assessment Working Groups and on an interseasonal basis. ICES should therefore ensure that resources are in place to evaluate these improvements.

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