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Stock Annex: White anglerfish (*Lophius piscatorius*) in divisions 7.b–k, 8.a,b,d (southern Celtic Seas, Bay of Biscay)

Stock-specific documentation of standard assessment procedures used by ICES

Stock	White anglerfish_mon.27.78abd
Working group	Working Group for the Bay of Biscay and Iberian Waters Ecoregion (WGBIE)
Last updated	May 2018
Revised by	WGBIE
Timeline of revisions	Febr 2018: WKAngler
	May 2018: WGBIE
Main modifications	Feb 2018: major revisions; new category I stock
	May 2018: applied ICES rounding rules to ref pts
Last Benchmarked	WKAngler, 2018

A. General

A.1 Stock definition

ICES considers white anglerfish in areas 27.7 and 27.8abd to be a stock for assessment purposes. However there is evidence of considerable potential for long-distance migration and it is not clear whether this stock definition is appropriate. Because there is currently insufficient information to change the stock boundaries, the current stock definition remains unchanged (except the inclusion of area 27.7a in 2018).

The TACs are set separately for areas 27.7 and 27.8 but for the two species of anglerfish combined (*L piscatorius* and *L. budegassa*).

A.2 Fishery

A.2.1 General description

Both species of anglerfish (*L piscatorius* and *L. budegassa*) are a taken in a mixed fishery, mainly with hake, megrim and *Nephrops*.

The fishery for anglerfish developed in the late 1960s and landings quickly reached around 25 thousand tonnes (for both *Lophius* species combined). Since then, landings have fluctuated between 20 and 40 thousand tonnes per year.

France takes the vast majority of the landings; followed by Spain, the UK and Ireland. Minor landings have been recorded for Belgium, Germany and Portugal.

A.2.2 Fishery management regulations

A.3 Ecosystem aspects

White anglerfish occur throughout the Northeast Atlantic and in the Mediterranean and Black sea. They are most abundant at depths of 200–800 m but also occur in coastal waters. Juveniles are mainly found offshore; medium-sized fish migrate inshore and the adults move offshore again. Therefore, anglerfish may exploit a number of ecological niches at various stages of their life cycle.

Anglerfish are ambush predators who feed opportunistically on passing prey, which is attracted using a fleshy lure on the *illicium*. The diet is dominated by fish and, to a lesser extent, cephalopods. Small gadoids have a relatively high importance in their diet (Power *et al.*, unpublished).

There are no reports of predators that specifically target anglerfish in European waters (Thangstad *et al.*, 2006). Indirect predation by seals of netted fish is common though and seals may prey directly on anglerfish as well. Anglerfish remains were found in one stranded sperm whale in the Netherlands (Santos *et al.*, 2002). In Faroese waters juvenile anglerfish remains have been found in the stomachs of large cod (Thangstad *et al.*, 2006).

B. Data

B.1 Commercial catch

B.1.1 Landings data

Landings are generally reported for the two species combined (*L piscatorius* and *L. budegassa*). The combined landings are split into species at national level, based on the species composition in the sampling data. Some countries use annual proportions of the two species, others estimate proportions by fleet, port and/or quarter. Spain catches the smallest proportion of *L. piscatorius* (around 50%) while the UK catches the largest proportion (around 95% *L. piscatorius*).

Some countries applied minor corrections for underreported landings.

In recent years landings data have been reported by quarter, ICES division and métier level 6. While the logbook data can be reported at this level of disaggregation, the sampling programmes are unable to support estimates for such a large number of strata (four quarters, 13 divisions, ~20 métiers). Therefore the number of samples in each stratum is generally low and aggregation of these data tends to result in imprecise estimates. The landings length distributions of the period covered by the latest data call (2002–2016) appear to be poorer at tracking cohorts than the data obtained from the period before that (1986–2001) when each country produced national estimates based on the stratification of their sampling programme.

The large number of métiers was reduced to a small number of gear groups (level 4 métiers):

- OTB_DEF (otter trawls targeting demersal fish)
- OTB_CRU (otter trawls targeting *Nephrops*)
- GNS DEF (gillnets targeting demersal fish)
- TBB_DEF (beam trawls targeting demersal fish)
- MIS_MIS (miscellaneous or unknown métiers)

The catches are dominated by OTB_DEF (consistently around 65%); GNS_DEF take just under 20% of the catches; TBB_DEF around 10% and OTB_CRU around 5%.

For landings strata that have no sampling data, the length–frequency distributions are imputed from samples of the same country, quarter and year, if available, otherwise from the combined sample data from all countries in the relevant quarter and year.

The historic WG landings did not include landings from area 27.7a. Official landings from EUROSTAT were added to the landings submitted to intercatch (all *Lophius* landings in 27.7a were assumed to be *L. piscatorius* as survey data indicate that *L budegassa* does not occur there), Additionally, certain countries with minor landings did not submit these to intercatch for the full period, Again, the official landings were used in these cases, multiplied by the international proportion of *L. piscatorius* in the combined *Lophius spp.* landings.

Table B1. Overview of official landings that were added to the landings reported to intercatch

Country	Period	Avg proportion of total landings
All countries 27.7a landings	1986-2017	3%
Belgium	2002-2011	3%
Germany	2002-2016	0.7%
Netherlands	2002-2015	0.02%

French landings

France takes nearly 60% of the landings of this stock. The sample sizes are generally between ten and 50 trips per stratum for the dominant strata. Overall, less than half the landings have sample data associated with them, resulting in considerable imputations.

Spanish landings

Spain takes 10–20% of the landings. Spanish samples sizes are generally low (<10 trips), even for strata that dominate the overall landings. However, most of the landings have sample data associated with them, so there is virtually no imputation required.

UK (England) landings

The UK also takes 10–20% of the landings. The sample sizes vary considerably from year-to-year and between strata, however England has very few strata that contribute more than 1% to the total estimate. Slightly more than half of the landings have associated sample data, resulting in considerable imputations.

Irish landings

Ireland takes just under 10% of the landings. Irish sample sizes are generally low (<10 trips) but Ireland has very few strata that contribute more than 1% to the total estimate. About two-thirds of the landings have associated sample data, resulting in a moderate amount of imputations.

Other landings

The remainder of the landings are mainly from Belgium, Scotland. They contribute very little to the overall landings.

B.1.2 Discards estimates

Discarding in this stock is relatively minor (in the order of 5–10%). For landings strata with missing discards, the discard volume was estimated using the proportions of the catch that were discarded for similar strata using the following hierarchy:

1. If discard data were available for the same country, gear group and year, these discard proportions were applied to the landings of the strata with missing discards;
2. If discard data were only available for the same gear group and year, these discard proportions were applied;
3. If discard data were only available for the year, these discard proportions were applied.

The correlation between landings and discards is quite poor, however no alternative method is available and the overall contribution of discards to the catch is relatively small.

For the period 1986 to 2002 no discard data were available. For this period the discards were estimated from the mean proportion of the catch that was discarded during the period 2003-16 (6.77%).

French discards

The sample sizes of the French discard estimates are relatively high (>20 trips). However, most landings strata did not have associated discard estimates which resulted in considerable imputations, making the overall discard estimates very uncertain.

Spanish discards

The Spanish discard estimates generally have a high sample size, the reason for this appears to be that all Spanish sampling data were combined and subsequently split out across the strata. This is likely to provide a more precise and accurate estimate than the French approach.

UK (England) discards

English sample sizes for discards are variable but generally >10 trips for the most significant strata.

Irish discards

Irish sample sizes were relatively low and data were estimated on an annual basis and subsequently divided across the strata based on the proportion of landings in each stratum. As anglerfish grow quickly during their first few years, the quarterly length distributions will be inaccurate.

Other discards

Belgium provided discard estimates for 2012 and 2013 only.

B.1.3 Recreational catches

Recreational catches are assumed to be zero.

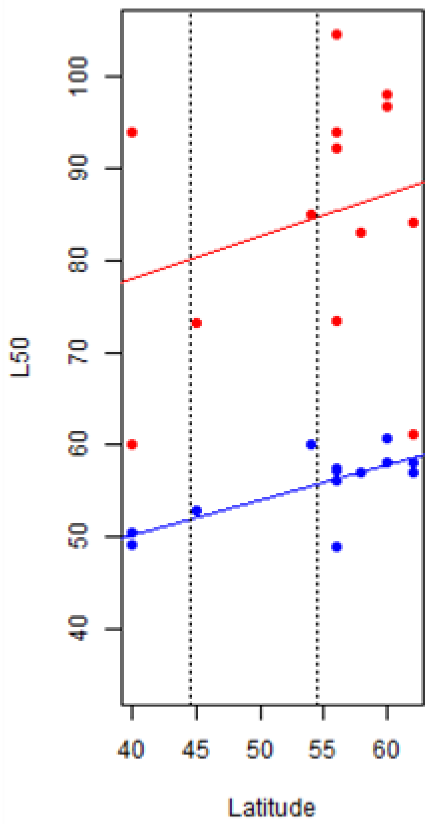
B.2 Biological sampling

B.2.1 Maturity

Spawning females are very rarely observed which makes it difficult to estimate maturity. Based on estimates from the literature and sampling data from Ireland, the mean length-at-first maturity was estimated to be around 80 cm for females. This corresponds to approximately age 5; knife-edge maturation was assumed (e.g. 0% mature at ages 0–4; 100% mature at ages 5+). WKAnglerfish (2018) decided to use female maturity in order to be conservative and also in an attempt to make SSB more closely related to the reproductive potential of the stock (assuming that this is limited by the biomass of mature females).

Figure and Table B.1. Estimates of L50 (mean length-at-first maturity) of *L. piscatorius* at various latitudes from the literature and unpublished data. The dotted lines indicate the extent of the stock area (27.7,8abd; 44.5–54.5 degrees North).

Reference	Area	Latitude	Sex	L50
Dyb in Thangstad, '06	W Norway	62	F	61
Dyb in Thangstad, '06	W Norway	62	M	57
Dyb in Thangstad, '06	North Sea	58	F	83
Dyb in Thangstad, '06	North Sea	58	M	57
Offstad, 2017	Faroe	62	F	84
Offstad, 2017	Faroe	62	M	58
Colmenero, 2017	NW med	40	F	60
Colmenero, 2017	NW med	40	M	49
Alfonso-Dias, 1996	W Scot	56	F	73.5
Alfonso-Dias, 1996	W Scot	56	M	48.9
Laurenson, 2003	Shetland	60	F	98
Laurenson, 2003	Shetland	60	M	58
Duarte, 2001	Iberian coast	40	F	93.9
Duarte, 2001	Iberian coast	40	M	50.3
Gordon, 2001	W Scot	56	F	92
Gordon, 2001	W Scot	56	M	56
Quincoces, 1998	Biscay	45	F	73.2
Quincoces, 1998	Biscay	45	M	52.7
Larensen, 2007	Shetland	60	F	96.7
Larensen, 2007	Shetland	60	M	60.6
Larensen, 2007	W Scot	56	F	93.8
Larensen, 2007	W Scot	56	M	57.1
Larensen, 2007	Rockall	56	F	104.4
Larensen, 2007	Rockall	56	M	57.3
Ireland, unpubl	W Ireland	54	F	85
Ireland, unpubl	W Ireland	54	M	60



B.2.2 Natural mortality

Then *et al*. (2014) analysed >200 independent, direct estimates of M and used cross-validation to select the prediction error of the estimators. They conclude that the maximum observed age (tmax) is the best predictor of M (by a considerable margin).

No direct observations of age are available for anglerfish; however the age composition of the catches can be estimated from growth parameters. This can then be used to simulate the oldest 'observed' age.

These growth parameters were used to estimate the age composition of the catches of ages 0 to 9+ (see: Section C.3.1). The mean numbers-at-age in the catches were then estimated for all years combined. Catch numbers for ages 9–30 were then extrapolated assuming a logarithmic decline in numbers based on the trend from ages 3–8. A million random samples were drawn from this age distribution to simulate the age observations of very large sampling programme. The resulting maximum 'observed' age was 20. The sensitivity to the growth model was investigated by repeating this procedure with faster and slower growth parameters (within the plausible range of growth):

- Fast growth: Linf = 244; K = 0.0727; t0 = 0
- Slow growth: Linf = 151; K = 0.1383; t0 = 0

Both alternative growth models resulted in lower maximum observed ages (18 and 16 years, respectively).

The estimator based on the maximum observed age proposed by Then *et al*. (2014) results in an estimate of M of 0.315 for a t_{max} of 20. However, the observation error around this estimate is considerable. After considering the fast growth, relatively old age at first maturity and cryptic lifestyle, it was assumed that the natural mortality of anglerfish is towards the lower end of the observation error of this estimate and M = 0.25 was assumed by WKAnglerfish (2018).

Natural mortality is likely to vary with age (smaller fish are more likely to suffer predation while mature fish may suffer from spawning mortality and older fish may also be more likely to succumb to parasites). WKAnglerfish considered that there is currently insufficient information to quantify age-varying (or time-varying) M.

B.2.3 Length and age composition of landed and discarded fish in commercial fisheries

Section B.1 describes how the length composition of the landings was estimated.

B.3 Surveys

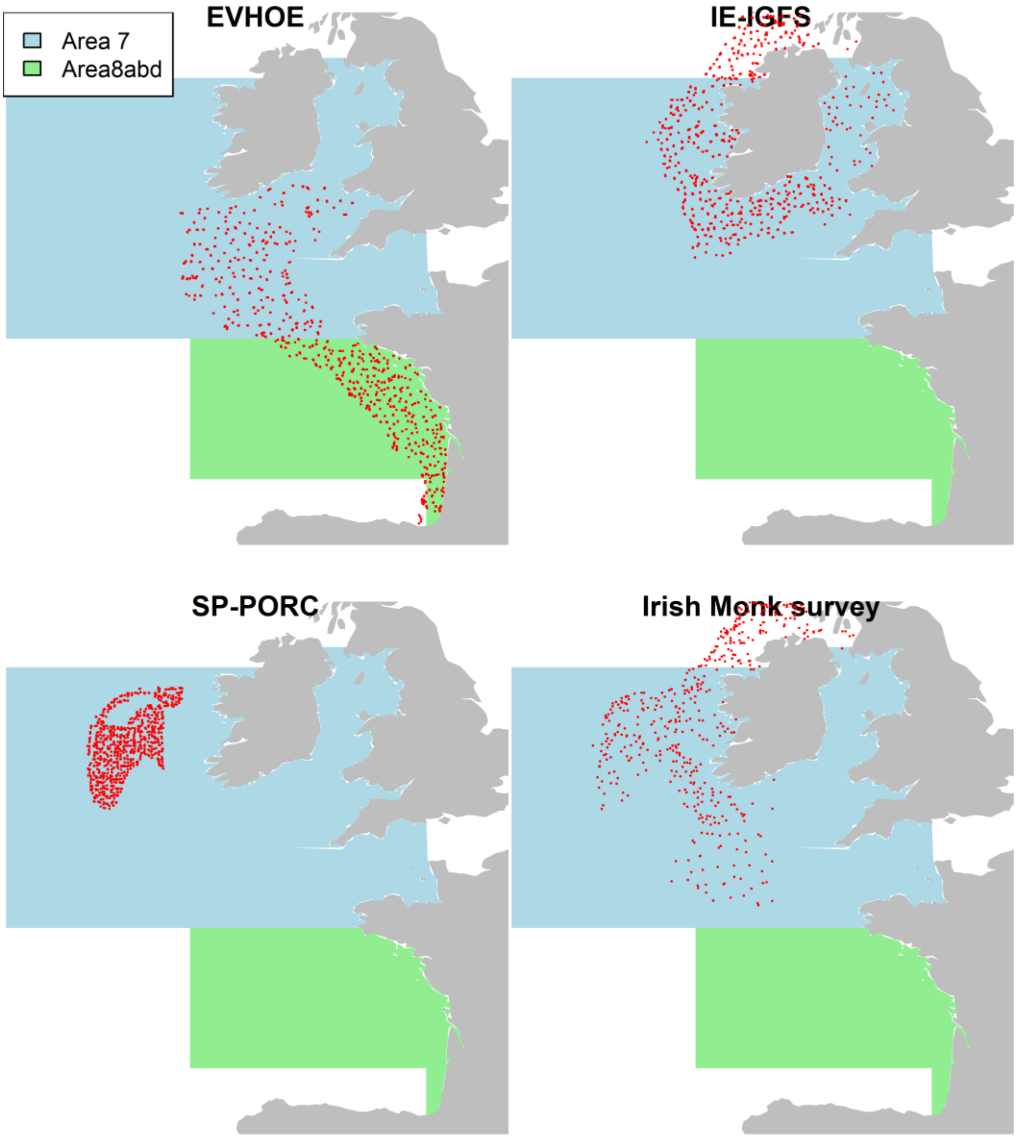


Figure B1. Spatial coverage of the available surveys. Red points indicate trawl positions; the full time-series is plotted so the number of trawl positions is not an indication of the annual number of trawls completed. The blue area represents 27.7 and the green area is 27.8abd.

B.3.1 Western IBTS Q4 EVHOE and IGFS surveys (France/Ireland) – FR_IE_IGFS

The Irish IBTS Q4 groundfish survey (IGFS-WIBTS-Q4) covers areas 27.7bgjk. The French EVHOE-WIBTS-Q4 survey covers areas 27.7j8ab. Both surveys are coordinated and largely standardised under WGIBTS and both use a GOV trawl. Together the two surveys cover the majority of the stock area up to depths of 200–300 m. This is where most of the young fish occur. Older fish migrate to deeper waters and are not fully available to these surveys.

Data for Irish and French IBTS Q4 groundfish surveys (IGFS and EVHOE) were obtained from DATRAS, quality checked and cleaned. The two surveys were combined by weighting their average catches by the area covered by each survey series (IGFS gets a weight of approximately 45% and EVHOE 55%). Because the main recruitment area appears to change over time and sometimes occurs in the Irish survey area, sometimes in the French area and sometimes in both; the combined survey gives a more coherent recruitment signal than the two separate surveys.

An index of catch numbers-at-length per hour fished was calculated for the years 2003 onwards.

B.3.2 Western IBTS Q4 Porcupine Survey (Spain) – SP_Porc

The Spanish Groundfish Survey in the Porcupine bank (SP-Porc) covers ICES divisions 27.7c,k and a small portion of 27.7b corresponding to the Porcupine Bank and the adjacent area in western Irish waters from longitude 12°W to 15°W and from latitude 51°N to 54°N, covering depths between 180 and 800 m. The survey takes place at the end of the third quarter (September), and the beginning of 4th quarter.

This survey catches larger anglerfish than the French and Irish IBTS surveys. The available survey index consists of catch numbers-at-length per 30 minutes fished for the years 2001 onwards.

B.3.3 Irish Anglerfish and Megrim Survey (Ireland) – IE_Monksurvey

Irish anglerfish survey data in area 27.7 are available for the years 2007, 2008 (under the acronym SIAMISS), 2016 onwards (IAMS). These surveys were designed to estimate the biomass of anglerfish and they cover a significant part of the stock in all depths up to 1000 m.

The survey index consists of catch numbers-at-length per swept-area.

The midpoint of the survey period is in January or February. However, because the survey data are available for the current year at the time of the assessment working group, it is beneficial to include the current year's survey in the assessment. The only way to do that in the current assessment framework is to offset the survey by a small amount so the survey is nominally taking place on the 31st of December of the previous year.

B.4 Commercial cpue

WKAnglerfish (2018) rejected the use of commercial cpue data due to concerns about changes in efficiency, targeting behaviour, quota restrictions, technical measures, discarding and compliance. However, trends in effort, landings and lpue or cpue may be used by the assessment working group as auxiliary information.

B.5 Other relevant data

Official landings data are available for the combined *Lophius* species since 1903. While the historic data cannot be separated into the two species and may suffer from inaccurate reporting, they provide useful insights in the development of the fisheries during before the period covered by the assessment.

C. Assessment methods and settings

C.1 Choice of stock assess model

Due to the strong cohort signals present in the catch data and survey indices, a statistical catch-at-age model was considered to be most appropriate to this stock.

C.2 Model used of basis for advice

Model used: a4a (+length-split based on VBGF to estimate age comp)

Software used*:* R package Fla4a (version 1.1.3) in R (version 3.4.1)

C.3. Assessment model configuration

Table C.1. Input data to the assessment.

Type	Name	Year range	Age range	Variable from year to year
landings	Landings in tonnes	1986–presnt	All	Yes
discards	Discards in tonnes	2003–present	All	Yes
landings.n	Landings-at-age in numbers	1986–present	0–7+	Yes
discards.n	Discards-at-age in numbers	2003–present	0–7+	Yes
catch.wt	Weight-at-age in the commercial catch	1986–present	0–7+	Yes
stock.wt	Weight-at-age of the spawning stock at spawning time.	1986–present	0–7+	Yes
m.spwn	Proportion of natural mortality before spawning	1986–present	0 all ages	No
f.spwn	Proportion of fishing mortality before spawning	1986–present	0 all ages	No
mat	Proportion mature at age	1986–present	Knife-edge age 5	No
M	Natural mortality	1986–present	0.25 all ages	No
Index1	Combined Irish/French IBTS	2003–present	0–2	Yes
Index2	Irish Monkfish Survey	2006–present but no data 2008–2014	1–5	Yes
Index3	Spanish Porcupine Survey	2001–present	2–6	Yes

C.3.1 Estimating numbers-at-age

Age data are not available for this stock. The age compositions of the catch and tuning indices are estimated (outside the assessment model) by applying a length-split to the length–frequency distributions. This is done in the following way:

- The mean lengths-at-age are estimated from a von Bertalanffy growth function (VBGF) with the following parameters: Linf = 171 cm; K=0.1075; t0=0. These parameters are based on:
    - Length–frequency analysis of the Irish/French IBTS survey data (to identify the mean length of the first two cohorts);
    - Tagging data (to estimate the growth rate of larger fish);
    - An estimate of Linf that is 90% of the largest observed fish (190 cm).
- For each quarter, a mixture distribution is estimated for the length–frequency distribution of the catch and indices with normal curves that have mean values predicted by the VBGF and standard deviations that increase linearly from 3 cm at age 0 to 10 cm at age 9.

- The mixture distribution is then used as an Age–Length Key (ALK) and applied to the catch, landings and discard numbers-at-length to estimate the numbers-at-age for each quarter. Separate mixture distributions are estimated for each index and applied to the index numbers-at-length.
- Weights-at-length are estimated using length–weight parameters (a= 3.03e–05; b=2.82). Weights-at-age are estimated in the same way as numbers-at-length.
- Quarterly age compositions of the catch, landings and discards are combined into annual estimates.

C.3.2 Missing discard numbers at age

Discard data are not available before 2003. Because all 0-group and most 1-group fish are discarded, the catch numbers at those ages were set to NA for the years 1986–2002. This allows the separable model to estimate the F-pattern at these ages for the period where discard data are available and use this to estimate the missing catch numbers under the assumption of unchanged catch selectivity and on-board selectivity. Discards and landings numbers-at-age can then be estimated from the modelled catch numbers-at-age. For years with missing discard data, 100% discarding was assumed for age 0; for age 1 it was assumed that 78% of the catch was discarded (average 2003–2016). For older ages 0% discards were assumed.

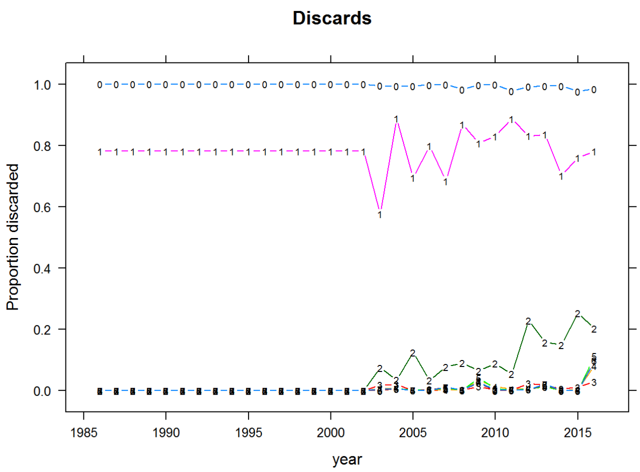


Figure C.1. Proportion of the catch discarded by age and year. Prior to 2003 the proportions were estimated.

C.3.3 Model configuration

Submodels:

```
fmodel: ~factor(replace(age, age > 6, 6)) + factor(year)
srmodel: ~factor(year)
n1model: ~factor(age)
qmodel:
  FR_IE_IBTS:    ~1
  IE_MONKSURVEY: ~I(1/(1 + exp(-age)))
  SP-PORC:       ~factor(replace(age, age > 5, 5))
vmodel:
  catch:         ~s(age, k = 3)
  FR_IE_IBTS:    ~1
  IE_MONKSURVEY: ~1
  SP-PORC:       ~1
```

- The F model is a separable model. The shape of the F-at-age pattern is independently estimated for each age except ages 6 and 7+, which are assumed to have the same F. This pattern in F is then scaled up and down independently for each year.
- Stock–recruit model: Freely estimated for each year.
- Catchability models:
    - For the IBTS survey, catchability is assumed to be the same for all ages.
    - For the Monk survey, catchability is assumed to increase asymptotically.
    - For the Porcupine survey catchability is freely estimated for each age but ages 5 and 6 are bound (i.e. same catchability for these two ages).
- N1 model (population in the first year of the time-series): default value a4aSCA function (independently estimated for each age)
- Vmodel (the shape of the observation variances): default value a4aSCA function: smooth function for the catch numbers-at-age and 'flat' for the indices

The f-bar range was set to ages 3–6

D. Short-term prediction

Model used: stf() and fwd() functions in R packages FLAssess and FLCore

Software used*:* R packages FLAssess (version 2.6.1) and FLCore (version 2.6.7) in R (version 3.4.4)

Weight-at-age in the stock: average last five years

Weight-at-age in the catch: average last five years

Proportion discards-at-age in the catch: average last three years

GM recruitment: full time-series excluding the last two years

Recruitment assumptions: GM recruitment in the intermediate year and advice year. Recruitment in last year of assessment is not replaced with GM unless the estimate is highly uncertain or there appears to be a retrospective bias.

Exploitation pattern: average F in last three years unless there is a trend in F or the forecasted catches in the intermediate year are likely to be constrained by the TAC.

Stock–recruitment model used: None

E. Biological reference points

Model used: eqsim

Software used: R packages msy (version 0.1.18), FLCore (version 2.6.5) in R (version 3.4.1) and icesAdvice (version 1.4.0)

Inputs: a4a assessment-final run of WKAngler 2018.

Stock–recruit model: a weighted stock–recruitment model was estimated using segmented-regression, Ricker and Beverton–Holt. The stock–recruit relationship is considered to be type 5 according to the technical guidelines (ICES 2017). Therefore B_{lim} was set at B_{loss} (16 032 t).

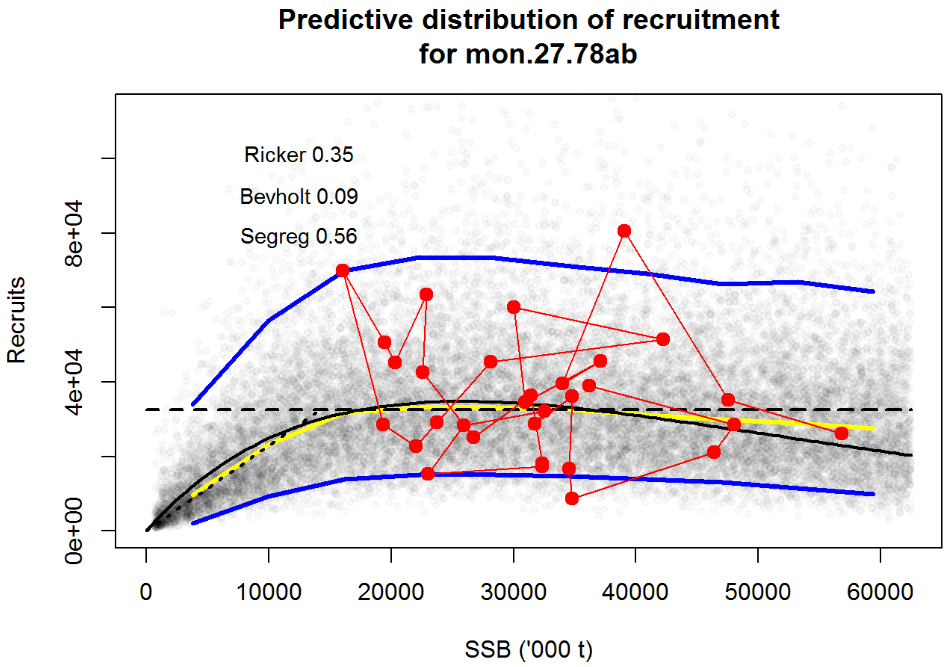


Figure E.1. Weighted stock–recruit model.

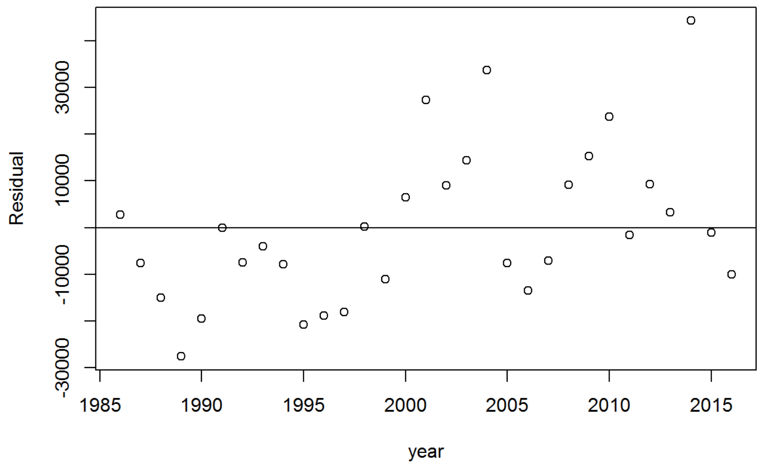


Figure E.2. Residuals in the stock–recruit relationship. In recent years the residuals are mostly positive, indicating higher recruitment than expected from the SR relationship.

Uncertainty parameters:

- F_{cv} = 0.233 (default value WKMSYREF4)
- SSB_{cv} = 0.20 (default value technical guidelines; only used for B_{pa} estimate)
- B_{lim} = B_{loss} = 16 023 t
- B_{pa} = B_{loss} with assessment error = 22 278 t
- F_{phi} = 0.423 (default value WKMSYREF4)

Selection pattern, biological parameters time period: ten years

Step 1: Eqsim base run without $B_{trigger}$

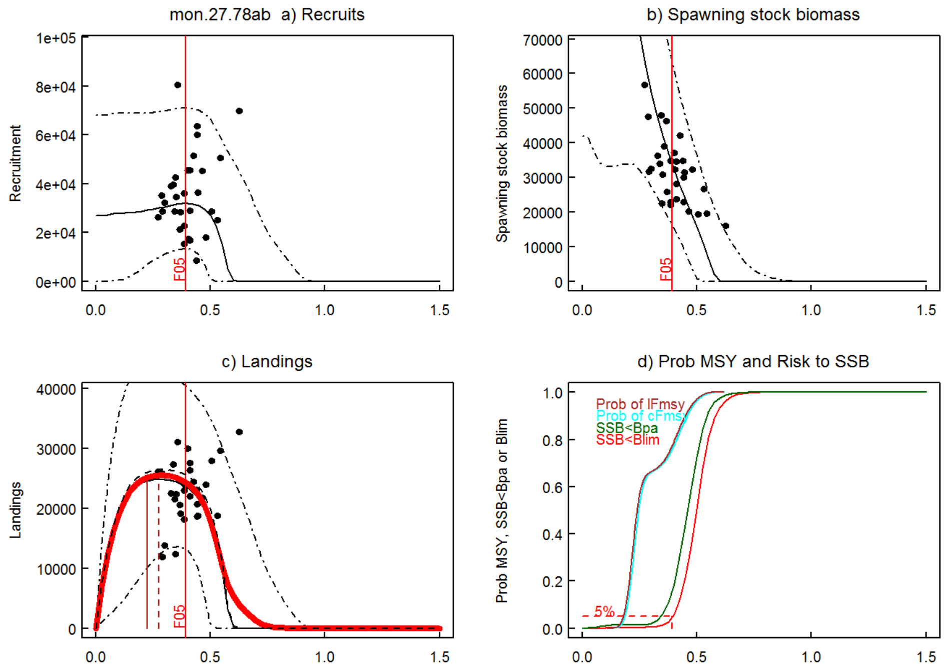


Figure E.3. Eqsim base run outputs. Panels a–c: historic values (dots) median (solid black) and 90% intervals (dotted black) recruitment, SSB and landings for exploitation at fixed values of F. Panel c also shows mean landings (red solid line). Panel d shows the probability of SSB less than B_{lim} (red), SSB less than BPA (green) and the cumulative distribution of F_{MSY} based on yield as landings (brown) and catch (cyan).

Following the first eqsim run, F_{MSY} was estimated as 0.279 with a range of 0.181–0.392

Step 2: Eqsim run with no error to select F_{lim}, F_{pa} and $B_{trigger}$

F_{lim} = 0.526; F_{pa} = 0.359; $B_{trigger}$ = 22 278t.

F_{pa} was estimated to be larger than F_{MSY} therefore the original estimate of 0.279 was carried forward

Step 3: Eqsim with $B_{trigger}$ to evaluate MSY advice rule

$F_{p.05}$ (F that gives 5% probability of SSB below B_{lim}) = 0.394

$F_{p.05}$ is slightly above the upper range of F_{MSY} estimate so the final choice of F_{MSY} remains 0.279 and the range remains unchanged as well.

Table E.1. Biological reference points

	TYPE	VALUE	TECHNICAL BASIS
MSY	MSY $B_{trigger}$	22 278 t	B_{pa}
Approach	F_{MSY}	0.28	Median Eqsim estimate for landings
	F_{MSY} range	0.181-0.39	
	B_{lim}	16 032 t	B_{loss}
Precautionary	B_{pa}	22 278 t	B_{lim} * exp(1.645*0.2)
Approach	F_{lim}	0.53	F with 5% probability of SSB <B_{lim}
	F_{pa}	0.36	F_{lim} * exp(-1.645 * 0.233)

F. Other issues

F.1 Biology of species

- Growth and possibly natural mortality is different for males and females. The available data are considered insufficient for a sex-specific assessment.
- As older fish migrate to deeper water, they may be less available to the fishing industry.

F.2 Stock assessment: historic overview

YEAR (Y)	2000(?)–2006	2006–2017	2018–
Model	XSA	None – survey trends	a4a
Software	vpa.exe/ FLXSA		FLa4a
Catch data	1986–		1986–
Age data	1–13+		0–7+
Fleets	FR-FU04 - commercial	FR-EVHOE	FR_IE_IBTS – survey
	SP-VIGO7 – commercial	IE_IGFS (2016, 17 only)	IE_Monk – survey
	SP-CORU – commercial	SP-PORC (2016, 17 only)	SP-PORC – survey
	EW0FU06 – commercial		
	FR-EVHOE – survey		

F.3 Current fisheries

See Section A1.

F.4 Management and advice

The TACs are set separately for areas 27.7 and 27.8 but for the two species of anglerfish combined (*L piscatorius* and *L. budegassa*).

F.5 Others

None.

G. References

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