Stock Annex: Black anglerfish (*Lophius budegassa*) in Divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Southern black anglerfish (Ank.27.8c.9a)
Working group:	Working Group for the Bay of Biscay and the Iberic waters Ecoregion (WGBIE)
Created:	
Authors:	
Last updated:	10 May 2018
Last updated by:	Ricardo Alpoim / Teresa Moura (WGBIE 2018)

A. General

A.1 Stock definition

The two species of anglerfish (the white, *Lophius piscatorius,* and the black, *L. budegassa*) are North-eastern Atlantic species, however black anglerfish has a more southerly distribution. White anglerfish is distributed from Norway (Barents Sea) to the Straits of Gibraltar (and including the Mediterranean and the Black Sea) and black anglerfish from the British Isles to Senegal (including the Mediterranean and the Black Sea). Anglerfish occur in a wide range of depths, from shallow waters to at least 1000 m. Information about spawning areas and seasonality is scarce, therefore the stock structure remains unclear. This lack of information is due to their particular spawning behaviour. Anglerfish eggs and larvae are rarely caught in scientific surveys.

ICES gives advice for the management of several anglerfish spp. stocks in European waters: one stock on the Northern Shelf area, that includes anglerfish from the Norwegian Sea - Division 2.a, Northern Shelf - Division 3.a, Subareas 4 and 6, and the stocks on the Southern Shelf area, one in Divisions 7.b-k and 8.a,b and d and the Southern stocks in Divisions 8.c and 9.a. The stock under this Annex is called Southern Black Anglerfish and is defined as black anglerfish in Divisions 8.c and 9.a. The boundaries of anglerfish in Divisions 7.b-k and 8.a,b and d and Southern Anglerfish stocks were established for management purposes and they are not based on biological or genetic evidences (GESSAN, 2002; Duarte *et al*., 2004; Fariña *et al.*, 2004).

Although the stock assessment is carried out separately for each species, white and black anglerfish are caught and landed together, due to that, the advice is given for individual and the combined species. There is a unique TAC for both species.

A.2 Fishery

Anglerfish in ICES Divisions 8.c and 9.a is mainly exploited by Spanish and Portuguese vessels, since 2000 the Spanish landings being more than 81% for both anglerfish total reported landings. France have reported catches of this stock since 2012, that represent an average of 2% of total landings. International catches for this stock have increased since the beginning of the 1980s, until a maximum was reached in 1988 (10 021 t). They

have decreased to 1 801 t–1 802 t in 2001–2002. In the 2003–2011 period the catches were between 2 300 t and 4 500 t. From 2011 to 2014 landings slightly increased to 3130 t, to decrease the next 3 years to 2307 t in 2017. Both species are caught on the same grounds by the same fleets and are marked together.

White and black anglerfish are caught together by Spanish and Portuguese bottom-trawlers and gillnet fisheries. Spanish and Portuguese bottom trawlers are mixed fisheries. The Spanish bottom-trawl fleet predominantly targets hake, megrim, Norway lobster and anglerfish. Since 2003 the alternative use of a trawl gear with High Vertical Opening (HVO) has taken place in larger proportion relative to previous years. This gear targets horse mackerel and mackerel with very few anglerfish catches.

The species proportion in the landings has changed since 1986. In the beginning of the time-series (1980-1986) *L. piscatorius* represented more than 70% of the total anglerfish landings. After 1986 the proportion of *L. piscatorius* decreased and in 1999-2002 both species had approximately the same weight in the annual landings. Since then the *L. piscatorius* proportion increased. The mean proportion of *L. piscatorius* in the landings from 2008 to 2017 is 63%.

Since 2008, the Spanish black anglerfish landings were on average 69 % from the trawl fleet, 26 % from the gillnet fishery and 5% from other fisheries. The Spanish gillnet fishery can use different artisanal gears, but most catches come from "Rasco" that is a specific gear targeting anglerfish.

Black anglerfish are caught by Portuguese fleets in trawl and artisanal mixed fisheries. Portuguese landings were on average, from 2008, 30 % from trawlers and 70 % from artisanal fisheries. The trawl fleet has two components, the trawl fleet targeting demersal fish and trawl fleet targeting crustaceans. In some years after 2005 Portuguese combined species landings were TAC constrained and very low landings were registered during the 4th quarter since then.

Discarding in black anglerfish is considered low for the trawl fishery, based on estimated data for Spanish trawl fleet (ICES, 2011) and information from Portuguese trawl fleet (ICES, 2012).

Each year, the European Union sets a combined TAC and quota for white and black anglerfish. There is no minimum landing size for anglerfish, but in order to ensure marketing standards a minimum landing weight of 500 g was fixed in 1996 by the Council Regulation (EC) No.2406/96.

As part of the Recovery Plan for the Southern hake and Iberian *Nephrops* stocks (Council Regulation (EC) No.2166/2005), in force since January of 2006, the fishing effort regulations are affecting the Spanish and Portuguese mixed trawl fisheries. As anglerfish are taken in these mixed trawl fisheries, these stocks are also affected by the recovery plan effort limitation.

A.3 Ecosystem aspects

Black anglerfish is a benthic species that occur on muddy to gravelly bottoms. It attains a maximum size of around 93 cm corresponding to a weight of approximately 12 kg. Historically black anglerfish has been considered a slow growing species, with a late maturation (Duarte *et al*., 2001). Nevertheless, new evidences from mar-recapture experiments indicate that the anglerfish growth could be faster (Landa *et al*., 2008).

The ovarian structure of anglerfish differs from most other teleosts. It consists of very long ribbons of a gelatinous matrix, within individual mature eggs floating in separate

chambers (Afonso-Dias and Hislop, 1996). The spawning of the *Lophius* species is very particular, with eggs extruded in a buoyant, gelatinous ribbon that may measure more than 10 m and contain more than a million eggs (Afonso-Dias and Hislop, 1996; Hislop *et al*., 2001; Quincoces, 2002). Eggs and larvae drift with ocean currents and juveniles settle on the seabed when they reach a length of 5-12 cm. This particular spawning leads to highly clumped distributions of eggs and newly emerged larvae (Hislop *et al*., 2001) and favourable or unfavourable ecosystem conditions can therefore have major impacts on recruitment.

Due to their particular reproduction aspects (that shows a high parental investment in the offspring) the population dynamics of these species is expected to be highly sensitive to external biological/ecosystem factors.

Vertical displacements of immature and mature white anglerfish from the seabed to the near surface have been recorded in the Northeast Atlantic (Hislop *et al*., 2001) and are suggested to be related to spawning or feeding.

Improvement of knowledge regarding growth, spawning behaviour, migratory behaviour and juvenile drift are essential to present and future assessment and management of both Southern Anglerfish stocks.

B. Data

B.1 Commercial Catch

Landings data are provided by National Government and research institutions of Spain, Portugal and France. Quarterly landings by country, gear and ICES Division are available from 1978. There were unrecorded landings in Division 8.c between 1978–1979, and it was not possible to obtain the total landings in those years. Portuguese landings were TAC constrained since 2005. Very low landings have been registered during the 4th quarters since then. France landings are only available for the period 2002–2016.

The two species are not usually landed separately, for the majority of the commercial categories, and they are recorded together in the ports' statistics. Therefore, estimates of each species in Spanish landings from Divisions 8.c and 9.a and Portuguese landings of Division 9.a are derived from their relative proportions in market samples.

After 1980, black anglerfish landings increased and reached a peak of 3 832 t in 1987. Since then, landings decreased and reached 810 t in 2002. From 2002 to 2007 landings increased to 1 306 t, decreasing afterwards to levels between 774–754 t in 2009–2010. From 2010 to 2016 catches fluctuated between 1 022 t and 1 250 t but decreased to 861 t in 2017.

Discards

The Spanish Discard Sampling Programme, in the ICES Divisions 8.c and 9.a, is being carried out for trawl fleets since 1994 and for gillnets fleets since 2011. However, the trawl time-series is not complete and years with discard data are 1994, 1997, 1999, 2000 and from 2003–2017. The raising procedure used to estimate discards was based on effort. The Portuguese Discard Sampling Programme recorded anglerfish data from 2004. The frequency of occurrence of black anglerfish in discard samples is very low and their discard is considered negligible.

B.2 Biological

Landing numbers at length

Since 2009 the quarterly Spanish and Portuguese sampling for length compositions is by métier and ICES Division. Length data from sampled vessels are summed and the resulting length composition is applied to the quarterly landings of the corresponding métier and ICES Division. The sampled length compositions were raised for each country and SOP corrected to total landings on a quarterly or half yearly basis (when the sampling levels by quarter were low). The average lengths of trawl caught anglerfish are lower compared to the artisanal fleets.

Catch numbers–at–age

No catch numbers-at-age are provided to the Working Group. At the WGHMM 2007 meeting (ICES, 2007), age length keys, based on *illicia* readings, were used to obtain catch number-at-age for each species. The exploratory analysis of estimates indicated that the biased age reading criterion does not allow following cohorts along years in either of the two species. The last research about white anglerfish ageing, *White Anglerfish Illicia and Otoliths Exchange 2011* (ICES, 2012), highlighted that neither *illicia* or otolith age readings have not been validated and, in the case of *illicia* studies, the agreement among readers and the precision were not acceptable. Therefore, it was concluded that the available age reading criteria for white anglerfish southern stock is not valid to build an ALK.

Growth curve

An agreed growth model is not available for black anglerfish *in* Divisions 8.c, 9.a.

Maturity–at–length

Different estimates of maturity ogive at length are available for *Lophius budegassa* (Duarte *et al*., 2001, Quincoces, 2002, Landa *et al*., 2008). The last study (Landa *et al*., 2012) indicates, for ICES Div. 8.c-9.a, a sex ratio of 1:1.01 (50.30% of females) and L50 values of 46.95 cm for combined sexes, 40.97 cm for males and 62.44 cm for females. These values of sex ratio and L50 are within the range given for this species in previous studies.

Natural mortality

Trial assessment, in the past, of the black anglerfish stock used a natural mortality rate of 0.15 yr-1. This value was adopted for all ages and years in the absence of any direct estimates.

Length–weight relationship

The weight at length relationship was calculated using data from an international project with a sampling that spatially covered a large proportion of the stock and which number of samples (BIOSDEF, 1998):

$W = 2.11 \times 10^{-5} \cdot L^{2.9198}$

where W = weight in kilograms and L = length in centimetres.

B.3 Surveys

SpGFS-WIBTS-Q4

The Spanish Groundfish Survey aims to collect data on the distribution and relative abundance, and biological information of commercial fish in ICES Divisions 8.c and Northern 9.a. Since 1983 it is annually carried out in fourth quarter (September/October) of the years, except for 1987. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species.

This survey is not used in the current assessment of black anglerfish.

SP-ARSA (SpGF-Cspr-WIBTS-Q1, SpGF-Caut-WIBTS-Q4)

The Southern Spanish Groundfish Survey on the Gulf of Cádiz is conducted in the southern part of ICES Division 9a, the Gulf of Cádiz. The covered area extends from 15 m to 800 m depth, during spring and autumn. This survey was identified during the WKANGLER-Data Evaluation meeting as a potential abundance index for *L. budegassa* in Divisions 8c9a. The series covers the period 1993-2017, two surveys by year (Q1 and Q4), and the biomass and abundance indices and the respective variance and length compositions are available.

This survey is not used in the current assessment of black anglerfish.

PtGFS-WIBTS-Q4

Portuguese Autumn Groundfish Survey has been carried out in Portuguese continental waters since 1979 in the fourth quarter of the years. Abundance indices for both anglerfish species are available since 1989. This survey was not performed in 2012. The abundance values detected by this survey are very low for the whole time-series, being insignificant for some years.

This survey is not used in the current assessment of black anglerfish.

PtGFS-WIBTS-Q1

Portuguese Winter Groundfish Survey has been carried out in Portuguese continental waters from 2005 till 2008 in the first quarter. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. The abundance values detected by this survey are very low for the whole time-series.

This survey is not used in the current assessment of black anglerfish.

PT CTS

Portuguese Crustacean Survey has been carried out in south of the Portuguese coast since 1997 in the second quarter. This survey was not performed in 2012. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. This survey detects better anglerfish (especially *L. budegassa*) but the area cover is very small compared with the anglerfish stocks distribution.

This survey is not used in the current assessment of black anglerfish.

PtGFS (Summer)

Portuguese Summer Groundfish Survey has been carried out in Portuguese continental waters from 1990–2001 (except 1994, 1996) in the third quarter. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. The abundance values detected by this survey are very low for the whole time-series, being insignificant for some years.

This survey is not used in the current assessment of black anglerfish.

Portuguese deep-water fish survey

Portuguese deep-water fish Survey has been carried out in Portuguese continental waters from 1997–2002. No indices are available only raw data.

This survey is not used in the current assessment of black anglerfish.

B.4 Commercial cpue

Six commercial series of landing-effort are available to the WG. Four of them are Spanish fleets in the ICES Division 8.c and two Portuguese fleets in the ICES Division 9.a. The Portuguese trawl fleet was split into fish trawlers and crustacean trawlers (WD12, Duarte *et al*., 2007 in ICES, 2007) according to the fleet segmentation proposed by the IBERMIX project (WD06, Castro *et al*., 2007 in ICES, 2007).

SP-CORTR8C

A Coruña trawl fleet fishing in Division 8.c is available for years 1982-2012. Data provided for A Coruña trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 18% of international catches of black anglerfish along the time-series. A standardized series from 1994–2006 is also available for this fleet with annual effort data (in fishing days) and annual LPUE.

It was agreed (WKANGLER 2018 – ICES, 2018) to use the data from this commercial LPUE series in the black anglerfish assessment.

SP-CEDGNS8C

Cedeira gillnet fleet fishing in Division 8.c is available for years 1999–2011. Data provided for Cedeira gillnets comprise quarterly standardized effort (in soaking days), landings and length composition of landings. This fleet represents an average of 1% of international catches of black anglerfish since 1999.

Information from this commercial series is not used in the current assessment of black anglerfish.

PT-TRF9A

Portuguese trawlers targeting fish: since 1989. Data provided for Portuguese trawlers targeting fish comprise quarterly effort (1000 hours trawling with occurrence of anglerfish), landings and length composition of landings. This fleet represents an average of 5% of international catches of black anglerfish along the time-series. A standardized series from 1989–2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual LPUE.

Data from this commercial LPUE has been used in the black anglerfish assessment since 2007.

PT-TRC9A

Portuguese trawlers targeting crustacean: since 1989. Data provided for Portuguese trawlers targeting fish comprise quarterly effort (1000 hours trawling with occurrence of anglerfish), landings and length composition of landings. This fleet represents an average of 3% of international catches of black anglerfish along the time-series. A standardized series from 1989–2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual LPUE.

Data from this commercial LPUE has been used in the black anglerfish assessment since 2007.

Other available commercial series of LPUEs that have never been employed in the assessment are:

SP-AVITR8C

Avilés trawl fleet fishing in Division 8.c is available for years 1986–2003. Data provided for Avilés trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average 3% of international catches of black anglerfish along the time-series. The effort series was interrupted in 2003.

SP-SANTR8C

Santander trawl fleet fishing in Division 8.c is available for years: years 1986–2010. Data provided for Santander trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 3% of international catches of black anglerfish along the time-series. Effort data for 2008 was not provided to the WG.

C. Assessment Methods and Settings

Until 2011 black anglerfish stock was assessed with a non-equilibrium production model (ASPIC, Prager, 1994; 2004). At WKFLAT 2012 (ICES, 2012) a new formulation, of the ASPIC, including 3 tuning indices (A Coruña, Portuguese Trawler fleet directing to crustaceans, Portuguese Trawler fleet directing to ground-fish) was considered more stable. From 2012 to 2017 this formulation of ASPIC was used, but from 2014-2017 B1/K was fixed 0.6 to stabilize the model. A new assessment model, stochastic surplus production model in continuous time (SPiCT; Pedersen and Berg, 2016), was accepted during WKANGLER 2018 (ICES, 2018). This model was considered more reliable since it does not require the fixation of parameters such as B1/K to be stable and was accepted as the basis for advice. The accepted configuration uses the same data as ASPIC.

Model:

Stock: black anglerfish (*L.budegassa)*

Assessment Model: a stochastic surplus production model in continuous time - SPiCT (Pedersen and Berg, 2017)

Software: SPiCT R package

Input data:

Total landings since 1980 (discards are considered negligible).

SPN A Coruña trawl (SPCORTR8c), 1982-2012 (Index)

PRT Bottom trawl crustacean (PT-TRC9a), since 1989 (Index)

PRT Bottom trawl fish (PT-TRF9a), since 1989 (Index)

Settings:

SPiCT data, all assumed at the beginning of the year:

Euler time step (years): 1/16 (default)

Production curve shape: assume Schaefer (n=2).

Alpha (Biomass observation and process errors ratio): estimated by the model (default priors for all indices).

Beta Catch observation and process errors ratio): estimated by the model (default priors).

Other parameters: default (estimated by the model).

D. Short–term projection

Model: SPiCT projections (Pedersen and Berg, 2017).

Software: SPiCT package (R project)

Stock forecasts should use the average of the last 3 years fishing mortality with the possibility of projecting with fishing mortality estimated in the final year depending on trends.

SPiCT, as it is setup, divide the year in 16 parts estimating 16 Fs during each year. The F (F *status quo*) in the intermediate year assumed as the mean of the Fs during the previous year (if the final year F is used).

Projections are performed based on SPiCT estimates.

Since SPiCT is not adequate for medium or long-term projections. Regarding short-time projections, if forecasts for F_{MSY} result in a large increase in the catches in the first projected year such as values never observed in the fishery, a stepwise increase in fishing opportunities advice should be considered.

E. Medium term projections

Since SPiCT is not adequate for medium or long-term projections, no medium-term projections are conducted for black anglerfish stock.

F. Yield and biomass per recruit / long-term projections

Since SPiCT is not adequate for medium or long-term projections, no long-term projections are conducted for black anglerfish stock.

G. Biological reference points

WKANGLER (ICES, 2018) endorsed the basis for MSY reference points previously assumed by ICES.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY Btrigger	50% BMSY	B_{MSY} is implicitly estimated from the surplus production model. 0.25*K	ICES (2018)
	F_{MSY}	Relative value	F_{MSY} is implicitly estimated from the surplus production model. Fishing mortality values are expressed relative to F_{MSY}. r/2	ICES (2018)
	F_{MSY} range	(0.78 F_{MSY}, F_{MSY})	Implicit, estimated from the surplus production model. Fishing mortality values are expressed relative to F_{MSY}.	ICES (2018)
Precautionary approach	Blim	30% B_{MSY}	B_{MSY} is implicitly estimated from the surplus production model. Biomass values are expressed relative to B_{MSY}.	ICES (2018)
	Flim	1.70 F_{MSY}	Implicit, estimated from the surplus production model. Fishing mortality values are expressed relative to F_{MSY}.	ICES (2018)

H. Other Issues

H.1. Historical Development of Assessment

Southern Anglerfish stocks were assessed for the first time in the 1990 ICES WG meeting. Different assessment trials were performed during the subsequent 8 years but analytical assessments indicated unrealistic results. The database (both biological and fisheries data) were improved along these years trying to apply an analytical assessment model. Since 1998 a non-equilibrium surplus production model ASPIC (Prager, 1994) was applied to each stock or to the combined stock data. These stock assessments were accepted by the ACFM and used to provide management advice. The assessment of black anglerfish as a separate stock has been carried out continuously from 2007. In 2012 during the benchmark (WKFLAT2012) it was agreed to include a third series in the assessment. Since WGBIE2014 B1/K was fixed at 0.6. A new assessment model, stochastic surplus production model in continuous time (SPiCT; Pedersen and Berg, 2016), was accepted during WKANGLER 2018. The history of black anglerfish assessment from 2007–2018 is presented in Table 1.

Table 1. History of southern black anglerfish assessment from 2007–2017.

WG	2007	2008	2009	2010	2011	2012–2013	2014–2017
Assessment Model	Non-equilibrium Surplus production model (Prager, 1994a)	No updated	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)
Software	ASPIC (v. 5.16)	No updated	ASPIC (v. 5.24)	ASPIC (v. 5.34)	ASPIC (v. 5.34.9)	ASPIC (v. 5.34.9)	ASPIC (v. 5.34.9)
Catch data range	1980-2006		1980-2008	1980-2009	1980-2010	Since 1980	Since 1980
cpue Series 1 (years)	PT-TRF9a (1989-2006)		PT-TRF9a (1989-2008)	PT-TRF9a (1989-2009)	PT-TRF9a (1989-2010)	PT-TRC9a (since 1989)	PT-TRC9a (since 1989)
cpue Series 2 (years)						PT-TRF9a (since 1989)	PT-TRF9a (since 1989)
Index of Biomass (years)	PT-TRC9a (1989-2006)		PT-TRC9a (1989-2008)	PT-TRC9a (1989-2009)	PT-TRC9a (1989-2010)	SPCORTR8c (1982-2010)	SPCORTR8c (1982-2012)
Error Type	Condition on yield		Condition on yield	Condition on yield	Condition on yield	Condition on yield	Condition on yield
Number of bootstrap	500		500	1000	1000	1000	1000
Maximum F	8.0 (y-1)		8.0 (y-1)	8.0 (y-1)	8.0 (y-1)	8.0 (y-1)	8.0 (y-1)
Statistical weight B1/K	1		1	1	1	1	1
Statistical weight for fisheries	1,1		1,1	1,1	1,1	8.59E-01, 1.20E+00, 9.81E-01	8.59E-01, 1.20E+00, 9.81E-01
B1/K -ratio (starting guess)	0.5		0.5	0.5	0.5	0.6	Fixed 0.6
MSY (starting guess)	3000 t		3000 t	3000 t	3000 t	1811.26 t	1811.26 t
K (starting guess)	20 000 t		20 000 t	20 000 t	20 000 t	18 112.6 t	18 112.6 t
q1 (starting guess)	1d-5		1d-5	1d-5	1d-5	8.2523E-04	8.2523E-04
q2 (starting guess)	1d-4		1d-4	1d-4	1d-4	1.1196E-07	1.1196E-07
q3 (starting guess)						2.7279E-07	2.7279E-07
Estimated parameter	All		All	All	All	All	All
Min and Max allowable MSY	2000 (t) -10000 (t)		2000 (t) -11500 (t)	2000 (t) -10000 (t)	2000 (t) -10000 (t)	181.126 (t) -3622.52 (t)	181.126 (t) -3622.52 (t)
Min and Max K	5000 (t) -500000 (t)		5000 (t) - 112000 (t)	5000 (t) -100000 (t)	5000 (t) -100000 (t)	1811.26 (t) -362252 (t)	1811.26 (t) -362252 (t)
Random Number Seed	1964185		1964185	1964185	1964185	1025957	1025957

Table 2. History of southern black anglerfish assessment from 2018 onwars.

WG	WKAngler2018
Assessment Model	A Stochastic Surplus Production Model in Continuous TIme (Pedersen and Berg, 2017)
Software	SPiCT (1.2.1)
Catch data range	1980-2016
LPUE I1 (years)	SPCORTR8c (1982-2012)
LPUE I2 (years)	PT-TRC9a (1989-2016)
LPUE I3 (years)	PT-TRF9a (1989-2016)
Iput data	all assumed at the beginning of the year
Euler time step (years)	1/16 (default)
Production curve shape: Prior logn	Disable Fixed at 2. Assume Schaefer
Prior logalpha (Index1)	dnorm [log(1), 2^2]
Prior logalpha (Index2)	dnorm [log(1), 2^2]
Prior logalpha (Index3)	dnorm [log(1), 2^2]
Prior logbeta	dnorm [log(1), 2^2]
Other parameters	default (estimated by the model)

I. References

Afonso-Dias, I. P. and J.R.G. Hislop. 1996. The population of anglerfish *(Lophius piscatorius*) from the northwest coast of Scotland. J. Fish. Biol. 49 (Suppl A): 18–39.

BIOSDEF. 1998. Biological studies of demersal fish. Ref.: EU, DG XIV, Study Contract 95/038.

Castro, J., Cardador, F., Santurtún, M., Punzón, A., Quincoces, I., Silva, C., Duarte, R., Murta, A., Silva, L., Abad, E. and Marín, M. 2007. Proposal of fleet segmentation for the Spanish and Portuguese fleets operating in the Atlantic national waters. ICES CM 2007/ACFM: 21

Duarte, R., Azevedo, M., Landa, J. and Pereda, P. 2001. Reproduction of anglerfish (*Lophius budegassa* Spinola and *Lophius piscatorius* Linnaeus) from the Atlantic Iberian coast. Fisheries Research 51: 349-361.

Duarte, R., Bruno, I., Quincoces, I., Fariña, A.C. and Landa, J. 2004. Morphometric and meristic study of white and black anglerfish (*Lophius piscatorius* and *L. budegassa*) from the south-west of Ireland to the south-western Mediterranean. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 22.

Duarte, R., Sampedro, P., Landa, J. and Azevedo, M. 2007. Revision of available data (landings, effort, length frequency distributions and age-length keys) from 1996-2005 for an age-structured assessment of Southern anglerfish stocks. ICES CM 2007/ACFM: 21

Fariña, A.C., Duarte, R., Landa, J., Quincoces, I. and Sánchez, J.A. 2004. Multiple stock identification approaches of anglerfish (*Lophius piscatorius* and *L. budegassa*) in western and southern European waters. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 25.

GESSAN, 2002. Genetic characterisation and stock structure of the two species of anglerfish (*Lophius piscatorius* and *L. budegassa*) of the north Atlantic. Ref.: EU DG XIV Study Contract: 99/013.

Hislop, J. R.G., Holst, J.C., Skagen, D. 2001. Near–surface captures of post-juvenile anglerfish in the North-east Atlantic- an unsolved mystery. Journal of Fish Biology 57: 1083-1087.

Hislop, J. R. G., A. Gallego, M. R. Heath, F. M. Kennedy, S. A. Reeves and Wright, P. J. 2001. A synthesis of the early life history of anglerfish, *Lophius piscatorius (Linnaeus, 1756*) in northern British waters. ICES Journal of Marine Science, 58, 70–86.

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 8 - 17 May 2007, Vigo, Spain. ICES CM 2007/ACFM:21. 700 pp.

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM), 5 - 11 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:11.625 pp.

ICES. 2012. Report of the Benchmark Workshop on Flatfish and Anglerfish (WKFLAT), 1-8-March 2012, Bilbao, Spain. ICES CM 2012/ACOM:47.

ICES. 2018. Report of the Benchmark Workshop on Anglerfish (WKAngler), 12–16 February 2018, Copenhagen, Denmark. ICES CM 2018/ACOM: 31.

Landa, J., Antolínez, A., Castro, B., Ámez, M., Barrado, J. and Hernández, C.,2012. Sexual maturity of black anglerfish (*Lophius budegassa*) caught by the Spanish fleet in north-eastern Atlantic waters. Working Document n 9 in WKFLAT 2012.

Landa, J., Duarte, R. and I. Quincoces. 2008. Growth of white anglerfish (*Lophius piscatorius*) tagged in the Northeast Atlantic, and a review of age studies on anglerfish. ICES Journal of Marine Science, 65: 72–80.

Pedersen, M.W. and Berg, C.W. 2017. A stochastic surplus production model in continuous time. Fish and Fisheries, 18: 226-243.Prager, M. H. 1994. A suite of extension to a non-equilibrium surplus-production model. Fish. Bull. 92: 374–389.

Prager, M.H., 1994. A suite of extensions to no-equilibrium surplus-production model. Fish. Bull. U.S., 92: 374-389, 29pp.

Prager, M. H. 2004. User's manual for ASPIC: a stock production model incorporating covariates (ver. 5) and auxiliary programs. NMFS Beaufort Laboratory Document BL-2004–01, 25pp.

Quincoces, I. 2002. Crecimiento y reproducción de las especies *Lophius budegassa* Spinola1807, y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. PhD Thesis. Basque Country University. 276pp.