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Report of the Workshop on Anglerfish and Megrim (WKAGME)

23–27 February 2009

Aberdeen, UK

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Executive summary

The **Workshop on Anglerfish and Megrim [**WKAGME] met in Aberdeen, 23–27 February 2009: it was co-chaired by Paul Fernandes (Scotland, UK) and Norman Graham (Ireland). The objectives of the meeting were to review the recent fishery-independent surveys of anglerfish and megrim, examine the research needs to improve survey estimates and consider survey-based harvest strategies. The Workshop also included examinations of self-sampling programmes, catch and effort data, and issues associated with ageing. There were 11 participants from five nations (Scotland, UK, Ireland, France, Denmark and Norway).

Because of the nature of the participants, only anglerfish and megrim on the northern shelf (ICES Subareas VI and IV and Division IIIa) and ICES Division IIa were considered. In these areas *Lophius piscatorius* is the dominant anglerfish species and *Lepidorhombus whiffiagonis* dominates the megrim catch. French, Irish and Scottish trawl fleets fish for these in Subarea VI; Scottish and Danish fleets in Subarea IV and Division IIIa; and a Norwegian coastal gillnet fishery operates in Division IIa. Historically, ICES did not consider megrim in Subarea IV, despite evidence that this may also be a continuous stock across the northern shelf. However, from 2009 the stock in VIa and IVa are considered as a unit stock.

Since 2005 Scotland has carried out dedicated annual surveys in collaboration with the fishing industry to estimate the abundance of anglerfish on the northern shelf. Ireland contributed in 2006 and 2007. These surveys incorporate factors to account for whole gear selectivity and visual methods to deliver absolute methods of anglerfish abundance. The estimates of absolute abundance of anglerfish from the surveys from 2005–2008 are inline with previous assessments of their abundance (total-stock biomass of 54 000 t in 2008). These are considered as minimum estimates, largely because there are strong indications of [whole gear] selectivity at-ages less than four, and large areas in Subarea IV and all of Division IIIa which are not surveyed. Work should be done to: improve estimates of footrope escapes; incorporate other survey data (e.g. IBTS) in the areas not surveyed; identify the location of younger anglerfish; improve the survey design; and estimate the two species of anglerfish separately. Estimates of megrim are limited to providing indices of abundance, but are noteworthy because they indicates that even the partially covered Subarea IV contains more megrim than Subarea VI in every year.

Elements of a computer simulation for management strategy evaluation for anglerfish were considered. A sounder stock assessment is required to establish a baseline population to parameterize the biological operating model, as well as an estimate of fishing mortality-at-age. Catch-at-age data, although currently not in a fit state to service this need, may improve in the near future as a consequence of the registration of buyers and sellers. Self sampling programmes have been useful to describe trends, but can suffer from variable participation if stakeholder expectations are not met. Notwithstanding all of the above, there are still some concerns over the ageing of anglerfish: with some doubts over the comparability of readings using the otoliths and illicia. An ageing workshop has been recommended to address these concerns.

1 Opening of the meeting

1.1 Introduction

Anglerfish is one of the most commercially important demersal species for several European fleets. In recent years, both the WGNSDS and WGHMM have failed to provide analytical assessments of stock biomass or exploitation rates as a consequence of deficiencies in catch data and ageing issues. No analytical assessment of megrim stocks in ICES Area VI has been performed since 1999 and despite significant landings, megrim in ICES Area IV are not considered by any ICES expert group. Since 2005, Scotland and Ireland have conducted surveys in conjunction with the commercial sector that are capable of providing minimum estimates of absolute abundance of anglerfish stocks and may present candidate surveys for relative abundance of megrim. This Workshop is intended to explore the data deficiencies associated with both stocks that preclude formal assessments and explore the potential use of the recently developed surveys and tallybooks as the basis of future fishing opportunities.

1.2 Terms of reference

Under ICES resolution 2008/2/ACOM28 a **Workshop on Anglerfish and Megrim [**WKAGME] (Co-chairs: Paul Fernandes (UK) and Norman Graham (Ireland), was established and met in Aberdeen, 23–27 February 2009 to:

a) Assess and review the utility of fishery-independent surveys to track the development of relative and absolute changes in abundance and biomass of anglerfish and megrim.

b) Identify and propose research needs to refine estimates of survey trawl herding and catch efficiency.

c) Identification of appropriate harvest strategies based on fishery-independent surveys.

d) Review utility of self-sampling (tallybook) programmes for monitoring stock dynamics and investigate their inclusion in scientific assessments.

e) Review and assess issues associated with commercial anglerfish catch and effort data as metrics to track stock status, exploitation rates and catch forecasts.

f) Review issues associated with ageing and conduct inter-institute comparisons of age–length-keys.

WKAGME will report by 9 March 2009 for the attention of ACOM.

1.3 Structure of the Report

This Report is structured around some of the background material supplied to the Workshop and answers to the Terms of Reference (ToR) above. An introductory section (Chapter 3) provides some background of the anglerfish and megrim fisheries, the assessments carried out by ICES, and important considerations of the population structure. Chapter 4 then deals with the industry science surveys carried out on the Northern Shelf, and reports the latest results available to the Workshop from these. A critical evaluation of the surveys is then provided in Chapter 5 in response to ToR (a), including a review of the research needs in response to ToR (b). In Chapter 6, the elements needed for a management strategy evaluation for anglerfish are considered in response to ToR (c) and some candidate harvest strategies are proposed for future such evaluations. It was felt that appropriate harvest strategies could only be determined from an evaluation and the needs of a full management strategy evaluation (MSE) reflect much of the work associated with having a full assessment of the stock. This chapter also includes a preliminary attempt to assess the [anglerfish] stock on the Northern Shelf. A review of self-sampling programmes (ToR d) is given in Chapter 7; and issues with the commercial catch and effort data are considered in Chapter 8 (ToR e). Finally, a review of the issues associated with ageing and age–length keys is given in Chapter 9 (ToR f).

2 Adoption of the Agenda

The list of participants is given in Annex 1. The Agenda as followed during the Workshop is given as Annex 2.

3 Background information for the Workshop

3.1 Anglerfish fisheries in and around the Northern Shelf

3.1.1 Fisheries in ICES Subarea VI

The fishery for anglerfish[1] 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 been less than 1000 t with the UK taking on average around 50% of the total.

The Scottish fishery for anglerfish in Division VIa comprises two main fleets targeting mixed round-fish. The Scottish Light Trawl Fleet (vessel length <27.4 m) takes around 60% of landings and the Scottish Heavy Trawl Fleet (vessel length ≥27.4 m) 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 round-fish 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 was an almost linear increase in landings from Division VIa since the start of the directed fishery until 1996 which has since been followed by a very severe decline, indicating the previous increase was almost certainly as a consequence of the expansion and increase in efficiency of the fishery.

There is no minimum landing size for anglerfish and discarding is known to occur at low levels in the targeted fishery for anglerfish, but also in other fisheries, for example for scallops. However, discard data are not routinely collated.

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. 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 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 signifi-

[1] Note that in this context (ICES Northern Shelf), the name 'anglerfish', in fact, refers to two species: *Lophius piscatorius* and *L. budegassa*. However, *L. budegassa* is a more southern species and generally constitutes less than 10% of landings. Furthermore, scientific data is sparse on *L. budegassa* in Northern Shelf waters. Therefore, in this Report the name 'anglerfish' refers largely to *L. piscatorius* unless otherwise specified.

cant (Anon, 2001). The fleet composition changed in 2001. Four vessels have recently been decommissioned and two new vessels have joined the fleet that target haddock.

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 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. In 2005 around 16 vessels participated in the fishery, 12 UK registered and four German registered.

3.1.2 Fisheries in the North Sea (IV) and Skagerrak (IIIa)

UK landings of anglerfish from the North Sea demonstrate a similar trend to those in Division VIa: a rapid increase in the late 1980s followed by a decline since 1996. Around 90% of the landings are taken in the northern North Sea and the fishery is dominated by the Scottish fleet which takes around 80% of the total landings in this area. As in Division VIa, the fishery in this region has moved into deeper more offshore areas.

The majority of Danish anglerfish landings are taken in the northeastern North Sea (IVa). Demersal trawl fisheries account for more than 90% of total Danish landings, the vessels being in the size range 20–40 m. Most of the Danish trawl fishery in the North Sea takes place in the Norwegian Deep, and the mesh size in the trawls is 120 mm. In the Skagerrak (IIIa) the two main Danish fisheries taking anglerfish are the (mixed) *Nephrops* fishery and the demersal trawl fishery. In both areas minor landings are taken in gillnets and Danish seines and as bycatch in fisheries for shrimp (*Pandalus*). The Danish fishery has in recent years accounted for around 10% of the total landings from the North Sea. Only minor anglerfish landings are reported from IVb.

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. The landings from this fishery have comprised around 6% of the total landings from Division IVa since 1999.

Landings from Division Skagerrak (IIIa) are low, accounting for less than 5% of the total Northern Shelf landings, with Denmark and Norway responsible for the bulk of the landings. Most of the Norwegian landings are taken in a directed gillnet fishery. Until the end of the 1990s the Danish landings were taken mainly as bycatches in fisheries for shrimp (*Pandalus*), Norway lobster (*Nephrops*) and mixed roundfish, but in recent years some Danish demersal trawlers and gillnetters have been targeting Anglerfish in IIIa.

3.1.3 Fisheries in the Norwegian Sea (IIa)

The Norwegian fishery for anglerfish in Division IIa is mainly conducted by small vessels in a directed gillnet fishery in coastal waters similar to the fishery in IVa. Fisheries with offshore gillnets, trawls and Danish seines also take place. The directed gillnet fishery has been the most important of these fisheries, catching 3000 tonnes in 1993. In recent years total landings have exceeded 4000 tonnes.

3.1.4 Fisheries in adjacent waters

In Faroese waters (Vb1), more than 5000 t have been landed annually in recent years. The Faroese fisheries are mainly demersal trawl and gillnet fisheries.

In Icelandic waters (Va) around 2000 t have been landed annually in recent years. The fisheries are mainly demersal trawl fisheries, but in recent years gillnet fisheries have also become important.

3.2 Anglerfish stock structure and stock identification

Anglerfish are widely distributed over the Northern Shelf, and occur in a wide range of depths, from quite shallow inshore waters down to at least 1000 m. Small anglerfish occur over most of the northern North Sea and Division VIa, but large fish, the potential spawners, are rarely caught. Little is known about when and where anglerfish spawn in northern European waters. This lack of knowledge is as a result of the unusual spawning habits of anglerfish. The eggs and larvae are pelagic, but whereas most marine fish produce individual free-floating eggs, anglerfish eggs are spawned in a large, buoyant, gelatinous ribbon which may contain more than a million eggs. As a consequence of this strange behaviour, anglerfish eggs and larvae are rarely caught in conventional surveys.

An EU-funded research project entitled 'Distribution and biology of anglerfish and megrim in the waters to the West of Scotland' (Anon, 2001) did however, improve our understanding. A particle tracking model was use to predict the origins of young fish and indicated that post-larval anglerfish may be transported over considerable distances before settling to the seabed (Hislop *et al*., 2001). Anglerfish in deeper waters to the west of Scotland and at Rockall could, therefore, be supplying recruits to the western shelf and the North Sea. Furthermore, results of micro-satellite DNA analysis carried out as part of this project demonstrated no structuring of the anglerfish stock into multiple genetic populations within or among samples from Divisions IVa, Division VIa and Rockall. In fact, this project also suggested that anglerfish from further south (Subarea VII) could also be part of the same stock.

On the other hand, following the recent development of fisheries for anglerfish in ICES Divs. IIa and Vb1 (Faroese waters), ICES (2004) considered the stock structure on a wider North Atlantic scale, and it was concluded that there was currently insufficient information to conclusively define new stock areas for assessment and further coordinated work is still required. Therefore, because no conclusive evidence was found to indicate an extension of the stock area northwards to include Division IIa, Anglerfish in IIa is currently treated as a separate stock. This also holds for anglerfish in Faroese and Icelandic waters. Thus, at present the anglerfish in IIa, Va and Vb1 (the Norwegian Sea, Iceland and Faroese waters) are considered separate stocks/units separated from the "Northern shelf stock". Given the request to ICES to assess anglerfish in Division IIa and that there may be an extension to include ICES Division V (including Icelandic waters) in the near future, the likely spatial disaggregation of the Northern shelf stock(s)/units (drift of larvae and possible migration of mature fish back into deeper water) means that any assessment model would need to be spatially structured, possibly supported by assessments for each of the stock units separately.

For management purposes, anglerfish on the Northern Shelf are currently, split into three management units: 1) Subarea VI (including Vb (EC), XII and XIV), 2) the North Sea (including IIIa and the EU waters of IIa), and 3) IIa, Norwegian waters.

From the above it appears that questions still remain as to the overall stock structure of anglerfish on the northern shelf, and the current stock delineation(s) are based partly on implications of larval drift, partly on lack of other conclusive scientific stock identification data, and in a rather large part on the basis of the current units for TAC based management (see Section 3.3 below). This is, however, no different from stocks of other demersal species which occur in the same area (e.g. cod and haddock, which are separated at a stock level by the 4° line of longitude).

3.3 Anglerfish stock assessments and management units

Prior to 2004, analytical assessments of the Northern shelf anglerfish stock were made using a length-based model taking account of the difference in growth patterns between males and females (ICES, 2008). Indices of recruitment were provided by the Scottish March West Coast survey. The model used a catch-at-length analysis (modified CASA; Sullivan *et al.*, 1990; Dobby, 2002). Input data covered the periods from 1993 to the most recent data year. This analytical assessment also provided the technical basis for optional catch predictions. However, since 2003, no analytic assessments have been carried out as a result of the lack of reliable fishery and insufficient survey information (i.e. only a 3-year time-series). There was also some doubt concerning the geographical coverage of the input data.

In recent years there have been no analytical assessments. Stock trends have been reported, based mainly on Scottish tallybook data and to a minor extent on commercial Danish lpue figures supplemented with data on size compositions in Danish, Norwegian and Scottish catches.

It has been suggested that any future assessments should be based only on a combined area (Northern Shelf) stock unit. This does not necessarily preclude the use of assessment methods which may take account of finer-scale spatial effects, or of the setting of separate area TACs. It has also been suggested to include ICES Area VII in the assessment. In this connection it should be emphasized, that at present, anglerfish in IIa as well as in Faroese (Vb1) and Icelandic waters (Va) are considered as separate 'units' (see Section 3.2 above).

Anglerfish in Northern Shelf waters are currently split into three management units for the purposes of setting TACs: 1) Subarea VI (including Vb (EC), XII and XIV), 2) the North Sea (including IIIa and the EU waters of IIa), and 3) IIa, Norwegian waters. At present ICES does not advise on the fisheries for anglerfish in Faroese and Icelandic waters.

3.4 Megrim fisheries

Megrim[2] is taken mainly as bycatch in demersal trawl fisheries in Subarea VI and in smaller amounts in the northern North Sea. A few vessels have been recorded to target this species occasionally, a practice which has been increasing in recent years.

3.5 Megrim stock identification

Megrim stock structure is uncertain and, historically, ICES has considered megrim populations in VIa and VIb as separate stocks. The basis for this separation has, however, been questioned. Data collected during an EC study contract (98/096) on the 'Distribution and biology of anglerfish and megrim in the waters to the West of Scotland' demonstrated significantly different growth parameters and significant population structure difference between megrim sampled in VIa and VIb (Anon, 2001). Spawning fish occur in both areas, but whether these populations are reproductively isolated is not clear. Catches of megrim from Subarea VI (Table 7.1.1) comprise both species, *Lepidorhombus whiffiagonis* and *L. boscii*. Information available to the Working Group indicates that *L. boscii*, are a negligible proportion of the Scottish and Irish megrim catch (Kunzlik *et al*., 1995 and Anon, 2001)[2].

The migratory behaviour of megrim is poorly understood, but commercial data does demonstrate clear seasonal patterns in catch rates (highest lpues in May each year). The biology of megrim suggests that this species is quite mobile when compared with other flatfish species in this area (e.g. plaice and sole). The ICES WGHMM considers megrim in Divisions VIIb, c, e–k and VIIIa, b, d to be a separate stock. Historically, ICES did not consider megrim in IV, despite landings from this division being at least equal to those taken in VIa. However, since 2009, ICES now also provides advice on megrim in Subarea IV (North Sea). This is because the spatial distribution of landings data and survey catches provide good evidence to suggest that megrim population is contiguous between IVa and VIa (Figure 3.5).

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[2] Note that in this context (ICES Northern shelf), the name 'megrim', in fact, covers 2 species: *Lepidorhombus whiffiagonis* and *L. boscii* .The quantities of *L. boscii* in Irish and Scottish landings of megrim from VI has been negligible and scientific data is sparse on *L. boscii* in Northern Shelf waters. Therefore, in this Report the name 'megrim' refers largely to *L. whiffiagonis* unless otherwise specified.

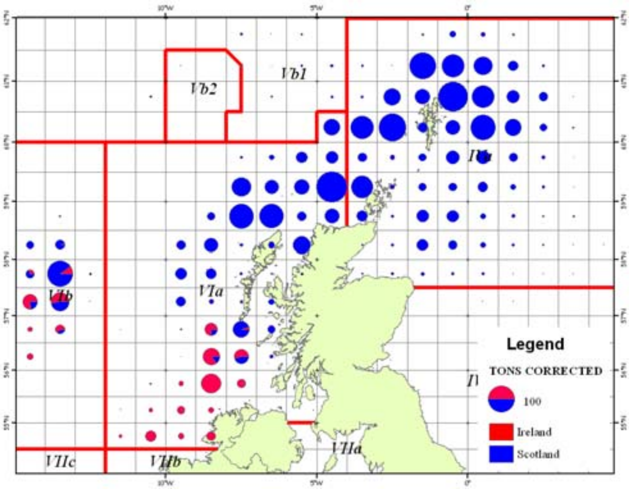

Figure 3.5. Map of the Northern shelf of the British Isles showing catches of megrim by vessels from France, Ireland and Scotland in 2006, by ICES statistical rectangle: circle size is proportional to catch size and shaded according to proportion caught by nation. The catches have been adjusted to account for estimated misreporting of megrim into area IV from Area VI. Source: ICES Working Group on the Assessment of Northern Shelf Demersal Stocks (ICES 2007).

Based on reported UK and Irish landings data, there appear to be four distinct areas of megrim concentrations in VIa: the Butt of Lewis, the slope North of the Hebrides, Stanton Bank and the slope NW of Ireland (Anon, 2001). How these relate to each other and to VIb, has not been clarified yet. Furthermore, it should be emphasized that megrim in IVa are not considered by ICES, and it is recommended, that any future work on stock assessment and identification of megrim also should include IVa megrim.

3.6 Assessments of megrim in Subarea VI

ICES has not conducted an analytical assessment of this stock since 1999. Megrim in Subarea VI continues to be a monitored stock and a benchmark analysis will be required before an assessment can be presented. There is evidence of substantial misreporting of commercial catch data which precludes any assessment based primarily on commercial catch data. Since 2005, several international surveys have been undertaken that have a better spatial coverage of megrim stocks in both VIa and VIb. These will potentially allow for survey based assessments of this stock in future. A WD presented to ICES WGNSDS (Fernandes, 2008) offers a potential methodology for such an analysis.

3.7 References

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4 The industry science surveys

4.1 Introduction

In 2005, Fisheries Research Services (FRS) initiated a new project to estimate the abundance and distribution of anglerfish on the Northern Shelf. The project is unique in two aspects: the aim is to produce an absolute abundance estimate (i.e. a total number and biomass of anglerfish), as opposed to an index of relative abundance which is normally produced from surveys; and, crucially, the project aims to involve the fishing industry throughout, from planning through to the execution of the surveys.

Four surveys have been carried out to date, in November 2005, 2006, 2007 and April 2008: these covered much of the area of the known distribution of Northern Shelf anglerfish (ICES Divisions IVa, VIa and VIb at Rockall), with the exception of the central and southern parts of Area IV and the Skagerrak and Kattegat (Division IIIa). As the area is so large, these are multi-vessel surveys, incorporating the research vessel FRV Scotia, and three commercial fishing vessels. In 2006 and 2007, the survey was extended south into Irish waters with the participation of the Irish Marine Institute (MI) in association with Bord Iascaigh Mhara (BIM). In 2008, however, the Irish were not able to participate.

This Section reports on the results of the 2008 surveys, and provides new abundance and biomass estimates associated with the 2005–2007 surveys. For anglerfish, absolute estimates are reported: however, it must be emphasized that these are provisional estimates that will be subject to further correction when account has been taken of the incomplete area coverage. The estimates presented here, therefore, constitute what are thought to be possible minimum values of the abundance and total-stock biomass of Northern Shelf anglerfish. It should also be noted that the estimates provide in this Section are based on methods developed prior to the Workshop. In the course of the Workshop several suggestions for improvements were made (see Section 5). The purpose of this section is to provide an update on the methods and results of the surveys to date.

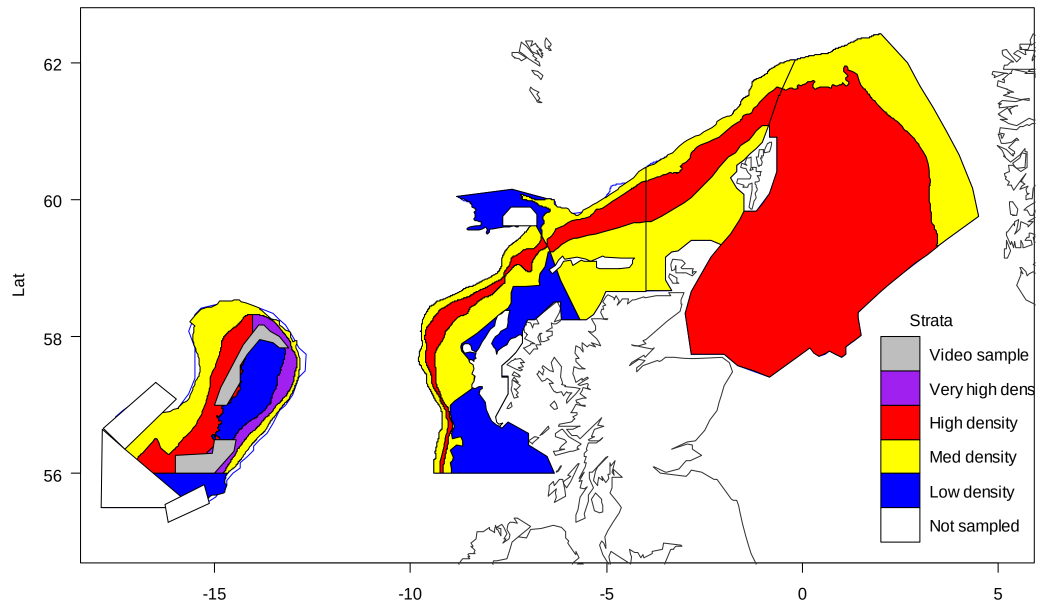

Figure 4.1. Map of the northern continental shelf around the British Isles showing the areas surveyed during the 2008 anglerfish survey, shaded according to the survey strata as indicated in the legend.

4.2 Material and methods

The survey area encompassed the northern shelf of the British Isles, north of latitude 56° to a northerly limit of 62° 30′ north. This area was further limited to areas where the depth was less than 1000 m. Four regions were proposed as distinct areas to be surveyed: Rockall; west of Scotland; north of Scotland; and east of Scotland (Figure 4.1). The 2008 anglerfish survey took place from 15–28 April and involved FRV Scotia and three commercial vessels: the MFV Genesis, MFV Ocean Venture, and the MFV Seagull; each vessel surveying one of the above regions. The surveys were carried out in April which is a change to previous surveys. This change was implemented because of the poor weather experienced in previous years in November, leading to considerable loss of survey time. On seeking an alternative, fishers' advice indicated that April was also a good time of year to obtain high catch rates of anglerfish.

There have been a number of high profile cases in recent years where survey results have been brought into question as a result of inconsistent gear specification (Van Zile, 2003). It was essential, therefore, that: (a) all vessels, including the Scotia, used the same trawl gear for the anglerfish surveys; (b) the gear was rigged in a consistent manner; and (c) no modifications to the trawl were employed. FRS therefore, purchased four new trawls to equip each vessel on the anglerfish survey with the same sampling tool. More importantly, the type of trawl used was that accepted by the industry as being the most effective to catch anglerfish. Details of the trawl specifications are given in Annex 5.

Further details of the survey methods are given in Fernandes *et al.*, 2007. However, there have been several developments since then which have lead to a revision of the methods used and, therefore, a revision of the time-series. In this paper the estimates represent the best available knowledge to date and as such they take into account the following factors:

1) herding of anglerfish by the trawl doors and sweeps;

2) escapes of fish under the trawl footrope;

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

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

Herding corrections were based on a model derived from observations of anglerfish behaviour using video cameras mounted on the sweeps: full details are described in Reid *et al.*, 2007 and summarized in Section 5.2.4.1. The number of fish escaping under the footrope has been estimated from experimental data using catching bags under the footrope. The number and size of anglerfish passing under and into these bags were measured. A size based model of footrope selectivity was then developed. 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. This correction is also described in more detail in Section 5.2.4.2.

Thus the average fish density at-age *a* in stratum *s*, ρ_{as} , is estimated from the weighted mean of fish densities corrected for the catchability of each trawl, as follows:

$$\hat{\rho}_{as} = \sum_{i \in s} w_i \left\{ \sum_{l \in a} \frac{n_{lai}}{v_{1i} \hat{Q}_{li}} \right\} = \sum_{i \in s} w_i \left\{ \sum_{l \in a} \frac{n_{lai}}{\hat{e}_l (v_{1i} + v_{2i} \hat{h})} \right\}$$

where:

n_{lai} is the number of fish of age *a* and length *l* caught in trawl *i*,

$$w_i = \frac{v_{1i} + v_{2i}}{\sum_i (v_{1i} + v_{2i})},$$

v_{1i} is the area swept by gear in trawl *i* (the area swept by the wing),

v_{2i} is the sweep area of gear in trawl *i* i.e. the area swept by the door minus that swept by the wing,

$\hat{Q}_{li} = \hat{e}_l + \hat{e}_l \hat{h} \frac{v_{2i}}{v_{1i}}$ is the catchability estimate for a fish of length *l* in trawl *i* , following the definition by Somerton *et al.*, 2007,

$\hat{e}_l$ is the estimated footrope selectivity-at-length *l*, described in Section 5.2.4.2 that is the proportion of fish of length *l* originally in the area swept by the wing which are caught by the net and do not escape under the footrope,

$\hat{h}$ is the estimated herding coefficient. ($\hat{h}$ =0.017).

A fish with missing age data is allocated an age distribution according to the proportions at-age given its length in the age–length key (ALK) for the whole survey that year. Variance is estimated by means of a bootstrap: The herding factor *h* is sampled from an exponential distribution with mean 0.017, while parameters for e_l are sampled from their asymptotic normal distributions estimated from the statistical model. Hauls are sampled with replacement from each stratum, creating a new ALK for each bootstrap replicate.

Strata with only one observation were allocated the CV of a stratum with the most similar estimated density, raised by the number of samples in that stratum.

Estimates of the proportion of anglerfish in the southern part of ICES Division VIa were derived from 2006 and 2007 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 and 13.6% in 2007; the proportions of biomass were 5.5% in 2006 and 7.4%. The average of these proportions (i.e. 11.1% for abundance and 6.4% for biomass) was used to raise the estimates of the surveys in 2005 and 2008 when the Irish did not participate.

Visual counts were carried out in 2008 in areas closed to trawling using a specially modified sled, mounted with lights and a video camera, towed just above the seabed. Counts of anglerfish were made along 2 transects in the North West Rockall closure and 3 transects in the Empress of Britain Bank closure. Details of these transects are given in Table 4.1. The average area surveyed by each of the visual transects was 102 000 m^2 (cf. area swept by the trawl of 150 000 m^2). In all four anglerfish were seen on all transects: these numbers were converted to densities and raised to the area of the closures to provide abundance estimate. Biomass was calculated by multiplying the abundance by the average weight of anglerfish in the adjacent trawl strata of the 2008 survey (blue and purple strata in Figure 4.1). The abundance and biomass of anglerfish in these areas was added to the 2008 estimates as additional strata (coloured in grey in Figure 4.1). The proportions of abundance and biomass in the closed areas relative to that in the adjacent two strata were then used to estimate the abundance and biomass in the closures in the 2005–2007 surveys.

The estimates currently do not take account of the following:

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

2) Inaccessible (to trawl) areas in Division VIa.

Methods to account for these are under development and are discussed in Section 5.3.

4.3 Anglerfish results

The sample locations for 2008 (n = 167) are illustrated in Figure 4.2 as the number density (number per square kilometre) and in Figure 4.3 as weight density (kilograms per square kilometre) of anglerfish. The highest densities of anglerfish occurred close to the 200 m contour in the northern and western areas, including the northern North Sea (particularly by weight). Very high densities were found on the east coast of the Rockall plateau.

The provisional results of the survey are presented by stratum in Table 4.2. The total estimate for the whole northern shelf in 2008 was 54 080 t. The 95% confidence limit estimates are not reported here as a result of the ongoing developments in error propagation. However, the Relative Standard Errors for the Scottish components, without taking into account of footrope escapes, were 9.1% and 10.6% for abundance and biomass respectively. Applying these to the current estimates give 95% confidence limits of 42 615–

65 545 tonnes for the Northern shelf.

The incomplete survey in ICES Area IV still gave a larger biomass of 29 723 t than the largely complete survey estimate in ICES Area VI of 24 356 t.

The estimates at-age (Figure 4.4) indicate that despite corrections for catchability, which largely affect the smaller, younger fish, there is still an issue with catchability which is unaccounted for. Methods to account for this have been considered and one interim solution is given in Section 6.2.2. The revised time-series estimates indicate a slight decline in numbers over the four year period (Figure 4.5), but a significant increase in biomass (Figure 4.6). The distribution of anglerfish has remained fairly consistent over the four year time-series, although in 2008 the trend towards the shelf edge was much more pronounced (Figure 4.7).

Table 4.1. Statistics of the visual surveys carried out in 2008 in areas closed to trawling at Rockall.

Transect	SurveyArea (m^2)	No. Angler	AnglerDensity ($n.km^{-2}$)	Closed area
1	79124	2	25.3	North West Rockall
2	82664	1	12.1	Empress of Britain Bank
5	163427	0	0.0	Empress of Britain Bank
6	82216	1	12.2	Empress of Britain Bank
11	102687	0	0.0	North West Rockall

Table 4.2. Abundance (millions of individuals) and biomass (tonnes) estimates from the 2005–2008 anglerfish surveys by strata.

	Abundance	Biomass		Abundance (millions)			Biomass (tonnes)		
Stratum	2005	2005	Stratum	2006	2007	2008	2006	2007	2008
East.200	10.242	11 919	East.L	0.076	0.402	0.589	476	2005	3184
East.500	0.344	1703	East.M	8.916	8.525	8.928	14 997	15 223	18 984
North.200.E	3.459	4789	North.H.E	1.139	0.772	1.407	2668	2024	3013
North.500.E	0.151	650	North.H.W	0.984	0.304	1.203	1700	710	2637
North.200.W	3.650	4503	North.L	0.033	0.000	0.329	100	0	1131
North.500.W	0.207	590	North.M1.E	2.900	5.807	1.033	2926	8370	1493
Rockall.500	0.914	2978	North.M1.W	1.878	1.132	0.899	1506	1649	1570
Rockall.1000	0.343	1936	North.M2.E	0.570	0.103	0.663	931	953	3050
Rockall.200	0.743	823	North.M2.W	0.027	0.014	0.386	63	173	1523
West.200	5.577	6071	Rockall.H	0.577	0.540	0.562	1455	2088	1960
West.1000	0.135	481	Rockall.L1	1.302	2.106	2.081	945	2325	3025
West.500	0.353	720	Rockall.L2	0.084	0.273	0.399	330	389	1143
			Rockall.M	0.339	0.307	0.191	1501	2645	1219
			Rockall.VH	0.800	0.842	0.628	2186	2736	1704
			West.H	0.168	0.291	0.962	327	769	2239
			West.L	4.442	0.997	0.386	3019	844	421
			West.M1	1.522	1.378	1.286	1843	1703	1188
			West.M2	0.164	0.090	0.331	623	557	1086
Survey Total	26.117	37 160	Survey Total	25.921	23.884	22.262	37 599	45 164	50 568
Irish area VI	2.900	2389	Irish area VI	2.878	2.652	2.472	2418	2904	3251
Rockall visual	0.048	212	Rockall visual	0.073	0.073	0.063	259	343	260
AreaIV (partial)	14.196	19 060	AreaIV (partial)	13.601	15.608	12.620	21 999	28 575	29 724
AreaVIa	12.822	14 753	AreaVIa	12.097	6.859	8.253	11 600	9310	15 045
AreaVIb	2.048	5948	AreaVIb	3.174	4.141	3.924	6676	10 527	9311
AreaVI	14.870	20 701	AreaVI	15.270	11.000	12.177	18 276	19 836	24 357
Northern Shelf (partial)	29.065	39 761	Northern Shelf (partial)	28.871	26.609	24.796	40 275	48 411	54 080
Irish area only			Area VII (partial)	4.824	6.220		8437	16 095	

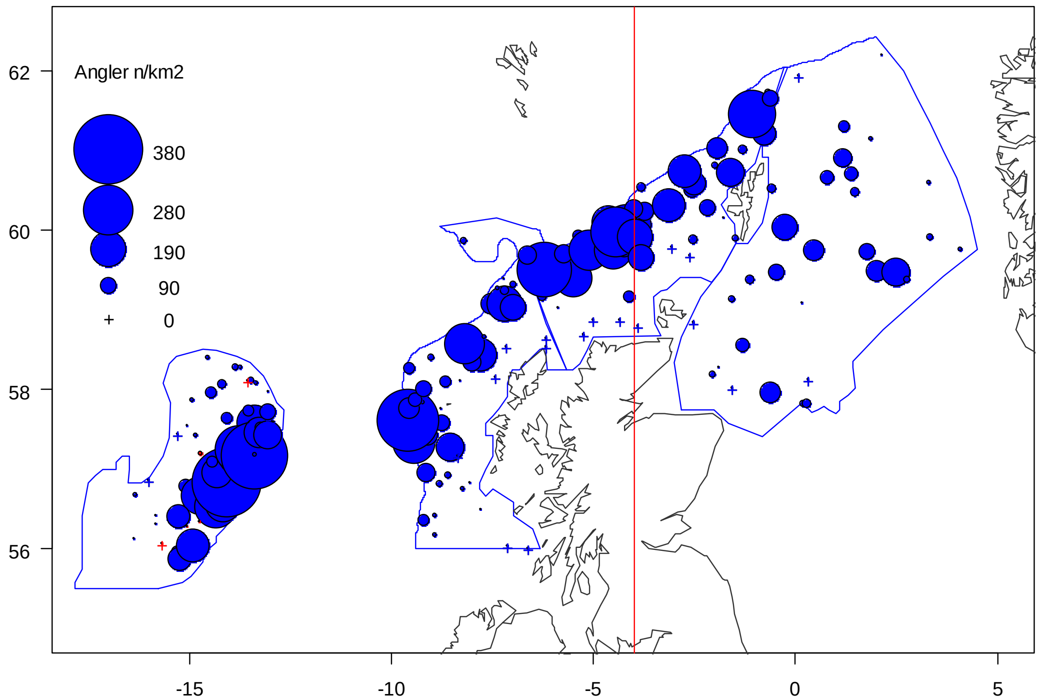

Figure 4.2. Map of the northern continental shelf around Scotland showing the number density of anglerfish during the 2008 surveys. Each circle is centred on the sample location and the size of the circle is proportional to the number density in n/km² according to the legend (top left). Blue circles represent trawl based densities; red symbols represent visual based densities. Trawl densities account for herding but not footrope escapes. The red line indicates the position of the 4° line of latitude which separates ICES Areas IV (east) and VI (west).

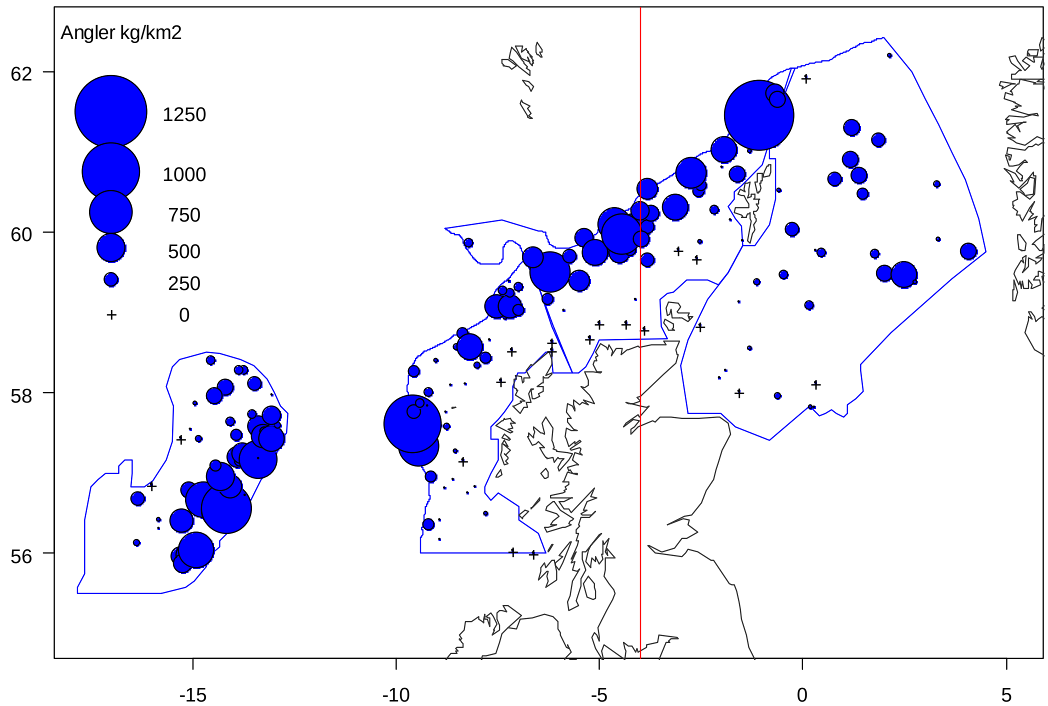

Figure 4.3. Map of the northern continental shelf around Scotland showing the weight density of anglerfish during the 2008 anglerfish survey. Each circle is centred on the sample location and the size of the circle is proportional to the weight density in kg/km2 according to the legend (top left). Trawl densities account for herding but not footrope escapes. The red line indicates the position of the 4° line of latitude which separates ICES areas IV (east) and VI (west).

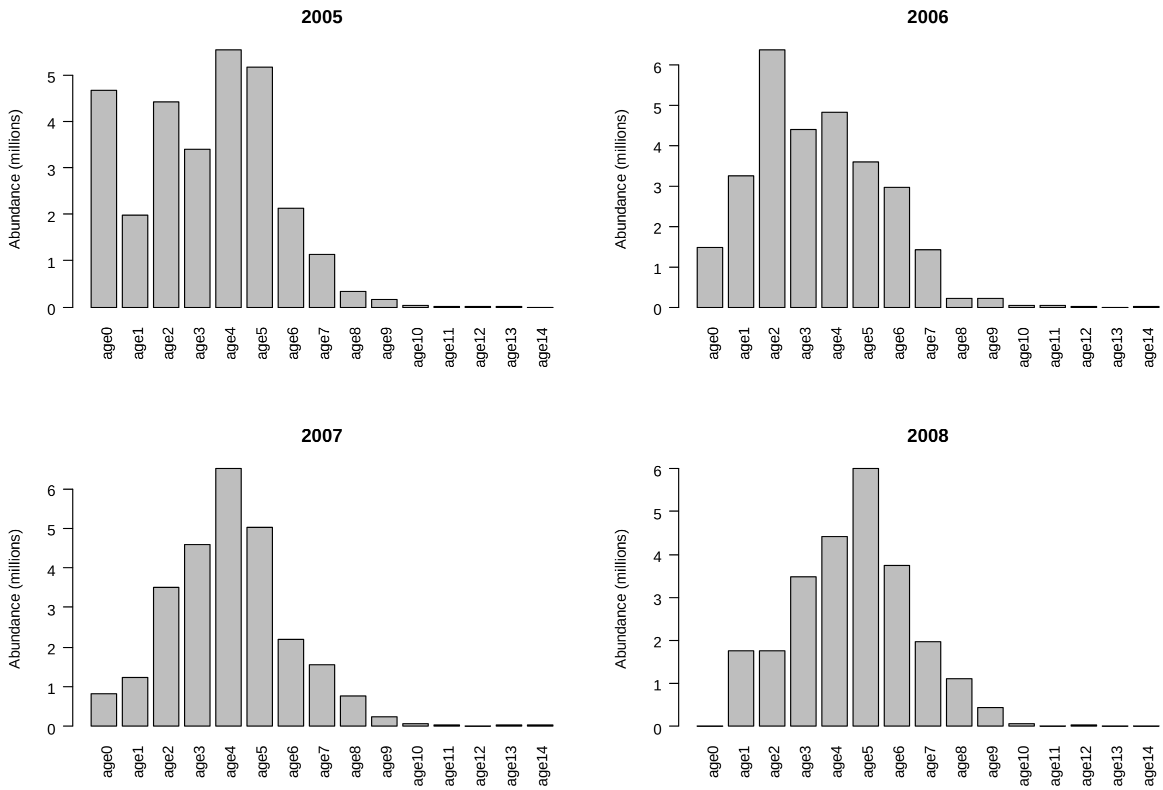

Figure 4.4. Estimates of total abundance-at-age for each of the anglerfish surveys 2005–2008.

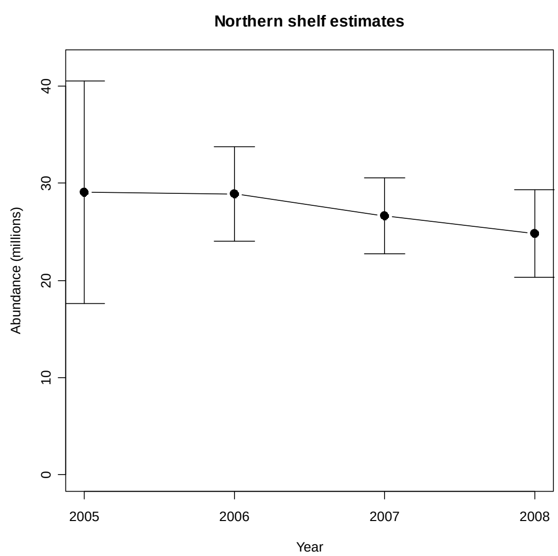

Figure 4.5. Estimates of total abundance of anglerfish for the Northern Shelf (black filled circles), with confidence intervals derived from variance estimates of the Scottish surveys without footrope catchability.

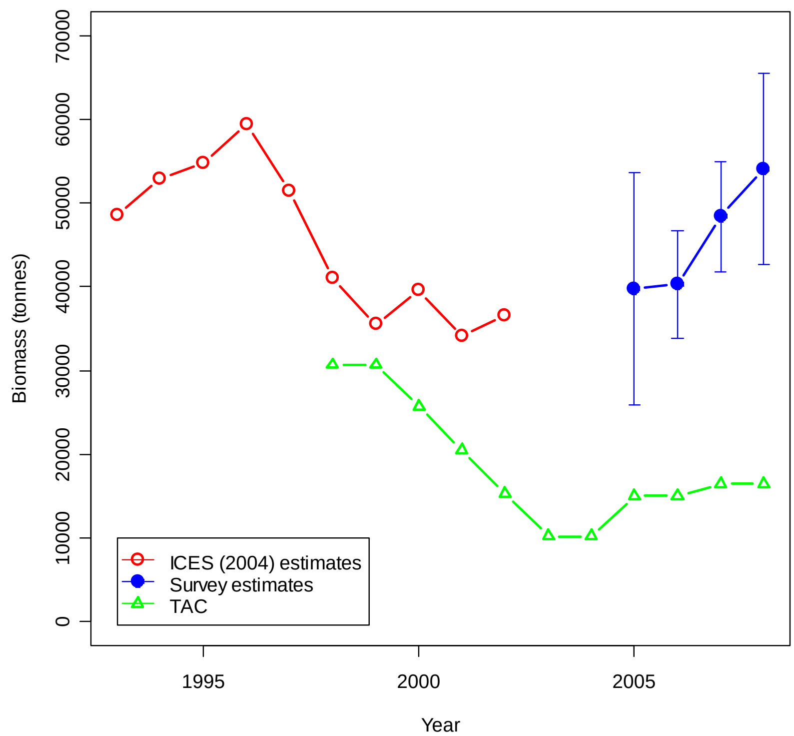

Figure 4.6. Estimates of total biomass of anglerfish for the Northern Shelf: blue filled circles are based on the FRS anglerfish surveys, with confidence intervals derived from variance estimates of the surveys without footrope catchability; red open circles are estimates derived by ICES, 2004; green open triangles are Total Allowable Catches (TAC).

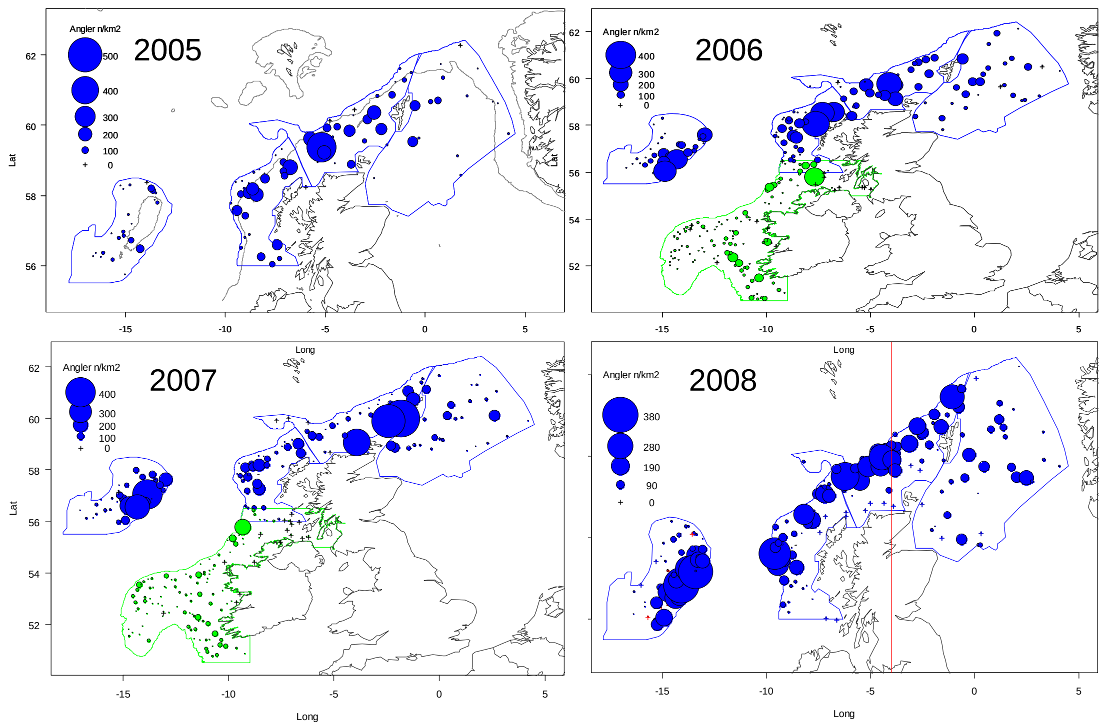

Figure 4.7. Maps of the northern continental shelf around Scotland showing the number density of anglerfish during the 2005–2008 surveys. Each circle is centred on the sample location and the size of the circle is proportional to the number density in n/km² according to the legend (top left). Blue circles represent trawl based densities based on Scottish surveys; green symbols Irish surveys. Trawl densities account for herding but not footrope escapes. The red line in the 2008 figure indicates the position of the 4° line of latitude which separates ICES Areas IV (east) and VI (west).

4.4 Megrim results

The sample locations are illustrated in Figure 4.8 as the number density (number per square kilometre) and in Figure 4.9 as weight density (kilograms per square kilometre) of megrim. The highest densities of megrim occurred close to the 200 m contour in the north and west areas, and on the eastern slopes of the Rockall plateau; high densities were also present in the northern North Sea.

The results of the survey are presented by ICES Subareas in Table 4.3. The abundance and biomass time-series are given in Figures 4.10 and 4.11 respectively. Estimates of biomass for 2005, 2006, 2007 and 2008 were 7096, 6757, 9766 and 11 158 tonnes; estimates of abundance were 17.2, 20.3, 28.6 and 33.4 million fish respectively. The increase in abundance and biomass on the Northern Shelf from 2005 to 2008 was 97% and 57% respectively: percentage increases for each year, relative to 2008, in each of the ICES Subareas, are given in Tables 2 and 3. In each case, over 50% of this abundance and biomass was contained in Subarea IV (North Sea). The percentage of total abundance contained in Subarea IV was 68%, 54%, 52% and 56% in 2005–2008 respectively; the percentage of total biomass in Subarea IV was 66%, 54%, 56% and 62% in 2005–2008 respectively.

Table 4.3. Estimates of abundance and biomass of megrim on the northern shelf by ICES areas from the 2005–2008 anglerfish surveys.

	Abundance (millions)				Biomass (tonnes)			
	2005	2006	2007	2008	2005	2006	2007	2008
Area IV (partial)	11.7	11.0	14.8	18.9	4652	3629	5509	6953
Area VI	5.5	9.3	13.8	15.0	2444	3127	4258	4206
Northern Shelf (partial)	17.2	20.3	28.6	33.9	7096	6757	9766	11159

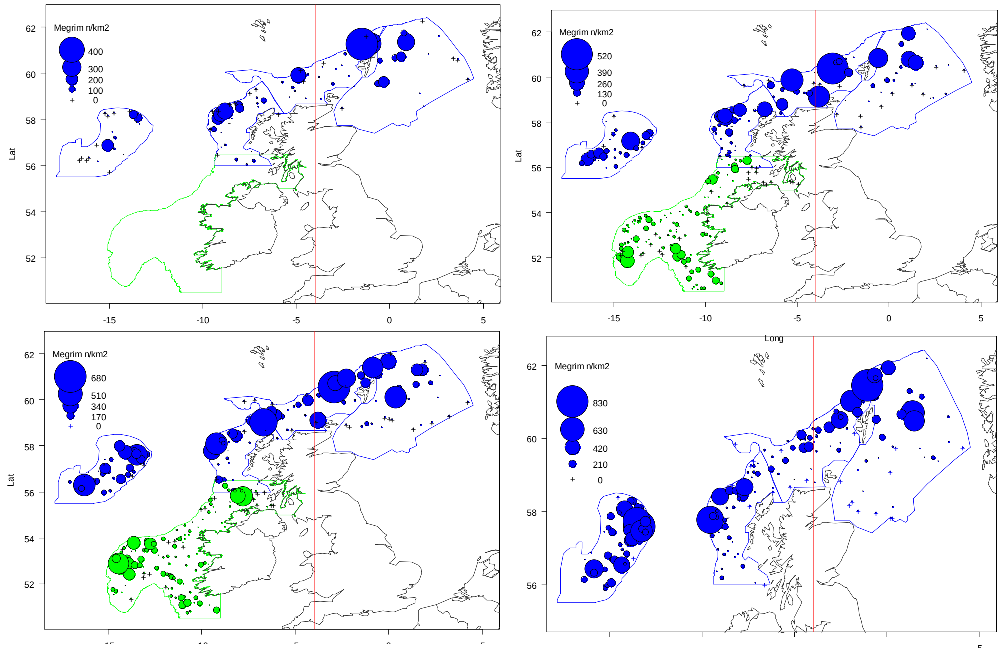

Figure 4.8. Maps of the northern continental shelf around the British Isles showing the number density of megrim caught during the anglerfish surveys 2005-2008. Each circle (blue for Scottish surveys; green for Irish surveys) is centred on the sample location and the size of the circle is proportional to the number density in n/km2 according to the legend (top left). The red line indicates the position of the 4° line of latitude which separating ICES areas IV (east) and VI (west).

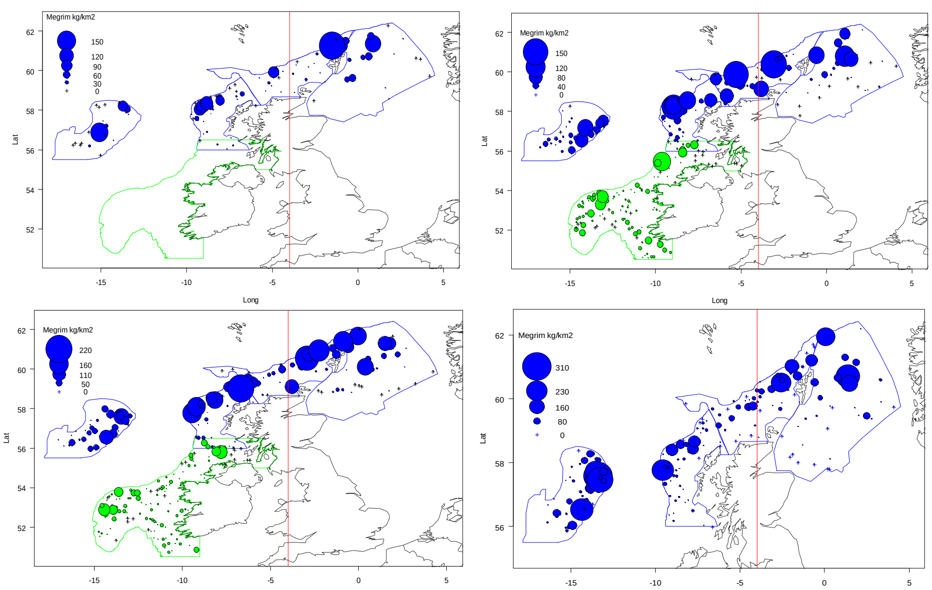

Figure 4.9. Maps of the northern continental shelf around the British Isles showing the weight density of megrim during the anglerfish surveys 2005-2008. Each circle (blue for Scottish surveys; green for Irish surveys) is centred on the sample location and the size of the circle is proportional to the weight density in kg/km2 according to the legend (top left). The red line indicates the position of the 4° line of latitude separating ICES areas IV (east) and VI (west).

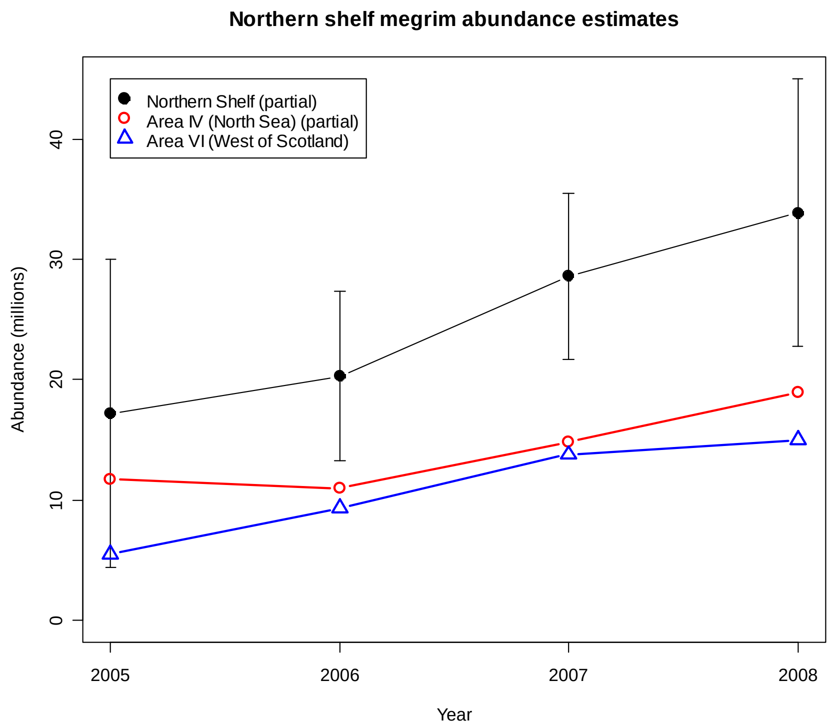

Figure 4.10. Estimates of the abundance of megrim on the Northern Shelf from the 2005–2008 anglerfish surveys. 95% confidence intervals are plotted as error bars on the total Northern Shelf estimates.

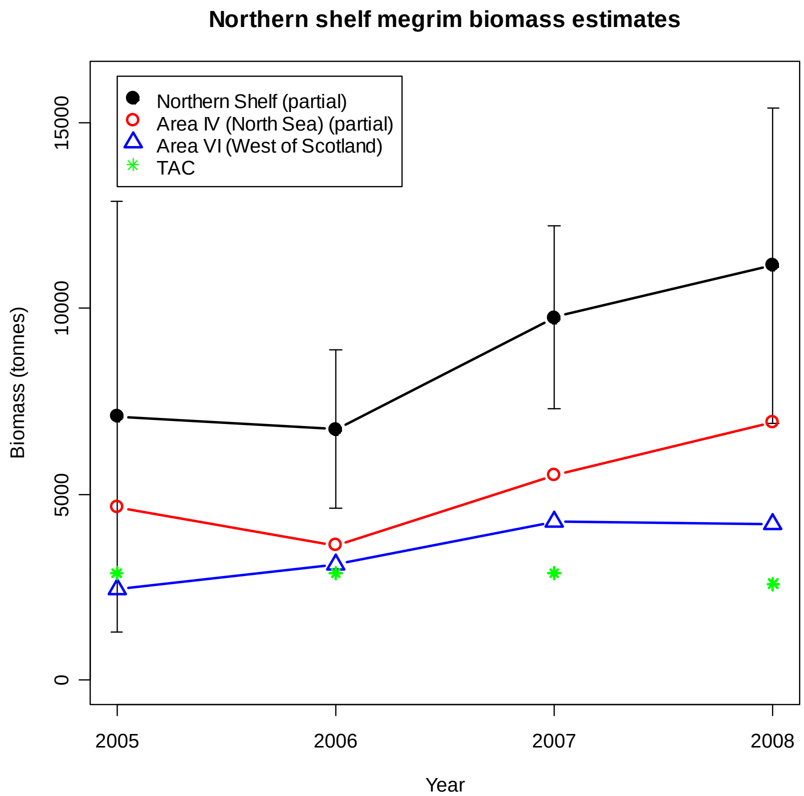

Figure 4.11. estimates of the biomass of megrim on the Northern Shelf from the 2005–2008 anglerfish surveys. 95% confidence intervals are plotted as error bars on the Northern Shelf estimates.

4.5 Discussion

The estimates of abundance of anglerfish from the surveys from 2005–2008 are in line with previous attempts to quantify their abundance (ICES 2004, Figure 4.6). There are still several factors which make the survey estimates likely to be slight underestimates or minimum estimates. These are discussed in the review of the surveys in Section 5.

The estimates of abundance of megrim from the surveys are much lower than previous attempts to quantify their abundance (ICES 2000, total-stock biomass in Subarea VI~35 000 t). This is particularly incongruous when one considers that the area considered by the survey is greater than that of the latter assessment. However, there are several factors which make the survey estimate likely to be an underestimate or a minimum. First, the survey sampling tool (trawl) has been designed to catch monkfish efficiently, not the smaller, flatter megrim. Escapes under the footrope are likely to be significant and accounting for these will raise the estimate quite significantly. Dahm and Wienbeck, 1992 observed that even with a relatively small rock-hopper trawl with 20 cm disks, escapement under the groundgear was typically >50% for many species of flatfish and >80% for long rough dab, witch and sole. Studies of the behaviour of megrim would be needed to understand the catchability of this species if an absolute abundance estimate was required. Second, the area considered was not complete, with a large part of Subarea IV being omitted, and certain areas remaining unavailable to trawling, either as a result of legislation (e.g. to protect coral), or as a consequence of hard untrawlable ground.

What is noteworthy is the significant proportion of megrim which occurs in Subarea IV around the northern North Sea. The survey indicates that abundance there is higher than in Subarea VI. This is significant because ICES does not consider megrim at all in Subarea IV. The finding is not surprising given the spatial distribution of megrim catches.

4.6 Other survey information

4.6.1 Irish industry science surveys in Division VIa and Subarea VII

In 2006 and 2007, the industry science surveys described above were extended into Irish waters by the Marine Institute (MI) in association with Bord Iascaigh Mhara (BIM). The area covered was from the coast of Ireland west to the Porcupine from 56.5ºN to 50.5ºN (see Figures 4.8 and 4.9). This survey was carried out to the same protocols as developed by FRS, using the same standard Jackson Trawl. In 2006 the survey was carried over a thirty day charter on three commercial fishing vessels; MFV Avro Warrior, MFV Catherine R and the MFV Marliona. The Irish survey added another dimension to the study by externally tagging and releasing 724 anglerfish with spaghetti dart tags. To date two of these fish have been recaptured displaying limited movement patterns for the fish in question. As a result of the latter exercise, however, the Irish fish were not aged. In 2007 the survey was carried over two periods as a consequence of bad weather. The first part took place from the 9 November to 3 December 2007, on two commercial boats: *Marliona*, from 9 to 22 November; and *Catherine R*, from the 23 November to 3 December. The second part was carried out on the *Catherine R*, from 16 to 23 January 2008. During the charter 123 stations were sampled.

Altogether 726 anglerfish were tagged and released in 2006 survey and 553 released in 2007 with the numbers released to date at standing at a combined 1279. Recaptures to date have been low with only two returns from our 2006 release. Both fish were released from the same site with one recaptured close to the release site while the other was recapture on the Porcupine Bank. To date only one fish from the 2007 deployment has been recaptured, but unfortunately this recapture does not include positional details. This low recapture rate may be as a consequence of a combination of factors i.e. natural mortality, tag induced mortality, tag loss, non-reporting of recaptures, etc. However, it is felt that the small numbers released in each area may be a significant contributing factor. The two that have been recaptured to date were both released on the same ground (Achill) and were subsequently recaptured a relatively short distance away by a French and an Irish vessel respectively. The reporting of the recaptures from both a domestic and foreign trawler highlights the interest of all fishers in increasing the awareness and understanding of the stock.

The results of the Irish surveys for Division VIa and part of Subarea VII are given in Table 4.2. These do not take into account the footrope selectivity corrections.

4.6.2 The ICES International Bottom Trawl Surveys

The International Bottom Trawl Surveys (IBTS) have their origins in the North Sea, the Skagerrak and the Kattegat where co-ordinated surveys have occurred since 1965. Initially these surveys only took place during the first quarter of the year, but between 1991 and 1996 co-ordinated surveys took place in all four quarters. Pressure on ship time caused the number of surveys to be reduced and currently co-ordinated surveys in the North Sea are only undertaken in the first and third quarters. The IBTSWG (ICES 2008b) assumed responsibility for co-ordinating surveys western and southern divisions in 1994. Initially progress in co-ordination was slow but in the last few years there has been a marked improvement and although data exchange, etc. is not at the level of that enjoyed in the North Sea, there is excellent co-operation between the participating institutes. The IBTS WG produces maps of relative anglerfish abundance (numbers per hour fished) for the western surveys (Figure 4.12).

Data from the North Sea IBTS are available from ICES' DATRAS database.

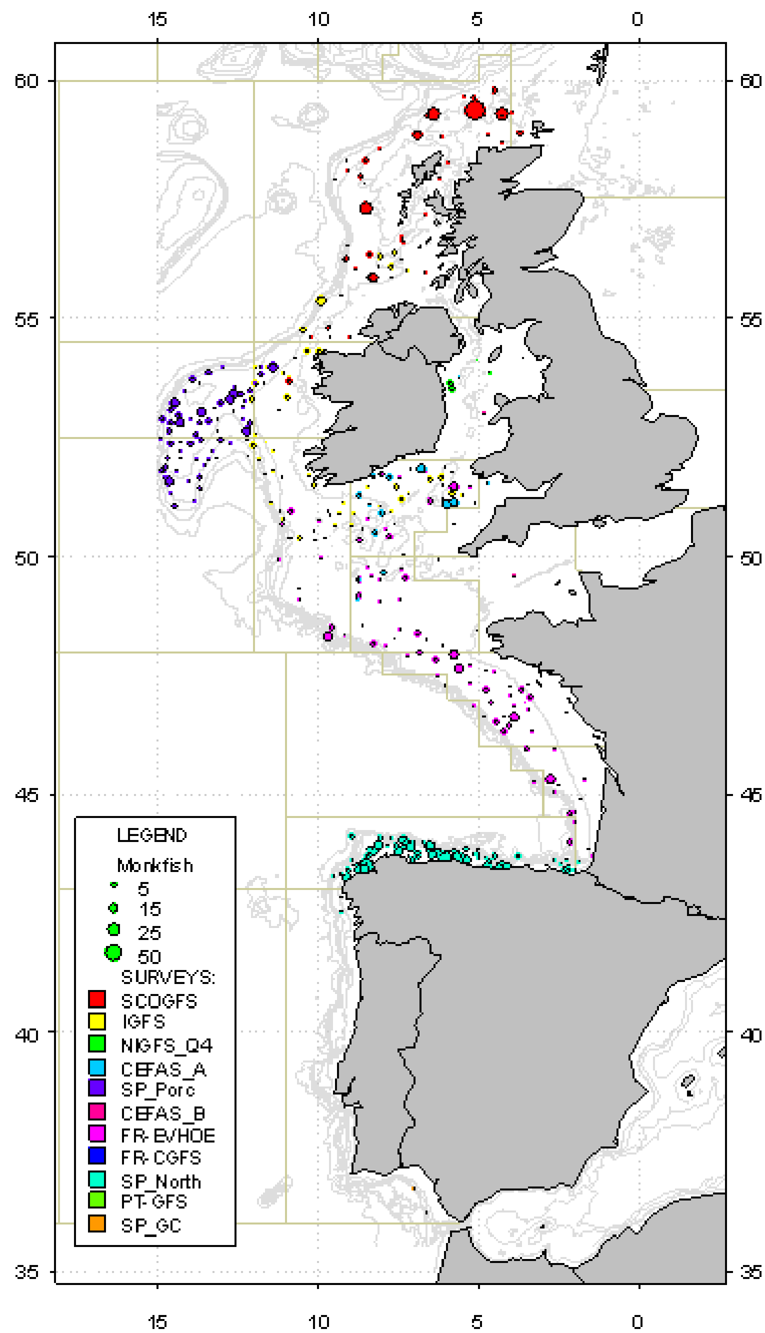

Figure 4.12. Catches in numbers per hour of monkfish, *Lophius piscatorius*, in autumn/winter 2007 IBTS survey s. The catchability of the different gears used in the WA surveys is not constant; therefore these maps do no t reflect proportional abundance in all the areas but within each survey.

4.7 Conclusions

The 2005–2008 industry science anglerfish surveys have provided minimum estimates of the abundance of anglerfish on the Northern Shelf which indicate an increase in biomass from about 40 000 t in 2005 to over 54 000 t in 2008. These estimates should be considered as underestimates as a consequence of survey coverage. The split in biomass between ICES Areas VI and IV was approximately 45:55 % in 2008.

The surveys have also provided indices of the abundance and biomass of megrim on the Northern Shelf. Biomass estimates over the past four years, which could be considered as minimum estimates, have risen from approximately 7000 tonnes to over 11 000 tonnes. Consistently, over half of the biomass occurs in ICES Subarea IV, where megrim is virtually ignored from an assessment point of view.

4.8 References

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5 Review and assessment of fishery-independent surveys for monkfish and megrim

5.1 Introduction

There are several conditions that have to be met for a scientific survey to provide unbiased absolute population or harvestable stock estimates:

1) The whole population, or harvestable population area is covered;

2) All components of catchability are known;

3) There are no sources of bias.

The whole population includes all age classes whereas the harvestable population corresponds to the age–length classes of the stock that are being harvested by the commercial fishery. As the two sexes of both monkfish, but also of both megrim populations do not have the same growth rate, the harvestable population is probably best defined by looking at the selection pattern of the fishery, thus considering a length cut-off rather than an age cut-off. If the four above conditions are not met, biased estimates will result. Neglecting conditions 1 and 2 (above) should lead to negatively biased estimates, and conversely, if these issues are inappropriately considered, positively biased estimates could result.

If relative population, or harvestable population estimates are required, condition (above) 2 may be replaced by

2) b. All components of catchability constant in space and time

In the next Section, starting from these conditions, the potential sources of bias and uncertainty inherent in the megrim and monkfish survey design and method used for estimating abundance and biomass are reviewed and their importance assessed. Catchability is broken down into herding, footrope escapes and trawl (incl. codend) selectivity.

5.2 Survey design issues potentially leading to biased estimates

5.2.1 Initial assessment

As a first approach to assessing the quality of the survey for monkfish, the estimated numbers-at-age for monkfish were considered (Figure 5.1). Based on population dynamics it is evident that there is a problem with ages younger than about four years, which seem to be substantially underestimated in most years. The question is whether this is an issue of area coverage, i.e. non-availability of younger ages in the survey area, or trawl catchability. In the following sections this question will be investigated when the different sources of bias are considered.

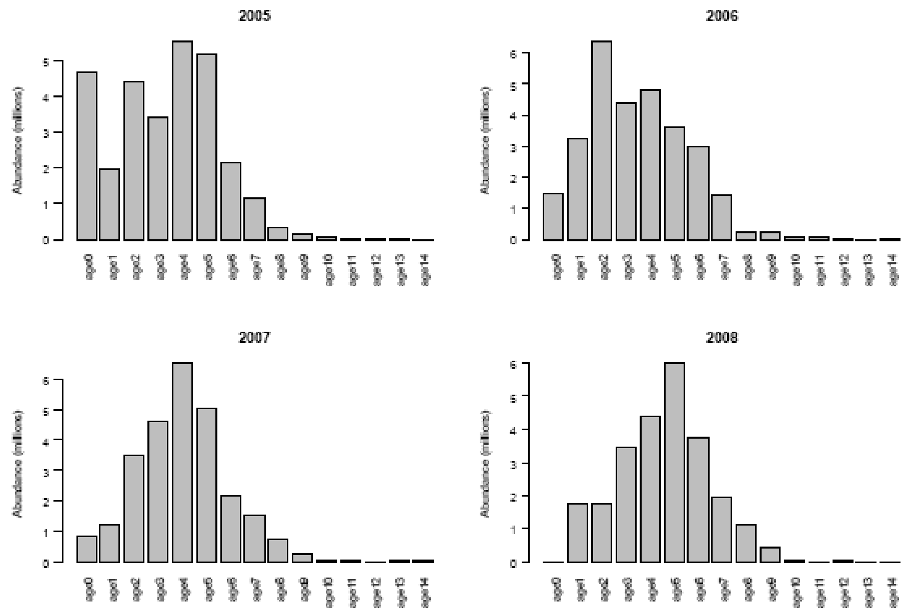

Figure 5.1. Estimated numbers-at-age for monkfish.

As megrims are not aged, only length–frequency distributions could be considered (Figure 5.2). These distributions indicate that the survey might also be catching young megrims.

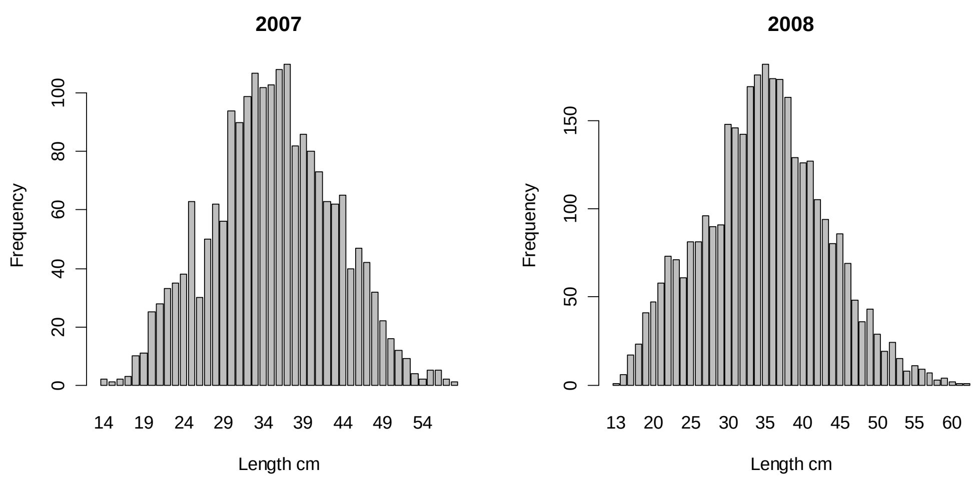

Figure 5.2. Length–frequency distributions for megrims in the 2007 (left) and 2008 (right) anglerfish surveys.

5.2.2 Spatial coverage

The definition of survey strata used for 2005 and 2006 onwards is shown in Figure 5.3. With respect to the current stock boundaries of the Northern Shelf monkfish, the survey does not cover the whole area in the North Sea, in ICES Area IV; in ICES Division VIa the Southern part was not covered in all years; and there are parts of Rockall that are closed to trawling which have not been covered in all years. Monkfish and possibly megrim occur in all these areas. In the next Sections the proportion of the stocks in these areas and potential methods for obtaining estimates are explored.

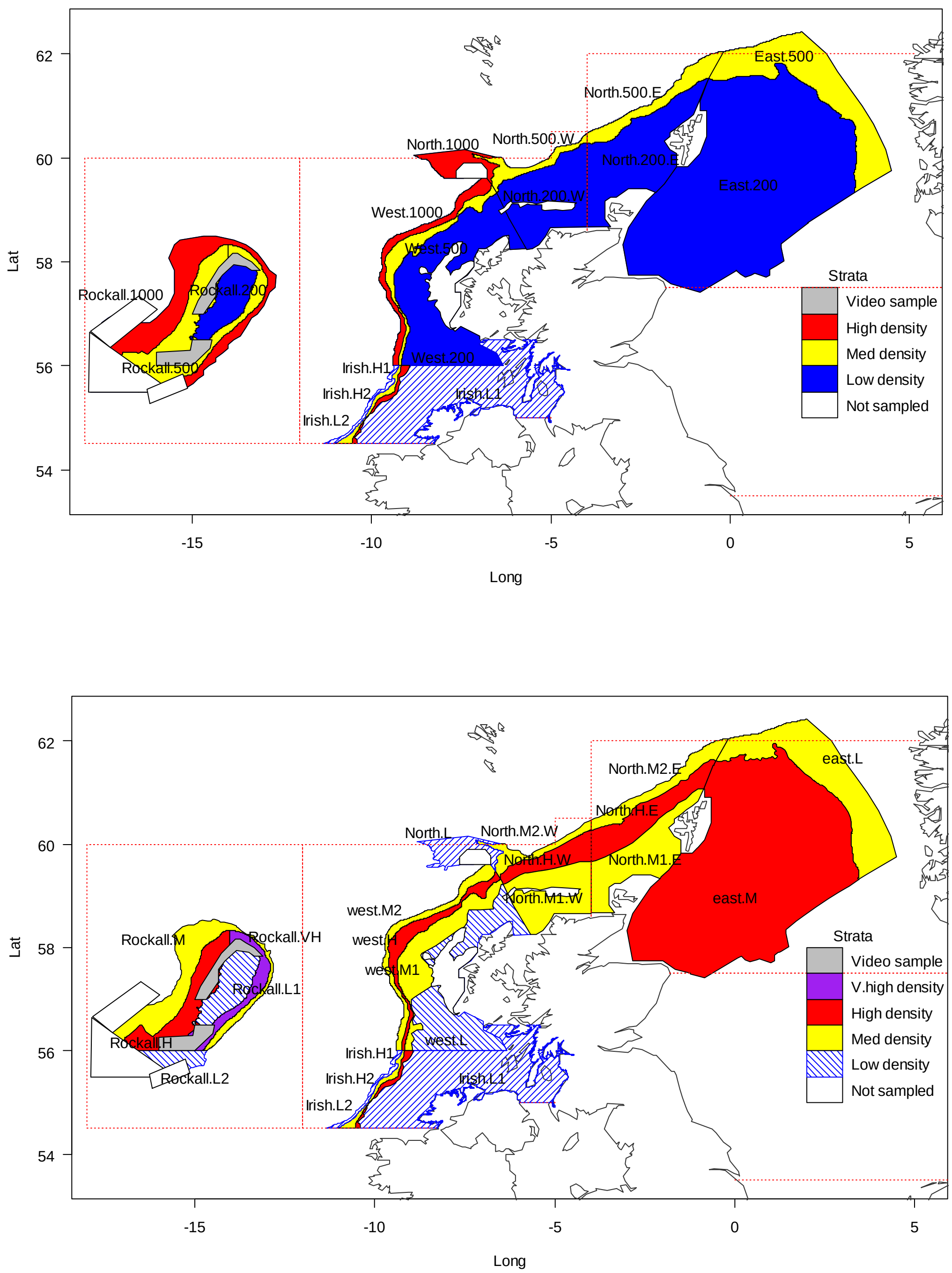

Figure 5.3. Definition of strata used in monkfish survey in 2005 (top) and 2006–2008 (bottom). The striped area was covered by the Irish Marine Institute in 2006 and 2007 and is estimated by interpolation in 2005 and 2008 (see Section 5.2.2.3).

5.2.2.1 North Sea extrapolation

Unfortunately, the FRS monkfish surveys do not cover the whole of the monkfish stock. In particular, they only partially cover Division IVa and do not go into Divisions IVb, IVc or IIIa. In order to provide estimates of abundance or biomass for ICES Division IV, it would be desirable to extend the survey coverage. In the absence of these data, it is possible to infer absolute estimates by utilizing the information from the IBTS survey. The ICES IBTS surveys cover IVa, IVb, IVc, IIIa and Via (albeit with different gear configurations; see Section 5.2.2.2 below) and there is good overlap of the two surveys in Division IVa. The IBTS data can therefore be used to extrapolate from the monkfish surveys into the IBTS survey areas. The simplest means of doing this, which we attempt here, is to raise IBTS mean catch rates in areas not surveyed by the monkfish survey by the ratio of monkfish mean catch rates to IBTS mean catch rates in areas surveyed by both surveys. There are a number of caveats associated with this approach that should be considered and the results presented here should be treated as indicative, at least until further data and/or analysis is available. The monkfish catch rates corrected for footrope selectivity at length were not available when this work was initiated and so the previous catch rates were used, which were corrected for herding and swept-area but assume e=1. More recently, data has become available that describes the selectivity of the groundgear of both the monkfish and IBTS 'B' gear survey trawls. Further analysis is required to compare the selectivity profiles of the two groundgears.

IBTS Q1 data for years 2005–2008, covering Subarea IV and Divisions IIIa and VIa, and containing number-at-length by 1cm length class for each haul, were obtained from ICES. It should be noted that the monkfish survey 2005–2007 was conducted in Q4 whereas the IBTS in Q1. This may result in differences in catchability (efficiency) as a consequence of external drivers such as water temperature or differences in morphological condition for example. Because age and weight data are not available for all fish, the first step was therefore to work with total numbers caught by haul (Figure 5.4). Eventually, however, the extrapolation will need to estimate numbers-at-age and biomass. The average IBTS catch rates in Divisions IVa, IVb, IVc, IIIa, and in each of the monkfish survey strata were calculated for each year. The ratio of the monkfish survey catch rates with those of the IBTS survey were compared for each of the monkfish survey strata in each year (Figure 5.5). It is clear that these are highly variable, in part as a consequence of low sample size in one or both of the surveys in some survey strata, but in general this ratio increases from year to year. One of the least variable strata is "East.M", situated in IVa, and with good coverage of both surveys. Because we are interested in extrapolating into Subarea IV and Division IIIa, we use the ratio of monkfish survey to IBTS catch rate in stratum East.M for each year to raise the IBTS mean catch rates in Divisions IVa, IVb, IVc, IIIa in those years (Table 5.1).

Total numbers in each division were calculated using the spatial area (in km^2) in each Division (Table 5.2). In Division IVa, the raised IBTS data were only used in areas not covered by the monkfish survey; areas covered by the monkfish survey use the monkfish mean catch rates for the relevant stratum. No monkfish were caught in Division IVc in IBTS surveys 2005–2008, so this division did not contribute to total numbers in Area IV. The numbers in Divisions IVa, IVb and IIIa increase fourfold over the four years. This is partly as a consequence of a doubling in the estimated raising factor, from 32 to 73, because of a halving of average density in East.M on the IBTS surveys, but also as a result of a change in distribution over these years; with the proportion of fish in IV and IIIa but outwith East.M increasing each year. This increase results in a corresponding increase in percentage difference from 25% to 90% over the four years.

Table 5.1. Raising factor and estimated monkfish mean densities (numbers km^{-2}) for strata in Subarea IV and Division IIIa, calculated by raising IBTS catch rates to monkfish survey catch rates in areas not covered by the monkfish survey for years 2005–2008.

Sector	Stratum	Area (km^2)	2005	2006	2007	2008
Raising Factor	-	-	32.44	42.35	50.86	72.73
IV IBTS	IVa IBTS only	113 267	10.07	28.80	42.39	44.16
IV IBTS	IVb	274 314	3.68	1.29	10.36	11.09
IV IBTS	IVc	69 070	0.00	0.00	0.00	0.00
IV IBTS	IIIa	59 190	1.38	2.02	2.37	16.91
IV monkfish	East.M	105 670	60.05	61.90	59.92	64.30
IV monkfish	East.L	23 912	13.41	3.38	16.33	19.78
IV monkfish	North.M1.E	14 249	110.57	136.43	344.10	55.23
IV monkfish	North.M2.E	5822	12.37	21.81	9.08	111.19
IV monkfish	North.H.E	10 176	90.50	90.73	58.89	120.20

Table 5.2. Estimated monkfish total numbers (millions) in Subarea IV and Division IIIa, calculated by raising IBTS catch rates to monkfish survey catch rates in areas not covered by the monkfish survey for years 2005–2008. The percentage increase resulting from the previous partial estimate in Subarea IV to the new estimate for the whole of Subarea IV and IIIa is also given at the bottom.

Sector	Stratum	Area (km^2)	2005	2006	2007	2008
IBTS	IVa	113 267	1.140	3.262	4.801	5.001
IBTS	IVb	274 314	1.010	0.355	2.841	3.043
IBTS	IVc	69 070	0.000	0.000	0.000	0.000
IBTS	IIIa	59 190	0.082	0.119	0.140	1.001
IV monkfish	East.M	105 670	6.346	6.541	6.332	6.794
IV monkfish	East.L	23 912	0.321	0.081	0.390	0.473
IV monkfish	North.M1.E	14 249	1.575	1.944	4.903	0.787
IV monkfish	North.M2.E	5822	0.072	0.127	0.053	0.647
IV monkfish	North.H.E	10 175	0.921	0.923	0.599	1.223
IBTS	Total	515 841	2.232	3.736	7.782	9.046
IV monkfish	Total	159 829	9.235	9.616	12.277	9.925
IV and IIIa	Total	675 670	11.467	13.352	20.059	18.970
%age increase	Total	322.75	24.17	38.85	63.38	91.15

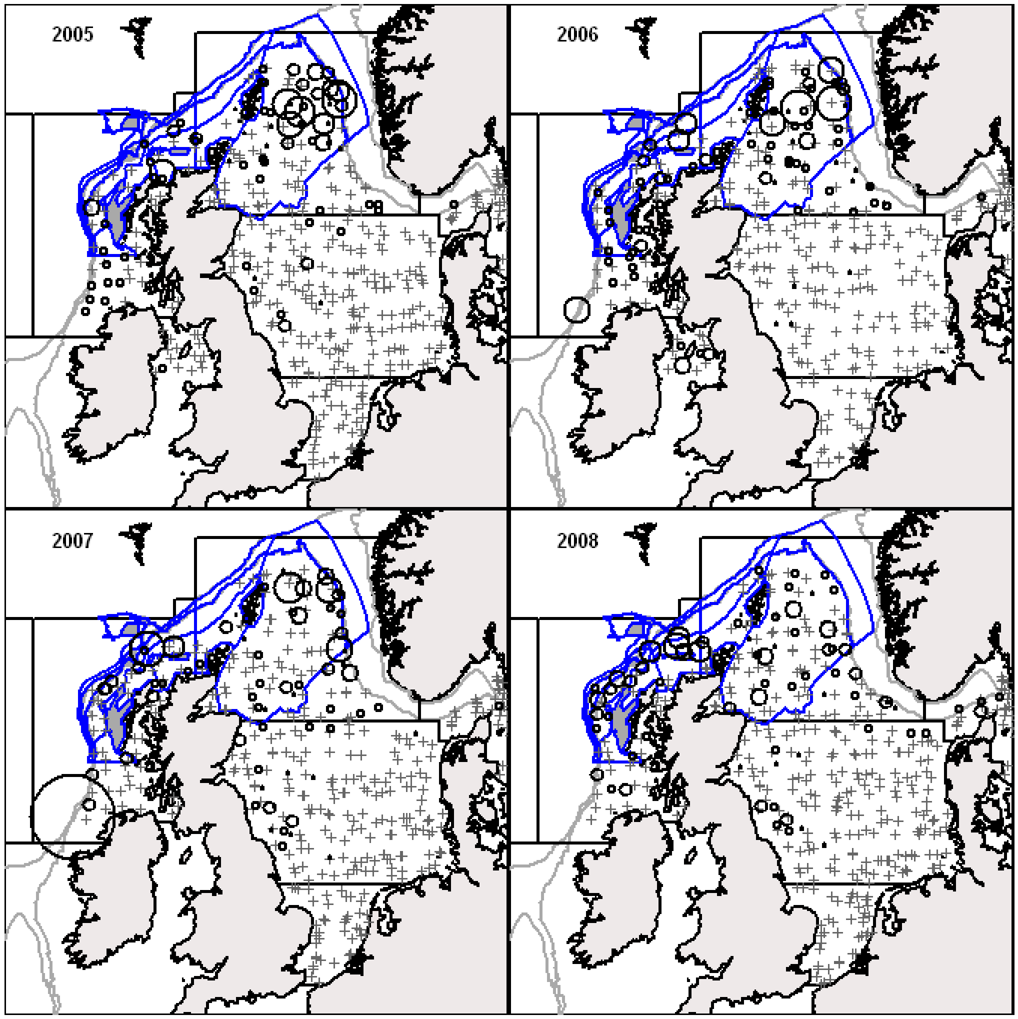

Figure 5.4. IBTS surveys for monkfish 2005–2008: total number caught by haul.

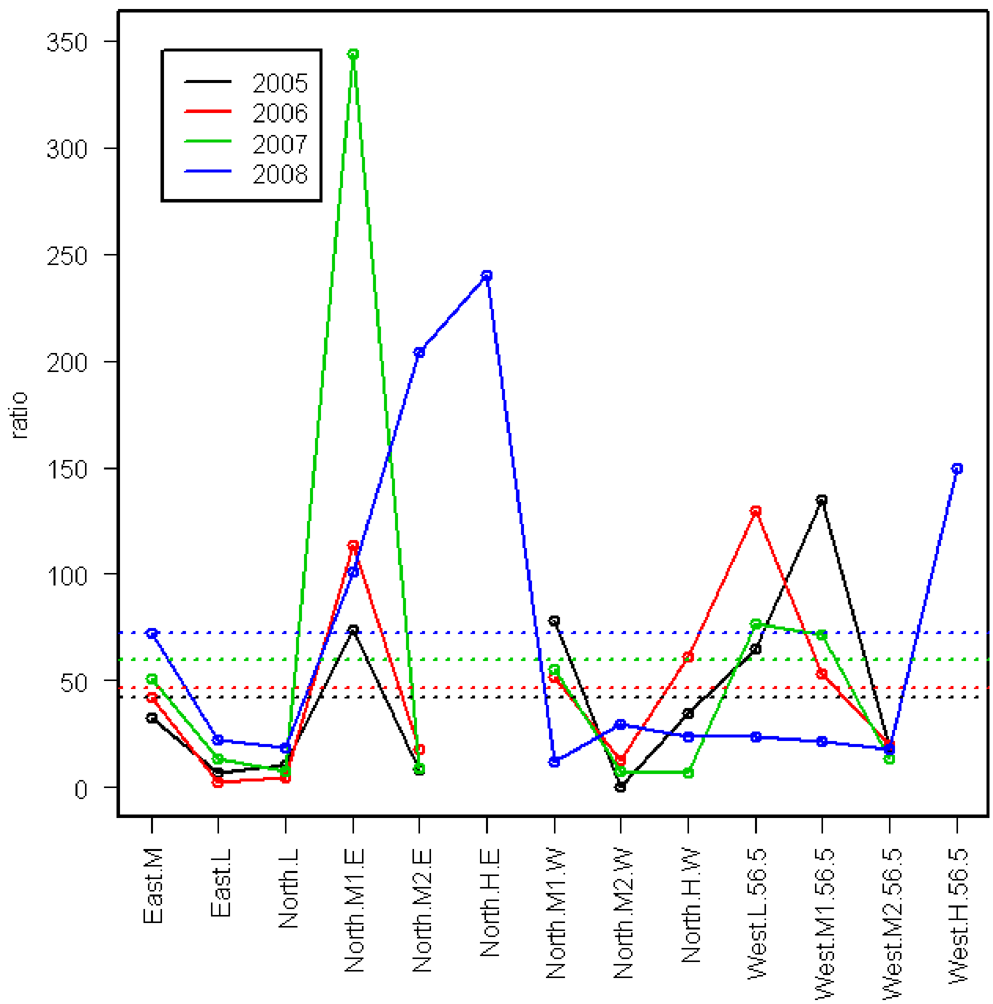

Figure 5.5. Ratio of monkfish average density to IBTS mean number caught per haul in each of the monkfish survey strata.

5.2.2.2 IBTS survey consistency

THE IBTS is supposed to be standardized in the use of a single trawl gear; the Grande Overture Vertical (GOV). There are several issues associated with standardization which need to be considered when comparing the data from the IBTS survey in the North Sea. First, the type of groundgear in use differs spatially (Figure 5.6): groundgear A is used in the North and western areas; groundgear B in the central North Sea and southern North Sea. These alphabet codes refer to the different weight of the groundgear. It is not clear how the differences may affect catchability of the trawl however; this could be an important consideration. A number of studies have revealed that fish escape under the groundgear or between the discs. These have demonstrated that the probability of escapement is both species and length dependant (Dahm, 2000; Engas and Godo, 1989; Ingolfsson and Jorgensen, 2006). Dahm and Weinebek, 1992 compared the length distributions of several species, unfortunately not monkfish, between the GOB rigged with groundgear 'B' (as used in IVa and groundgear 'A' (as used in IVb, c). They noted significant differences in catch length composition with nearly all species examined. The relationships differed considerably between species (positive or negative increase in catches with length). In conclusion, until formal comparisons between the two types of groundgears used on the GOV are examined, it is not possible to extrapolate with any confidence into areas where there is not spatial overlap in survey gears and the work presented should only be considered as a description of a possible methodological approach rather than indicative of biomass or abundance levels.

In their analysis of national equipment ICES (2006) described a "fundamental difference" between the GOV trawls used by three of the participants in the IBTS: these were to do with the type of netting used (polyamide or polyethylene) and headline wire (14 mm diameter or 22 mm). It is not clear how the differences may affect catchability of the trawl but these are not thought to be as significant as the changes in groundgear noted above.

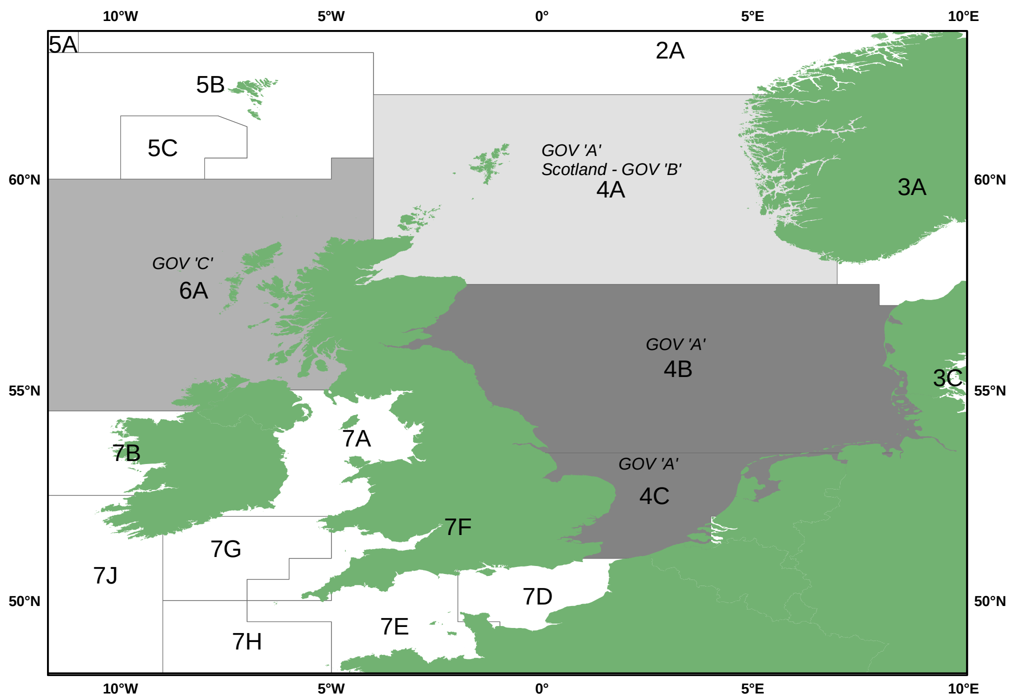

Figure 5.6. Map of the British Isles showing the type of groundgear used on GOV trawl for the IBTS.

5.2.2.3 Around Ireland extrapolation

In 2006 and 2007 the Marine Institute of the Republic of Ireland participated in the anglerfish surveys. In each of these years the abundance of anglerfish and megrim could be estimated for the whole of Area VI. In 2005 and 2008, the southern part of Area VI was not surveyed (Figure 5.7) as a consequence of resource limitations, so estimates for this area were not available. Instead an extrapolation method was used whereby the proportion of anglerfish contained in the area surveyed only by the Irish relative to the anglerfish contained in the whole survey area was used to estimate the abundance of anglerfish as follows:

1) Determine abundance in Area VI surveyed ***only*** by the Irish (shaded grey in Figure 5.7) in 2006 (=1.549 million) and 2007 (=2.518 million).

2) Determine proportion of abundance in step 1 relative to abundance in the whole survey area in 2006 (=0.086) and 2007 (=0.136).
3) Take the average of these proportions (=0.111).
4) Multiply this proportion by the whole survey abundance and add to the survey abundance. Abundance in years 2005 and 2008 = whole survey area abundance+ (whole survey area abundance x 0.111).
5) Do the same for biomass (average proportion = 0.064).

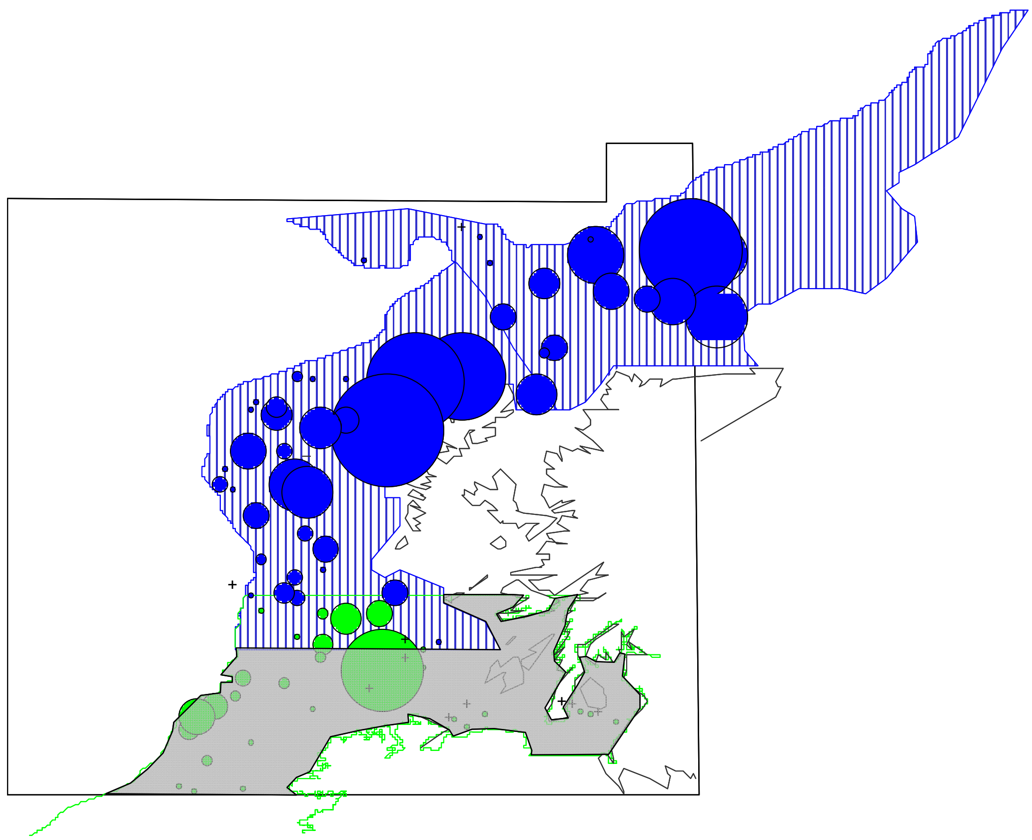

Figure 5.7. Map of the west of Scotland showing the regions surveyed (shaded areas) and trawl sample fish density (circles) estimates for the Irish (green) and Scottish (blue) surveys. The hatched area represents the areas of the Scottish west of Scotland and north of Scotland surveys; the grey solid shaded area represents the area surveyed by the Irish which was not surveyed by the Scottish. It is the latter area which was not surveyed in 2005 and 2008 when the Irish did not participate.

5.2.2.4 Rockall closed/non-fished area

Under Annex III, article 13, of the European Community Council Regulation No 40/2008, the Interim measures for the protection of vulnerable deep-sea habitats, it is prohibited to conduct bottom trawling and fishing with static gear, including bottom-set gillnets and longlines, within several areas around Rockall. There are two areas affected in the survey area that this regulation affects: the northwest Rockall and Empress of Britain Bank closures to protect deep-sea coral (see strata labeled as video sample in Figure 5.3). Although that regulation provides a derogation to fishing operations conducted solely for the purpose of scientific investigations it has been the policy of the Marine Laboratory to respect the regulation. These areas were, therefore, not sampled with the demersal trawl.

In 2008 these closed areas were sampled with a towed vehicle operating a colour video camera. At several video stations located in these areas (Figure 5.3), the vehicle was towed approximately 5 m above the seabed at a speed of approximately 3 knots (1.5 $m.s^{-1}$). Anglerfish were counted from inspection of the video and the area sampled was calculated taking into account the height of the vehicle, field of view of the camera and speed. The counts of anglerfish were the converted into densities and raised to the area of the closures to produce abundance estimates. The abundance estimates were converted to biomass estimates by multiplying the abundance by the mean weight of anglerfish which were caught in the adjacent strata (high density and very high density strata in Figure 5.3). The results are given in Table 4.1. The proportions of these estimates relative to the estimates for the two adjacent strata were then used to estimate the abundance and biomass in those areas for 2005–2007.

5.2.3 Location of younger ages of monkfish

Two sources of information were considered for investigating the question of whether survey spatial coverage might be inappropriate to younger ages of monkfish. In the Bay of Biscay and Celtic Sea, the Western IBTS survey indicates that 0-group individuals are offshore, together with older individuals (Figure 5.8). For the purpose of these figures, *Lophius budegassa* individuals smaller than 17 cm and *Lophius piscatorius* smaller than 26 cm were considered to belong to the 0-group, given the survey takes place in autumn. The second source of information comes from the Spanish survey on Porcupine bank using a baca trawl (Velasco *et al*., 2008, Figure 5.9). Around Porcupine bank, 0-group individuals seem to be between 100 and 300 m, but spatial spreading is a function of cohort strength with 0-group individuals being found in a wide area in 2001 and much more confined for example in 2005.

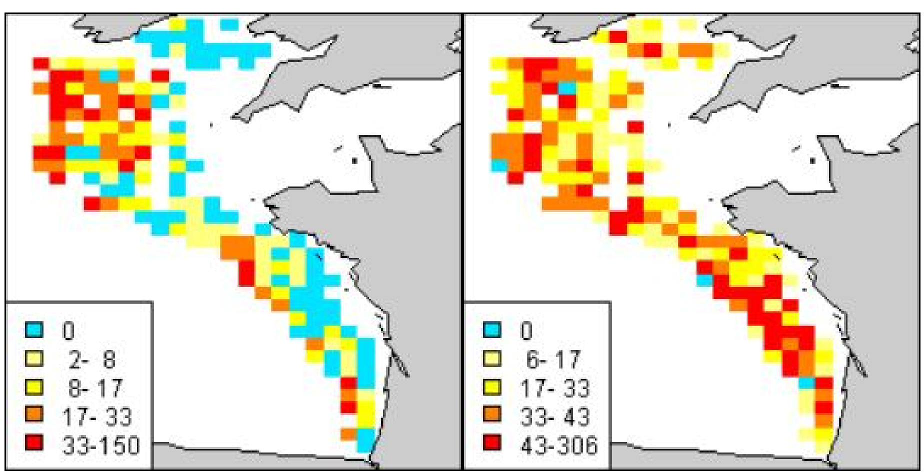

Figure 5.8. Mean numbers per km² for 0-group individuals in the Bay of Biscay from Western IBTS survey taking place in October–December averaged over the period 1997–2008 for *Lophius budegassa* (left) and *Lophius piscatorius* (right). Note that the colour scale is non-linear and represents quartiles.

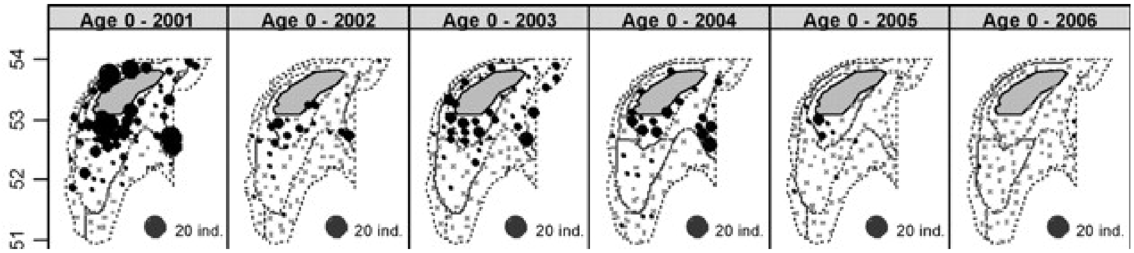

Figure 5.9. Number of 0-group individuals per haul of *Lophius piscatorius* on Porcupine bank (Baca trawl) from Velasco *et al.*, 2008.

The two examples cited above seem to indicate that young monkfish in the northern stock are located offshore. However, there is no information to corroborate or refute the hypothesis that this is also the case for the Northern Shelf stock. More investigations are required before one can be confident that the lack of young individuals is not caused by a mismatch between the survey area and their spatial location.

5.2.3.1 Location of younger ages of megrims

Two sources of information were considered for investigating the question of whether survey spatial coverage might be inappropriate to younger ages of megrims. Observations from a manned submersible in the Bay of Biscay have revealed the existence of a nursery of small (<15 cm) megrim (*Lepidorhombus whiffiagonis*) on the shelf slope at depths below 180 m (Y. Desaunay, pers. comm.). Information on the location of larvae in the Celtic Sea and to the West of Ireland demonstrated that these are also distributed along the shelf break (Figure 5.10). Thus taken together, this provides evidence that the survey should cover younger ages of megrims and hence the lack of them in the survey catch might be caused by low catchability, which is treated below.

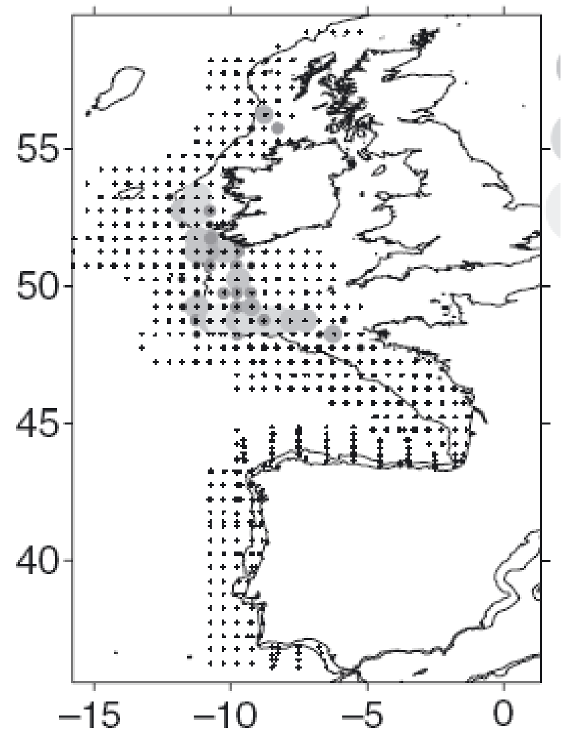

Figure 5.10. Distribution of *Lepidorhombus whiffiagonis* larvae abundance. Redrawn from Ibaibarriaga *et al.*, 2007.

5.2.4 Catchability

Trawl catchability is determined by the trawl design, as well as survey speed and roughness of the ground. For the monkfish survey a commercial trawl was adapted, thus it might be expected that it is particularly suitable for commercial sized monkfish. The available information concerning different components of catchability is considered in details below.

5.2.4.1 Herding by sweeps

Currently only a herding factor for monkfish has been estimated based on a single experiment with videos attached to the trawl and a small ROV (Reid *et al.*, 2008). This experiment was carried out in three locations with a similar habitat. The mean estimate for herding from the area between the wings and the doors was 4%. This seems rather low, however, video footage and observations from submersibles confirm that monkfish require a strongly stimulus in order to move. Thus, herding by sweeps seems to be low and might not be worth considering any further. However, no information was available for megrims.

5.2.4.2 Footrope selectivity

The experimental data described in Reid *et al.*, 2007 are used to estimate footrope selectivity for the gear used in the monkfish surveys (Figure 5.11). These data consist of 245 fish caught in 14 hauls. Between 5 and 42 fish were caught per a haul, with a median of 15. 163 fish were caught in the codend, the remaining 81 in the bags below the footrope. Few fish were caught below 25 cm, and none over 63 cm whereas the length range of the abundance estimation data is 12–146 cm.

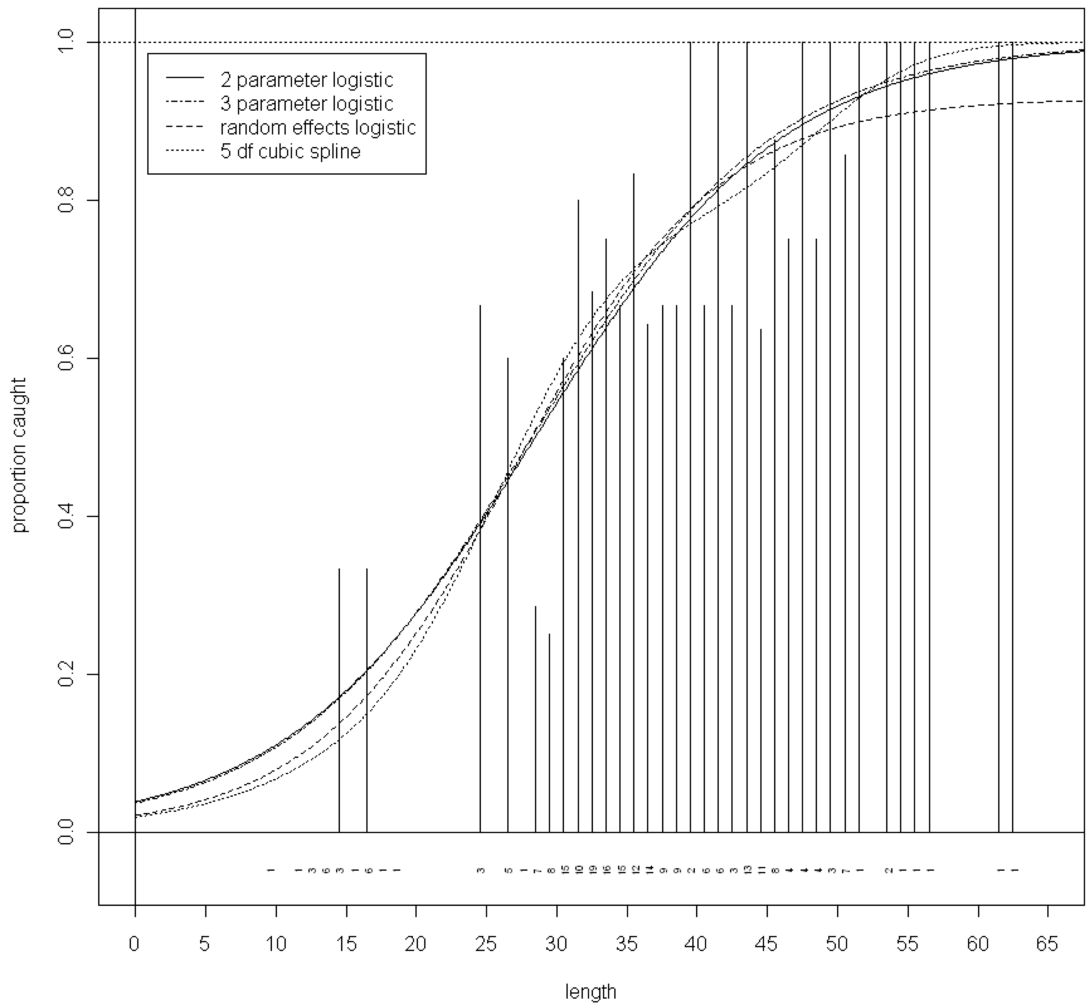

Figure 5.11. Footrope selectivity experimental data, shown as proportions caught at length over all hauls for each 1 cm length class, and the four models fitted to the data as described in the text. The number of fish caught in each length-class is shown along the bottom of the plot.

A standard 2-parameter logistic model and a 3-parameter logistic model were both fitted to the data assuming a Binomial error distribution. These models can be represented by the following equation:

$$\pi_i = \frac{\gamma}{1 + \exp\{-(\beta_0 + \beta_1 l_i)\}},$$

where π_i is the probability of being caught by the net, β_0 β_1 and γ are parameters to be estimated and $\gamma = 1$ in the2-parameter model. The 3-parameter model has a substantially lower asymptote (0.929) and is lower at shorter lengths (Figure 5.11). This lower asymptote does not fit the available data at the largest lengths (where few fish were caught, of which none had escaped under the footrope) but allows the model to fit the data better both at lower lengths and at the centre of the length distribution, where the bulk of the data lie. Comparison of AIC and χ^2 goodness-of-fit statistics (Table 5.3) demonstrates that both the models fit the available data, with similar AIC values, so statistically the 3-parameter model was not found to be an improvement on the 2-parameter model (Table 5.3). Thus the 2 parameter model (with coefficients $\beta_0 = -3.223$ and $\beta_1 = 0.114$) was used in the abundance estimation.

Table 5.3. Comparison between 2-parameter and 3-parameter logistic models.

	2-PARAMETER	3-PARAMETER
AIC	267.42	268.97
p-value(χ^2 test)	0.860	0.768

A 2-parameter logistic model was also fitted as a GLMM with haul as a random effect in the slope parameter β_1 (following AIC comparison of models with random effects in the intercept and/or slope). The resulting curve is very similar to the 2-parameter model (Figure 5.11). It is envisaged that this model will eventually be included in the abundance estimation.

The curves described above are all symmetric and it is difficult to tell whether such models are appropriate given the few data at small lengths, where the application of the selection curve will have the most effect on estimated numbers-at-length. A generalized additive model (GAM) using a cubic smoothing spline with 5 fixed degrees of freedom was therefore also fitted to the data to try to detect any evidence of asymmetry in the selectivity curve. There is some evidence (Figure 5.11) that an asymmetric model would be more appropriate, because the smoothing spline and the 3-parameter logistic model are both lower than the more constrained 2-parameter logistic models at short lengths. Furthermore, the smoothing spline tends towards 1 quicker than the other curves. It should be noted however that model selection on the gam results in the 2-parameter logistic being selected over the 5 d.f. spline. More data are required to ascertain the shape of the selection curve at lengths below 30 cm; however it is suggested that an asymmetric selection function should be used in the abundance estimation.

No quantitative information was available on megrim footrope selectivity. However, given their body shape and habit to sit on the seabed (Figure 5.12), it is rather conceivable that individuals of all sizes, but in particular small ones, should have high escapement under the footrope.

Figure 5.12. Megrim (*Lepidorhombus whiffiagonis*) observed at 120 m in the Bay of Biscay at 48°N, 5°40′W on sand dunes (0.5–2 m high, 5–10 m wide). Source: Ifremer submersible observations.

5.2.4.3 Codend selectivity

The monkfish survey trawl is based on a commercial trawl design, including the mesh sizes used. This could possibly result in some degree in mesh selection in both the main body of the trawl and the codend (100 mm). Thus, the catch rates observed could, for the smaller length classes, be an underestimation as a consequence of mesh selection. However, given the morphological form of monkfish, this is thought not to be a significant issue, but with the lack of selectivity data for this species, loss of small individuals through the codend and main body of the trawl cannot be fully discounted. Escapement through the groundgear is considered to be the main factor for smaller length classes.

5.2.4.4 Catchability of GOV

To further explore the issue of trawl catchability being responsible for a certain lack of younger individuals in survey catches, length–frequency distributions obtained in the Bay of Biscay and Celtic Sea using the GOV were investigated (Figure 5.13). The survey takes place in autumn and 0-group fish (<26 cm) are quite distinct on the annual histograms, though interannual recruitment strength leads to variable heights of peaks. Thus the GOV clearly catches young monkfish rather well.

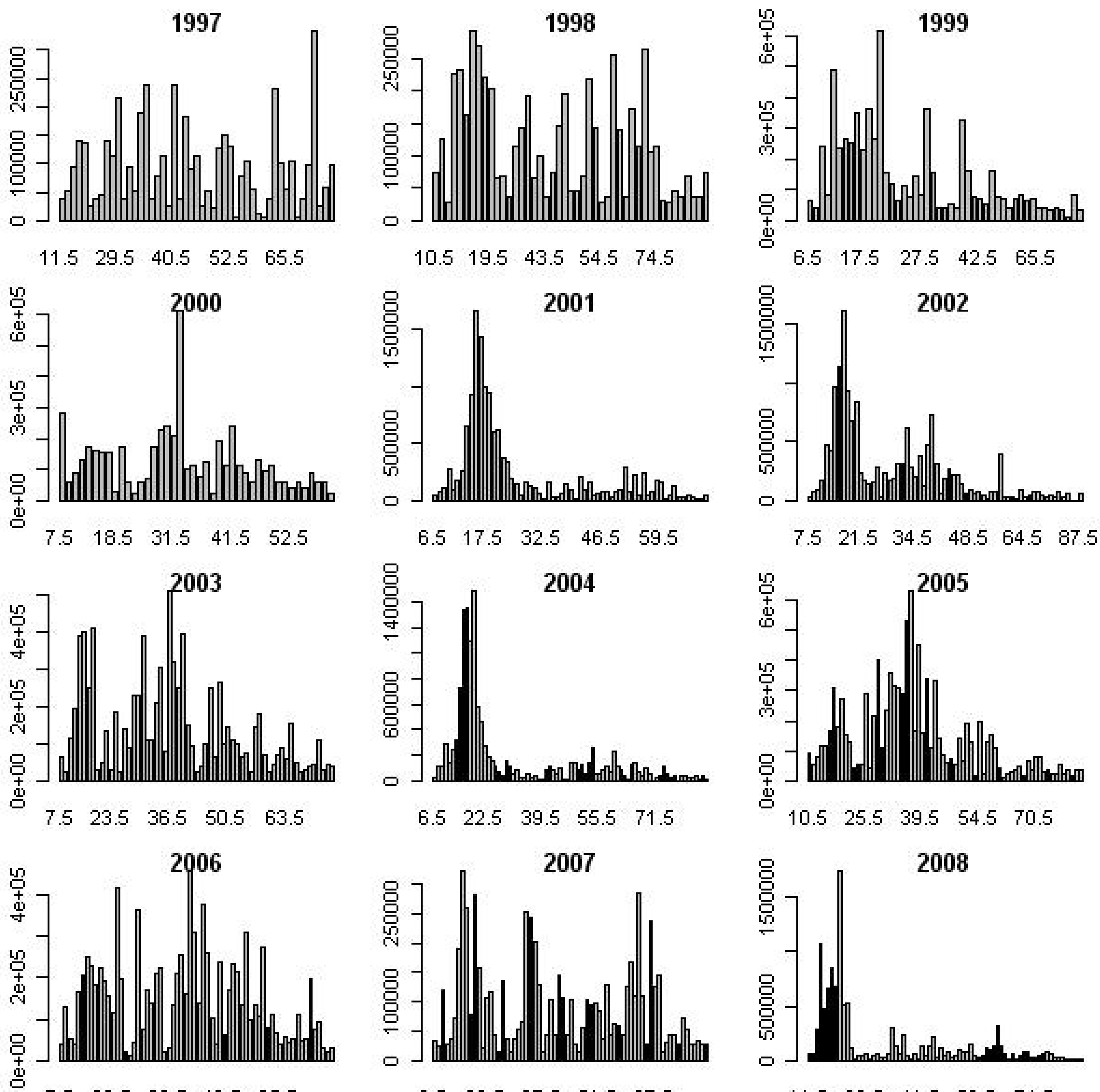

Figure 5.13. Length–frequency distributions for *Lophius piscatorius* in Bay of Biscay and Celtic sea for Western IBTS survey data.

The length distributions for 2005–2008 combined in Division IVa and IVb have proportionally a lot more smaller fish (less than 20 cm) than in Division VIa (Figure 5.14), whereas Division VIa has proportionally more fish of length 45–50 cm. This could be either an area effect or a gear effect, as the survey uses a different gear in VIa. Division IVb has proportionally a lot fewer fish larger than 40 cm compared with IVa, however this is much less pronounced in the annual length distributions (Figure 5.15). In general, the annual length distributions are quite variable in all three divisions.

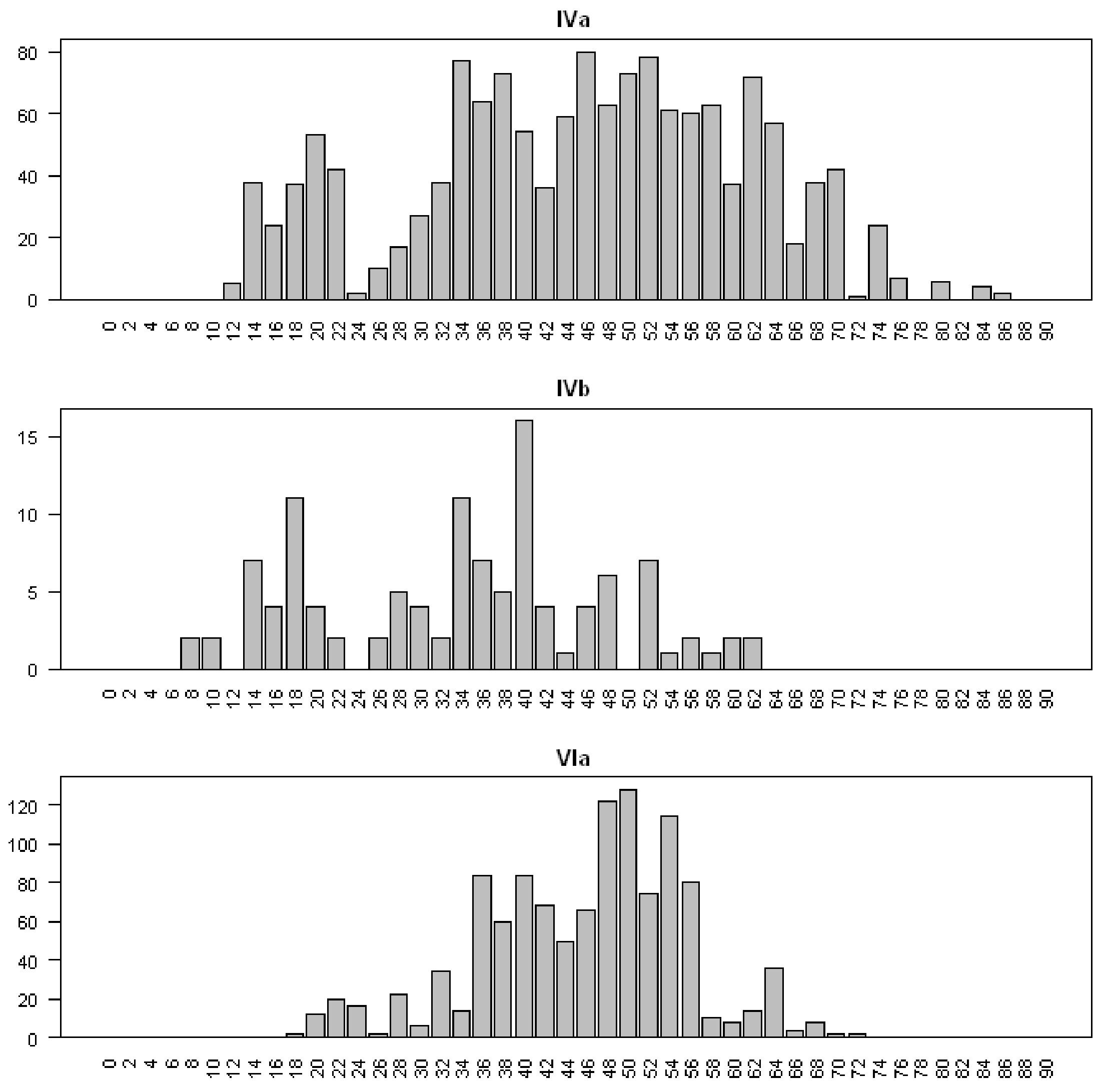

Figure 5.14. The length–frequency distribution of the IBTS data by 2cm length-class by ICES division for years 2005–2008 combined.

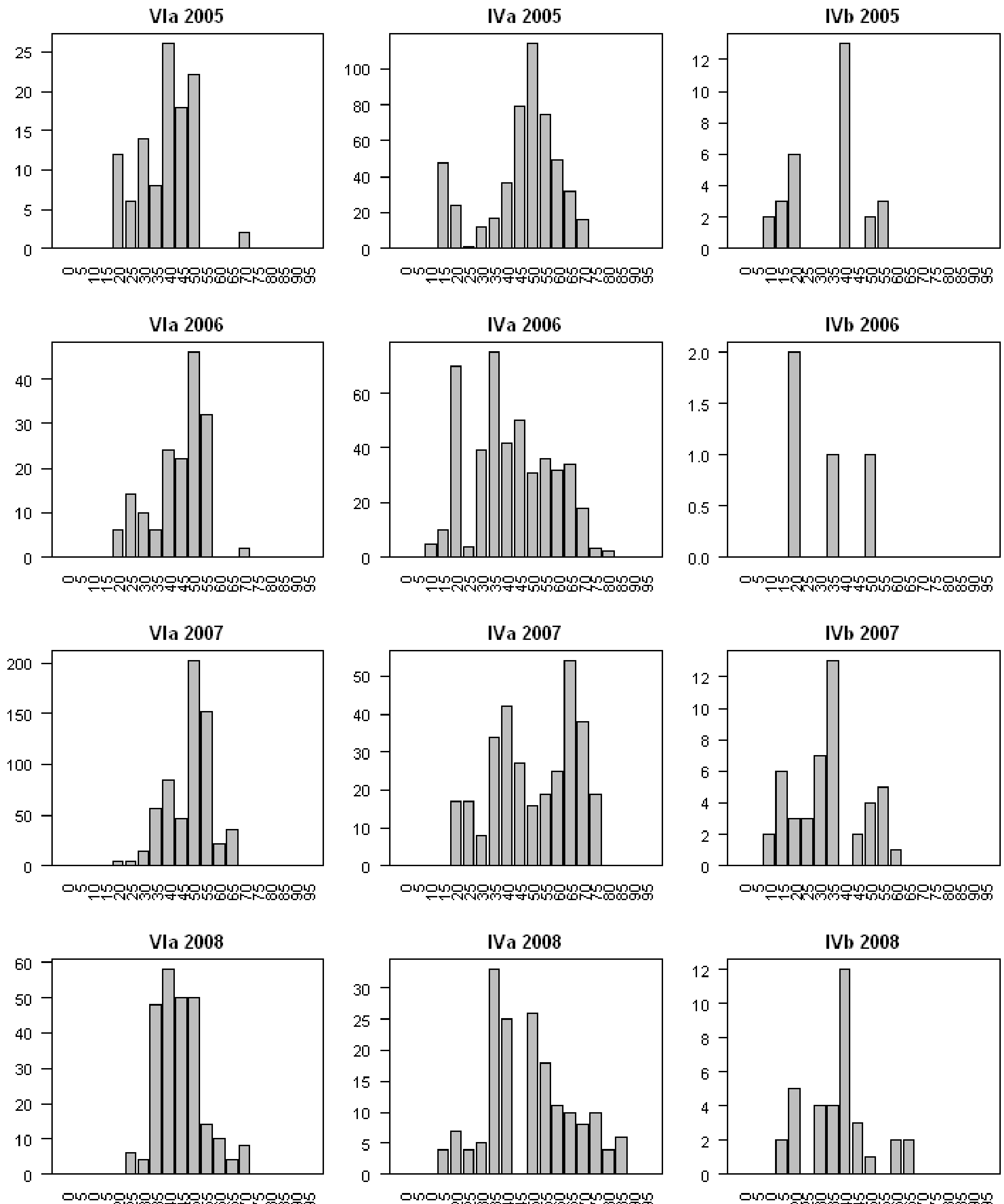

Figure 5.15. The annual length–frequency distribution of the IBTS data by 2cm length class by ICES division for years 2005–2008.

5.2.4.5 Comparison of length distribution between survey and commercial catches

For monkfish, the length–frequency distribution of survey catch and in commercial hauls (Laurenson *et al.*, 2008), were compared (Figure 5.16). The mode of the two distributions seem to be in the same place at around 40 cm, indicating that the survey is clearly surveying the harvestable stock.

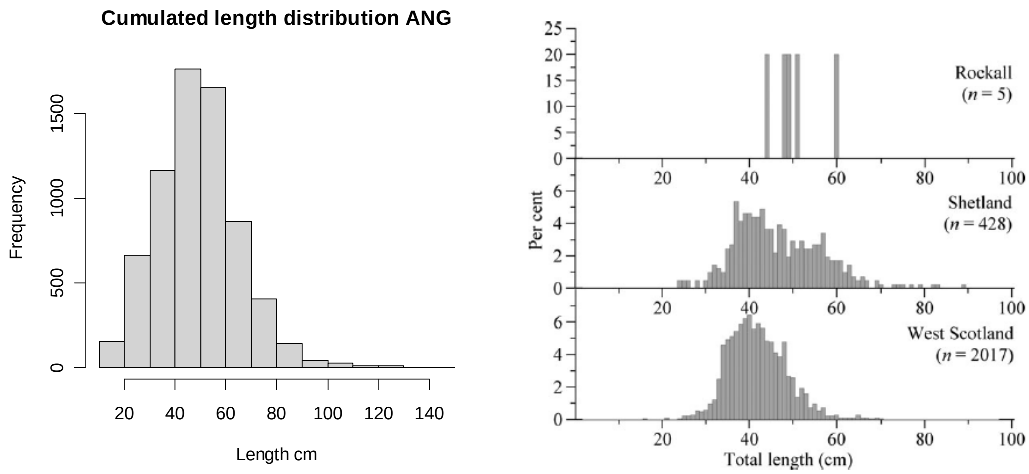

Figure 5.16. Monkfish length–frequency distribution in commercial catches (reproduced from Laurenson *et al.*, 2008) and monkfish survey (right).

No information was made available for megrim.

5.2.5 Summary of survey design recommendations

The following Table summarizes the assessment of survey design issues. The assessment was primarily carried out for monkfish and to a lesser extent for megrims as a consequence of lack of information.

ISSUE	DETAILS	ASSESSMENT	RECOMMENDATION
Spatial coverage	General	Current stock area for monkfish only partially covered; stock area unknown for megrim	Quantify potential biomass, abundance and age–length structure in areas not usually covered by survey (see below)
	North Sea extrapolation	IBTS gear catches monkfish but has different catchability	Explore and compare different ways of extrapolating estimates using IBTS Q1 data for unsampled areas; explore the use of other data (e.g. VMS) for both monkfish and megrims
	Around Ireland extrapolation		Explore extrapolation by depth strata monk and megrim
	Rockall closed/non-fished area	Not enough data for monkfish and none for megrims	Collect more data to evaluate local density and time-trends
	Coverage of younger ages	Evidence from elsewhere suggests that younger individuals of monkfish and megrims should be covered by survey	Further analyses required to determine location of ages <4 years for monkfish and megrims
Catchability	General	Survey trawl does not seem to catch small monkfish well; no information available for megrims	See below
	Herding by sweeps	Available data suggests that there is little herding for monkfish; no information available for megrims	Consider using appropriate variance estimate of herding coefficient (skewed distribution).
	Footrope selectivity	Monkfish smaller than about 30 cm are poorly represented in the experiment	Evaluate different models for footrope selectivity, e.g. smoothers, non-symmetrical logistic function; carry out additional bag experiments in different habitats and trying to cover smaller individuals.
	Cod end selectvity	No data available	Carry out experiments or analyse existing data

5.3 Sources of uncertainty in abundance and biomass estimates

5.3.1 Survey design

The survey design includes 18 strata (since 2006). The number of realized hauls per stratum varied between 1 and 27 (Figure 5.17). Strata with less than three hauls pose a problem for point and variance estimates. For strata with only one haul, the estimated coefficient of variation from a stratum with the most similar density is applied and raised by the square root of the number of samples in that stratum.

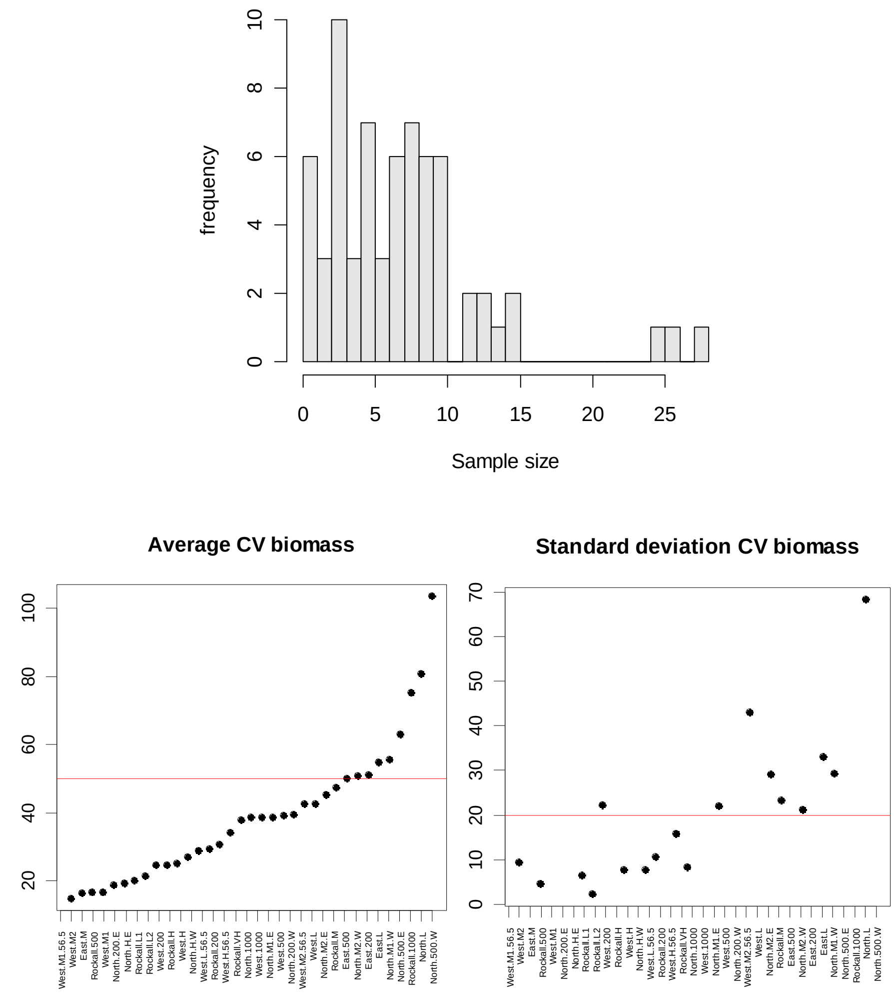

Figure 5.17. Number of hauls per stratum for the period 2005–2008, average CV per stratum and standard deviation of interannual CVs for monkfish biomass estimates. The red horizontal lines indicate the limits considered for satisfactory CV values.

Strata with average CVs (across) higher than 50% or interannual variations (standard deviations) of CVs of more than 20 can be considered undersampled. The details for these strata are provided in Table 5.1. Among the strata with too high CVs for monkfish, for North.L in two years only one haul was available, hence these estimates came from elsewhere. There are three strata, East.L, North.M1.W and North.M2.W which should be reconsidered. Either the number of hauls should be increased or they should be merged with suitable neighbouring strata. Merging strata would present the advantage of obtaining point estimates and uncertainty estimates for the same units instead of applying uncertainty estimates from elsewhere in case where there are not sufficient hauls.

Table 5.1. Coefficient of variation (Standard deviation/mean) for monkfish biomass estimates by stratum. n= number of hauls. Bold letters indicate strata whose design should be reconsidered.

Stratum	Year	n	CV monkfish
East.200	2005	12	51.17
East.L	2006	3	52.3
East.L	2007	4	23.26
East.L	2008	5	89
North.500.E	2005	4	62.82
North.500.W	2005	2	103.38
North.L	2006	1	159.67
North.L	2007	1	44.77
North.L	2008	2	37.88
North.M1.W	2006	6	27.19
North.M1.W	2007	5	53.66
North.M1.W	2008	7	85.81
North.M2.W	2006	3	74.27
North.M2.W	2007	3	44.77
North.M2.W	2008	2	33.32
Rockall.1000	2005	9	75.11

5.3.2 Estimators

The estimator for numbers or biomass includes several variables which are measured with uncertainty or could otherwise impact the uncertainty of the estimates

- swept-area
- gear efficiency
- herding
- missing age data

5.3.3 Swept area variability

It has been found that catches are not necessarily linearly related to swept-area for certain species. For the monkfish survey, haul duration is fixed to 60 mins (120 mins in 2005), but swept-area can vary as a consequence of variations in vessel speed or having to shorten a haul for various reasons. The range of swept-area v1 (between wing tips) extended from around 30 to 230 thousand km^2 with hauls with larger swept-areas leading to generally larger catches in numbers (Figure 5.18). When standardizing numbers by the swept-area, the swept-area effect largely disappeared, though the density for hauls with the swept-areas >200 thousand km^2 remained surprisingly low (Figure 5.18 right). Thus there is no evidence that the variability of swept-area might bias abundance estimates or increase variance.

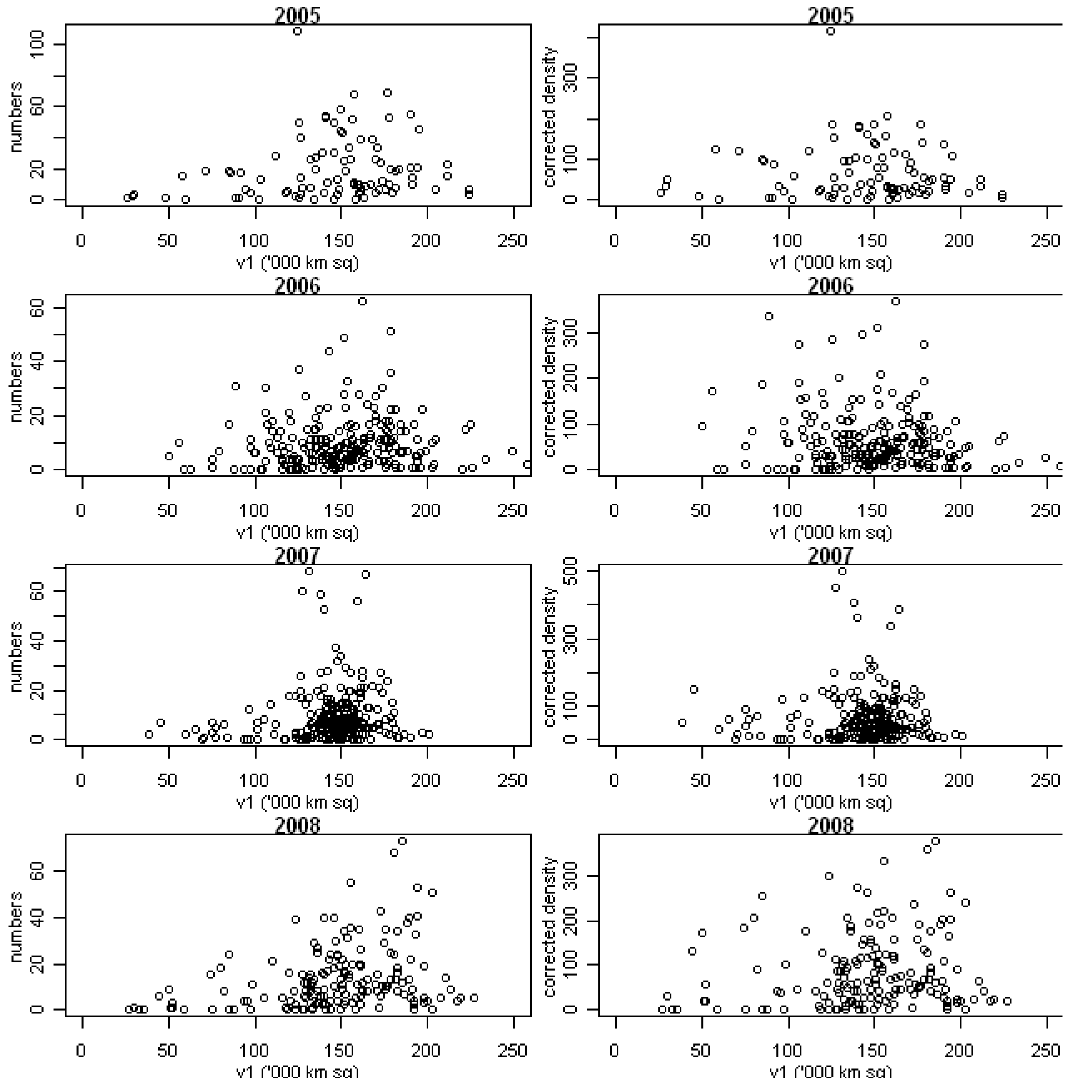

Figure 5.18. Number of monkfish per haul as a function of the area swept by trawl wings per haul (left) and numbers divided by swept-area as a function of the actual swept-area (right). This shows that the difference in swept-area accounts for differences between hauls.

5.3.4 Gear efficiency

Depending on which model is fitted to the data from the monkfish escapement under the footrope experiment, different estimates of variability of gear efficiency-at-length are available and have to be taken account. Further research is required to characterize inter-haul variability of gear selectivity and possibly variability between habitat types.

5.3.5 Herding variability

The between haul variability of herding for monkfish was evaluated using an individual based model (Reid *et al.*, 2008). The histogram of simulated values suggests that this variability is right-skewed: most hauls had no herding, with an occasional large herding factor (Figure 5.19). The skewness in herding should be incorporated in the uncertainty estimate for monkfish numbers and biomass.

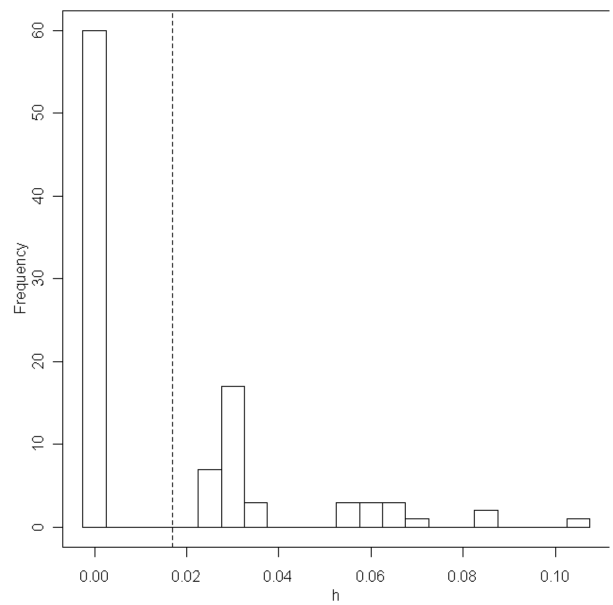

Figure 5.19. Histogram of herding h estimates for monkfish from individual based model described in Reid *et al.*, 2008. The vertical line indicates the mean.

5.3.6 Missing age data

The survey protocol prescribes that all monkfish individuals should be aged. However, in certain cases there can be missing ages, e.g. if the ageing fails or the individuals are tagged. Table 5.4 and Figure 5.20 provide an overview of the number of individuals with missing ages, which has been between 2–4% of the total number sampled each year. There is no consistent pattern of missing ages in any particular stratum or length-class. In these cases it is necessary to assign an age to these individuals using the age distribution-at-length. Given for each species the two sexes have different growth rates and that the two monkfish species have different growth rates, the uncertainty in estimated age might be reduced by considering the sex and species in addition to total length in the age prediction procedure.

Table 5.4. The number of unaged fish in the FRS monkfish surveys by year and survey region.

Year	Region	Number sampled	Number unaged	Percentage unaged	Number sampled	Number unaged	Percentage unaged
2005	East	263	1	0	1779	40	2
	North	592	18	3			
	Rockall	283	12	4			
	West	641	9	1			
2006	East	281	1	0	1418	46	3
	North	303	34	11			
	Rockall	384	0	0			
	West	450	11	2			
2007	East	237	9	4	1390	39	3
	North	397	15	4			
	Rockall	404	5	1			
	West	352	10	3			
2008	East	291	15	5	2219	88	4
	North	622	21	3			
	Rockall	823	20	2			
	West	483	32	7			

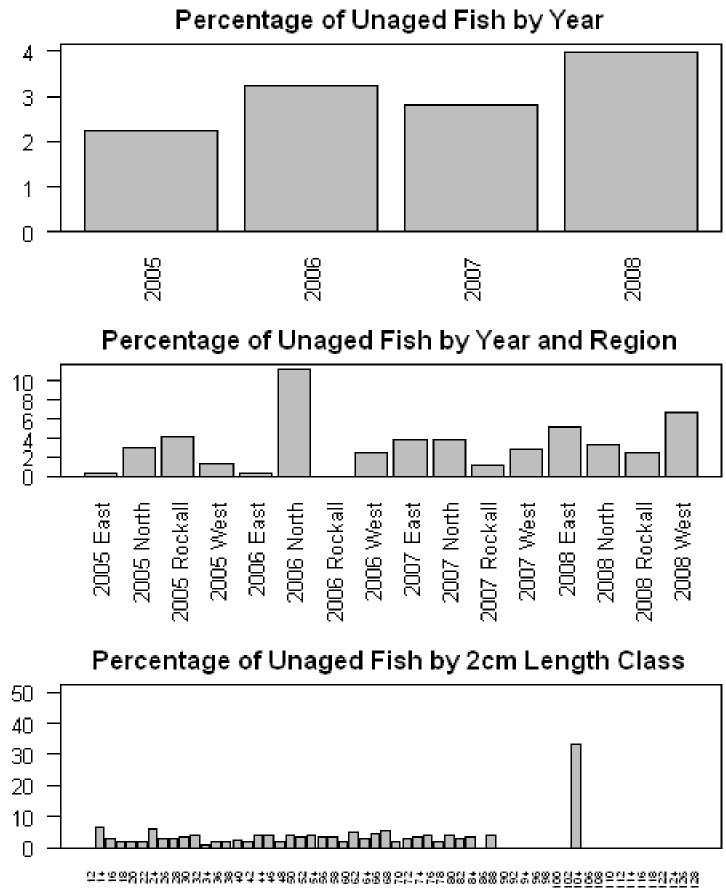

Figure 5.20. The percentage of unaged fish in by year, region and year, and 2 cm length class for years 2005–2008 combined.

5.3.7 Distribution assumption for confidence intervals

Variance estimates for abundance and biomass estimates are obtained using the Delta method. Approximate confidence intervals are then obtained assuming normality. The validity of this assumption should be investigated.

5.3.8 Joint treatment of species

Currently both monkfish species *L. budegassa* and *L. piscatorius* are combined before estimating abundance or biomass. Though, *L. piscatorius* is dominant in most areas, the ratio between the two species can vary. Given the two species can exhibit distinct population dynamics, as the example for Bay of Biscay and Celtic Sea demonstrates (Figure 5.21), it seems advisable to treat the two species separately and only combine the estimates when considering setting quotas. The added advantage of treating species separately is that cohort tracking becomes possible.

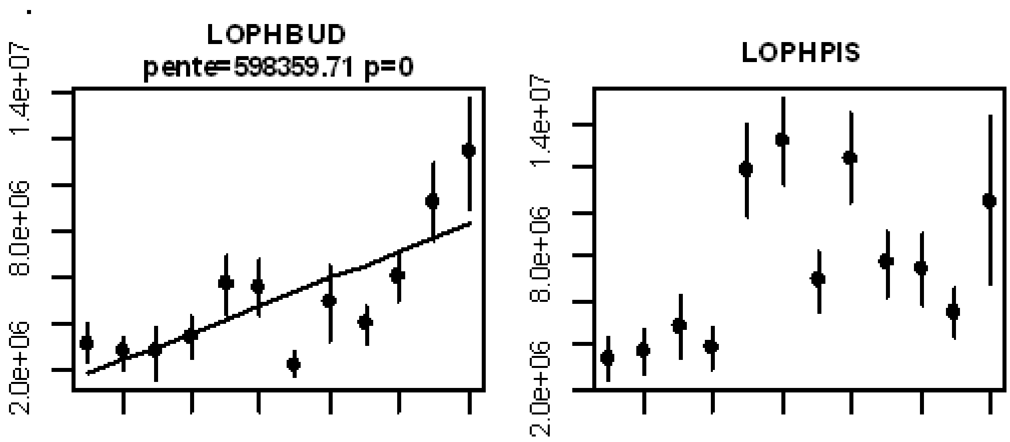

Figure 5.21. Abundance estimates for *Lophius budegassa* (LOPHBUD) and *Lophius piscatorius* (LOPHPIS) in the Bay of Biscay and Celtic Sea derived from Western IBTS survey data (GOV trawl). The two monkfish species show different time-trends indicating separate population dynamics.

5.3.9 Summary of recommendations for reducing uncertainty and bias in abundance/biomass estimates

Issue	Assessment	Recommendation
Survey design	About three strata have too little hauls leading to high CVs	Consider merging or post-stratifying strata to consistently treat point and uncertainty estimates
Swept area variability	Swept area variability does not seem to impact density estimates	none
Gear efficiency	Available gear efficiency estimates for monkfish do not allow to appreciate inter-haul or inter-habitat variability	Further work necessary to characterize inter-haul variability and variability between habitat types
Herding variability	Herding variability is non-symmetrical, hence mean herding rates are not that informative; overall herding rates seem low	Could try setting h=1, i.e. not account for herding as it seems low
Missing age data	There are not many missing age data but ignoring sex and species might increase uncertainty in numbers-at-age	Include sex and species in age prediction
Distribution assumption for confidence intervals	No justification was found for normality assumption other than theoretical reasons, but sample size are small so that central limit theorem might not be sufficient	Explore suitability of assumption
Joint treatment of species	Both *Lophius* and *Lepidorhombus* species are treated together making cohort analysis doubtful.	Provide separate abundance and biomass estimates per species

6 Management strategy evaluations

6.1 Introduction

The following is taken from the first Report from the Study Group on Management Strategies in 2005 (SGMAS 2005) to describe the process of management strategy evaluation. ICES is increasingly being asked to evaluate harvest control rules or management plans as a step to move from away from short-term crisis management towards long-term management. A harvest control rule is a component in a wider management strategy which includes:

- A decision (explicit or implicit) on longer term management objectives and performance criteria;
- A decision on the relevant knowledge base for tactical management decisions;
- Tactical management decisions regarding the fisheries in the current or coming fishing season (including harvest control rules);
- A decision on implementation measures (mainly input or output control, etc.).

A management strategy thus includes what is called a knowledge system, a decision-making system and an implementation system (Figure 6.1). The fleet adaptation system and the underlying resource system represent the objects of management and are thus external to the management strategy itself. This external system should be incorporated in any management strategy evaluation in terms of achievements of objectives, robustness and risk relative to external factors.

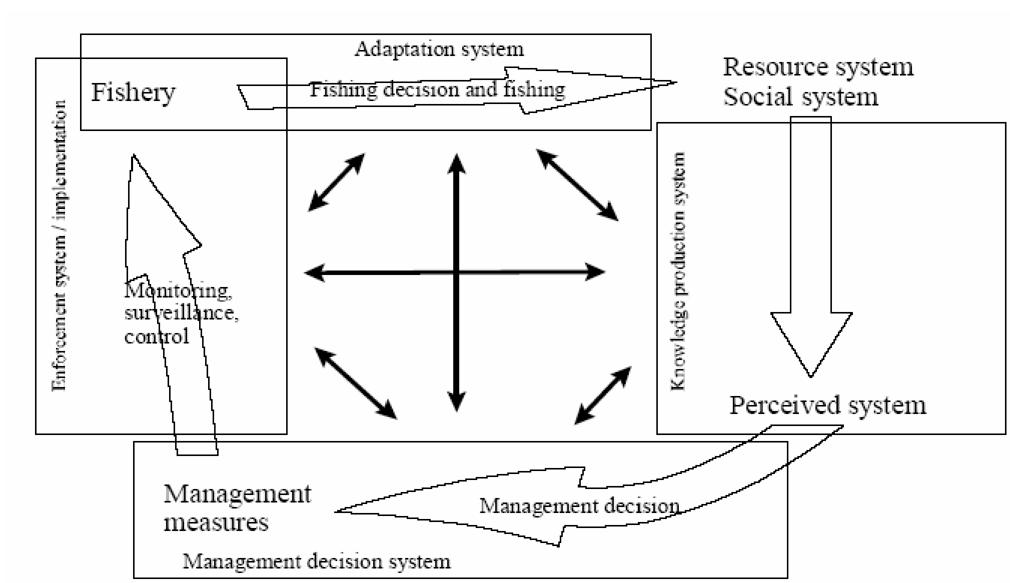

Figure 6.1. The fisheries system. The management strategy identifies the knowledge production system, the management decision system and the implementation system. The adaptation of the fleets and the natural changes in the resource system are external constraints. (ICES, 2001).

The development of fisheries management strategies is a long and complex process where many fisheries managers, politicians, stakeholders and scientists participate. Management strategies are often at a multinational level and relate to overarching international agreements (e.g. Rio declaration, FAO code of conduct, Johannesburg summit). If we take the EU Common fisheries Policy (CFP, ref) as an example of a management strategy, the development of that strategy took a number of years and involved an analysis of the previous strategy, a hearing process of stakeholder groups, the formulation of an initial proposal, a commenting process by stakeholder groups, a final proposal and the political agreement.

6.2 An MSE for northern shelf anglerfish

In terms of Northern Shelf anglerfish the MSE process is merely starting and the following describes this starting point. The MSE is, in this first instance at least, restricted to identifying some of the technical components associated with setting up simulation tools to conduct experiments that evaluate the response of the fishery system to a simple candidate management strategy. The latter might be a simple change in Total Allowable Catch (TAC) in proportion to the change in total biomass from the survey, or it may follow recent proposals from the European Commission for Managing Fish Stocks without Catch Option Tables (the so called "Category 6" stocks).

6.2.1 Parameterization of the operating model

The operating model implemented is a population dynamics model and more specifically an "age-structured production model" (McAllister *et al.*, 1994; Punt, *et al.*, 2002) that was developed in the Fishery Independent Survey Based Operational Assessment Tools (FISBOAT) project.

The biological operating model for NS anglerfish includes several components based on current stock data. The population is structured into 15 age groups (0 to 15+, 15+ being an age plus group) and is based on a single-stock and single area definition, following ICES WGNSDS guidelines. The natural mortality rate at-age (0.15) is based on previous ICES WGNSDS estimates and is constant over years. The fraction mature and weight-at-age is variable over time and is based on a random selection of the measurements made in any one of the survey years.

The biological operating model has to be seeded with a 'true' population. This requires at least one of the current survey estimates (at-age) to be converted to estimates of the population size (at-age) i.e. a stock assessment. This is described in Section 6.2.2 below. It also requires selectivity information on the catch-at-age in the fishery to run forward in time. This was estimated by adapting the selectivity ogive from the last assessment (ICES 2003) to conform to an estimate of the current fishing mortality. The latter was determined by subtracting the natural mortality from the total mortality as estimated in Section 6.22 below.

The next stage in parameterizing the operating model is to decide on how to simulate recruitment. Normally, recruitment is estimated from a number of stock–recruit model types (e.g. Beverton–Holt, a Ricker and a hockey stick or 'segmented regression') which are fitted individually to the stock–recruit data using a maximum likelihood estimation method. Akaike Information Criterion (AIC) are then calculated and the model which minimizes this AIC value is the best statistical fit to the data and is used. For anglerfish data there are only 3 data points for in the stock recruit plot (Figure 6.3) which is clearly not sufficient to fit a model. Instead the following conservative procedure was adopted to fit a hockey stick style model to the available data. A geometric mean of recruitment was taken; this mean value was assumed to be the level of recruitment for all values of SSB beyond the minimum SSB level. For values of SSB less than the minimum observed a linear reduction in recruitment to the origin of the stock recruit plot was assumed. This resulted in a conservative hockey stick function (Figure 6.3).

The current TAC equates to a harvest rate H and this value of H and the selectivity ogive were used to set the initial exploitation regime.

6.2.2 Provisional stock assessment

A simulation to run a management strategy evaluation requires a starting population that is as close as possible to the true population size. This is normally provided from a stock assessment. For the purposes of this exercise the following procedure was used:

1) The survey was assumed to be fully representative of the absolute number and biomass of adult anglerfish beyond and including age 5. This in effect means that the selectivity of the index, q, at-ages 5–15 was equal to 1. This was based on inspection of the survey estimates of abundance-at-age (Figure 5.1) as well as an inspection of the abundance (catch) curves, which demonstrate the presence of 'hooks' at the younger ages that are typical to many catch and survey data. Abundances-at-ages 5–15+ were therefore assumed to be estimated directly from the survey. Estimates were therefore required for the abundances-at-age 0–4.

2) The mean total mortality ($\bar{Z}$) for the 1999–2002 year classes (ages 6–9 in 2008) was then estimated. These ages are closest to those ages that were being estimated. $\bar{Z}$ was estimated as the mean of the 4 gradients of the abundance (catch) curves for consistent (i.e. z>0) segments of the abundance (catch) curves. In the current 'assessment' these were as follows:

Year class	Age in 2008	Z (2005–2008)
1999	9	0.627
2000	8	0.625
2001	7	0.436
2002	6	0.632
	$\bar{Z}$	0.580

3) $\bar{Z}$ was then applied to the survey abundances-at-age 5 to back-calculate the appropriate numbers-at-age in the population-at-age matrix according to:

$$N_{t,a} = Index_{t_1,a+1}.e^{\bar{Z}.(t_1-t)}$$

The use of specific time t rather than a simple integer for year is important here because of the change in survey timing from November in 2005–2007, to April in 2008.

4) The selectivity, q, of the index for age 4, could then be estimated from comparison of the three index values and the three new abundance estimates at-age 4 from the procedure in (3) above:

$$q_{a=4} = \frac{1}{3}\sum_{t=2005}^{2007}\frac{index_{a=4}}{N_{a=4}}$$

5) The estimate of abundance-at-age 4 in the terminal year (2008) was then determined by dividing the index value by $q_{a=4}$ determined above.

6) The procedure (3–5 above) was then repeated in an iterative fashion to estimate abundances-at-ages 3, 2, 1 and 0 and the respective q at-age.

The results of this procedure can be seen compared with the survey estimates in Figure 6.2. Clearly there are alternative ways to conduct such an assessment of the population and these will be explored in due course. One possibility, for example, is the use of a separable stock assessment model similar to that proposed by Cook, 1997.

6.2.3 Observation model (description of surveys)

The aim of the observation [error] model is to describe how observations are sampled from the operating model and it simulates the data utilized in the harvest control rule. The observation error model simulates an anglerfish survey between 2009 and 2030. It is based on simulating an age disaggregated relative abundance index according to:

$$Index_{a,y} = q_a N_{a,y} + \varepsilon_a$$

The error term (ε_a) is based on the CV's of the survey.

6.2.4 Harvest control rule

A relatively simple harvest control rule has been incorporated here, which is based directly on the survey data and is relatively simple to understand and to simulate:

$$TAC_{y+1} = TAC_y \left(\frac{Index_y}{Index_{y-1}} \right)$$

The observation index is the output of the observation error model and the value of the TAC in the next year will depend on the TAC of the current year and the ratio of the observation index of the current year and the observation index of the previous year. If the ratio is larger than one this means there is an increase in the observation index which can be interpreted as an increase in the SSB of the stock so catches can be raised proportionally.

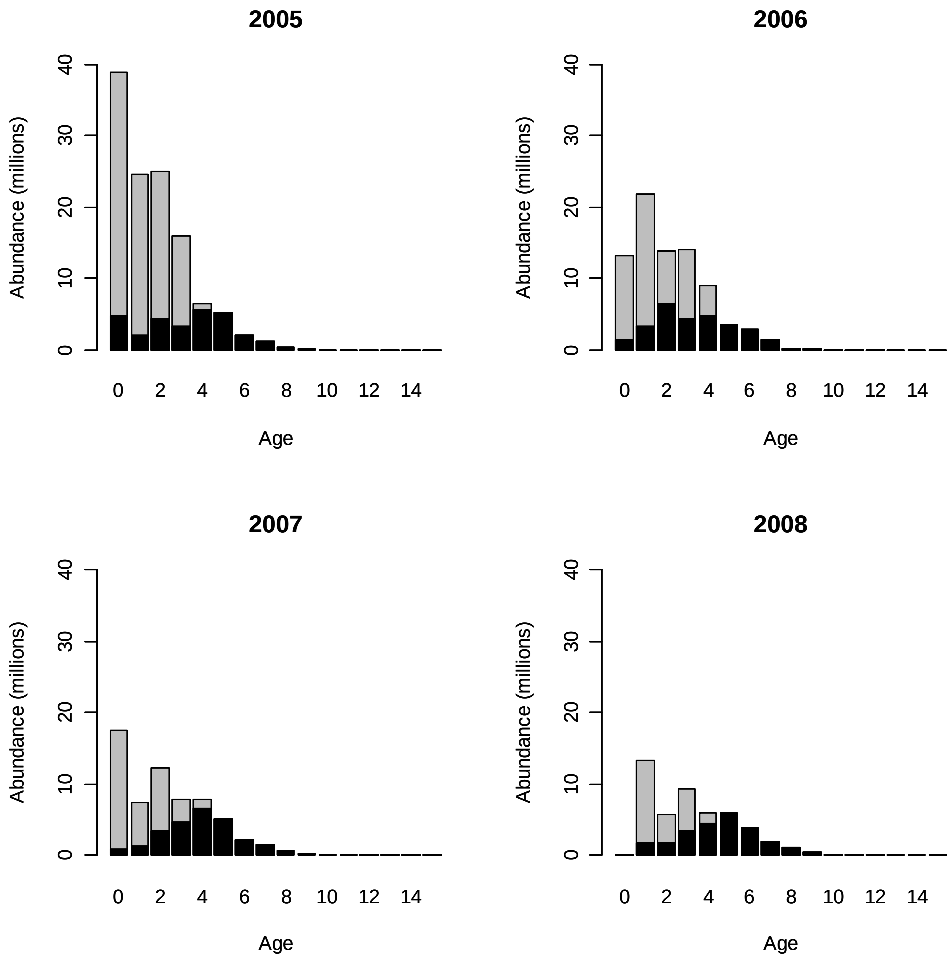

Figure 6.2. Estimated numbers-at-age for monkfish from the surveys (in black) and assessment routine described in Section 6.2.2 (in grey).

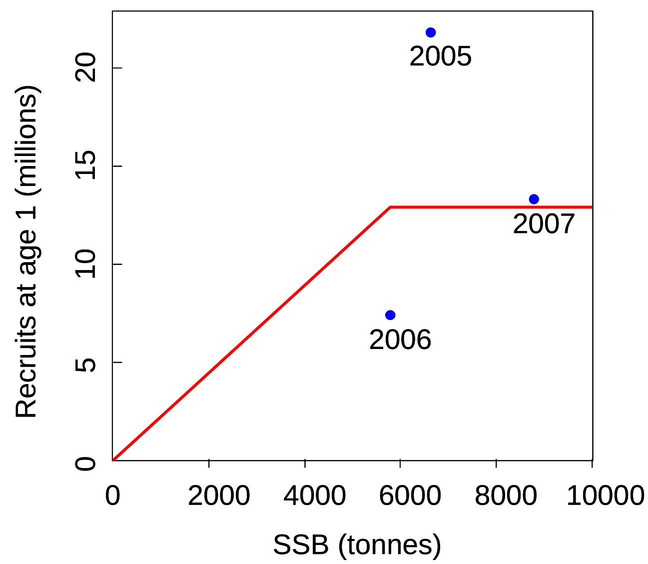

Figure 6.3. Stock–recruit data (Spawning–stock biomass in tonnes against recruitment-at-age 1 in millions) from the anglerfish surveys. Red line is the conservative hockey stick style recruit model that was sued in the simulation.

6.2.5 Initial MSE results

Although these should be considered as preliminary, some results of the simulation are shown in Figure 6.4 based on 100 iterations of the simulation going out to the year 2030. One of the key components is the starting point for the TAC: in 2009, the TAC was set at 18 000 t. This maintains the fishing mortality at levels that are higher than that would derive a long-term yield. However, initial investigations at TACs equivalent to F closer to $F_{0.1}$ in a yield-per-recruit, although rendering a higher long-term yield, do not yield as much in total over the 21 year period. Further investigation is therefore still required to determine an optimum start point for the TAC. The TAC eventually stabilizes at around 21 500 t, with a total stock level at around 75 000 t.

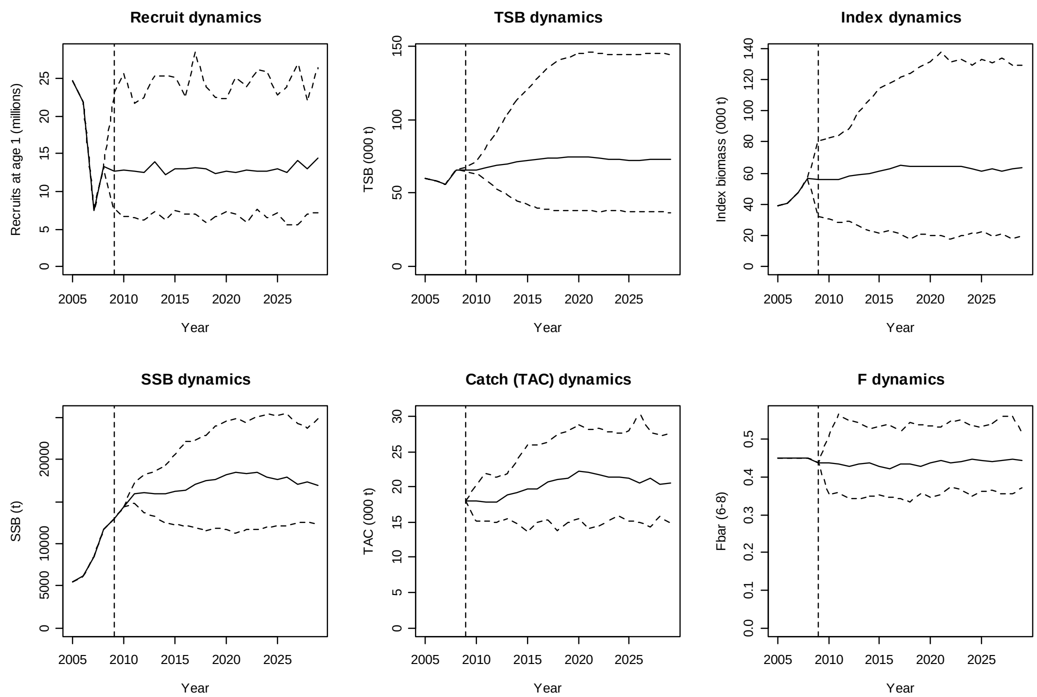

Figure 6.4. Results from a simulation of the Northern Shelf anglerfish population based on a simple harvest control rule (TAC change is directly proportional to change in survey index) from 2009 to 2030. Solid line are median values from the 100 iterations of the simulation, dotted lines represent where 95% of the remaining iterations lie.

7 Self sampling

7.1 Anglerfish tallybook scheme

In addition to the industry-science dedicated anglerfish survey a further component of the FRS scientific programme of work on anglerfish has been the implementation of a voluntary tallybook scheme. This was initiated in response to recommendations made by ICES and the European Commision (EC) STECF that programmes should be set up to collect catch-and-effort data on both target and bycatch species. Analysis of private diary data provided by fishers in late 2004 and 2005 had provided valuable information to ICES (ICES, 2005) on temporal and spatial trends in catch rate and the tallybook project was set up to formalize this data collection process.

Following consultation with the Scottish fishing industry in 2005 the scheme began in January 2006 with a limited number of returns from December 2005. At the outset, it was emphasized that such a scheme would be a long-term approach and realistically several years' data would be required before being useful as an index for monitoring changes in stock abundance.

The scheme is being run in collaboration with NAFC Marine Centre and the Scottish Fishermen's Federation (and initially also Fishermen's Association Ltd and Pêcheurs de Manche et Atlantique) who are responsible for distributing the tallybooks provided by FRS, coordinating the returns and allocating vessel codes before the anonymous tallybook sheets or data are forwarded to FRS. The tallybooks are completed on a haul-by-haul basis. Skippers record catches of anglerfish (by size category) and other species where possible, together with information on haul location, duration and depth. These data are stored in a relational database at FRS.

Tallybook returns have been received from in all 37 fishing vessels with a wide spatial coverage (see Figure 7.1) across the Northern Shelf area (over 18 000 hauls), although participation levels have varied considerably over the 3 years that the project has so far been running. Initial participation was high, but fell to around 12 regular participants in 2007 and again to only four vessels in 2008. Dobby *et al*., 2008 present an analysis of the tallybook catch rate data from the 12 vessels which participated in the scheme during 2006 and 2007. These vessels are typical of the larger sample in that there are some with low catch rates of anglerfish (apparently targeting *Nephrops)* and some for whom anglerfish is a much more important component of their catch. The total landings recorded in the tallybooks of these 12 vessels are approximately 30% of the total official landings in 2006 and 20% in 2007, although this coverage varies from area to area.

A generalized additive modelling (GAM) approach is used to model catch-rate in $kghr^{-1}$ incorporating seasonal, annual, spatial, and vessel dependent effects. (The term 'catch-rate' is not strictly true. Many of the vessels do not record discards, but from the limited data available and anecdotal reports, anglerfish discards are likely to represent only a very small percentage of the catch of Scottish vessels). The annual effects from the model are quite uncertain, but do indicate a significant increase (~15%) in catch rates between 2006 and 2007. Estimated seasonal patterns demonstrate declines in catch rate during summer although there is some variation in the timing of this decrease (and subsequent autumnal increase) between ICES Divisions. In terms of spatial effect, highest standardized catch-rates in this analysis are to be found in the statistical rectangles to the eastern and southeastern side of Rockall and west of Shetland and the Outer Hebrides. (Further details of the analysis can be found in Dobby *et al*., 2008).

The Scottish tallybook scheme provides relatively extensive information on the spatial and depth distribution of catch rates in the Scottish anglerfish fishery which is unavailable from other sources. A time-series of such data could provide an indicator useful for stock monitoring. However, at present there are problems in the scheme in terms of falling participation levels and the current level of participation (four vessels) is unlikely to give a representative picture of the fishery.

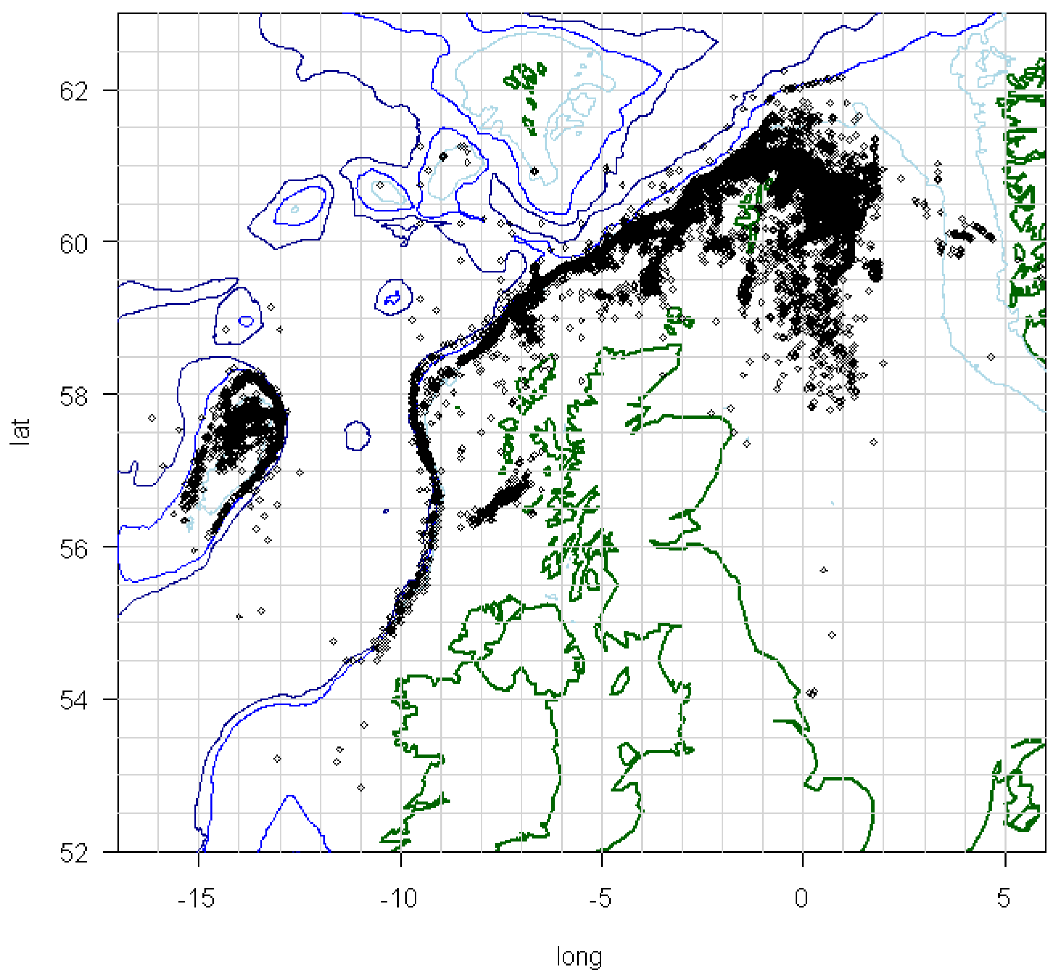

Figure 7.1. Spatial distribution of hauls recorded in the monkfish tallybook database.

7.2 Megrim tallybook pilot project

As part of a Scottish Industry Science Partnership (SISP) funded project titled 'Collection of fisheries and biological data on megrim in ICES Subarea IVa', NAFC Marine Centre initiated a 6-month pilot tallybook scheme (Laurenson and MacDonald, 2008). The scheme involved 9 vessels (seine, single and twin trawlers) operating out of Shetland and also from mainland Scotland fishing in ICES Division IVa and VIa. Initial analysis has focused on understanding the reasons for discarding (bruised, under marketable size, etc.) and quantifying discard rates. Analysis on the spatial distribution of catch-rates has revealed that megrim catch-rates are very patchy and can be extremely high in localized areas. The experience, in terms of fisher participation, has been much the same as that in the anglerfish scheme with diminishing enthusiasm demonstrated by skippers as the scheme progressed.

Utility of tallybooks

Following the presentations on the FRS' tallybook scheme and the Norwegian reference fleet, the utility of data from self sampling programmes and possible inclusion in future stock assessments was discussed.

The current FRS' tallybook scheme has provided temporal and spatial commercial catch per unit of effort (cpue) data which could be used as an index of abundance. The scheme provides a rich dataset, covering a broad area with continuous, high-resolution sampling. It is therefore considered that with appropriate standardization to account for factors influencing catchability, these data could provide useful information on relative stock abundance.

The scheme provides fine scale information on the spatial (and depth) distribution of fishing activity and could therefore prove useful for monitoring changes in the fishing activity and behaviour of the fishing fleet. In addition, the description of gear which is entered in each tallybook may provide insight into technological creep and fishing efficiency over time.

Although the survey and tallybook data have similar spatial coverage, the tallybook data represents much higher intensity sampling across the high density areas in particular. Survey design may be improved by referring to the tallybook data.

The tallybook data revealed clear seasonal and spatial patterns in the cpue for different areas around Scotland and this could be compared with previous studies on anglerfish movements and migrations. If additional information on size composition and catches of spawning females and the level of discards was available, this could provide further insight into the spawning behaviour of anglerfish.

Problems

The largest problem facing the current tallybook scheme is the diminishing levels of participation. It was made clear to the industry at the outset of this study that the aim was to implement a long-term approach to improving the quality of the scientific data available on anglerfish. The scheme has been running for three years and participation levels have dropped from the original 37 vessels in 2006 to only four at the end of 2008. Maintaining motivation has been difficult because the fishers apparently expected more immediate returns for their work, although the increased paperwork associated with current EU regulations may also have contributed to their reduced willingness to additionally complete a voluntary tallybook. It is clear that the objectives of such data-collection schemes need to be fully discussed with and understood by potential participants at the outset. Improving the quality of data and consequently the assessment is clearly not a great enough incentive for most fishers to continue participating in the scheme. Constant communication and feedback between parties is vital to the long-term success of the project.

Voluntary logbook schemes appear to be only very rarely successful at providing long-term data with wide participation. Those that do succeed appear to be operated by the fishing industry rather than scientists. The French fishing industry collect catch composition data on a haul by haul basis from their deep-water fleet (together with haul duration, location and depth) which, for a number of species is used to provide an indicator of abundance. Data on catch rates of anglerfish by French deep-water vessels in Division VIa are therefore available and would be a useful supplement to the data collected within the Scottish tallybook scheme.

If the tallybook scheme is to continue, FRS should investigate the potential for increasing the participation levels. The dataset could also be enhanced by including data from the French deep-water vessels.

The issue of data accuracy was also discussed at the Workshop. Because the tallybooks are anonymous there is little incentive for fishers' to deliberately record inaccurate information, however this also means there is no straightforward means of cross-checking the data. Some data validation was carried out by FRS observers when the scheme was initially launched, but it was felt that further validation of this type could be usefully carried out from more recent observer trips. Data are scrutinized thoroughly before analysis and checked for internal consistency, with records that include hauls of atypical duration or too many hauls per day, for example, excluded at the outset. Additional checks on the spatial distribution of fishing activity could be made by considering VMS data.

7.3 Norwegian self-sampling from coastal gillnetting

Since autumn of 2005, a programme for collecting data on catch composition, length distributions and effort have been established through "the Coastal reference fleet" (CRF), a self-sampling programme. This is a network of contracted 9–15 m long vessels that are trained and paid to provide samples from their own fishery. The anglerfish stock north of N 62° (ICES Division IIa) has never been assessed quantitatively. It is not covered by any groundfish survey and no mandatory logbook schemes for the coastal fishing vessels exist. A brief overview of the development of the fishery and the self-sampling programme is given below and some results so far are presented.

Prior to 1990 small amounts of anglerfish were caught as bycatch in different fisheries in Division IIa and annual landings were well below 500 tons. During the early 1990s a directed gillnet fishery developed, and this was typically carried out by one-man vessels fishing close to their homeports using large meshed gillnets. The first regulations of this fishery were introduced in 1993, and have been further developed on several occasions thereafter. The main components of these regulations are: Since 1995, a minimum mesh size of 360 mm and maximum soaking time of 2 days, since 2003 a minimum landing size, maximum number (500) of gillnets per vessel and a moratorium during March, April and May. January and February were added to the moratorium for areas north of N 67° in 2007. It is an open access fishery with neither vessel nor total quotas.

The recent developments in the fishery have led to an increased demand for science-based advice to the managers, but information about anglerfish in Norwegian waters has been scarce. The coastal waters within Division IIa are covered by different groundfish surveys, but they are primarily focused on coastal cod, saithe and redfish, and anglerfish are not caught frequently. None of these surveys have proven to be of any value in previous attempts to assess the state of the anglerfish stock. There is, furthermore, a lack of data from the fisheries. No vessels below 21 m loa have to submit their logbooks to the Directorate of Fisheries, and, as the majority of vessels targeting anglerfish are smaller than 21 m, no data on effort is available for this fishery. Some limited information about the fishery is found in the national register of sales slips.

A realization of the need for improved data from the coastal fleet led to the establishment of a cooperation with selected vessels along the Norwegian coast in 2005. A fleet of cooperating offshore vessels, the "reference-fleet" was already established, providing detailed logbooks and sampling their own catch for species composition, length- and age distribution and the same approach was followed for the coastal vessels. Vessels in the size range 9–15 m, fishing with gillnets close to their home-ports most of the year was asked to participate in the project, and two vessels within each statistical area were selected among those displaying their interest. The crew of these are trained and paid to provide detailed logbooks and samples from their own fishing activities according to contracts. Some of the vessels in this coastal reference fleet (CRF) targets anglerfish in parts of the year and an exploration of the data they have submitted so far and an evaluation of the usefulness in indicating trends in the anglerfish stock north of N 62° are presented. The vessels operated under yearly contracts since the initiation, but new contracts for a period of four years were signed in late 2008 and results presented here will give guidelines for establishing time-series of data that can be used in future assessments of anglerfish.

Two main sources of information are used in the analysis: the national register of sales slips and the data collected by the CRF. The sales slips are filled in and registered for each sale providing, among other, vessel registration number, number of fishers, fishing area, quantum, quality, processing level and price for each species delivered. The database was coupled with the national registry of vessels to get overall length of vessel, etc. From the CRF detailed information of the fishing operation is given: i.e. fishing area and location, number of nets, mesh size, soaking time, fishing depth and catch. In addition, a sampling scheme giving a random sample of the length distribution of up to 60 fish for one day of fishing within each week is followed. The fishers sample the data under contract with the Institute of Marine Research (IMR), and are chosen based on the geographical distribution required (two vessels per statistical area), the type of main fishery and size of vessel.

The development of the fishery for anglerfish in ICES Division IIa is shown in Figure 7.2.1. High catch rates and price level during the first years caught the attention of larger gillnetters and many of these entered the fishery in 1993. This led to a sevenfold increase in the total catch just north of N 62°, but also a collapse in the market and most of the large vessels withdrew from the fishery the following year. The increased landings from Division IIa in late 1990s came from smaller, coastal gillnetters in the southern parts of IIa, and after 2000 the fishery expanded northwards resulting in annual landings of about 4000 tonnes for the last three years.

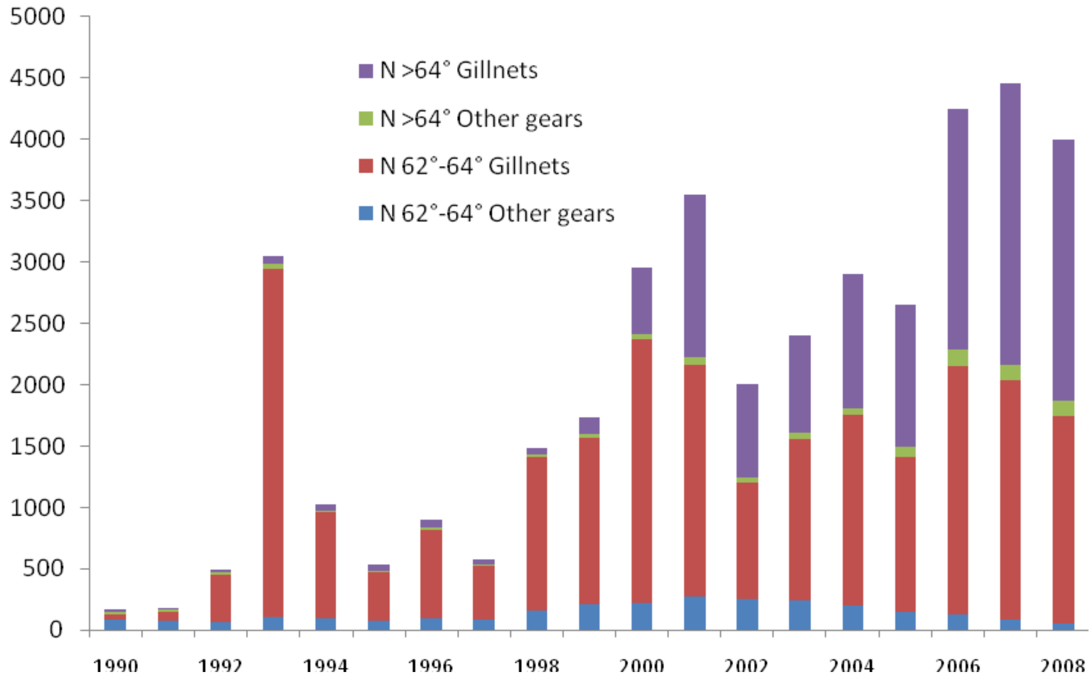

Figure 7.2.1. Norwegian landings of anglerfish (tonnes) caught by gillnets and other gears south and north of N 64° in ICES Division IIa during 1990–2008.

The geographical distribution of landings for 2004 (the year prior to the establishment of the CRF) was taken from the registry of sale-slips and plotted in Figure 7.2.2. Data on location of catches are in most cases rather poor in quality, but gives a relatively good indication of the spatial patterns in coastal fisheries like this. Figure 7.2.2 also gives the spatial distribution of the CRF-vessels providing data on their fishery for anglerfish and the period they have provided data for. Division IIa is split into four Norwegian statistical fishing areas, and two of these (area 07 and 00) are covered by two vessels in each for the whole period. For area 06, between N 64° and N 67°, there are only data available from one vessel for one year.

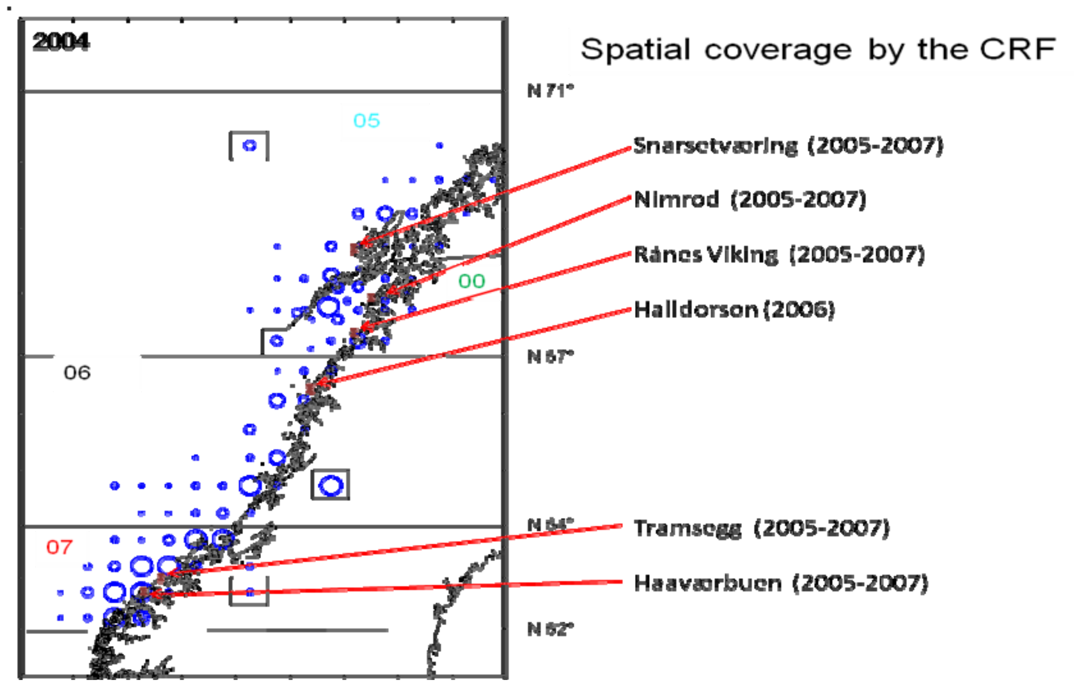

Figure 7.2.2. Geographical distribution of Norwegian anglerfish landings in 2004 within statistical fishing areas 07, 06, 05 and 00, taken from the national registry of sale-slips. Symbols in squares indicate landings not allocated to locations within the statistical areas. Homeports and sampling period for six CRF-vessels providing data on anglerfish are also indicated.

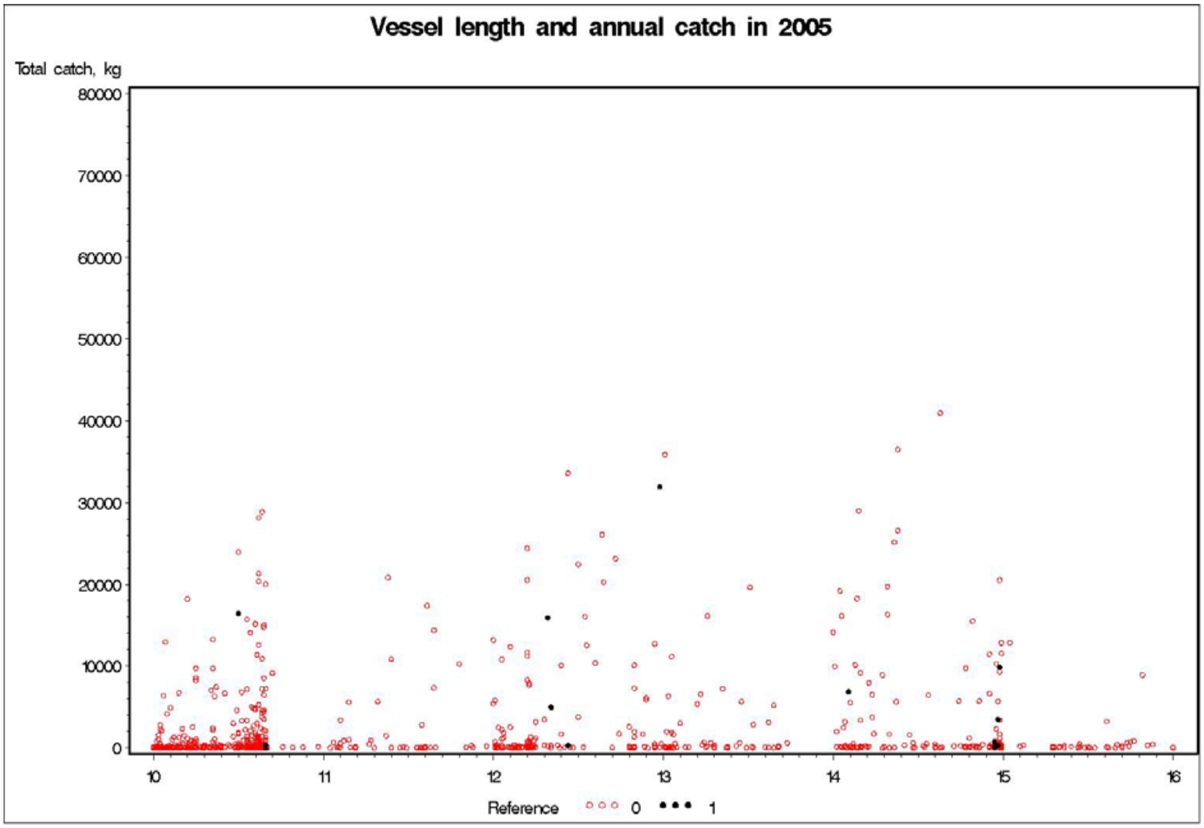

Figure 7.2.3a. Distribution of total catch of anglerfish to total length of vessel in the coastal fleet landing anglerfish north of 62° N in 2005. CRF-vessels are marked with black.

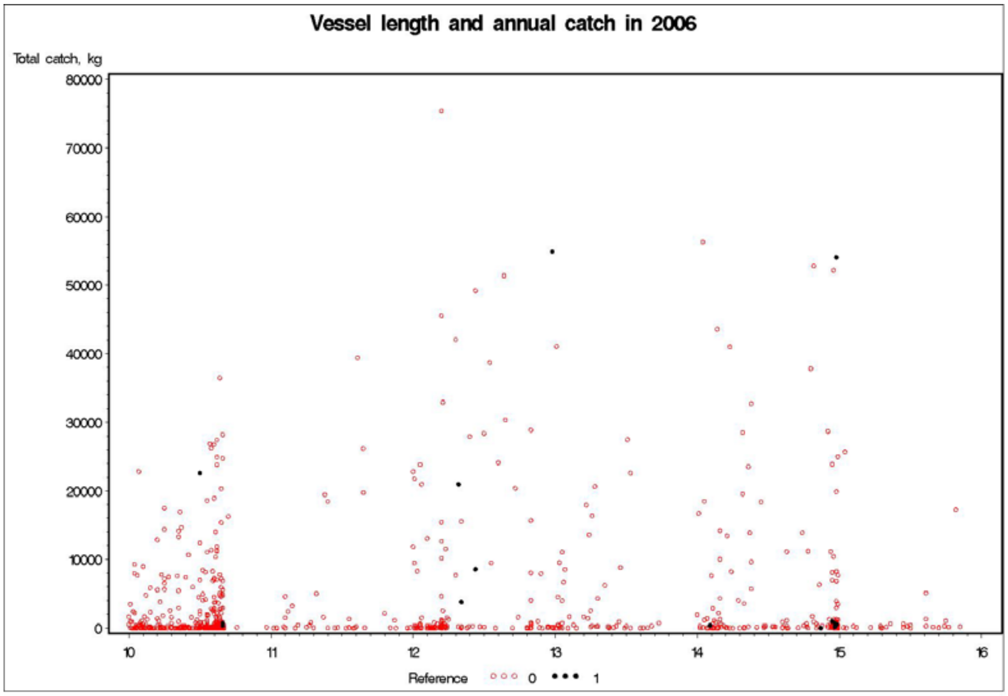

Figure 7.2.3b. Distribution of total catch of anglerfish to total length of vessel in the coastal fleet landing anglerfish north of 62° N in 2006. CRF-vessels are marked with black.

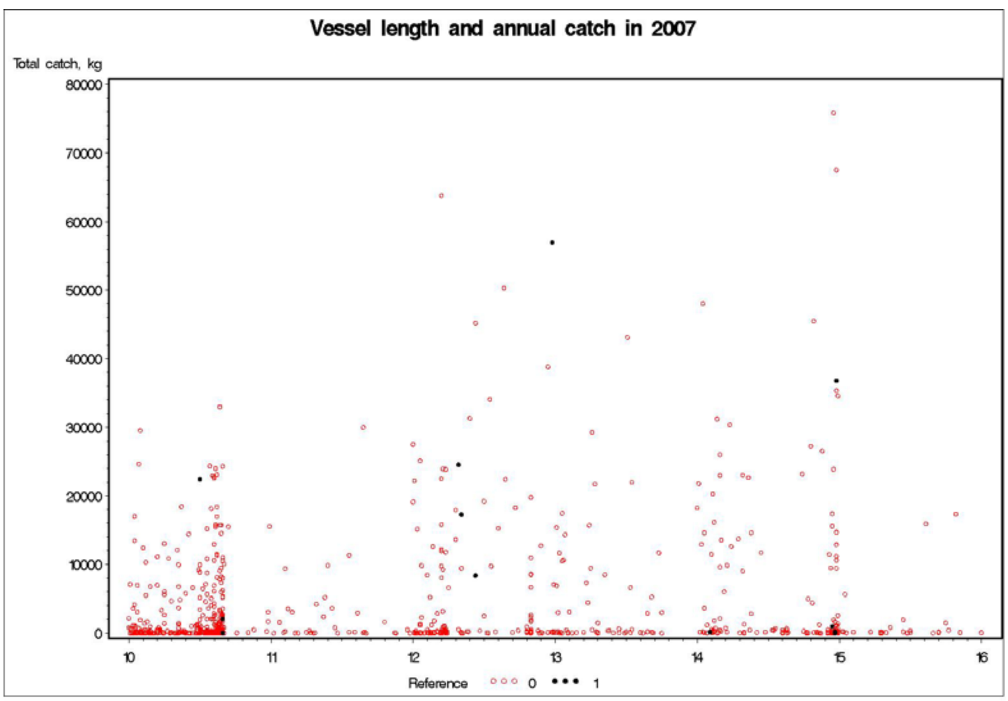

Figure 7.2.3c. Distribution of total catch of anglerfish to total length of vessel in the coastal fleet landing anglerfish north of 62° N in 2007. CRF-vessels are marked with black.

The registry of sale-slips also gives us the length distribution of all coastal vessels landing anglerfish and the annual landings of each vessel for each year (Figure 7.2.3a-c). The CRF vessels are larger and have higher annual landings than the other vessels (Wilcoxon Scores, $p<0.05$). The total number of vessels landing more than 20 tonnes of anglerfish was doubled from 2005 to 2006 and 2007, probably explaining much of the increase in total Norwegian landings in the same period.

The end of the moratorium, in late May, starts the fishing period which peaks in intensity during late summer/early autumn in the southernmost areas, whereas fishing starts and peaks later further north (Figure 7.2.4).

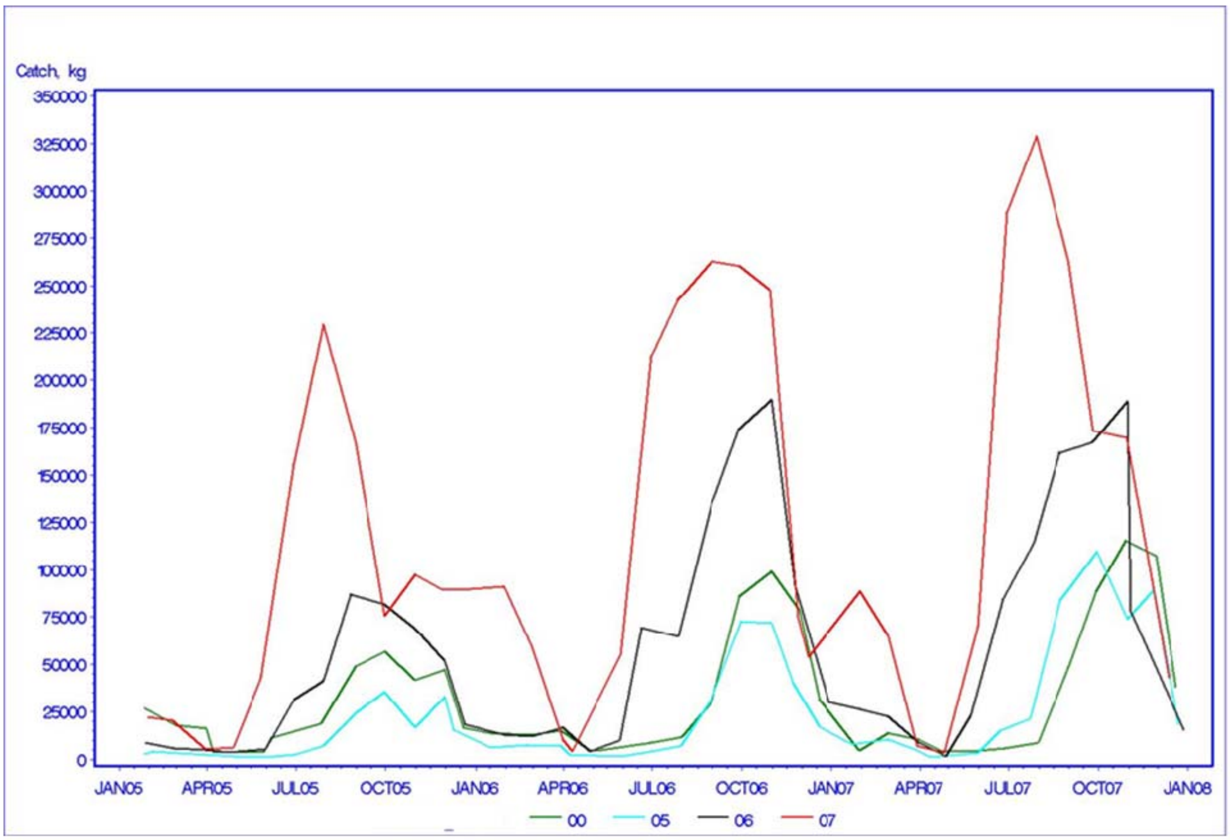

Figure 7.2.4 Monthly Norwegian landings of anglerfish within the fishing areas of Division IIa shown in Figure 7.2.2 during 2005–2007.

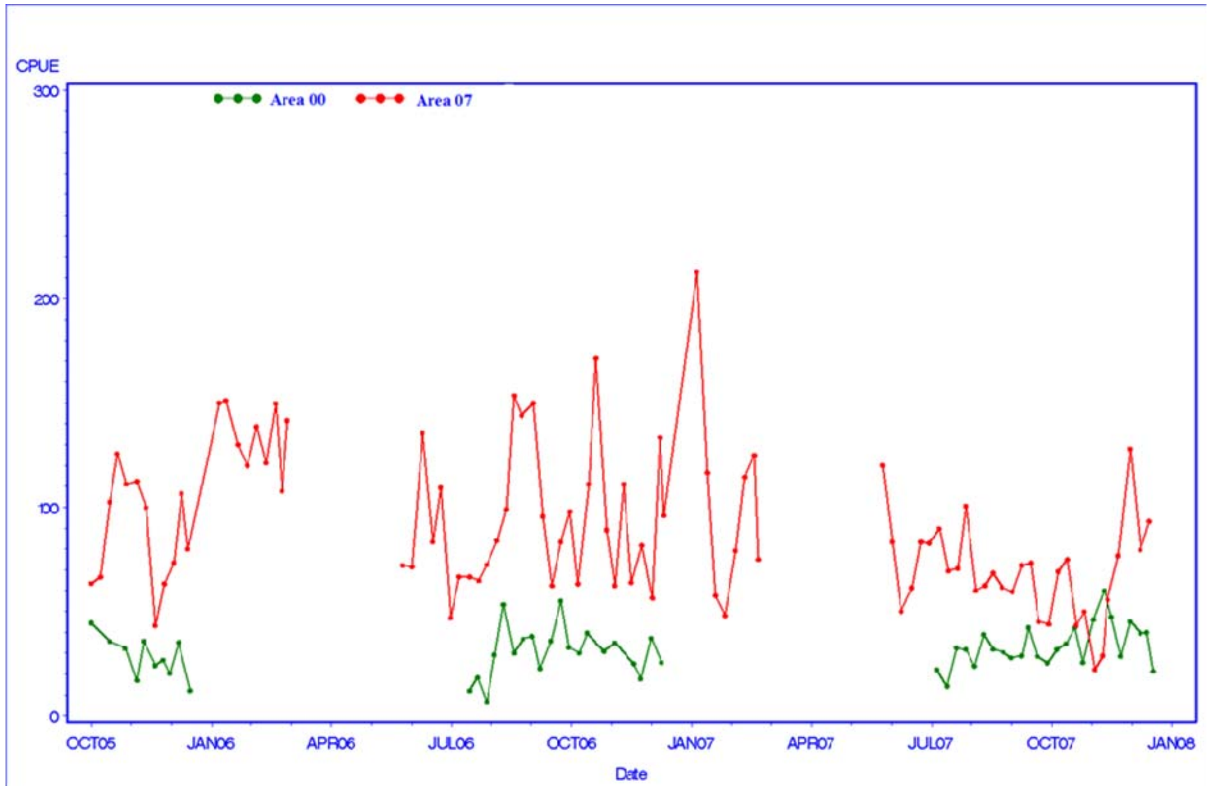

Figure 7.2.5. Median weekly cpues (kg per 100 nets/24 hours) for anglerfish in fishing areas 00 and 07 of Division IIa, data provided by two CRF-vessels in each area.

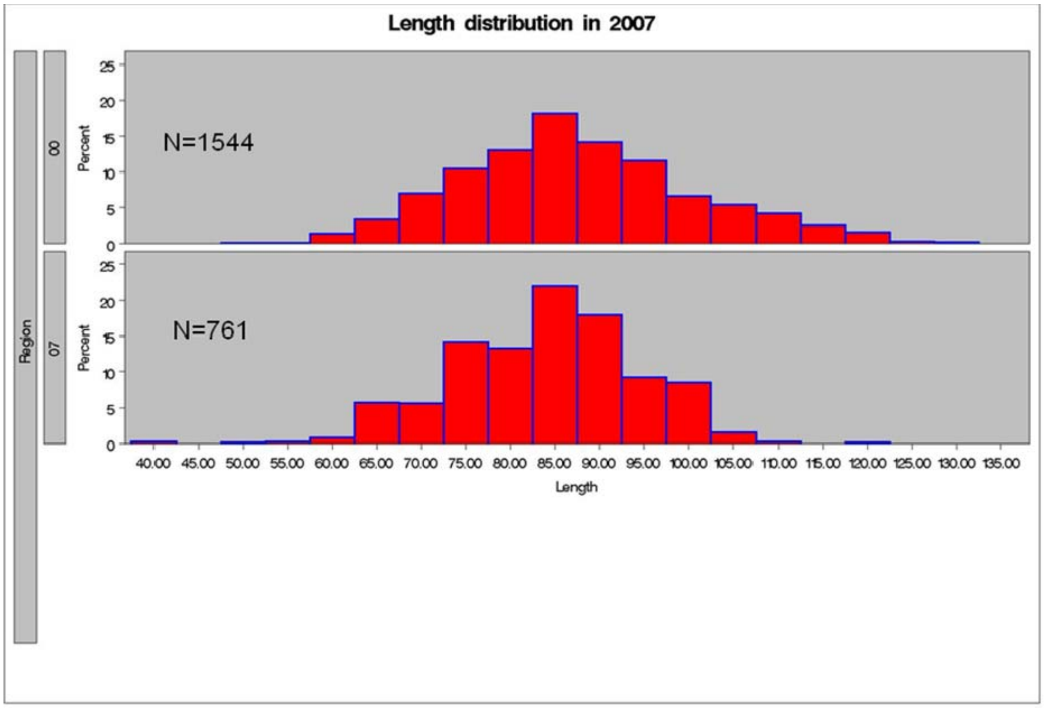

Figure 7.2.6. Length distribution of anglerfish in areas 00 and 07 within Division IIa for 2007. Data collected through self-sampling by two CRF-vessels in each area.

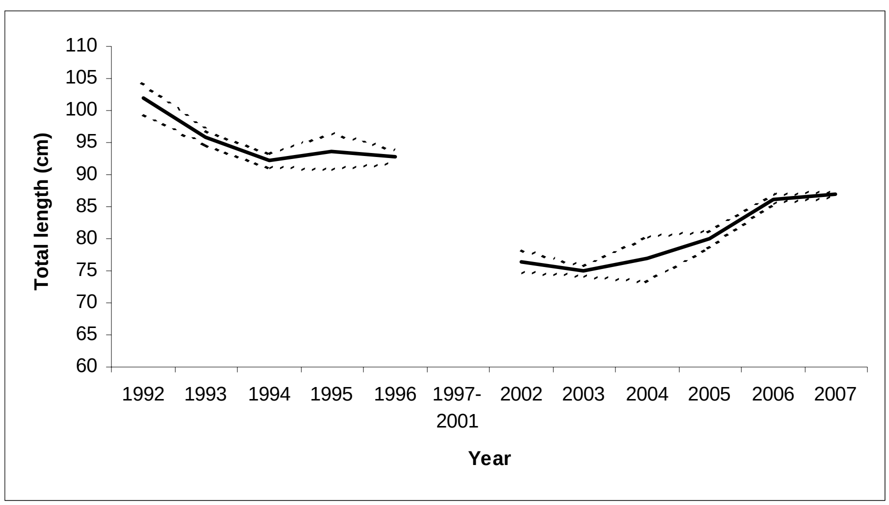

Figure 7.2.7. Mean length of anglerfish caught by coastal gillnetting in Division IIa during 1992–1996 and 2002–2007. Prior to 2006 mostly port sampling, 2006 and 2007 is mostly CRF self-sampling.

7.4 Utility of tallybooks

Following the presentations on the FRS' tallybook scheme and the Norwegian reference fleet, the utility of data from self sampling programmes and possible inclusion in future stock assessments was discussed.

The current FRS' tallybook scheme has provided temporal and spatial commercial catch per unit of effort (cpue) data which could be used as an index of abundance. The scheme provides a rich dataset, covering a broad area with continuous, high-resolution sampling. It is therefore considered that with appropriate standardization to account for factors influencing catchability, these data could provide useful information on relative stock abundance.

The scheme provides fine scale information on the spatial (and depth) distribution of fishing activity and could therefore prove useful for monitoring changes in the fishing activity and behaviour of the fishing fleet. In addition, the description of gear which is entered in each tallybook may provide insight into technological creep and fishing efficiency over time.

Although the survey and tallybook data have similar spatial coverage, the tallybook data represents much higher intensity sampling across the high density areas in particular. Survey design may be improved by referring to the tallybook data.

The tallybook data revealed clear seasonal and spatial patterns in the cpue for different areas around Scotland and this could be compared with previous studies on anglerfish movements and migrations. If additional information on size composition and catches of spawning females and the level of discards was available, this could provide further insight into the spawning behaviour of anglerfish.

Problems

The largest problem facing the current tallybook scheme is the diminishing levels of participation. It was made clear to the industry at the outset of this Study that the aim was to implement a long-term approach to improving the quality of the scientific data available on anglerfish. The scheme has been running for three years and participation levels have dropped from the original 37 vessels in 2006 to only four at the end of 2008. Maintaining motivation has been difficult because the fishers apparently expected more immediate returns for their work, although the increased paperwork associated with current EU regulations may also have contributed to their reduced willingness to additionally complete a voluntary tallybook. It is clear that the objectives of such data collection schemes need to be fully discussed with and understood by potential participants at the outset. Improving the quality of data and consequently the assessment is clearly not a great enough incentive for most fishers to continue participating in the scheme. Constant communication and feedback between parties is vital to the long-term success of the project.

Voluntary logbook schemes appear to be only very rarely successful at providing long-term data with wide participation. Those that do succeed appear to be operated by the fishing industry rather than scientists. The French fishing industry collect catch composition data on a haul by haul basis from their deep-water fleet (together with haul duration, location and depth) which, for a number of species is used to provide an indicator of abundance. Data on catch rates of anglerfish by French deep-water vessels in Division VIa are therefore available and would be a useful supplement to the data collected within the Scottish tallybook scheme.

If the tallybook scheme is to continue, FRS should investigate the potential for increasing the participation levels. The dataset could also be enhanced by including data from the French deep-water vessels.

The issue of data accuracy was also discussed at the Workshop. Because the tallybooks are anonymous there is little incentive for fishers to deliberately record inaccurate information, however this also means there is no straightforward means of cross-checking the data. Some data validation was carried out by FRS observers when the scheme was initially launched, but it was felt that further validation of this type could be usefully carried out from more recent observer trips. Data are scrutinized thoroughly before analysis and checked for internal consistency, with records that include hauls of atypical duration or too many hauls per day, for example, excluded at the outset. Additional checks on the spatial distribution of fishing activity could be made by considering VMS data.

References

Dobby, H., Allan, L., Harding, M., Laurenson, C. H. and McLay, H. A. 2008. Improving the quality of information on Scottish anglerfish fisheries: making use of fishers' data. ICES J. Mar. Sci., 65: 1334–1345.

ICES. 2005. Report of the Working Group on the Assessment of Northern Shelf Demersal Stocks (WGNSDS), 10–19 May 2005, Murmansk, Russia. ICES Document CM 2006/ACFM:13. 757pp.

Laurenson, C. H. and P. MacDonald. 2008. Collection of fisheries and biological data on megrim in ICES Subarea IVa. Scottish Industry Science Partnership (SISP) Project 003/08.

8 Catch and effort data

In general terms, there appears to be variability of the precision of both landings and effort data for both anglerfish and megrim depending on area. ICES (2002–2008) has consistently raised concerns about the precision of both landings data of both megrim and anglerfish and effort data associated with the otter trawl fleets exploiting the fishery. ICES (2006) note that there may be substantial underreporting of landings from VIa as a consequence of a restrictive TAC and these landings have historically been allocated to the adjacent area in the North Sea (IVa). From the most recent ICES Working Group report (ICES, 2008) the following observations are made:

Catches of megrim from Subarea VI comprise two species, *Lepidorhombus whiffiagonis* and *L. boscii*. Information available to the Working Group indicates that *L. boscii*, are a negligible proportion of the Scottish and Irish megrim catch (Kunzlik *et al*., 1995; Anon, 2001). It is not clear to the WG whether landings of other countries are accurately partitioned into *Lepidorhombus whiffiagonis* and *L. boscii* Megrim are caught in association with anglerfish by some fleets and are area misreported along with anglerfish (See Section 6.1.2.2). The official statistics differ substantially from Working Group estimates in recent years. As with anglerfish, the reported Subarea VI landings have traditionally been adjusted to the Working Groups estimate of catch by including landings declared from Subarea IV in the ICES statistical rectangles immediately east of the 4 degree W line. Area misreporting peaked in 1996 and 1997 when around 50% of the estimated Working Group landings for Division VIa were area misreported.

For a number of years, anglerfish in Subareas VI, XII, XIV and Division Vb (EU zone) were subjected to a precautionary TAC (8600 t) based on average landings in earlier years. In 2002 the TAC was set at 4770 t and was further reduced to 3180 t in 2003 and 2004. The TAC for 2005 has been increased to 4686 t. ICES (2003) highlighted that the reduction of the TAC in 2003 to just two-thirds of that in 2002 would likely imply an increased incentive to misreport landings and increase discarding unless fishing effort was reduced accordingly. Anecdotal information from the fishery in 2003 to 2005 appears to suggest that the TAC has been particularly restrictive in these years. The official statistics for these years are, therefore, likely to be particularly unrepresentative of actual landings. The absence of a TAC for the adjacent Subarea IV prior to 1998 means that prior to then, 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 unfortunately for current and future reporting purposes, the TAC was set in accord with recent catch levels from the North Sea which includes a substantial amount misreported from Subarea VI. The area misreporting practices have thus become institutionalised and the statistical rectangles immediately east of the 4°W boundary (E6 squares) have accounted for a disproportionate part of the combined VIa/North Sea catches of anglerfish.

In addition to the issues associated with official catch data, there are concerns relating to the reliability of effort data for some of the key fleets. Robust effort data (in terms of hours fished) are not available from the Scottish trawl fleets as a consequence of changes in the practices of effort recording and non-mandatory effort recording in recent years. However, there appears to be issue with reported effort from other countries engaged in the fisheries.

While some attempts have been made to interpret lpue data and an indicator of relative trends in stock biomass where effort data are considered sufficiently reliable, clearly the issues identified above preclude overreliance of lpue trends as an indicator of stock trends. Lpue estimates covering a small proportion of total removals is provided by Ireland (for VIa) and Denmark (for IVa), but it should be noted that the activity of vessels from both countries only cover a small proportion of the fishery and may only therefore provide a view of trends on a sub component of the stock. Alternative sources of catch and effort data have been developed, namely the Scottish voluntary tallybook scheme reported in Section 7.

Although lpue trends could provide a good indicator of stock trends if the data issues identified above could be resolved, it is also important to note that interpretation of lpue data is also susceptible to changes in spatial and temporal in fishing pattern and technological creep.

Technological creep is generally difficult to quantify and therefore factor into lpue time-series. However, one of the major trends in demersal fisheries over the past few decades has been the introduction of multiple rig trawling. This been widespread in the majority of Northern European fleets targeting both crustacean (*Nephrops* and *Pandalus*) as well as several demersal fish fisheries, including the targeted anglerfish fishery in IVa and VI. Unfortunately, there is no distinction made between single and multi-rig trawls in official logbooks and they are simply grouped as 'Bottom Otter Trawl' (OTB). An analysis presented to WKAGME from Denmark illustrated how lpue data can be corrected for technological creep. Denmark routinely provides lpue trends for Danish vessels operating in IIIa and IVa to WGNSDS/WGCSE. Effort indices have been corrected to by factoring in the relationship between vessel power and trawl size in terms of volume. When these corrections were applied to the historical lpue estimates, the perception of the trajectory of stock abundance changed considerably. This work focused on technological changes associated with the *Pandalus borealis* fishery which has an important bycatch of monkfish. The unadjusted lpues indicated a stable stock size, whereas the corrected cpues suggest a significant decline in lpue. It should be noted that swept volume is an appropriate proxy for catching efficiency of *Pandalus*, however not clear if this is true for monkfish as swept-area rather than swept volume is more important.

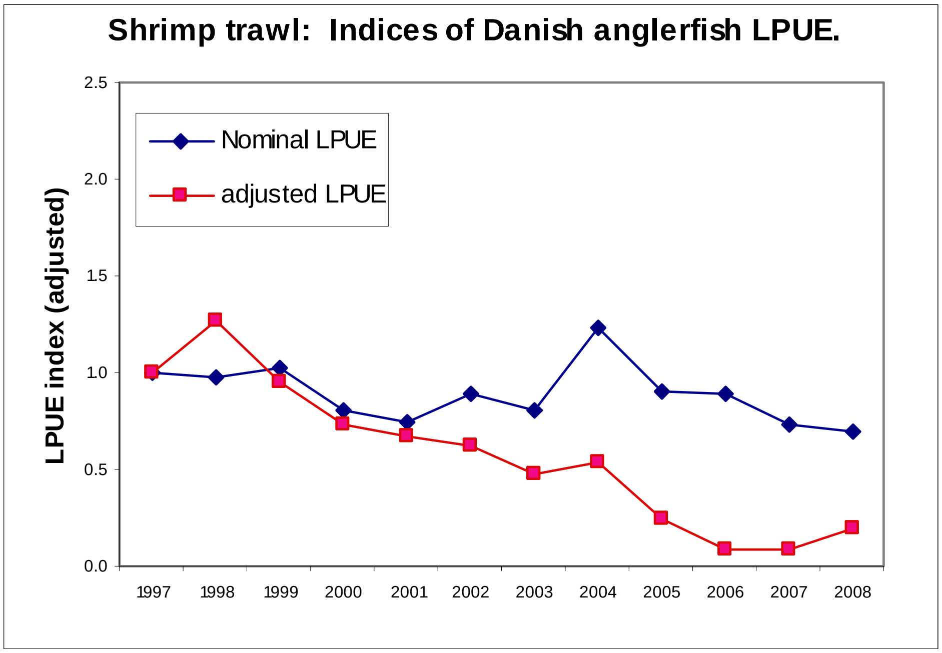

Figure 8.1. Contrast of nominal and adjusted trends in lpue based on increases in swept volume associated with increase in power of the Danish *Pandalus* fishery.

9 Ageing and age–length keys

9.1 Monkfish

In addition to information from the northern and southern shelves, this review considers information from Iceland, Faroe and Norway. Although the distributions of *L. piscatorius* and *L. budegassa* overlap, the catches of *L. budegassa* is negligible (<1%) in Area IV, is generally <10% in Area VI, but increases to become the dominant species on the southern shelf.

9.1.1 Ageing methods

There are two main structures used for ageing:

1) Otoliths, read either whole or sectioned;

2) Sectioned illicia.

Several other structures have been examined, including sectioned teeth and vertebrae, but these have been rejected.

Otoliths are the structure used routinely for ageing in the UK. Currently readers from most other countries have adopted illicia as the preferred structure. There are however known problems with both structures and it has previously been recognized that variations in length-at-age estimations exist.

9.1.2 Ageing issues

There are a number of known issues regarding the ageing of anglerfish and Ageing Workshops have previously been held in 1991, 1997 and 1999 using material collected from the southern shelf (Anon., 2000) and in 2004 using material from both the northern and southern shelves and a larger group of participants (Duarte *et al.*, 2005). Although the issues are known and recognized they have still not been fully addressed although some progress has been made with verification through modal analysis and tag-recapture data. Landa *et al.*, 2008 has recently produced a review of age studies of *L. piscatorius*. However it is clear that further work is needed, in the form of additional research and/or through further workshop style cooperation between readers before a consensus can be reached on standardizing structures and methodologies. From the work that has been completed to date it is also clear that once a standardized structure and methodology have been agreed that, from a quality control perspective, there should be regular exchange of material and between readers' comparisons.

Given that there are known differences in ageing between structures and between readers, it is considered that these issues should be addressed before progress is measured through inter-institute comparisons of age–length keys.

9.1.2.1 Validation using modal analysis

In many publications clear modes do not seem to be visible, possibly as a result of data being pooled over periods that mask any cohorts progressing through the distribution. In some datasets, such as those collected from some commercial fisheries there limited numbers of small fish as a consequence of the selectivity of the gear, and hence those representing the 0-, 1- and possibly 2-groups, where cohorts would be at their most defined are generally missing. There are however a number of publications where modes thought to represent cohorts have been presented, but there appears to have been only a limited number of studies where there has been any attempt to follow these over time (e.g. Laurenson, 2003; Jónsson, 2007; Velasco *et al.*, 2008).

The best example of modal analysis comes from the anglerfish catch in the Icelandic *Nephrops* survey (Jónsson, 2007) where a strong cohort entered the system in 1999 and could be clearly followed until 2003. Another strong cohort was recorded in 2002 and followed and additional strong cohorts have been recorded in recent years. From the modal progression it is estimated that growth decreased from around 15 cm/year in 1-year olds to around 7 cm/year in 5 year olds, at least in Icelandic waters. Length–frequency distributions from Iceland demonstrating the strong presence of cohorts are shown in Figure 9.1.

Some limited modal analysis was conducted on length distribution data collected at Shetland (Subarea IVa) between 1998 and 2001 (Laurenson, 2003) and from these, growth rates of 8–10 cm/yr were evident during the first three years.

On the Porcupine bank strong recruitment was observed in both 2001 and 2004. Length–frequency analysis in subsequent years indicated that growth is underestimated when based on illicia readings, at least in the first three years (Velasco *et al.*, 2008).

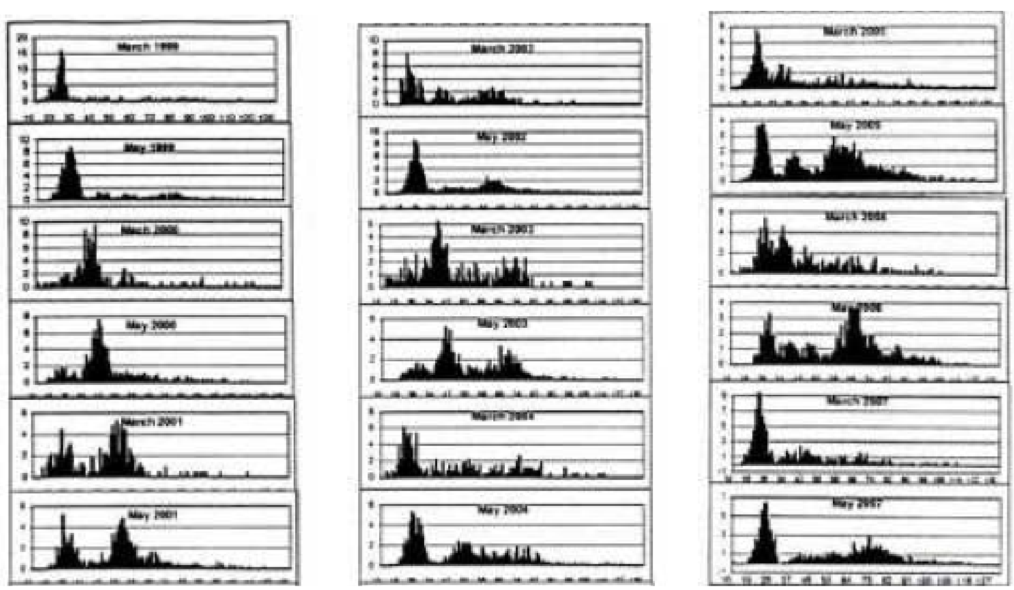

Figure 9.1. Length–frequency distributions of *L. piscatorius* in March and May surveys at Iceland from March 1999–May 2007 (from Jónsson, 2007).

9.1.2.2 Validation using growth from tag recaptures

Growth of *L. piscatorius* has been published as the result of two separate tagging studies. The first was at Shetland (Subarea IVa) (Laurenson *et al.*, 2005) where the average growth was 9.4 cm/year (based on 20 fish after removal of outliers and those with short times at liberty) and the second on the southern shelf (Landa *et al.*, 2008) where the growth was 13.6 cm/year (based on 4 fish). Growth data has also been obtained from a tagging study at Norway (O. Bjelland, unpublished data) and is in line with that recorded in IVa. Some tagging has been undertaken at both Faroe and Iceland. To date fourteen recaptures at Faroe (after >180 days) reveal average growth rates decreasing from 8.6 cm/year for fish 60–69 cm to 6.6 cm/year for fish 70–87 cm at release and all recaptures were female (L.H. Ofstad, *pers. comm.*).

The available growth data from tagged fish are all from fish of lengths above 29 cm, therefore verification of growth by tagging in smaller fish does not exist and the estimated mean length-at-age has been variable even at smaller lengths (0- and 1- group) between structures as a consequence of the problem of the assignation of the first annulus which Wright *et al.*, 2002 demonstrated to be causing an overestimation of +1 year in illicia readings.

It is recommended that although current tagging studies have provided useful information on growth, additional data would be desirable, particularly for the southern shelf where data from only four fish is available.

9.1.2.3 Microstructure analysis

The formation of the first annulus was investigated in small anglerfish (<27 cm) by Wright *et al*., 2002 using microstructure analysis in lapilli otoliths and comparing the ages determined in those to the formation of the first translucent zone in both saggital otoliths and illicia in the same fish. The main conclusion was that the first translucent zone that formed in illicia was not a true annual annulus and therefore the ages of those fish could be overestimated by one year if illicia were used.

9.1.2.4 0-groups and spawning season

Wright *et al*., 2002 noted that there could be considerable overlap in the lengths of anglerfish between ages, even at the younger ages with some individuals reaching 27 cm by September of their first year; however fish of a similar size caught in spring would be aged as 1-group.

It is known that the spawning season is prolonged. Although it is probably mainly between around December and late spring (Afonso-Dias, 1997; Laurenson, 2003) early descriptions suggested that it extended into July (Bowman, 1920) or August (Fulton, 1903). Newly spawned egg masses recovered at Shetland during 2005 (Laurenson, 2006) and 2008 (unpublished data) confirm spawning into at least mid-June.

The prolonged spawning period has certain implications for the range of possible lengths of 0- and 1-group fish and will contribute to the overlap in lengths between ages. At the end of any given year the 0-group fish could vary from between around 5 and 12 months in age and will have a correspondingly large range in sizes. It is also unknown the extent to which the timing of spawning affects consequent survival and growth.

9.1.3 Other relevant biological information

9.1.3.1 Male and female growth rates

In studies where growth has been investigated by sex, differences in growth rate have been identified (e.g. Dupouy *et al.*, 1986; Afonso-Dias, 1997; Landa *et al.*, 1998).

9.1.3.2 Length-at-maturity

Length-at-maturity has been estimated throughout the distribution range of both species of *Lophius* in the northeastern Atlantic. A common theme between studies is the small numbers of mature females within the fisheries/surveys and therefore some studies suggest caution over the $L_{50\%}$ estimates. In general most studies are estimating $L_{50\%}$ maturities of between 80 and 100 cm for females and of around 55 cm for males. Some published $L_{50\%}$ values are displayed in Table 9.1.

Table 9.1. Examples of estimated $L_{50\%}$ maturities in male and female *L. piscatorius*.

Study	Area	$L_{50\%}$ Females	$L_{50\%}$ Males
Laurenson *et al.*, 2008	IV & VI	102.4	58.3
Ofstad and Laurenson, 2007	Vb	82.8	57.3
Afonso-Dias, 1997	VI	73.5	48.9
Anon, 2001	VI	92.3	56.4
Duarte *et al.*, 2001	VIII & IX	93.9	50.3
Quincoces *et al.*, 1998	VIIIa,b & d	83.6	54.6

The maturity scale used appears to be similar between Institutes however some concerns have been encountered regarding consistency in assigning maturity stages between observers. As $L_{50\%}$ is based on stages 3–5 being mature, the assignation of stage 2 (immature/resting) to both virgin fish and to those mature fish who have spawned and have returned to a resting stage introduces a source of error into the estimation of length-at-maturity as some mature fish are not included in the $L_{50\%}$ calculation. This is most likely to be problematic for females sampled in Qr4 as a consequence of both the usually small numbers of large fish and the proportions of non-virgin fish in the resting (stage 2) state being at the highest. This problem has been debated at length in other meetings (e.g. Thangstad *et al.*, 2006). From experience, the introduction of an additional stage that is macroscopically identifiable and reliably distinct, to distinguish between immature virgin and resting non-virgin fish does not seem a feasible option.

9.1.3.3 Proportion female at-length and seasonal and depth variations

Similar patterns of proportion female at-length have been recorded on shelf waters throughout the distribution of *L. piscatorius* with approximately equal numbers of males and females at-lengths less than around 60–70 cm, above this the proportion female increases and at-lengths greater than around 100 cm generally no males are recorded.

Recently the difference in proportion female at-length between different depth strata has been recognized in Area VI, where at depths ≥450 m there are much larger proportions of males at smaller lengths, increasing to all female at-lengths above 100 cm (Figure 9.2) but this also differs between seasons (Laurenson *et al.*, 2008).

Such variations will have implications for both obtaining representative samples; estimating the proportions of mature fish in the landings; estimating SSB and these variations should be recognized and considered when investigating different management strategies.

It is currently unknown whether similar patters exist for *L. piscatorius* through the remainder of its distribution or whether similar patterns exist for *L. budegassa*.

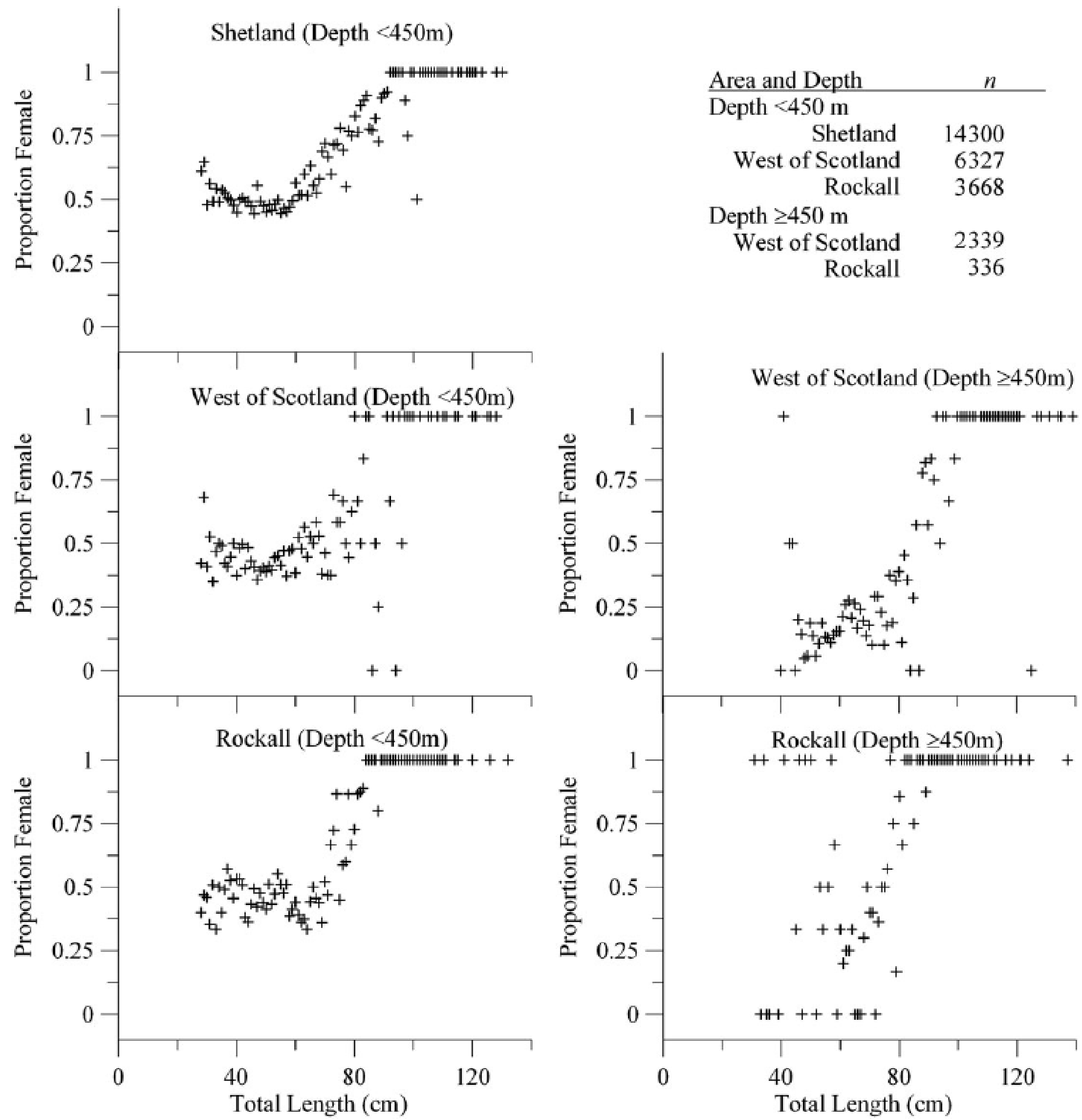

Figure 9.2. Proportion female at-length at Shetland (IVa), West of Scotland (VIa) and Rockall (VIb) in waters <450 m and ≥450 m (Laurenson *et al.*, 2008).

9.1.3.4 Migration

Information obtained from the tagging studies that have been undertaken have demonstrated that in addition to smaller scale movements within areas larger distance migrations can occur. For example, there is migration from waters around Shetland (IVa) to Iceland, Faroe, and Norway (Laurenson *et al.*, 2005) and monkfish released at Norway have been recaptured in waters close to Shetland. On the southern shelf, monkfish (*L. piscatorius*) released in the southern stock area (VIIIc) have been recaptured in northern stock areas (VIIIa, b) (Landa *et al.*, 2001). Although these studies have provided evidence that there is transfer between stock areas, it is currently unknown the extent to which these movements are occurring.

9.1.4 Comparison of length-at-age estimations

Although age–length keys were requested from other countries for comparison at this workshop, only data from Scotland and Iceland was received. Most of the comparisons are therefore restricted to the mean lengths-at-ages and von Bertalanffy growth equations available in the published literature.

Published and additional mean length-at-age data have been complied and are shown in Figure 9.3. There is clearly a large variation in values that are obtained between different studies, with ageing structure, age reader and possibly geographical variation all contributing to the observed differences.

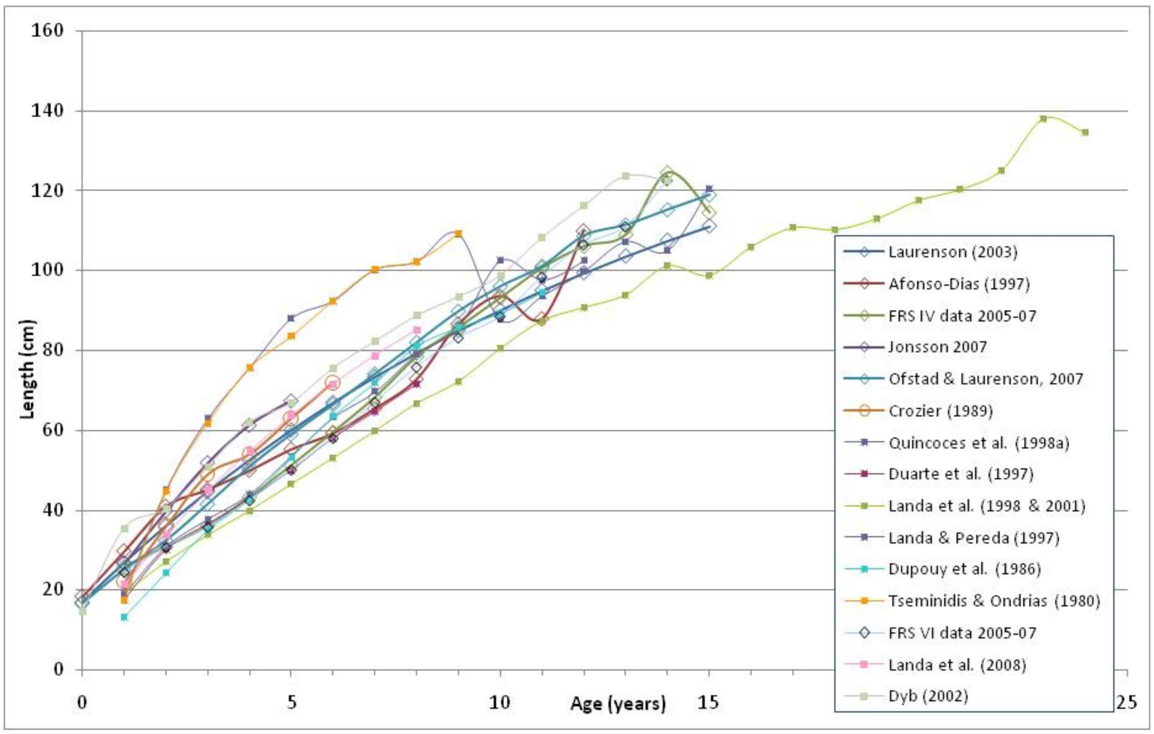

Figure 9.3. Mean lengths-at-age of *L. piscatorius*.

For the Northern Shelf and Norway, Faroe and Icelandic waters available mean length-at-age data are shown in Figure 9.4. There is close agreement on mean length-at-age at-age 0, above which there is some divergence. The mean length-at-age given by Jonsson for illicia readings are almost identical with mean length-at-age estimates based on modal analysis on length frequency distributions at Iceland (Jónsson, 2007). The mean length-at-ages presented by Dyb, 2002 for Norwegian waters are mostly very similar to those presented by Jonsson, 2007 and both reveal higher mean length-at-ages for ages above 3 years, when compared with other available data. The mean length-at-ages given by Laurenson, 2003 for IVa (otolith readings) and Ofstad and Laurenson, 2007 for Faroese waters (illicia readings) are similar up to age 8, beyond which there is some divergence.

Data made available by FRS (Aberdeen) for Areas VI and IV for 2005–2007 demonstrate almost identical mean length-at-age estimates for both areas. These estimates are however lower than the other available length-at-age estimates at-ages between 2 and 7 years.

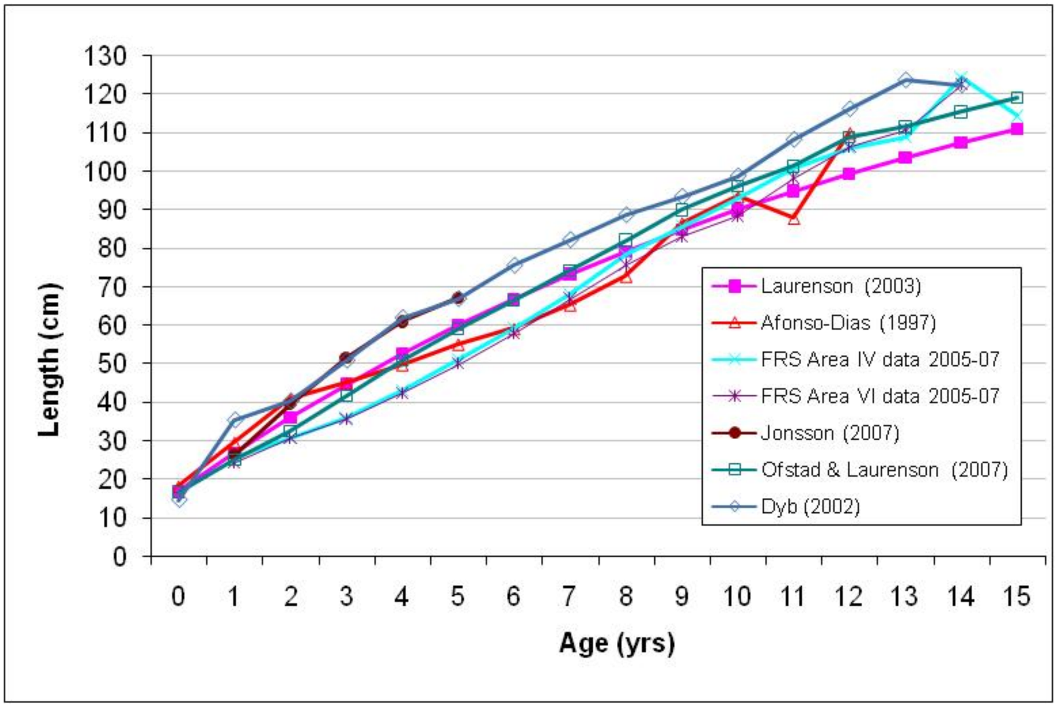

Figure 9.4. Mean length-at-age of *L. piscatorius* in Northern Shelf and Nordic waters. NB Mean length-at-ages from otolith readings except for Dyb, 2002; Ofstad and Laurenson, 2007; Jonsson, 2007, which are derived from illicia readings and cover Norwegian, Faroese and Icelandic waters respectively.

9.1.5 Comparison of von Bertalanffy estimations

Available von Bertalanffy estimates are demonstrated in Table 9.2 and Figure 9.5. In some of the fitted equations the L_∞ (asymptotic length) is constrained as a consequence of unrealistically high values being obtained when the best fit of the equation is achieved. Constraining has been done in a number of ways, for example, using the maximum observed length or using some value*maximum observed length.

Landa *et al.*, 2008 reviewed information from a number of sources including tagging studies, length–frequency analysis and microstructure analysis and found that parameter values of L_∞ = 140 cm and k = 0.11 best represented the available verified growth data. This confirmed the underestimation of ages when illicia are used as the ageing structure.

Table 9.2. von Bertalanffy parameters for *L. piscatorius* from available publications.

NB * indicates L∞ values that have been constrained.

Author	Structure	L∞	k (y-1)	t0 (y)
Laurenson, 2003	Otoliths	205.7	0.046	-1.99
Afonso-Dias, 1997	Otoliths	140.43*	0.079	-1.341
Crozier, 1989	Otoliths	105.55	0.1759	-0.38
Landa *et al*., 2001	Illicia	163.5*	0.065	-0.38
Landa *et al*., 1998	Illicia	140.5*	0.08	0.232
Landa and Pereda, 1997	Illicia	132.05*	0.1086	0.664
Duarte *et al*., 1997	Illicia	121.54	0.102	0.032
Dupouy *et al*., 1986	Illicia	166.66	0.077	0.395
Dyb, 2003	Illicia	146	0.120	-0.34
Staalesen, 1995	Illicia	320	0.038	-0.342
Ofstad and Laurenson, 2007	Illicia	210.73	0.05	-0.62
Landa *et al*., 2008		140*	0.11	not given

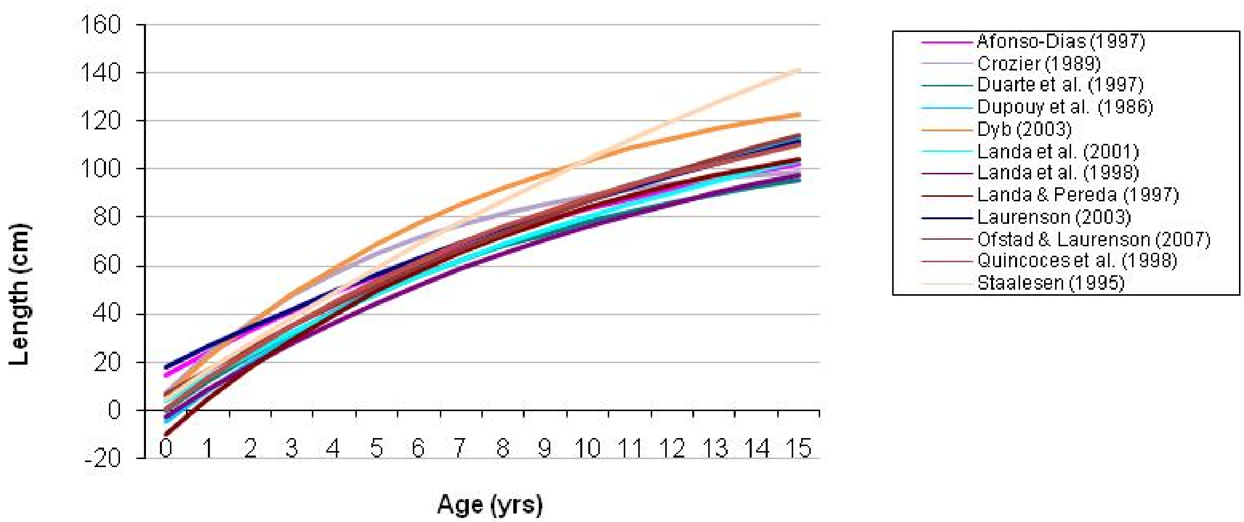

Figure 9.5. von Bertalanffy growth curves for *L. piscatorius* from available sources.

9.2 Megrim

Although there is a combined TAC for megrim on the southern shelf there are separate assessments for *L. whiffiagonis* and for four-spot megrim (*L. boscii*). On the northern shelf there is currently no assessment for either species. As a consequence of the distribution of the species, data from the northern shelf mostly refers to *L. whiffiagonis* although in more southern areas data relating to both *L. whiffiagonis* and *L. boscii* is generally available.

9.2.1 Ageing methods

Otoliths or sectioned fin rays can be used for age determination of megrim. Whole hydrated otoliths read flat seem to be the preferred ageing structure. The last Ageing Workshop for Megrim (*L. whiffiagonis*) was held through otolith exchange and attendance of a workshop in 2004 (Egan *et al.*, 2004). The otoliths used were obtained from megrim caught in VIIIa, b, d; however participating readers represented both northern and southern shelf areas. Ageing criteria in that workshop was agreed as that described from the previous ageing workshop (Anon, 1997) and the majority of readers reached a 'high' agreement for fish younger than 6 years. The ageing criteria used for *L. whiffiagonis* can also be used for *L. boscii* (Egan *et al.*, 2004).

9.2.2 Comparison of length-at-age estimations

Although the last Ageing Workshop (Egan *et al.*, 2004) has demonstrated that it is possible to achieve good agreement on ageing, within available studies it is suggested that there is significant differences in length-at-age both within areas and between areas. Although differences found in a given study may represent significant differences between those sampled areas, it should be noted that as the consistency in reading is not known between studies, it is difficult to draw generalizations or patterns relating to growth between areas covered in different studies.

On the northern shelf detailed information is limited to one report for Area VI (Anon., 2001) and only preliminary ageing data are available for area IVa (Laurenson and Macdonald, 2008). Some unpublished data were made available from Icelandic waters (E. Jonsson, *unpubl. data*). For the southern shelf publications are more numerous and age–length keys are submitted to be used in the assessments undertaken by the WGHMM.

Anon, 2001 reported significant differences in growth between sexes of *L. whiffiagonis* both within and between Areas VIa and VIb and preliminary ageing data from IVa suggests that there are differences in growth between that area and area VI (Laurenson and Macdonald, 2008). Age–length scatterplots for Area VI and for Icelandic waters are shown in Figures 9.6 and 9.7 respectively. In the data from Iceland, megrim aged at 10 and above are generally all >50 cm, larger lengths than those given in the data for VI but it is not known whether these apparent differences are because of differences in growth between the two areas, differences in age assignment or bias as a consequence of relatively few samples at the largest sizes. Collaborative work would be needed to determine between reader agreement for these areas.

On the southern shelf a significantly higher growth rate, longer lengths and older ages were recorded in females and greater lengths and ages were found further north compared with further south (Landa and Pineiro, 2000). Additionally, in the first three age classes a faster growth rate was observed from more southerly areas (Landa and Pineiro, 2000).

Although the last Ageing Workshop indicated good agreement between the readers involved, which likely reflects the use of a standardized methodology, Landa *et al.*, 1996 illustrated the differences in growth curves determined from a number of authors with in VIIghjk (Figure 9.8).

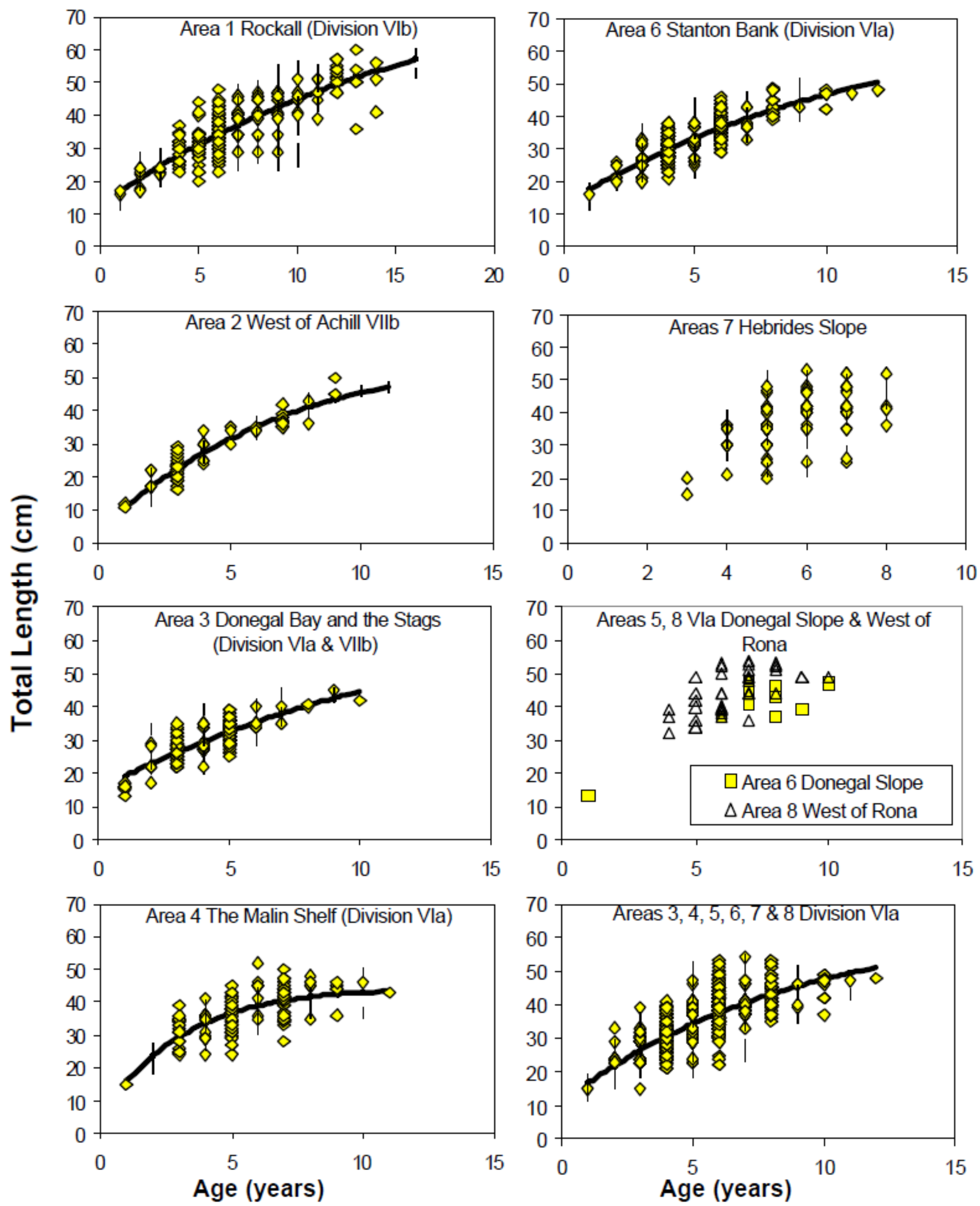

Figure 9.6. Age–length scatterplots and fitted von Bertalanffy models for female *L. whiffiagonis* in VI (Anon., 2001).

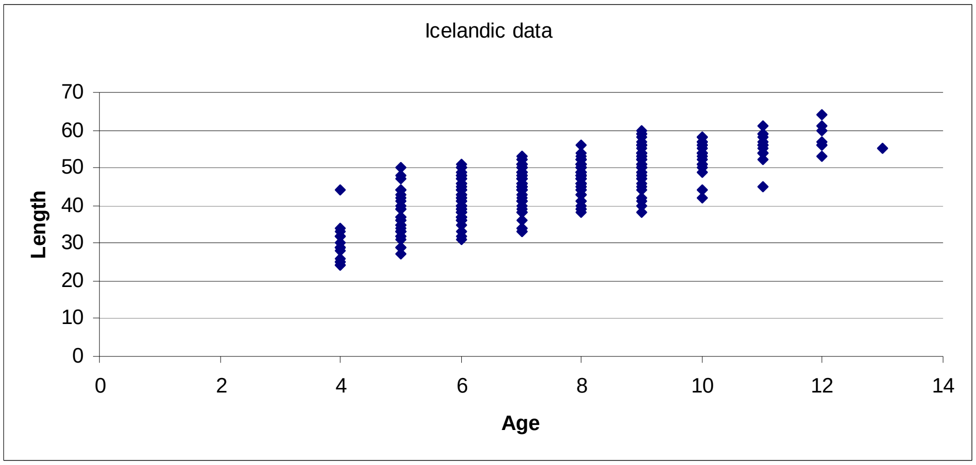

Figure 9.7. Age–length data for megrim in Icelandic waters.

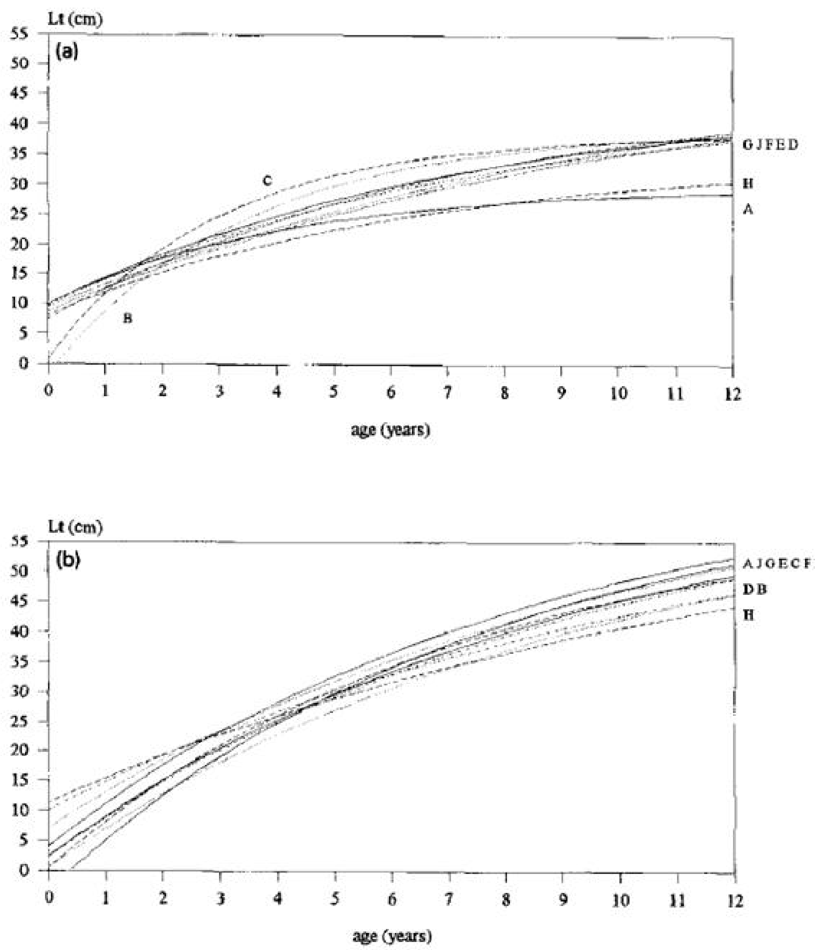

Figure 9.8. Growth curves for *L. whiffiagonis* in VIIghjk from a number of published sources males (top) and females (bottom) (from Landa *et al.*, 1996).

9.2.3 Ageing issues

All available age–length scatterplots for megrim indicate a substantial overlap between length-at-age, for example in data from VI Anon, 2001 megrim at around 35 cm in length could be from around 4 to at least 10 years old. This significant overlap combined with the variability of the length distributions from different areas and over time suggests that-age validation through cohort analysis may be unlikely. This overlap will be contributed to by the reported differences in growth between males and females.

Some age readers have described difficulty in reading ages in the largest megrim (e.g. G. Henderson, FRS, *Pers. comm.*; Landa and Pineiro, 2000) and one of the conclusions of the 2004 Ageing Workshop was that readers from northern areas tended to underestimate ages in megrim >35 cm compared with those readers from southern areas (Egan *et al.*, 2004).

There is indirect validation through investigation of the formation of the opaque margin through the year (e.g. Anon., 2001) but there is currently no growth verification data available through tagging studies or through otolith microchemical or microincrement analysis. It is therefore recommended that these types of studies should be undertaken.

9.2.4 Other relevant biological information

In general there are still aspects of the biology of megrim that are not known or understood, particularly on the northern shelf. A more thorough understanding of the biology of the species would be desirable, particularly on the northern shelf, before the implications of the current exploitation patterns and the effectiveness of any management measures could be fully evaluated.

Of the information that is known, it has been demonstrated that in Areas IV and VI catches from both surveys and commercial catch data indicate that females attain a larger size and age (60 cm and16 years) compared with males (~45 cm and 12 years) (e.g. Anon., 2001) and this is also the case for the southern shelf (Landa and Pineiro, 2000). The catches within the commercial fishery in IV and VI and in data provided from Iceland demonstrate a heavy bias towards females with, for example 91% of the catch being female in IVa (Laurenson and Macdonald, 2008). The female bias in catches is likely to be as a result of a combination of the lengths attained by males and females and the selectivity of the fishing gear. Examples of length distributions from the fisheries in IV and VI and the proportions female are shown in Figure 9.9. It has also been demonstrated that the proportion female can vary with depth. In IVa the percentage male increased from around 5 to 15% of the catch between 100 to 200 m (Laurenson and Macdonald, 2008). The distribution of megrim can be described as 'patchy' with some small areas with extremely high abundances compared with others; however the possible seasonality of some of these areas is not understood.

The spawning season is between January and April in VIa (Anon., 2001) but extends later in IVa (Laurenson and Macdonald, 2008). As a consequence of the possibility that megrim mature earlier in southern waters the consequent likelihood of differences in growth rates between areas should be recognized (Egan *et al.*, 2004).

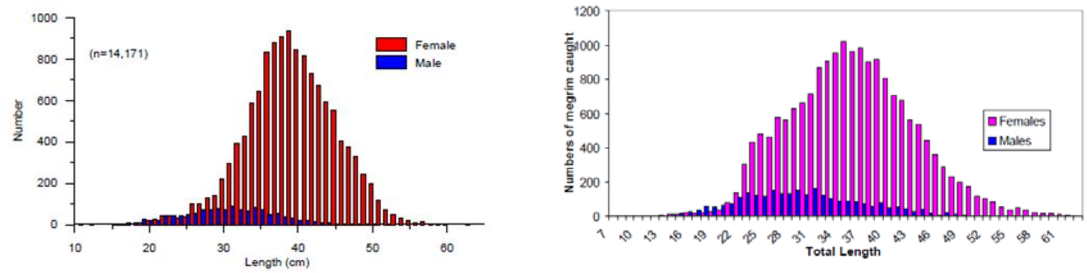

Figure 9.9. Length distributions of catches by sex for (left) Area IVa in 2008 (Laurenson and Macdonald, 2008) and (right) area VI in 1998–2001 (Anon., 2001).

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Annex 2: Agenda

Monday 23 February 2009

TIME/LOCATION	ITEM/PERSON	PROCESS	OUTPUT
1500–1530 Conference room	Welcome, housekeeping introductions and confirmation of agenda Fernandes	Presentation and Introductions	Familiarisation and logistics; agree meeting ground rules
1530–1600 Conference room	Review of survey time-series Fernandes	Presentation, followed by discussion	Update all participants. Contribution to WK report. Discuss review process.
1600–1630	Statistical considerations of estimation procedure Yuan	Presentation, followed by discussion	Update all participants. Contribution to WK report.
1630–1700 Coffee			
1700–1800 Conference room	Review of surveys for absolute estimation of monkfish and megrim (TOR a) Trenkel	Discussion	Pros and cons of current approach. Identify requirements for improvements.

Tuesday 24 February 2009

TIME/LOCATION	ITEM/PERSON	PROCESS	OUTPUT
0900–0915 0915–0945 Conference room	Herding coefficients Clarke and Yuan TOR (b): Survey catchability review part 1 -Herding Graham	Presentation Discussion	Clarification of current assumptions identify requirements for improvements and/or new experiments.
0945–1000 1000–1015 Conference room	Catchability statistics Clarke and Yuan TOR (b): Survey catchability review part 2 - Footrope Graham	Presentation Discussion	Clarification of current assumptions; identify requirements for improvements and/or new experiments.
1030–1100 Coffee			
1100–1200 Conference room	TOR (a): Survey review – sources of error. Trenkel	Presentation and discussion	List sources of bias and error in surveys. Suggest possible solutions.
1200–1230 Conference room	Report on TOR (b) All	Writing	Contribution to WK report
1230–1330 Lunch			
1330–1500 Conference room	TOR (c): Harvest strategy evaluation. Fernandes	Presentation and discussion	Update participants Contribution to WK report.
1500–1530 Coffee			

Time/Location	Item/Person	Process	Output
1530–1700 Conference room	TOR (c): Harvest strategy evaluation. All	Discussion	Identification of additional harvest control rules; critical evaluation of approaches. Contribution to WK report.

Wednesday 25 February 2009

Time/Location	Item/Person	Process	Output
0900–1030 Conference room	TOR (d): Self sampling schemes (tallybook) review Dobby	Presentation	Update participants
1030–1100 Coffee			
1100–1230 Conference room	TOR (d): Utility of self sampling schemes (tallybook) Dobby	Discussion	Determine how tallybook data might be used in future assessments Contribution to WK report.
1230–1330 Lunch			
1330–1500 Conference room	TOR (e): Commercial catch data review Graham	Presentation	Update participants Determine whether catch data can be used.
1500–1530 Coffee			
1530–1700 Conference room	Danish cpue/lpue Munch-Petersen	Presentation	Update participants.
	TOR (e): Commercial catch data review All	Discussion	Contribution to WK report.

Thursday 26 February 2009

Time/Location	Item/Person	Process	Output
0900–1030 Conference room	TOR (f): Ageing and ALK comparison Laurenson	Presentation	Update participants
	Ageing issues All	Discussion	Determine any problems with ageing;
1030–1100 Coffee			
1100–1230 Conference room	Other biological data Laurenson	Discussion	Consider biological data needs for assessment and management evaluation Contribution to WK report.
1230–1330 Lunch			

TIME/LOCATION	ITEM/PERSON	PROCESS	OUTPUT
1330–1500 Conference room	Report writing All		
1500–1530 Coffee			
1530–1700 Conference room	Report writing All		
1900 Evening social event			
Friday 27 February 2009			
TIME/LOCATION	ITEM/PERSON	PROCESS	OUTPUT
0900–0930 Conference room	Outstanding issues Fernandes and Graham	Discussion	Additional material for report
0930–1045 Conference room	Report review Fernandes	Reading	Modified report sections
1045–1115 Coffee			
1115–1200 Conference room	Final writing schedule Fernandes	Discussion	Joint agreement on additional inputs to the report and deadlines
1200 Close			

Annex 3: Recommendations

Recommendation	For follow up by:
WKAGME recommends that the survey be used to provide advice on anglerfish according to the latest proposals from the commission. This and other harvest control rules should, however, be subjected to management strategy evaluation.	WGCSE , ACOM, STECF.
WKAGME recommends that the survey be used to provide trends on the abundance of megrim which can be used to provide advice according to the latest proposals from the commission.	WGCSE, ACOM, STECF
WKAGME recommends that the monkfish and megrim industry science survey include participation of other countries, the most important of which are Scotland, Ireland (to cover areas VI and VII), Denmark (area III and IV) and Norway (part of area IV) to cover the entire northern shelf. If area VII is to be complete then France would also need to participate.	National administrations (Scotland, Ireland, Denmark, Norway and France), ICES, DGMare
WKAGME recommends that consideration should be given by the commission to fund this survey under the DCF.	EC DGMare
WKAGME recommends that nations in other areas consider applying the same survey approach to estimating the abundance of anglerfish and megrim (in particular Norway in area IIa; and Faroe and Iceland in area V).	National administrations (Norway, Iceland and Faroese Islands), ICES, DGMare
WKAGME recommends that further work be carried out on the selectivity of the survey trawl and groundgear.	ICES FTFB
WKAGME recommends that measures be taken to achieve international consensus among age readings for anglerfish and megrim, particularly in stock unit areas such as the northern shelf. This might best be achieved through a collaborative project whose aims should take into account recommendations of previous workshops.	PGCCDBS, EC DGMare (DCF)
WKAGME recommends that further tagging studies should be carried out to assess the extent of migration between stock areas and individual growth rates. Otolith morphology should be considered as a tool to aid in stock identification.	ICES, EC DGMare (DCF)
WKAGME recommends that self-sampling schemes such as the Scottish tallybook programme be re-established to the same level. This will provide indicators of stock status that would improve relations with the fishing industry.	North Sea RAC, North west waters RAC, National fisheremen's organizations.
WKAGME recommends that catch at length data for anglerfish and megrim should be supplied to the WGCSE at a national level. These data should be collated at the apppropriate stock unit level (e.g. Northern Shelf data should comprise areas IIIa, IV, and VI).	ICES WGCSE stock co-ordinators,
WKAGME recommends that further quantitative analyses of the influence of technological changes on catch efficiency should be carried out in relation to anglerfish and megrim.	National administrations, ICES SGEM, WG FTFB (for evaluation)

After submission of the Report, the ICES Secretariat will follow up on the recommendations, which will also include communication of proposed terms of reference to other ICES Expert Group Chairs. The "Action" column is optional, but in some cases, it would be helpful for ICES if you would specify to whom the recommendation is addressed.

Annex 4. The industry science trawl specification

FRS monkfish survey gear

In 2005 FRS Marine Laboratory contracted netmakers to supply monkfish trawls to be used to conduct the Industry Science survey of monkfish. Each trawl is towed in a single trawl configuration by chartered commercial fishing vessels and FRV Scotia. The trawl design is typical of that used by the Scottish fleet targeting the west coast monkfish fishery down to water depths of 1000 m and is suitable for vessels with main engine power in excess of 1200 hp. A schematic of the net diagram is given in Figure A.1; the bridle and groundgear arrangements are given in Figure A.2.

The trawl includes the following basic features:

1) Ground gear length of 150 ft.

2) Rockhopper discs in the centre of 16″ diameter.

3) Rockhoppers rigged on 19 mm chain.

4) To ensure no monks pass over the headline the design incorporates a ‘ballooned’ top sheet (approximately 20% more) similar to that already supplied to the fleet.

5) A mesh size in the lower wings of 120 mm to ensure small monks and megrims are retained.

6) The codend consists of a 20 mm mesh blinder inside 100 mm mesh.

7) 90 mm square mesh panels will NOT be fitted.

8) High tenacity twine is used throughout the trawls construction.

9) Both the headline and footrope are wrapped with rope and include selvedge ropes.

10) Design incorporates measures to give added strengthening to weak points around the mouth and belly of the trawl. This strengthening is similar to that which is normally built into commercial scraper trawls (i.e. top and bottom guard meshes and tearing strips, etc).

11) Includes a tickler chain of 19 mm chain as per standard length to suit this gear.

12) The wire rig consists of 6 x 20 fm lengths of 26 mm wire single spreaders, 2 x 10 fms of 22 mm chain and 20 fm double spreaders, 18 mm wire for the top and 19 mm chain on the bottom.

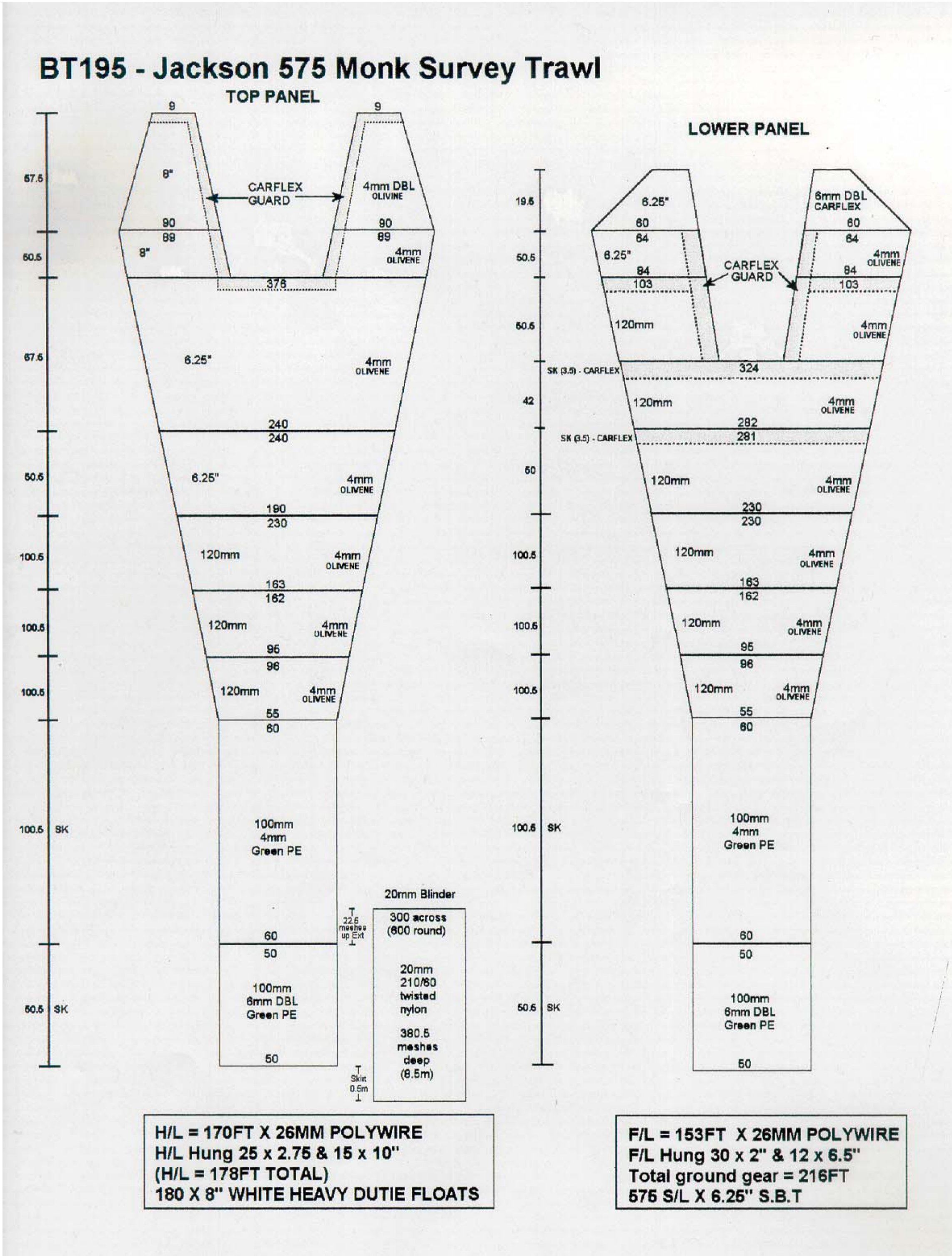

Figure A.1. Schematic net diagram of the new monkfish survey trawl.

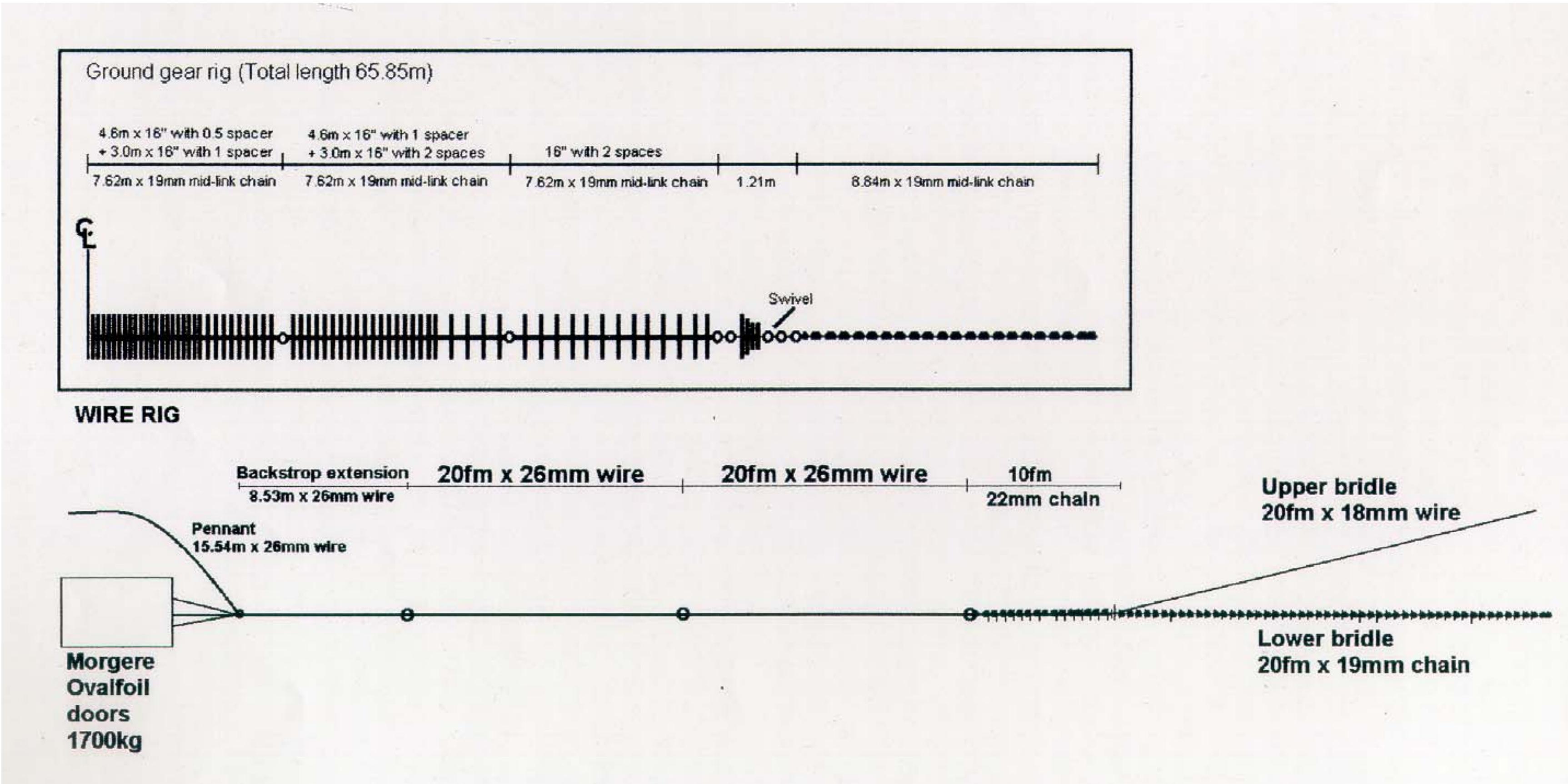

Figure A.2. Ground gear and bridle rig for the new monkfish survey trawl. Note: trawl doors will be as per vessels own door, but should be approximately similar to FRS' Morgere set (Ovalfoil 1700 kg, 5.82 m²).

Tickler chain

Full length of chain is approximately 135 ft (41.16 m).

Length of tickler chain to be used during monkfish survey is 123 ft (37.5 m). All ticklers will have hammerlocks and swivels positioned at the correct distance (123 ft) to be connected into the butterflies.

The chain connects into the spare hole in each butterfly, see Figure A.3.

Figure A.3. Tickler chain attachment to the groundgear of the FRS monkfish trawl. Please note to allow ease of handling by Jackson's at the end of the cruises all tickler chains to be removed from the trawls.

Patching/chandlery

Each vessel will get the following:

1 x spare 100 mm x 6 mm DBL codend.

Assorted patching 200 mm, 160 mm, 120 mm and 100 mm and 160 mm Carflex for guard meshes.

Assorted spools of twine for the trawl and codend.

1 x coil of rope to rig lazy deckie to suit each vessel.