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Report of the Workshop on Nephrops Stocks (WKNEPH)

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Executive Summary

General

WKNEPH met in Copenhagen 24–27th January 2006. 17scientists attended covering most of the Nephrops FUs within waters dealt with by ICES. The group tackled 8 ToRs and produced a report with 5 substantive sections covering the broad topic areas listed below. Several recommendations (section 7) arose from the meeting including one specific proposal for an ICES Workshop (Annex 3)

Feedback from the area based working groups

The feedback from the area based assessment WGs was mixed. The fisheries assessment groups generally have a large membership with high levels of technical expertise and it was felt that being part of these groups has the potential to improve *Nephrops* stock assessments and the advice on fisheries interactions. However, it was agreed that too much time at the assessment WGs was devoted to assessment data compilation and on top of this, the extensive lists of ToR meant there was little time available to actually consider mixed fisheries issues. In addition, functional units in some of the larger management areas (e.g. Subarea VII) were assessed by three different WGs using three different methods making it particularly difficult for ACFM to collate the landings and provide advice for the TAC area as a whole. The group recommended continuation of regional WGs with some suggestions for improved operation.

Aspects of Nephrops fisheries

The identification of *Nephrops* metiers is progressing and in the future this will enable fishery based predictions to be carried out. Subarea IV (the North Sea) has the most complete data although even within this area, the method of metier definition differs between countries, with some countries using cluster analysis of catch composition data and others using gear and mesh categories. The upcoming revision of the EU's Data Collection Regulation (DCR) includes a change from the current stock-based data collection scheme to a fleet-based one. However, for such a scheme to function in an effective manner and yield the requisite data, additional fields in logbooks will have to be made mandatory.

For a number of years, concerns have been expressed that the official landings of some *Nephrops* stocks do not reflect the actual landings. While there is some anecdotal information to suggest that there has been an improvement in the accuracy of reported landings in 2005 in some areas, it seems likely that misreporting is still extensive. The new UK legislation on the registration of buyers and sellers which came into force in 2006 should improve the accuracy of future UK reported landings. In addition, the increase in TAC in areas IV, VIa and VII should reduce the need to mis-report, assuming that fishing effort does not increase.

Sampling and parameters

A number of approaches to evaluating precision levels in *Nephrops* sampling were presented at the meeting. Preliminary results from a Belgian study indicate that the current sampling scheme may not be sufficient to meet the precision levels required by the EU DCR. Results from an Irish example showed that an increase in the number of samples, without increasing sample size would improve the precision and accuracy of the sampling. However, the workshop concluded that the results of these studies did not imply an urgent need for a change in sampling strategy.

Under the EU DCR, six-yearly updates of sexual maturity and growth parameters are required for *Nephrops* stocks. WKNEPH began an analysis of the maturity data collected between 2001 and 2005. For purposes of comparability, all stocks were analyzed using the same

statistical methods and the female data were restricted to those datasets collected in the appropriate pre-spawning time period. The results of the analysis showed differences in the female size at maturity for different stocks, although there also appeared to be some within stock variability. In particular, the southern Iberian stocks show a much higher size at maturity, re-emphasizing the idea that the biological characteristics of these deep-water stocks more closely resemble those of the Mediterranean stocks rather than those of the other north Atlantic stocks. Male size-at-maturity, as estimated from the change point in the growth rate of the appendix masculina, did not appear to differ significantly between stocks. It was recommended that this work be written up into papers for submission to scientific journals.

Stock assessment developments

The discussion on assessment methods was split into two parts: i) developments in length- and spatially-structured models, and ii) fishery independent methods.

A number of flexible modelling frameworks have been presented to the Study Group on Age-length Structured Assessment Models (SGASAM) which are available for the development of length-structured assessment models, and able to incorporate dynamics which are appropriate for *Nephrops* stocks. The models generally make use of size-transition matrices that require either estimates or assumptions about mean growth and it's variability. In many stocks in the ICES area there are insufficient data to estimate even von Bertalanffy growth parameters so construction of appropriate size transition matrices may not be possible without further collection of growth data. It was recommended that efforts be made to gain funding for a coordinated study of growth.

Due to concerns about the accuracy of the reported landings of *Nephrops* stocks, underwater TV (UWTV) surveys are increasingly being used to provide estimates of stock biomass. However, there are a number of issues with regard to this estimation procedure which still require further exploration, such as: assumption of 100% burrow occupancy, correct identification of burrow complexes in high-density areas, relationship between survey biomass and 'exploitable' biomass. Once an estimate of abundance has been obtained, an appropriate catch level can be calculated by applying a precautionary harvest rate. Further development of suitable precautionary harvest rates is considered a priority. A recommendation and proposal was made for a workshop in 2007 focussing on TV techniques.

Technical measures

Size selection of *Nephrops* from currently used meshes is poor as escape can be impeded by their shape and claws, resulting in discarding. In the Swedish fishery a 70 mm square mesh cod-end used in conjunction with a rigid grid has been shown to improve selectivity. However, the minimum landing size in the Skagerrak is much larger than that in the Irish and North Sea and the use of a 70 mm square mesh cod-end in these fisheries would most likely result in large reductions in the catch of marketable *Nephrops*. Recent studies have focussed more on developing trawls to reduce the unwanted by-catch of finfish in *Nephrops* trawls. Analysis of the results of these recent studies is ongoing and the group considered that a fresh appraisal of technical measures progress should be made after these projects report.

1 Introduction

1.1 General remarks

The Nephrops Working Group WGNEPH last met in 2004 prior to the ICES reorganisation of assessment activities into area groups. Some reservations were expressed about the loss of a focus for Nephrops development work and there were concerns about how the process of Nephrops assessment would work out within much larger groups. ICES agreed that a Workshop on Nephrops (WKNEPH) should be set up to meet in 2006 to review the experience of the area groups and to further develop certain aspects of Nephrops assessment and biology. This report is the output from the meeting of WKNEPH 2006.

Transport disruption delayed the arrival of the Chairman until 1400. The meeting was instead opened at 1000 on 24th by Dr Frank Redant. The meeting closed at 1800 on 27th January.

1.2 ToR

2005/2/ACFM24 [Agreed at the 2004 ASC] A **Workshop on *Nephrops* Stocks** [WKNEPH] (Chair: N. Bailey, UK) will meet at ICES Headquarters from 24–27 January 2006 to:

a) review feedback on *Nephrops* assessments from the area-based working groups (WGNSSK, WGNSDS, WGSSDS and WGHMM) and follow up with recommendations for future action;

b) review progress made on the identification of *Nephrops* metiers and fisheries and consider the implications for measurement of directed effort and the likely consequences for stock assessments;

c) review progress made on the calculation of precision levels for the *Nephrops* landings and discard sampling programmes, and the consequences this may have for the design of these programmes;

d) review new information on reporting levels for landings and examine the implications for assessments and advice;

e) consider the application of fishery-independent methods in stock assessment and the provision of catch options;

f) review progress made on the updates of sexual maturity parameters;

g) continue the Working Groups's investigations on the applicability of alternative and current assessment techniques, focussing in particular on length-structured approaches and spatially-structured models and examining robustness to the particular features of *Nephrops* biology;

h) evaluate the effects of mesh size regulations on the catchability of small *Nephrops*.

WKNEPH will report by mid-February for the attention of ACFM, as well as RMC, FTC and LRC.

WKNEPH tackled all 8 of the ToR although time constraints prevented some from receiving as much attention as the topics merited. The outcomes of the group's work are reported below in a series of sections that deal with ToRs grouped according to broad topic. Sections 2 considers the experiences of Nephrops assessment work in the larger area working groups (ToR a). Section 3 deals with two fishery aspects, identification of metiers (ToR b) and reporting levels (ToR d). Sampling precision (ToR c) and sexual maturity parameters (ToR f) are covered in Section 4 on sampling and biological parameters. Section 5 deals with Stock assessment issues, specifically length structured and space structured models (ToR g) and Underwater TV (ToR e) and Section 6 provides an update of mesh selectivity work (ToR h).

1.3 Participants

A list of participants and their contact details is provided in Annex 1.

2 Review of feedback from the area-based working groups (WGNSSK,WGNSDS,WGSSDS and WGHMM)

2.1 General experiences of conducting Nephrops assessments in area based Working Groups

At present, the general aim of ICES is to merge various stock assessment WGs into larger, area based WG, in order to broaden the coverage to also include advice on ecosystem issues and the mixed fisheries, eg. the consequence of bycatch of fish and/or *Nephrops* in the different fisheries for *Nephrops*. Not only the members of the former WGNEPH but all the participants of the current WGNSSK, WGNSDS, WGSSDS and WGHMM felt that this issue was given too little attention in the area based WGs. One reason for this was that the assessment of some species was not finished before the start of the meeting and too much time was devoted for data compilation and adjusting assessments except for technical reasons. Another reason was the large number of ToR and many species to be dealt with. Arguably, some of the groups were beyond a manageable size. On the other hand, a potential advantage with these large groups may be the broadening of expertise on both the technical aspects of the assessment and fisheries interactions.

2.2 Comparison of assessment approaches used in the different area based Working Groups

Of major concern was that functional units of larger management areas (eg Area VII) were assessed by up to three different WGs comprising of different members and using different methods. This resulted in problems later at ACFM collating the advice and landings for the TAC area as a whole.

The type of *Nephrops* assessment methods differed between Functional Units and Working Groups due to various conditions on data availability and quality etc. Below is given a description of assessments carried out in the WGs and an overview of the methods used in the different FUs is presented in Table 2.1.

2.2.1 WGNSSK

Skagerrak and Kattegat.

The assessment of *Nephrops* in Management Area E (Skagerrak and Kattegat) was done as in earlier years using indicator assessment. Uncertainties in growth and slicing into age groups resulted in cohort analysis being considered inappropriate and no analytical assessment was carried out on this MA. As the quotas are not limiting the fishery, landings and effort data from log books data are considered reliable resulting in indicator assessment as in previous WGNEPH. There was no obvious difference in the *Nephrops* assessment in this WG compared to earlier WGNEPH.

North Sea.

Official landings from areas MA I, F and G were not considered reliable and reservations about the age slicing method meant no analytical assessments were presented. Where TV survey data was available this was used to provide harvest options for the stocks in those areas. Without reference to current landings it was difficult to provide a steer for managers to what might be considered the best harvest option.

2.2.2 WGNSDS

There was a general concern about accuracy landing statistics for most species in this WG. Tuning information from commercial *Nephrops* fleets were considered problematic but survey data were available for several stocks. Although analytical age-based assessments were performed with catch data for the west of Scotland (FU11, FU12 and FU13) and Irish Sea (FU14 and FU15) stocks, these were rejected by the group and placed in the Appendix of the WG Report.

The previous ICES practice of basing TAC recommendations on reported landings where there is evidence of under-reported landings was not appropriate, as these stocks appear to be sustainable with higher catch rates. As TACs implemented appear not to limit catches it seemed more appropriate to manage *Nephrops* by effort control rather than by TAC in the short term. It was noted that in such an effort control management regime it would be important to take into account changes in efficiency, fishing patterns and to document catches and effort accurately. In the absence of reliable analytical catch-based assessments the WG recommend a harvest ratio approach based on UWTV survey data for *Nephrops* stocks. As in WGNSSK without reference to current landings it was difficult to provide a steer for managers as to what might be considered the best harvest option.

2.2.3 WGSSDS

The heterogeneity of the Celtic Sea fishery (FU 20–22) was the major problem: the area is exploited by two very different trawling fleets (French: multi-purpose, Irish: more directed *Nephrops*), using different mesh sizes and restrictions on landing size. Otherwise, datasets are different (French assessment since 1987, but poor discard samples; Irish data since 2002 by applying DCR). Hence, XSA (only on male component of the French fleet) gave inconsistent results. Three experimental assessments were carried out by WG and the results indicate the importance of regular time series of discard data. Ultimately the ACFM advice of recent average landings was based on the apparent stability of LPUE trends and landings trends and indications form size data the stock was stable. RGSSDS have recommended further examination of the LPUE trends on a finer spatial scale and an examination of geo-referenced, sediment VMS and survey data to gain a greater understanding of spatial extent of stocks in this area..

2.2.4 WGHMM

XSA was used in the assessment of *Nephrops* as in previous WGNEPH. A Working Document about pooling or assessing sexes separately was presented. Males and females were assessed separately south of Portugal and pooled in the other FUs ie. 23–24, 25 and 26–27. Slicing procedure was discussed. Short term predictions were performed but not taken into consideration for the ACFM advice. Only cpue/lpue and assessment trends were used. A presentation on the mixed fishery issue gave no conclusive results, and did not modify any advice for Southern Shelf stocks.

2.3 Prospects for improvements in the short and longer term

It was the general opinion that there is a potential in area-based assessment WG if data arrives and is worked up in good time before the meeting and less time is used for re-running assessments during the meeting. It is also important for WG members to get early knowledge of what ToR are to be dealt with during the meeting. An alternative to the massive area-based groups and many stocks may be to split into smaller region-based groups providing opportunity for discussions on forecasts in mixed fishery context.

2.4 Recommendations

The general view was that the large regional groups should be given every chance to develop, fully integrate and function efficiently. Although there were some organisational difficulties and disadvantages, the potential gains for consideration of mixed fisheries issues and related topics were too great to rearrange the groups prematurely. It was felt that a useful activity at the beginning of meetings would be a resume of approaches used and background information on stocks such as Nephrops which had previously been dealt with separately. It was also recommended that Chairs of meetings could facilitate efficiency and improved integration by establishing small groups within the Working Group to review and consider outputs. If possible such groups should be established before the meeting and begin to communicate preliminary results and discussion issues early. This would leave more time during the meeting for discussing advice, mixed fishery issues and other ToR topics.

Table 2.1 Summary of assessments carried out in the WGs and an overview of the methods used in the different FUs

	WG	**WGNSSK**										**WGNSDS**					**WGSSDS**	**WGHMM**								
	Management Area	E		F		G	H		I		S	C			J		m	L			N	O		Q		
	Functional Unit	3	4	9	10	7	5	33	6	8	32	11	12	13	14	15	20-22	16	17	18-19	23-24	25	31	26-27	28-29	30
Assessment	XSA								(X)			(X)	(X)	(X)	(X)	(X)	(X)				X	X		X	X	
	LCA			(X)					(X)	(X)																
	Indicator (LPUE)	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Indicator (Mean size)	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X		X(19)	X	X	X	X	X	X
	TV survey			X		X		X	X	X		X	X	X	X	X										
	No assessment																									

(X) NOT USED

3 Aspects of Nephrops fisheries

3.1 Progress on the identification of Nephrops metiers

3.1.1 Background on the approach to metiers in the NE Atlantic

The issue of fleet-based data collection systems was first tackled by the ICES Study Group on the Development of Fishery-based Forecasts (SGDFF), which agreed on the concept of "métiers" as the basic strata for which landings, effort, biological and economic data should be collected (ICES, 2003a, 2004a). Several methods for the determination of metiers were investigated with an emphasis on the use of cluster analyses on landings data. No single methodology has been adopted with detrimental consequences for the groups attempting to analyse the mixed fishery data.

3.1.2 Description of metiers by different countries and evaluation of overall picture

3.1.2.1 Current status

ICES and STECF have been attempting to collate data on landings, discards and effort by métier for the past few years with limited success. During the latest round of assessment working groups, significant progress was made with more nationalities submitting data in the required format and the data for 2004 is the most complete to date. Data for 2003 have also been compiled although there are more missing or poorly defined strata for that year. There remain deficiencies, particularly in discard data and the procedures used to fill missing strata are not ideal.

The ICES division with the most complete data is IV and the following descriptions focus solely on that area. Metier definition is non-standard amongst countries. Some countries have used cluster analysis of catch composition to determine their fleets, others used gear and mesh categories, whilst others have provided no information regarding the technical details of fleets landing Nephrops. Although data were available by metier, the Commission requested that analyses in 2005 should be undertaken at a much higher level of aggregation with fisheries defined by gear and mesh size, combining data over countries. These aggregations are displayed in figures 3.1 and 3.2

Figure 3.1 shows the proportion of Nephrops in the total catch (weight) by fishery where fishery is defined by gear and mesh size. Only those fisheries landing at least 0.5% Nephrops are included, and only catches of the main commercial species (cod, haddock, whiting, saithe, plaice, sole and Nephrops are considered). It can be seen that the catches of otter trawls operating with 70–79 mm are around 75% Nephrops, indicating a highly directed fishery. Otter trawls with 80–99 mm are on the whole operating in a more mixed fishery with around 40% of their landings being Nephrops.

Figure 3.2 shows the proportion of the total catch of Nephrops taken by each fishery segment, only those fleets landing more than 0.5% of the total are shown. From this picture it appears that the dominant fishery is the one operating 80–99 mm otter trawls, identified in figure 3.1 as operating in a mixed demersal fishery, although the more targeted 70–79 mm fishery is increasing in importance.

Figure 3.3 shows the distribution of Nephrops landings by metier as defined by each individual country. All Nephrops metiers have been grouped into one, demonstrating that the majority of Nephrops landings (>70%) are taken in fisheries considered to be targeting Nephrops. This is in contrast to the Commission's use of gear and mesh where the majority of Nephrops catches appear to come from mixed fisheries. There also appears to have been a slight reduction in the proportion of Nephrops landed by specific Nephrops fleets in 2004 compared to 2003.

Experiences in area III (Skaggerak/Kattegat) in relation to the definition of Nephrops directed fisheries indicate significant difficulties in the production of a fixed specification and these are described in detail in the Working Document by Andersen and Munch-Petersen included in Annex 4. In Kattegat and Skagerrak the Nephrops fisheries have been defined on a national level. In Denmark two Nephrops related fisheries were defined: A directed Nephrops fishery using 70–90 mm mesh size and a mixed fishery using 90–105 mm mesh size (where Nephrops, sole, cod and plaice are the most important species). The directed Nephrops fishery (70–90 mm) is primarily determined by the regulation of a minimum of 30% of Nephrops in weight in the catches. From 1 March 2004 the 70–90 mm fishery was further restricted by introduction of compulsory use of square mesh netting in the cod-end (and from 2005 additional compulsory use of a sorting grid). Due to these significant restrictions, all Danish fishermen switched to the 90–105 mm cod-end for targeting *Nephrops*, and presently a *Nephrops* fishery can no longer be distinguished by explanatory physical variables (gear and mesh size specifications) available from either logbooks or sale slips records. For the Swedish fishery, more detailed information in the logbooks is available (such as selection device, single or twin trawl) to separate a directed Nephrops fishery from the mixed fishery.

It appears that catch composition can change within season as a result of biological (migration) and management factors, and also change significantly between seasons as a result of changing stock levels and management rules. The fixed positioning of a threshold dramatically alters the perception of the level of Nephrops targeting through time.

Metier definition around the Iberian Peninsula is also evolving, with a new project getting underway in 2006.

3.1.2.2 The future

Although Nephrops fleets within countries appear to be reasonably well defined, the collection of landing, discard and effort data for the majority of species are not collected by metier in a standardised manner across countries. In addition, these definitions are not necessarily at the level of disaggregation required by fishery-based catch predictions (such as in the MTAC model) or for the evaluation of fishery-based management strategies. In line with these developments, the upcoming revision of the EU's Data Collection Regulation will also include a shift from the current stock-based to a fleet-based data collection system.

The metier concept was further developed and refined by a dedicated workshop under the umbrella of the EC (the so-called Nantes workshop). During this meeting, there was agreement to base the future collection of fisheries data on a matrix-like approach, splitting the information by métier/fishery on the one hand (for the collection of landings, effort and biological data) and by vessel LOA-class on the other (for the collection of economic data). The purpose of this approach was (i) to propose a common data collection framework for both biologists and economists, and (ii) to define a more accurate and generally approved stratification for sampling purposes and international coordination. In this approach, a métier is defined as "a fishing activity which is characterised by one catching gear and a group of target species, operating in a given area during a given season, within which the catches taken by any unit of fishing effort account for the same pattern of exploitation by species size group" .

In autumn 2005, the proposal made by the Nantes workshop was further discussed by the Regional Co-ordination Meetings North Sea and East Arctic (RCM NS-EA) and North-East Atlantic (RCM NEA). The RCMs concluded that a hierarchical sampling framework should be developed, based on the concept of the métier as the lowest level of disaggregation, and proposed a data-collection framework in which métiers are defined as a combination of fishing gear, target assemblage and mesh size (whenever appropriate, combined with other selective features of the gear that affect the species and size composition of the catches, such as separator panels or sorting grids). The table underneath is a partial transcript of the framework suggested by the RCMs, with particular emphasis on the métiers that are of relevance to *Nephrops* as a target or as a by-catch species.

Fishing gear	Target assemblage	Selective properties	Vessel LOA (a)				
Bottom otter trawl	Demersal fish	(b) (c)					
	Mixed demersal - Crustaceans	(b) (c)					
	Crustaceans	(b) (c)					
Multi-rig otter trawls	Demersal fish	(b) (c)					
	Mixed demersal - Crustaceans	(b) (c)					
	Crustaceans	(b) (c)					
Beam trawl	Mixed demersal - Crustaceans	(b)					
Pots	Crustaceans	All					
(a) Sub-division to be decided by STECF Sub-Group on Economic Affairs (SGECA)							
(b) Sub-division by reported mesh size, following EU Regulation 850/1998 and future amendments							
(c) Using a sorting grid or not							

According to the information available to WKNEPH, it should be possible to allocate all fisheries that have *Nephrops* as a target or a by-catch species in the above data matrix, and with respect to the selective properties of the fishing gears used, in the cells corresponding to the 70–89 and ≥90 mm (Kattegat and Skagerrak), 70–79, 80–99 and ≥100 mm (Regions 1 and 2, except Kattegat and Skagerrak), and 55–59, 60–69 and ≥70 mm (Region 3).

The Group was supportive of the approach outlined above, although one outstanding issue that remains to be decided on, is the thresholds (in terms of percentages of *Nephrops* in the landings or revenues by fishing voyage). In particular the thresholds to distinguish between a "clean" demersal fishery and a mixed fishery for demersals and *Nephrops* on the one hand, and between a mixed fishery for demersals and *Nephrops* and a "clean" *Nephrops* fishery on the other.

3.1.3 Implications for the measurements of directed effort

Although the majority of Nephrops landings come from metiers defined as targeting Nephrops, the lack of standard definition for what compromises a Nephrops targeting fleet is unsatisfactory when considering how to combine datasets and raise missing strata. The proposed data collection regime should result in a dramatic improvement in the quality of fishery based data and provide a more rigorous platform for the raising of any missing strata. The current methodology for the filling in of missing strata (i.e. the production of landing and discard numbers at age) is somewhat ad-hoc and global age compositions are often resorted to.

The use of uniform definitions for what constitutes a Nephrops directed fishery raises some interesting issues. At present, where a large number of fish stocks are in a depleted state and quotas are highly restrictive, landings constituting a high proportion of Nephrops (by weight or value) may be common either because the catches were relatively clean, or lack of quota leads to high discarding levels. Should stock recovery occur, using a high fraction of Nephrops as the defining criterion may result in an apparent shift of effort away from a directed fishery. It might be preferable to define Nephrops directed trips as those operating with relevant gear on known Nephrops grounds, however it is hard to see how this level of definition might be incorporated into the proposed structure.

3.1.4 Consequences of assessment and management procedures

In order for the proposed metier definition and data collection regime to function effectively there will need to be additions made to the mandatory fields recorded in logbooks. Simply requesting that the additional fields are recorded on a voluntary basis is unlikely to generate the high level of full data reporting required. In a similar vein it will become even more important that the relevant national data collection agencies to be more thorough in their record keeping. A failure to record key parameters such as gear type or mesh size will compromise the validity of the database.

3.2 Information on reporting levels for Nephrops landings

This section addresses ToR d. Review new information on reporting levels for landings and examine the implications for assessments and advice

Concerns were first expressed at the 2003 meeting of WGNEPH that official landings did not reflect actual landings for some of the Nephrops stocks. Since then the impact of mis-reporting has been considered at each subsequent meeting and round of assessments.

Misreporting, if not accounted for, not only raises problems in drawing conclusions about stock status but also for managers in setting appropriate TACs, particularly since Nephrops TACs are precautionary and a number are based on historic landing

3.2.1 Updates on reporting levels

At the 2004 WGNEPH meeting the implications of mis-reporting for analytical stock assessments were investigated (ICES, 2004b). A simulation was carried out that demonstrated that a constant level of misreporting would have a scaling affect on the stock estimates. Absolute estimates of stock size and recruitment would be incorrect but trends and inferred status, including absolute estimates of F could still be valid. At the time, with little other than anecdotal information, the assumption was, with those stocks affected, that any misreporting had been constant and therefore would not affect the signals from their assessments. Catch forecasts would, however, be impaired.

Since this investigation the UK Nephrops industry action group provided a series of estimated landings which demonstrated the scale of the problem but the detail was insufficient to make a decision on the consistency of under reporting or revise the reported landings used in the round of 2005 assessments. As a consequence of this uncertainty, analytical assessments were not presented at the regional WGs for some of the Nephrops stocks (See Section 2).

The problems associated with misreporting are not exclusively a Nephrops problem, and to help ACFM, a suggestion was made at the WGSSDS that for each stock assessed, a standard table was completed listing the possible types of misreporting - whether it be species or area misreporting, under or over reporting. Details were included on occurrence, the scale of the problem, if any, and whether it was accounted for. Further comment was given on the potential impact on the assessment and whether matters were expected to improve. The approach was adopted by WKNEPH to demonstrate the extent of the problem within Nephrops stocks. Table 3.1 is a first attempt at summarising information and comments refer to 2005 data only. These data are still likely to be reviewed in preparation for the 2006 regional WGs.

3.2.2 Prospects for improvements in reporting levels in 2006

Although there is anecdotal information to suggest there has been an improvement in the accuracy of reported landings in 2005 for some of the FUs affected in 2004, misreporting seems likely to still be common and wide spread. UK legislation on the registration of buyers and sellers, in place for 2006, should improve confidence in future reported landings for the

UK. Some countries already have the approach of comparing official statistics with sales notes and correcting for discrepancies. The new UK legislation adopts the same procedure but enforces correction if any discrepancy occurs. This should improve figures for the 2007 assessments but historic landings are unlikely to be corrected and therefore analytical assessments, dependent on time series of landings, are unlikely to be reliable for some time in those stocks affected.

Recent increases in TACs for areas IV, VIa and VII for 2006 may relieve some of the more quota restrained fisheries within these areas but only if effective effort is restrained. Even if TACs do not appear to be restrictive – the way quotas are managed at a national and local level (divided amongst FPOs and non-sector vessels) means that individual quotas can still be restrictive.

3.2.3 Implications of recent information on reporting levels

It is clear that uncertainties in historic landings limits the opportunities for using analytical assessments such as XSA which require long time series of landings data. With little prospect of revising the earlier figures for those stocks affected, it will be some time before a sufficient time series is built up.

Despite the potential improvements in national and international estimates of Nephrops landings which should benefit assessments in 5–10 years, there is an increased risk of misreporting if vessels diversify from more restricted fisheries to Nephrops stocks and the current, more generous, Nephrops TACs again become restrictive. As well as investigating what the differences are between official and unrecorded landings, renewed effort needs to go into limiting the potential for misreporting and ensuring reported landings are more robust.

The assessment of these stocks does not depend entirely on the results of XSA, other lines of evidence are reviewed to gain an appreciation of stock status. Trends in mean size, LPUE and CPUE can be indicative of stock status although it is difficult to know whether trends in LPUE and CPUE are entirely independent of misreporting since different rates of mis-reporting of landings and effort figures would distort the trends

The use of fishery independent estimates of abundance, for example underwater TV burrow counts, is providing an alternative approach to advice and management that is potentially robust to the existence of misreporting for a number of stocks where such surveys have been carried out. In the past, trends in these indices were used as a means of corroborating and interpreting trends in the XSA results. For the Fladen stock, harvest rates have been calculated and used to provide advice since 1999; this approach was extended to other areas in 2005.

In 2005 at WGNSSK, available TV surveys were used to provide management options for all those stocks where landings were uncertain. A series of harvest options in the form of harvest rates and potential future landings were provided for managers. It was difficult, however, to provide a steer on the most appropriate choice and ACFM made reference to current landings when considering the best option. In situations of uncertain reporting accuracy, use of landings is likely to lead to inappropriate catch advice. STECF made use of the TV data in conjunction with yield per recruit based target mortality rates to guide the choice of harvest rates – this method is discussed in Section 5.

The ability to estimate current levels of F would provide a better way of steering management advice towards an appropriate harvest option. Despite reservations, length cohort analysis (LCA) may be an appropriate method as it does not need an extended time series of data relying instead on the shape of the length distribution.

For the future, a series of correct landings with coincident abundance estimates will provide a range of observed harvest ratios. Assuming some understanding of conditions for sustainability it would be easier to focus on a harvest option for the coming year. Currently, uncertainties about some historic landings means it is unclear just what harvest ratios have actually been sustained by Nephrops stocks.

While Nephrops stocks are managed by TACs, reference to current landings will remain important, so that ensuring these figures are correct or bias-corrected should always be a priority irrespective of the method used to assess the stock.

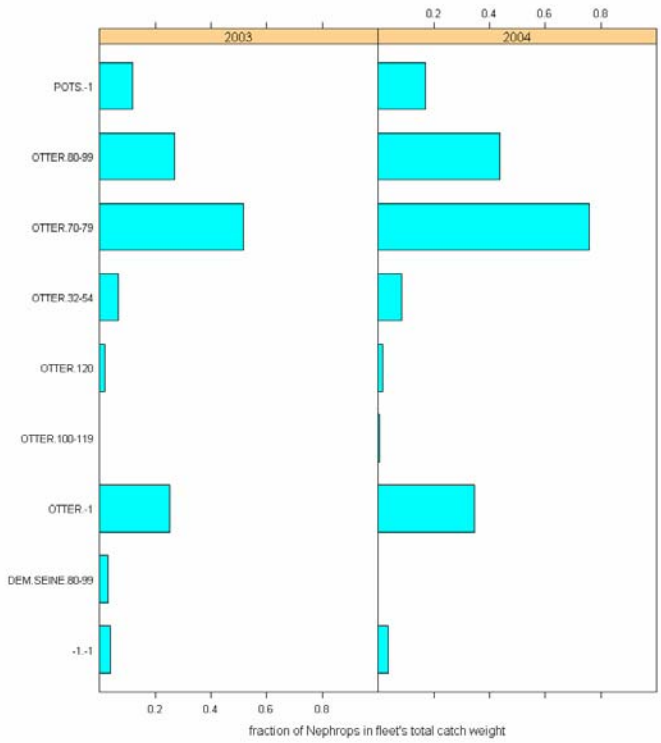


Figure 3.1. Proportion of Nephrops in the total catch of a fleet. Catch defined as landings plus raised discards as estimated by STECF, species included are cod, haddock, whiting, saithe, plaice, sole and Nephrops. Only those gear types where the proportion of catch is greater than 0.5% are shown. Fleets defined here by gear type and mesh size, summed over all countries. –1 indicates unspecified gear or mesh. Data are for area IV only.

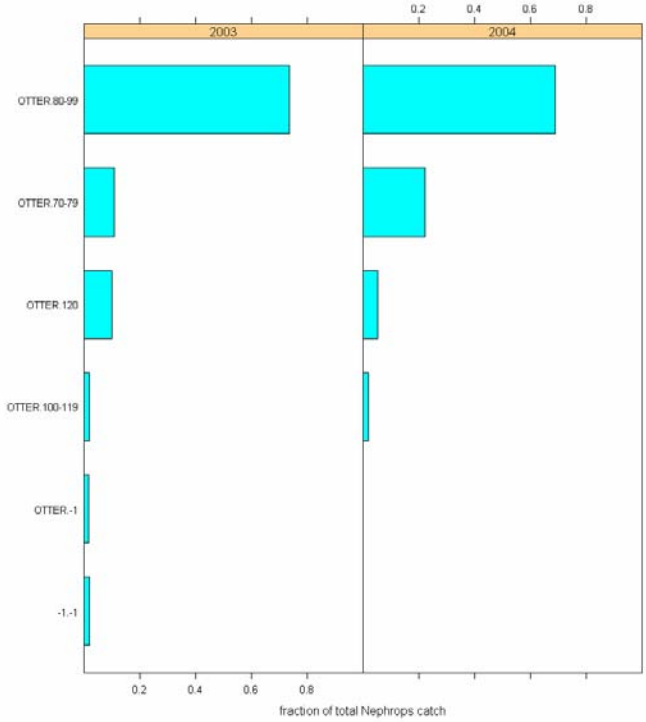


Figure 3.2. Proportion of total Nephrops catch by fleet. Only those gear types where the proportion of catch is greater than 1% are shown. Fleets defined here by gear type and mesh size, summed over all countries. –1 indicates unspecified gear or mesh. Data are for area IV only.

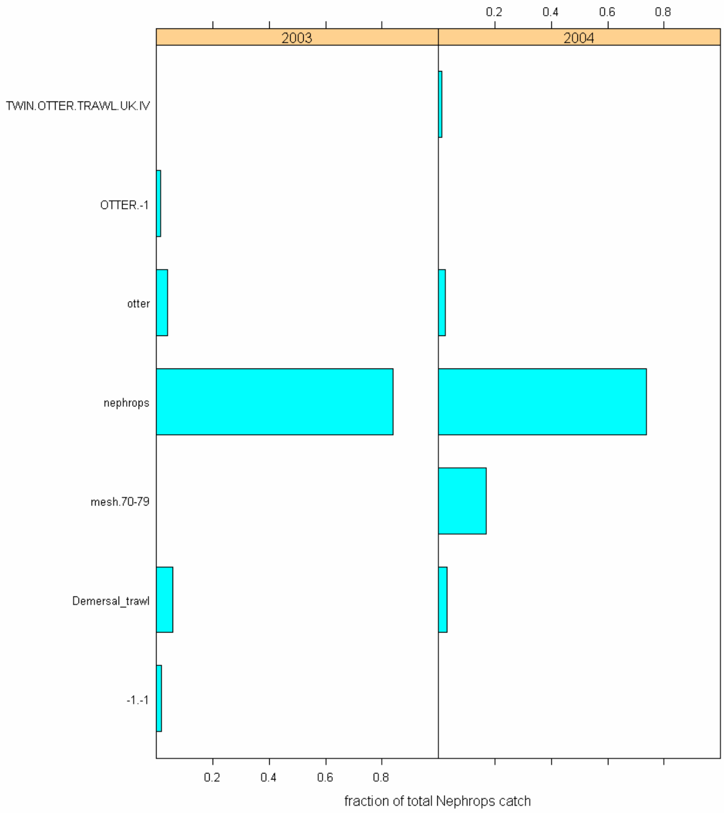


Figure 3.3. Proportion of total Nephrops catch by fleet. Only those gear types where the proportion of the total catch is greater than 1% are shown. Fleets defined here are metiers as defined by individual country except for specific Nephrops metiers which are grouped together. –1 indicates unspecified gear or mesh. Data are for area IV only.

Table 3.1. Summary of the levels of reporting of Nephrops landing statistics by stock.

Year	MA	FU	Countries	TAC area	Countrries	Area misreporting	Under reporting	Over reporting	Species misreporting	Impact and forecast/Comments
2005	A	1	Iceland	?	Iceland	?	?	?	?	?
	B	2	Faroes	?	Faroes	?	?	?	?	?
	C	11	North Minch	VIa	UK	N	M	N	N	**2005:** Only minor levels of under-reporting. Anecdotal evidence to suggest some over reporting did happen historically, but none in 2005. TV surveys are conducted for each of these stocks. **2006:** UK Registered Buyers and Sellers legislation will improve accuracy. TAC less rectrictive.
		12	South Minch	VIa						
		13	Clyde	VIa						
	E	3	Skagerrak	IIIa	Denmark Sweden Norway	N	N	N	N	**2005:** Confident that any mis reporting is insignificant. Official landings come from corroboration of sales notes and EU logbooks. TAC is not restrictive. **2006:** As 2005
		4	Kattegat	IIIa						
	F	9	Moray Firth	IV	UK	N	M	N	M	**2005:** Annecdotal evidence to suggest some fleet specific under and species mis-reporting. TAC restrictive. TV survey conducted for Moray stock. **2006:** UK Registered Buyers and Sellers legislation will improve accuracy. TAC less rectrictive.
		10	Noup	IV						
	G	7	Fladen	IV	UK	N	S	N	M	**2005:** Annecdotal evidence suggests that under-reporting has been substantial. TAC restrictive. TV survey conducted. **2006:** UK Registered Buyers and Sellers legislation will improve officia statistics. TAC still rectrictive but less so.
					Denmark	N	N	N	N	**2005:** Effort appears to have increased. Confident that any mis reporting is insignificant. Official landings come from corroboration of sales notes and EU logbooks. TAC is not restrictive. **2006:** As 2005

U = Unknown; N = Not a problem; C = Corrected in landing statistics M = Minor S = Substantial

Table 3.1. Contd.

Year	MA	FU	Countries	TAC area	Countrries	Area misreporting	Under reporting	Over reporting	Species misreporting	Impact and forecast/Comments
2005	H	5	Botney Gut	IV	Belgium	N-C	C	N	N	**2005:** Sales notes are compared with reported landings and figures are corrected. So levels of misreporting of Nephrops are not a concern. TAC non-restrictive. **2006:** As 2005
					Denmark	N	N	N	N	**2005:** Confident that any mis reporting is insignificant. Official landings come from corroboration of sales notes and EU logbooks. TAC is non-restrictive. **2006:** As 2005
					Netherlands	U	N	N	N	**2005:** There is no evidence to suggest that vessels would misreport the area fished, but confident that any mis-reporting is insignificant. Official landings come from EU logbooks. TAC is not restrictive. **2006:** As 2005
					UK	U	U	U	U	**2005:**. Little suggestion that there is any misreporting of Nephrops from this area **2006:** Landings from this area have increased in recent years. will need closer monitoring. UK Registered Buyers and Sellers legislation will improve confidence in the landings. TAC less rectrictive.
		33	Off Horn Reef	IV	Denmark	N	N	N	N	**2005:** Confident that any mis reporting is insignificant. Official landings come from corroboration of sales notes and EU logbooks. TAC is non-restrictive. **2006:** As 2005
					Belgium	N-C	C	N	N	**2005:** Sales notes are compared with reported landings and figures are corrected. So misreporting of Nephrops is not a concern. TAC non-restrictive. **2006:** As 2005

U = Unknown N = Not a problem C=Corrected in landing statistics M=Minor S=Substantial

Table 3.1. Contd.

YEAR	MA	FU	COUNTRIES	TAC AREA	COUNTRRIES	AREA MISREPORTING	UNDER REPORTING	OVER REPORTING	SPECIES MISREPORTING	IMPACT AND FORECAST/COMMENTS
2005	I	6	Farn Deeps	IV	UK	N	M	N	N	**2005:** Annecdotal information suggests some under reporting occurs. TAC is restrictive. TV survey conducted for both stocks. **2006:** UK Registered Buyers and Sellers legislation will improve official statistics. TAC still rectrictive but less so. May continue to be restrictive if effort increases.
		8	Firth of forth	IV						
	S	32	Norwegian Deep	IV	Denmark	N	N	N	N	**2005:** Confident that any misreporting of Nephrops is insignificant. Official landings come from corroboration of sales notes and logbooks. TAC was exceeded. . **2006:** Increases in the EU TAC increases the risk of misreporting landings from outside EU as caught inside. Landings should be closely monitored.
					Norway	?	?	?	?	?
	J	14	Irish Sea East	VII	UK	N	S	N	N	**2005:** Evidence suggests there was considerable under-reporting in this area. TV surveys conducted in FU15. TAC restrictive. **2006:** UK Registered Buyers and Sellers legislation will improve UK official statistics. TAC less restrictive but evidence suggests that reporting levels are unlikely to improve.
		15	Irish Sea West		Ireland	N	U	U	U	**2005:**. Levels of undereporting are unknown, but there is some evidence of misreporting. **2006:** As 2005
	L	16	Porcupine Bank	VII	France	N	N	N	N	**2005:**. Little suggestion that there is any misreporting of Nephrops from this area. **2006:** As 2005
					Ireland	N	U	U	U	**2005:**. Levels of misreporting are unknown **2006:** As 2005
					Spain	N	N	N	N	**2005:** Confident that any mis reporting is insignificant. Landings data come from sales notes. TAC is non-restrictive. **2006:** As 2005

U = Unknown   N = Not a problem   C=Corrected in landing statistics   M=Minor   S=Substantial

Table 3.1. Contd.

YEAR	MA	FU	COUNTRIES	TAC AREA	COUNTRRIES	AREA MISREPORTING	UNDER REPORTING	OVER REPORTING	SPECIES MISREPORTING	IMPACT AND FORECAST/COMMENTS
2005	L (contd.)	17	Aran Grounds	VII	Ireland	N	U	U	U	**2005:**. Levels of misreporting are unknown but there is some evidence of under reporting in the past for individaul trips **2006:** As 2005
		18-19	Irish Coast	VII	France	U	U	U	U	**2005:**.Little suggestion that there is any misreporting of Nephrops from this area **2006:** As 2006
					Ireland	N	U	U	U	**2005:**. Misreporting practices in this area are unknown. **2006:** As 2005
					Spain	N	N	N	N	**2005:** Confident that any mis reporting is insignificant. Official landings come from corroboration of sales notes and EU logbooks. TAC is non-restrictive. **2006:** As 2005
					UK	U	U	U	U	**2005:**. Little suggestion that there is any misreporting of Nephrops from this area. **2006:** As 2005
	M	20-22	Celtic Sea	VII	France	N	N	N	N	**2005:**. Little suggestion that there is any misreporting of Nephrops from this area. **2006:** As 2005
					Ireland	N	U	N	U	**2005:**. Misreporting practices in this area are unknown. Reported landings from this area have increased over the last few years **2006:** As 2005
	N	23-24	Bay of Biscay	VIIIa,b	France	N	U	N	N	**2005:**. Little suggestion that there is any misreporting of Nephrops from this area. However TAC uptake was swift and a increase was negotiated half way through the year. **2006:** TAC still restrictive. Close monitoring of the landings statistics needs to be maintained.

U = Unknown N = Not a problem C=Corrected in landing statistics M=Minor S=Substantial

Table 3.1. Contd.

YEAR	MA	FU	COUNTRIES	TAC AREA	COUNTRRIES	AREA MISREPORTING	UNDER REPORTING	OVER REPORTING	SPECIES MISREPORTING	IMPACT AND FORECAST/COMMENTS
2005	O	25	North Galicia	VIIIc	Spain	N	N	N	N	**2005:**. Confident that any mis reporting of Nephrops is insignificant. TACs are not restrictive. 2004 and 2005 landings had to be estimated from market sampling programme. **2006:** As 2005
		31	Cantabrian Sea	VIIIc	Spain	N	N	N	N	**2005:** Confident that any misreporting of Nephrops is insignificant. Landings come from sales notes. TAC is non-restrictive. **2006:** As 2005
	Q	26-27	West Galicia and North Portugal	XIa	Spain	N	N	N	N	**2005:** Confident that any misreporting of Nephrops is insignificant. Official landings come from sales notes. TAC was non-restrictive. **2006:** As 2005
		28-29	SW and S Portugal	XIa	Portugal	N	C	N	N	**2005:** Confident that any misreporting of Nephrops is corrected. Official landings come from sales notes and EU logbooks. No reason for area to be misreported but spatial information not available. TAC was non-restrictive. **2006:** Hake and Nephrops recovery plan has restricted fishing. Landings will need to be closely monitored
		30	Gulf of Cadiz	XIa	Spain	N	N	N	N	**2005:** Confident that any misreporting of Nephrops is insignificant. Official landings come from corroboration of sales notes and EU logbooks. TAC was non-restrictive. **2006:** As 2005

U = Unknown N = Not a problem C=Corrected in landing statistics M=Minor S=Substantial

4 Biological Sampling and population parameters

4.1 Progress in the estimation of precision levels in Nephrops sampling

4.1.1 Introduction

Following EU regulation 1639/2001, member states are obliged to provide precision levels for landings and discard sampling programmes. In order to fulfil this obligation, three projects have been carried out over the last year and one study started just recently. At the Sea Fisheries Department in Belgium a study was started on the accuracy of different regimes for the length-sampling of the *Nephrops* landings in the market sampling. The Marine Institute in Ireland and Ipimar in Portugal began a study on the evaluation of the precision of length-frequency samples from the Western Irish Sea and Portuguese waters, respectively. The Instituto Español de Oceanografía developed a tool for calculating the precision of biological sampling as carried out under the Data Collection Regulation.

Limited studies have been carried out to calculate precision levels for the Nephrops discard sampling programmes.

4.1.2 Examples of attempts to investigate precision levels in Nephrops samples

Belgium

The approach taken in this study on the accuracy of different regimes for the length-sampling study was the one suggested by Hampton and Majkowski (1987), and which had already successfully been applied to selectivity studies and the length-sampling of brown shrimp, *Crangon crangon* (Polet and Redant, 1999; Redant, 1996).

The starting point in this approach is a theoretical, user-defined population, composed of a succession of age cohorts of known size, which grow along a user-defined Von Bertalanffy growth curve, and which are subjected to user-defined natural and fishing mortality rates. This theoretical population is then "fished" along user-defined catchability and selectivity patterns (and in the case of *Nephrops*, along user-defined availability curves for the females, to reflect high accessibility to trawling during the non-berried season and low accessibility during the berried season), to create a theoretical, unsorted catch of known size and sex composition. The catch is then sub-divided into discards and landings by means of a user-defined fishermen's selection curve, and the landings are further sub-divided into market classes by means of user-defined grading curves. The outcome is a set of market classes (tails, medium and large whole *Nephrops*) of known size and sex compositions. All parameters used in the "generation process", are based on observations in the field, to ensure realistic size compositions of the catches, landings and market categories.

The market categories thus generated are then "sampled" through a system of computer-generated random sampling, using different sampling strategies with respect to sample size, sampling of sorted versus unsorted landings, etc. Next, the numbers in the total landings are back-calculated from the "samples", using the appropriate raising factors, and the back-calculated size-frequency distributions are compared to the real size-distribution of the theoretical landings, across a pre-set number of repetitions of each sampling regime. The outcome of the exercise gives an idea on the accuracy of the sampling regimes tested, and allows definition of the optimum sampling regimes with respect to the estimates of the numbers-at-length (for males and females separately and for the two sexes combined), the sex ratios by size class, etc.

The analysis of the data has not been completed yet, but preliminary results show that the current sampling regimes applied in the Belgian *Nephrops* sampling programme (200-300 animals per market category per sampling) may not be sufficient to meet the precision requirements laid down in the EU Data Collection Regulation.

Ireland

A working document (Annex 5, Gerritsen *et al*., 2006) was presented to the workshop describing the evaluation of the precision of length-frequency samples from the Western Irish Sea. The two main sample types collected by the Marine Institute are catch and discards (this includes small Nephrops and heads from Nephrops where the tails were retained).

The precision of individual samples during 2003–2004 was examined by obtaining the mean weighted coefficient of variation (MWCV). The mean CV of the total length distribution is weighted by the number of fish in each length class as the precision of the abundant length class is more important than the rare length classes. During 2003–2004 a total of 146 samples were taken, most of them could be split into catch and discard components and further split up by sex ending up with a total of 480 samples. The MWCV of these samples is closely related to the sample size divided by the number of length classes in the sample. The precision increases rapidly up to sample sizes of around 10 measurements per size class. Increasing the sample size much over 30–40 per size class results in a negligible increase in precision. As a rule of thumb a sample size of 10 times the number of size classes in the sample is suggested. An increase in the width of the size classes e.g. from 1mm to 2mm, would result in an increase in precision in each size class and therefore also in the MWCV. The width of the size classes is therefore an important consideration. Ultimately if length data is sliced into age data covering several size classes then this may reduce the requirement for extremely precise data for each 1mm interval.

The precision of population estimates was estimated by the MWCV of the population length frequencies. As a sample from one haul is not considered to be a random sample from the population, bootstrapping was used to take into account the between sample-variation. Samples from the Irish Sea were taken as an example to explore the precision of the estimates of the length distribution in the population. The MWCV was only weakly related to the number of individuals per size class in the sample. As the MCWV was not clearly related to the number of samples in the estimate, there is an indication that the population was not uniformly mixed and that a proportion of the variability is due to differences between samples. This implies that to improve the accuracy and precision of the population estimates, the number of samples should be increased without the need of increasing the sample size. However, the time and cost required to obtain individual samples is rather high compared with the time and cost spent processing the sample.

Spain

The Instituto Español de Oceanografía in Spain developed a tool (INBIO) to calculate the precision levels of the biological sampling of species, including Nephrops, as described in the DCR. The application was used to determine the precision levels of the sex ratio of landings in all Spanish *Nephrops* stocks and was also applied to the sexual maturity sampling in FU 30 (Spain, Technical Report of DCR Programme – 2004). The INBIO tool could also be used to calculate the precision level of length distributions.

4.1.3 Consideration of sampling designs and future plans for estimation of precision

Scotland is in the process of analysing and reviewing its discard and market sampling programmes and started with demersal fish sampling on the west coast of Scotland. Recently its focus has shifted to the North Sea and work is planned to examine precision in sampling programmes using adaptations of methods developed for the Norwegian catch sampling programmes. Norwegian sampling involves collecting age, length and weight data for all fish in a sample of 80 from each vessel sampled. The variance estimation takes account of measurement error at the vessel level, inter-vessel variability and also structural errors from sampling different areas and seasons. In the case of the latter, the model includes previous information about structure so as to constrain the process. The adaptation to Scottish sampling methods will take some time and part of the study may draw on techniques being proposed for development in the Common Tools project led by Joel Vigneau from IFREMER, hopefully in 2006. So far, the Scottish analysis has not considered Nephrops sampling but is expected to do so once methodologies have been established.

The preliminary results from the Belgium study show that the current sampling scheme might not be sufficient to meet the precision requirements from the EU Data Collection Regulation. Nevertheless, the examples described above and the conclusions drawn from these studies do not result in an urgent need to change the sampling strategy on the short term. An increase in the number of samples, without increasing sample size, could improve the precision and accuracy of the population estimates as shown in the example from Ireland. The extra time and cost required to obtain extra individual samples is high compared to processing a larger sample.

4.2 Sexual maturity parameters

4.2.1 Background on the estimation of size of sexual maturity in Nephrops

In the wake of the 2004 meeting of WGNEPH, an extra meeting day was organized on data collection issues in relation to *Nephrops*, more particularly on the six-yearly updates of sexual maturity and growth that are required under the EU Data Collection Regulation (DCR), and on how these updates could be harmonized across countries and stocks. Outcomes of this meeting included agreement on a common timeframe for the updates of sexual maturity (and growth) and on a standard methodology for the maturity updates for both males and females.

At its 2006 meeting, WKNEPH reviewed the data collected in 2001–2005 on male and female sexual maturity. In order to ensure maximum comparability between the outcomes for the different stocks, it was decided to:

- Analyse all datasets with the same statistical tools.
- Restrict the analysis of both the male and the female data to the datasets that showed sufficient size coverage on both sides of the presumed size at 50% maturity (L_{50}).
- Restrict the analysis of the female data to datasets that were collected within the same time-window relative to the onset of spawning. This was considered to be of critical importance, since data that are collected too long before or after the onset of the spawning season may underestimate the numbers of mature females per mm size class, and hence give an over-estimate of the L_{50}'s.

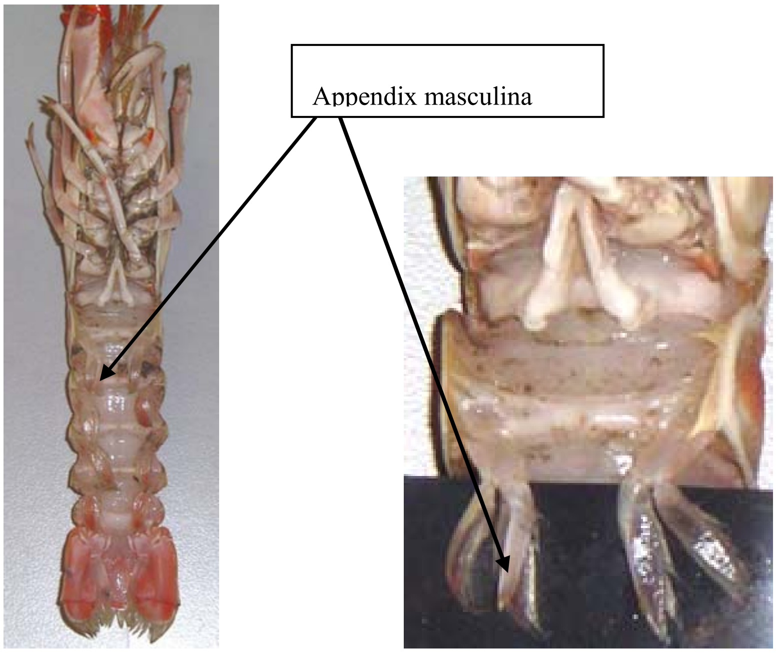
An overview of the stocks covered, the number of sexual maturity datasets collected on each stock, the numbers of animals in each dataset and their size ranges, is given in Table 4.1.

4.2.2 Methodology for a consistent approach to estimating male maturity

Functional maturity in males is thought to be related to a change in growth rate of the appendage masculina. Although spermataphores are present in small males, they do not appear to be physically capable of mating until a certain size is reached.

The standard methodology for measuring appendix masculina on male *Nephrops* is as follows.

- Figure 4.1 shows the ventral surface of a male *Nephrops* indicating the position of the second pleopod and appendix masculina.
- Remove second pleopod at base for easier measurement (Figure 4.2). No significant difference (P>0.05) was found on comparing measurements of appendix masculina on the left and right pleopods (McQuaid, 2002).
- If not measuring immediately, then store in 70% alcohol.
- To measure place the pleopod on a Petri dish and remove the base and second endopodite which does not have the appendix masculina attached.
- The appendix masculina is then gently stretched away from the endopodite (Fig 4.3) and the length measuredto 0.1mm. The endopodite could be removed but for smaller individuals this would have to be done under a microscope to ensure that the base of the appendix masculina is not removed also. Figure 4.3 indicated where the length was measured at the centre of the appendix masculina from the base to the tip below the hairs.



a b

Figure 4.1. Ventral view of male (a) with location of appendix masculina indicated (b).

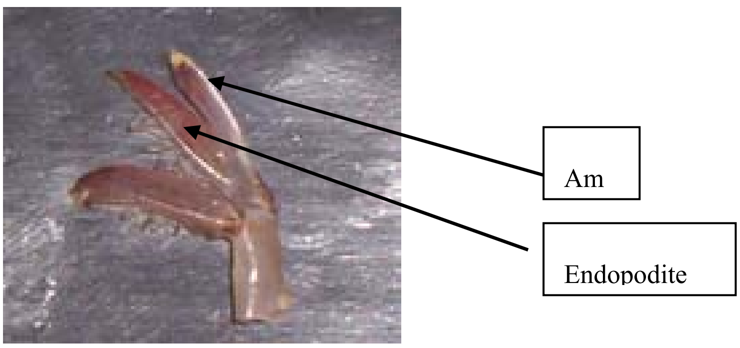


Figure 4.2. Second pleopod with appendix masculina and endopodite labelled.

Measure of Appendix masculina length

Fig 4.3. View at x 64 magnification (incl. objective lens) with ocular micrometer visible. The black arrow indicate where the appendix masculina length measurement is taken.

Changes in growth rate of the appendage masculina from four *Nephrops* functional units were identified using the segmented regression function in R. This function searches for the optimal value from the dependent variable at which to split the series into two and returns the regression statistics for both lines along with the breakpoint value itself.

Breakpoints have been estimated for a number of functional units, and where possible intra-unit variation in breakpoint has been explored by analysing hauls separately. Seven functional units are explored plus samples from the shelf edge off the west coast of Scotland.

4.2.3 Results on the size of sexual maturity in males

Figure 4.4 shows the split regression lines, breakpoints, standard errors of the breakpoints and the resulting number of observations above and below the breakpoint. Each figure gives the estimate of breakpoint, its standard error and the number of data points above/below the breakpoint respectively. Data are also summarised in Table 4.2

No breakpoint could be found for FUs 4,7, 28 nor the shelf edge stock. For all other FU's or hauls the splitting of the data into two as indicated by the breakpoint was highly statistically significant.

In the majority of cases the breakpoint is estimated to be around 30mm. In those cases where the breakpoints are significantly lower than 30mm, the difference is only a couple of mm. This may be as a result of differences in growth rate rather than any significant differences in maturity at age.

The analyses of four hauls within FU5 show that there is considerable variation in the breakpoint estimates within a ground both in terms of the position of any breakpoint, but also in the magnitude of change in growth rate. The range of breakpoints within this area covers the range of those seen across all other FU's suggesting that apparent regional differences in breakpoint are simply noise.

Figure 4.5 shows the breakpoints for the various FUs for ease of comparison. The more southerly FU's, whilst having relatively low breakpoints are no lower than those of more northerly latitudes.

Strictly speaking, there is measurement error in both the carapace length and the appendage masculina length and any regressions should be functional regressions which take this into account. It was widely accepted within the group however that the measurement error is considerably greater in the appendage masculina compared to the carapace and standard linear regression was therefore justifiable. Although protocols for the measurement of the appendage masculina have been put forwards, different approaches are taken within the various labs and sometimes even by personnel within the labs undertaking the measurement. These differences may introduce different levels of bias in the appendage masculina measurements. It is therefore unwise to merge datasets between laboratories and where possible analyses should be undertaken using disaggregated data (i.e. haul). Such biases should not affect the estimation of breakpoints in carapace length.

4.2.4 Methodology for a consistent approach to estimating female maturity

Input data sets for female sexual maturity analysis are summarized in Table 4.1. In total, 46 datasets were available, for 17 different stocks.

Analysis of the maturity data included the plotting of maturity ogives to the proportions of mature females over the full range of mm size classes examined. Plots were either of the asymmetrical log-log or of the symmetrical logit type, depending on the overall shape of the relationship between proportions mature and size. Estimates of the L_{50}'s were then derived from the maturity ogives, as the length corresponding to 50% maturity on the plots. The results (a and b values of the maturity ogives and estimates of the L_{50}'s for all datasets) are summarised in Table 4.3. Examples of the maturity plots for females are shown in Figure 4.6. A graphical overview of the L_{50}'s for the different stocks is shown in Figure 4.7.

A Working Document presented by Colm Lorden (Annex 6) discusses precision issues associated with estimation of female maturity.

4.2.5 Results on the size of sexual maturity in females

The following general conclusions can be drawn from the preliminary analysis made by WKNEPH:

- The L_{50}'s of female *Nephrops* are generally higher in the Skagerrak and Kattegat (FUs 3 and 4) than in the adjacent North Sea area.
- Within the North Sea and the western waters (FUs 5 to 23–24), there are no systematic differences in the L_{50}'s between stocks. The levels of variability in the L_{50}'s within stocks are of the same order of magnitude as the differences between stocks.
- The L_{50}'s of the southern Iberian stocks (FUs 28 to 30) are considerably higher (between 28 and 38 mm CL) than in the western waters. This seems to confirm the general idea that the biological features of the deep-water stocks on the southern edge of the Iberian Peninsula resemble those of the Mediterranean deep-water stocks, rather than those of the other, more northern Atlantic stocks (Bell *et al*., 2006).
- For stocks where such a comparison was possible (FUs 5, 13, 15, 23-24 and 29), the L_{50}'s calculated by WKNEPH were similar to those reported in the literature from earlier studies (see Bell *et al*., 2006, for an overview).

The level of variability in L_{50}'s between smaller locations within a same stock (sub-areas, stations, hauls), or between successive years, can be considerable (see e.g. the results for FUs 3, 12, 15 and 23–24). Due to time constraints, WKNEPH was unable to fully analyse all the available datasets, but it would be worth giving this further attention to better appreciate the geographical and annual differences in L_{50}, and their possible causes.

4.2.6 Consequences of findings for the assessment and management of Nephrops

For stocks where the L_{50}'s differ substantially between locations, the choice of an appropriate average L_{50} for the calculation of the spawning stock biomass (SSB) may be problematic. The choice for a higher (or lower) L_{50}, will result in lower (or higher) proportions of mature animals in the younger age groups, and hence in a lower (or higher) estimate of the SSB.

However, since maturation in *Nephrops* seems to be age- rather than size-dependent (see Bell *et al.*, 2006, for an overview), the choice for a higher (or lower) L_{50} should, in principle, go with the choice for a faster (or slower) growth rate, and the effect of the choice of the maturity parameters on the estimates of the proportions of mature males or females at age should be limited. A critical limitation here is that data on the variability in growth rate within *Nephrops* FUs is ultimately scarce. In the absence of such information, the generation of nominal age groups through slicing of the size frequency distributions is bound to make use of "average" growth curves, and there is no opportunity so far for a fine-tuning of the choices for the growth and maturation parameters.

4.3 Comments on other parameter requirements

Although the focus implied by the ToRs was the provision of an update of maturity parameters, there was also some discussion of other biological parameters. The group agreed that the most pressing requirement is for information on growth rate and also the variability of growth between individuals (see Section 5.1). Before significant progress can be made in the application of emerging length structured models, growth parameter values are required for many of the Functional Units. In some cases values are currently ‘borrowed’ from other stocks and even where estimates have been made these need updating. Although the EU Data Regulation, in principle, has in place a requirement to update growth parameters, WKNEPH does not believe that the type of information being gathered will provide suitable material. A coordinated growth study utilising tagging and other methodologies is urgently needed. Unfortunately, at present, national laboratories are not generally funding such work to the required scale and the group felt that a coordinated approach to the European Commission might be worthwhile.

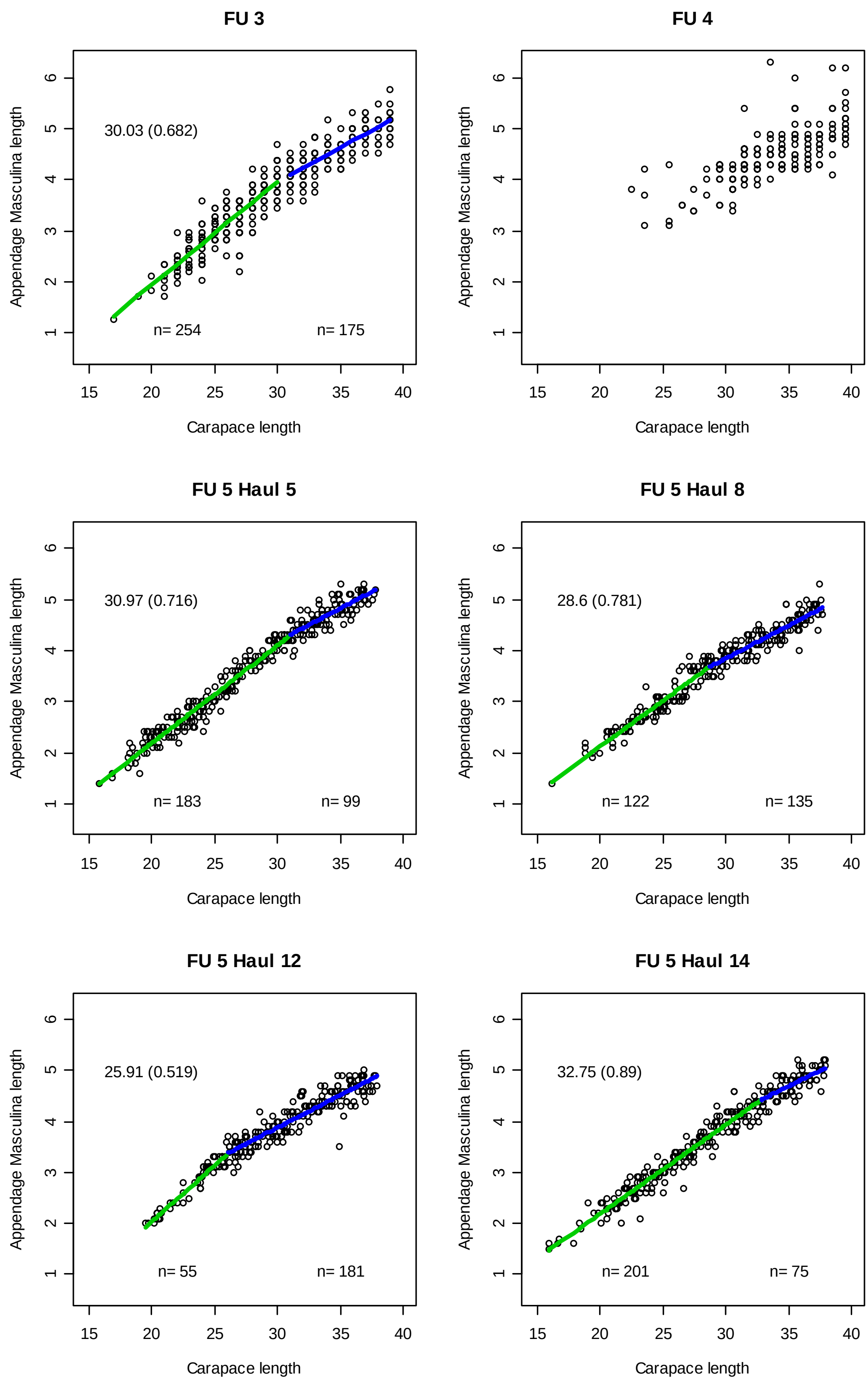


Figure 4.4 Appendage masculina length (mm) vs carapace length (mm) for seven functional units of *Nephrops*, plus shelf edge samples from the west of Scotland. Segmented regression lines with breakpoints are shown except for FUs 4, 7,28 and the shelf edge where no significant breakpoints could be found. Values shown are the breakpoint with the Standard error given in brackets

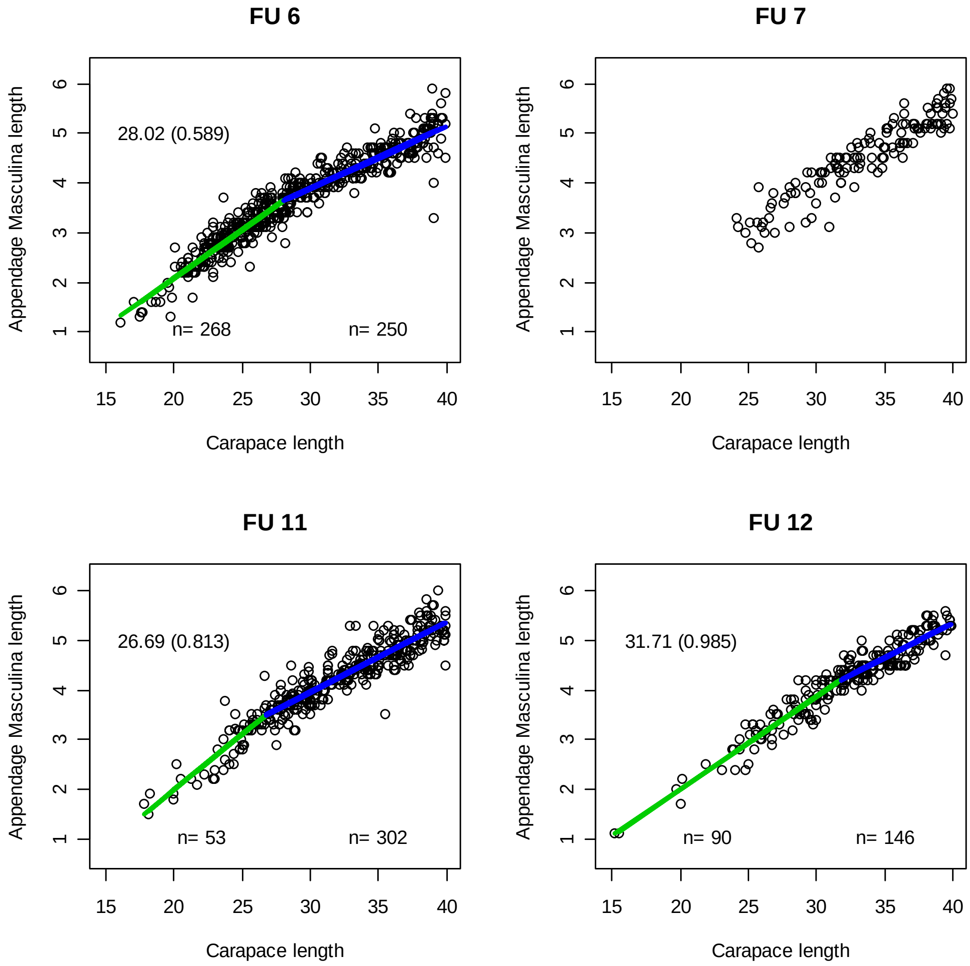


Figure 4.4. Contd.

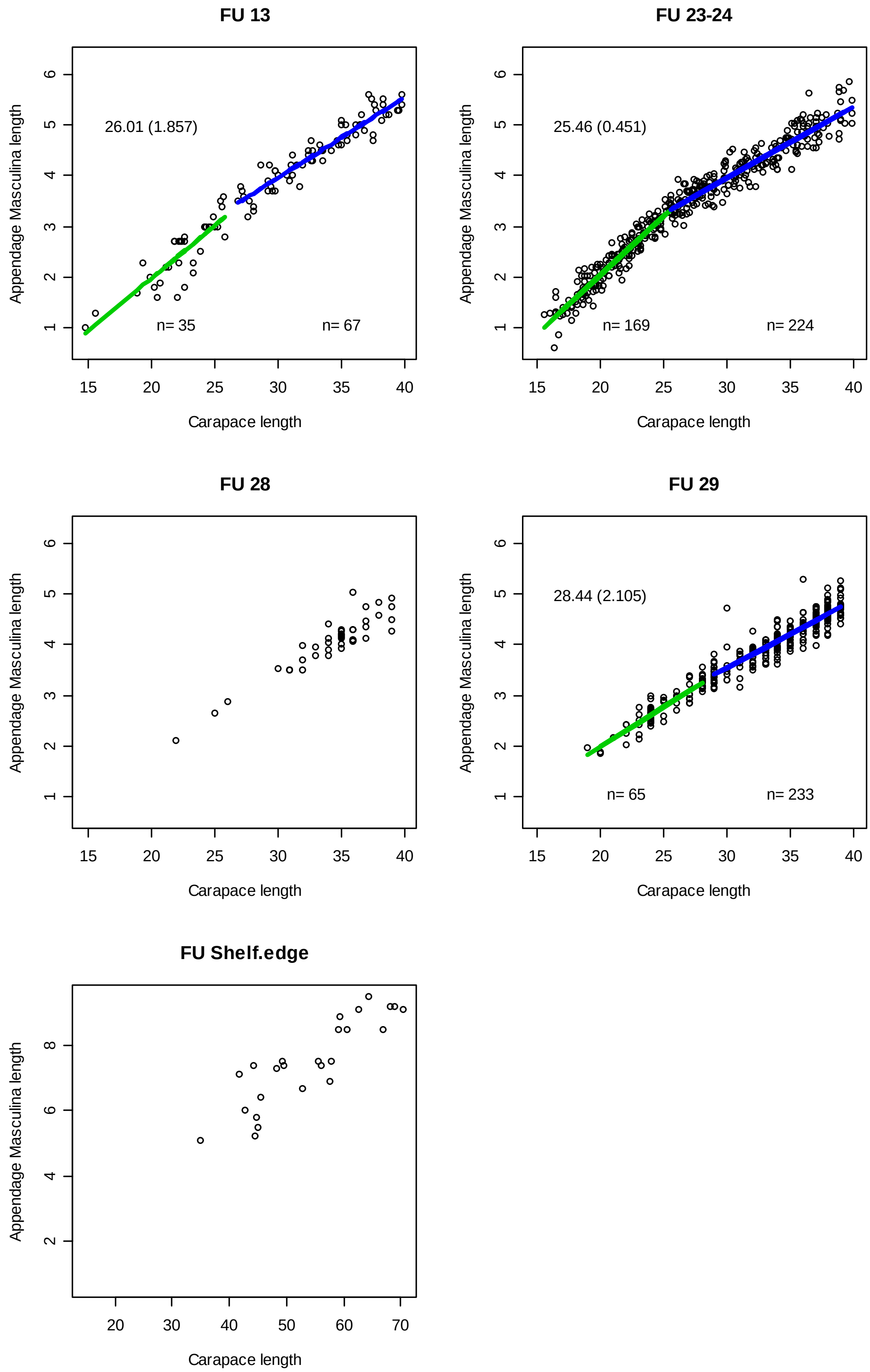


Figure 4.4. Contd.

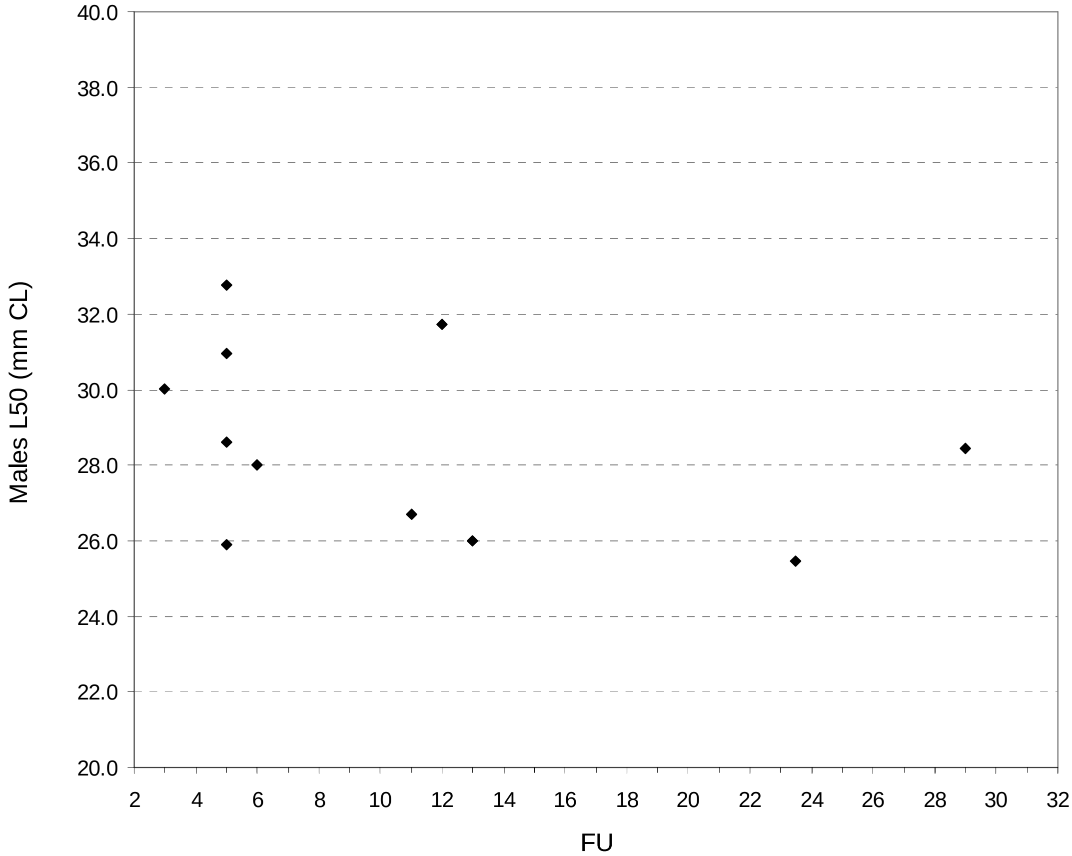
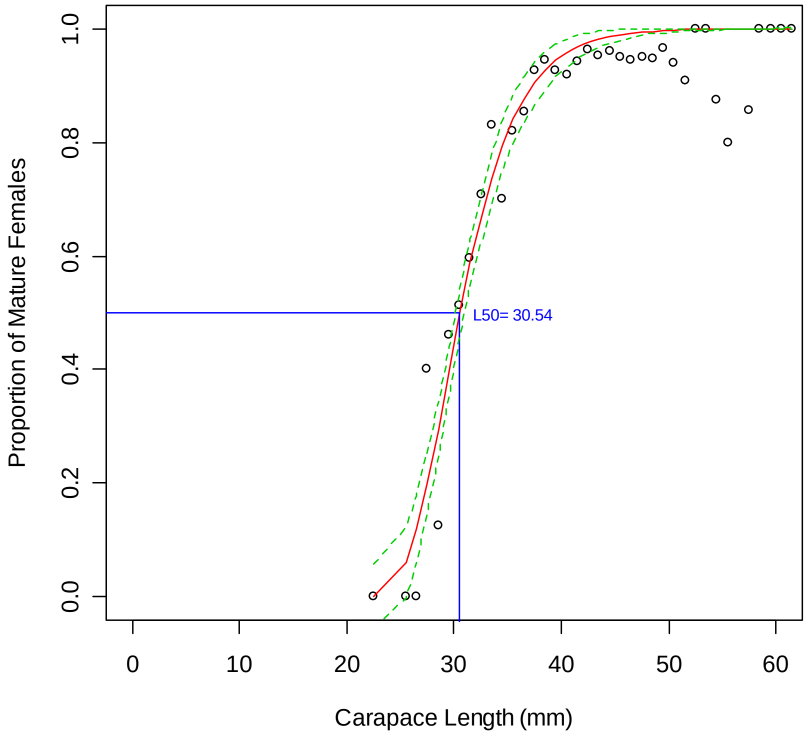


Figure 4.5. Breakpoint in the relationship between appendix masculina and carapace length for male Nephrops by functional unit (FU).

FU 3 (05-08/2001)



FU 14 (08/2004)

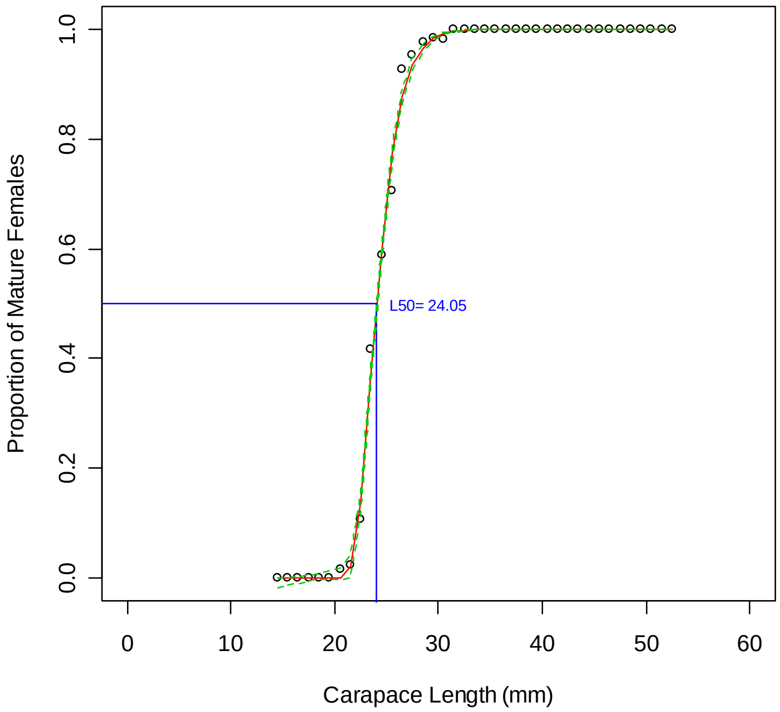


Figure 4.6. Examples of sexual maturity plots for female *Nephrops*. Examples shown are for the Skagerrak (FU 3), the Eastern Irish Sea (FU 14).

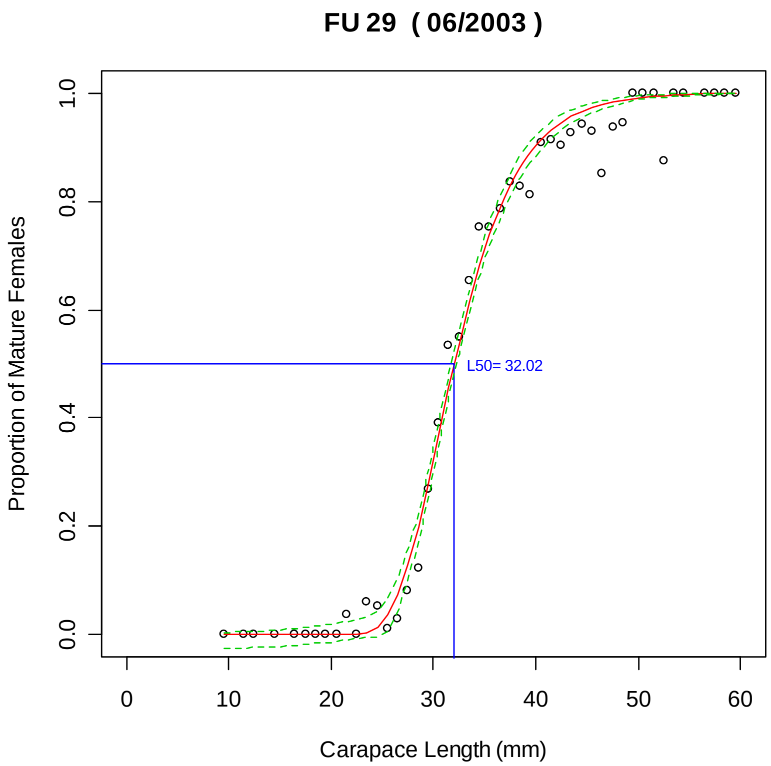


Figure 4.6. Contd. Examples of sexual maturity plots for female *Nephrops*. Example shown is South Portugal (FU 29).

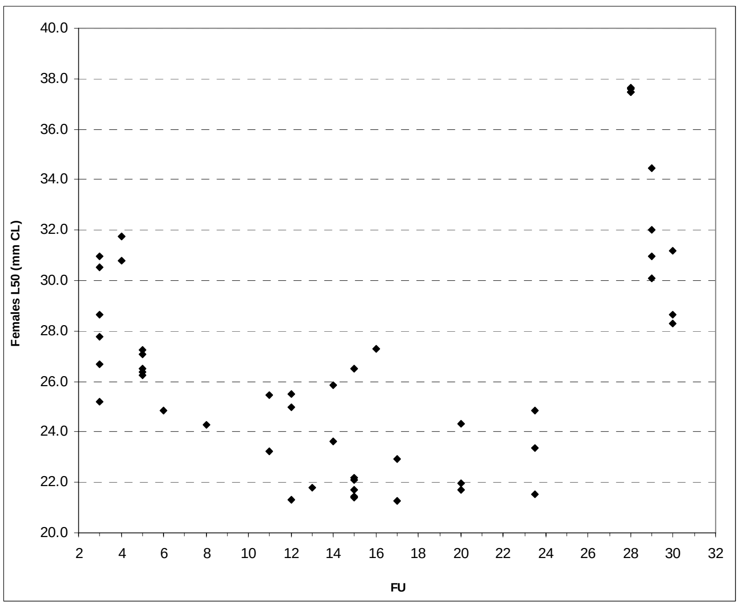


Figure 4.7. Females: Overview of sizes at 50% maturity (L50) in different *Nephrops* Functional Units (FU).

Table 4.1. Details of FU datasets, sample sizes and sex-range for maturity analysis

Males

FU	Country	Year	Season	Datasets	No. measured	Size range	Data source
3	Sweden	2004-05	Jan-Dec	Different locations	435	17-40	Commercial catch
4	Denmark	2004	Sep-Nov	Different locations	595	22-67	Commercial catch
5	Belgium	2004	Sep	BioNeph Haul 5	280	16-38	Commercial catch
				BioNeph Haul 8	255	19-38	Commercial catch
				BioNeph Haul 12	235	19-38	Commercial catch
				BioNeph Haul 14	275	16-38	Commercial catch
6	UK - England	2004	Sep-Nov	Different locations	600	16-47	Commercial catch
7	UK - Scotland	2004	Sep	Different locations	250	24-54	RV Survey
11	UK - Scotland	2004 and 2006	Sep 2004 and Jan 2006	Different locations	465	17-56	RV Survey
12	UK - Scotland	2004	Sep	Different locations	245	15-43	RV Survey
13	UK - Scotland	2004	Sep	Station 04/372	115	14-46	RV Survey
CS (*)	UK - Scotland	2004	Sep		25	34-70	RV Survey
23-24	France	2004	May-Sep	Different locations	415	16-50	Commercial catch
28	Portugal	2004	Jun	Different locations	125	22-70	RV Survey
29	Portugal	2004	Jun	Different locations	435	19-60	RV Survey
(*)	Continental shelf (outside FUs) West of Scotland						

Females

FU	Country	Year	Season	Datasets	No. measured	Size range	Data source
3	Sweden	2001	May-Aug	Different locations	3160	22-61	Commercial catch
		2002	May-Aug	Different locations	1705	20-60	Commercial catch
		2003	May-Aug	Different locations	1295	22-57	Commercial catch
		2004	May-Aug	Different locations	915	23-63	Commercial catch
		2005	May-Aug	Different locations	1175	23-59	Commercial catch
4	Sweden	2004	May-Aug	Different locations	1020	24-63	Commercial catch
		2005	May-Aug	Different locations	630	20-57	Commercial catch
5	Belgium	2004	Sep	BioNeph Haul 5	1395	15-50	Commercial catch
				BioNeph Haul 8	785	18-48	Commercial catch
				BioNeph Haul 12	770	16-47	Commercial catch
				BioNeph Haul 14	995	16-50	Commercial catch
6	UK -England	2004	Sep-Oct	Different locations	1050	13-41	Commercial catch
8	UK - Scotland	2004	Jun	Different locations	195	22-54	RV Survey
11	UK - Scotland	2005	Jun	Station 05/192	245	17-43	RV Survey
				Station 05/203	480	19-44	RV Survey
12	UK -Scotland	2005	Jun	Station 05/195	395	19-43	RV Survey
				Station 05/200	555	17-51	RV Survey
				Station 05/201	555	19-49	RV Survey
13	UK -Scotland	2005	Jun	Stations 05/197-199	930	17-40	RV Survey
14	UK - NI	2003	Aug	Different locations	1500	10-40	RV Survey
		2004	Aug	Different locations	1900	10-41	RV Survey
15	Ireland	2004	Jun	Different locations	3435	17-41	Commercial catch
			Jul	Different locations	5645	18-47	Commercial catch
			Aug	Different locations	2575	16-44	Commercial catch
			Sep	Different locations	3820	14-42	Commercial catch
	UK - NI	2003	Aug	Different locations	6090	10-40	RV Survey
		2004	Aug	Different locations	8550	10-40	RV Survey
		2005	Aug	Different locations	7375	10-40	RV Survey
16	Spain	2002	Jul-Sep	Different locations	420	16-47	Comm catch & RV Survey
17	Ireland	2004	Jun	Different locations	1280	17-44	Commercial catch
			Jul	Different locations	3605	15-48	Commercial catch
20	Ireland	2004	Jun	Different locations	1840	18-43	Commercial catch
			Jul	Different locations	3745	15-47	Commercial catch
			Aug	Different locations	1130	17-41	Commercial catch
23-24	France	2004	Jun	Different locations	740	15-44	Commercial catch
			May	Different locations	660	13-43	Commercial catch
		2005	Jun	Different locations	485	15-50	Commercial catch
28	Portugal	2003	Jun	Different locations	480	20-58	RV Survey
		2004	Jun	Different locations	145	23-61	RV Survey
		2005	Jun	Different locations	150	27-60	RV Survey
29	Portugal	2003	Jun	Different locations	1300	9-84	RV Survey
		2004	Jun	Different locations	670	17-59	RV Survey
		2005	Jun	Different locations	1430	12-57	RV Survey
30	Spain	2004	Jul	Different locations	85	21-44	Commercial catch
			Aug	Different locations	95	19-38	Commercial catch
			May-Aug	Different locations	420	18-44	Commercial catch

Table 4.2. Male sexual maturity: Regressions calculated and estimated L50's (truncation point between lower and upper regression lines)

FU	Country	Year	Season	Datasets	Lower line		L50	Upper line		Comments
					Intercept	Slope		Intercept	Slope	
3	Sweden	2004-05	Jan-Dec	Different locations	-2.112	0.202	30.0	-0.044	0.134	
4	Denmark	2004	Sep-Nov	Different locations						Insufficient data points below presumed L50
5	Belgium	2004	Sep	BioNeph Haul 5	-1.650	0.192	31.0	0.265	0.130	
				BioNeph Haul 8	-1.494	0.181	28.6	-0.009	0.129	
				BioNeph Haul 12	-2.383	0.221	25.9	0.066	0.127	
				BioNeph Haul 14	-1.318	0.175	32.8	0.388	0.123	
6	UK - England	2004	Sep-Nov	Different locations	-1.803	0.194	28.0	0.105	0.126	
7	UK - Scotland	2004	Sep	Different locations						Insufficient data points below presumed L50
11	UK - Scotland	2004 and 2006	Sep 2004 and Jan 2006	Different locations	-2.461	0.223	26.7	-0.292	0.142	
12	UK - Scotland	2004	Sep	Different locations	-1.749	0.187	31.7	-0.240	0.140	
13	UK - Scotland	2004	Sep	Station 04/372	-2.182	0.208	26.0	-0.780	0.158	
CS (*)	UK - Scotland									Insufficient data points below presumed L50
23-24	France	2004	May-Sep	Different locations	-2.558	0.231	25.5	-0.237	0.140	
28	Portugal	2004	Jun	Different locations						Insufficient data points below presumed L50
29	Portugal	2004	Jun	Different locations	-1.179	0.159	28.4	-0.452	0.133	
(*)	Continental shelf (outside FUs) West of Scotland									

Table 4.3. Female sexual maturity: Maturation models calculated, a and b values for maturity plots, and estimated L50's

FU	Country	Year	Season	Dataset	Model (*)	a value (*)	b value (*)	L50 mm CL	Comments
3	Sweden	2001	May-Aug	Different locations	Log-Log	-8.110	0.278	30.5	
		2002	May-Aug	Different locations	Log-Log	-5.910	0.235	26.7	Very few data points below L50
		2003	May-Aug	Different locations	Log-Log	-2.572	0.117	25.2	Very few data points below L50
		2004	May-Aug	Different locations	Log-Log	-5.983	0.205	31.0	Very few data points below L50
		2005	May-Aug	Different locations	Log-Log	-9.797	0.355	28.6	Very few data points below L50
		All years	May-Aug	Different locations	Log-Log	-3.144	0.126	27.8	
4	Sweden	2004	May-Aug	Different locations	Log-Log	-8.287	0.281	30.8	
		2005	May-Aug	Different locations	Logit	-18.733	0.590	31.7	
5	Belgium	2004	Sep	BioNeph Haul 5	Log-Log	-23.025	0.887	26.4	
				BioNeph Haul 8	Log-Log	-23.443	0.874	27.2	
				BioNeph Haul 12	Log-Log	-19.818	0.769	26.3	
				BioNeph Haul 14	Log-Log	-28.866	1.080	27.1	
				All combined	Log-Log	-21.983	0.843	26.5	
6	UK - England	2004	Sep-Oct	Different locations	Logit	-21.332	0.859	24.8	
8	UK -Scotland	2004	Jun	Station 04/128	Log-Log	-9.679	0.414	24.3	Very few data points below L50
11	UK - Scotland	2005	Jun	Station 05/192	Log-Log	-10.018	0.447	23.2	
				Station 05/203	Log-Log	-25.160	1.002	25.5	
12	UK - Scotland	2005	Jun	Station 05/195	Log-Log	-15.416	0.619	25.5	
				Station 05/200	Log-Log	-10.418	0.506	21.3	Very few data points below L50
				Station 05/201	Log-Log	-27.723	1.124	25.0	
13	UK - Scotland	2005	Jun	Station 05/199	Log-Log	-19.235	0.900	21.8	
14	UK - NI	2003	Aug	Different locations	Log-Log	-17.917	0.707	25.9	
				Different locations	Logit	-26.545	1.020	26.0	
		2004	Aug	Different locations	Log-Log	-16.567	0.717	23.6	
				Different locations	Logit	-23.846	1.003	23.8	

Table 4.3. Female sexual maturity (cont)

FU	Country	Year	Season	Dataset	Model (*)	a value (*)	b value (*)	L50 mm CL	Comments
15	Ireland	2004	Jun	Different locations	Log-Log	-2.975	0.126	26.5	
			Jul	Different locations	Log-Log	-3.768	0.238	17.3	Very scattered data points on both sides of L50
			Aug	Different locations	Log-Log	-11.011	0.532	21.4	
			Sep	Different locations	Log-Log	-13.271	0.629	21.7	
	UK - NI	2003	Aug	Different locations	Log-Log	-18.810	0.869	22.1	
		2004	Aug	Different locations	Log-Log	-13.402	0.642	21.5	
		2005	Aug	Different locations	Log-Log	-14.840	0.685	22.2	
16	Spain	2002	Jul-Sep	Different locations	Log-Log	-7.619	0.293	27.3	
17	Ireland	2004	Jun	Different locations	Log-Log	-36.501	1.734	21.3	
			Jul	Different locations	Log-Log	-19.364	0.861	22.9	
20	Ireland	2004	Jun	Different locations	Log-Log	-11.852	0.556	22.0	
			Jul	Different locations	Log-Log	-9.795	0.469	21.7	
			Aug	Different locations	Log-Log	-5.725	0.250	24.3	
23-24	France	2004	Jun	Different locations	Log-Log	-4.717	0.236	21.5	
		2005	May	Different locations	Log-Log	-23.699	1.031	23.4	
		2005	Jun	Different locations	Log-Log	-15.296	0.631	24.8	
28	Portugal	2003	Jun	Different locations	Log-Log	-12.274	0.337	37.5	
		2004	Jun	Different locations	Log-Log	-33.739	0.906	37.6	Very scattered data points on both sides of L50
		2005	Jun	Different locations	Log-Log	-20.610	0.560	37.5	
		All years	Jun	Different locations	Log-Log	-13.599	0.371	37.6	
29	Portugal	2003	Jun	Different locations	Log-Log	-7.882	0.239	34.4	
		2004	Jun	Different locations	Log-Log	-9.472	0.327	30.1	
		2005	Jun	Different locations	Log-Log	-7.360	0.249	31.0	
		All years	Jun	Different locations	Log-Log	-7.320	0.240	32.0	
30	Spain	2004	Jul	Different locations	Logit	-24.807	0.877	28.3	
			Aug	Different locations	Logit	-11.677	0.375	31.2	Very scattered data points on both sides of L50
			May-Aug	Different locations	Logit	-18.232	0.637	28.6	
(*)	Log-Log	Proportion mature = exp(-exp(-(a + b * CL)))							
	Logit	Proportion mature = 1 / (1 + exp(-(a + b * CL)))							

5 Stock assessment developments

5.1 Investigations on length structured and spatially-structured models

g) continue the Working Groups investigations on the applicability of alternative and current assessment techniques, focussing in particular on length-structured approaches and spatially-structured models and examining robustness to the particular features of *Nephrops* biology

5.1.1 Length-structured models for Nephrops populations

One of the main difficulties in assessing *Nephrops* is that they cannot be easily aged and therefore appropriate data for input to the commonly used age-based assessment methods is not readily available. In recent years the standard procedure has been to split the catches at length into catches at age by deterministic slicing so that each length class is allocated to a particular age class on the basis of assumed von Bertalanffy growth parameters. The resulting ‘age’-structured catch data and CPUE are then used as the input in standard age-based assessment methods such as XSA.

One of the main effects of this artificial slicing of length structured data into age classes is that fluctuations in year class strength tend to be smoothed out. Clearly this slicing procedure does not take account of the variability in individual growth rate and hence the variability in length-at-age. Each so-called ‘age class’ will therefore contain a mixture of year-classes which becomes a greater problem with increasing length. The fluctuations in the estimates of recruitment and biomass obtained from age-based assessments therefore also tend to be smoothed out to recent mean values. In the past, methods such as MULTIFAN and MIX have been used in attempts to decompose length-structured data into more appropriate ‘age classes’, based on a mixture of distributions. However, length distributions from commercial catch data for Nephrops stocks rarely exhibit clear modes, making the identification of possible age classes problematic.

Length-structured assessment methods have the advantage that they can make direct use of length-structured data and a number of approaches (using size transition matrices) which may be relevant to Nephrops have been presented at recent meetings of the Study Group on Age-Length Structured Assessment Models (ICES, 2003b, 2005).

Various flexible modelling frameworks have been presented to SGASAM which are available for the development of length-structured assessment models. Both Stock Synthesis (Methot, 2005) and the GADGET (Begley, 2005) modelling framework, which are under continual development are able to incorporate dynamics which are appropriate for *Nephrops* stocks i.e. sex and maturity dependent growth, reduced catchability of females due to decreased emergence. A number of models are being specifically developed for *Nephrops*.

A length-structured assessment of Firth of Forth *Nephrops* was presented to WGNEPH 2004 (ICES, 2004b). This model assumes sex and maturity specific growth and catchability, with mean growth increment derived using assumed von Bertalanffy growth parameters which are used in the length slicing procedure for this stock. Preliminary results indicate similar stock trends and levels to the XSA assessment (biomass estimates, fishing mortality), with the exception of estimated recruitment which shows much greater fluctuations than seen in the age-based assessment results. Further details can be found in Working Documents submitted to 2003 and 2004 Nephrops Working Groups (Dobby, 2003, 2004).

A length-structured model is also currently under development for *Nephrops* in Icelandic waters (ICES, 2005). A multiple stock, seasonal model is being developed using the

GADGET framework, with the size-transition matrix being estimated from recent tagging data. No results are as yet available from this model.

Applications of these types of models are more common in the Southern hemisphere where several invertebrate stocks are currently assessed in this way:

- Southern rock lobster (*Jasus edwardsii*) stocks off New Zealand & Australia (Breen *et al*., 2002; Starr *et al*., 2003)
- Paua (an abalone) (*Haliotis iris*) (Breen *et al*. 2001, 2003; Breen and Kim, 2004)

The CASAL (C++ Algorithmic Stock Assessment Laboratory) software suite (Bull *et al.,* 2005) which has been developed at NIWA in New Zealand is being used to construct Bayesian length-structured assessment models for a number of different invertebrate species (e.g. *Metanephrops challengeri* , ICES, 2004b; Cryer *et al*, 2005). Like other integrated approaches (e.g. GADGET and Stock Synthesis), CASAL can make a wide range of assumptions about the dynamics of the stock and fishery and is able to utilize many different data types in the estimation procedure including tagging data which allows for the estimation of growth within the assessment model.

All the models described above make use of size transition matrices and therefore require either assumptions or estimates of growth. The growth parameters relate the loss of individuals with length to disappearance with time/age which is the mortality signal and as a consequence, estimates of fishing mortality are confounded with the assumed growth parameters which should therefore be estimated (or fixed) externally (e.g. Punt *et al*. 1997) unless there are good age-length or growth data available. In addition to estimates of a mean growth increment curve, the construction of a size transition matrix requires some estimates or appropriate assumptions of the variability of growth. In many of the stocks considered within the ICES area there are insufficient data to estimate even von Bertalanffy growth parameters so the construction of an appropriate size transition matrix from actual growth data may not be possible without further collection of growth data.

5.1.2 Spatially structured models

The commonly used analytic stock assessment methods (including those described above) make dynamic pool assumptions about the population i.e. that i) the population is homogeneously distributed in space, ii) that the age/size structure are completely mixed and iii) that either the fishing effort is applied uniformly over the range of the population or that the population is able to redistribute itself after fishing has occurred. For more mobile demersal and pelagic fish species, it may be reasonable to make such assumptions. However, for sedentary species, models which make dynamic pool assumptions may result in error if there is spatial variability in fishing effort.

Nephrops are essentially sedentary animals exhibiting quite territorial behaviour in the defence of their burrows and making only small scale movements (Chapman, 1980). This behaviour implies that if fishing effort is not distributed uniformly over the whole population then population density will not be uniform as individuals will be unable to redistribute themselves over the stock area. Moreover, environmental variability is likely to affect the population biology so that growth and density vary quite considerably even at a local scale. Distribution maps of fishing activity indicate that spatial targeting of fishing effort does occur (Marrs *et al*., 2000) which may be related to the spatial variability in Nephrops size and density.

The robustness of Nephrops assessment results to these dynamic pool assumptions could be investigated using a simulation modelling approach. Such an approach requires an operating model which can be used to simulate the spatially disaggregated population dynamics using appropriate parameter values. The generated data, which may include potential problems such as noise and biases, can then be spatially aggregated so that it is appropriate for use with the assessment model under evaluation. The performance of the dynamic pool assessment model can then be evaluated by comparing estimated parameters/stock trends with the known 'true' values. Length-structured operating model approaches which can include spatially dependent growth, fishing mortality and recruitment are currently under development at both FRS and CEFAS.

The population dynamics of the spatially explicit operating model which is being developed at FRS are length dependent. The population is assumed to be divided into a number of 'sub-populations' which are not linked by migration. The main features of the simulation model are:

- Total recruitment is dependent on the total spawning stock biomass over the whole population through a specified stochastic stock recruitment relationship with the total number of recruits then randomly distributed across sub-populations according to some distribution function.
- Growth is allowed to be sex and maturity dependent with different growth parameters for different sub-populations.
- Fishing mortality can also include spatial structure and the distribution of effort over the sub-populations is assumed to be dependent on the spatial distribution of catch rate at the previous time interval. VMS data will also be useful for parameterizing this component of the model.

Appropriate parameterization of this model is ongoing and should be completed in the near future.

The model under development within CEFAS is largely similar to the FRS model, the emphasis being upon modelling fleet dynamic behaviour in relation to spatial management options. The model also has the ability to simultaneously handle multiple species and therefore the capacity to investigate mixed fishery issues.

If these spatial features of the fishery and population dynamics are found to significantly affect the perceived stock status, then assessments may be required on a finer spatial scale or using a spatially explicit model. Some of the modelling frameworks referred to in Section 5.1.1 can already incorporate elements of spatial structure into the assessment model. However, these methods would necessarily require more, finer scale data which may not be readily available. Therefore rather than relying on assessment methods which require the recreation of detailed historical stock dynamics it may be more appropriate to focus on methods which have lower data needs.

5.2 Application of fishery-independent methods in stock assessment

5.2.1 Fishery independent data available for Nephrops stocks

There has been and increasing focus on fishery independent surveys for *Nephrops* stocks. The surveys known to the workshop which provide *Nephrops* data that is currently considered as part of the stock assessment process are listed in Table 5.1. In the past these surveys have not widely been used to calibrate catch-at-age or catch-at-size assessments. This has been for two main reasons. There was an a priori assumption that 'catchability' of *Nephrops* in trawl was highly variable due to variation in emergence patterns related to various well know factors (tide, time of day, season etc.). Trawl catch rates vary markedly over short time intervals and often bear little resemblance to overall population abundance. The other reason was that where UWTV surveys existed they tended to give substantially higher biomass estimates than in XSA assessments calibrated with commercial tuning data. The cause of this mismatch could not be easily resolved.

In this section some newer developments in the application of fishery independent data are discussed by country. Other potential fishey-independent methods such as mark recapture and mortality estimation from tagging may be appropriate for *Nephrops* but information on the application of these was not presented at this workshop.

Portugal

During 2005, IPIMAR tested the use of UWTV coupled with the fishing gear (crustacean trawl). The various tests yielded very promising results, especially considering that the coupling of the two pieces of equipment allowed not only optimization of vessel-time but also immediate acquisition of data on abundance vs. burrow density. The equipment has proven to be easy to use and the overall video quality is also suitable for other types of analysis, e.g. assessment of the impact of fishing gear on the sea floor, behaviour/reaction of the animals at the moment of catch (using the camera pointing towards the cod end for this purpose), etc.

In 2005 a camera was attached to the trawl headline to look forward in front of the trawl. In this setup the trawl head rope is around 1.5 m off the seabed and images can be grabbed from video. The tow duration is typically around 30 min and SCANMAR sensors provide data on wingspread. Distance over ground covered during a typical trawl is around 1.5 miles. Video recording is done sub-surface which has the benefit that no cables are required to carry live footage to the surface. The main disadvantage that recording has to be set on a timer and the quality of the footage is unknown until after the tow has been hauled back.

The analysis of the video footage is a very time-consuming task as the whole duration of the trawl is recorded (generally 30 minutes). For this reason future analysis will involve the video track being imported into a computer hard drive so that it can be more easily processed using video editing software. The use of such software will allow the analysis to be shortened by removing irrelevant video frames in short duration (10 min) image sequences. As such, a large volume of information can be rapidly processed and analysed.

The main problem with the method is that of the accurate quantification of field of view. Two possible methods might resolve this using either convergent lasers or a range finder unit. Sediment samples have also been collected using a box core and some analysis of the sediment composition was presented (Leotte *et al*., 2005). This year the nematode fauna of the sediment will be examined to characterise the sediment type.

Spain

There was no new analysis of trawl survey data however the indices for the Porcupine survey were presented at WGHMM in 2005.

Denmark

There is no new fishery independent survey data but a proposal to develop TV surveys is being prepared during 2006.

Sweden

There is no UWTV work currently taking place but Sweden have sledge and camera systems. There has been some tagging work taking place in a creel fishery but it is too early to consider this data in assessment of growth or mortality rates.

Northern Ireland

There are two annual trawl and beam trawl surveys carried out in April and August. Data on catch rates for both surveys and catch rates of small (<20mm) and large (>30mm) *Nephrops* for the summer survey were presented at WGNSDS in 2005. Results were used as an indicator of stock trends in a qualitative way. Data from the surveys (particularly from the beam trawl catches) is used to quantify the occurrence, abundance and distribution of other benthos and burrowing species.

Previously, larval surveys were used to estimate biomass of the *Nephrops* stock in the western Irish Sea from data collected in 1994 and 1995 (Briggs *et al.,* 2002). The results of these surveys were presented a previous WGNEPH and indicate some differences between the biomass estimate in the survey and that for an XSA tuned with commercial CPUE data.

Since 2002 a joint UWTV survey has been carried out with Ireland and the size distribution in the trawl survey are used to work up a biomass estimate.

Ireland

Ireland began UWTV work in 2002 in co-operation with Northern Ireland and FRS in Scotland. Since then surveys have been developed in three FUs (See table). The current plan is to repeat the Aran and Irish Sea surveys annually and build up a time series of data for those stocks. Both surveys were presented at ICES working groups (WGNSDS and WGHMM) in 2005 but their short time series has so far limited their utility as stock indicators. A pilot survey in the Celtic Sea in November 2005 was unsuccessful owing to poor weather conditions for the duration of the 10-day vessel charter. A repeat survey is planned for July 2006 with some input from France if possible. In general, the UWTV surveys have become increasingly multidisciplinary in nature and now include seabed mapping using multi-beam and grab sampling and also the collection of oceanographic data.

Nephrops catches on the Irish western IBTS trawl survey are routinely weighed, sexed and measured. The survey covers ICES Divisions VIa, VIIb,c,j,k,g. The nature of this survey's random stratified design is not ideal for *Nephrops* but there is some discussion of modifying the survey design to include a number of *Nephrops* stations or strata. Recent work in co-operation with CEFAS indicates that trawl survey data for the Celtic Sea may be of some utility in detecting longer-term trends in size structure. This may provide indicative proxies for mortality and recruitment. Previous dedicated *Nephrops* trawl surveys in FU15 have been discontinued in favour of UWTV.

France

Nephrops catches on the EVHOE bottom trawl survey are routinely weighed, sexed and measured. Investigation of this data set is planed for 2006. No other independent investigation is planned in the FU 20–22 but France may participate in the Irish UWTV during June–July 2006.

In the FU 23–24 the RESGASC bottom trawl survey was carried out by IFREMER for more than ten years, but it was much more directed towards sole than to *Nephrops*. This survey series was presented to WGNEPH in 2002 but has not been used to calibrate and analytical assessment. This survey was carried out mainly in the FU 24 (VIIIb; South of the Bay of Biscay) and did not cover the main *Nephrops* fishery to the North of the Bay of Biscay. This survey series stopped in 2001. A new twin trawl survey (called ORHAGO) will be conducted on the whole central mud bank of the Bay of Biscay in April 2006.

UK England &Wales

Since 1996 UK England and Wales have conducted annual UWTV surveys in the Farn Deeps and data and trends in abundance have been presented at WGNEPH since 1999. At WGNSSK the survey results were used to provide harvest options for the management advice.

Two UWTV surveys were conducted in 1997 and 1998 in the Eastern Irish Sea but poor weather limited their success. Because of uncertainties about landings from the Irish Sea it might be worthwhile either resurrecting this survey or extending a survey into this area.

The Celtic Sea trawl survey has been carried out annually every March since 1984. The survey was designed primarily to provide abundance indices for demersal finfish stocks but the data collected for *Nephrops* is being reviewed by Ireland and appears to be providing useful indices as mentioned above.

The annual Irish Sea and Bristol Channel beam trawl survey is carried out every Sep–Oct. This survey is primarily looking at abundance indices for demersal species but its fixed grid survey design means some of the stations occur on both Irish Sea Nephrops grounds. This series started in 1979 as a standard Irish Sea trawl survey and in 1989 the survey was extended to include the Bristol Channel and the gear was switched to a beam trawl. The data on Nephrops have not been reviewed.

UK Scotland

FRS has been conducting UWTV surveys for use in Fishery Independent advice at Working Groups since 1992 on the east coast and since 1994 on the west coast of Scotland. This follows a number of trials (at various locations and to varying extents) to establish the viability of this technique. Since the establishment of the methodologies, FRS has used its own research vessels, RFV Clupea and RFV Scotia to complete these annual surveys. Survey design is based on a stratified random approach, using digitised BGS sediment charts to inform the strata size and shape, a number of fixed stations within each Functional Unit are also visited on each survey.

More recently, additional areas have been incorporated into the survey programme as well as the six main Functional Units surveyed. This has been achieved through improved efficiency in collecting the data, extra days at sea, and utilising the UWTV system on cruises that visit areas not covered by the traditional UWTV survey areas. Since 2002, in addition to the 3 dedicated UWTV surveys (East Coast; Fladen and West Coast; and West Coast Sea Lochs), the UWTV system has been incorporated into the Rockall and Shelf Edge Deepwater cruise, providing information on this relatively new and possibly sensitive fishery, from which market samples are very infrequent.

At each TV station the TV camera is deployed for 10 minutes (bottom time) using an umbilical towing cable and preliminary video interpretation is conducted at sea in real time. Although preliminary, the real time results can be used as first sweep estimates in an adaptive survey approach which is carried out if time allows. Final verification of burrow complex identification and visible *Nephrops*, is carried out at a later date by trained members of staff, independently of each other, and assessed thereafter. Over the last two years, greater emphasis has been placed on recording other observations as well as Nephrops burrows, including fish species, crustaceans, other fauna, sediment variation, quality of the footage, sea pens and any anomalies. These additional data have been of great interest to FRS and numerous NGO's, including SNH (sea pens and related fauna), and JNCC (coldwater corals).

Sediment samples are collected on all dedicated trips at each TV station, and these samples are now being analysed by staff at FRS, to provide sediment size composition which will be used in *Nephrops* population studies. It is hoped that this particle size analysis will improve the BGS data, assessment results and survey design. Trawling is also carried out at stations located within all six functional units, with the aim of obtaining *Nephrops* samples from each strata. *Nephrops* are measured and morphometric and biological data are collected for use in refining maturity data in the assessments at Working Groups.

With increasing interest in these of UWTV as a non-destructive method of assessment and surveying, more countries are purchasing suitable equipment to conduct surveys in their seas. This has led to collaboration between countries to standardise data gathering, and calibration of video interpretation, which to date has involved staff from FRS (Scotland, UK), Marine Institute (Ireland) and NIWA (New Zealand) attending international cruises. Calibration exercises have been held at Lowestoft, and there are plans to repeat this exercise in the near future.

5.2.2 The potential of fishery-independent methods in Nephrops stock assessment

The main developments in fishery-independent method in *Nephrops* stock assessment has been the application of UWTV surveys to directly estimate stock sizes from burrow densities (Bailey *et al*., 1993; Marrs *et al*., 1996; Froglia *et al*., 1997; Tuck *et al*., 1997). This approach has several major advantages; it avoids the catchability issues associated with trawl surveys, it is direct and the distribution of the stock is general known or can be mapped.

For several stocks around Scotland there are now quite long time series of survey data available. UK England and Wales have carried out UWTV surveys since 1996 and there have been more recent developments of survey series by Ireland and Northern Ireland (Table 5.1). Initially the survey density and abundance estimates were used as relative indicators of stock status. Although there may be some scope to use the surveys as fishery independent calibration indices where time-series of reliable catch and size data exist, there has not been much development in this area.

Owing to concerns about the accuracy of reported landings levels for *Nephrops,* the UWTV surveys have increasingly been used to directly estimate stock biomass. This involves applying a harvest rate to the estimated survey abundance to calculate an appropriate catch number which is then adjusted to provide catch in weight. For several stocks in VIa and IV this was the approach taken in 2005 to define catch options for 2006. This approach essentially bases advice on survey data only and is relatively new in the ICES system but is more common in North America and Canada, especially for certain shellfish.

5.2.3 Outstanding issues in the Underwater television approach

Using UWTV surveys directly requires some consideration of methodological issues and also consideration of the assumptions required to calculate absolute biomass levels. In the discussion here some attempt has been made to rank these in terms of importance.

Burrow occupancy

To date most UWTV survey abundance estimate assume 100% occupancy. This is almost certainly not the case. Most of the data in the literature on this issue comes form shallow ‘diveable’ areas and reported occupancy rates have been variable. Burrows may last for sometime even when unoccupied and in areas that are heavily fished some burrows may remain although the fishery has removed the occupants. The more active male component of the population may be more vulnerable to removal by the fishery than the females. Occupancy rates are likely to be different between stocks and even between different parts of grounds as removal rates, trawl frequency, sediment type, sedimentation processes and bottom current activity may all differ somewhat.

Accuracy of counts for high-density areas

Where densities of *Nephrops* and other burrowing species are extremely high there are some concerns that accuracy of burrow complex identification may deteriorate. This is primarily a problem in high density areas such as the Western Irish Sea and the in the southern parts of the

Clyde and may not be an issue in other areas. There is potential to examine internal consistency of burrow identification between multiple counters and to use new image analysis and data capture systems to compare inter-counter burrow identification on a fine spatial scale.

Relationship between the biomass in the survey area and the 'exploitable' biomass

Often the survey area does not correspond to the distribution of the fishery. This is primarily because the fishery tends to be rather conservative in nature taking the risk adverse approach of concentrating effort in areas that yielded good economic return with minimal risk of gear damage. The evolution of the fishery on the Fladden ground is a good example of this where the fishery was initially limited to only part of the survey area but over time the fishery has expanded to exploit newer areas. Increasingly VMS data area available to countries and these may have some potential in examining how fishing effort is distributed within stock area on a finer geographical scale than was hitherto available.

Underlying population structure

To calculate biomass from the burrow abundance an assumption is made concerning underlying population structure of the burrow forming *Nephrops* population. Thus far the underlying population structure is estimated either from commercial data or from survey data. It is thought that in trawl fisheries *Nephrops* first appear in catches when they become more active foragers on the seabed surface, having left the "juvenile stage" and created their own burrows. Gear selectivity, spatial differences between the UWTV survey and the fishery or trawl survey and using annual data from the fishery could potentially bias the population structure used. A critical issue is establishing what size of Nephrops occupies the smallest observed burrows.

Survey design issues

The Scottish UWTV survey are generally stratified random in design. The stratification is based on seabed sediment data from the British Geological Survey (BGS) and subsequent analysis follows traditional parametric methods . The Irish survey design uses a randomised fixed grid design. This is primarily for geostatistical purposes and because seabed sediment data was generally not available with high resolution. A full discussion of the pros and cons of the survey designs was not possible at the workshop but is an area that requires further examination.

Local populations of *Nephrops* may vary considerably in density, individual size composition and growth rate (Tuck *et al*., 1997). Individual growth rate may be reduced in high density conditions as a result of increased competition for food. Chapman and Bailey (1987) suggested that high population densities were usually found on coarser muds with a relatively high sand content, whereas lower burrow densities (and animals of larger size) were associated with finer muddy substrata. More recent work suggests that the peak in density occurs on mixed sediments of sand, silt and clay, with lower densities on very coarse or fine substrata (Tuck *et al*., 1997), and that the main cause of local variation in population density may be the intensity of juvenile settlement rather than any direct effect of sediment type. In a survey design context the stations should at an appropriate spatial scale such that it reflects the underlying sediment structure on the seabed. However, the linkage between sediment structure and density is not yet clear. Information on sediment structure is generally collected during surveys and there is some potential to examine this in more detail in the future.

Methodological problems

A number of methodological uncertainties remain with some UWTV surveys. These mainly relate to the accuracy of the field of view. Many of these have been solved with increasing used of newer technologies such as range finders to measure height of cameras off the seabed and odometer wheels or underwater positioning systems to calculate distance over ground. The problem of "edge effects" remains. This occurs where burrow complexes, that are counted as they disappear off the bottom of the screen, may result in increase the effective field of view beyond the edges of the screen resulting in an underestimate of the area counted.

5.2.4 Developing an approach for providing catch options from fishery independent methods

Where catches of *Nephrops* are known and reliable it should be theoretically possible to adaptively adjust the input (effective effort) and/or the out take (catch) based on stock development in UWTV surveys. However for several stocks (see Section 3.2) there is concern about the accuracy of the landing and/or catch data. During 2005, WGNSDS and WGNSSK considered that for a number of *Nephrops* stocks in the North Sea and West of Scotland current levels of exploitation appeared sustainable based mainly on UWTV survey data. The ACFM advice was for no increase in effort, and for mandatory collection of accurate data to assist in the future assessment process.

Potential catches, based on applying a range of possible harvest ratios to the TV abundance data, were also provided by the WGs. Suggestions on which harvest rate to apply were informed by reference to yield per recruit calculations from the LCA programme (ICES, 1990). However, in order to provide TAC advice for 2006, ACFM made comparisons between predicted catches from different harvest rates and reported landings. Harvest rates yielding catches above reported landings were regarded as not being in accordance with the advice (no increase in effort) and shaded accordingly in the catch tables. Given the poor quality of landings and other official data, (noted in the ACFM report), the approach has been questioned. STECF considered that the shaded regions must be considered very uncertain.

$F_{0.1}$ has been used successfully as a management reference point for Icelandic *Nephrops* stocks for a number of years, and is used as a reference fishing mortality in New Zealand for both cockles (Morrison and Cryer, 1999) and scallops (Cryer, 1998). Located on the left hand limb of the yield per recruit curve, it is arguably more stable than attempts to exploit a population at Fmax. In general, ICES is trying to move from advice based on short-term considerations to longer-term targets. STECF in 2005 investigated the use of the $F_{0.1}$ target and considered it appropriate to use the catch corresponding to this as the basis for management advice thus breaking the dependence on unreliable catch data (STECF, 2005). STECF considered that utilising a precautionary harvest rate around $F_{0.1}$ was suitably precautionary to avoid overexploitation difficulties. The approach could be developed and refined as more data emerge.

The WK considered that using the LCA approach has a number of potential weaknesses relate to the simplicity of the model and strong inherent assumptions. The assumptions include fixed growth parameters, a natural mortality assumption and concerns that the stocks are not in fact in equilibrium (either in terms of recruitment or fishing mortality). Although increasing complexity of the assessment model does not necessarily result in a better assessment and management advice there remains scope to investigate this approach further by examining sensitivity to the assumptions. A further step would be to evaluate the robustness of the approach to errors in estimation of reference point values and TV abundance given the uncertainties spelt out in Section 5.2.3.

Given the need to break the cycle of basing advice for *Nephrops* stocks on unreliable reported landings WKNEPH considered that the STECF approach was an appropriate first step despite some uncertainties and that further consideration of the method should occur in the area based WGs during 2006. However, there are some concerns about the adequacy of management measures to ensure the limitation of effective effort and to ensure improved reporting of accurate landings.

Improvements in understanding of the relationship between the distribution of effort and stock density should provide a greater link between actual landings, abundance estimates and the application of optimum harvest rates. Consideration also needs to be given to the year on year variability in stock estimates and to how catch levels might not be applied in these circumstances.

5.2.5 Facilitating progress in the development and wider application of fishery independent methods

Participants of the workshop considered that given the potential and outstanding issues associated with UWTV surveys that further collaboration in this area is required. The form of this could be an ICES workshop or a workshop under the auspices of SGRN (Study Group on Research Needs). The latter option might encourage participation from workers in the Mediterranean mainly Greece, Italy and Spain and would also make funding available to participants under the DCR (Data Collection Regulation). Previously, funding of an UWTV workshop has been discussed but not progressed. WKNEPH suggest that regardless of funding a Workshop UWTV surveys should be progressed through ICES for 2007.

Issues discussed above would form the main focus and full details of the work to be tackled by the Workshop is provided in the Recommendations section with a specific proposal also included at Annex 3

Table 5.1

Functional Unit	Survey Type	Country	Month	Years	Comments	Source
1						
2						
3	None					
4	None					
5	None					
6	UWTV	UK England	Spring	1996-2004	Random BGS and grid stratification and known clear trawls, Excluding 2001, 2003, 2004	WGNSSK 2005
			Autumn	1996-2004	Random BGS and grid stratification and known clear trawls, Excluding 1996, 99, 2000	WGNSSK 2005
7	UWTV	UK Scot	June	1993-2004	Adaptive regular grid stratification, Excluding 1996	WGNSSK 2005
	Trawl	UK Scot	June	1993-2004	Hauls taken at intervals during TV survey	N. Bailey FRS
8	UWTV	UK Scot	July-August	1993-2004	Random BGS sediment strata stratification, Excluding 1995 & 97	WGNSSK 2005
	Trawl	UK Scot	July-August	1993-2004	Hauls taken at intervals during TV survey	FRS
9	UWTV	UK Scot	July-August	1993-2004	Random BGS sediment strata stratification, Excluding 1995	WGNSSK 2005
	Trawl	UK Scot	July-August	1993-2004	Hauls taken at intervals during TV survey	FRS
10	UWTV	UK Scot	June	1994 & 1999	Random BGS sediment strata stratification	WGNEPH 2004, WGNSSK 2005
11	UWTV	UK Scot	June	1994-2005	Random BGS sediment strata stratification, Excluding 1995 & 97	WGNSDS 2005, WGNSDS 2005
	Trawl	UK Scot	June	1994-2005	Hauls taken at intervals during TV survey	FRS
12	UWTV	UK Scot	June	1995-2005	Random BGS sediment strata stratification	WGNSDS 2005, WGNSDS 2005
	Trawl	UK Scot	June	1995-2005	Hauls taken at intervals during TV survey	FRS
13	UWTV	UK Scot	June	1995-2005	Firth of Clyde, Random BGS sediment strata and latitude stratification	WGNSDS 2005, WGNSDS 2005
					Sound of Jura, Random BGS sediment strata stratification, time permitting (1995-96, 2001-03)	WGNSDS 2005, WGNSDS 2005
	Trawl	UK Scot	June	1995-2005	Hauls taken at intervals during TV surveys	FRS
14	UWTV	UK England	March	1997-1998	Random BGS and grid stratification and known clear trawls	WGNSSK 2005
	UWTV	UK England	Oct	1997-1998	Random BGS and grid stratification and known clear trawls	WGNSSK 2005
	Beam Trawl	UK England	Sept-Oct	1979-2005	ISBC Beam Survey (fixed grid)	IBTSWG 2005
	Trawls	UK NI	August	1999-2004		WGNSDS 2005

Table 5.1. Cont.

FUNCTIONAL UNIT	SURVEY TYPE	COUNTRY	MONTH	YEARS	COMMENTS	SOURCE
15	UWTV	Ire & UK NI	Aug-Sept	2003-2005	Randomized fixed grid design	WGNSDS 2005
	Trawl	Ireland	Aug	1980-2000	Replace with UWTV survey	Unpublished
	Trawl & Beam	UK NI	Aug	1994-2005		WGNSDS 2005
	Trawl	UK NI	Apr	1994-2005		WGNSDS 2005
	Larval	UK NI	Spring-Summer	1994 & 1995	Experimental	Briggs *et al.* 2002, WGNEPH 2004
16	Trawl	Spain	Sep	2001-2005	Western IBTS (random stratified design)	WGHMM 2005
17	UWTV	Ireland	Jun	2002-2005	Randomized fixed grid design	WGHMM 2005
	Trawl	Ireland	Nov	2001	Exploratory survey	Lordan unpublished
17, 18, 19, 20-22	Trawl	Ireland	Oct-Nov	2003-2005	Western IBTS (random stratified design)	IBTS 2005
19 & 20-22	Trawl	UK E&W	Mar	1986-2005	Celtic sea groundfish survey (fixed grid)	Lordan unpublished
20-22	UWTV	Ireland	Nov	2005	Exploratory survey unsuccessful due to weather	Lordan unpublished
	Trawl	France	Oct-Nov	1987-2005	EVHOE bottom trawl survey	IBSTWG 2005
23	None					
24	Trawl	France	May	1993-2001	Ressgasc bottom trawl survey	WGNEPH 2002
			Oct	1993-2001	Ressgasc bottom trawl survey	WGNEPH 2002
25	Trawl	Spain	Sept-Oct	1988-2005	Mixed Survey	WGNEPH 2004
26	Trawl	Spain	Sept-Oct	1988-2005	Mixed Survey	WGNEPH 2004
27	None					
28 & 29	Trawl	Portugal	Summer	1989-2001	Groundfish survey (Excluding 1994, 1996, 2002-2004)	WGHMM 2005
			Autumn	1989-2005	Groundfish survey	WGHMM 2005
			June	1994-2005	Crustacean survey (Excluding 1995 & 1996, 2004)	WGHMM 2005
30	Trawl	Spain	March	1993-2005	Mixed Survey	WGHMM 2005
31	Trawl	Spain	Sept-Oct	1988-2005	Mixed Survey	WGNEPH 2004
32	None					
33	None					

6 Technical measures issues

WKNEPH is indebted to Dick Ferro (UK Scotland) and Dominic Rhian (Ireland) for providing text contributions relating to Nephrops selectivity work.

6.1 Effect of mesh size regulations on the catchability of small Nephrops

6.1.1 Overview

Selection of *Nephrops* is not consistent with some hauls showing a typical s-shaped curve of proportion retained against carapace length while others show little or no indication that retention is a function of length ie a constant proportion captured over the whole range of lengths. Unlike finfish, *Nephrops* tend not to swim actively towards meshes and may be more dependent on passive escape. Escape can be impeded by their shape and appendages, which can hook onto meshes or other animals in the trawl.

Analysis of *Nephrops* selectivity data in the past often omitted hauls that did not exhibit length-related selection. The remaining data, which fitted the sigmoid selection curve model, were analysed and used to produce estimates of selection parameters (e.g. 50% retention length (L50) and selection range (SR)). The proportion of hauls, which do not show, length-related selection varies but can be as much as 50%. The resulting models may not therefore represent true selection by commercial vessels, especially in the smaller size range of *Nephrops*. In 1995 an FTFB *ad hoc* group attempted to assess the effect of codend mesh size on *Nephrops* and showed a significant positive relationship between mesh size and both L50 and selection range. However, recent experimentation has shown that this assessment is not robust and that *Nephrops* selectivity by diamond mesh codends is generally poor. Most experiments showed no length dependency with low L50's and high selection ranges. Recently methods have been developed which do not require a fit to a logistic or similar curve but make use of all the data to give a more representative model of *Nephrops* retention.

6.1.2 Existing selection model

Nephrops selection data were collated by ICES WGFTFB in 1995 (Table 6.1). These have been used to produce a model relating L50 and SR to mesh size, twine thickness and open meshes round the circumference of the codend (Table 6.2).

$$L50 = 28.12 + 0.447 * MS – 4.87 * Ts – 0.095 * MR$$

and

$$SR = 2.32 + 3.21 * Ts$$

where MS is mesh size in mm, Ts is equivalent nominal single twine thickness mm and MR is number of open meshes round codend circumference. For double twine with thickness Td, it is assumed that a single twine with the same total twine cross-section is equivalent, i.e. Ts = SQRT(2 * Td * Td). The formulae for L50 and SR should be used with caution and only within the range of codend designs used to derive them (see Table 6.1). They may be derived using only hauls exhibiting length-related selection.

6.1.3 Review of research

Selectivity experiments carried out by FRS in Scotland on the Minches grounds showed 70 mm and 80 mm x 4 mm double twine codends to be unselective. Nephrops of 20 to 45 mm carapace length were encountered during these trials and no Nephrops above 21 mm escaped from the 70 mm codend. Catch comparison trials carried out as part of this study did show a significant difference between the 70 mm and 80 mm codends but only in the 25–30 mm length range with 27% fewer Nephrops being caught in the 80mm codend. Further trials with a 100 mm x 5 mm double twine showed some length-related selection, giving a 50% retention length of 26.7 mm and selection range of 3.6mm. Increasing mesh size from 70–100 mm gave a 70% reduction in catch of Nephrops in the size range 20–25 mm and a loss in catch of 36% in the 25–30 mm length range. Increasing mesh size from 80mm to 100mm showed a reduction of 65% in the 20–25 mm size range only. Another FRS study found no significant difference in catches of Nephrops comparing a 80 mm x 4 mm against a 100 mm x 5 mm double twine codend. Irish Sea studies (Briggs *et al*., 1999) demonstrated that vessel size affects Nephrops selectivity. A 70 mm mesh trawl towed by a small single-rig vessel gave similar Nephrops selectivity as a larger vessel towing twin-rig trawl of 80mm mesh. Results from a series of western waters studies by BIM using a range of mesh and twine sizes supported the variable results obtained by FRS.

Norwegian studies in 2001 compared 100 and 120 mm codends and showed overall reductions in Nephrops catches by around 30% but with no length dependency. Experiments in the Mediterranean using diamond mesh codends of 16 mm, 20 mm, 24 mm and 26 mm half mesh size showed none of these mesh sizes to be selective for Nephrops, since all estimates of L50 were lower than the length at first maturity and L25 was lower than the legislated minimum landing size. Further work in the North West Mediterranean with five different mesh sizes (38, 42, 45, 52 and 60 mm) again showed these mesh sizes to be unselective giving L50‘s once again below the length of first maturity.

6.1.4 Cod end construction

It is apparent that Nephrops selectivity by diamond mesh codends can be poor, suggesting a need to consider all aspects of codend design including mesh size, twine thickness, meshes round the circumference and attachments such as lifting bags. The effect of twine thickness was assessed by BIM in 2000 through a series of catch comparison experiments in the Irish Sea. A 80 mm x 3.5 mm single twine codend was compared with a 80 mm x 6 mm single and a 80 mm x 8 mm single twine codneds. The Nephrops catches with the 6mm and 8mm increased by 34% and 38% respectively compared to the smaller twine codend suggesting reducing twine thickness may improve Nephrops selectivity. Other trials on the Labadie Bank off the south coast of Ireland showed little difference between catch rates with a 80mm x single 6mm codend and a 90mm x double 4mm codend. The length frequency and trawl ratio data also indicated there was no difference in the size range of Nephrops being retained by the 80mm and 90mm codends, while there was no differences in the mean carapace size of Nephrops retained or in the percentage of undersized Nephrops caught by each codend. This suggests that the selectivity characteristics of these codends had similar retention characteristics and the increase in mesh size by 10mm was negated by the use of double 4mm twine. Northern Ireland studies in the Irish Sea (Briggs *et al*., 1999) drew similar conclusions.

In 2002 FRS compared the difference in Nephrops catches between 100mm and 110mm diamond mesh codends and 80 mm and 90 mm square mesh codends. Results were not consistent with some hauls and failed to show clear length-related selection.

A selectivity analysis carried out on Portuguese stocks tested 44, 60 and 70 mm diamond mesh codends with a full square mesh codend constructed from 55 mm netting. The data although limited due to small catch sizes, showed there was no significant difference in L50 for the three diamond mesh codends but gave a higher L50 for the square mesh codend.

6.1.5 Work on a new model

FRS Marine Laboratory and other institutes have completed several more trials on Nephrops selectivity since 1995. The intention is that Scottish data from 6 cruises (Table 6.3) will be analysed together using smoothing techniques to make use of the data from all hauls regardless of whether it displayed length related selection.

6.1.6 Other selective devices

IMR, Sweden has assessed the effectiveness of square mesh codends constructed entirely from 70mm square mesh netting, compared with conventional 70 mm diamond mesh codends. The L50 increased from 18.6 mm to 24.6 mm carapace length showing square mesh codends to be more selective for Nephrops than the conventional diamond mesh codends. Further work in Sweden has shown that a rigid sorting grid with a 35 mm bar spacing, in combination with a 70 mm square mesh codend can significantly reduce the fish by-catch and also reduce the discards of Nephrops by 66%. It must be remembered however that the MLS for Nephrops in Swedish waters is much higher than generally applied in the EU (40 mm carapace length as opposed to 25mm in most EU waters) and the addition of a grid in front of the codend reduces the catch bulk which makes escape from the codend easier.

There have been several studies to develop alternative methods of selecting Nephrops than through meshes. In particular grids have been tried with some limited success (EU Project NETRASEL). An extensive set of trials over 805 days at sea with 2074 observed hauls carried out by IFREMER in France since 2003 in the Bay of Biscay has shown average escapee rates of 36% to 57% for undersize Nephrops using a flexible grid placed in the extension piece in a titled configuration with commercial losses of approximately 0.1 kg of Nephrops per trawl. This device looks particularly promising in directed Nephrops fisheries. Although such devices improved selection practical difficulties are sometimes experienced in handling the grid in rough weather or with mechanized equipment such as power blocks. Fishing time may be lost e.g. in multi-rig trawls. Grids also can become blocked with debris, catch or even mud in some circumstances. There may be a loss of other commercial by-catch species such as sole through a grid.

6.1.7 Conclusions on selectivity

The size selection of Nephrops from diamond mesh codends currently used in Nephrops fisheries is poor, resulting in discarding. The problems are associated with low L50 or the absence of length related selection. To improve Nephrops selectivity mesh size needs to increase, but an increase in mesh size must take account of potential loss of marketable catch. The mechanism of Nephrops selection should also be investigated and the principal factors affecting size selection in all areas of the trawl, such as mesh size, shape, twine characteristics, cutting rates used in trawls causing meshes to close and the effect of codend attachments need to be identified.

Square mesh codends have been shown to improve selectivity to some degree, particularly in the case of the Swedish fishery in conjunction with a rigid grid. However, these results need to be treated with caution as the mls for Nephrops in the Skaggerak, where the grid and square mesh codend are currently used, is 40mm carapace length compared to 20/25 mm in the Irish and North Seas. The 70 mm square mesh codend would undoubtedly exclude large amounts of marketable Nephrops if used in the Irish and North Sea fisheries. Suitable material for construction of square mesh codends also remains a serious issue.

The results from the French flexible grid look promising and the results show clear size selection of Nephrops. This device should be tested in other fisheries to confirm these findings and provide better definition of appropriate bar spacing.

6.2 The focus of recent Nephrops gear research

In addition to improving Nephrops selection, recent emphasis has been put on developing species selective trawls to reduce the unwanted by-catch of finfish in Nephrops trawls. Multinational collaborative EC funded projects such as RECOVERY and NECESSITY have included extensive trials with a range of net configurations and novel devices to exclude catches of unwanted by-catch species. Results from these studies are currently undergoing analysis and should soon be available. Comprehensive information on appropriate designs of innovative gear for each of the main European Nephrops fisheries are given in Graham and Ferro (2004).

Table 6.1. *Nephrops* selectivity data collated in ICES CM 1995/B:2

NEPHROPS TRAWL DATA FROM ICES FTFB REPORT 1995/B:2							
All polyethylene (PE) material							
Twine size mm	Mesh size MS mm	Equiv single twine size mm	Open meshes round	50% retention length L50 mm	Selection range SR mm	Selection factor =L50/MS	No of hauls
2.5s	55.2	2.50	218	23.9	9.7	0.43	13
2.5s	60.3	2.50	200	25.7	10	0.43	11
2.5s	70.6	2.50	170	26.9	12.4	0.38	10
4s	71.1	4.00	122	26.1	8.4	0.37	6
4s	72.7	4.00	100	28.4	13.6	0.39	5
4s	74.2	4.00	143	24.5	14.7	0.33	5
4d	81.4	5.66	82	30.3	23.9	0.37	2
4d	83.2	5.66	100	28	18.7	0.34	3
4d	83.5	5.66	118	26.4	25.1	0.32	2
4d	106.8	5.66	85	41.3	15.4	0.39	5
4d	108	5.66	70	43.2	20.5	0.40	4
4d	108	5.66	100	39.7	21.7	0.37	3
2.5d	72.8	3.54	94	37.1	16.2	0.51	10
2.5d	72.9	3.54	94	37.9	16.4	0.52	10

Table 6.2. Output of unweighted regression of L50 and SR using *Nephrops* selection data of table 1.

L50 REGRESSION						
SUMMARY OUTPUT Constant, no weight						
Regression Statistics						
Multiple R	0.9215346					
R Square	0.8492261					
Adjusted R Square	0.8039939					
Standard Error	3.0384944					
Observations	14					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	520.0126594	173.3376	18.77482	0.000197214	
Residual	10	92.32448349	9.232448			
Total	13	612.3371429				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	28.12087	8.866224175	3.171685	0.009959	8.365687768	47.87605171
mesh size mm	0.447461	0.092883465	4.817445	0.000705	0.240503716	0.654418303
twine size mm	-4.8713567	1.309281839	-3.72063	0.003971	-7.78861892	-1.95409444
meshes round	-0.0949205	0.030041301	-3.15967	0.010165	-0.16185675	-0.02798435
SR REGRESSION						
SUMMARY OUTPUT Constant, no weight						
Regression Statistics						
Multiple R	0.7979397					
R Square	0.6367078					
Adjusted R Square	0.6064334					
Standard Error	3.297425					
Observations	14					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	228.6731429	228.6731	21.03126	0.000625917	
Residual	12	130.4761428	10.87301			
Total	13	359.1492857				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	2.3200677	3.150795423	0.736343	0.475671	-4.544925719	9.185061028
twine size mm	3.2095854	0.699868245	4.585985	0.000626	1.684703526	4.734467296

Table 6.3. Summary of codends tested between 2001 and 2005 by FRS, Aberdeen

Cruise	Mesh size mm	Twine size mm	Open meshes	Lifting bag?
Concorde	80D	4s	120	Yes
	100D	5d	100	No
Osprey	80D	4s	120	Yes
Zenith	80S	5s	100 bars	Yes
	95S	5s	100 bars	Yes
	105D	5d	100	No
	110D	5d	100	No
Reliant	80D	4s	120	Yes
	90D	4s	120	Yes
	100D	4s	100	Yes
	110D	4s	100	Yes
Adele	90D	5d	100	No
	100D	5d	100	No
Ocean Trust	80D	4s	116	Yes

S or D indicates full square or diamond mesh codend
s or d indicate single or double twine

7 Conclusions and Recommendations

7.1 Conclusions

Area based Working Groups

The general view was that the large area groups should be given every chance to develop, fully integrate and function efficiently. Although there were some organisational difficulties and disadvantages, the potential gains for consideration of mixed fisheries issues and related topics were too great to rearrange the groups prematurely. It was felt that a useful activity at the beginning of meetings would be a resume of approaches used and background information on stocks such as Nephrops which had previously been dealt with separately. It was also recommended that Chairs of meetings could facilitate efficiency and improved integration by establishing small groups within the Working Group to review and consider outputs. If possible such groups should be established before the meeting and begin to communicate preliminary results and discussion issues early. This would leave more time during the meeting for discussing advice, mixed fishery issues and other ToR topics.

Metier approach

WKNEPH was generally positive about the way the metier approach is developing and for the future this will facilitate mixed fishery assessments in which Nephrops plays a part and also potentially improve CPUE indices. It is expected that the full implementation of a data gathering scheme incorporating the principles described will take place by 2008 and it is from then on that more rapid progress can be expected. It was noted that for this approach to be fully effective, numerous fields in Official logbooks need to be treated as mandatory by all countries. At present there seem to be different emphasis placed by some authorities on the different data fields – a more unified approach is necessary.

Quality of landings information

The quality of commercial landings information on Nephrops remained of concern in a number of countries during 2005. It is essential that reliable information is made available if progress towards assessments of Nephrops stock status and dynamics using fishery data is to be made. Recent developments on the registration of buyers and sellers and the increased TACs in a number of areas may have positive effects in improving landings data quality. It was not felt that Working Groups were in a position to actively improve the quality of landings data but perseverance by all concerned in keeping this issue high on the agenda is important.

Precision level

WKNEPH noted the early attempts at estimating precision of sampling Nephrops and considers that these and other ongoing initiatives will ultimately result in workable methods for routinely providing precision estimates. For the present the implications for future sampling are not completely clear. The group's discussions drew attention to the obligation under the EU Data Collection Regulation to provide estimates of precision and this requirement is likely to accelerate progress in providing more estimates for a wider range of stocks.

Maturity

Prior to and during the meeting, good progress was made in collating, analysing and comparing data on the size of first sexual maturity. Most progress was made with female datasets and a preliminary synthesis of information across Functional Units was made. The group agreed that there was sufficient material to put together an overview paper describing the latest results from a wide geographic area. This will be taken forward by communication amongst members . Progress was also made in the estimation of size of male first maturity although rather more work still needs to completed and a longer time frame for an overview paper was considered appropriate.

Assessment development

Presentations were made of progress on size based assessment models and an overview of new work on spatially structured models was provided. It was felt that there was generally insufficient expertise within the group of Nephrops biologists to fully address the ToR relating to these topics and that the group was likely to be a beneficiary of developments taking place elsewhere in ICES. Specifically, attention was drawn to the Study Group on age-length assessment models SGASAM, which was considered the appropriate forum for the developmental phases. In the future, notification of promising approaches could perhaps lead to members of SGASAM attending a Nephrops meeting to demonstrate applications in a Nephrops context.

Discussions focussed on the ongoing need for reliable growth data in order to implement some of the length structured approaches. Scope for new work on growth parameter estimation seems to be limited in national laboratories at the present time. Under the DCR there is a requirement to furnish growth data periodically but WKNEPH felt that the type of data being gathered (mainly length compositions) would not, of itself, permit growth to be estimated. It was agreed that the Chair would write to the Commission to open up a discussion of the possibilities for funded projects to provide relevant material.

An overview of progress on the use of Underwater Television to provide fishery independent estimates of stock is included in the report. This draws attention to the value and use of the method and its application in providing stock advice for some stocks at present. It also highlights outstanding issues and areas of development that need to be progressed as soon as possible. There was insufficient time within this meeting to tackle many of these points and it was agreed that a dedicated Workshop on the use of UTV was needed. Proposals were drawn up and details are included below. Value could be added to such a meeting if attendance were possible by UTV experts from outside the ICES community and there was some discussion of funding possibilities. It was agreed that efforts would be made to include a workshop of this type under the eligibility for funding in the EU's DCR programme for 2007.

Gear conclusions

New information on Nephrops selectivity was scarce but updates were provided of ongoing fishing gear work which has a broader remit to tackle mixed fishery issues and the separation of unwanted by-catch (including from Nephrops gears). Several of these major EU funded projects are due to complete soon and WKNEPH considered that it was better to wait until the new work emerged and then take stock of the findings.

7.2 Recommendations

The group considered carefully the main outcomes of the meeting and drew up a limited number of recommendations in order to avoid unrealistic and unachievable targets being set. These are listed below and also summarised in Annex 2 together with suggested actions and responsibilities.

1) Continue with regional WGs, improve efficiency through early assessment and establishment of internal 'review' groups prior to meeting and devote more time to mixed fishery issues etc.
2) Hold TV Workshop in 2007 (see Annex 3 for details of a formal proposal and justification)
3) Produce broad based overview paper updating maturity information for female Nephrops
4) Continue maturity work (leading to paper as above) on males
5) Initiate a coordinated approach to generating new growth data on Nephrops
6) Establish future forum for continuing developmental work on Nephrops

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Annex 2: Recommendations

The following Table summarises the main recommendations arising from the WKNEPH and identifies responsibilities for action

RECOMMENDATION	ACTION
1.Continue with regional WGs, improve efficiency through early assessment and establishment of internal 'review' groups prior to meeting and devote more time to mixed fishery issues etc.	ACFM and Regional WG chairs to note
2.Hold TV Workshop in 2007	WKNEPH Chair and Colm Lorden to take forward. For Consideration as 2006 ICES Resolution. See Annex 3
3.Produce broad based overview paper updating maturity information for female Nephrops	WKNEPH members to take forward with lead from Frank Redant and Cristina Silva
4.Continue maturity work (leading to paper as above) on males	WG Neph members
5.Initiate a coordinated approach to generating new growth data on Nephrops	Approach to be made by WKNEPH Chair to EU Commission
6.Establish future forum for continuing developmental work on Nephrops	ICES Committees (eg Living Resources) for consideration

Annex 3: Further Workshop proposal

WKNEPH considered that the most pressing requirement in the area of Nephrops assessment development was an opportunity to bring together UTV expertise during a dedicated workshop. The proposal below outlines the main topics to be covered.

A Workshop on the use of UWTV surveys for determining abundance in *Nephrops* stocks throughout European waters [WKNEPHTV ??] (Chair: Colm Lordan) will take place in Heraklion, Crete, from ??-?? April 2007 to:

Terms of Reference:

1) Review and report technological developments used in underwater TV surveys for *Nephrops*.

2) Compare survey designs employed in different areas and evaluate, where possible, the relative performance of these.

3) Report on work addressing outstanding issues influencing the accuracy and precision of TV estimates of abundance *inter alia* burrow identification, occupancy rate, counting method, survey data analysis, raising procedures.

4) Document the protocols used to conduct surveys across the range of European stocks, highlighting standard practices and 'norms' adopted in UWTV work.

5) Investigate and make recommendations on procedures for inter-calibration, quality assurance and the reporting of precision from TV surveys.

6) Report on developments in the translation of survey estimates into stock assessment information and catch forecast advice, recommending where additional work is most urgently required.

7) Consider the wider utility of the techniques employed in *Nephrops* UWTV surveys for estimation of other benthic species and habitat assessment.

Supporting Information

See Table below

PRIORITY:	This Workshop will provide an opportunity for significant update and progress in the area of UWTV surveys for Nephrops. For a number of stocks, ICES WGs and ACFM indicated that TV results presently provide the most reliable indicator of stock status. Consequently, these activities are considered to have a very high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	Action Plan No: ?.[NB needs to id this]. Given the recent use made of TV in the Nephrops advisory process, the growing number of institutes making use of TV methodology and the continuing uncertain quality of fishery data available to proceed with other forms of assessment this workshop is essential and timely. The Workshop will serve several purposes. For those embarking on the technique it will give an up to date resume of the state of play and give excellent technology transfer opportunities. It will provide an opportunity for several outstanding issues to be investigated and hopefully dealt with. It will enable progress to be made in a number of key developmental areas especially the link between surveys and the provision of advice and it will provide the stimulus to more formally collate a Europe wide synopsis of the applictaion of UWTV. ToR 1 will enable the latest developments to be publicised and is expected to lead to more effective use being made of European ship time in the collection of UWTV (and associated) data. ToRs 2 and 3 are intended to progress resolution of important issues associated with the method while ToR 4 provides an opportunity to document in a consistent form, the various approaches being employed. This picks up on a ToR in PG CCDBS requiring the documentation of protocols for surveys. The expectation for ToR 5 is that a process of intercalibration work will be initiated with a view to addressing quality issues. ToR 6 is an important requirement given the use now being made of UWTV to form the basis of catch advice. Surveys need to be conducted so as to best provide data in a form suitable for appropriate assessment and forecasting methods . The Final ToR 7 involves a look at the broader use of TV and the great potential for collecting benthic and bentho-pelagic information in an efficient and low impact way – with the likely increasing importance of monitoring for wider ecosystem considerations, developments in Nephrops UWTV have an important role to play.
RESOURCE REQUIREMENTS:	Several national labs and universtiy departments are using the approach and data and expertise can already be drawn on. It is expected that outcomes from the group will be picked up by users of the technology and existing funding focussed more effectively as a result. Additional resources in the future may be required.
PARTICIPANTS:	The Workshop is expected to attract wide interest across the ICES Nephrops community and is also expected to involve other guest experts who can potentially add value to the process. A participation of around 30 is expected
SECRETARIAT FACILITIES:	None.
FINANCIAL:	To ensure wide attendance of relevant experts some additional funding may be required and efforts will be made to explore a range of funding opportunities including the EU DCR.
LINKAGES TO ADVISORY COMMITTEES:	There is a direct link to ACFM through a number of regional assessment Working Groups wih responsibilities for Nephrops assessment. Several of these in 2005 advised that TV survey data provided the most reliable indicator of stck staus for a number of stocks. The Workshop is expected to develop the utility of the survey material and enhance the nature of the advice given. ToR 7 provides an opportunity to broaden the discussion of the technique into its adaptation for assessing other benthic organisms. The EU DCR is currently reviewing the requirement for RV surveys to collect a wider range of data so as service the needs of the Ecosystem Approach. TV surveys offer an efficient and low impact approach which should have important resonance in ACE
LINKAGES TO OTHER COMMITTEES OR GROUPS:	There will be important outcomes from this Workshop of interest to the Living Resouces Committee and Resource Management Committee.
LINKAGES TO OTHER ORGANIZATIONS:	Outcomes from this Workshop will have relevance to a variety of groups involved in the use of UWTV and especially those assessing Nephrops. Mediterranean organisations have already expressed an interest for example and offerred facilities to host the meeting.
SECRETARIAT MARGINAL COST SHARE:	????.

Annex 4: Working Document *by* Andersen and Munch-Petersen

Identification of Danish directed *Nephrops* fisheries in Kattegat in a mixed fishery

By Bo Sølgaard Andersen and Sten Munch-Petersen

In a recent study by Ulrich and Andersen (2004)[1] two Danish *Nephrops* related fisheries were defined in Kattegat: a directed Nephrops fishery using 70–90 mm mesh size and a mixed fishery using 90–105 mm mesh size (*Nephrops*, sole, cod and plaice being the most important species). The directed *Nephrops* fishery (70–90 mm) was primarily determined by the regulation of a minimum of 30% of *Nephrops* (by weight) in the catches. Figure 1 shows the development from 1990 to 2004 of the relative contribution of these two fisheries to total landings from Kattegat and Skagerrak by Danish vessels.

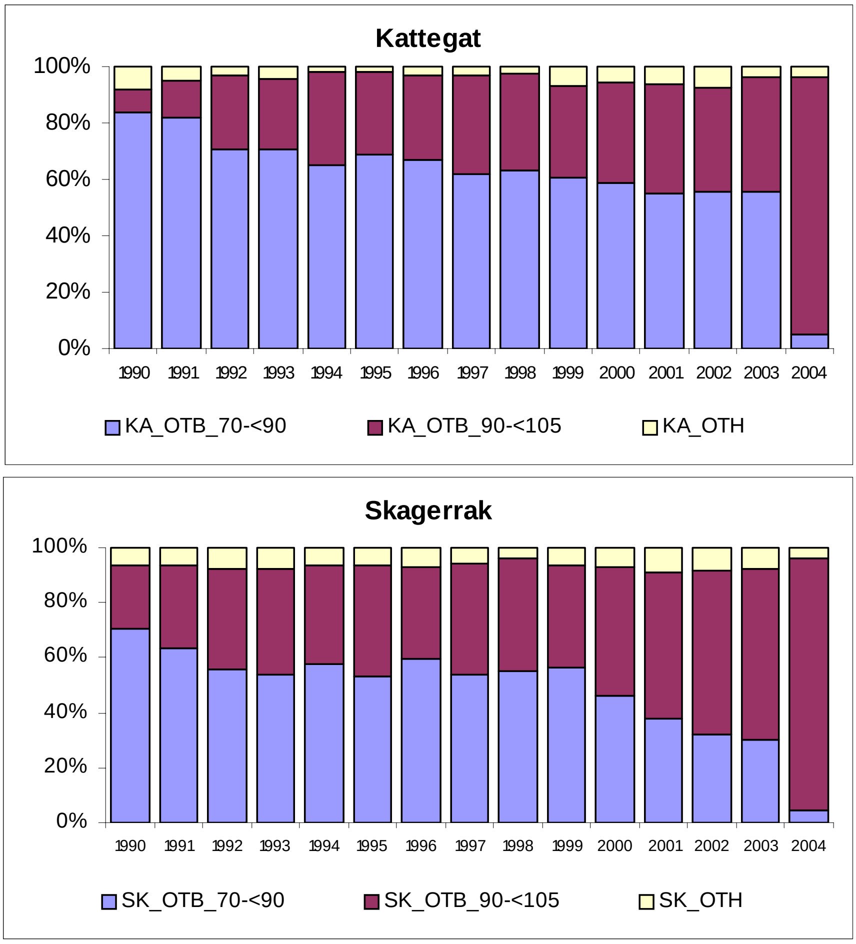

Figure 1. The relative distribution of *Nephrops* related fisheries in Kattegat(A) and Skagerrak(B) from 1996 to 2004.

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1 Ulrich,C. and Andersen B.S. 2004. Dynamics of fisheries, and the flexibility of vessel activity in Denmark between 1989 and 2001. ICES Journal of Marine Science, 61: 308–322.

From 1 March 2004 the 70–90 mm fishery was further restricted by introduction of compulsory use of square mesh netting in the cod-end (and from 2005 additional compulsory use of a sorting grid). Due to these significant restrictions, all Danish fishermen switched to the 90–105 mm cod-end for targeting *Nephrops*. Thus, today we are in a situation, where a *Nephrops* fishery no longer can be distinguished by explanatory physical variables (gear and mesh size specifications) available from either logbooks or sale slips records. Only data on catch composition and to a lesser extent fishing grounds can be used to segregate a directed *Nephrops* fishery from other fisheries.

In this study we have highlighted some of the problems of using the landings profile (or the proportion of *Nephrops* in value) as explanatory variable to define a directed *Nephrops* fishery among the mixed trawl fisheries with 90–105 mm cod-end. Based on official logbook and sale slip information from 1990 to 2004 it was observed that the total landed *Nephrops* in the mixed fishery increasingly are coming from trips with a high proportion of *Nephrops* (in value), see Figure 2.

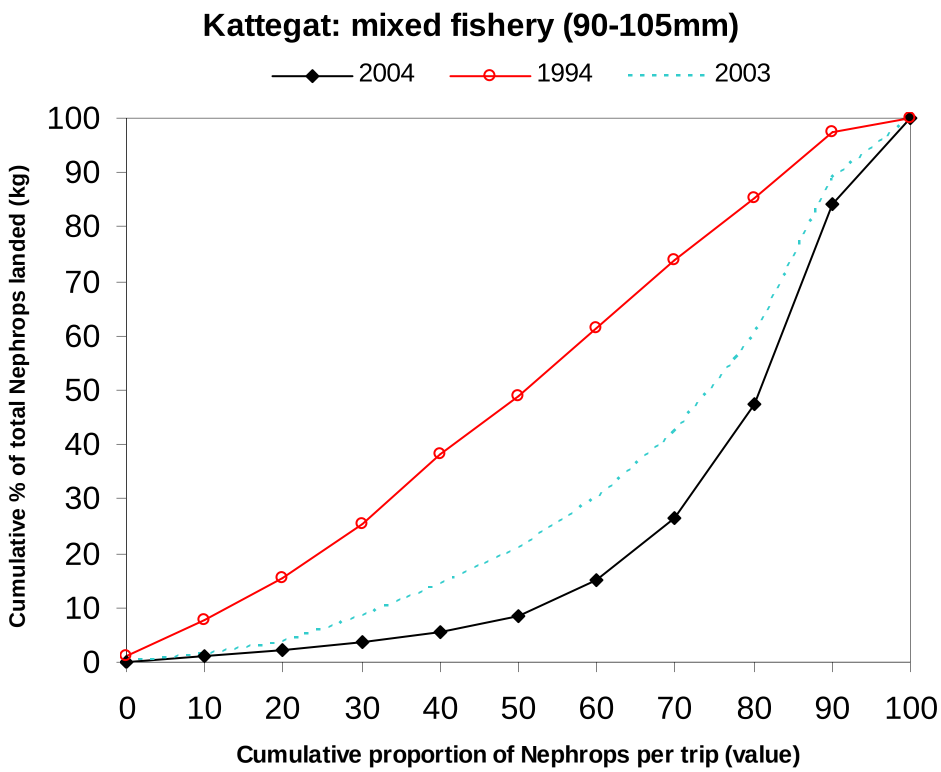

Figure 2. The cumulative % distribution of the total landed *Nephrops* against cumulative proportion (%) of *Nephrops* per trip in value, in the mixed fishery (90–105mm) in Kattegat. The x-axis gives the cumulative % *Nephrops* in single trips (in value), e.g. the point '50' corresponds to all trips with up to 50% *Nephrops* in the landing.

For example, in 1994, around 50% of the total landed *Nephrops* was caught in trips with a proportion higher than 50%, whereas in 2004 around 90 % total landed *Nephrops* was caught in trips with a proportion of 50% or higher.

Figures. 3 and 4 show the landing composition for the mixed fishery in Kattegat against increasing proportion of *Nephrops* in the landings per trip.

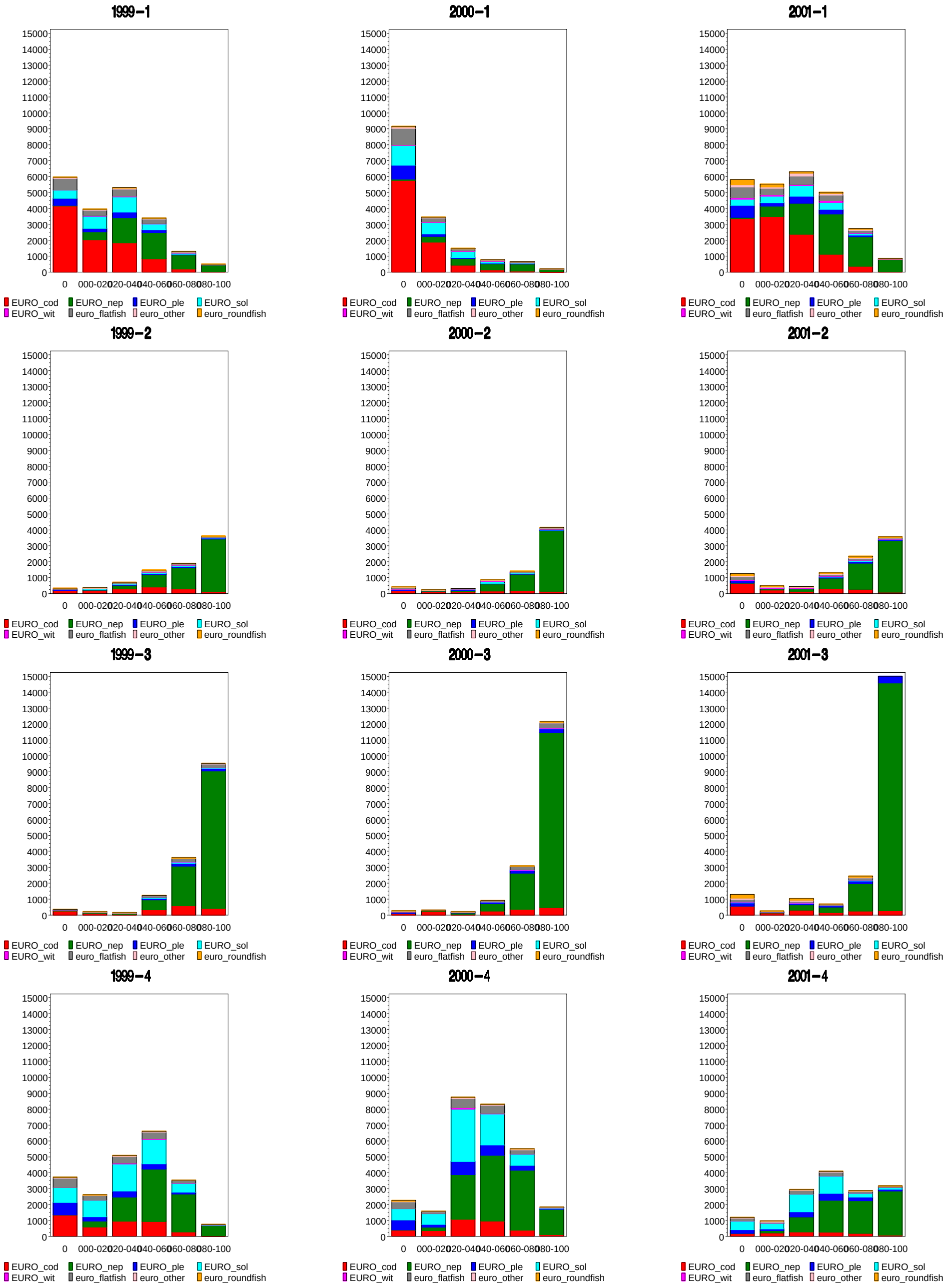

Figure 3. Mixed fishery in Kattegat. The landing composition against the increasing proportion of *Nephrops* (in value) for each quarter from 1999 to 2001. The y-axis: the landing in Danish kr.

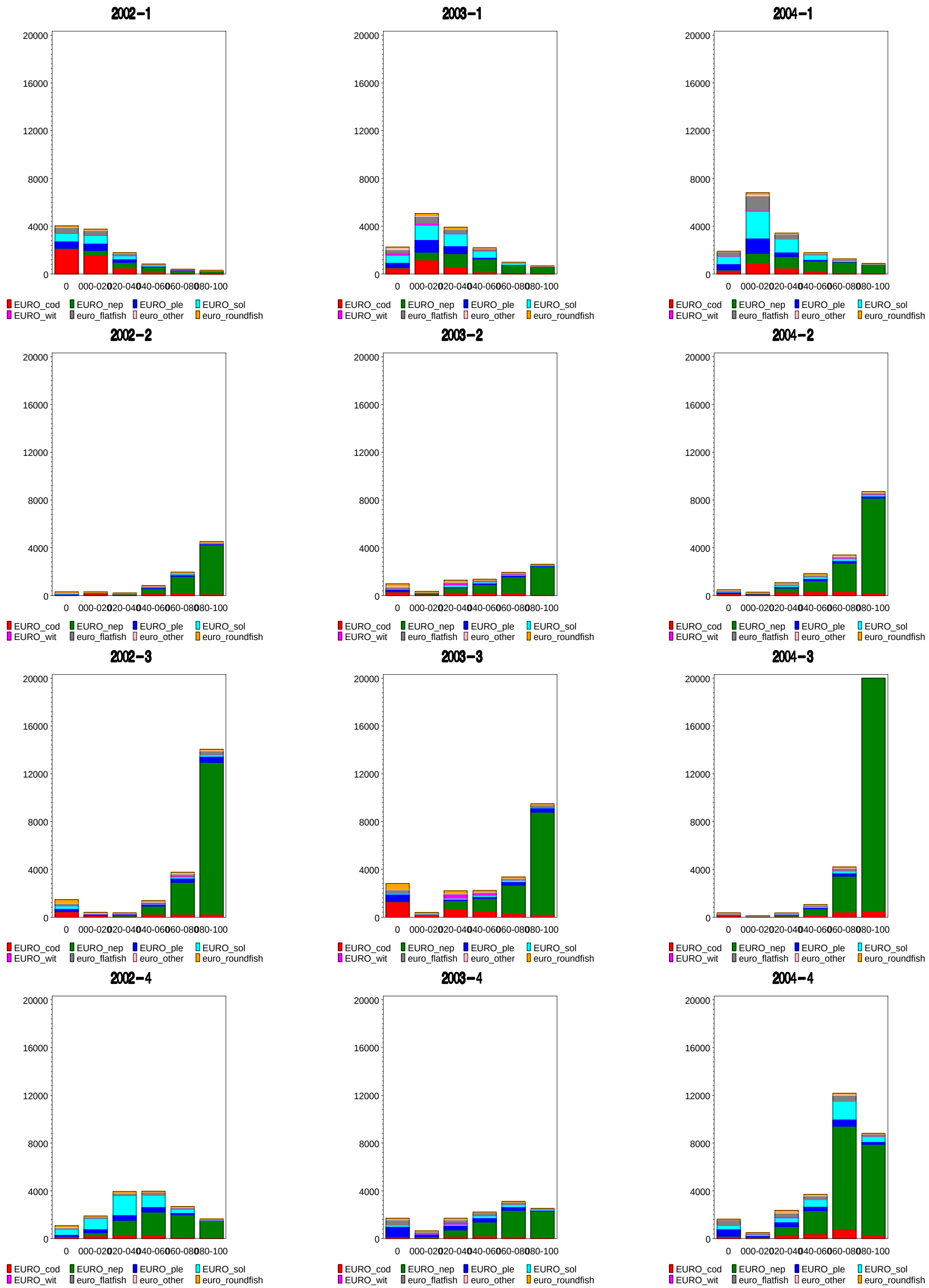

Figure 4. Mixed fishery in Kattegat: The landing composition plotted against the increasing proportion of *Nephrops* (in value) for each quarter from 2002 to 2004. The y-axis: the landing in Danish kr. presented

A clear seasonal pattern in the species composition was found in the mixed fishery: A sole/cod/*Nephrops* mixed fishery mainly take place in quarters 1 and 4, whereas a more clean, directed *Nephrops* fishery is conducted in quarters 2 and 3 (Figure 3).

Discussion/conclusion

- No unique definition of a Danish *Nephrops* directed fishery in Kattegat and Skagerrak is possible at present.
- No specific gear information is recorded in the available fishery databases (official logbook, sale slips and vessel register data) – Species compositions by value of landings are used to identify *Nephrops* directed fishery.
- The results indicate, that a more specific directed *Nephrops* fishery take place in 2 and 3 quarters, and that effort and corresponding landings and thus CPUE figures for these quarters may provide better indices for trends in the *Nephrops* stocks.

Annex 5: Working Document *by* Gerritsen, Doyle and Lordan

An Evaluation of the Precision of length-frequency samples of *Nephrops* from the Western Irish Sea (FU 15)

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Abstract

The precision of individual length frequency samples and population estimates was investigated and considerations for sampling design were discussed. As a rule-of-thumb a sample size of 10 times the number of size classes in the sample is suggested.

The majority of the *Nephrops* samples had more than 10 measurements per size class, while some had more than 50 after which the improvement precision becomes negligible. As the number of observations in each sample was reasonably high, the number of samples was the most important consideration for the precision of the population estimates.

Introduction

In order to estimate the optimum sample size in any sampling design, one must be able to estimate the precision of the parameter that is estimated. The precision of an estimate is often described in terms of a mean and variance, however in the case of length-frequency samples, the mean length is often of limited interest; the shape of the distribution is often more important. This creates a problem in defining the precision of a length frequency. Most previous studies have dealt with this by comparing the length frequency of a sample to that of an expected distribution, i.e. the entire catch or a mean distribution (Müller, 1996; Gomez-Buckley *et al.*, 1999; Vokoun *et al.*, 2001). Unfortunately, the expected distribution is rarely known in practice, therefore it would be advantageous to describe the precision in terms of a mean coefficient of variation (CV) of all length classes (e.g. Knuckley and Gason, 2001; Griggs, 2005).

Methods

Dataset

The precision of the *Nephrops* sampling by the Marine Institute during 2003-4 was examined. The main sample types are catch and discards, other sample types were omitted from the present analysis.

Definition of a *Nephrops* sample.

Nephrops sampling for many stocks around Ireland is complicated by the fact that *Nephrops* maybe landed either graded whole or as graded tails. Proportions of the catch landed as tails varies considerably by landings depending on several factors. In the case of the Irish Sea West stock (FU 15) the following 'two part sampling methodology' has been in place for many years: An unsorted 'catch sample' and an unsorted 'discard sample' (which includes heads from *Nephrops* which are landed as tails) is obtained either at sea or from vessels as they land. This self-sampling is augmented by observer trips where samples are also obtained.

The small *Nephrops* discards and the heads in the 'discard sample' are then used to calculate a discarding ogive on a quarterly basis. The unsorted 'catch sample' is then split into a discarded and landed component on the basis of this discard ogive.

This 'two part sampling methodology' has also been in place for *Nephrops* stocks in FUs; 15, 17 and 20–22. For other stocks such as FU 16 or FU 19, where *Nephrops* are mainly landed whole, unsorted catch samples and landings samples are obtained.

Current Sampling Protocol.

A random box of unsorted catch from any haul and a random box of discards from any haul during the trip is obtained from the returning vessel or at sea.

Nephrops samples continue to be handled in three parts; unsorted catch, undersized whole prawns and discarded 'heads' of *Nephrops* landed as tails.

The current sampling target sizes 'n' are given in the table below for the types of the *Nephrops* sample, however, in practice these targets are regularly exceeded.

Types of *Nephrops* sample	Category	Target 'n'
Part 1: Unsorted Catch	Catch	250
Part 2: Discarded whole *Nephrops*	Discards	250
Part 3: Discarded heads of the tailed *Nephrops*	Heads	250

The unsorted catch and discard samples of *Nephrops* are sorted into the component parts by sex and female maturity category (immature, maturing, and mature non-ovigerous and ovigerous females). The heads component of the discard samples is also sorted. The component parts are then weighed and the length frequency data are captured electronically by the NEMESYS measuring system.

Precision of individual samples

The occurrence that a random individual falls into a particular length category can be described by the binomial distribution of counts (Zar, 1999). Therefore the standard deviation (σ) of the number of fish in length category i is given by:

(1) $$\sigma = \sqrt{n_i(1 - \frac{n_i}{N})}$$

where n_i is the number of individuals at length i and N is the total number in the sample. This standard deviation provides an estimate of the precision of a single sample; it describes the variability that would occur if one could repeatedly take a length-frequency sample at the same location and time. The CV for each length class is given by:

(2) $$\mathrm{CV}_i = \frac{\sigma}{n_i}$$

As the precision of abundant length classes is more important than the precision of rare length classes, the mean CV should be weighted by the number of fish in each length class to obtain a mean weighted coefficient of variation (MWCV):

(3) $$\text{MWCV} = \frac{\sum n_i CV}{N} = \frac{\sum \sigma}{N}$$

Precision of population estimates

A sample from one haul is not a random sample from the population because fish caught together are often more similar than those in the general population (Pennington, 2001). One haul would only be a random sample if there was no structure in the population, i.e. it would be uniformly mixed. For this reason, Equation (1) cannot be used to estimate the precision of a length frequency that consists of more than one sample. Although an analytical approach might be possible, this tends to get rather complicated, particularly when sampling is stratified (Cochran, 1977). A more straightforward approach appears to be to use bootstrapping techniques (Efron and Tibshirani, 1993). The bootstrapping unit should be the individual samples, not individual fish as the latter would ignore the between-sample variation and lead to an under-estimate. This is because the observations of proportions at length are not independent which is assumed if individual fish are re-sampled.

When the length samples are used as bootstrapping units, there should be at least 10 samples available for the stratum of interest as this is advised as the minimum sample size for which bootstrapping is effective (Efron and Tibshirani, 1993). A problem with using samples as bootstrapping units is that, unless all sample sizes are equal, the total number of individuals in the bootstrap samples is not equal to the total number of individuals in the original data. In order to deal with this problem, an algorithm was used that repeatedly re-sampled the length-samples with replacement until the total number of individuals exceeded that of the original samples, next a random selection of individuals were omitted until the total number of individuals equalled that of the original samples. Next the standard deviation and confidence intervals were estimated and Equations (2) and (3) were used to estimate the MWCV of the population length frequencies.

Results

Individual samples

During 2003–4, a total of 146 samples were taken, most of them were split up in a catch and discard component. When each of these is then split by sex, a total of 480 samples. Figure 1 shows that the MWCV of the samples was closely related to the sample size divided by the number of length classes in the sample. The mean sample size of the samples where the sexes were combined, was 34 per size class, corresponding to a mean MWCV of 0.18. When the samples were separated by sex, the mean sample size was 19 and the mean MWCV was 0.25.

It appears from Figure 1 that the precision increases rapidly up to sample sizes of around 10 per size class. It would therefore be advisable use this as a minimum sample size in order to obtain a reasonably precise estimate of the length frequency of one particular haul. On the other hand, there seems to be little value in increasing the sample size much over 30 or 40 per size class as the increase in precision with increasing sample size will be negligible.

It can be seen from Figure 1 that there was a large range in sample sizes; when the sexes were combined, most sample sizes exceeded 10 per size class, however there were also a large number of samples that had more than 50 samples per size class, which seems like unnecessarily high, unless the samples were to be further divided by sex and maturity stages.

Population estimates

The Irish Sea samples were taken as an example to explore the precision of the estimates of the length distribution in the population. The Irish Sea (FU 15) was chosen as the number of samples was relatively high. Even so, only in quarters 2 to 4 of 2003 and quarters 2 and 3 of 2004 were there more that 9 samples available; the other quarters had fewer samples still and were therefore not suitable for bootstrapping. The population estimate of the length distribution was obtained by combining all samples without weighting.

The precision estimates, obtained by bootstrapping are shown in Figure 2. The MWCV of the population estimates of the length frequency distributions was generally between 0.1 and 0.2. The MWCV was only weakly related to the total numbers of individuals measured per size class. Nevertheless, samples with very high sample sizes did tend to have the lowest MWCV. The MWCV was not clearly related to the number of samples in the estimate. However, this number only varied from 9 to 16, this is probably not enough for an improvement in precision to become obvious. If the population were uniformly mixed, the precision estimates would be expected to lie on the same curve as those in Figure 1. As the estimates lie above the curve this indicates that the population was not uniformly mixed and that a proportion of the variability is due to differences between samples.

Discussion

Individual samples

The precision of the individual samples was closely related to the sample size divided by the number of size classes. This allows one to set sampling targets to achieve a certain precision level. As the number of size classes tended to vary from 20 to 30, a sample size in the order of 200–300 individuals would result in reasonably precise length frequencies. An increase in the width of the size classes e.g. from 1mm to 2mm, would result in an increase in precision in each size class and therefore also in the MWCV. The width of the size classes is therefore an important consideration.

The sample sizes that were taken in 2004 varied considerably, although most were larger than 10 per size class. On the other hand, there were a number of samples that had more than 50 measurements per size class, which is a bit extravagant.

Another consideration is the importance of having precise length distributions for each sex or each maturity stage. If the sexes are assessed separately, targets should be set accordingly, however the various maturity stages might not need to be determined all year round with high precision.

Finally, in order to obtain a precise population estimate, it is not necessary for the individual samples to have a high precision, in fact, if one measures 1000 individuals, it would be better to measure one individual per sample and take 1000 samples than to take one sample and measure 1000 individuals in that one sample. However, in practice it is time-consuming and costly to obtain samples, so the number of samples is usually limited by practical considerations.

Population estimates

Figure 2 shows that the precision of the population estimates is only weakly related to the sample size. Reducing the sample size by splitting the samples into the sexes or even into maturity stages, will therefore only increase the MWCV slightly.

Figure 2 also indicates that the Irish Sea *Nephrops* population is not uniformly mixed. In other words there is a significant amount of variability between the samples. The MWCV was rarely less than 0.1 even in cases where the total sample size was very large. It seems that, in order to improve the precision any further it will be necessary to increase the number of samples, not the sample size of the individual samples. However there was no obvious difference between quarters where 9 samples were taken, versus quarters with 16 samples. The number of samples will probably have to increase considerably to improve the precision any further. This is probably not feasible and it is probably not necessary either, but this depends on the ultimate use of the length distribution information.

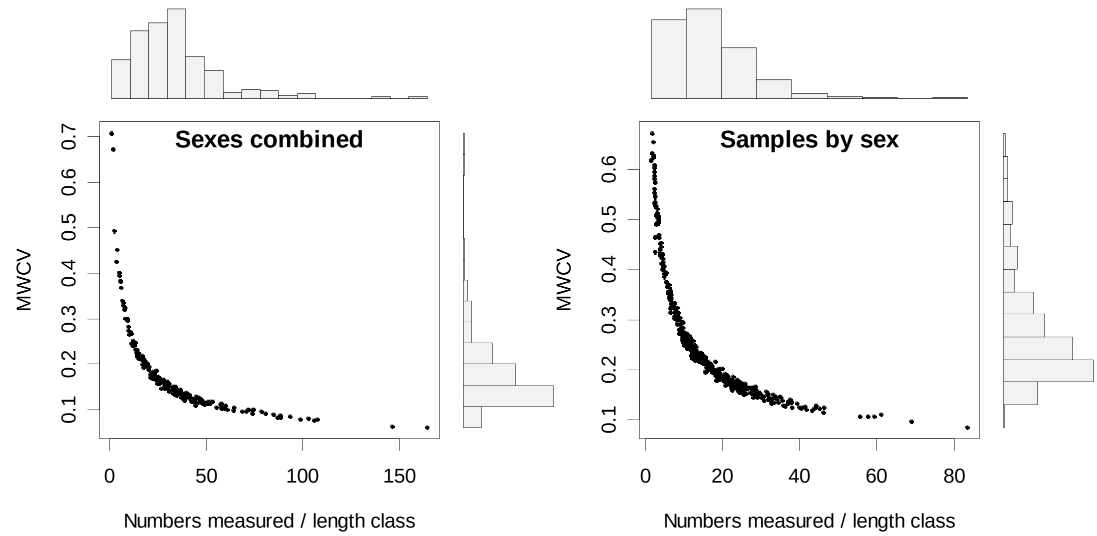

Figure 1. The mean weighted CV (MWCV) was closely related to the sample size divided by the number of length classes in the sample. Dividing the samples by sex (right) resulted in a reduction in the sample sizes and resultant MWCV.

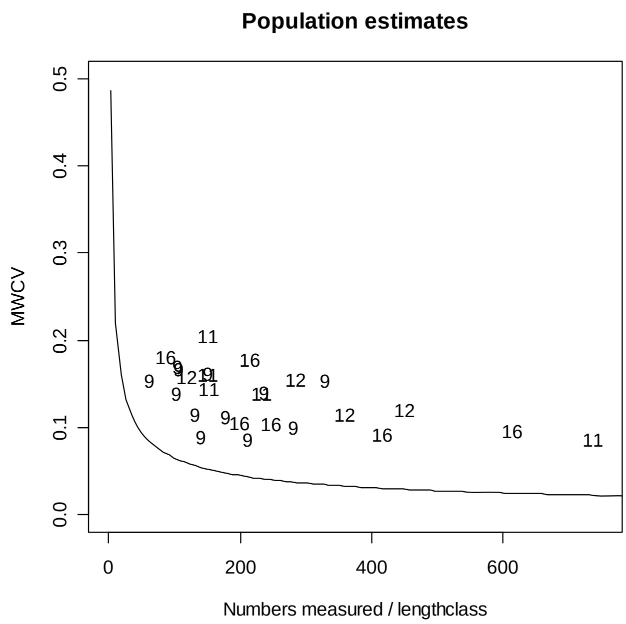

Figure 2. The numbers indicate the number of samples that were taken for the population estimates of the length frequencies in the Irish Sea during 2003–4. The curve shows the expected relationship for single samples from Figure 1. If the population were uniformly mixed, the values would be expected to lie on this curve. The MWCV of the population estimates was only weakly related to the sample size divided by the number of length classes in the sample.

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Annex 6: Working Document *by* Lordan and Gerritsen

The accuracy and precision of maturity parameters from sampling of female Nephrops from stocks around Ireland

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Introduction

Accurately and precisely defining size or age at maturity is important when assessing any exploited fish or shellfish resource. The levels of accuracy and precision required will depend on what these parameters will be ultimately used for to a certain extend. For many *Nephrops* (and fish) stocks within the ICES area maturity data are used as a fixed vector to convert biomass into a spawning (mature) component and immature component when implementing a VPA. Little attention is paid to the possibility that maturity may vary inter-annually or even within the maturity schedule of the population.

EC Regulation 1639-2001 (the "Data Regulation") requires regular updates of a number of biological parameters (sex ratio, sexual maturity, fecundity and growth) for all commercially important fish and shellfish stocks (see Appendix XVI of the Data Regulation). At a meeting in Lisbon in April 2004 the visual assessment of ovary maturation described in Redant (1994) was agreed as the basis for assessment of female *Nephrops* maturity throughout Europe. The results presented here are preliminary studies that have been used to investigate optimum timing of sampling for female maturity parameters.

Methods

Marine Institute sampling data from 2004 was used. All sampling categories (catch, discards and landings) were included in the data. Although the discards and landings categories were subject to size selection, this should not influence the results if maturity is expressed as proportions mature per length-class. As the maturity stages of males were not presently available, only females were analysed. The pale maturity stage and reabsorbing were considered immature, while the medium, dark and berried stages were considered mature.

For illustrative purposes of determining maturity schedules the sex-ratio and maturity of samples of female *Nephrops* collected from FU 17 the Aran Grounds over a 3 year period are also examined. Females spend most of the year in their burrows and are only caught in large numbers in the summer months. A useful definition of maturity could be that individuals that are likely to spawn in the current season are mature. Therefore it might not be particularly useful to refer to maturity outside the spawning season.

GLM models with a binomial link function (McCullagh and Nelder, 1989; Collett, 2003) were applied to the data on a monthly basis for each functional unit. Standard errors for the model and for the estimated length at 50% maturity (L50) were provided by the modelling software. Models were fitted using the R-language (R-Development-Core-Team 2003). The 95% confidence for the individual proportions at length were estimated using methods given in Zar (1999).

Results

Linear models did not provide a good fit to the data in every month of the year, but during the summer months they generally did fit well. In some occasions there were large (>30 mm) individuals that were considered as immature, resulting in bad fitting models. These entries might have been the result of misidentification of maturity stage or possibly mature prawns that had not yet commenced maturation for the forthcoming spawning season.

Western Irish Sea FU15

The precision of the L50 estimates is generally very well estimated during the summer months when sample sizes are high. The accuracy does not appear to be very good, though, the L50 estimate varies from 24.5 mm in June to 18.4 in July and 20.2 in august. The number of samples is reasonably low, so some of this variability could be due to differences between the samples (i.e. different gear types, sampling areas etc). Differences between these months could also be due to changes in emergence of the females in the various maturity stages. The fit in for the June estimate is not great; there are a large number of >30mm prawns that appear to be immature. These individuals were probably prawns that had spawned previously but their gonads had not yet begun to mature for the late summer spawning season.

Porcupine Bank FU16

Only the June and July samples contained females in FU16, and very few individuals were immature. It was therefore not possible to estimate the length-at-maturity in this area.

Aran Grounds FU17

In July sampling coverage was good for females in FU17, the L50 was very precisely estimated as 22.3 mm. In June, the sampling intensity was much lower, however the L50 estimate of 20.4 mm was still very precise. The sex ratio and maturity of female Nephrops sampled over a three-year period are presented on a monthly basis in Figure 2.

South and Southwest Coast of Ireland FU19

The only month with reasonable data was April, which might be a bit early in the year to get a reliable estimate.

Celtic Sea FU20

Data was good for June, July and August, L50 was estimated in all months with high precision, but again there were differences between the months.

Discussion

The timing of when maturity-sampling studies should take place for *Nephrops* is complicated by a number of factors. A period should be chosen that is (a) late enough relative to the start of the maturation cycle, to make sure that all females which are likely to participate in reproduction can be detected, but (b) not too late, to make sure that the berried females have not yet disappeared in their burrows. The optimum period differs between stocks, but for most stocks it seems to be summer or early autumn. Thus a detailed examination of maturity schedules is required before commencing maturity studies.

The results here suggest that although relatively high levels of precision can be obtained from routine market sampling of *Nephrops* the L50 from month to month can vary somewhat. The results here show the L50 varying by up to 3cm from month to month for *Nephrops* stocks in FU 15, 17 and 20–22. This may de due to catchability changes and emergence patterns. Thus timing of maturation studies may bias the derived parameters. This in turn leads one to consider how accurate any maturity parameters estimated might be at the population level.

A further factor to be considered is that in some areas the maturation schedule may vary considerably within the Functional unit. For example in FU 17 surveys in November 2001 and in June 2002 demonstrated considerable differences between the maturity schedules of female *Nephrops* sampled in shallower waters of Galway Bay compared with the Aran

Grounds. This implies that there will be problems in estimating population maturity parameters accurately.

We conclude that to accurately estimate population maturity in *Nephrops* may not be possible due to confounding problems such as spatio-temporal variations in these parameters and unknown catchability variations. In the context of analytical assessments a sensitivity analysis could be preformed to ascertain impact of any potential bias on a forecast and management advice. For several of these stocks no analytical assessments are possible due to data and methodological problems. Therefore the investment in research effort in trying to assess these parameters might be more wisely invested in alternative research that might lead to an improved understanding of both biology and stock dynamics.

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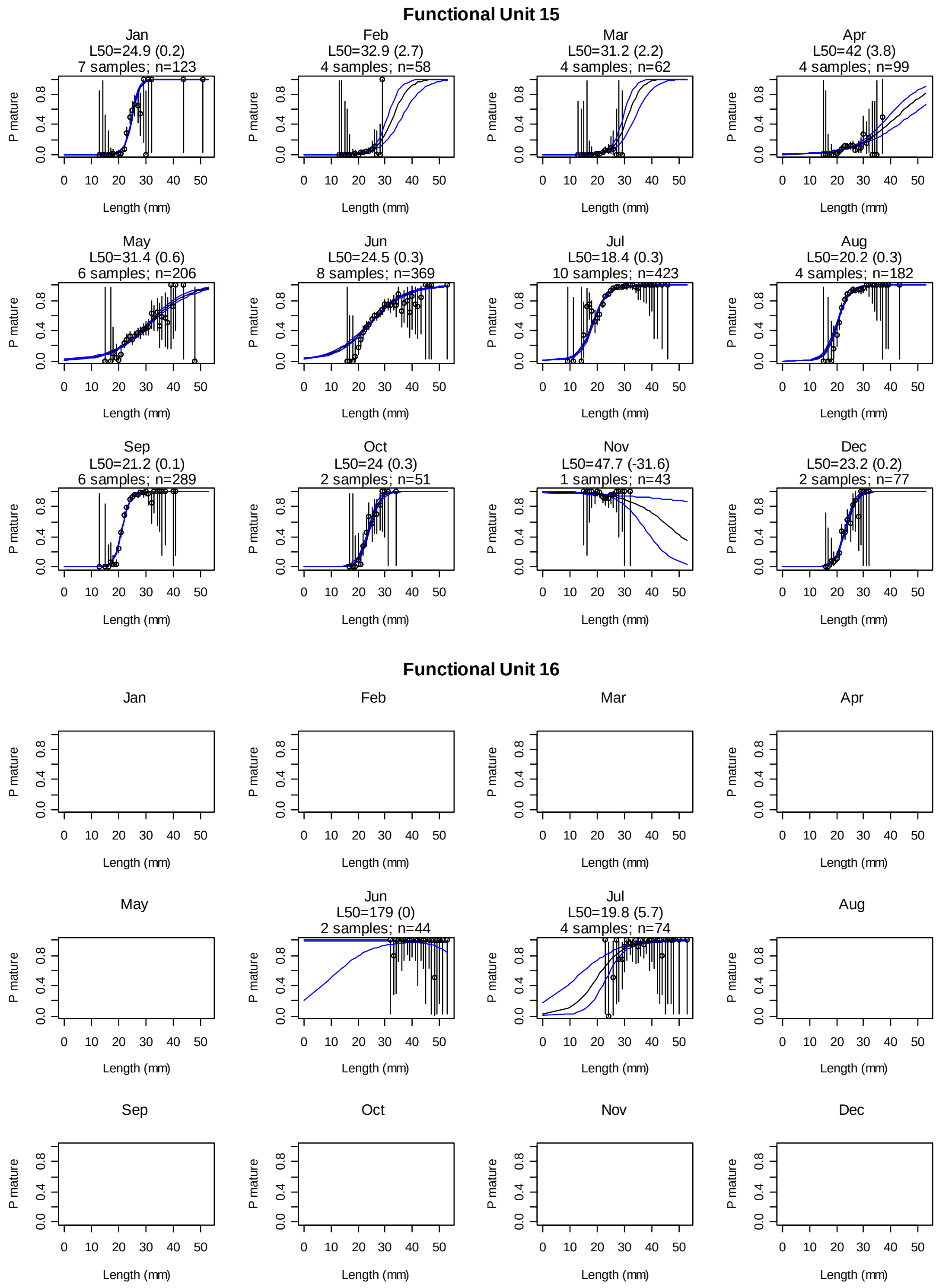

Figure 1a. Female proportions mature-at-length for FU 15 and 16. The 95% confidence limits of the proportions mature-at-length are indicated by the vertical bars. The black curve indicates the model and its standard errors are given by the blue lines. The L50 is the estimated length at 50% maturity and its standard error is given between brackets. Blank plots indicate no sampling took place.

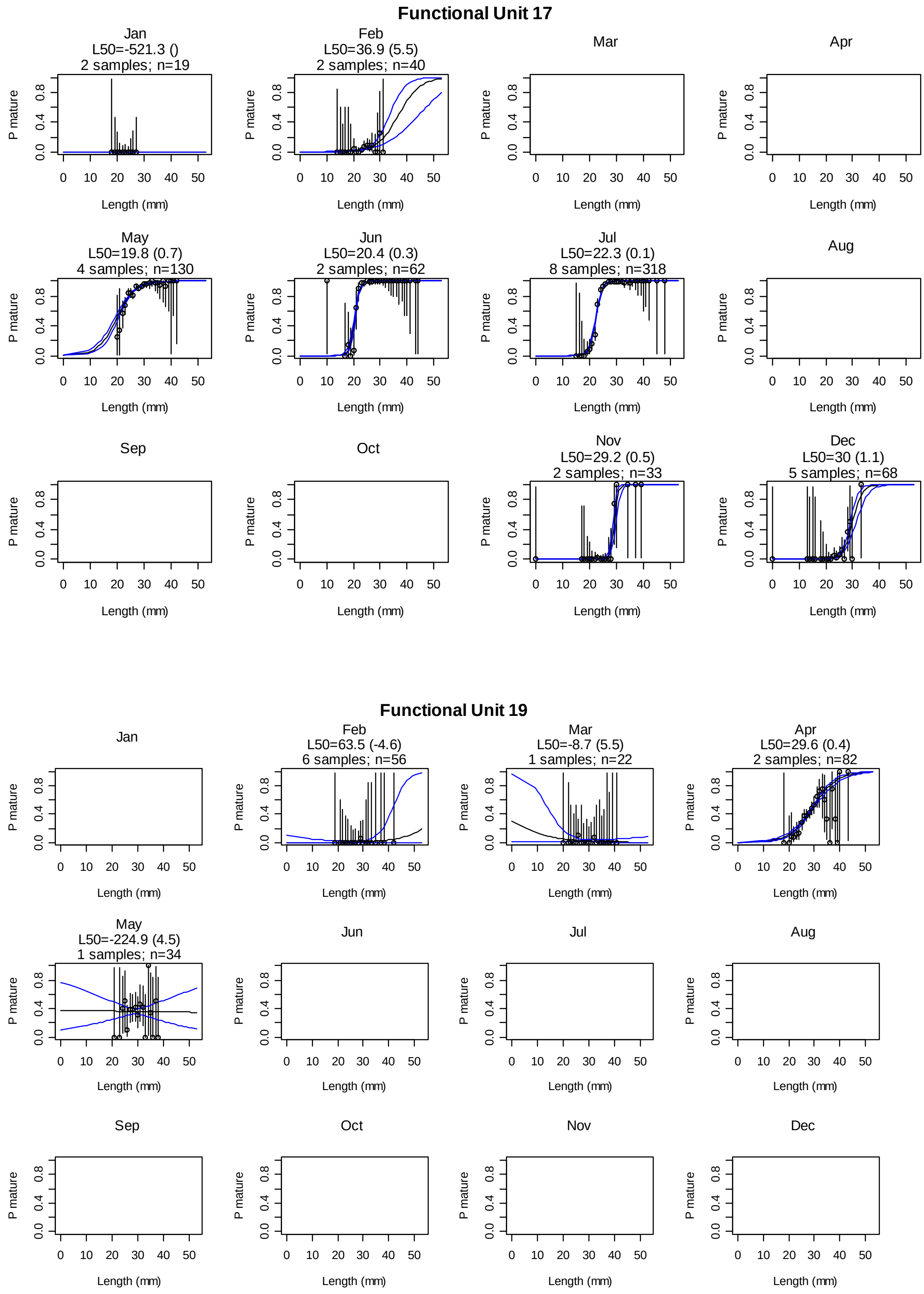

Figure 1b. Female proportions mature-at-length for FU 17 and FU 19. The 95% confidence limits of the proportions mature-at-length are indicated by the vertical bars. The black curve indicates the model and its standard errors are given by the blue lines. The L50 is the estimated length at 50% maturity and its standard error is given between brackets. Blank plots indicate no sampling took place.

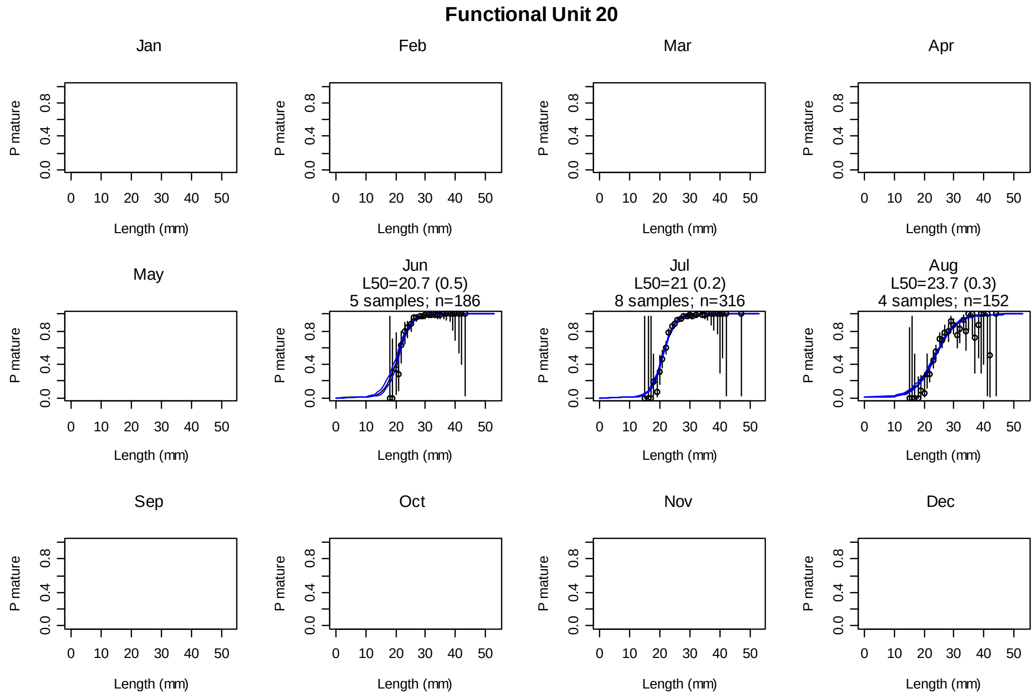

Figure 1c. Female proportions mature-at-length for FU 20–22. The 95% confidence limits of the proportions mature-at-length are indicated by the vertical bars. The black curve indicates the model and its standard errors are given by the blue lines. The L50 is the estimated length at 50% maturity and its standard error is given between brackets. Blank plots indicate no sampling took place.

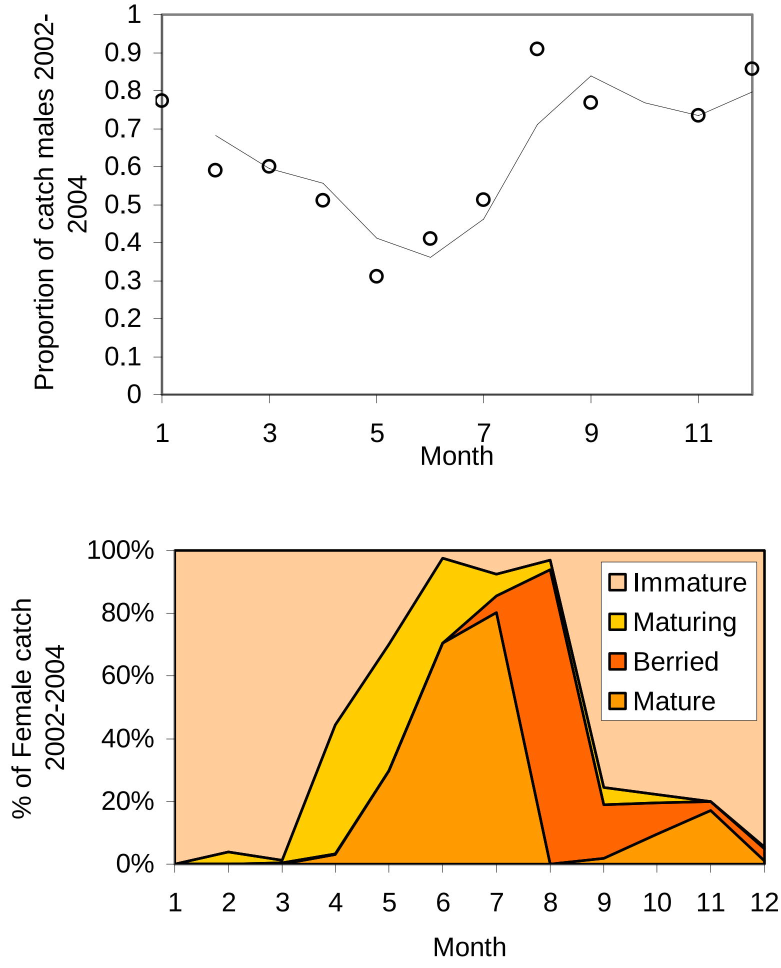

Figure 2. Monthly sex ratio and female maturity for *Nephrops* sampled from the Aran grounds between 2002–2004.