stock Annex: template

Stock Annex **Northern Shelf Anglerfish**

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Anglerfish (*Lophius piscatorius and L. budegassa*) in Division IIIa, and Subareas IV and VI
Working Group:	Working Group on the Celtic Seas Ecoregion
Date:	1 April 2013
Revised by	WKROUND 2013 Liz Clarke.

A. General

A.1. Stock definition

Evidence from Anon (2001) and Hislop (2001) indicate that anglerfish Divisions IVa, Division VIa and Rockall should be treated as a single stock. The stock might in fact extend into VII, V or IIa, although there is currently insufficient evidence to support an extension of the stock area.

A.2. Fishery

UK vessels account for more than 50% of the total reported anglerfish landings from the Northern Shelf area. The Danish and Norwegian fleets are the next most important exploiters of this stock in the North Sea while Irish and French vessels take a significant proportion of the landings to the West of Scotland. The fishery for anglerfish in Subarea VI occurs largely in Division VIa with the UK and France being the most important exploiters, followed by Ireland. Landings from Rockall (Division VIb) are generally less than 1000 t with the UK taking on average around 50% of the total. In the North Sea, the majority of landings are reported in Division IVa which reflects the northerly distribution of the species within the North Sea (Knijn *et al*., 1993).

A general description of the anglerfish fisheries of the most important nations taking part in this fishery is given below:

Scottish (UK) fishery

The Scottish fishery for anglerfish in Division VIa comprises two main fleets targeting mixed roundfish. The Scottish Light Trawl Fleet takes around 60% of landings and the Scottish Heavy Trawl Fleet over 20%. Around 10% of landings are bycatch from the *Nephrops* trawlers. The development of a directed fishery for anglerfish has led to considerable changes in the way the Scottish fleet operates. Part of this is a change in the distribution of fishing effort; the development of a directed fishery having led to effort shifting away from traditional roundfish fisheries in inshore areas to more offshore areas and deeper waters. The expansion in area and depth range fished has been accompanied by the development of specific trawls

and vessels to exploit the stock. There has been an almost linear increase in landings from Division VIa since the start of the directed fishery until 1996 which has been followed more recently by a very severe decline, indicating the previous increase was almost certainly due only to the expansion and increase in efficiency of the fishery. More recent declines in landings (2002–2004) may have been due to restrictive TACs and the decline is not necessarily representative of the actual landings.

The Scottish fleet operating in VIb consists mainly of large otter trawlers targeting haddock and anglerfish at Rockall. Their activity is dependent on weather and the availability of haddock quota in VIb.

The Scottish fishery for anglerfish in the North Sea is located in two main areas: on the Shelf Edge to the north and west of Shetland and at the Fladen Ground. It expanded in a similar manner since the 1980s to that operating in Division VIa. The fishery to the north and west of Shetland operates as an extension to that in Division VIa and consists mainly of light trawlers targeting mixed round-fish. The highest reported landings in recent years come from the statistical rectangles around Shetland. The landings from the fishery at Fladen are lower but still significant (around 15% of the total) with anglerfish caught as a bycatch in the *Nephrops* fishery which consists of approximately 200 vessels. A small component of the landings (~10% in recent years) comes from the gillnet fishery which operates on the shelf edge in the far northwest of Division IVa. A large proportion of the landings in the gillnet fishery are taken by Spanish owned, UK registered vessels.

Irish fishery

The Irish fleet which takes around 15–20% of the total Division VIa landings is a light trawl fleet targeting anglerfish, hake, megrim and other gadoids on the Stanton Bank and on the slope northwest of Ireland. This fleet uses a mesh size of 80 mm or greater. Irish Division VIa landings come mainly from the Stanton bank with some landings from Donegal Bay and the slope northwest of Ireland. Since 1996 there has been an increase in the number of vessels using twin rigs in this fleet. There have also been changes to the fleet composition since 2000, with around ten vessels decommissioned and four new vessels joining the fleet. The activity of this fleet is not thought to have been significantly affected by the recent hake and cod recovery plans.

The Irish fleet otter trawl in Division VIb take anglerfish as a bycatch in the haddock fishery on the Rockall Bank. The fleet targeting haddock uses 100 mm mesh and twin rig trawls. Occasionally Irish-Spanish flag vessels target anglerfish, witch and megrim with 80 mm mesh on the slope in VIb. Discarding practices of these vessels are not known although discarding of anglerfish from the fleet targeting haddock in Division VIb is not thought to be significant (Anon, 2001). The fleet composition changed in 2001. In 2006 and 2007, the effort of the Irish fleet operating at Rockall has increased with the increase in Rockall haddock TAC.

Danish fishery

According to logbook records, the majority of Danish anglerfish landings are taken in the northeastern North Sea, in the part constituting the Norwegian Deeps, situated in the Norwegian EEZ of the North Sea. Other important fishing areas for anglerfish are the Fladen Ground (also in IVa) and in the Skagerrak (IIIa). More than 80% of the Danish landings come from ICES Divisions IVa and IIIa. The remaining part is from the most northern part of Division IVb.

The majority of the Danish vessels are taking anglerfish with demersal trawls with over 90% of these vessels in the size range 20–40m.

Fishery definitions by gear type and mesh size as currently used by Danish Fisheries Directorate for the North Sea are given in the following text table:

Fishery/gear	Mesh size, mm
Dem. Trawl	>= 100 mm
Nephrops trawl	70–99 mm
Shrimp trawl	33–69 mm
Industrial trawl	< = 32 mm
Beam trawl	>= 80 mm

Note that in the North Sea demersal trawls account for more than 90% of total Danish landings. However, it is necessary to further specify that at present the majority of the Danish catches of anglerfish are taken by fisheries in the Norwegian zone of IVa applying demersal trawls with mesh size >= 120 mm. In 2006, the fishery with demersal trawl in the Norwegian Deeps (in the Norwegian zone) accounted for around 75% of total Danish landings by all gears from the entire North Sea. In the Skagerrak (IIIa) the two main fisheries taking anglerfish are the (mixed) *Nephrops* fishery and the demersal trawl fishery. In both areas minor landings are taken in gillnets and as bycatch in fisheries for shrimp (*Pandalus*).

Typically anglerfish constitutes less than 15% by weight of the landings from demersal trawlers fishing in the Norwegian Deeps.

Norwegian fisheries

A Norwegian directed gillnet fishery (360 mm mesh size), targeting large anglerfish, carried out by small vessels in coastal waters in the eastern part of the Northern North Sea started in the early 1990s. These vessels are responsible for around 60–70% of the total Norwegian landings from this area and they comprise around 6% of the total landings from Division IVa since 1999. The remaining Norwegian landings in IVa are mostly bycatch in various trawl fisheries. A similar pattern of fishing is found in the Skagerrak (IIIa). The third quarter has in recent years been the most important season for the directed fishery, while the second quarter is apparently most important for other gears.

Other fisheries

French demersal trawlers also take a considerable proportion of the total landings from this area. The vessels catching anglerfish may be targeting saithe and other demersal species or fishing in deep water for roundnose grenadier, blue ling or orange roughy.

Since the mid-1990s, a deepwater gillnet fishery targeting anglerfish has been conducting a fishery on the continental slopes to the West of the British Isles, North of Shetland, at Rockall and the Hatton Bank. These vessels, though mostly based in Spain are registered in the UK, Germany and other countries outside the EU such as Panama. Gear loss and discarding of damaged catch are thought to be substantial in this fishery. Until now these fisheries have not been well documented or understood and they seem to be largely unregulated, with little or no information on catch composition, discards and a high degree of suspected misreporting.

A.3. Ecosystem aspects

Sea temperature limits the distribution of anglerfish to the north of the Northern shelf particularly at depths where cold-water currents of polar descent occur. *Lophius piscatorius* is predominant throughout the area,

with *Lophius budegassa* occurring in greater density towards the southern part of the area as befits the more general distribution of these two species (Fariña *et al.*, 2008).

B. Data

B.1. Commercial catch

B.1.1. Fishery landings data:

Fishery landings data for this stock are compiled from official statistics supplied by individual countries for ICES Divisions IIIa, IVa, IVb, IVc, VIa and VIb. Historical UK landings based on official statistics have been adjusted to correct for area misreporting for reasons described below.

The TACs for both the West of Scotland and North Sea areas were reduced substantially in 2003 and 2004, and at previous WGs it has been highlighted that these reductions would likely imply an increased incentive to misreport landings and increase discarding unless fishing effort was reduced accordingly (Section 6.4.6, ICES WGNSDS 2003). Anecdotal information from the fishery in 2003 to 2005 appeared to suggest that the TACs were particularly restrictive in these years. The official statistics for these years are, therefore, likely to be particularly unrepresentative of actual landings. The introduction of UK & Irish legislation requiring registration of all fish buyers and sellers may mean that the total reported landings from 2006 onwards are more representative of actual total landings in the UK & Ireland.

The absence of a TAC for Subarea IV prior to 1999 means that before 1999, landings in excess of the TAC in other areas were likely to be misreported into the North Sea. In 1999, a precautionary TAC was introduced for North Sea anglerfish, but was set in accord with recent catch levels from the North Sea which included a substantial amount misreported from Subarea VI. The area misreporting practices thus became institutionalised and the statistical rectangles immediately east of the 4°W boundary (E6 squares) accounted for a disproportionate part of the combined VIa/North Sea catches of anglerfish. The Working Group historically (prior to 2005) applied the following method to correct for area misreporting:

1. Estimate a value for the true catch in each E6 square and then allocate the remainder of the catch into VIa squares in proportion to the reported catches in those squares.

2. Estimate the 'true' catches in the E6 squares by replacing the reported values by the mean of the catches in the adjacent squares to the east and west. This mean is calculated iteratively to account for increases in catches in the VIa squares resulting from reallocation from the E6 squares. Such a re-allocation of catches may still inadvertently include some landings taken legally in Division IVa on the shelf-edge to the west of Shetland, but these are likely to comprise fish within the distribution of the Division VIa stock component.

From WGCSE 2010, this procedure was adjusted to reallocate data to the whole of Area VI: i.e. not just VIa but including Rockall (VIb). This was based on information received from Marine Scotland Compliance indicating that some vessels fishing for anglerfish at Rockall are reporting large catches in the E6 squares from the same voyage. The distribution of landings this new scheme produced was more in keeping with the distribution of the stock as indicated from the anglerfish surveys.

B.1.2. Split of landings data by species (L. piscatorius and budegassa)

The landings data are not currently split by species.

B.1.2. Fishery discards estimates

Sampling schemes are in place through DCF to estimate discards in European fleets, and with no MLS discard rates appear to be very low. Scottish discard rates estimated from Scottish observer scheme (see next section for details) have been low in recent years.

The Irish fleet otter trawl in Division VIb take anglerfish as a bycatch in the haddock fishery on the Rockall Bank. The fleet targeting haddock uses 100 mm mesh and twin rig trawls. Occasionally Spanish vessels target anglerfish, witch and megrim with 80 mm mesh on the slope in VIb. Discarding practices of these vessels are not known. Discarding of anglerfish from the fleet targeting haddock in Division VIb is not thought to be significant (Anon, 2001).

Since the mid-1990s, a deep-water gillnet fishery targeting anglerfish has operated on the continental slopes to the West of the British Isles, North of Shetland, at Rockall and the Hatton Bank. These vessels, though mostly based in Spain are registered in the UK, Germany and other countries outside the EU such as Panama. Gear loss and discarding of damaged catch are thought to be substantial in this fishery. Until now these fisheries have not been well documented or understood and they seem to be largely unregulated, with little or no information on catch composition, discards and a high degree of suspected misreporting.

B.1.3. Fishery length compositions

Scotland

Scottish anglerfish catch compositions are estimated from data collected under the Scottish demersal market and observer sampling programmes. Data are currently recorded for both anglerfish species but reported for both species combined. Anglerfish discards have been very low in recent years.

The demersal market sampling scheme is stratified by market, aiming to visit each of the 4 major Scottish markets, which account for around 80% of demersal species landings by weight, at least 36 weeks per year. Random selection sheets are used to pick which vessel's landings to sample, and the sampling team check there are no missing categories for the relevant species before sampling. Boxes are selected from each sale size category and all the fish from a selected box are measured on a cm measuring board. Otoliths are taken for eight major Scottish species, including anglerfish. Annual sample size by species for the market sampling scheme is around 200 fishing trips from area IV, and around 40 fishing trips from area VI.

The demersal observer programme comprises 68 trips a year, allocated in very rough proportion to landings across areas IV and VI, and covering the three main vessel groups that land the majority of Scottish demersal species: demersal trawlers, small *Nephrops* trawlers which mainly work inshore, and large *Nephrops* trawlers which mainly work offshore. Each trip in each area and vessel group combination is selected by contacting consecutive vessels on a randomly ordered vessel list until a vessel is found that intends to fish in the correct area, will accept the observer on board, and the observer considers meets their logistical and safety criteria. Annual sample sizes are approximately 50 fishing trips for area IV and 20 for area VI.

Estimates for landed numbers at age and length are obtained by "raising" market samples to the 6 vessel group and area combinations by quarter, by means of post-stratification, including appropriate sampling probabilities, and using species landed weight as an auxiliary variable. Estimates for discarded numbers at age and length are obtained by "raising" discard samples to the 6 vessel group and area combinations by year, including appropriate sampling probabilities and using gadoid landed weight as an auxiliary variable. Mean weights at age and length are obtained using survey based weight-length relationships.

A total international catch-at-length distribution for Division VIa was obtained by summing national raised catch-at-length distributions and then raising this distribution to the WG estimates of total international catch from this area. Landings officially reported to ICES were used for countries not supplying estimates

directly to the WG. Since 2001, the Scottish market sampling length–weight relationships (given below) have been used to raise the sampled catch-at-length distribution data Working Group estimates of total landings for Division VIa. Length–frequency data availability for VIb has been limited to Scottish and Irish samples.

Year Range	Formula (L – length in cm, W – weight in g)	Source
1992–2000	W=0.01626L2.988	Coull *et. al*., 1989
2001 onwards	W=0.0232L2.828	Scottish Market Sampling

As a first step in assembling assessment data for the North Sea component of the stock, length compositions from Scottish market sampling have been raised to Working Group estimates of total landings in the past. The Working Group estimate of total landings was assumed equal to the landings obtained by national scientists plus official landings as reported to ICES for those countries not providing landings data to the Working Group.

Total international catch-at-length distribution data for the whole Northern shelf (Division IIIa, Subarea IV and Subarea VI) have previously been obtained by summing the length distributions from the individual areas and assuming that this distribution is representative of the whole Northern Shelf. This was then raised to Working Group estimates of total landings for the Northern Shelf.

B.2. Biological

B2.1. Growth and ageing

An international ageing exchange in 2011 (ICES 2012) found little agreement between age estimation from both otoliths and illicia and concluded that anglerfish ages could not determined accurately enough for the purposes of producing an international catch-at-age dataset for stock assessment purposes.

WKFLAT (ICES 2012) concluded that for *Lophius piscatorius* the studies of growth of Landa *et al*. (2012) should be used as the basis for length based assessments, and this growth rate is supported by data in Laurenson *et al* (2005). However the available growth curves assume asymptotic growth whereas anglerfish data from the Sco-IV-VI-AMISS-Q2 survey described below show linear growth.

WKFLAT (ICES 2012) also concluded that for anglerfish in Divisions IIa and IIIa, Subarea IV and Subarea VI, ageing based on otoliths exists and age based assessments could be considered for this stock if the internal consistency of the age composition of the data were examined in more detail and sensitivity to growth assumptions considered. Further growth and (ageing) age validation studies taking sex into account are required.

B2.2. Maturity

Historically, the catch-at-age analysis of anglerfish in Division VIa used the same maturity ogive as that applied to anglerfish in Subareas VII and VIII by the Working Group on the Assessment of Southern Shelf Demersal Stocks. However, a number of more recent maturity studies based on the VIa stock indicate that maturity does not occur until much later than previously estimated. Afonso-Dias and Hislop, 1996 give a length–maturity ogive for this stock, 50% maturity at approximately 74 cm in females, and 50 cm in males. However, this study was based on few samples. New information has become available from the EU-funded project (Anon, 2001) which indicates female 50% maturity at approximately 94 cm and males at 57

cm. The corresponding age-based ogives indicate 50% maturity at approximately age 9 in females and age 5 in males. This has also been supported by more recent studies by Laurenson et al., 2005.

B2.3. Natural mortality

Previous assessments of this stock used the natural mortality rate applied to anglerfish in Division VI adopted by an earlier Hake Assessment Working Group of 0.15 yr^{-1}.

B.3. Surveys

B 3.1. Sco-IV-VI-AMISS-Q2 survey

In previous length-based assessments of this stock, a recruitment index was used which had been obtained from the Scottish March West Coast survey. The index consisted of numbers of anglerfish less than 30 cm caught per hour. However, meetings of the WG around 2003/2004, it was concluded that the IBTS groundfish surveys are ineffective at catching anglerfish and do not provide a reliable indication of stock size. As a result of this conclusion, and the urgent requirement for fishery independent data, Marine Scotland Science began a new joint science/industry survey in 2005 (current survey name is Sco-IV-VI-AMISS-Q2).

B 3.1.1 Design of survey

This is a targeted anglerfish survey with a scientific design using commercial gear, currently covering part of IVa and the whole of VIa and VIb. In 2005, 2008 and 2010, the survey covered VIa down to 56°. In 2006, 2007 and 2009, Ireland also participated, extending the anglerfish survey to cover the remaining part of VIa (from 54°30' to 56°39'). In 2011 and 2012, the Scottish survey covered the whole of VIa. The survey area is stratified into 4 main areas, East – East of Orkney & Shetland, North – North of Scotland, West – West of Scotland and Rockall, as shown in Figure x, which are stratified by depth (0-200, 200-500, 500-1000), and with the 0-200 stratum being further stratified in all except the East Stratum, based on industry perceptions and the results of the 2005 survey. Within a stratum, the expected densities in substrata are defined as "very high", "high", "medium" or "low". The sampling effort within each substratum is allocated according to its expected density, and the sample locations are chosen at random from grids of points within strips of equal area. This is to ensure equal probability of selection and even coverage within a stratum. Approximately 100-150 tows are taken each year. Tow duration is 1 hour. Each stratum is surveyed by one vessel, with at least one stratum being surveyed by MSS RV Scotia and with the other 2-4 strata being surveyed by industry charters. Each vessel on the survey employs exactly the same gear, the specification of the of which was drawn up in partnership with industry. Every anglerfish caught is measured for length, sex, maturity, total weight and gutted weights, and otoliths and illicia taken. In 2005-2007, surveys took place towards the end of October and beginning of November. However bad weather affected survey coverage to the extent that the survey was moved to April from 2008 onwards. The stratification and station locations used in 2012 are presented in Figure x.

A more detailed description of of the survey including information on design, sampling, gear and vessel can be found in Fernandes et al (2007). However, estimation has been further developed since then and is described below.

B 3.1.2 Estimation of abundance and catchability components

a) The estimation of abundance and biomass from these surveys is described below.The estimates represent the take into account the following factors: herding of anglerfish by the trawl doors and sweeps;

b) escapes of fish under the trawl footrope (details given below)

c) anglerfish abundance and biomass in the southern part of Area VI not covered in 2005, 2008 and 2010;

d) visual counts of anglerfish in areas closed to trawling at Rockall

e) variability due to:

- sampling;
- missing ages;
- herding (based on experimental data);
- footrope escapes (based on experimental data).

The estimates currently do not take account of the following:

areas in the central and southern North Sea (eastern part of ICES Division IVa and all of IVb and IVc);

areas inaccessible to the trawl in Division VIa.

To estimate the total number of anglerfish, *N*, from the survey, *S*, carried out in year *y*, $\hat{N}_y$, a Horvitz-Thompson estimator is used. This requires the inclusion probability, π_f, of each fish, *f*, captured in the survey (i.e. the probability of that fish being captured on the survey), which we also need to estimate:

$$\hat{N}_y = \sum_{f \in S} \frac{1}{\hat{\pi}_f}$$

It is assumed that the inclusion probability of a fish depends on its length *l*, the haul *i*, and the stratum *s*, of the survey the haul is in, as we shall see below, so that $\pi_f = \pi_{ils}$. Since the inclusion probability is the same for fish of the same length on the same haul, the estimation equation can be written as

$$\hat{N}_y = \sum_{s \in S} \sum_{i \in s} \sum_{l} \frac{n_{ils}}{\hat{\pi}_{ils}}$$

where n_{ils} is the number of fish of length *l* captured in haul *i* of stratum *s*.

Millar and Fryer (1999) partition the probability of capture for a fish in the population into 3 parts, potentially all being a function of length *l*: the probability of being retained in the net given the fish has encountered the net, r_l, the probability that the fish encounters the gear given that it is available to the gear, and the probability of the fish being available to the gear.

It is assumed that all fish in a stratum are randomly distributed in that stratum so that they have equal probability of encountering the gear, so that the probability that a fish is in the path of haul *i* towed in the stratum *s* is given by v_i / A_s, where v_i gives the area swept by the doors (and the net) on tow *i* and A_s gives the area of stratum *s*.

Somerton et al (1999) show that the probability that a fish contacts the fishing net given that it was in the area swept by the haul *i* is given by $\frac{v_{1i} + hv_{2i}}{v_{1i} + v_{2i}}$, where v_{1i} is the area swept by the net in haul *i* (the area swept by the wings), v_{2i} is the sweep area in trawl *i* i.e. the area swept by the doors minus that swept by the wings, and *h* is the herding coefficient, which gives the proportion in v_{2i} herded into v_{1i}.

Thus the inclusion probability of a fish of length *l* is given by the following equation:

$$\pi_{il} = \hat{r}_l \left(\frac{v_{1i} + hv_{2i}}{v_{1i} + v_{2i}} \right) \frac{v_i}{A_s}$$

where

$\hat{r}_l$ is the estimated probability that a fish which encounters the net is retained in the cod-end of the fishing net, i.e. does not escape under the footropes,

$v_i = v_{1i} + v_{2i}$,

and N_y can be estimated by:

$$\hat{N}_y = \sum_{s \in S} \sum_{i \in s} \sum_{l} \frac{n_{ils}}{\pi_{ils}} = \sum_{s \in S} \sum_{i \in s} \sum_{l} \left[\frac{n_{ils}}{\hat{r}_l \left(\frac{v_{1i} + hv_{2i}}{v_{1i} + v_{2i}} \right) \frac{v_{1i} + v_{2i}}{A_s}} \right] = \sum_{s \in S} \left\{ A_s \sum_{i \in s} \left[\frac{1}{(v_{1i} + hv_{2i})} \sum_{l} \left(\frac{n_{ils}}{\hat{r}_l} \right) \right] \right\}$$

Similarly, the biomass B_y in year *y* is estimated by:

$$B_y = \sum_{s \in S} \left\{ A_s \sum_{i \in s} \left[\frac{1}{v_{1i} + hv_{2i}} \sum_{l} \left(\frac{1}{\hat{r}_l} \sum_{j=1}^{n_{ils}} w_{ilsj} \right) \right] \right\}$$

where w_{ilsj} is the weight of fish *j* of length *l* on haul *i* of stratum *s* of survey *S*.

a) Estimation of herding of anglerfish by the trawl doors and sweeps

The estimation of the herding coefficient ($\hat{h} = 0.017$) is described in Reid et al (2007a). An individual-based particle-tracking model at to simulate the capture process was constructed using behavioural observations of 54 anglerfish captured from TV footage from the wing ends and along the sweeps. Detailed analysis of the recordings showed that the fish did not appear to herd and

many of the encounters with the wires were passive. All fish in the path of the net were captured, whereas more than half of the fish between the wings and the doors were not.

b) Estimation of escapes of fish under the trawl footrope

The proportion of fish at length that escaped below the gear was estimated from a series of experimental trawls using bags below the fishing line. These trials are described in Reid *et al* (2007b). Selectivity functions were fitted to these data in a GLM f ramework assuming a Binomial distribution. A comparison of 3 selectivity functions were made: simple logistic, asymmetric logistic (estimating an asymptote parameter) however the simple logistic curve was found to be adequate for these data:

$$r(l) = \frac{\exp(\beta_0 + \beta_1 l)}{1 + \exp(\beta_0 + \beta_1 l)}$$

This model was then applied to the length data from each survey to correct for those fish that were likely to escape under the net as described above.

c) anglerfish abundance and biomass in the southern part of Area VI not covered in 2005, 2008 and 2010;

Estimates of the proportion of anglerfish in the southern part of ICES division VIa were derived from 2006, 2007 and 2009 when Ireland contributed to the survey and covered this area completely. The proportions of abundance in this area relative to the whole Northern shelf were 8.6% in 2006, 13.6% in 2007 and 4% in 2009; the proportions of biomass were 5.5% in 2006, 7.4% in 2007 and 2.5% in 2009. The averages of these proportions (i.e. 8.7% for abundance and 5.1% for biomass) were used to raise the estimates of the surveys in 2005, 2008 and 2010 when Scotland did not survey this area and the Irish did not participate.

d) Estimation of anglerfish abundance in areas closed to trawling at Rockall

Visual counts of anglerfish in areas closed to trawling at Rockall have been carried out in all years since 2007, as described in McIntyre *et al*, (in press). A deep towed vehicle was developed, equipped with video, lights and other sensors, to enable visual surveying at depths of over 300 m, at speeds of up to 3 knots and altitudes of up to 10 m (from the seabed). This vehicle was used to survey large areas of the seabed around Rockall, in areas which are closed to trawling due to the presence of the deep-water coral *Lophelia pertusa*. Counts were made from visual inspection of the TV footage. The total area surveyed by video was calculated by summing the area surveyed every second over the entire transect, the latter being calculated from the trapezoid between the midpoints of one image frame and the next image frame a second later.

The number of anglerfish $N_{c,y}$ in closed area *c* in year *y* was estimated by:

$$\hat{N}_{c,y} = A_c \hat{\rho}_{c,y},$$

where A_c is the surface area of the closed area *c* (km^2)

and $\hat{\rho}_{c,y}$ is the mean density of closed area *c* in year *y*, estimated from the survey in year *y* as follows:

$$\hat{\rho}_{c,y} = \frac{1}{t_{c,y}} \sum_{i \in c} \frac{n_{i,c,y}}{A_{i,y}} \qquad (11)$$

where:
$t_{c,y}$ is the number of tows in closed area c in year y
$n_{i,c,y}$ is number of anglerfish recorded in tow i in closed area c in year y
A_i is the area of the seabed (km^2) surveyed by the visual tow i in year y.

Biomass in these areas was calculated by multiplying the abundance by the average weight of anglerfish in the adjacent trawl strata of each survey. The abundance and biomass of anglerfish in the north-west Rockall closure was added to the estimates as additional strata The proportions of abundance and biomass in the north-west Rockall closed areas relative to that in the adjacent two strata were then used to estimate the abundance and biomass in the Empress of Britain bank closure.

Abundances in the closed areas surveyed between 2007-2011 have been estimated by this method as 150-220 thousand fish, approximately 1% of anglerfish in numbers on the Northern Shelf.

B 3.1.3 Estimation of length and age compositions

Each fish caught on the survey is measured and aged and so the number at length, N_{ly} and the number at age N_{ay} are estimated from the survey data in a similar way to the total numbers and biomass:

$$\hat{N}_{ly} = \sum_{s \in S} \left\{ A_s \sum_{i \in s} \left[\frac{n_{ils}}{\hat{r}_l \left(v_{1i} + h v_{2i} \right)} \right] \right\}$$

and

$$\hat{N}_{ay} = \sum_{s \in S} \left\{ A_s \sum_{i \in s} \left[\frac{1}{v_{1i} + h v_{2i}} \sum_{l} \frac{n_{ilsa}}{\hat{r}_l} \right] \right\}$$

where n_{ilsa} is the number of fish of age a and length l on haul i of stratum s of survey S.

The ages are estimated from otoliths read for all surveys by the same experienced reader.

B.4. Commercial CPUE

B.4.1. Official logbook data

Previous length-based assessments attempted to use effort data to constrain the temporal trend in fishing mortality. Scottish Light Trawl data, disaggregated into an inshore and offshore component, the latter of which is associated with the anglerfish fishery, for both West of Scotland and Shetland (N Sea) were provided to the Working Group. However, these data are no longer considered to be reliable due to non-mandatory recording of hours fished in the logbook data. Further details of the Scottish fleet effort recording problem can be found in the report of the 2000 WGNSSK (ICES, 2001). Since these data are considered unreliable, they are not presented here.

Irish lpue data in terms of hours fished have been presented to the WG for Division VIa and Division VIb for all fleets up to 2006. The measure of kWdays is believed to be a more reliable proxy for effort than hours fished due to reporting issues and these data are now presented in the WG report.

Danish landings and effort data (hours fished) from logbook data are also available to the WG for Division IIIa and Division IVa. Although these data are considered to be reliable (in terms of accuracy of reporting), it is not know to what extent they are useful in providing *an* indicator of stock size due to management regulations in the Norwegian zone (TAC constraints) and technological creep.

B.4.2. Tallybook data

Analysis of skippers' personal diary information collected in 2004 and 2005 in an attempt to improve knowledge of the state of the stock and of the Scottish anglerfish fishery provided valuable information to ICES (Bailey, *et al*., 2004) on temporal and spatial trends in catch rate. Following the success of this data collation exercise, ICES advised the process to continue and a more formal scheme was proposed by FRS.

Extensive discussions with the fishing industry during 2005 resulted in FRS implementing the monkfish tallybook project at the start off 2006. The project is part of a long-term approach to providing better information on the monkfish fishery and the state of the stock, and is being operated in conjunction with fishers' organisations (Scottish Fishermen's Federation, Fishermen's Association Limited and Pecheurs de Manche et Atlantique) and the North Atlantic Fisheries College (NAFC) Marine Centre, Shetland. These organisations have been responsible for distributing the tallybooks, co-ordinating the returns and allocating a vessel code before the anonymised tallybook sheets are forwarded to FRS. The tallybooks are filled in on a haul-by-haul basis to give weight caught by size category and information on haul location, duration and depth in a standardized format as well as gear and mesh being used. Additionally information on mature females has been requested. Data are stored in a database at FRS.

The time-series is relatively short, with the first returns from fishing trips at the end of December 2005 and the most recent from March 2008. Initial participation in the scheme was high with returns received from up to 37 vessels with a wide spatial coverage (across Subarea VI, Division IVa, IIa and Vb) and different target species. Of the 37 vessels which supplied information, two were French and these operated towards the southern end of the shelf edge in Division VIa northwest of Ireland. The haul depth information collated indicates that most of the hauls were taken in depths between 100 and 400 m although there are a significant number of hauls from depths between 600 and 800 m. The records from the deeper waterwere largely from the French vessels although a number of the Scottish vessels make occasional trips into deeper water. Average catch rates are similar to those previously seen in the diary data and observer data (presented in previous WG reports) and range from around 10 kg/hr for boats targeting *Nephrops* to over 100 kg/hr for some whitefish boats.

Analysis of the catch rate data is presented in the WG report and in Dobby *et al.*, 2007.

B.5. Other relevant data

C. Assessment: data and method

Since 2012, this stock has been assessed in accordance with the approach suggested by ICES (2012) for data limited stocks, category 3: survey only assessments, method 3.2.0 for if the are survey data on abundance but there is no survey-based proxy for MSY $B_{trigger}$ and F values or proxies are not known.

1. Determine the catch advice from the survey adjusted status-quo catch:

$$C_{y+1}^{SASQ} = C_{y-1} \frac{\frac{1}{2}\sum_{y-2}^{y-1} I_i}{\frac{1}{3}\sum_{y-5}^{y-3} I_i}$$

where I_i is the biomass index from the survey in year *i*.

2. Apply the 20% Uncertainty Cap to the catch advice:

$$C_{y+1}^{UC} = \begin{cases} 0.8C_{y-1} \text{ if } C_{y+1}^{SASQ} \le 0.8C_{y-1} \\ C_{y+1}^{SASQ} \text{ if } 0.8C_{y-1} \le C_{y+1}^{SASQ} \le 1.2C_{y-1} \\ 1.2C_{y-1} \text{ if } C_{y+1}^{SASQ} \ge 1.2C_{y-1} \end{cases}$$

Apply this cap to the catch advice to address uncertainty or noise in the data and its potential influence on the catch advice. This cap should be applied to all quantitative advice for data limited stocks, regardless of category; however if the advice is simply based on last year's advice, no uncertainty cap is applied.

3. Then apply the Precautionary Buffer to the catch advice:

$$C_{y+1}^{PB} = \begin{cases} 0.8C_{y+1}^{UC} \text{ unless exceptions apply} \\ C_{y+1}^{UC} \text{ given exceptions e.g. } \frac{\frac{1}{2}\sum_{y-2}^{y-1} I_i}{\frac{1}{3}\sum_{y-5}^{y-3} I_i} \ge 1.5, \text{ or decreasing effort} \end{cases}$$

Apply this buffer when reference points are unknown; how if substantial increases in abundance indices are consistently observer or there are substantial reductions in fishing mortality or effort in the target fishery, this precautionary buffer may not apply to catch advice.

When the precautionary buffer is applied, the catch advice should apply for at least three years unless new information or analyses indicate a new situation (e.g. there is a clearly marked increase in stock indicators.)

D. Short-Term Projection

Not applicable.

E. Medium-Term Projections

Not applicable.

F. Long-Term Projections

Not applicable.

G. Biological Reference Points

Not known.

H. Other Issues

In previous ('catch-at-length') assessments of this stock, the SSB was always estimated to be at a very low level. The length data have been based on the U.K. landings only (in Subdivisions. IVa and VIa), where very few individuals over 80 cm appear in the catch and therefore the model predicts very few in the population. Since females do not mature until they are over 90 cm in length the SSB is estimated to be very low. The length data from the eastern part of the North Sea (Danish and Norwegian fisheries) for the recent years indicate a higher amount of larger individuals in the catches. Although the Danish and Norwegian landings are small in comparison to the UK landings, the inclusion of the Danish and Norwegian length frequencies in the data used for any future assessment may change the concept of the magnitude of the SSB.

The fact that mature female anglerfish are rarely observed either on scientific surveys or by observers on board commercial vessels supports a very low estimate of spawning–stock biomass, yet there is little evidence of reduction in spatial distribution as fish are still recruiting to relatively inshore areas. It has been hypothesized that females may become pelagic when spawning as they produce a buoyant, gelatinous ribbon of eggs, and would therefore not appear in the catch of trawlers. (Anglerfish have been caught near the surface, Hislop *et al*., 2000). This would imply different exploitation patterns for males and females: a dome-shaped pattern (decreased exploitation at larger sizes) for females and a logistic pattern for males. It is also not known whether anglerfish are an iteroparous or semelparous species. The latter would also account for the almost complete absence of spawning females in commercial catches or research vessel surveys.

The key features of the species' life history in relation to its exploitation are the location of the main spawning areas, and whether or not there is any systematic migration of younger fish back into the deeper waters to spawn. At present, despite the large increase in catches during the mid 1990s, there is no apparent contraction in distribution; fish are still recruiting to relatively inshore areas such as the Moray Firth in the northern North Sea. The fact that spawning may occur largely in deep water off the edge of the continental shelf may offer the stock some degree of refuge. However, this assumes that the spawning component of the stock is resident in the deep water, and is thus not subject to exploitation. It is not known to what extent this is true, but if such a reservoir exists then the currently used assessment methods which make dynamic pool assumptions about the population are likely to be inappropriate. Nevertheless, it is clear that further expansion of the fishery into deeper water is likely to have a negative effect on the SSB and given the spatial development of the fishery, it cannot be ruled out that the serial depletion of fishing grounds has been occurring. In addition, some life-history characteristics of anglerfish suggest that it may be particularly vulnerable to high exploitation. A detailed discussion of the fishery development and biology can be found in Sections 7.5.4 and 7.5.5 of the 2000 Report of this Working Group (ICES, 2001).

H.1. Historical overview of previous assessment methods

A length based model was used up to 2003 (Dobby 2002) but was subsequently abandoned due to lack of confidence in the landings data. Since then WGs have presented trends from the Sco-IV-VI-AMISS-Q2 survey.

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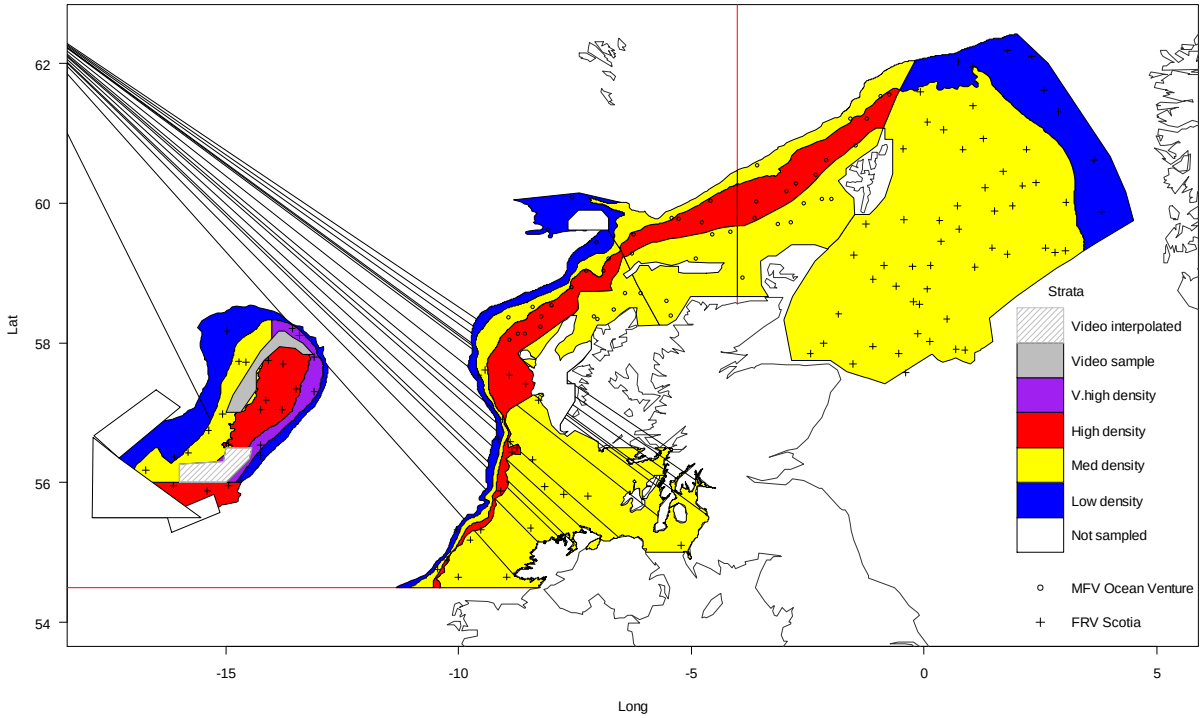

Figure **1.** Map of the northern continental shelf around the British Isles showing the areas surveyed during the anglerfish surveys in 2011, shaded according to the survey strata as indicated in the legend. Sample positions (n=153) are indicated by the black crosses (FRV Scotia, n=104) and black circles (MFV Ocean Venture, n=49).