Stock Annex: Southern black anglerfish (*Lophius budegassa*) in Divisions 8.c, 9.a

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Southern black anglerfish (Divisions 8c, 9a)

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Revised by Ricardo Alpoim (WGBIE2016)

A General

A.1 Stock definition

The two species of anglerfish (the white, *Lophius piscatorius*, and the black, *L. budegassa*) are Northeastern 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 Northern Shelf–Division 3.a, Subarea 4 and Subarea 6, and Norwegian Sea–Division 2.a, 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 are exploited by Spanish and Portuguese vessels, since 2000 the Spanish landings being more than 81% for both anglerfish total reported 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. 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. Since 2005, the Spanish landings were on average 72 % from the trawl fleet, 22 % from the gillnet fishery and 6% from other fisheries. The Spanish gillnet fishery can use different arti-sanal gears, but most catches come from "Rasco" that is a specific gear targeting an-glerfish.

Anglerfish are caught by Portuguese fleets in trawl and artisanal mixed fisheries. Por-tuguese landings were on average, from 2005, 32 % from trawlers and 68 % from arti-sanal fisheries. The trawl fleet has two components, the trawl fleet targeting demersal fish and trawl fleet targeting crustaceans. Since 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 esti-mated 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 (Coun-cil Regulation (EC) No.2166/2005), in force since January of 2006, the fishing effort reg-ulations 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 ex-periments 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 and Quincoces, 2002). Eggs and larvae drift with ocean currents and juve-niles 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 sensi-tive 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 and Portugal. Quarterly landings by country, gear and ICES Division are available from 1978. There were unrecorded landings in Division 8c 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. The Portuguese landings were relatively stable during the first two years, but have decreased substantially from 2006–2010. In 2011 and 2012 Portuguese landings have increased by 16 and 116% respectively.

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 8c and 9a and Portuguese landings of Division 9a 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 a minimum in 2002 of 770 t. From 2002–2007 landings increased to 1 301 t, decreasing afterwards to near 790 t in 2010 and 2011, but in 2012 catches reached 1 139 t.

Discards

Since 1994 a Spanish Discard Sampling Programme is being carried out for trawl fleets operating in the ICES Divisions 8.c and 9.a. However, the time-series is not complete and years with discard data are 1994, 1997, 1999, 2000 and from 2003–2009. 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. 8c-9a, 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 8c 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 actual 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 actual 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 actual 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 actual 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 actual 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 actual 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 8c and two Portuguese fleets in the ICES Division 9a. 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 8c 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 (WKFLAT 2012) to use the data from this commercial LPUE series in the black anglerfish assessment.

SP-CEDGNS8C

Cedeira gillnet fleet fishing in Division 8c 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 actual 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 8c 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 8c 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 software).

A revised series from the Spanish fleet 'A Coruña' was available at WKFLAT2012, historical survey series data, discard data and other commercial LPUE series. The 'A Coruña' series is the longest of the potential tuning series and represents the bulk of the fishery and it was concluded that this series should be included in the modelling. At WKFLAT2012 three potential models were applied to the data: a Bayesian surplus

production model, SS3, and numerous formulations of ASPIC. The SS3 showed promise but it was determined that more exploration would be required before the model could be accepted as the basis for advice. A new formulation of ASPIC which included 3 tuning indices (A Coruña, Portuguese Trawler fleet directing to crustaceans, Portuguese Trawler fleet directing to groundfish) was presented which tracks the central trend in the indices and is more stable than previous assessment. This was accepted as the basis for advice.

Model, input data and settings:

Assessment Model: Non-equilibrium Surplus production model (Prager, 1994; 2004)

Software: ASPIC (v. 5.34.9)

Stock: black anglerfish (*L.budegassa*)

Catch data range: Since 1980

cpue Series 1 (years): PT-TRC9a (since 1989)

cpue Series 2 (years): PT-TRF9a (since 1989)

Index of Biomass (years): SPCORTR8c (1982-2012)

Error Type: Condition on yield

Number of bootstrap: 1000

Maximum F: 8.0 (y-1)

Statistical weight B1/K: 1

Statistical weight for fisheries: 8.59E-01; 1.20E+00; 9.81E-01

B1-ratio (starting guess) : 0.6 (fixed at 0.6 since the WGBIE2014)

MSY (starting guess): 1.81126E+03 t

K (starting guess): 1.81126E+04 t

q1 (starting guess): 8.2523E-04

q2 (starting guess): 1.1196E-07

q3 (starting guess): 2.7279E-07

Estimated parameter: All

Min and Max allowable MSY: 1.81126E+02 (t); 3.62252E+03 (t)

Min and Max K: 1.81126E+03 (t); 3.62252E+05 (t)

Random Number Seed: 1025957

D. Short-term projection

Model: ASPIC projections (Prager, 1994).

Software: ASPICP

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.

Projections are performed based on ASPIC estimates. Projections are performed for the following scenarios,:

- Taking in account the Reference Points

- F sq (status quo)

- Zero catches

- TAC, - 15% TAC and + 15% TAC

E. Medium term projections

No medium term projections are conducted for black anglerfish stock.

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

None

G. Biological reference points

WKFLAT (ICES, 2012) endorsed the basis for MSY reference points previously assumed by ICES. WKMSYRef4 (ICES 2016b)/ ICES (2016a) approved new reference points as described in the following table.

FRAMEWORK	REFERENCE POINT	VALUE	TECHNICAL BASIS	SOURCE
MSY approach	MSY $B_{trigger}$	50% B_{MSY}	B_{MSY} is implicitly estimated from the surplus production model. 0.25*K	ICES (2012)
	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 (2012)
	FMSY range	(0.78 FMSY, FMSY)	Implicit, estimated from the surplus production model. Fishing mortality values are expressed relative to FMSY.	(ICES, 2016a)
Precautionary approach	B_{lim}	30% BMSY	BMSY is implicitly estimated from the surplus production model. Biomass values are expressed relative to BMSY.	ICES (2016b
	F_{lim}	1.70 FMSY	Implicit, estimated from the surplus production model. Fishing mortality values are expressed relative to FMSY.	ICES (2016b

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. The history of black anglerfish assessment from 2007–2016 is presented in Table 1.
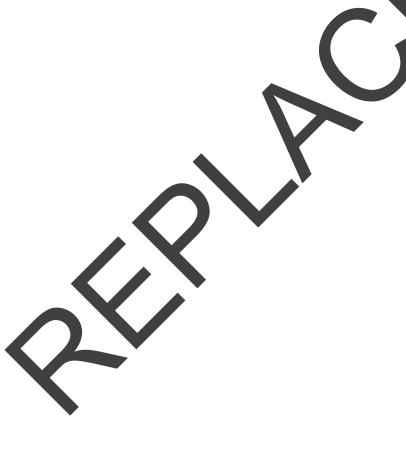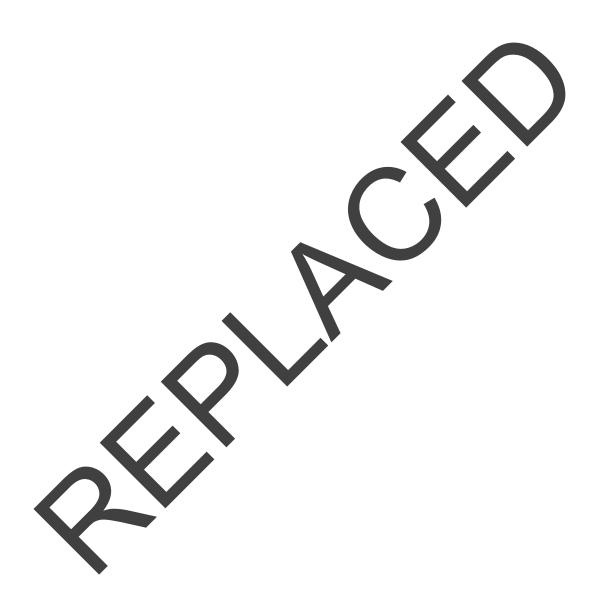
Table 1. History of southern black anglerfish assessment from 2007–2016.

WG	2007	2008	2009	2010	2011	2012–2013	2014–2016
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-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)

WG	2007	2008	2009	2010	2011	2012–2013	2014–2016
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

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