# International Program of Standardised Trawl Surveys

Final report to the Commission of European Communities

Contract Reference DG XIV Study Contract 98-057

Ifremer

Marine Laboratory, Aberdeen

Marine Institute
Foras na Mara

## IPROSTS Project

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July 2001

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# International Program of Standardised Trawl Surveys (IPROSTS) – EU Study contract 98-057

**Final Report**

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# Contents

## Scientific Summary and Keywords

The IPROSTS project had two main objective :

- Completionn of research vessel surveys in the autumn of 1999 and 2000 in ICES areas VI, VII and VIII in order to provide abundance indices at age for the major commercial species exploited in these areas,
- Standardisation of the methodology used in bottom trawl surveys.

For completion of the first objective, the French Research institute IFREMER conducted surveys in the Celtic Sea and the Bay of Biscay on board the Research Vessel, Thalassa. The Marine Institute of Dublin conducted surveys in the Irish Sea and Celtic Sea on board the Research Vessel Celtic Voyager and in the Western area of Ireland on board two chartered commercial fishing vessels (Marliona and Shauna Ann). The Marine Laboratory of Aberdeen conducted suveys in subareas Via, northern Irish Sea and northern part of subarea VIIb on board the research vessel SCOTIA. The SCOTIA and THALASSA used standard GOV bottom trawl, the Celtic Voyager a GOV designed bottom trawl but smaller, adapted to the size of the vessel. The commercial fishing vessel used Rock hopper commercial gear fitted with a 20 mm codend liner.

From the data collected, time series of abundance indices at age were completed to be used as tuning indices in Assessment Working Groups.

Regarding the second objective, two field of study were identified. The first is related to gear performance.

The first question is are research vessels fishing together with similar gear getting similar catches. To answer this question, two intercalibration experiment were undertaken between the SCOTIA and CELTIC VOYAGER and between the THALASSA and CELTIC VOYAGER. Initially intercalibration was also planned between the Irish Research and commercial vessels but a national decision was taken after the start of the study to build a new ship to undertake the surveys in the area covered with the commercial vessel. It was therefore decided to abandon this part and to carry the intercalibration with the new vessel when she is on duty. The analysis showed that there was no statistical evidence to support the hypothesis that the catches were different. The second question considered whether, on a single vessel using the same gear, gear performance varies in relation to external factors and whether or not this affects catchability. Conclusions were that all surveys produced major depth related changes in gear performance and that each net, including those of identical construction, display individual gear geometry; this may have an effect on the catch performance.

The second field of study was sampling strategies. A study was undertaken on sampling for age and showed that optimisation can be achieved by choosing the strategy adapted to the biological characteristics of the target species.

Finally from the hydrological data collected during the SCOTIA and THALASSA surveys, hydrological maps of surface and bottom temperature were produced.

**Keywords :** Bottom trawl surveys, gear calibration, conversion coefficients, species distribution, sampling strategies, gear performance, abundance indices at age.

## Summary for non-specialist

In the North-Eastern Atlantic national surveys have been conducted by Portugal, Spain, France, United Kingdom, Scotland and Ireland. This piecemeal approach left gaps in the areas surveyed and in 1997 it was decided that the surveys should have a more co-ordinated methodology. Moreover, since those surveys cover adjacent areas, abundance indices for some species do not cover their entire range of distribution. In considering the use of a combination of indices from different surveys, standardisation of the protocol used in the different surveys has to be carried.

A first project of standardisation (SESITS) covered the surveys carried by France in divisions VIIg,h,j, and VIIa,b Spain in divisions VIIIc and IXa and Portugal in Division IXa during the fourth Quarter.

The present project aimed to extend this standardisation process to the North and involved France for Divisions VIIg,h,j and VIIa,b , Ireland and Scotland for Divisions VI and VII.

The IPROSTS project aimed at two main objectives :

- Conduction of research vessels surveys in the fall of 1999 and 2000 in ICES areas VI, VII and VIII in order to provide abundance indices at age for the major commercial species exploited in these areas,
- Standardisation of the methodology used in bottom trawl surveys.

For the completion of the first objective, the French Research institute IFREMER conducted surveys in the Celtic Sea and the Bay of Biscay on board the Research Vessel Thalassa, The Marine Institute of Dublin conducted surveys in the Irish Sea and Celtic Sea on board the Research Vessel Celtic Voyager and in the Western area of Ireland on board two chartered commercial fishing vessels (Marliona and Shauna Ann). The Marine Laboratory of Aberdeen conducted suveys in subareas Via, northern Irish Sea and northern part of subarea VIIb on board the research vessel SCOTIA. The SCOTIA and THALASSA used standard GOV bottom trawl, the Celtic Voyager a GOV designed bottom trawl but smaller, adapted to the size of the vessel. The commercial fishing vessel used Rock hopper commercial gear fitted with a 20 mm codend liner.

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Finally from the hydrological data collected during the SCOTIA and THALASSA surveys, hydrological maps of surface and bottom temperature were produced.

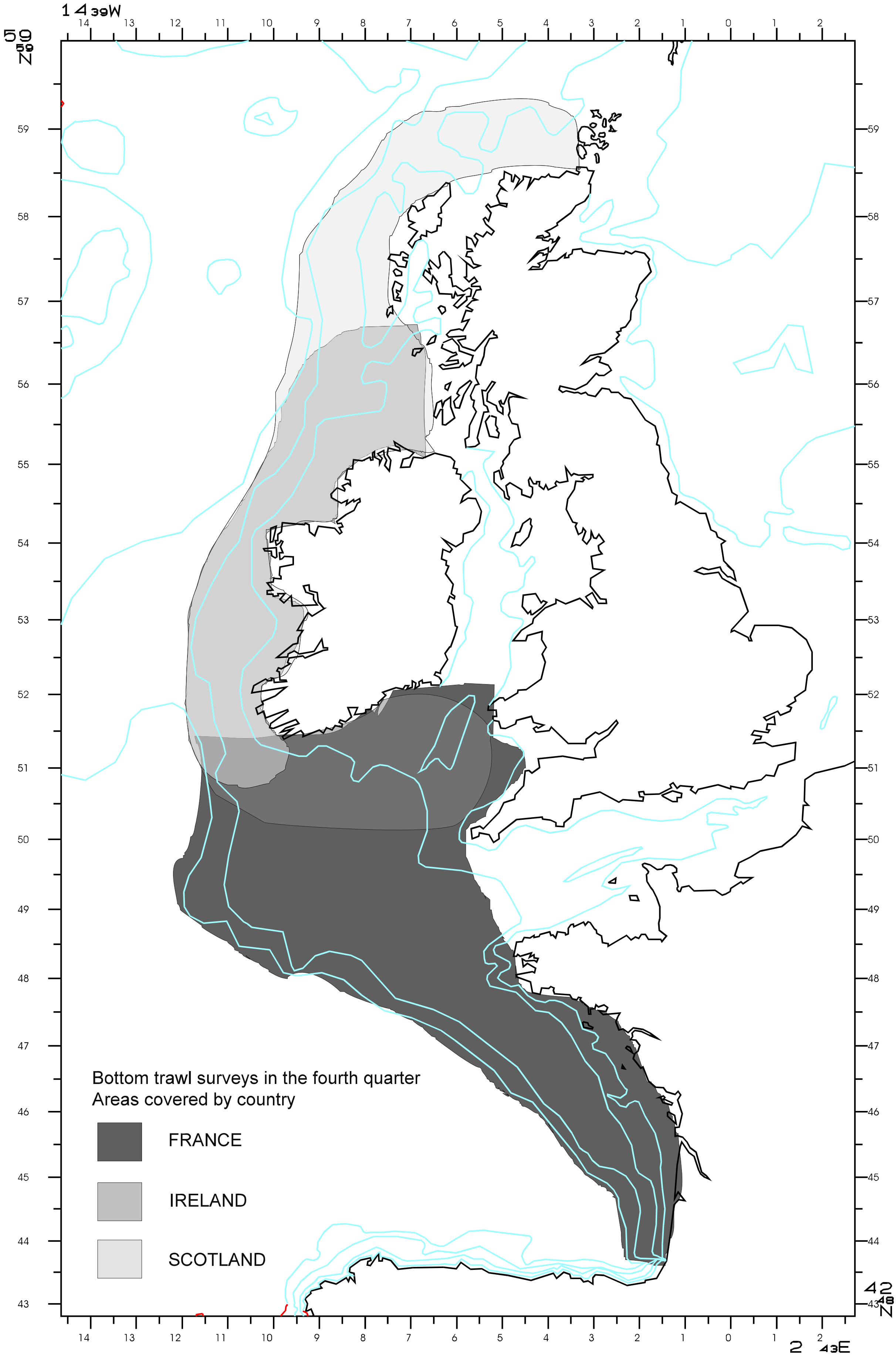



Figure 1. Area covered by countries involved in the IPROSTS project

# 1. Introduction

Assessment working groups dealing with stocks of the Western European continental waters make use of time series of abundance indices derived mostly from commercial fleets and to a lower extent of scientific surveys in calibrating sequential population analysis. The reason for not using scientific surveys to the extent that could be expected are related to partial stock area coverage of some surveys and short time series of data. The recent increase in technology used by commercial fleets has resulted in an increase of fishing power making the use of these data as tuning indices problematic. Scientific surveys are therefore gaining more and more interest among fisheries scientists. Moreover they also provide information on the evolution of faunistic communities. In order to fulfil the objectives of reliability and stability in catchability, survey methodologies have to be standardised in both fields of area sampling and catch sampling strategies.

In the North Sea, an ICES Working Group (IBTS) was created in 1990 in order to achieve these objectives. Since 1997 representatives from the countries carrying surveys in the Whole North-Eastern Atlantic have joined the Working Group.

In the North-Eastern Atlantic national surveys have been conducted by Portugal, Spain, France, United Kingdom, Scotland and Ireland. This piecemeal approach left gaps in the areas surveyed and in 1997 it was decided that the surveys should have a more co-ordinated methodology. Moreover, since those surveys cover adjacent areas, abundance indices for some species do not cover their entire range of distribution. In considering the use of a combination of indices from different surveys, standardisation of the protocol used in the different surveys (stratification and biological sampling) has to be carried and catchability coefficients for the participating Research Vessels have to be estimated (by mean of comparative towing).

The ICES International Bottom Trawl Working Group appointed Dr. Paul Connolly of FRC, Dublin as the co-ordinator and the first co-ordinated international survey occurred in November 1997. Ireland, the UK and France discussed the survey grids and station positions before the surveys and a series of comparative tows were carried out. This first attempt highlighted areas that contain deficiencies. However, in the absence of an IBTS meeting in 1998, there is no forum in which to discuss the comparative tow results and further plan for the 1998 results. The IPROSTS project was proposed in order to rectify perceived problems and improve the quality and quantity of data from areas in which limited resources are deployed.

A first project of standardisation (SESITS, EU funded Study Contract 96-029) covered the surveys carried by France in divisions VIIg,h,j, and VIIa,b Spain in divisions VIIIc and IXa and Portugal in Division IXa during the fourth Quarter.
The International Program of Standardised Bottom Trawl Surveys off NorthWestern Europe (IPROSTS – EU contract 98-057) officially started on 1st of April 1999. This project aims to conduct surveys in 1999 and 2000 and pursue the standardisation process already started in the North Sea and in the south-western Europe to the North and will involve France for Divisions VIIg,h,j and VIIIa,b , Ireland and Scotland for Divisions VI and VII (Figure 1).

## 2. Objectives and Tasks of the Study

Two main objectives were defined for the IPROSTS project : the building of time series of abundance indices from bottom trawl surveys and standardisation of the methodology used in bottom trawl surveys. To cover these objectives 5 tasks were defined.

### Task 1 – Conducting Surveys

In order to continue the time series of surveys already initiated, France, Ireland and Scotland conducted integrated surveys during October-November of 1999 and 2000. The research vessels Celtic Voyager, Scotia, Thalassa, and an Irish commercial trawler were deployed in the area marked on the attached map.Half-hour tows using a GOV trawl were made according to a standardised stratification scheme taking into account the IBTS working group recommendations by the Thalassa, Celtic Voyager and Scotia. An Irish commercial trawler also conducted surveys in the western area of Ireland making one hour tow using a commercial trawl equipped with a small mesh cod end cover.

### Task 2 - Standardisation

Even working within the framework of the ICES International Bottom Trawl Working Group it is evident that some aspects of the survey work have drifted from agreed standards; this is a perfectly understandable situation given that most effort of the Working Group has been concentrated in the North Sea.

Two areas of standardisation were investigated:

- Comparison of gear performances and investigation of their variation and possible effect on catch rate
- Investigation of age sampling strategies carried on survey catches for two major species (Megrim and Whiting)

### Task 3 - Calibration

The principal question addressed in this Sub-Task can be stated simply: Are similar catches observed on research vessels fishing together? Answering this question requires that similarity be defined. In this study the similarity between vessels was considered at several levels:

- Species composition,
- Species richness,
- Individual species abundance,
- Individual species size and age composition.

A hierarchical approach was adopted that first compared the species composition between vessels, and then compared the catches of individual species.

### Task 4 - Environmental data

After each set, a CTD profile was recorded. Surface and bottom temperature data were processed to monitor any change in the basic environmental characteristic of the area surveyed.

### Task 5 - Storage of data.

Each institute has its own database format and it was planned to define an agreed database format for exchange. This task was to benefit from the results of the SESITS program that came concluded in 1999

# 3. Task 1 – Description and conduct of the surveys

## Introduction

Ten surveys were undertaken during the period of this contract. Though they have a common objective to produce abundance indices used in ICES stock assessment working groups, they are different in several characteristics including the vessel (scientific or commercial), area covered, gear design and rigging, sampling strategy and computation of abundance indices. This section presents, by country involved in this contract, the characteristics of the surveys. Figure 3.1 shows the maps of fishing operations undertaken during the surveys in 1999 and 2000.

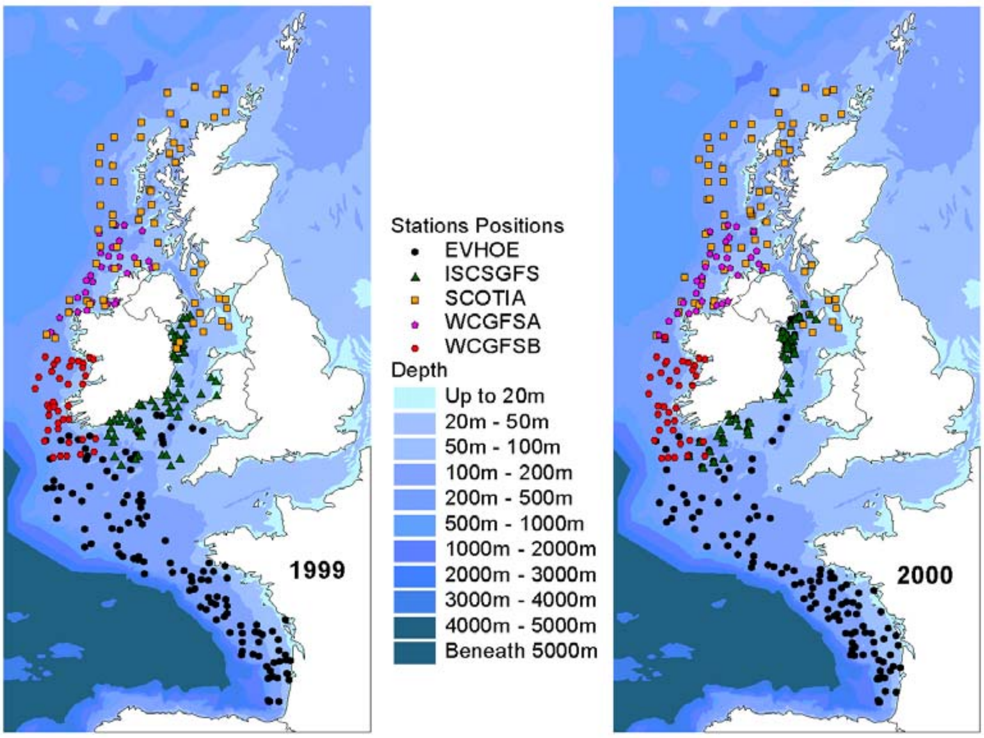



Figure 3.1 – Trawling station positions of the different surveys involved in the IPROST project in 1999 and 2000.

## 3.1 Scotland

### *Background:*

A west coast survey had been conducted by Scotland in the 4th quarter of each year since the middle of the 1980's. However, this survey had been targeted towards mackerel and had concentrated on surveying the shelf edge from north of the Shetland Isles to the south-west of Ireland. Unfortunately it was difficult to reconcile the results from this survey with a VPA using fishery dependant data and in 1996 it was decided to re-direct the objectives of this west coast survey whilst the mackerel data were re-analysed. Thus in 1996 the objectives of the fourth quarter survey were altered slightly to reduce the importance of mackerel and at the same time place a greater emphasis on cod, haddock and whiting.

### *Area covered and season*

Since 1996 and during 4th quarter, the survey focused more on the continental shelf in ICES sub-area VIa with an extension into the Irish Sea; however, some stations were maintained on the shelf edge in order to continue a watching brief on the mackerel stocks. This contract has allowed the Marine Laboratory to extend the new data series by 2 years and at the same time made provision for international co-operation of surveys along the north-eastern Atlantic seaboard; a feature that was missing before the contract .

### *The gear*

In both 1999 and 2000 the Scottish survey was undertaken by FRS *Scotia,* a 68 metre research vessel which was commissioned in March 1998. The gear deployed was the standard survey gear as recommended in the International Bottom Trawl manual (Addendum to ICES CM1996/H:1), i.e. the 36/47 GOV trawl fitted with heavy ground gear (ground gear C) and a 20 mm internal liner. An Exocite kite is flown from the middle of the headline to give an approximate opening of 4.5m.(fig. 3.1.1)

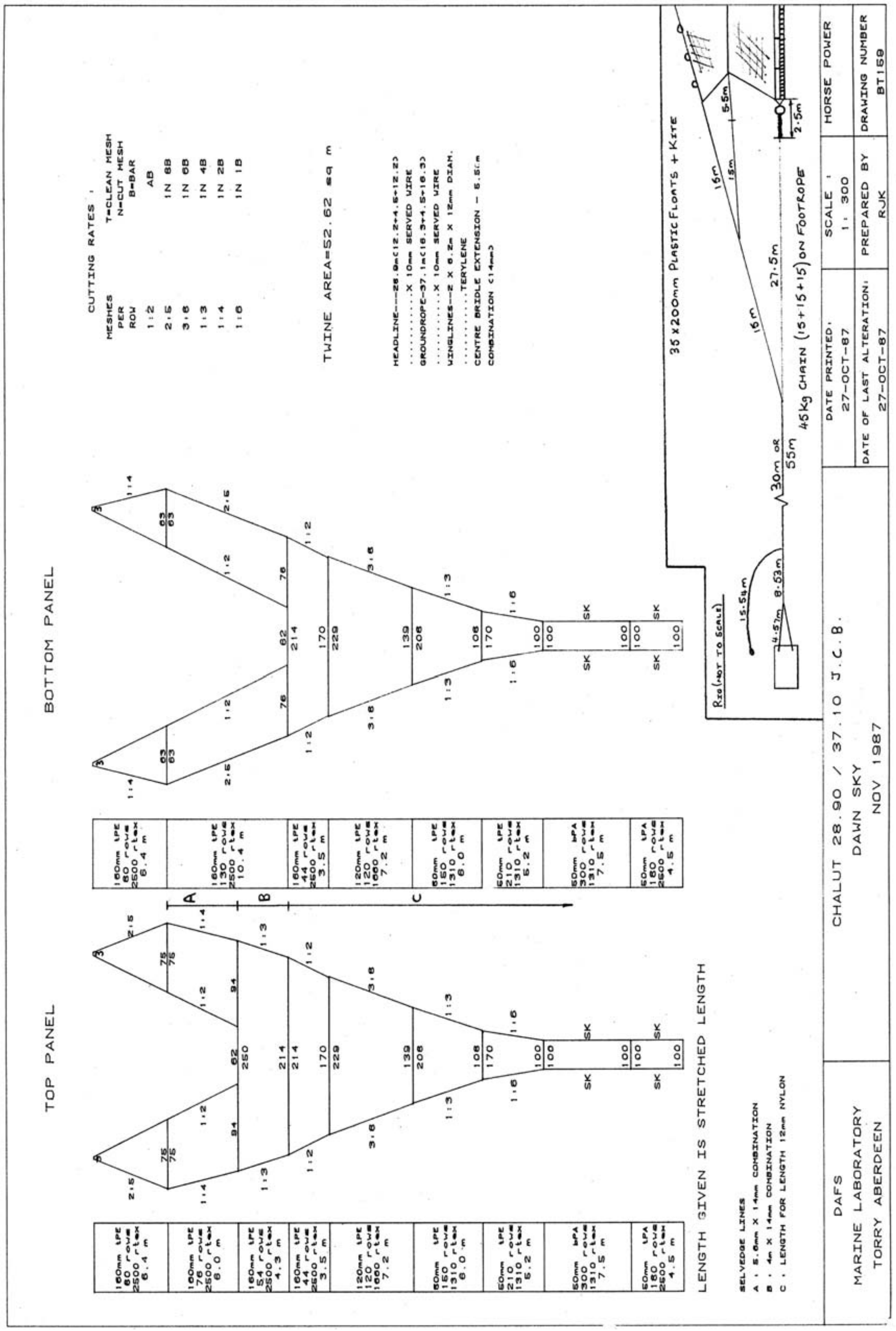



Figure 3.1.1 GOV net and rigging used on the R/V Scotia.

### *Sampling strategy*

The fourth quarter survey samples fishing grounds of less than 200 metres depth based on a stratification of one haul per ICES statistical rectangle in ICES sub-areas VIA (West of Scotland), the northern half of VIIA (Irish Sea) and the northern half of VIIb (West Ireland) (Figure 3.1.2).

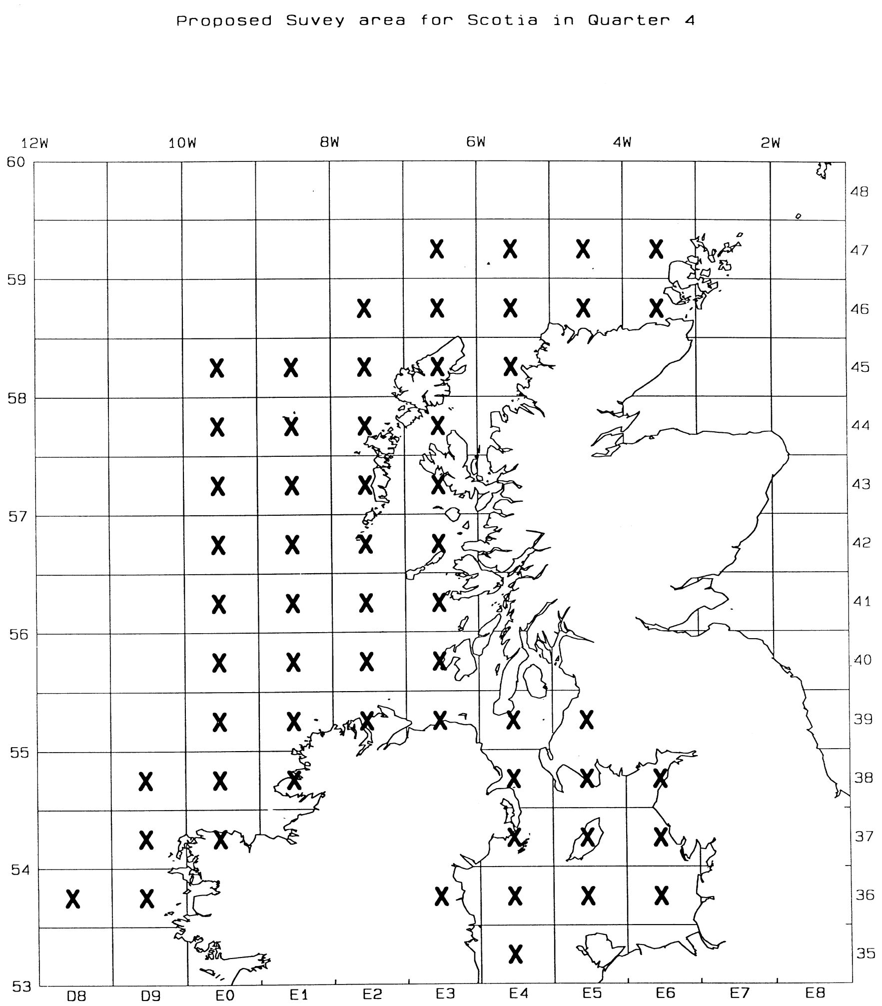



Figure 3.1.2. Sampling strategy in area covered by the Scotia survey

### *The hauls*

During daylight 30 minute tows were made at stations which were known to offer the opportunity of ‘clear’ tows. The fishing gear was monitored continuously by Scanmar equipment for headline height, wing spread, door spread and net speed through the water. Additionally a number of navigational parameters were also monitored.

In 1999 a total 55 hauls were made during the routine aspect of the survey; 39 valid half hour tows were conducted in ICES sub-area VIa, 5 in VIIb and a further 11 tows were undertaken in the Irish Sea (VIIa). In addition 20 hauls were carried out in conjunction with *Celtic Voyage*r as a comparative fishing exercise (see task 3). This gave an overall total of 75 hauls.

In 2000 a total of 72 hauls were made in the western division; 55 in ICES sub-area VIa, 5 in VIIb and 12 in the Irish Sea (VIIa). The lack of any comparative fishing in 2000 (in this year the comparisons were between Celtic Voyager and Thalassa) meant that extra effort could be devoted to sub-area VIIa where attempts were made to increase fishing by depth stratification. At the end of the routine survey three days were assigned to gear trials of the trawl using underwater TV in order to achieve a greater understanding of the GOV's performance.

Table 3.1.1 provides an overall summary of the work undertaken during the period of the contract.

| Year | Start Date | End Date | Days | Tows | | | | | Hydro | Comp. Fish | Gear Trial |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IVa | VIa | VIIa | VIIb | Total | | | |
| 1999 | 13/11 | 5/12 | 23 | 2 | 39 | 11 | 5 | 58 * | Yes | Yes | No |
| 2000 | 12/11 | 4/12 | 23 | 2 | 55 | 12 | 5 | 74 | Yes | No | Yes |

* plus 20 for comparative fishing

Table 3.1.1 - Summary of Work undertaken by Scotland 1999 & 2000

### *Information collected*

The catches were sampled and analysed according to established Scottish principles which, in turn, are also based on recommendations from the IBTS working Group. Each catch is fully sorted into species components and then each species is sampled for length. If the catch is greater than can be handled by the available scientific staff some sub-sampling will occur. Historically this was based on volume but with the purchase of reliable marinised weighing systems sub-sampling by weight is becoming the recognised convention. Otoliths are extracted from cod, haddock, whiting, saithe, Norway pout, herring, mackerel and sprat; with the exception of mackerel and sprat the sex and maturity are also determined when the otoliths are removed. Sex is not routinely associated with length measurements except for elasmobranchs and Nephrops norvegicus. Composition and occurrence of bottom fauna are not recorded.

Table 3.1.2 lists the amount of otoliths read from each survey.

| Year | Hauls | Cod | Haddock | Whiting | Saithe | N Pout | Herring | Mackerel | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1999 | 78 | 250 | 800 | 772 | 29 | 382 | 802 | 275 | 3388 |
| 2000 | 74 | 142 | 1002 | 973 | 18 | 480 | 936 | 311 | 3936 |
| Total | 152 | 392 | 1802 | 1745 | 47 | 862 | 1738 | 586 | 7324 |

Table 3.1.2 - Number of Otoliths Read from Scottish surveys 1999 & 2000

### *Abundance indices*

One of the main objectives of this survey is to provide indices of abundance for the relevant ICES working groups e.g. Northern Shelf Demersal Assessment. Indices of abundance for demersal species are based on determining the age frequency distribution within discrete Scottish sampling areas. These individual distributions are weighted by the number of valid hauls in each area and then aggregated to produce a mean value for each ICES sub-area.

### *Environmental data*

CTD data were collected during the surveys.

## 3.2. Ireland

### *Areas covered*

### *West Coast Groundfish Survey (WCGFS)*

Ireland's WCGFS has been undertaken annually since 1990. The WCGFS is carried out in two parts: Part A conducted in ICES Division VIa (south) and VIIb (north); Part B conducted in ICES Division VIIb and VIIj. This survey is carried out on the chartered commercial fishing vessels each year. Where possible the same vessels have been used each year. The net is fitted with a 20-mm codend liner. The sets are straight tows, of one-hour duration and are undertaken during daylight at a towing speed of 3.5 knots. The details of the surveys conducted in 1999 and 2000 are given in Table 3.2.1.

| Year | Survey | Dates | Vessel (*MFV*) | Net type [a] | Doors | Net Monitoring |
|---|---|---|---|---|---|---|
| 1999 | Part A | 4th-13th Oct | *Marliona* | Rockhopper Fine Gear | No.13 Bison | Furuno Ch24 [b] |
| 1999 | Part B | 12th-20th Jan 2000 | *Marliona* | Fine Gear | No.13 Bison | Scanmar RX400 [c] |
| 2000 | Part A | 6th-13th Oct | *Marliona* | Rockhopper Fine Gear | Morgere A8 Polyfoil | Scanmar RX400 [c] |
| 2000 | Part B | 17th-26th Oct | *Shauna Ann* | Rockhopper with 12 inch discs | 11 inch Thyboron | Scanmar RX400 [c] |

[a] 30 fathom of Double Bridles and 30 fathom of single bridles with 1½ inch rubbers.

[b] Headline Height.

[c] Headline Height and door spread.

Table 3.2.1. - Details of Irish WCGFS conducted in 1999 and 2000.

### *Irish Sea and Celtic Sea Groundfish Survey (ISCSGFS)*

Each November since 1997 the Marine Institute's Marine Fisheries Services Division has conducted the ISCSGFS from the *RV Celtic Voyager*. The sets are straight tows, 30 minutes long and are undertaken during daylight at a towing speed of 3.5 knots. The fishing gear used is a GOV 28.9/37.1 Trawl with Morgere Kite (0.85 by 0.85m). Morgere Polyvalent doors (Type AA4.5) are used (Figure 3.2.). Gear performance is monitored throughout the survey using the SCANMAR (RX400) net monitoring system (Headline height, Door spread).

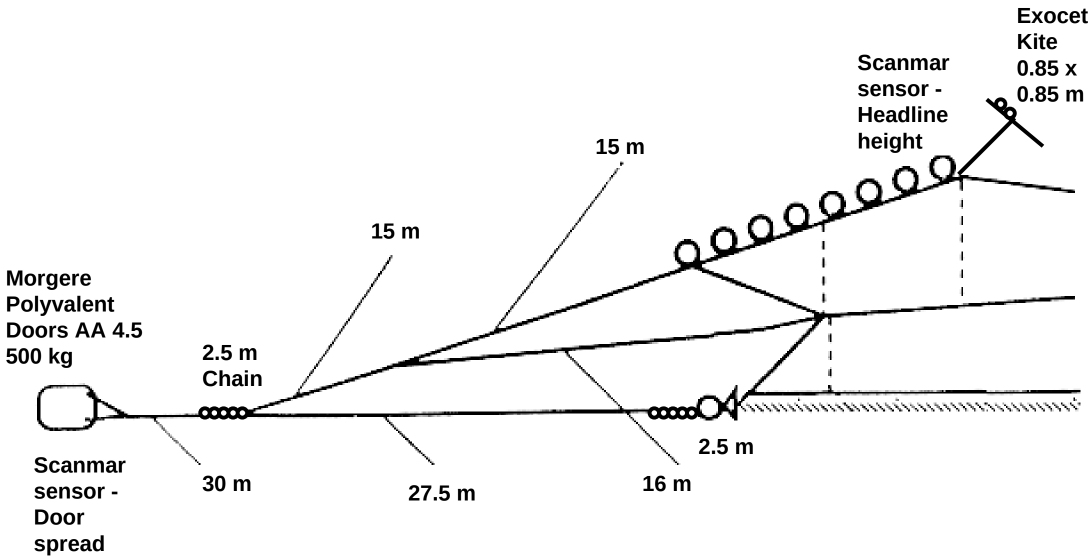



Figure 3.2.1. - Rigging of Irish GOV 28.9/37 trawl used on ISCSGFS in 1999 and 2000.

On both the WCGFS and ISCSGFS trawling is undertaken at stations which are known to offer the opportunity of 'clear' tows and the stations are distributed using an ICES rectangle based strategy (Figure 3.2.2). Two to three stations are normally fished per ICES rectangle.

### *The hauls*

During daylight, in 1999 and 2000, a total of 133 and 123 validated hauls, respectively, were made during the routine aspect of the survey. In 1999 22 hauls were carried out with RV *Scotia* as a comparative fishing exercise in the northern Irish Sea. In 2000 comparative hauls were carried out with RV *Thalassa* at the same 22 stations in northern Irish Sea sampled by the RV *Celtic Voyager* and RV *Scotia* in 1999. In 2000, 10 comparative hauls were also made in the northern Celtic Sea with the RV *Thalassa*.

Table 3.2.2 provides a summary of the number of tows undertaken on Irish groundfish surveys during the period of the contract.

| | Number of tows in ICES Sub-areas | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | VIa | VIIa | VIIb | VIIf | VIIg | VIIj | Total |
| 1999 | 27 | 38 | 22 | 1 | 25 | 20 | 133 |
| 2000 | 33 | 36 | 18 | | 13 | 23 | 123 |

Table 3.2.2. Summary of Groundfish Surveys undertaken by Ireland in 1999 and 2000.

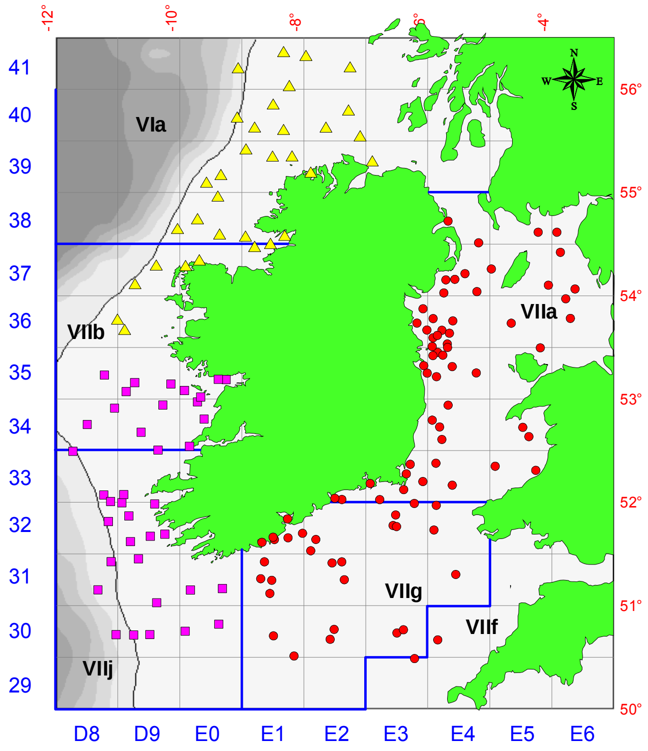



Figure 3.2.2. - Irish survey trawl positions for the West Coast Groundfish surveys (Part A – triangles, Part B – squares) and Irish Sea Celtic Sea Groundfish surveys (circles).

### *Information collected*

On the ISCSGFS survey the total catches are normally weighed raw and then sorted by species. When huge catches of one dominant species are taken only a fraction of the catch is sorted. On the WCGFS a sub-sample of two fish baskets is taken from the catch and sorted by species.

On both the WCGFS and ISCSGFS sub-samples are raised to the total catch using the total to sample ratios as raising factors. The initial raising factor on the WCGFS is by volume and subsequent raising by species is done by weight. On the ISCSGFS all raising is done by weight. All species of fish are measured, and for some species other biological data is gathered (e.g. weight, maturity, measurement by sex, ageing material). Ageing material is collected following a stratified allocation by length class and in some cases by sex. The sampling requirements are given in the Table 3.2.3:

| Species | Ordinary sampling requirement | Otolith sampling requirement |
|---|---|---|
| Plaice<br>Haddock<br>Whiting | Measure length | 1 per cm group per ICES rectangle |
| Cod<br>Hake<br>Dover (Black) sole | Sex all individuals sampled for ageing | Juveniles: 5 per cm group per ICES Division<br>Adults: 10 per cm group per ICES Division |
| Megrim | Measure length<br>Sex all individuals | |
| Elasmobranchs | | Not applicable |
| Herring<br>Sprat | Measure length (to the 0.5 cm) | |
| Squid<br>Other fish species | Measure length | |

Table 3.2.3. - Sampling requirements by species on Irish groundfish surveys.

Table 3.2.4 below lists the amount of otoliths read from each survey.

| | 1999 | | | 2000 | | |
|---|---|---|---|---|---|---|
| Species | ISCSGFS | WCGFS A | WCGFS B | ISCSGFS | WCGFS A | WCGFS B |
| Whiting | 461 | 319 | 361 | 472 | 171 | 355 |
| Haddock | 199 | 456 | 175 | 262 | 317 | 334 |
| Cod | 187 | 31 | 72 | 396 | 125 | 62 |
| Plaice | 192 | 186 | 118 | 179 | 86 | 103 |
| Hake | 438 | 77 | 546 | 187 | 6 | 140 |
| Sole | 39 | 10 | 48 | 84 | 16 | 27 |
| Megrim | 68 | 456 | 274 | 97 | 30 | 415 |

Table 3.2.4. - The number of otoliths read from Irish groundfish surveys of selected commercial species.

All information is stored in a database in SQL Server 7 format.

### *Computation of abundance indices*

The main objective of the surveys is to provide indices of abundance for relevant ICES working groups. Abundance data is aggregated to produce a mean value for each ICES sub-area.

### *Environmental data*

CTD data were collected during the ISCSGFS in 2000. However, there were problems with the electronic equipment and the data are sporadic. No environmental data are recorded on the WCGFS.

## 3.3 The EVHOE survey (France)

***Area covered and season***

For the 1987 to 1996 period, the Survey EVHOE has been conducted in the Bay of Biscay on an annual basis with the exception of the years 1993 and 1996. It has been conducted in the third or fourth quarter except in 1991 where it took place in May. In 1988 two survey were conducted, one in May the other in October.

The Celtic Sea was surveyed from 1990 to 1994 but the sampling was restricted to a small geographical area. The duration is between 40 to 45 days depending on year and availability of ship. Since 1997, the survey covered all the Celtic Sea and Bay of Biscay during the $4^{th}$ quarter.

***Objectives***

Since 1997 the main objectives have been :
- the construction of time series of abundance indices for all the commercial species in the Bay of Biscay and the Celtic Sea with an emphasis on the yearly assessed species where abundance indices at age are computed.
- to describe the spatial distribution of the species and to study their interannual variations.
- to estimate and/or update biological parameters (growth, sexual maturity, sex ratio...)

***Sampling strategy.***

The stratification scheme adopted defines 6 depth strata according to the following criteria:

| depth stratum | depth range |
|---|---|
| 1 | 0- 30m |
| 2 | 31 - 80 m |
| 3 | 81-120 m |
| 4 | 121 - 160 m |
| 5 | 161 - 200 m |
| 6 | 201 - 400 m |

A geographic stratification separates the Bay of Biscay in 2 areas and the Celtic Sea in 3 areas according to the Figure 3.3.1.

The sampling strategy is of a stratified random allocation the number of set per stratum being optimised by a Neyman allocation on numbers variance averaged on the 4 most important commercial species (hake, monkfishes and megrim) leaving of course at least two stations per stratum. 140 sets are planned every year. This number of sets is adjusted according to the time at sea available.

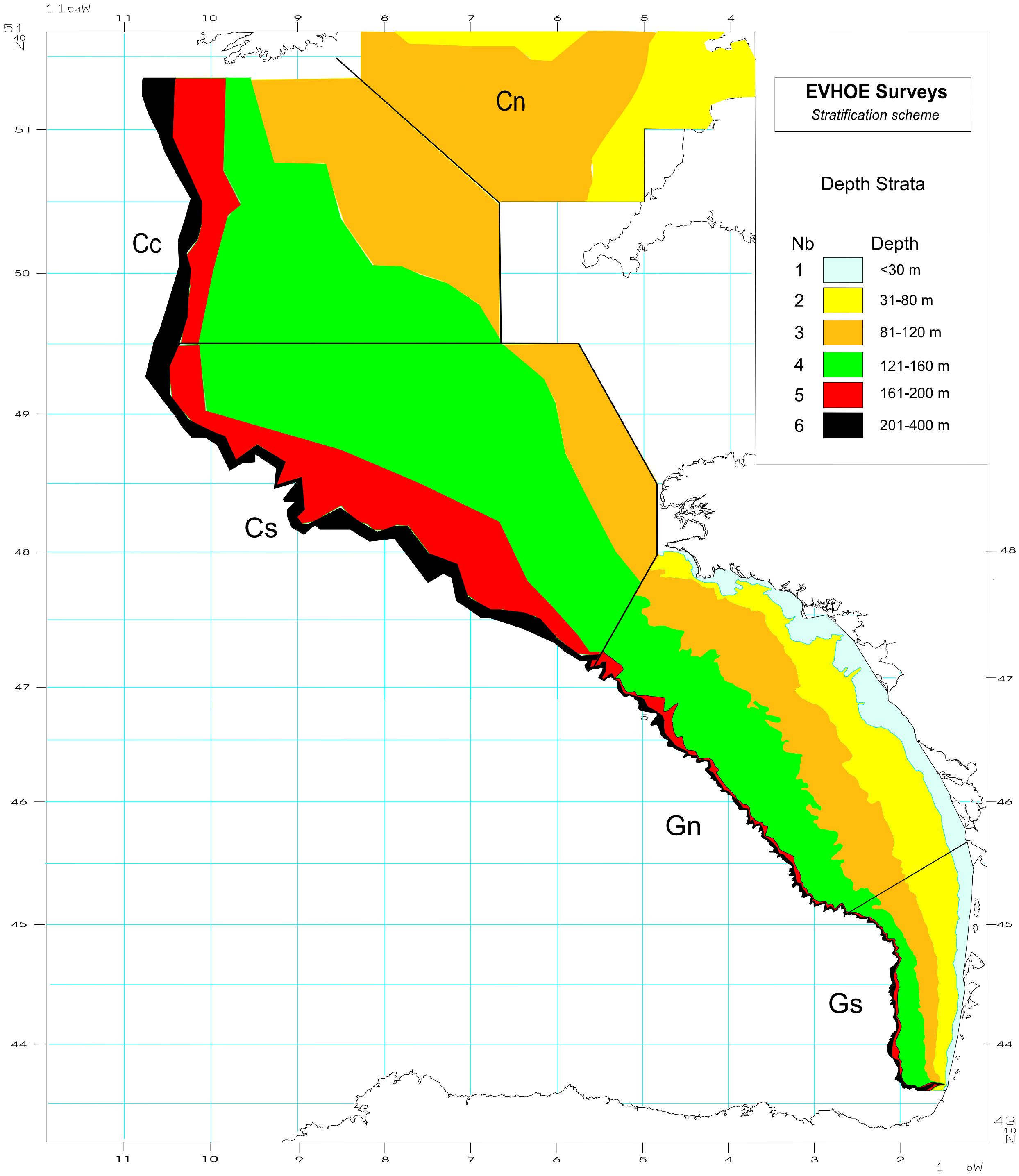
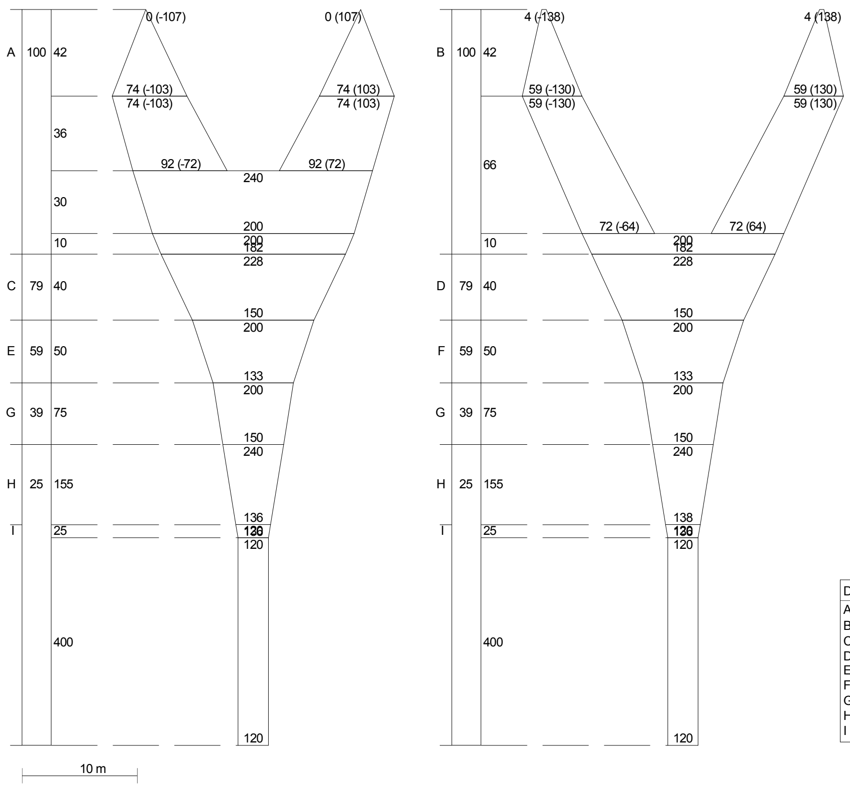



Figure 3.3.1. - Area covered and stratification used in the EVHOE surveys

***The Gear***

The trawl is a GOV 36/47 as described in the IBTS Survey manual except that the exocet Kite is replaced by additional buoyancy 66 floats instead of 60 and weight of Scanmar sensors placed in the middle of the headline has been balanced by adding 21 4l floats. Generally, the gear has a horizontal opening around 20 m and a vertical opening of 4 m. The doors are plane-oval of 1350 Kg. The net is fitted with a 20 mm codend liner. The characteristics of the gear and the rigging are given in Figures 3.3.2 and 3.3.3.




| Description | Material | Runnage (m/kg) | Mesh side (mm) | Diameter (mm) |
|---|---|---|---|---|
| A | PA | 280 | 100 | 2.87 |
| B | PA | 140 | 100 | 4.5 |
| C | PA | 280 | 80 | 2.87 |
| D | PA | 180 | 80 | 3.8 |
| E | PA | 280 | 60 | 2.87 |
| F | PA | 180 | 60 | 3.8 |
| G | PA | 280 | 40 | 2.87 |
| H | PA | 280 | 25 | 2.87 |
| I | PA | 180 | 25 | 3.8 |

Figure 3.3.2 – The GOV 36/47 trawl used on board the R/V Thalassa

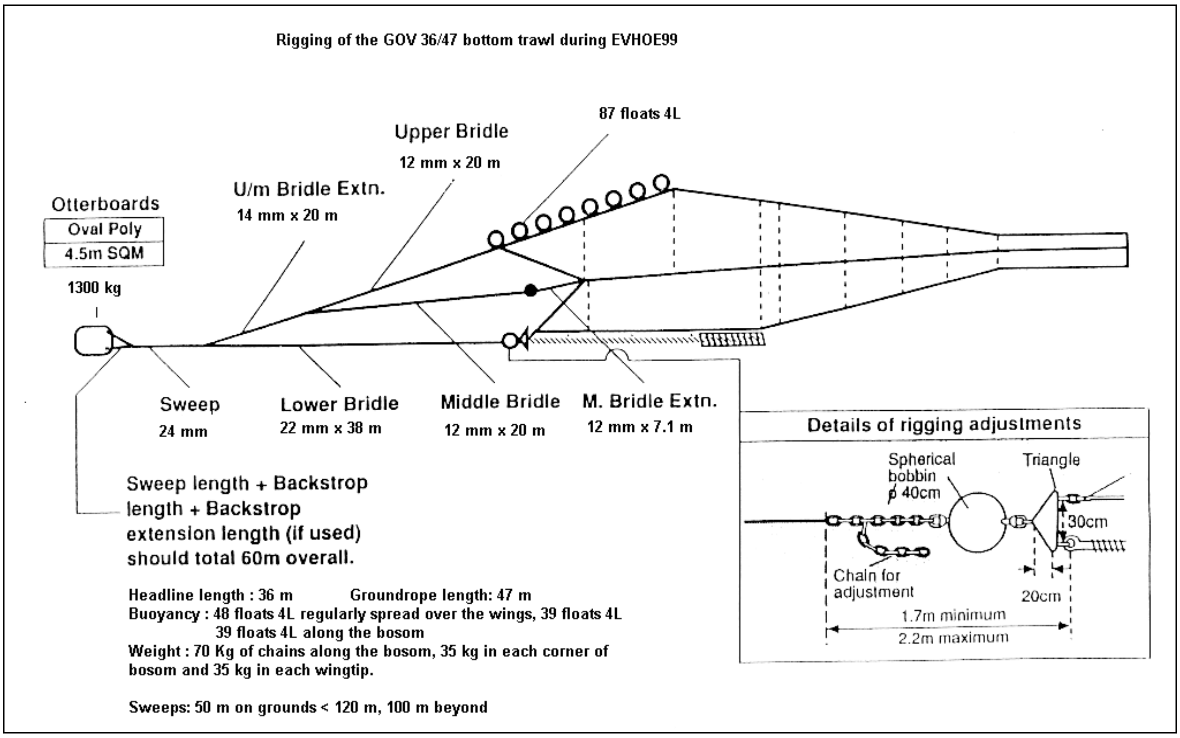



Figure 3.3.3 Rigging of GOV 36/47 used during EVHOE surveys

### *The hauls*

Starting in 1997, the survey is has been undertaken on the R/V *Thalassa*, a stern trawler of 73.7 m long by 14.9 m wide, gross tonnage of 3022 t.
The sets are straight tows, 30 minutes long and are carried during daylight at a towing speed of 4 knots. During the sets, the gear parameters are monitored by Scanmar and the parameters are stored in the boat computer system. The parameters that are monitored are door spread, wing spread, headline height, height of groundrope. Additionaly, a number of navigational parameters were also monitored.

In 1999 and 2000, a total of 120 and 118 validated hauls were respectively made during the routine aspect of the survey. In 2000 and in addition, 22 comparative hauls were carried out with R/V *Celtic Voyager* as a comparative fishing exercise on the comparative fishing positions in northern Irish Sea used by *Celtic Voyager* and R/V *Scotia* in 1999. 10 comparative hauls were also made in northern Celtic Sea. This gave an overall total of 140 hauls in last year.

The following table summarises the operations during the period of the contract.

| Year | Dates | N° of days | N° of tows |
|---|---|---|---|
| 1999 | 10/11- 23/12 | 44 | 120 |
| 2000 | 18/10- 01/12 | 45 | 140 |

### *Information collected*

The treatment of the catch is identical to the method used in the ISCGS surveys. The total catches are always weighed raw and are sorted by species except in the case of a huge catch of one dominant species where only a fraction of the catch is sorted. In case of sub sampling, the total to sample weigh ratio is used as raising factor. All species of fish are measured, for some species other biological samplings are made (individual weight, maturity, measurement by sex, ageing material). All commercial species are sexed when measured and the ageing material collected is following a stratified allocation by length class and by sex, therefore separate ALKs per sex are constructed. The allocations per length class are different depending on species and area and are given in the following table.

| Species | Otoliths | N° otoliths 1999 | N° otoliths 2000 |
|---|---|---|---|
| Whiting | 1/10/cm/sex/haul (1) | 770 | 479 |
| Angler fishes | 3/cm (2) | 168 | 134 |
| Pollock | 3/cm | | |
| Megrim | 5/cm | 427 | 317 |
| Sole | 5/cm | | |
| Hake | 8/cm/sex/area (1) | 952 | 867 |
| Ling | all | 22 | 5 |
| Cod | all | 41 | 67 |

(1) Separate ALKs are constructed for the Celtic Sea and the Bay of Biscay areas
(2) Illicium and 2nd ray of first dorsal fin

***Computation of abundance indices***

The construction of abundance indices (stratified mean $\overline{Y}_{st}$ and its variance $V(\overline{Y}_{st})$) are computed following the stratified random sampling formulas as described by Pennington and Grosslein (1978) [2]:

$$\overline{\boldsymbol{Y}}_{\boldsymbol{st}} = \frac{1}{\boldsymbol{A}} * \sum_{h} \boldsymbol{A}_{h} * \overline{\boldsymbol{Y}}_{h}$$

$$\boldsymbol{V}(\overline{\boldsymbol{Y}}_{\boldsymbol{st}}) = \frac{1}{\boldsymbol{A}^{2}} * \sum_{h} \left( \frac{\boldsymbol{A}_{h}^{2} * \boldsymbol{S}_{h}^{2}}{\boldsymbol{N}_{h}} \right)$$

where :

$A_h$ = area of the $h^{th}$ stratum

$A$ = the total area

$\overline{Y}_h$ = sample mean catch per tow in the $h^{th}$ stratum

$N_h$ = number of tows in the $h^{th}$ stratum

$S_h^2$ = sample variance in the $h^{th}$ stratum

[2] Pennington M.R. and M.D. Grosslein, 1978. Accuracy of abundance indices based on stratified random trawl surveys. ICNAF Res. Doc. 78/IV/77 : 42 p.

***Environmental data***

Hydrological stations are occupied after each set by mean of a CTD probe (Temperature and salinity by depth). All information is stored in a database in MS Access format.

# 4. Task 2 – Standardisation

Although all three institutes are members of the ICES International Bottom Trawl Survey Working Group most of the historical effort on standardisation has been applied to surveys in the North Sea. This contract allowed more effort to be devoted to obtaining a greater degree of standardised protocols etc. in surveys conducted off north-western Europe. Meetings were held to review the individual institute's survey designs and protocols and a fuller analysis was made of two different aspects. These are discussed below as separate sub-tasks.

## 4.1 Biological sampling strategy (Ageing whiting and megrim)

### 4.1.1 Introduction

The usual practice in IBTS surveys in age sampling is to measure and collect otoliths regardless of sex and to apply the combined Age Length Key to the total length composition. Some species however show differential growth by sex and in some cases, sex ratio can also depend on length and depth. In such cases, taking in consideration the generally low level of sampling for age relative to the sampling for length composition, the accuracy of the estimated age composition can be strongly altered by not separating the sampled fish by sex. A sex-stratified sampling could give better accuracy with limited increase in effort. In order to evaluate the incidence of sampling strategies on accuracy of abundance indices at age, an experiment was conducted during the EVHOE 1999 French survey on two species:

- whiting, ( which shows some sex differential growth and length dependent sex-ratio) and
- megrim ( which shows stronger sex differential growth and length and depth dependant sex-ratio).

### 4.1.2 Material and methods

***Field sampling protocols***

For the purpose of simulating different sampling strategies, the following sampling procedure was established:

*Megrim*

At each fishing station and on the sample or sub sample, fish are measured and otoliths are taken before sexing and the chronological number of sampling is recorded on the envelope. The fish is then sexed and length is recorded by sex on the length recording form and on the otolith envelope. Otoliths are taken up to a maximum of 5 otoliths per station and length class. All fish sampled are separated by sex and the samples weights are recorded by sex. During the whole survey, the procedure is carried on and otoliths are taken until a minimum sample of 5 otoliths per sex and length class is achieved.

*Whiting*

The same procedure as for megrim is used except that a proportional sampling strategy is applied for otolith collection. Every 5 fish per length class and station is sampled for age, All fish measured are sexed.

Having all otolith taken sorted by chronological order of collection, different sampling strategies can be simulated in a way closer to the field reality than bootstrap simulation methods.

***Calculations***

*a. First phase, computation of average numbers at length and associated variances.*

Estimation of average numbers at length *j* for a group of *h* strata (stratified mean $\overline{E}_j$) and its variance $V(\overline{E}_j)$) is computed according to the random sampling strategy described by Cochran:

For each length class *j* :

$$\overline{E}_j = \frac{1}{A} * \sum_h A_h * \overline{E}_{jh} \qquad (1)$$

$$V(\overline{E}_j) = \frac{1}{A^2} * \sum_h \left( \frac{A_h^2 * V\left(\overline{E}_{jh}\right)}{N_h} \right) \qquad (2)$$

where :

$A_h =$ area of stratum *h*

$A =$ total area of the group of strata *st*

$\overline{E}_{jh} =$ mean number per haul in length *j* for stratum *h*

$N_h =$ number of hauls in stratum *h*

$V\left(\overline{E}_{jh}\right) =$ variance of the mean number in length class *j* for stratum *h* *b. Second phase, building the age-length key, computation of the proportions at age i per length class j and associated variances.*

For each length class *j* the proportion of age *i* and its variance is computed :

$$p_{ij} = {n_{ij}}/{n_j} \qquad (3)$$

$$V\left(p_{ij}\right) = \frac{p_{ij}\left(1 - p_{ij}\right)}{n_j} \qquad (4)$$

where :

$n_{ij} =$ number of otoliths of age *i* in the length class *j*

$n_j =$ total number of otolith in the length class *j*

*c. Third phase, computation of mean numbers at age and the associated variances.*

The mean numbers at age are given by :

$$\overline{E}_i = \sum_j \overline{E}_j * p_{ij}$$

The associated variance :

$$V\left(\overline{E}_i\right) = \sum_j \left[V\left(\overline{E}_j\right)p_{ij}^2 + \overline{E}_j^2 V\left(p_{ij}\right) + V\left(p_{ij}\right)V\left(\overline{E}_j\right)\right] \qquad (5)$$

These computations are done by sex in the case of age length keys per sex and the total age composition is given for each age *i* by:

$$\overline{Et}_i = \overline{Em}_i + \overline{Ef}_i$$

Its variance :

$$V\left(\overline{Et}_i\right) = V\left(\overline{Em}_i\right) + V\left(\overline{Ef}_i\right) \qquad (6)$$

The sampling being independent on sex the covariance is not considered.

In the case where a combined sexes age-length key is used, the mean numbers at length *j* sexes combined and their variances are obtained by summing the length composition at the haul level:

$$\overline{Et}_j = \overline{Em}_j + \overline{Ef}_j$$

The computations described in 1,2 and 3 are are then applied to these length compositions

### 4.1.3 Results and Discussion

***Whiting and megrim– Biological data***

*Growth and sex ratio*

Figure 4.1.1 shows that in both species males are slower growing than females and that females are living longer. The difference is however much more important in megrim.

Figure 4.1.2 illustrate that average sex-ratio increase in favour of female with length as a result of the difference in growth. Again, the difference is more pronounced in megrim.

If we look at those parameters with respect to depth (fig. 4.1.3), no difference appear in the sex ratio per length for whiting when data is separated by depth range. For megrim, females are found in greater proportion in shallower waters (fig. 4.1.4). This combined with differential growth rate result in showing different pattern of sex-ratio per length depending on depth especially in the range of length around 20 to 30 cm where males and females are present (males are scarce at length over 30 cm) and in post juvenile condition.

***Comparison of sampling strategies***

*Whiting*

Six strategies were tested:

- Reference : 1 otolith per length class per station, sexes combined, length composition sexes combined
- Proportional 1/5 sexes separated
- Proportional 1/5 sexes combined
- Proportional 1/10 sexes separated
- Proportional 1/10 sexes combined
- Stratified 5/cm/sex

The reference sampling strategy is a strategy commonly used in bottom trawl surveys conducted in the IBTS area.

The first comparison is to look at the age composition resulting from the reference strategy and the strategy with the higher sampling level (proportional sampling1/5 sexes separated). The age compositions (fig. 4.1.5 and table 4.1.1) show very little difference. The tables 4.1.2 and 4.1.3 show the comparison of precision obtained with the strategies tested. The results are given relative to the reference strategy. The first conclusion is that a stratified sex separated sampling of 5 otolith/cm/sex while results in no change in precision with lower sampling level (233 otoliths vs 325) The second conclusion is that in order to achieve substantial gain in precision (more than around 10% per age) the sampling level has to be almost doubled (605 otoliths). The gain in precision obtained by stratification by sex is small.

*Megrim*

Three strategies were tested :

- Reference : 1 otolith per length class per station, sexes combined, length composition sexes combined
- Stratified 5/cm/sex
- Stratified up to 10/cm/sex

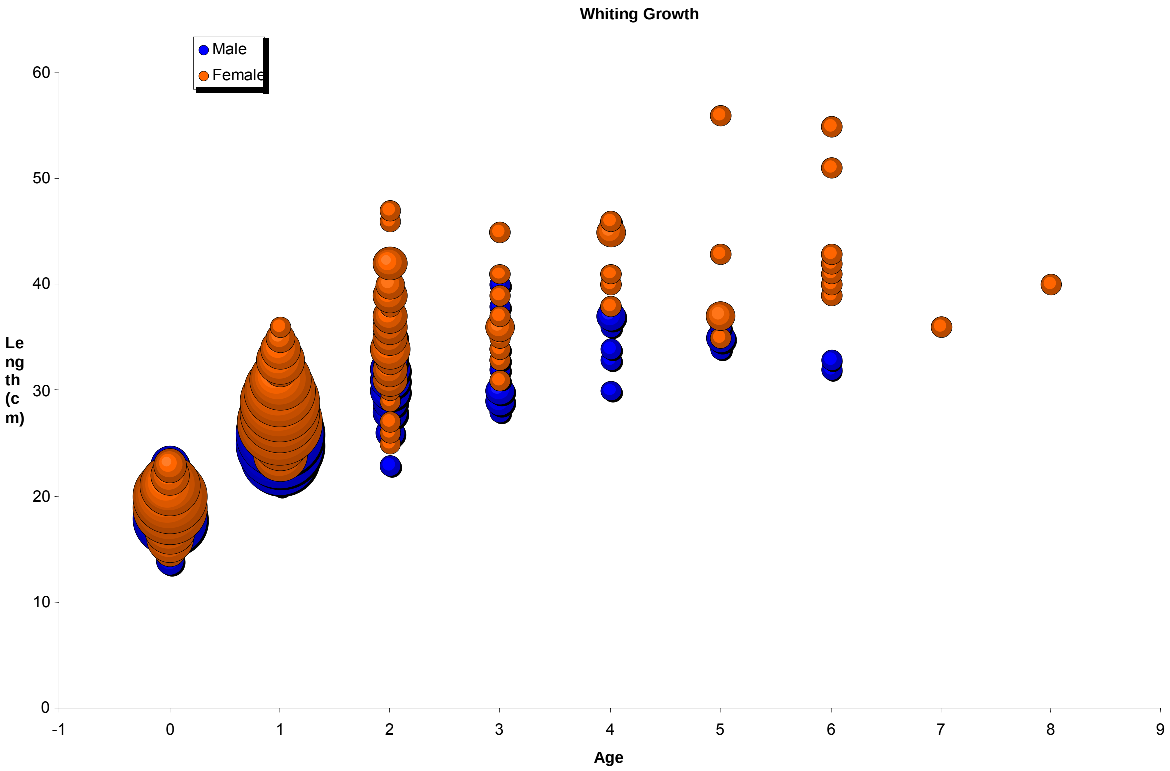
The age composition resulting from the three strategies are quite different particularly for ages 3 and 4 where the relative abundance is reversed (fig. 4.1.6). Comparison of the precision of the estimates in relation with strategy (table 4.1.3) shows that quite a substantial gain is obtained by just using a sex stratified sampling with hardly no increase in the level of sampling (288 otoliths vs 250). A more substantial increase in precision is obtained with a 45% increase of the sampling level (419 otoliths).

### 4.1.4 Conclusion

For species that show sex differential biological and depth and/or spatial distribution characteristics, stratification by sex for computation of abundance indices at age must be used. This strategy substantially increase the precision of the estimate with no increase in the level of otolith sampling. The fact that samples have to be separated and measured by sex increases the effort devoted to the species. However, the treatment by sex also increases the level of biological data collected in the survey which taking into account the cost of sea time is not negligible. In scientific surveys, this increase in effort can be managed by lowering ageing effort on other species for which fair precision is achieved at lower sampling level. For example, the sampling strategies used in EVHOE survey for whiting and megrim were, up to 1999, respectively proportional 1/5, sex separated and stratified 5/cm sexes separated. In view of the results we decided to lower the sampling for whiting to proportional 1/10 sex separated and to increase the sampling for megrim to stratified 8/cm sexes separated.

## References

COCHRAN, W.G. 1977. Sampling Technics. J. Wiley & Sons. 428 p.



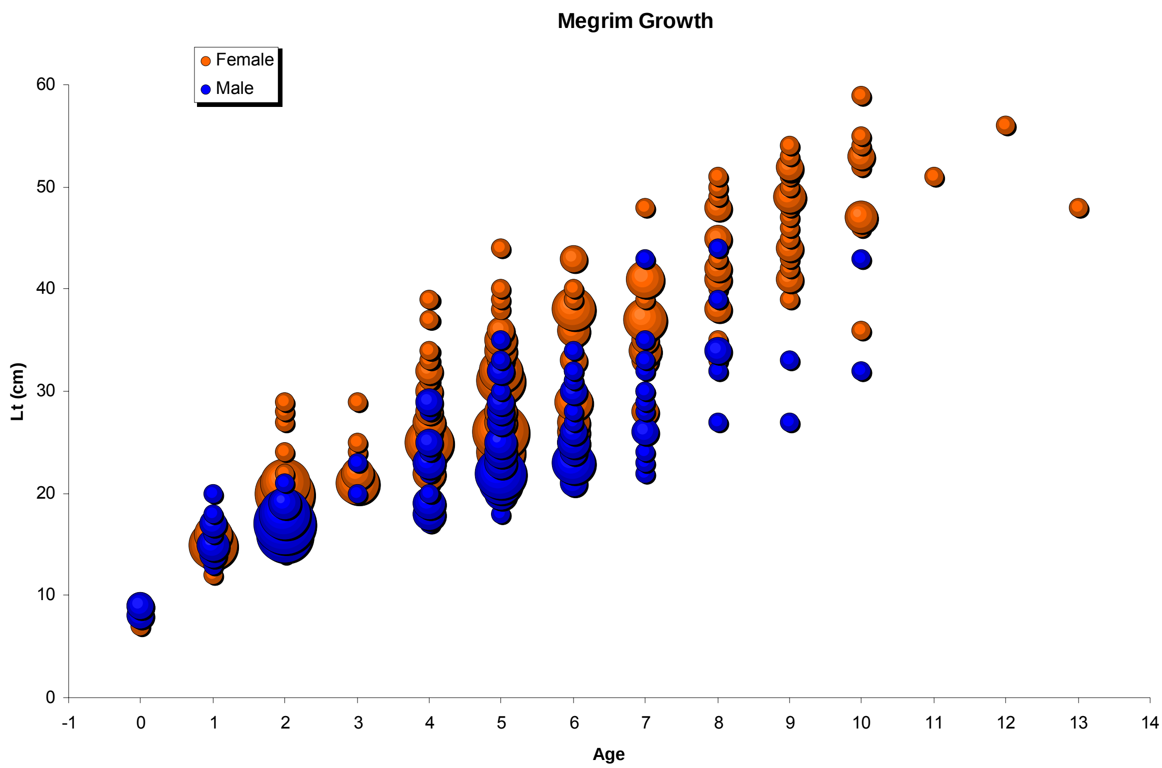
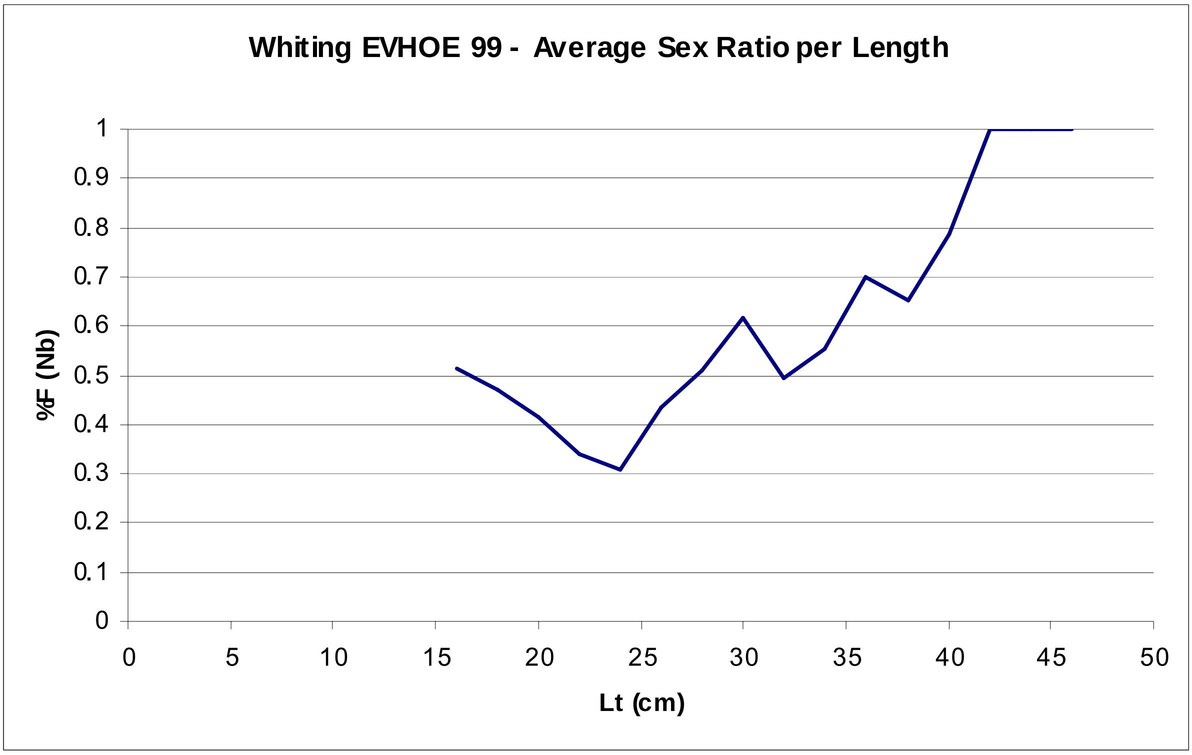




Figure 4.1.1 – Whiting and megrim observed lengths at age. EVHOE 1999 survey



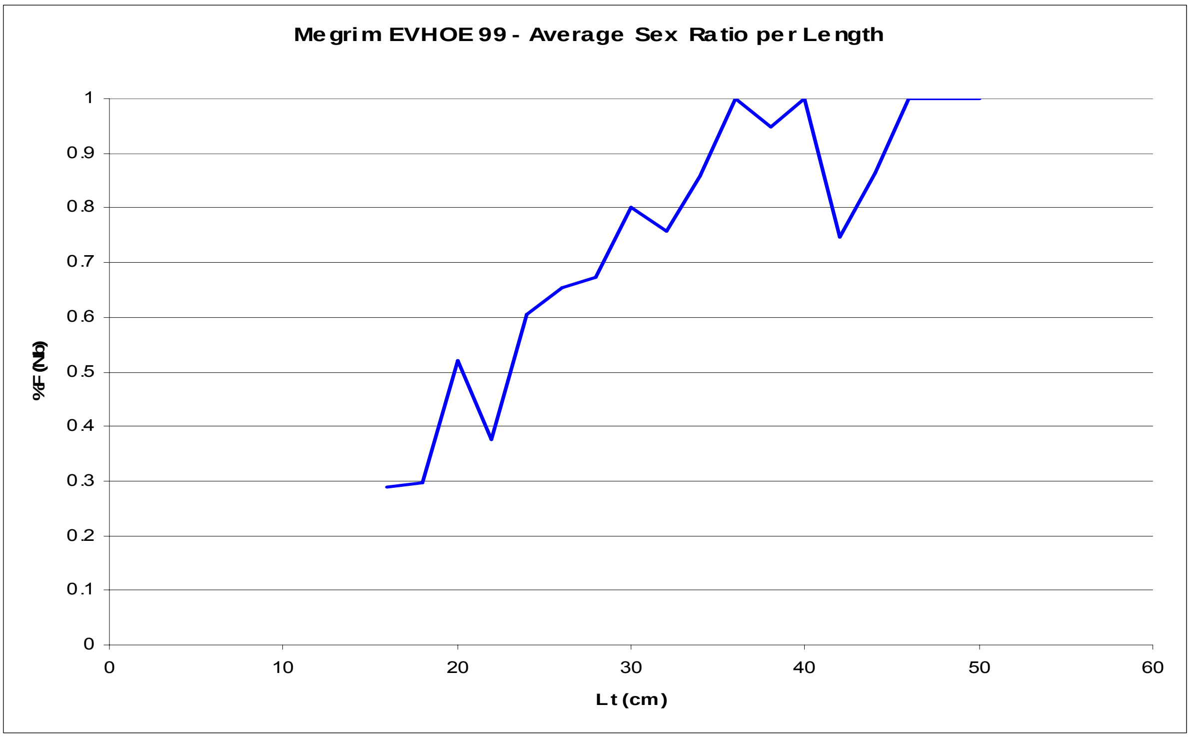
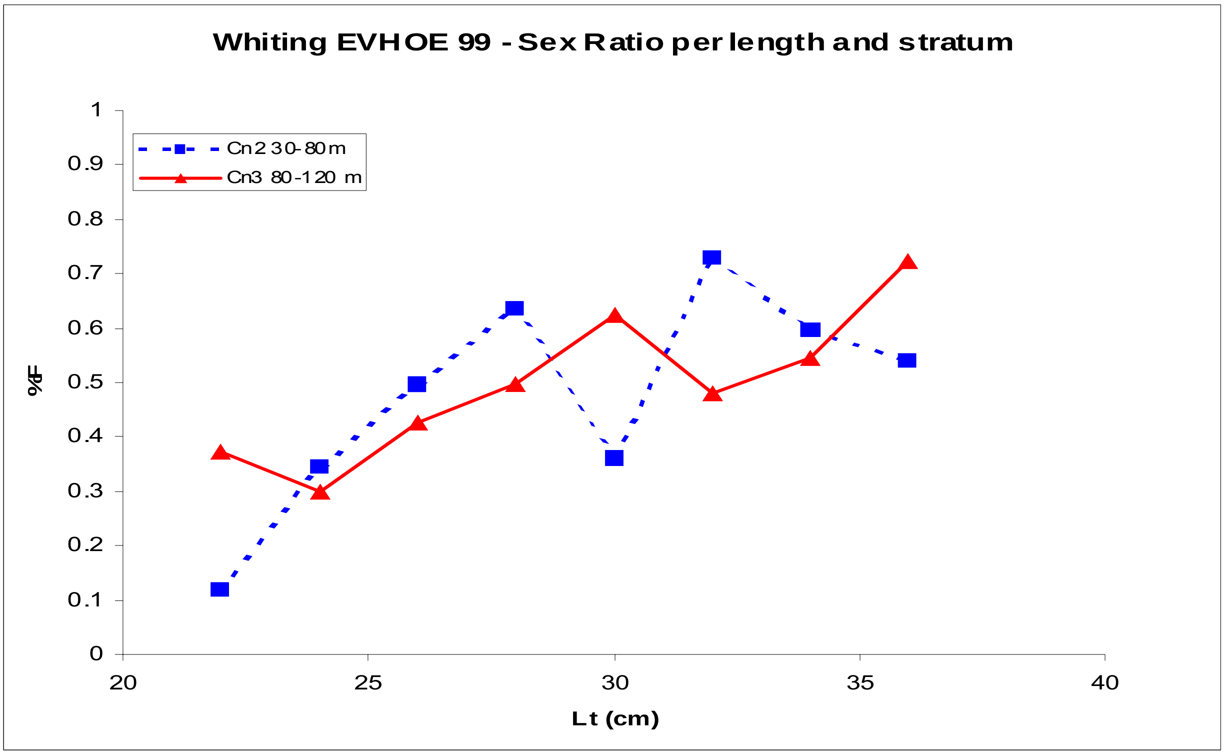




Figure 4.1.2 – Whiting and megrim observed sex ratio at length – EVHOE 1999 survey.



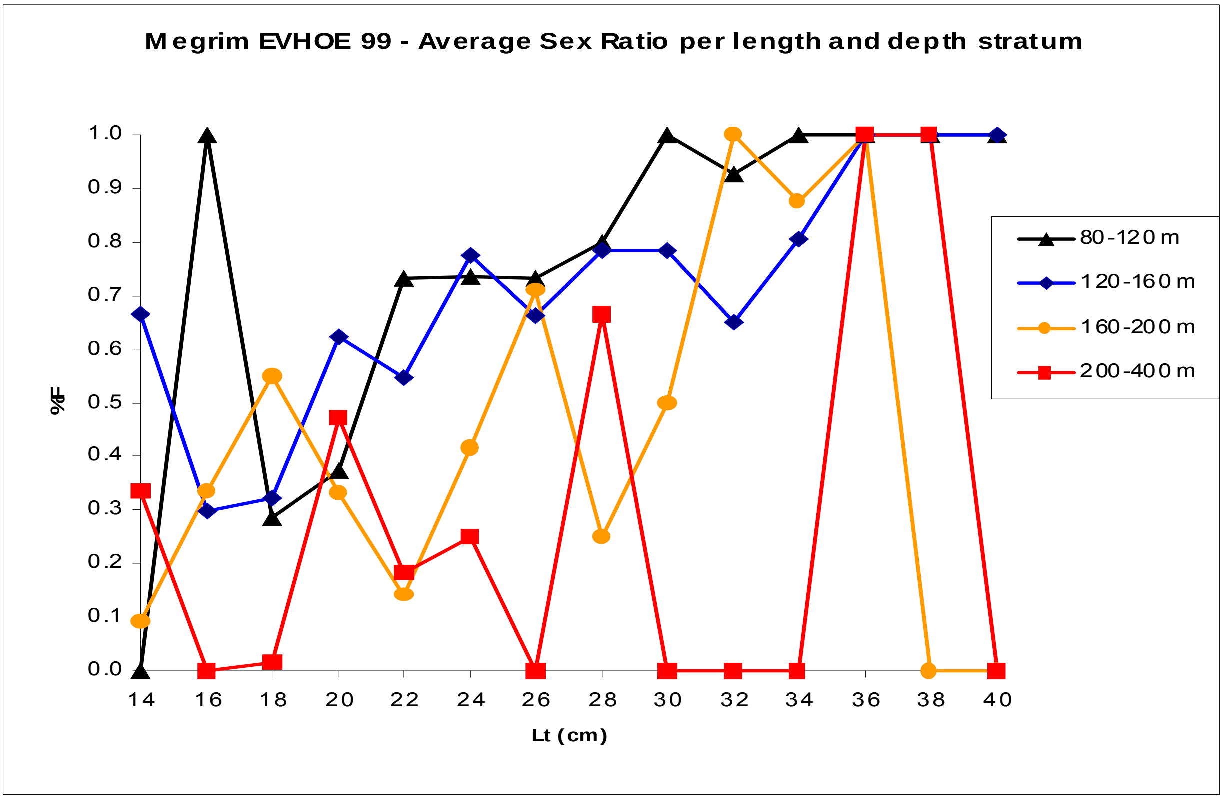




Figure 4.1.3 – Whiting and megrim sex ratio per length and per depth range – EVHOE 1999 survey.

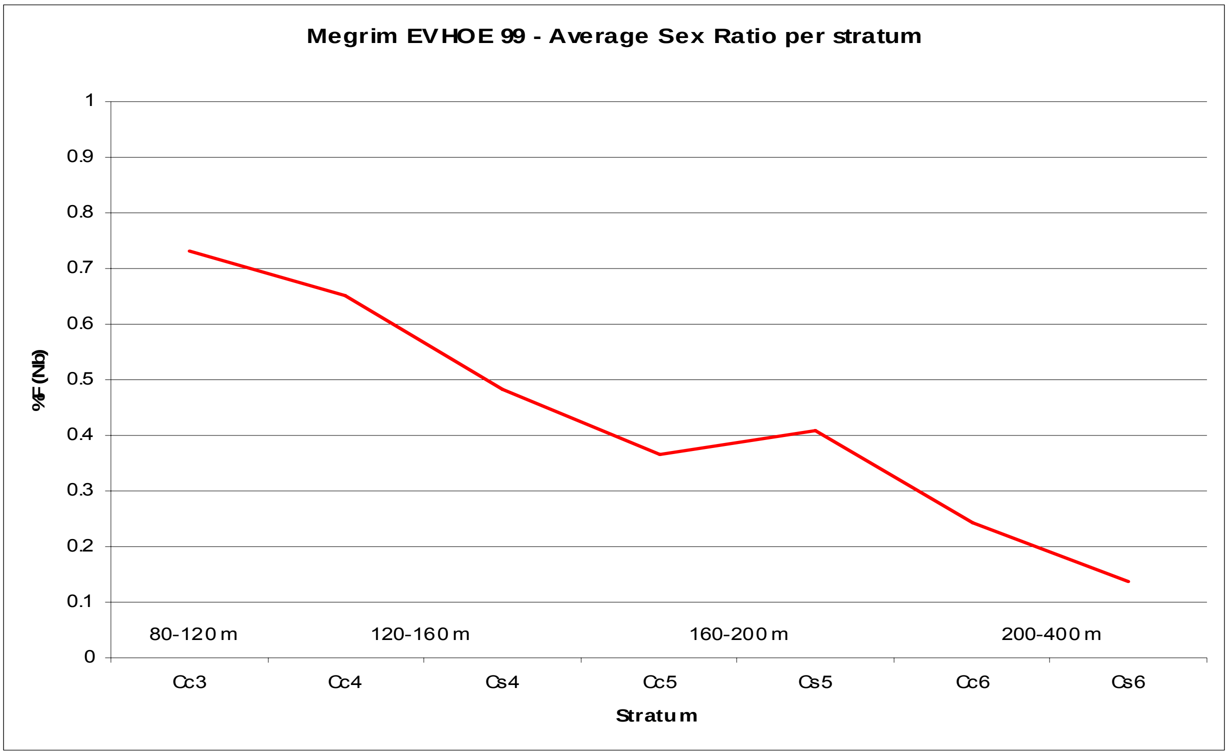



Figure 4.1.4 – Overall proportion of female megrim found with respect to depth range during EVHOE 1999 survey.

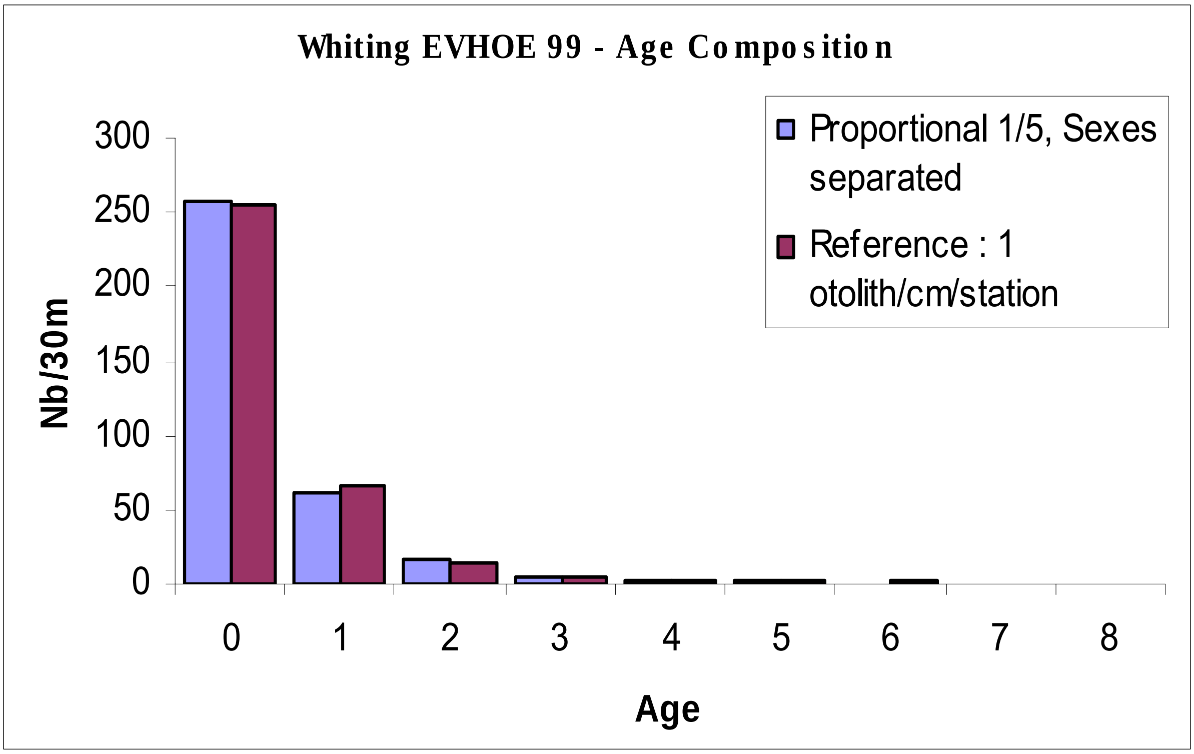
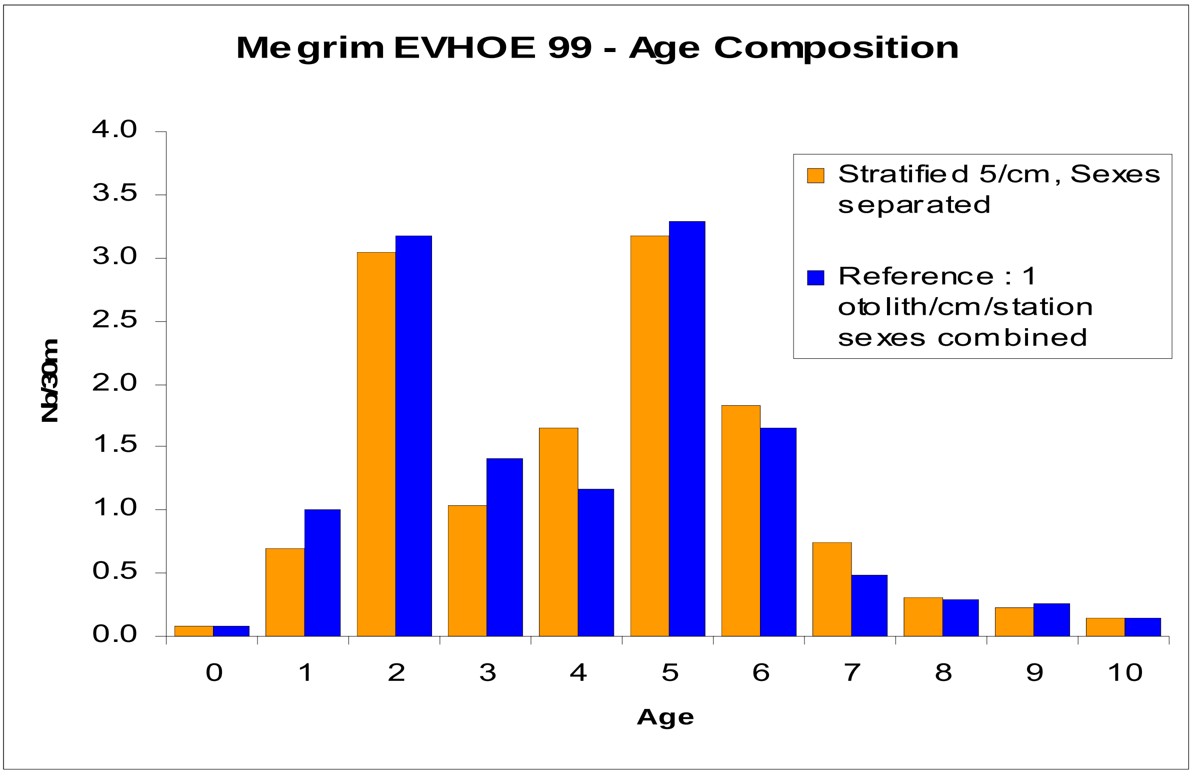



Figure 4.1.5 – Comparison of age composition derived from different otolith sampling strategies applied to whiting – EVHOE 1999 survey.



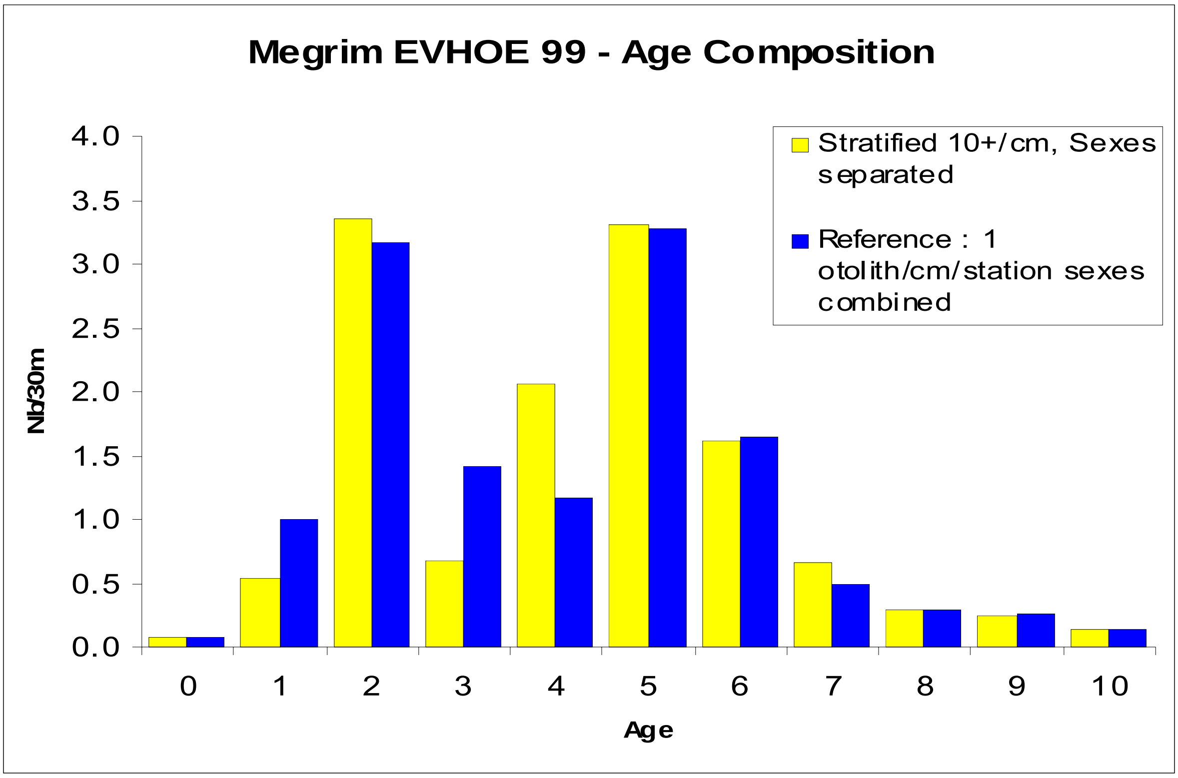




Figure 4.1.6 - Comparison of age composition derived from different otolith sampling strategies applied to megrim – EVHOE 1999 survey.

| Reference : 1 otolith/cm/station - Nb otoliths : 325 | | | | | |
|---|---|---|---|---|---|
| | Proportional 1/5, Sexes separated | Proportional 1/5, Sexes combined | Proportional 1/10, Sexes separated | Proportional 1/10, Sexes combined | Stratified 5/cm, Sexes separated |
| Age | Gain CV | Gain CV | Gain CV | Gain CV | Gain CV |
| 0 | -0.01 | 0.00 | -0.01 | 0.00 | -0.01 |
| 1 | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 |
| 2 | 0.04 | 0.04 | 0.02 | 0.02 | 0.01 |
| 3 | 0.09 | 0.08 | 0.03 | 0.02 | -0.00 |
| 4 | 0.03 | 0.02 | 0.00 | 0.01 | -0.01 |
| 5 | 0.05 | 0.03 | 0.00 | 0.00 | 0.05 |
| 6 | 0.04 | 0.04 | 0.01 | 0.02 | -0.01 |
| 7 | -0.06 | -0.01 | -0.03 | 0.00 | -0.03 |
| 8 | 0.04 | 0.00 | 0.04 | 0.00 | 0.04 |
| | | | | | |
| Nb otoliths | 605 | 605 | 418 | 418 | 233 |

Table 4.1.1 – Summary of absolute gain in precision obtain with different whiting otolith sampling strategy compared to the reference strategy.

| Reference : 1 otolith/cm/station - Nb otoliths : 325 | | | | | |
|---|---|---|---|---|---|
| | Proportional 1/5, Sexes separated | Proportional 1/5, Sexes combined | Proportional 1/10, Sexes separated | Proportional 1/10, Sexes combined | Stratified 5/cm, Sexes separated |
| Age | Gain % CV | Gain % CV | Gain % CV | Gain % CV | Gain % CV |
| 0 | -7 | 0 | -7 | 0 | -0 |
| 1 | 14 | 6 | 10 | 1 | 0 |
| 2 | 25 | 21 | 13 | 11 | 0 |
| 3 | 27 | 26 | 9 | 8 | -0 |
| 4 | 7 | 7 | 1 | 2 | -0 |
| 5 | 11 | 8 | 1 | 0 | 0 |
| 6 | 7 | 9 | 3 | 3 | -0 |
| 7 | -6 | -1 | -2 | 0 | -0 |
| 8 | 4 | 0 | 4 | 0 | 0 |
| | | | | | |
| Nb otoliths | 605 | 605 | 418 | 418 | 233 |

Table 4.1.2 – Summary of relative gain in precision obtain with different whiting otolith sampling strategy compared to the reference strategy.

| | Reference : 1 otolithe/cm /station | Stratified 5/cm, Sexes separated | | | Stratified 10+/cm, Sexes separated | | |
|---|---|---|---|---|---|---|---|
| Age | Nb oto. | Nb oto. | Gain CV | Gain (% CV) | Nb oto. | Gain CV | Gain (% CV) |
| 0 | 6 | 8 | 0.05 | 14 | 8 | 0.05 | 14 |
| 1 | 18 | 23 | 0.09 | 22 | 26 | 0.14 | 33 |
| 2 | 27 | 41 | 0.02 | 10 | 73 | 0.04 | 24 |
| 3 | 6 | 9 | 0.10 | 24 | 13 | 0.11 | 26 |
| 4 | 17 | 25 | 0.14 | 38 | 50 | 0.20 | 55 |
| 5 | 49 | 52 | 0.04 | 21 | 92 | 0.07 | 37 |
| 6 | 39 | 41 | 0.07 | 25 | 57 | 0.10 | 36 |
| 7 | 30 | 30 | -0.08 | -38 | 37 | -0.02 | -10 |
| 8 | 22 | 23 | 0.01 | 3 | 25 | 0.02 | 10 |
| 9 | 21 | 20 | -0.00 | -2 | 22 | 0.00 | 1 |
| 10 | 12 | 13 | 0.01 | 4 | 13 | 0.01 | 5 |

Table 4.1.3 - Summary of absolute and relative gain in precision obtain with different megrim otolith sampling strategy compared to the reference strategy.

### 4.2 Gear Performance Variability

All three institutes deploy the GOV trawl during the surveys but it soon became apparent that there were significant differences in the gear. For example, Scotland employs a GOV 36/47 trawl with a kite and heavy ground gear; France also uses the GOV 36/47 but without a kite and with light ground gear. A third factor was that because the *Celtic Voyager* is much smaller than *Thalassa* and *Scotia* the GOV used by the Irish vessel is a cut-down version of the standard net. Thus it was decided to investigate the variability of the gear performance.

Gear performance parameters normally available include:

- Headline height (distance from headline to seabed)
- Wing spread (distance between wing ends)
- Door spread (distance between doors)
- Distance towed (over the ground)

Measures of swept area, and swept volume, for both net and gear are also usually available, although the precise basis for the calculation of these parameters may not be consistent between institutes.

The results are graphed in Figures 4.2.1 – 3 and summarised in tables 4.2.1-3 for each institute. The main finding was that the behaviour of the gear varied dramatically with depth. For example, in the Scottish data headline height dropped by around 40% over a 175m depth range, while wing and door spread increased by around 25%. Swept area also increased by between 25 and 32% for the net and the full gear respectively.

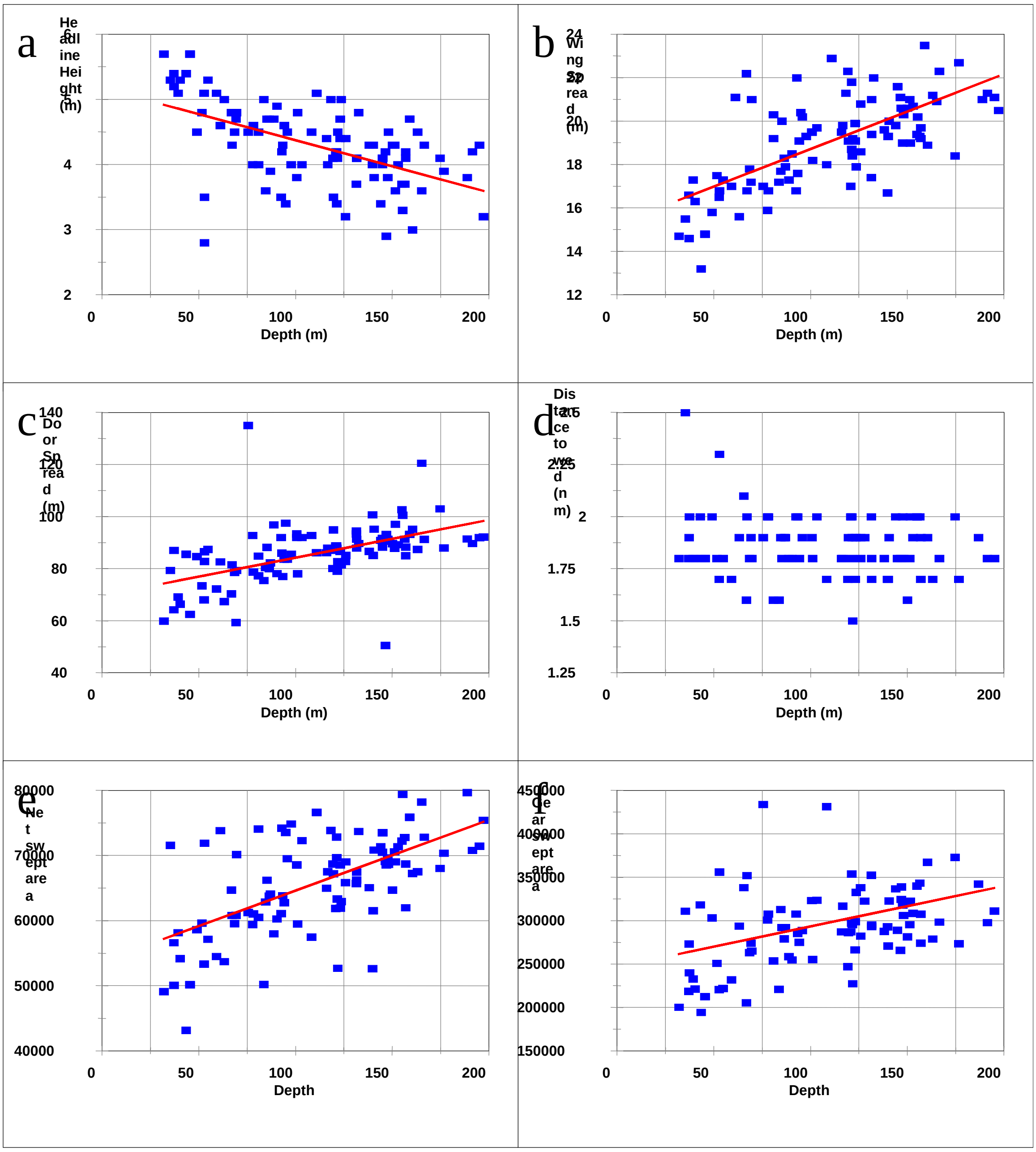



**Figure 4.2.1 Scatter plots and regressions for the six main gear parameters recorded on the two Scottish surveys. a. Headline height b. Wing spread c. Door spread d. Distance towed e. Net swept area & f. Gear swept area.**

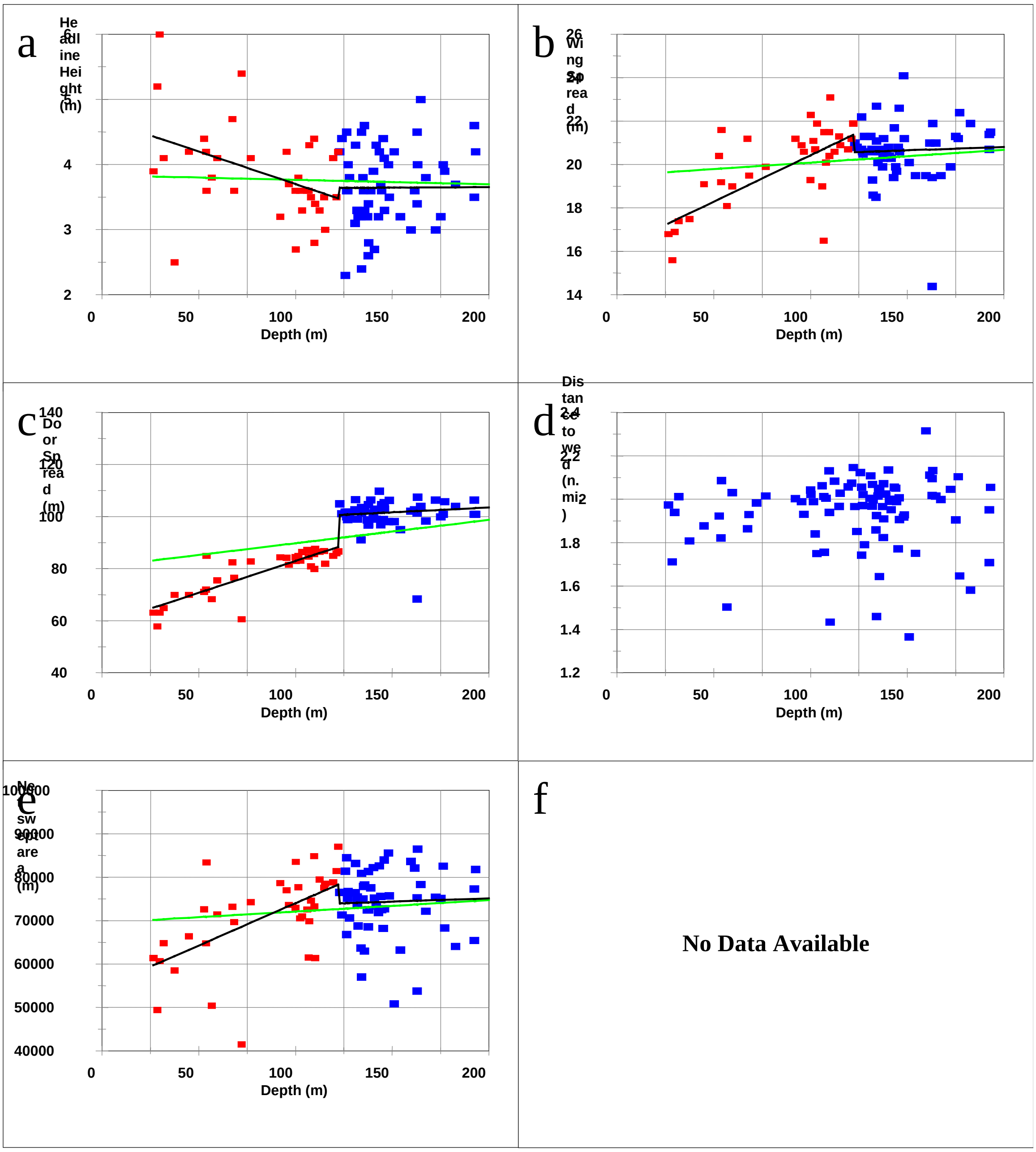



**Figure 4.2.2 Scatter plots and regressions for the six main gear parameters recorded on the French survey. a. Headline height b. Wing spread c. Door spread d. Distance towed e. Net swept area & f. Gear swept area.**

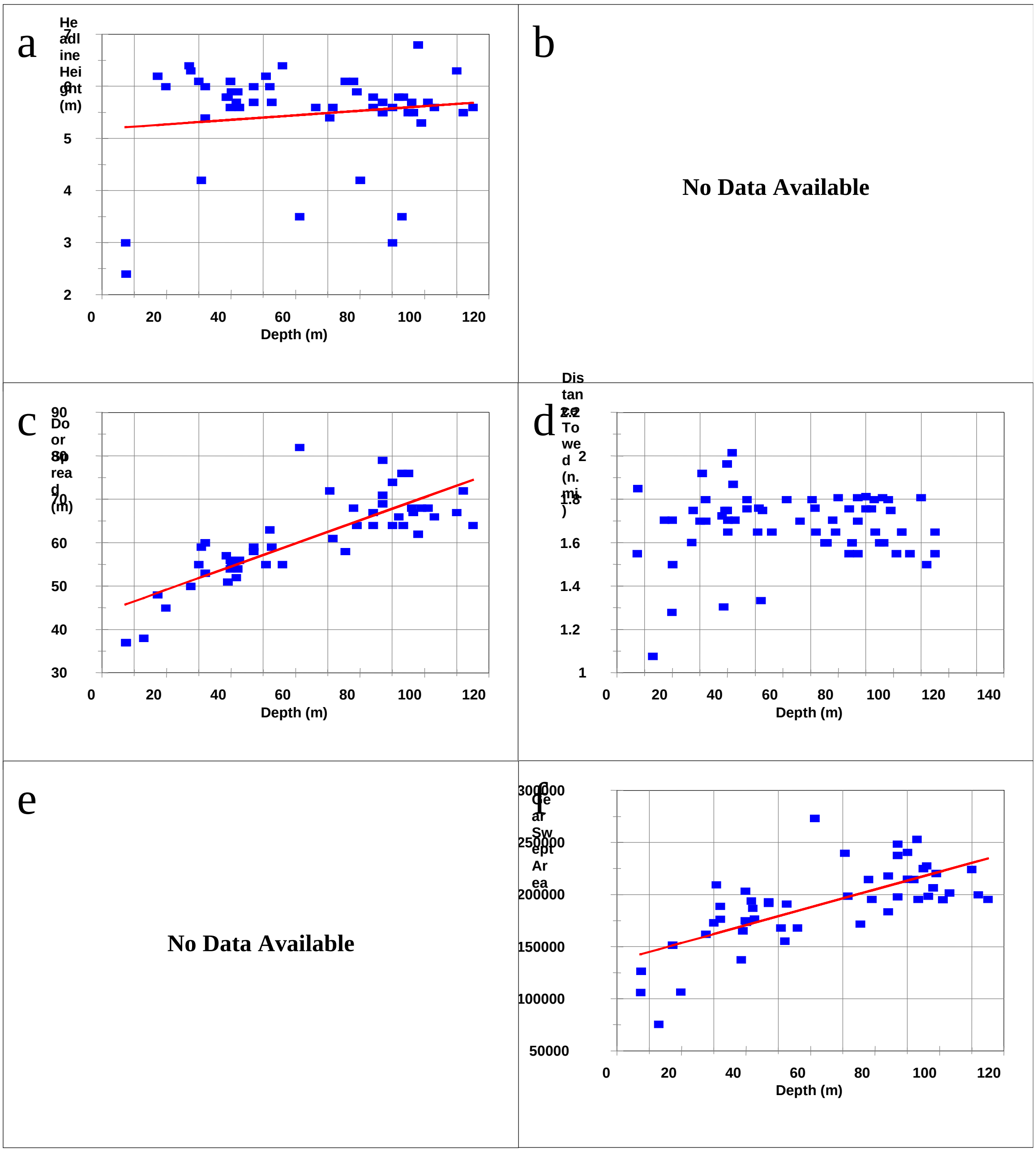



**Figure 4.2.3 Scatter plots and regressions for the six main gear parameters recorded on the Irish survey. a. Headline height b. Wing spread c. Door spread d. Distance towed e. Net swept area & f. Gear swept area.**

Table 4.2.1 Summary of trawl surveillance data for the two Scottish surveys (pooled data).

| Parameter | $R^2$ | Slope | Value at 25m | Value at 200m | Change | Change % |
|---|---|---|---|---|---|---|
| **Headline Height (m)** | 0.210 | -0.008 | 5.00 | 3.58 | 1.42 | 39.7 |
| **Wing Spread (m)** | 0.444 | 0.035 | 16.13 | 22.25 | 6.12 | 27.5 |
| **Door Spread (m)** | 0.293 | 0.145 | 73.34 | 98.72 | 25.38 | 25.7 |
| **Net Swept Area ($m^2$)** | 0.362 | 108.74 | 56450 | 75480 | 19030 | 25.2 |
| **Gear Swept Area ($m^{2)}$** | 0.192 | 465.91 | 258433 | 339966 | 81533 | 31.55 |

The accepted method for controlling these depth related changes is to use different sweep lengths in different depth ranges. The IBTS manual recommends short sweeps (60m including back strops) in depths less than 70m and long sweeps (110m) in greater depths. This is for Q1 North Sea IBTS, for other surveys a sweep length of 60m is considered adequate. IFREMER use these sweep lengths in the western area but change over at 125m. A summary of the French 1999 data with this rigging is presented in table 4.2.2.

Table 4.2.2. Summary of trawl surveillance data for the French survey.

| Parameter | $R^2$ | Slope | Value at 25m | Value at 125m | Change | Change % |
|---|---|---|---|---|---|---|
| | **Short sweeps – depths < 125m** | | | | | |
| **Headline Height (m)** | 0.184 | -0.01 | 4.45 | 3.45 | 1.00 | 28.99 |
| **Wing Spread (m)** | 0329 | 0.043 | 17.22 | 21.52 | 4.30 | 19.98 |
| **Door Spread (m)** | 0.731 | 0.245 | 64.63 | 89.08 | 24.45 | 27.45 |
| **Net Swept Area ($m^{2)}$** | .0344 | 195.07 | 59381 | 78888 | 19507 | 24.73 |
| **Gear Swept Area ($m^{2)}$** | Na | na | na | na | na | na |
| | **$R^2$** | **Slope** | **Value at 125m** | **Value at 200m** | **Change** | **Change %** |
| | **Long sweeps – depths > 125m** | | | | | |
| **Headline Height (m)** | .001 | 0.001 | 3.64 | 3.66 | 0.02 | 0.55 |
| **Wing Spread (m)** | 0.069 | 0.003 | 20.58 | 20.82 | 0.24 | 1.15 |
| **Door Spread (m)** | 0.349 | 0.037 | 100.93 | 103.88 | 2.95 | 2.84 |
| **Net Swept Area ($m^{2)}$** | 0.044 | 15.15 | 74092 | 75304 | 1212 | 1.61 |
| **Gear Swept Area ($m^{2)}$** | Na | na | na | na | na | na |

Using the short sweeps, the same depth dependence was seen as in the Scottish surveys, with changes in the order of 25% over the 100m depth range. In deeper waters, and with the longer sweeps, the gear performance was much more consistent.

The net used in the Irish survey is not a GOV, but was designed as a small boat version of the GOV. Trawl surveillance data for this net are presented in table 4.2.3. The operating depth range was less than for the other two vessels and only short sweeps were used. There was no major change in headline height over this depth range, but strangely, there was a substantial increase in door spread of around 35%, with a concomitant increase in swept area.

Table 4.2.3. Summary of trawl surveillance data for the Irish survey.

| Parameter | $R^2$ | Slope | Value at 25m | Value at 125m | Change | Change % |
|---|---|---|---|---|---|---|
| **Headline Height (m)** | 0.015 | 0.004 | 5.29 | 5.73 | 0.44 | 7.68 |
| **Wing Spread (m)** | Na | Na | na | na | Na | Na |
| **Door Spread (m)** | 0.661 | 0.267 | 50.50 | 77.15 | 26.65 | 34.54 |
| **Net Swept Area ($m^{2)}$** | Na | Na | na | na | Na | Na |
| **Gear Swept Area ($m^{2)}$** | 0.480 | 854.06 | 157874 | 243280 | 85406 | 35.11 |

A full report of this work was presented at the ICES ASC in Bruges, Belgium in September 2000 as part of theme session K on incorporation of external factors in marine resource surveys, entitled “Quantifying variability in Gear Performance on IBTS surveys: Swept area and volume with depth”. A copy is attached to this report as Annex I.

The previous work demonstrated that different rigs of the GOV will have different fishing characteristics; this is not an entirely unexpected outcome. However, the basic assumption is made that identical nets will have identical fishing performances. In order to test this hypothesis, data was collected during the French EVHOE 1999 survey and a comparison was made between the performances of the three different trawls used. The characteristics of each trawl were checked by the manufacturer before the survey, and it was concluded that the three trawls were identical. Theoretically, the performance of these trawls should therefore have been identical. In fact, variations were observed, mainly in values of headline height and wing spread between trawls (table 4.2.4). The reasons for these differences in performance can not currently be explained.

Table 4.2.4 Summary of trawl surveillance data for three different trawls for the French survey

| Trawl No. | Sweep length (m) | Headline height (m) | s.e. | Wing spread (m) | s.e. | Door spread (m) | s.e. | Nb Stations |
|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 3.1 | 0.3 | 19.6 | 0.9 | 104.9 | 7.9 | 5 |
| 2 | 100 | 4.1 | 0.3 | 21.5 | 0.9 | 104.1 | 3.6 | 17 |
| 3 | 100 | 3.6 | 0.6 | 20.6 | 1.6 | 102.3 | 9.2 | 53 |
| 2 | 50 | 4.3 | 0.2 | 21.5* | na | 88.3 | 3.7 | 2 |
| 3 | 50 | 3.8 | 0.7 | 19.7 | 2.3 | 79.8 | 8.3 | 43 |

* one station only

## Conclusions

Two major areas for concern can be identified:

- All surveys produced major depth related changes in gear performance.
- Each net, including those of identical construction, display individual gear geometry; this may have an effect on the catch performance

These surveys are designed to produce a relative abundance (CPUE) index. Depth changes in gear performance could therefore be considered as of minor importance, as they would be expected to be consistent between years for the same vessel/gear combination. However, this will only be true if there are no major changes in depth distribution of the target species, and that the gear performance is consistent between years. The first assumption is unlikely to be true, and the second is definitely false i.e. *Thalassa* demonstrated different parameters between identical nets on the same survey.

In these surveys it can be assumed that the design is predicated on the principle of a fixed swept area. Hauls are ideally of fixed time, at a fixed speed and using a standard gear. If gear performances remained constant, these stipulations would deliver a fixed swept area.

Survey data are also used to produce maps that are widely used in management and international negotiations. These maps could be biased by the depth related performance of the gear. The impact of these depth related gear performance changes on the catch rates in the surveys is presently unclear. An analysis of this was attempted for the Scottish surveys. However, there was considerable confounding of both gear and catch parameters with depth, and modelling efforts were usually dominated by the depth signal. Using reduced depth ranges ameliorated this but also reduced the number of data points. Notwithstanding this there were some tentative suggestions that gear parameters were linked to haddock CPUE. This will be investigated further in work outside the scope of the current contract.

In recognition of the problems identified in gear variability all three institutes are now collecting as many trawl parameters as possible during a survey. These parameters include:

- Headline height
- Wing spread
- Door spread
- Distance towed – over the ground (the method of calculation should be explicit)
- Speed over the ground AND through the water – where possible.

# 5. Intercalibration

## 5.1 Methodology

### 5.1.1 Protocols adopted at sea during the 1999/2000 comparative fishing trials

During the comparative fishing trials reported here the vessels operated side by side not more than half a nautical mile apart. Gear deployment and retrieval was undertaken on each vessel within minutes of the other vessel. During tows each vessel maintained the same heading. Intercalibration between the SCOTIA and CELTIC VOYAGER was carried in 1999 and between the CELTIC VOYAGER and THALASSA in 2000. The locations of the comparative tows are given in figure 5.1.1.

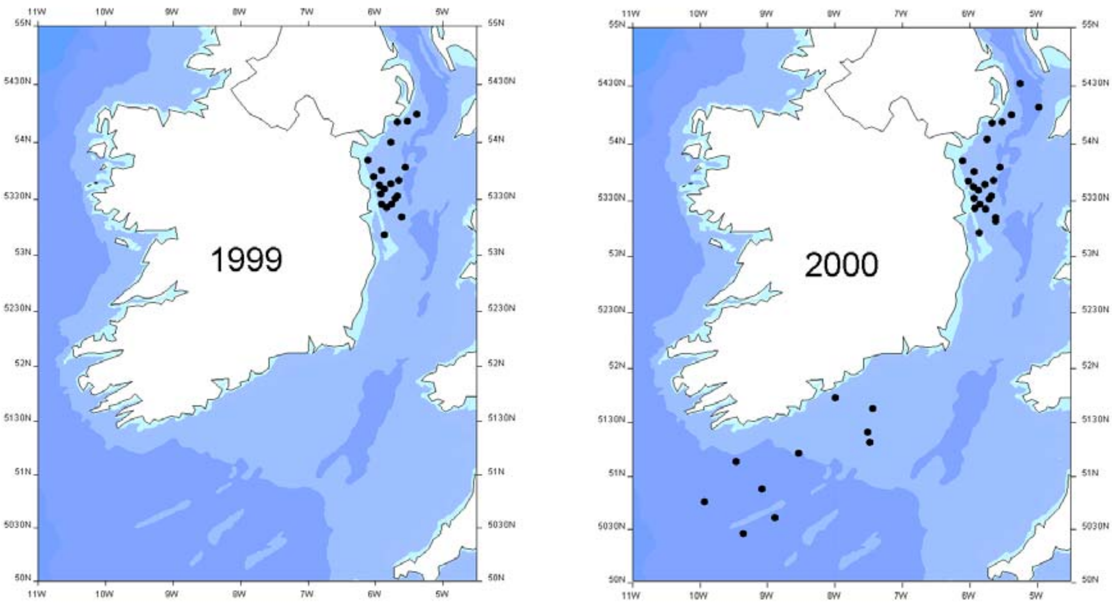



Figure 5.1.1 – Positions of the comparative tows made in 1999 and 2000.

### 5.1.2 Statistical analyses of inter-calibration data

As stated in section 2, the principal question underlying this study is whether similar catches are observed on research vessels fishing together. In order to answer this question, the similarity between vessels was studied on different levels. Firstly the total numbers per species per boat was considered. Hence, each species is represented by N values for each boat, where N is the number of hauls. Simple statistical tools (e.g. the t-test, histograms, scatter plots, boxplots) were used to analyse each species separately. This approach provides a quick overview of the main patterns and can be applied on any species.

In the second stage of the analyses the total numbers per species per boat was considered in a multivariate context. Hence, the data consists of M species measured at N hauls. Because there are two boats, we basically have 2M response variables. By using multivariate techniques like the principal component analysis (PCA) biplot, interactions between the 2M response variables can be detected. Response variables corresponding to the same species were of particular interest. Additionally, inferences can be drawn from comparisons of the species composition between hauls. The advantage of this approach over the techniques used in the initial analyses is that it provides more detailed information. A disadvantage is that outliers and zero catches occurring on both vessels influence multivariate techniques. Whilst the identification of outliers is extremely difficult (Krzanowksi 1988) the influence of large values (and potential outliers) was reduced in this analysis by applying a log transformation to the data. Unfortunately when either vessel fishing at the same station does not observe particular species the correlation function will suggest that these species are similar. Such species were excluded from our analysis on the basis that they are rare species. Species were only included in the analysis if they were caught at 5 or more stations, for each vessel, and 100 or more individuals were caught by both boats in total.

The disadvantage of the methods mentioned so far is that no information on length classes is compared. The t-test might reveal that there is a significant difference between the raised number for both boats for a particular species, but is does not give any information about at which length classes these differences occurred. Furthermore, differences between the vessels may remain masked when only considering totals per haul per species. For these reasons, a length-frequency-based analysis was applied in the third stage of the analysis. Hence the data consists of L length classes measured at N hauls for each species analysed. The disadvantage of the length-frequency analysis is that it can only be applied to species measured in reasonable numbers in terms of length classes and hauls. Consequently, this approach was limited to a small number of selected species. In the length-frequency-based analysis an average relative catch rate was estimated for each length class (for each of the selected species). Bootstrapping was used to generate confidence intervals around this average relative catch rate. These confidence intervals were used for an informal assessment of whether the data were consistent with an average relative catch rate of 1 (i.e. both boats display a catch ratio of 1:1 per length class for the same species). Ultimately, a formal hypothesis test is applied to ascertain a measure of statistical confidence.

## 5.2 Individual species comparisons between surveys

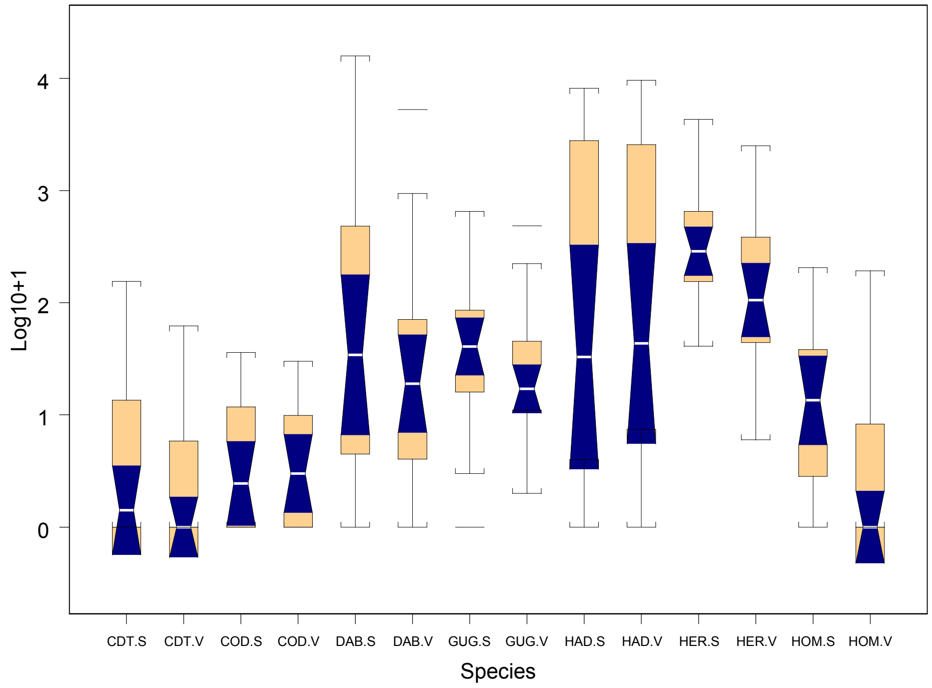
### 5.2.1 Boxplots analysis

Boxplots are also useful graphical tools for exploratory data analysis. They show the centre and dispersion of the data, extreme points and indicate skewness. As well as which notches can be drawn on the boxplots where, if the notches on two boxes do not overlap, this indicates a difference in the median at roughly the 5% significance level. By plotting the boxplots of the same species besides each other, informal information in the similarity between two boats can be inferred.

The log transformed catch data for both trials are given in figures 5.2.1 and 5.2.2 with the suffixes V, T and S denoting the vessels Voyager, Thalassa and Scotia respectively. It can be clearly seen that species like whiting, sprat and poor cod were the main catch components in both trials. Also, it is immediately apparent that there is good overlap between box notches for virtually all species meaning medians are not significantly different.

Where a species only occurred at a small number of stations, in other words there is a high proportion of null catches, the median appears at the x-axis and the catches appear as outliers. This was the case for boarfish (BOF.V and BOF.V) in Fig 5.2.2 for example, where this species was only caught in 6 and 5 hauls respecively. It should be borne in mind, however, that the catches from the Thalassa Voyager trial in 2000 encompass catches from both the Irish and Celtic Seas that are reasonably spatially distant. We would expect, therefore, that some species may be absent in one of these areas resulting a high number of null catches.

Fig 5.2.1 Boxplot of Scotia - Voyager Raised Catches



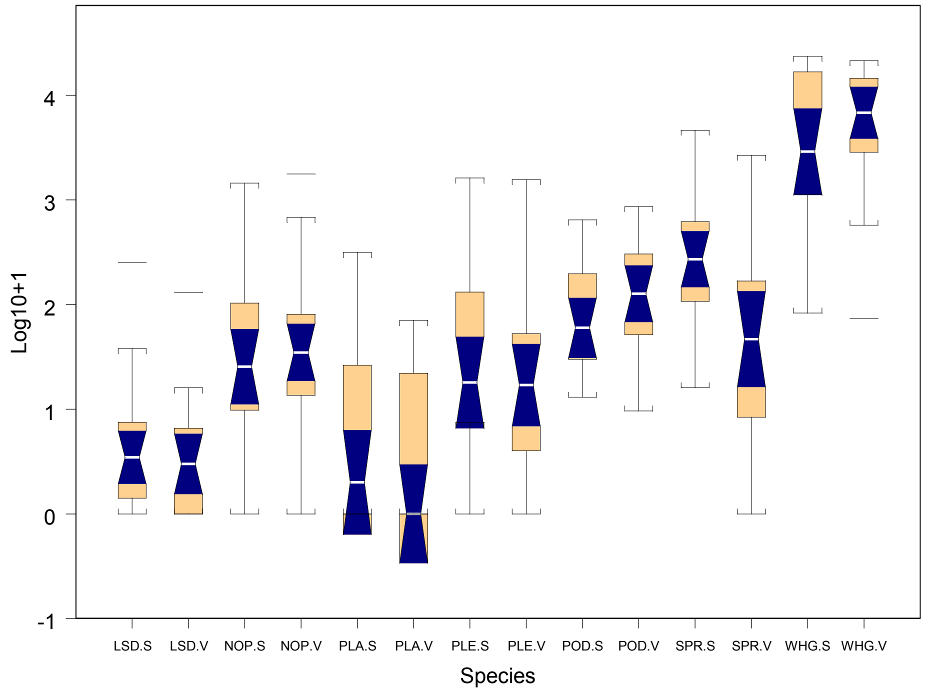
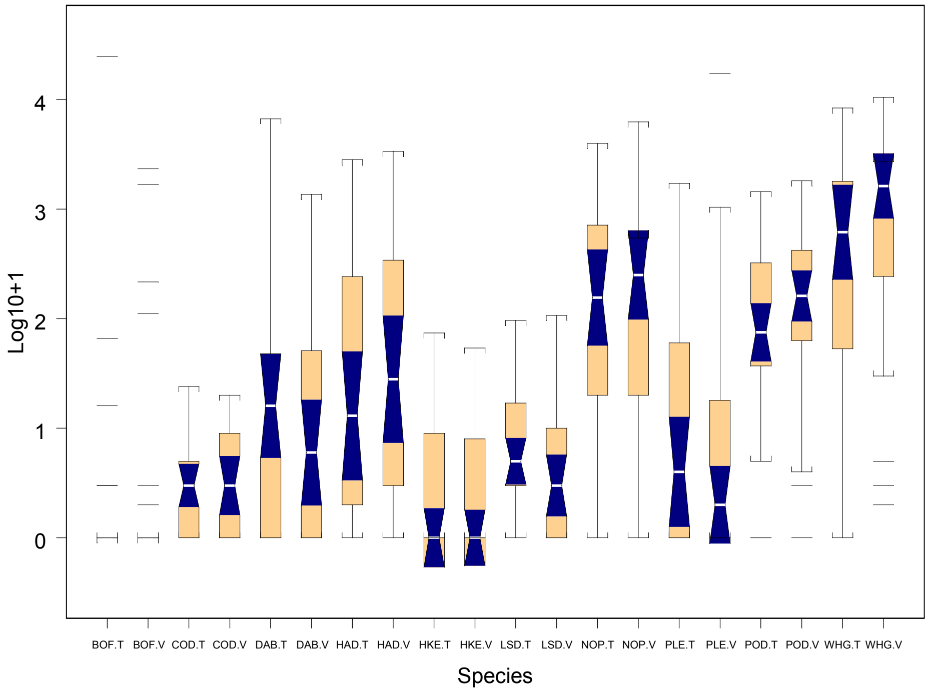
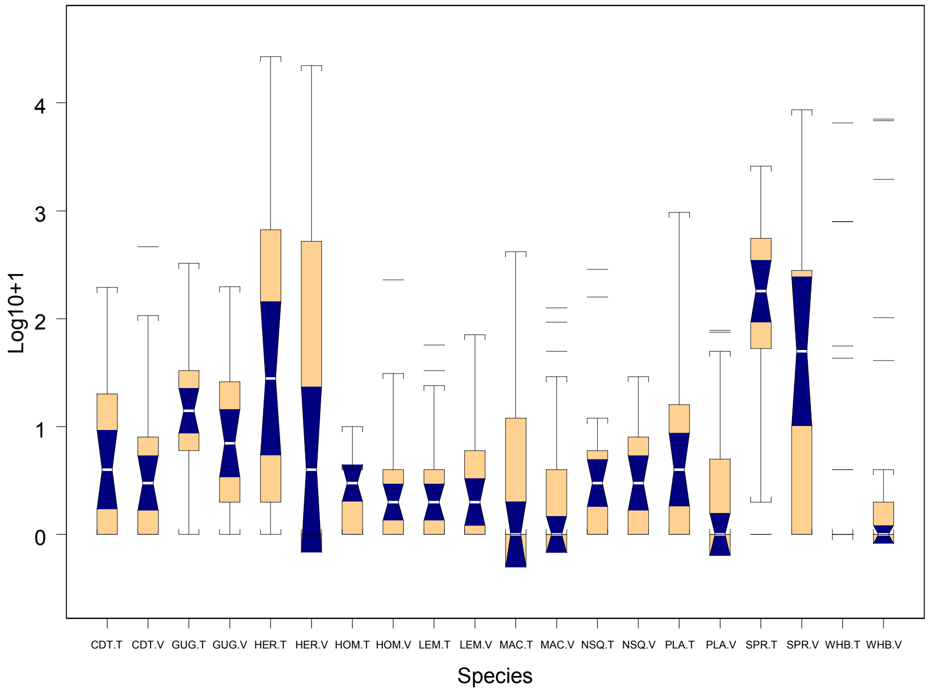



Fig 5.2.2 Boxplot 0f Thalassa - Voyager Raised Catches



### 5.2.2 T-test analysis

The abundance of species caught by the *Celtic Voyager* was compared with that of the *Thalassa* and *Scotia* using paired two-tailed Student's *t*-tests. These univariate comparisons tested the null hypothesis that the log of the abundance caught on each haul by the Celtic Voyager divided by the abundance caught on each haul by the Thalassa or Scotia equaled 0:

$$H_0 : \sum \log\left( Abund_{Voyager} \big/ Abund_{Vessel2} \right) = 0$$

where Vessel 2 is the *Thalassa* or *Scotia*. The results of these comparisons are presented in Table 5.2.1.

Student's *t*-tests only found significant differences between the catches of herring, grey gurnard, cod and sprat between the *Celtic Voyager* and *Scotia* (*P*: 0.002, 0.036, 0.037 and <0.001 respectively). Differences were found between the *Celtic Voyager* and *Thalassa* only in the catches of dab, long rough dab and sprat (*P*: 0.012, 0.001 and <0.001 respectively).

| | | Average ratios | | | Average ratios | |
|---|---|---|---|---|---|---|
| Species | $P$ (H=H$_0$) | log (Voyager/ Scotia) | Voyager/ Scotia | $P$ (H=H$_0$) | log (Voyager/ Thalassa) | Voyager/ Thalassa |
| CALL-LYR | 0.212 | 0.306 | 1.359 | 0.212 | -0.246 | 0.782 |
| CAPR-APE | | | | 0.761 | -0.109 | 0.897 |
| CLUP-HAR | **0.002** | 0.449 | 1.566 | 0.087 | -0.250 | 0.779 |
| EUTR-GUR | **0.036** | 0.257 | 1.293 | 0.062 | -0.274 | 0.761 |
| GADU-MOR | **0.037** | 0.133 | 1.142 | 0.616 | -0.049 | 0.952 |
| HIPP-PLA | 0.130 | 0.252 | 1.286 | **0.012** | -0.525 | 0.591 |
| LIMA-LIM | 0.282 | 0.182 | 1.200 | **0.001** | -0.573 | 0.564 |
| LOLI-FOR | | | | 0.790 | 0.035 | 1.036 |
| MELA-AEG | 0.345 | -0.085 | 0.918 | 0.899 | -0.011 | 0.989 |
| MERL-MCC | | | | 0.153 | -0.123 | 0.884 |
| MERL-MNG | 0.059 | -0.170 | 0.843 | 0.953 | 0.005 | 1.005 |
| MICR-KIT | | | | 0.236 | 0.168 | 1.183 |
| MICR-POU | | | | 0.309 | 0.281 | 1.325 |
| PLEU-PLA | 0.151 | 0.157 | 1.170 | 0.178 | -0.205 | 0.815 |
| SCOM-SCO | | | | 0.057 | -0.503 | 0.605 |
| SCYL-CAN | 0.331 | 0.119 | 1.126 | 0.323 | -0.098 | 0.906 |
| SPRA-SPR | **<0.001** | 0.741 | 2.097 | **<0.001** | -0.52 | 0.60 |
| TRAC-TRU | 0.906 | 0.030 | 1.030 | | | |
| TRIS-ESM | 0.299 | -0.086 | 0.918 | 0.133 | 0.103 | 1.108 |
| TRIS-MIN | 0.131 | -0.174 | 0.841 | 0.825 | 0.023 | 1.023 |
| All species | 0.527 | -0.048 | 0.953 | 0.220 | -0.326 | 0.722 |

Table 5.2.5. Results of *t*-tests comparing the abundance of species caught by the *Celtic Voyager* with that of the *Scotia* or *Thalassa*. *P*: Probability that the null hypothesis is true, significant differences are shown in bold type. Full species names are given in the Annex.II.

## 5.3 Multi-Species Catch Correlations – Multivariate Analysis

### 5.3.1 Introduction

The underlying question addressed in this section is: *are the interactions between catches of the species measured at boat 1 similar to that on boat 2?* Addressing this question demands that "interactions between catches of species" be defined. In this study we defined $A_{ih}$ as the total number (raised number) of fish of a particular species at haul h on boat i, *i=1,2* and $B_{ih}$ as that of another species. Our analysis attempted to quantify whether $A_{1h}$ and $A_{2h}$, $B_{1h}$ and $B_{2h}$, $A_{1h}$ and $B_{2h}$, $A_{2h}$ and $B_{2h}$, $A_{1h}$ and $B_{1h}$, and $A_{2h}$ and $B_{1h}$ were similar over all hauls? For analyses such as this one where a large number of species are involved detecting patterns in a cross-correlation matrix is difficult. Our approach was therefore to present a low-dimensional approximation of the correlation matrix such as that depicted in a principal component analysis (PCA) biplot.

The PCA biplot (Jolliffe 1986) is a dimension reduction technique that gives a low dimensional graphical presentation of the correlation (or covariance) matrix. In the biplot, variables are shown as vectors where the relationship between variables is interpreted by the angle between them, with angles of less than 90 degrees indicating a positive correlation between them. The length of the vector is indicative of the amount of variance in the original data explained by the two components of the biplot, and the vectors direction showing either a positive or negative relationship between that variable and the first and second components. The samples or observations are displayed as individual points on the biplot. Drawing a perpendicular line between a sample point and a given variable will indicate the correlation between the two. Only the positive portion of the vector is shown in our biplots, hence a perpendicular that falls on the vector where it is extended through the origin is considered to indicate a negative relationship.

Related techniques to the PCA biplot include correspondence analysis, multidimensional scaling (MDS), discriminant analysis, redundancy analysis and canonical correspondence analysis. All these techniques begin by defining a measure of similarity; from the Chi-square distance function in (canonical) correspondence analysis, to a much wider choice in MDS (e.g. absolute differences, Euclidean distances, Bray-Curtis distances), followed by a low dimensional approximation of these similarities. All of these dimension reduction techniques were applied to our data, but because all techniques gave the same message, only the results of the PCA biplot are presented.

### 5.3.2 Results

Results of the Principal Component Analysis for the intercalibration exercise between the Celtic Voyager/R.V. Scotia and the Celtic Voyager/Thalassa are presented below in the form of biplots. The biplot is a simple way of visualising correlations between large numbers of variables, and exploring possible structure within the dataset.

The amount of variance in the original data accounted for by the first two components of the biplot is $\lambda_1$ = 0.351 and $\lambda_2$ = 0.139 respectively (Fig 5.3.1), or a cumulative proportion of 49.01%. For the purposes of exploratory data analysis Fig5.3.1 is a reasonable representation of the correlations within the data for most of the variables. However, caution should be exercised with inferences for the shorter vectors such as the Voyager and Scotia poor cod variables (S.POD and V.POD respectively) as they are less well explained by components 1 and 2, indicated by their shorter length.

What can be seen from Fig 5 3.1 is that there is clearly a close correlation between the catch for a species "A" from one boat with the catch for the same species on the second boat (ie is $A_{1h}$ similar to $A_{2h}$). For example the sprat catches for both boats are virtually superimposed as are the haddock catches. There is also good correlation between species indicated by the acute angle between most of the variables in the analysis.

Individual hauls have been labelled here according to depth stratum to visualise the relationship between catches and depth. It is important to bear in mind that, with the exception of two hauls, all station depths greater than 100m were found in the Celtic Sea and as a consequence there is also a significant spatial component to the depth strata. It is evident that the shallow water stations (s) are, for the most part, associated with above average catches for most species. Sprat is the only species in the biplot with a strong positive correlation with mid-depth stations (m).

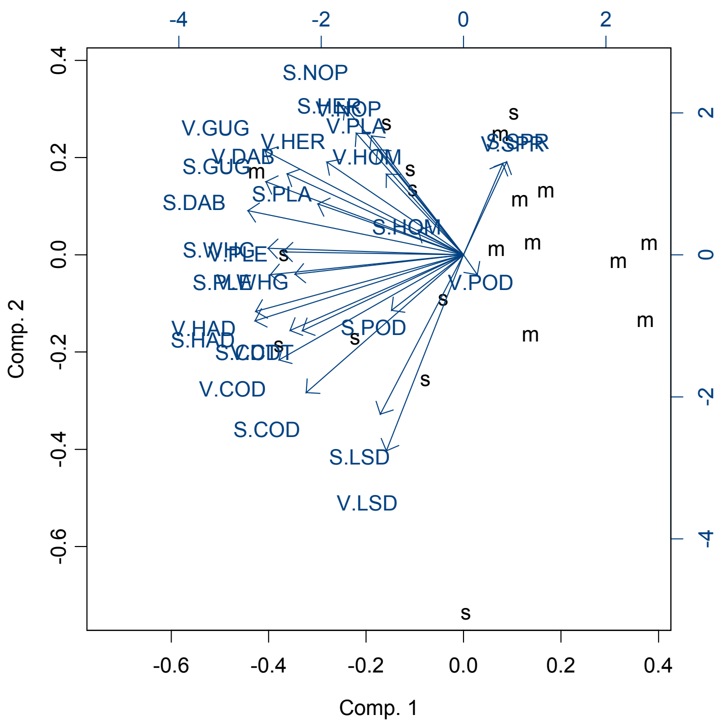



Fig 5.3.1 Biplot for Voyager/Scotia Intercalibration 1999
Prefix: Scotia (S); Celtic Voyager (V) followed by 3 letter species code
Stations as Depth Strata (S= shallow [<50m]; M= mid-depth [50-100m])

For simplicity the analysis has been re-run using only the main commercial species of interest (Fig 5.3.2) resulting in eigen values of $\lambda_1$ = 0.467 and $\lambda_2$ = 0.195. As in Fig 5.1.1 above, there is a clear within species correlation between boats, as well as higher than average catches associated with shallow water stations. If we move clockwise around the biplot from the twelve o'clock position there is a higher correlation between species such as poor cod and Norway pout than between poor cod and the flatfish, plaice and dab. This might reasonably be interpreted as species generally found at similar depth being caught together, or, alternatively an overall shift in species composition with depth.

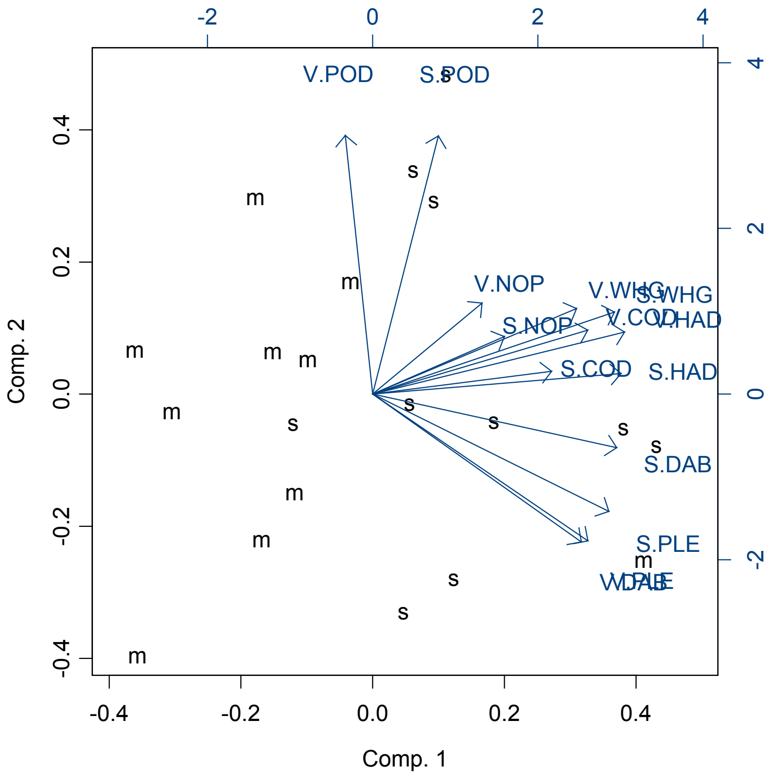



Fig 5.3.2 Biplot for main commercial species for the Voyager/Scotia Intercalibration 1999

Fig 5.3.3 shows the biplot for the Thalassa and Celtic Voyager intercalibration carried out in November 2000. The eigen values for this PCA analysis were $\lambda_1$ = 0.261 and $\lambda_2$ = 0.176 respectively. These values are appreciably lower than those for the Voyager/Scotia intercalibration however, which is likely to be as a result of the increased numbers of samples and variables, as well as the increased depth and spatial coverage of this second comparative fishing. Variables are dispersed through c.230 degrees in the biplot (Fig. 5.3.3) in contrast to c.180 degrees for the earlier intercalibration (Fig. 5.3.1). However, when data from the two years are compared strictly for analogous variables we get $\lambda_1+\lambda_2$= 0.477 which is a 1.32% difference in the variance explained by the biplots between years.

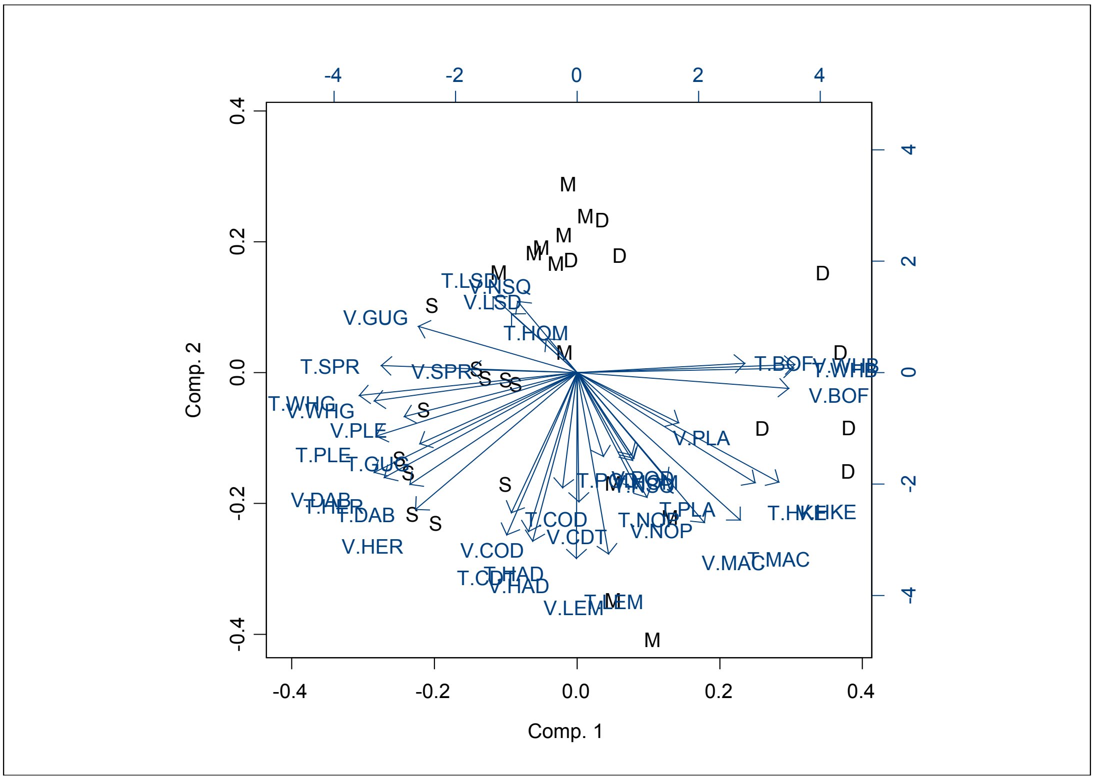



Fig 5.3.3 Biplot of Voyager/Thalassa Intercalibration 2000

Prefix: Thalassa (T); Celtic Voyager (V) followed by 3 letter species code

Stations as Depth Strata (S= shallow [<50m]; M= mid-depth [50-100m]; D= deep [100-150m])

Notwithstanding the greater dispersal of variables, for our purposes, there is little to suggest from the PCA analysis that the catch in numbers from one vessel for a given species is not being clearly reflected in the catch from the second vessel for the same species, that is that $A_{1h}$ is similar to $A_{2h}$. Similarly, between species correlations are as might be expected, with for instance both flatfish species (plaice – PLE, and dab – DAB) having a narrow acute angle between them on the biplot. In addition, these variables are also associated more closely with the shallow depth strata where catches would generally be assumed to be higher.

The function of the PCA was to assist in identifying where possible differences in overall catches might lie and to facilitate some exploration of possible anomalies. Such differences may occur if particular species or stations were displaying an unusual relationship with the rest of the dataset. Analysis from both trials is showing very similar outcomes even given the high variability and moderate size of the datasets. Further, when the dataset is distilled down to the main commercial components of the catch, and the eigen values improve, we can be reasonably confident that the PCA is not undermining our contention that these vessels are capturing similar signals in fish abundance.

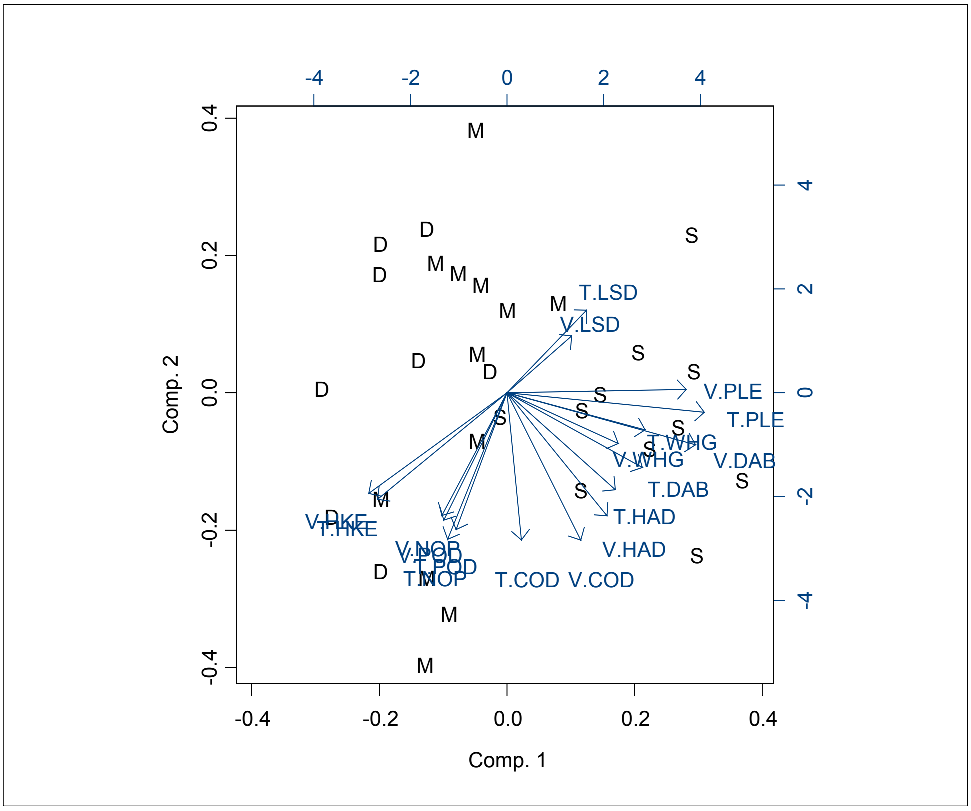



Fig 5.3.4 Biplot for main commercial species for Voyager/Thalassa

## 5.4. Population Structure – Comparative Length Frequency Analysis

### 5.4.1 Introduction

Having evaluated catch correlations and derived reasonable confidence that the vessels were producing acceptably similar overall catches, in terms of total numbers per species and species diversity, we turn to the final level of the analysis. The ultimate question to be addressed in order that surveys operating under IBTS protocols can be compared is "are there differences in the reported population structure from different vessels". The role of the IBTS surveys is ostensibly to provide an independent index of abundance (numbers at age) which may be used in the assessment of a number of internationally managed fish stocks.

The simplest way to directly interrogate the implied age structure of the catch is to compare numbers at length. What we are interested in knowing is if, at a given length, the relative catch $s_h(l)$ between vessels remains constant over a number of spatially separated standard survey stations. Also, whether there is a simple linear relationship over all lengths or, alternatively, whether numbers at length for one vessel can be modelled as a simple function of the other. If $s_h(l)$ is constant for a species then, accepting normal sub-sampling and ageing bias, we can be confident of producing comparable numbers per age.

In the absence of any other reasonable *a priori*, what we will test for is a 1:1 relative catch at length between boats. Deviation from this will suggest that a correction or scaling factor should be applied to one of the boats. Results for the length frequency based analysis are presented below with a detailed example for whiting from the Thalassa Voyager trial, followed by summary results for all species analysed in the two comparative trials.

### 5.4.2 Methodology

A full description of the statistical background plus an application of the length-frequency-based comparative fishing trial between two boats is given in Zuur *et al.* (2001). Here, a short summary is given.

The length-frequency-based analysis consists of three steps. In the first step, a general model for a single paired tow is developed. The second step combines information over tows to estimate some *average relative catch rate.* Bootstrapping is used to generate confidence intervals around this average relative catch rate. These bootstrap confidence intervals allow an informal assessment of whether the data are consistent with an average relative catch rate of 1 (both boats measure the same). In the last step, this approach is formalised with an appropriate hypothesis test. The disadvantage of the length-frequency analysis is that it can only be applied on species measured at a reasonable numbers of hauls.

Each of the steps is discussed next.

**Step 1: General model for a single paired tow**

In the first step, a model that relates the numbers at length caught by boat 1 to those caught by boat 2 in a single paired tow is developed. The theory is analogous to that used for analysing selectivity trials with paired tows (Millar & Fryer 1999).

Assume that, in paired haul $h$, fish of a particular species became available to boat 1 and boat 2 according to a Poisson process with a common rate $\lambda_h(l)$. Let $r_{1h}(l)$ and $r_{2h}(l)$ be the available selection curves for boat 1 and boat 2 respectively; that is the probability that a fish of length $l$ is caught and retained by a boat given that is was available to the boat (Millar & Fryer 1999). Further, let $p_1$ and $p_2$ be the relative fishing intensities of boat 1 and boat 2. These we can take to be $p_1=1$, $p_2=1$ since boat 1 and boat 2 fished equally long. Finally, let $d_{1h}(l)$ and $d_{2h}(l)$ denote the subsampling fractions for boat 1 and boat 2. It is assumed that the measured number of fish at length $l$ on boat 1 and boat 2, $Z_{1h}(l)$ and $Z_{2h}(l)$, are Poisson distributed with expectation $\lambda_j(l)\ r_{jh}\ (l)\ p_j\ d_{jh}\ (l)$, $j=1,2$ respectively. Since $p_1=1$, $p_2=1$, we have:

$$Z_{1h}\ (l) \sim \text{Poisson}\ (\lambda_1\ (l)\ r_1\ (l)\ d_{1h}(l))$$
$$Z_{2h}\ (l) \sim \text{Poisson}\ (\lambda_2\ (l)\ r_2\ (l)\ d_{2h}(l))$$

It can be shown (McCullagh & Nelder 1989) that conditional on the total measured catch, $Z_{1h}(l)+Z_{2h}(l)$, the measured number of fish of length $l$ on boat 1 follows a binomial distribution with probability $\varphi_h(l)$. That is:

$$Z_{1h}(l)\ |\ Z_{1h}\ (l) + Z_{2h}\ (l) \sim \text{Binomial}\ (Z_{1h}(l) + Z_{2h}(l),\ \varphi_h\ (l)),$$

where $\varphi_h(l)$ is defined by:

$$\varphi_h(l) = r_1(l)\ d_{1h}(l)\ \ /\ \ (\ r_1(l)\ d_{1h}(l) + r_2\ (l)\ d_{2h}(l)\ ) \qquad (1)$$

Using the logit link function, equation (1) can be rewritten as:

$$\text{logit}\ (\varphi_h(l)) = \log\ (\ \mathrm{d_{2h}(l)/d_{3h}(l)} + \mathrm{s_h}(l)\ )$$

where

$$\mathrm{s_h}(l) = \log(1) + \log\ (\mathrm{r_{2h}}(l)\ /\mathrm{r_{3h}}(l))$$

The term $s_h(l)$ is the log relative catch rate as a function of $l$. We are not really interested in $r_{1h}(l)$ or $r_{2h}$(l) but more in the form of $s_h(l)$. We can estimate $s_h(l)$ non-parametrically using generalised additive modelling techniques (Hasti and Tibshirani 1990). We are especially interested whether $s_h(l)$ = log(1), $s_h(l)$ = constant ≠ log(1) or whether $s_h(l)$ is a general smoothing function.

Note that, although all the analysis will be done on the logistic scale, we will generally back-transform results for presentation. The back-transformed formula is given in Zuur *et al.* (2001). Consequently, the results will lie between zero and one, and are interpreted as the catch rate of boat 1 relative to the total catch rate of the two vessels. A relative catch rate of 1 corresponds to a value of 1/2 on this [0, 1] scale (i.e. half of the fish are caught by boat 1). There are two advantages to this back-transformation. First, it makes graphical presentation simpler when relative catch rates are very large or very small. Second, it allows us to superimpose the raw data on the fitted curves, in the form of the (raised) proportions of fish at length caught by boat 1.

**Step 2: Combining information over tows**

Clearly, there can be considerable between-tow variation in relative catch rates, and we need to combine information over tows to estimate some *average relative catch rate*. There are several possible ways of doing this. One approach would be to combine the catch data over tows and then fit the binomial model to the combined data set. An alternative, which we pursue here, is to combine the fitted curves $\hat{s}_h(l)$. Specifically, we calculate a weighted average of these curves,

$$\check{s}(l) = \sum_{h=1}^{N} w_h \, \hat{s}_h(l)$$

where the weights $w_h$ are equal to the total number of the particular fish species measured by both boats in tow *h* divided by the total number of the particular fish species measured by both boats in all tows:

$$w_h = \left( \sum_l Z_{1h}(l) + Z_{2h}(l) \right) \Big/ \left( \sum_h \sum_l Z_{1h}(l) + Z_{2h}(l) \right)$$

We obtain confidence intervals for $\check{s}(l)$ by bootstrapping. Millar (1993) used bootstrapping to simulate between- and within-tow variation in selectivity data, and we follow his approach. Between-tow variation is introduced by bootstrapping on paired-tows with replacement. Within-tow variation is simulated by drawing abundances $\check{Z}_{1h}(l)$ from a binomial distribution $Bi(Z_{1h}(l)+Z_{2h}(l), \underline{\varphi}_h(l))$, where $\underline{\varphi}_h(l)$ are the fitted probabilities obtained by fitting the binomial model to the original data. We then estimate the weighted average $\check{s}^b(l)$ for each bootstrapped data set, $b=1,\ldots,B$.

Zuur *et al.* (2001) generated $B=1000$ bootstrapped estimates, the minimum number generally required to give reasonable confidence intervals (Efron and Tibshirani 1993). Various methods exist to translate these bootstrapped estimates into 95% pointwise confidence intervals. We present results of the quantile method, though other methods gave similar outcomes. The quantile method works as follows. For each length *l*, the 1000 bootstrapped estimates $\check{s}^b(l)$ are sorted. The 25th and 975th elements are then taken to be 95% confidence limits of $\check{s}(l)$.

**Step 3: Hypothesis testing with the bootstrap**

The bootstrap confidence intervals allow an informal assessment of whether the data are consistent with an average relative catch rate of 1. We now formalise this assessment with an appropriate hypothesis test. Again, we use the bootstrap to do this, since we have no parametric model for either the form of the curves $s_h(l)$ or for how they vary between-tows. Efron and Tibshirani (1993) discuss bootstrap hypothesis tests in detail. Strictly, we test the null hypothesis

$$H_0: E[\, s_h(l) \,] = \log(1) \text{ for all } l$$

(where the expectation is taken over all possible tows), since we have been working on the logistic scale throughout.

As a test statistic, we use

$$T = \sum_h D_h(\check{s}(l)) - \sum_h D_h(\log(1))$$

where $D_h(\check{s}(l))$ and $D_h(\log(1))$ are the deviances of the data from tow *h* when $s_h(l) = \check{s}(l)$ and $s_h(l) = \log(1)$ respectively. The test statistic thus measures how well $\check{s}(l)$ fits the entire data set compared to a constant value of log(1).

To assess whether the observed test statistic is significant, we construct a bootstrap hypothesis test. Essentially, this means that we bootstrap *b=1,..,B* data sets that satisfy the null hypothesis, and for each, we calculate the corresponding test statistic $T^b$, say. The values $T^b$, *b=1,..,B* then form a bootstrap reference distribution of *T* under the null hypothesis. If the observed test statistic is "large" relative to the bootstrap reference distribution, then it indicates evidence against the null hypothesis.

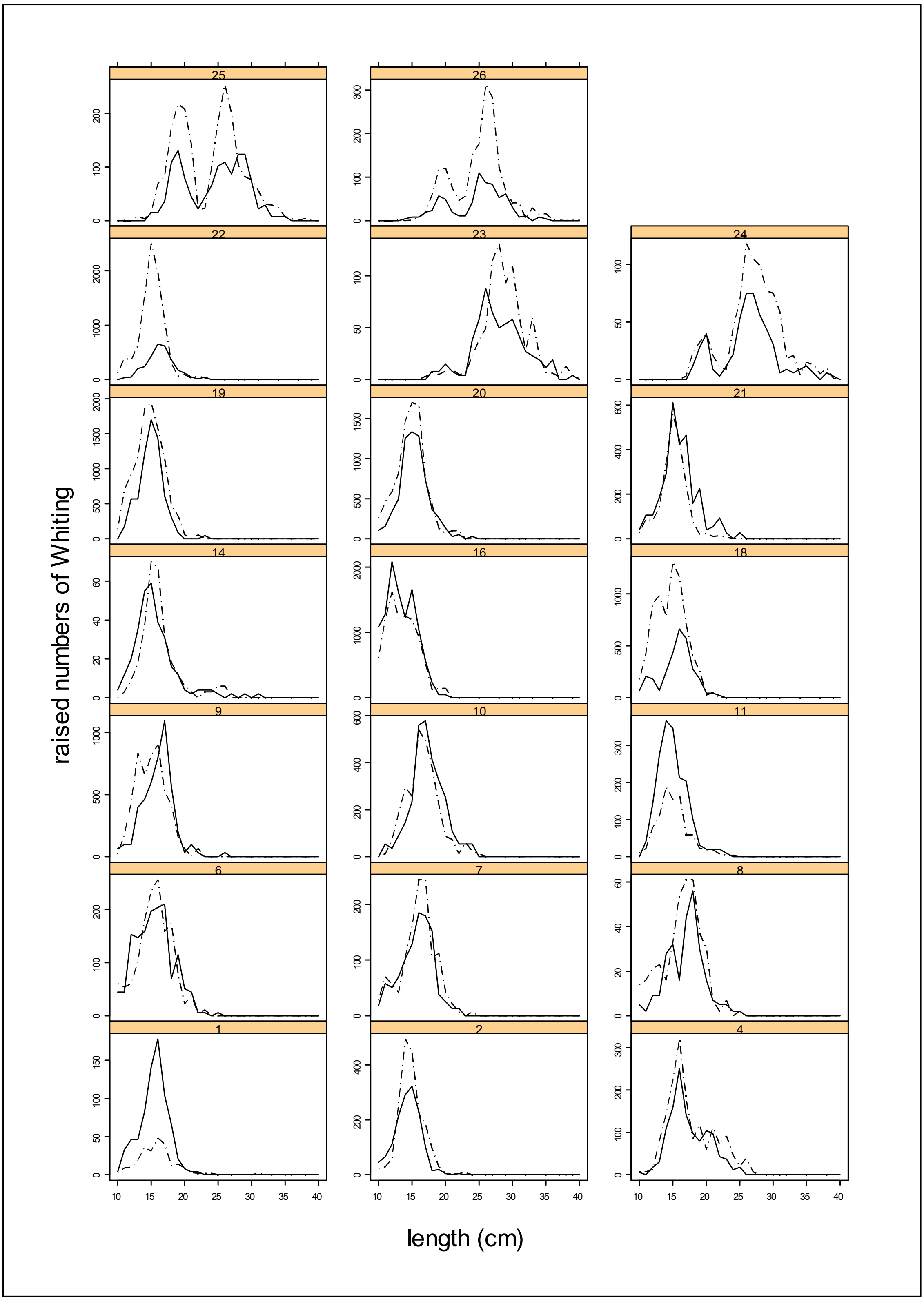
### 5.4.3 Results

Fig. 5.4.1 shows the raised numbers at length for whiting from the Thalassa Celtic Voyager inter-calibration exercise. Hauls where less than four fish were landed by either or both boats have been omitted as a minimum of four data points are required to generate the smoothing curves in the next step of the analysis.

Twenty hauls were suitable for analysis with length distributions generally between 10-25cm. Raised numbers were generated by multiplying the numbered of measured fish by the raising fraction which is simply the ratio of sample weight to total catch weight for a species.

Considerable within and between tow variation is evident from the length frequency distributions. While, generally speaking, both boats have picked up similar shaped length frequency distribution curves and modes, there are obviously samples where there is either a disparity in modes and/or an extra peak in the distribution. In haul 9 for example the length distributions are equivalent, but the frequencies are quite different. The Celtic Voyager has retained a higher proportion of whiting at smaller length frequencies and is showing a somewhat bi-modal distribution for instance. While this is not unreasonable given the high variability of fisheries data, it’s impact will be obvious in the next stage of the analysis when we calculate the relative catch rate at length for each haul.

Fig. 5.4.1 Raised numbers of whiting retained by the Celtic Voyager (dashed line) and Thalassa (solid line) for the 20 hauls used in the analysis.



Information per tow is combined to produce the relative catch curves presented in Fig 5.4.2. Again, the variation in relative catch rate is evident from the variation in curves between many of the plots. Haul 9 is clearly reflecting the Voyager's greater retention of smaller whiting at this station, but relatively lower catch of larger sized fish compared to the Thalassa. However, on inspecting all hauls in the analysis there is no obvious relationship, either positive or negative, other than the centre or abundant portion of the distribution tending towards the 0.5 or 50% relative catch rate.

To integrate the information from all 20 hauls such that a more meaningful general picture can be presented, a weighted average of the individual tows is presented in Fig 5.4.3a, allied with the bootstrapped 95% confidence intervals. The lower panel of the figure illustrates the number of paired tows for which there was data for each length class. It is immediately obviously that there is still a good degree of noise at the extremes of the frequency distribution. However, where there is a higher abundance of data, between circa 12-22cm, the relative catch curve stabilises close to the 0.5 catch rate with reasonably narrow confidence intervals.

While it would be impossible to draw inferences as to what is going on beyond the stable portion of the curve, what is worthy of note is the dramatic stabilising affect of small increases in the number of paired hauls. For this whiting example, as we move from a maximum number of 20 paired hauls at about 20cm length to 15 at about 23cm, there is a significant increase in noise, and vice versa.

These smoothed relative catch curves were fitted using four degrees of freedom which was felt to be an over fit for species such as poor cod and Norway pout which have a more constrained length distribution. The relative catch rates for these species were then refitted using three degrees of freedom, but this produced no real perceptible difference in the curves as a result. Relative catch rates for the remaining species are given in Fig 5.4.3b-g. Of the remaining species herring has by far the most significant shift from the 0.5 rate. However, paired hauls were very few for this species and the data are heavily reliant on a small number of very big catches, well below the number of paired hauls where we have seen reasonable stability in the model for other species. Therefore, caution must be exercised when interpreting this apparent trend in lower catches of herring for Voyager compared to Thalassa.

Fig 5.4.4a shows the outcome of the formal hypothesis test comparing 500 bootstrapped predictions of the Null Hypothesis i.e. a relative catch rate of 1, with the observed test statistic ($T$), for the same whiting sample. The observed value $T$ = 158.34 is well within the bootstrapped distribution of $T$ and therefore there is no statistical evidence to reject a relative fishing rate of 0.5 (i.e. 1:1).

Histograms of the hypothesis test for the remaining species are given in Fig 5.4.4b-g. Of these, as eluded to in the discussion above, the observed value of $T$ for herring (108.48) is lying towards the extreme right of the predicted distribution, suggesting that there is some evidence to reject a relative catch of 0.5 for this species.

Fig. 5.4.2 Back-transformed smoothed relative catch rates $S_h(l)$ and catches for Celtic Voyager for whiting in 2000.

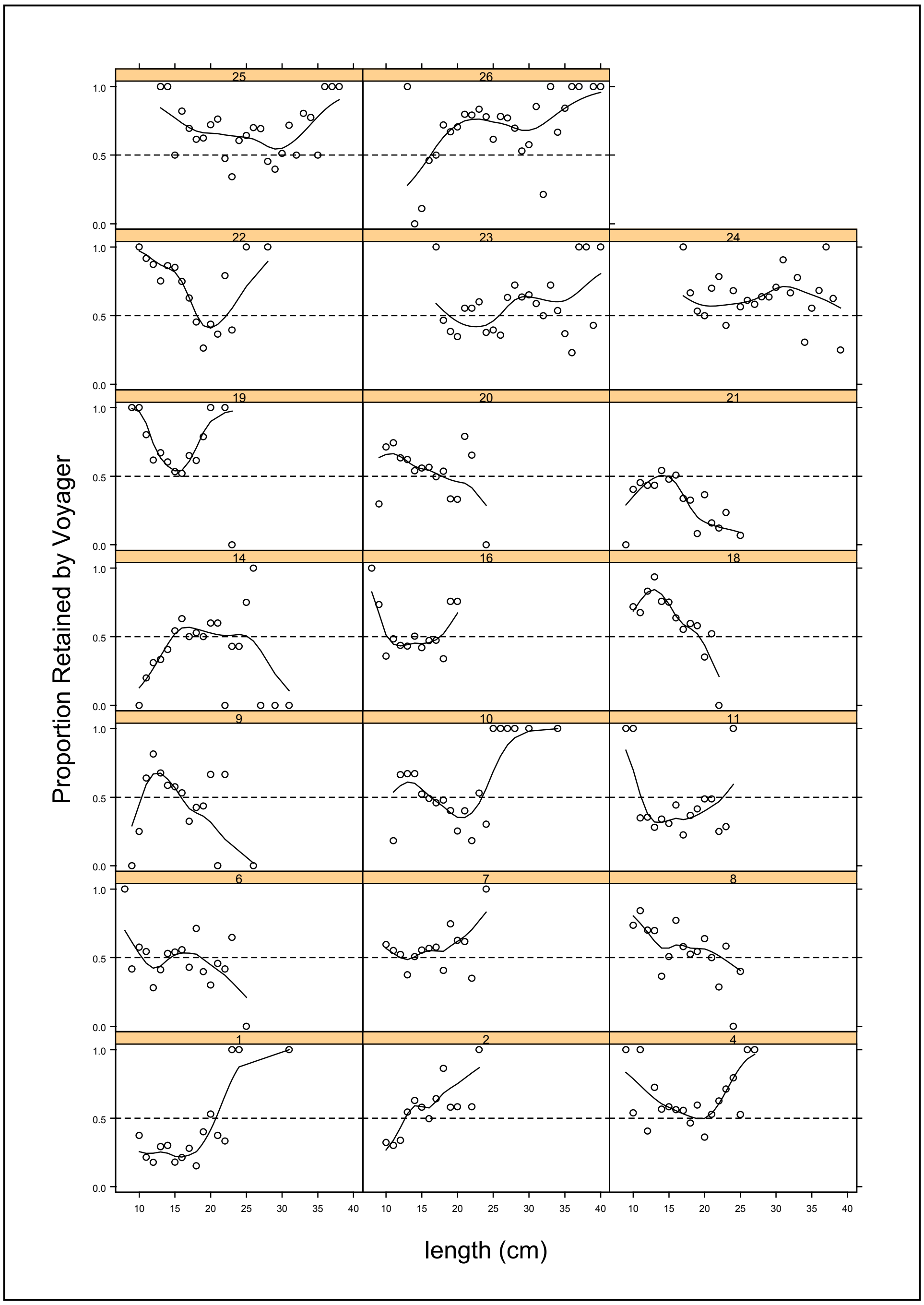


Fig 5.4.3a Upper panel shows the weighted average back-transformed smoothing curve with 95% confidence intervals for whiting in 2000. Lower panel gives the number of paired tows used in the analysis.

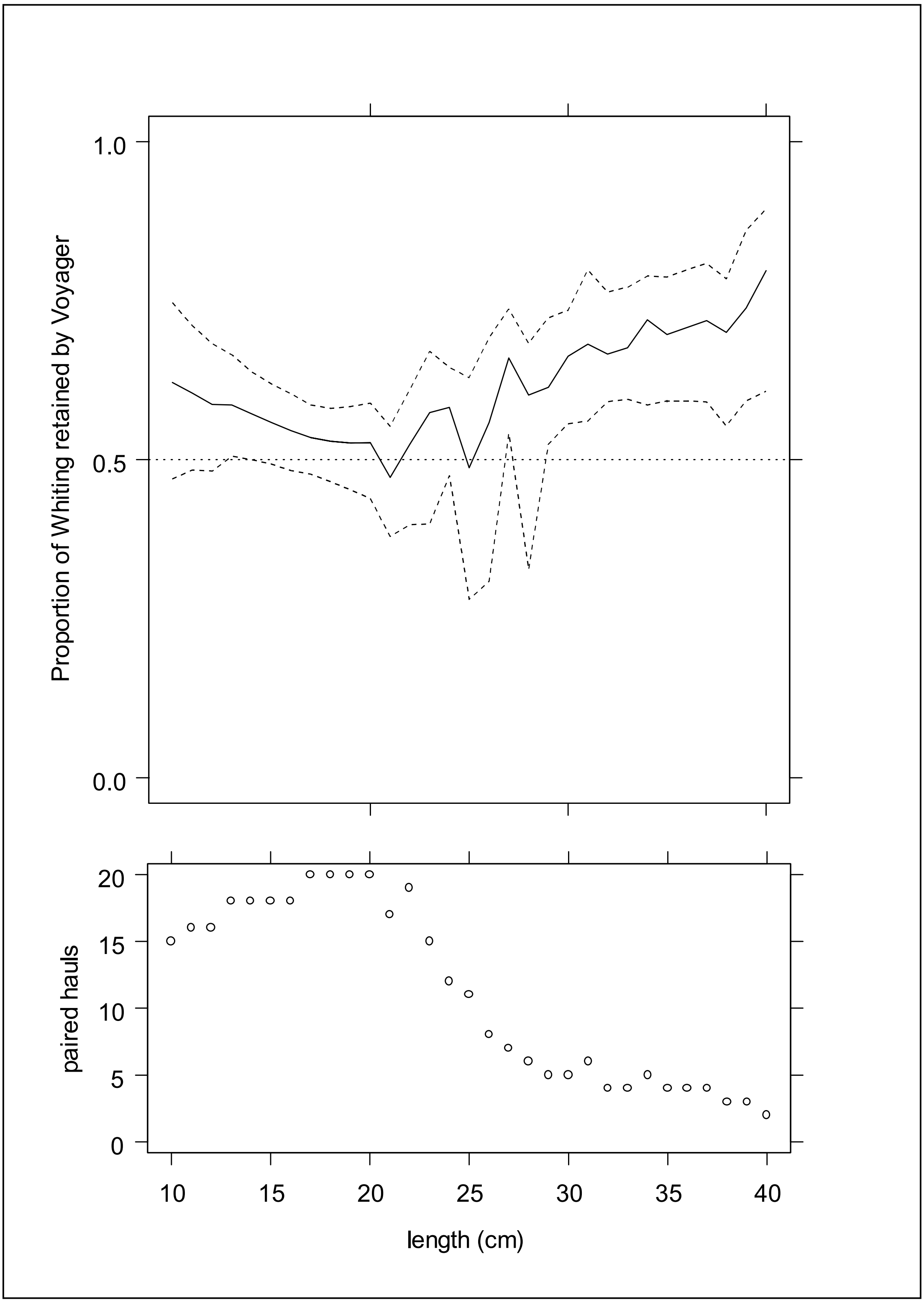


Fig 5.4.3b Upper panel shows the weighted average back-transformed smoothing curve with 95% confidence intervals for haddock in 2000. Lower panel gives the number of paired tows used in the analysis.

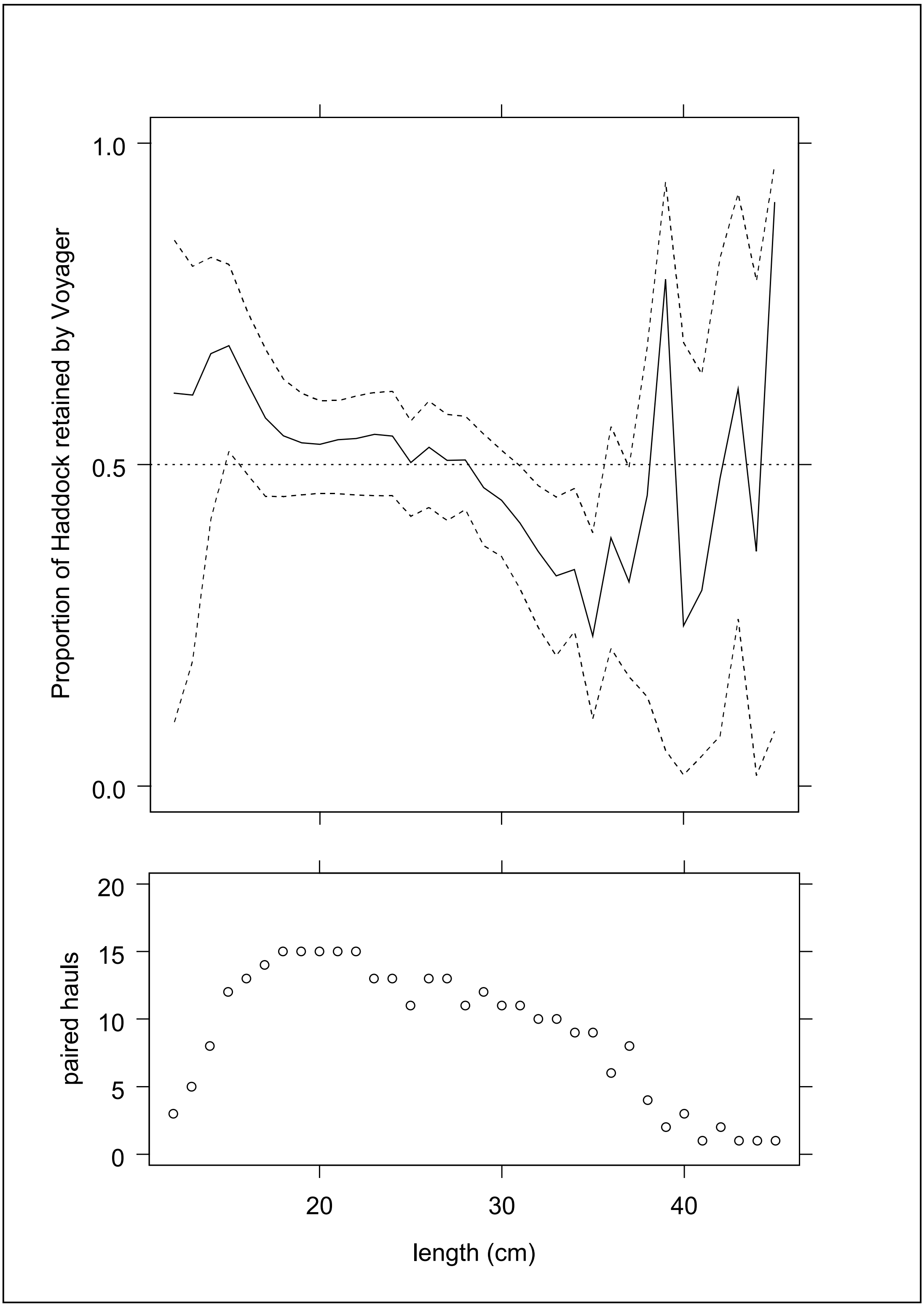


Fig 5.4.3c Upper panel shows the weighted average back-transformed smoothing curve with 95% confidence intervals for poor cod in 2000. Lower panel gives the number of paired tows used in the analysis.

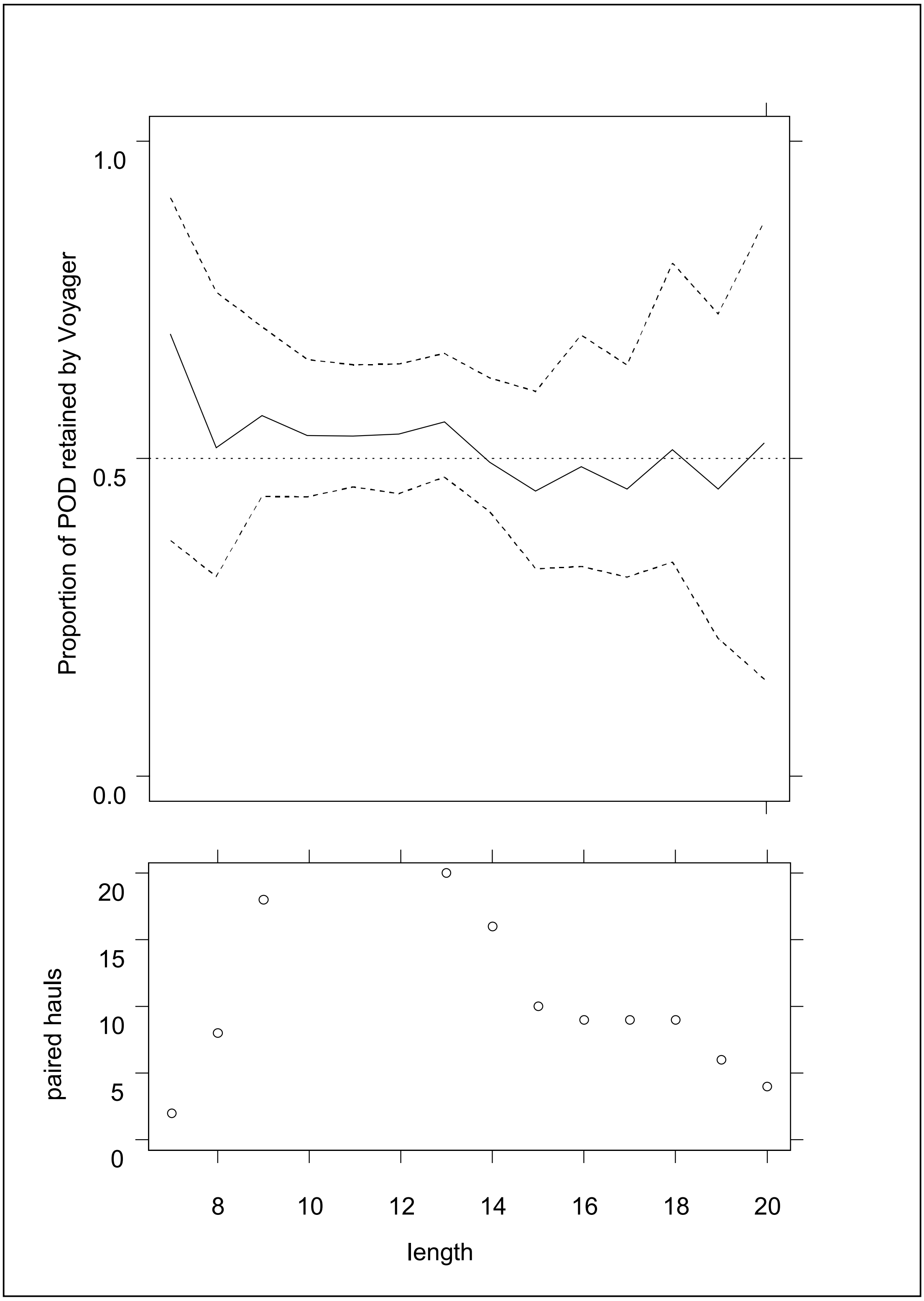


Fig 5.4.3d Upper panel shows the weighted average back-transformed smoothing curve with 95% confidence intervals for Norway pout in 2000. Lower panel gives the number of paired tows used in the analysis.

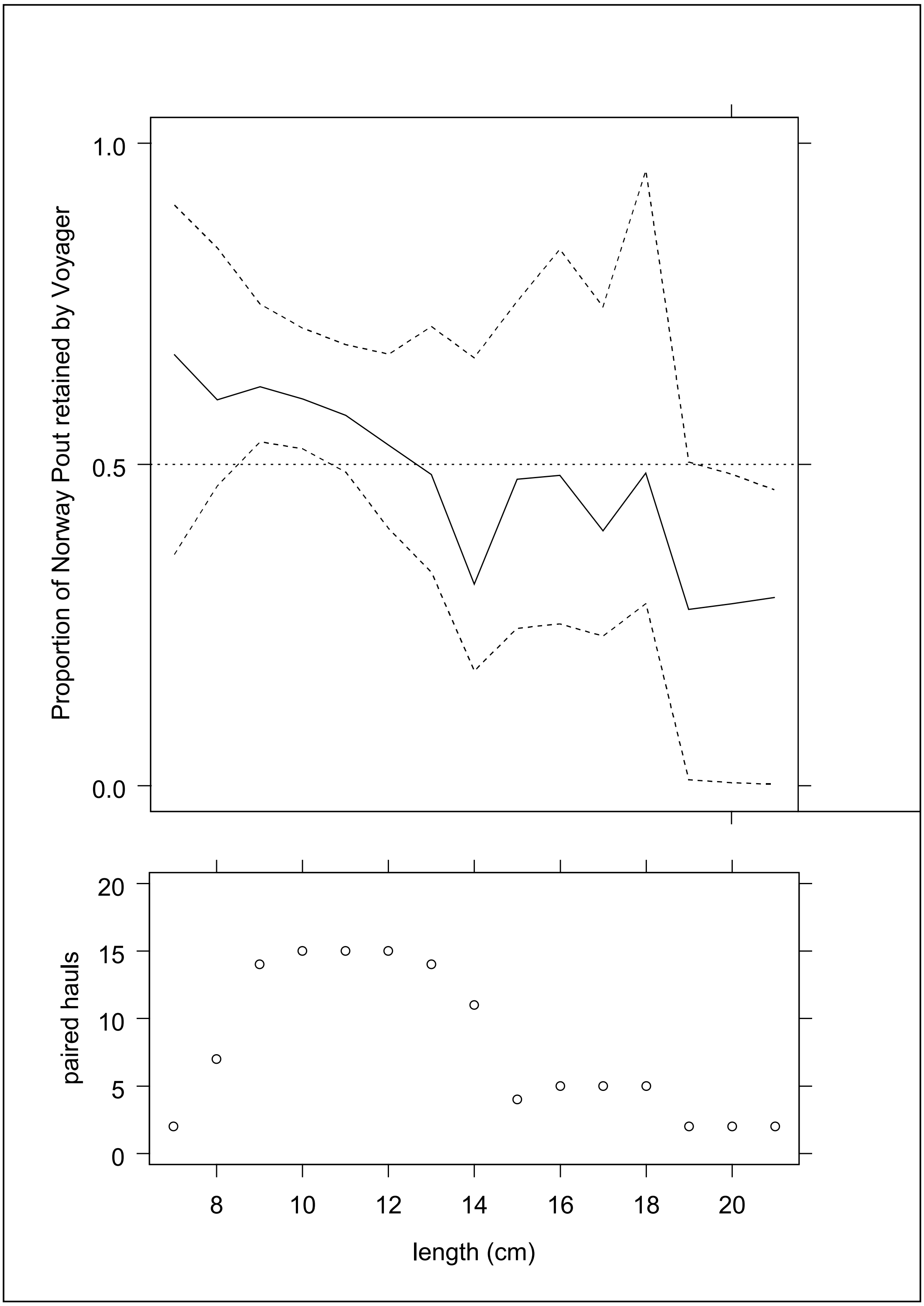


Fig 5.4.3e Upper panel shows the weighted average back-transformed smoothing curve with 95% confidence intervals for herring in 2000. Lower panel gives the number of paired tows used in the analysis.

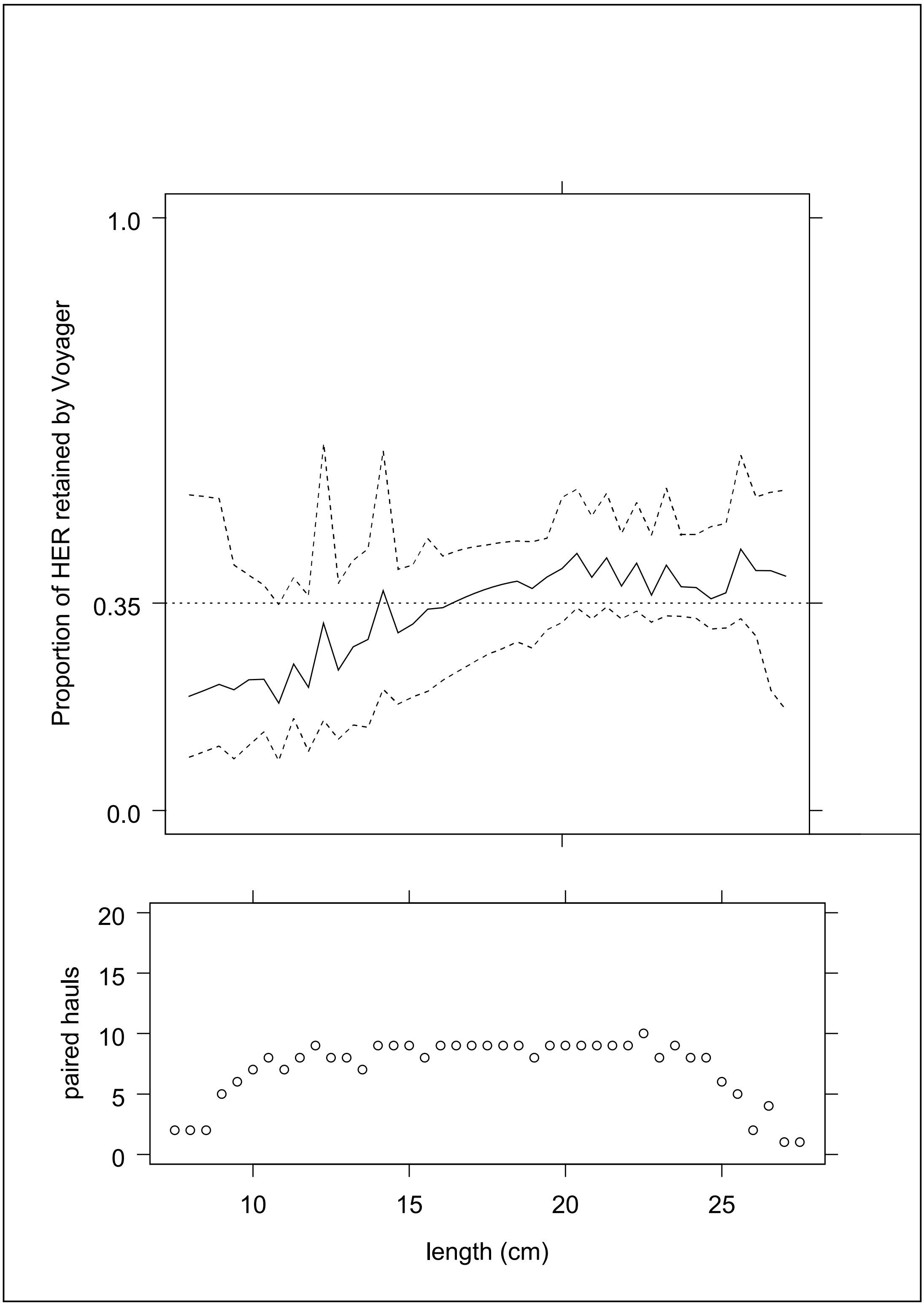


Fig 5.4.3f Upper panel shows the weighted average back-transformed smoothing curve with 95% confidence intervals for whiting in 1999. Lower panel gives the number of paired tows used in the analysis.

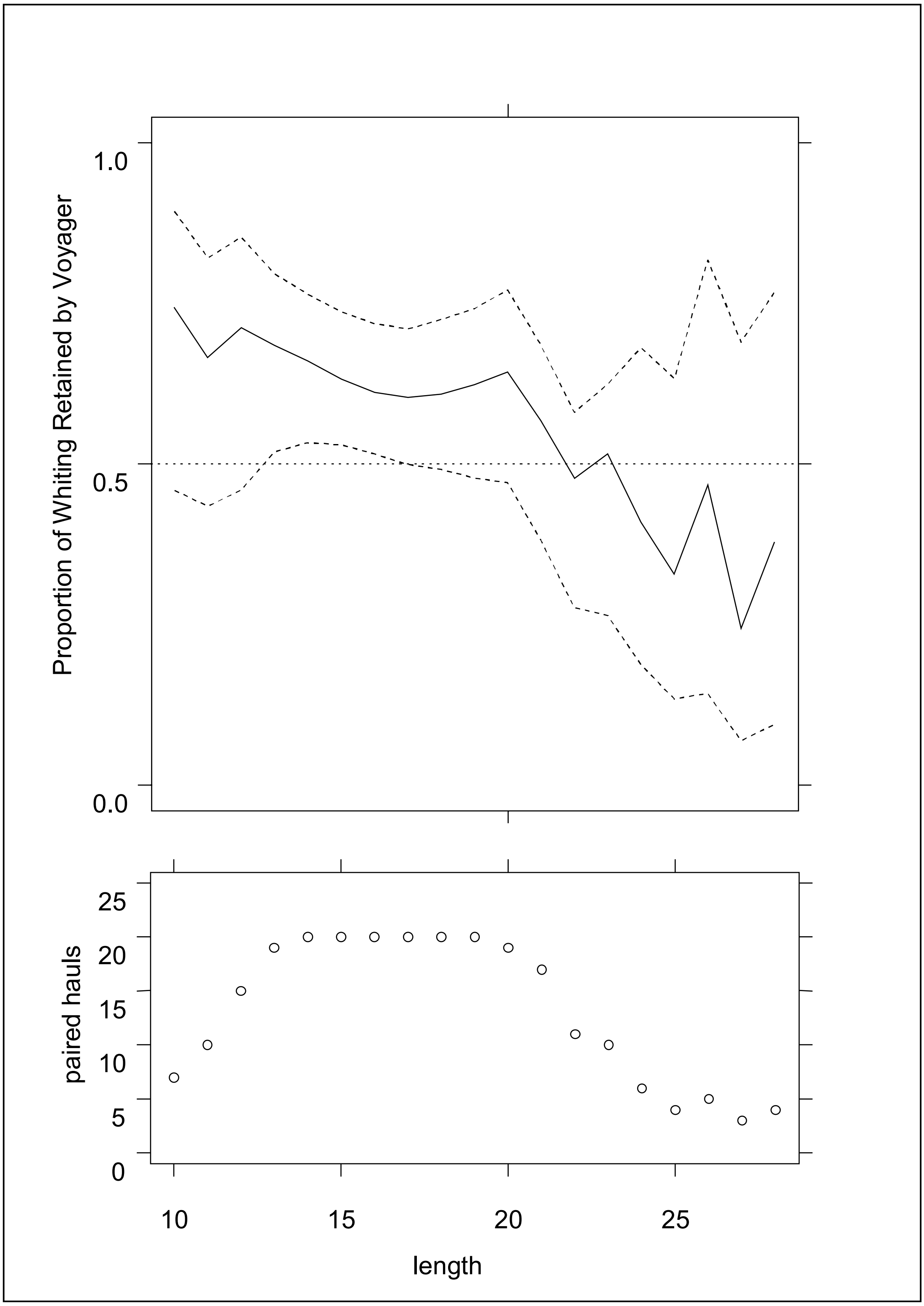


Fig 5.4.3g Upper panel shows the weighted average back-transformed smoothing curve with 95% confidence intervals for haddock in 1999. Lower panel gives the number of paired tows used in the analysis.

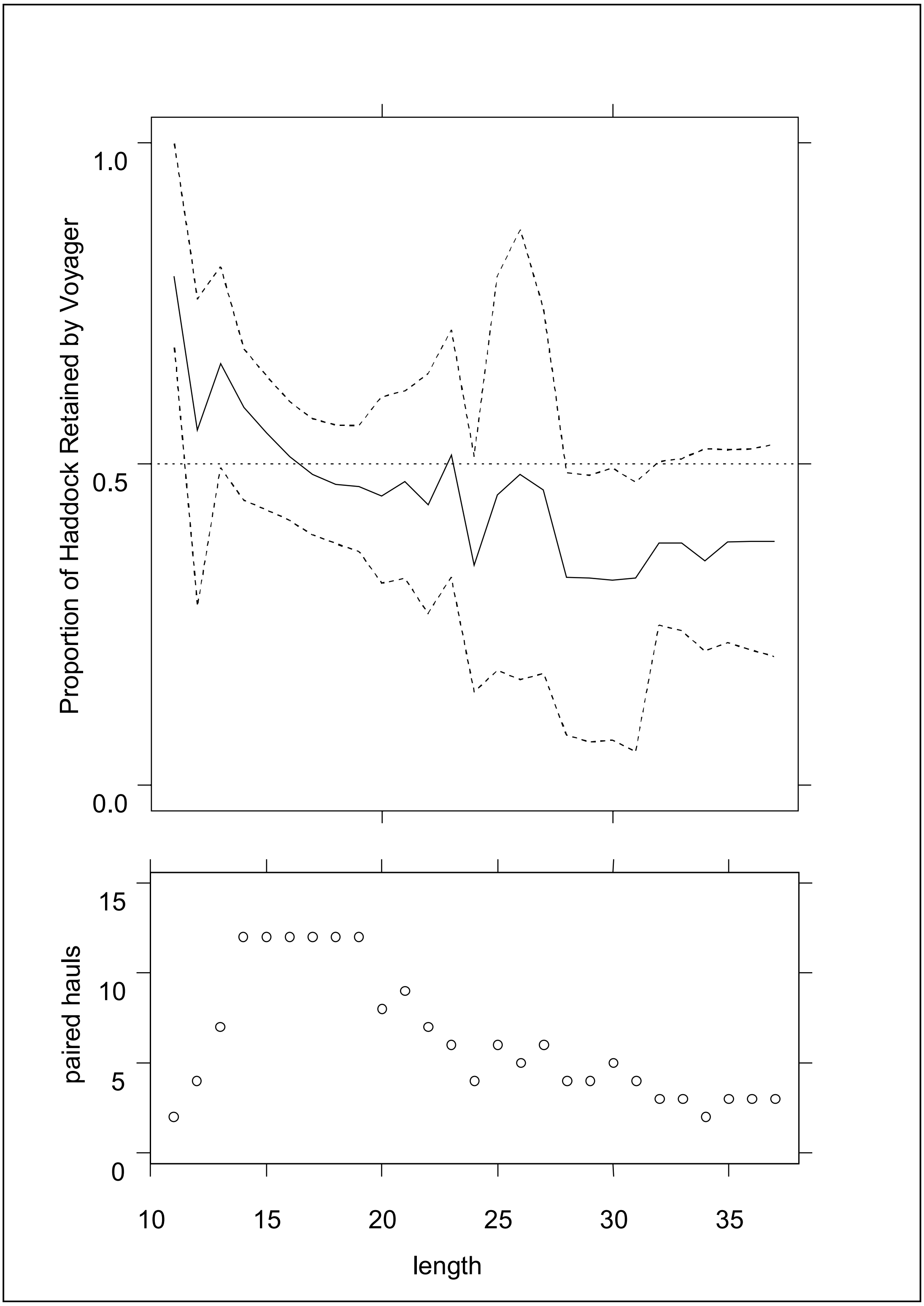


Fig 5.4.4 Histograms showing 500 bootstrapped realisations of the null distribution of T with the observed value represented as a vertical solid line.

Whiting 2000, observed difference *T* = 158.3452

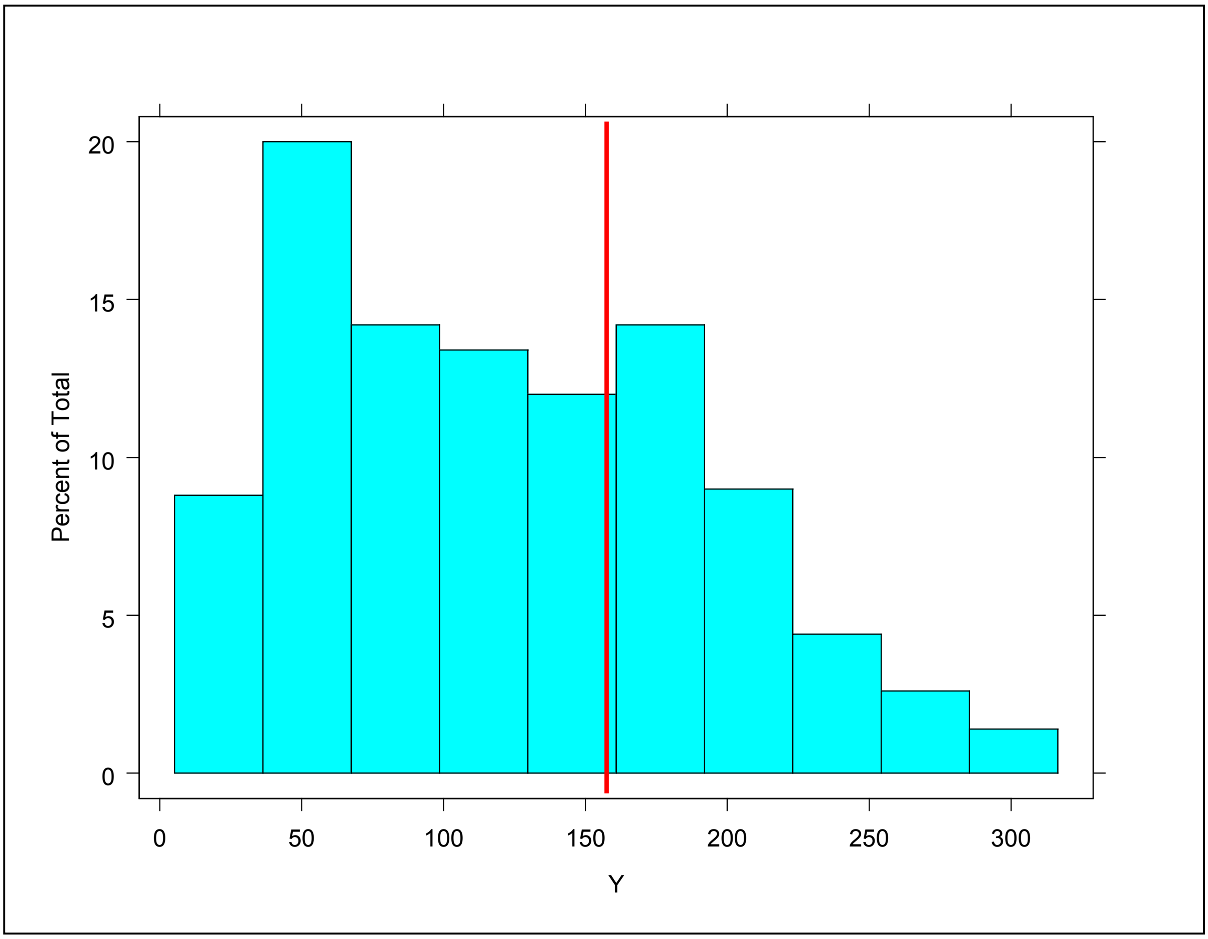
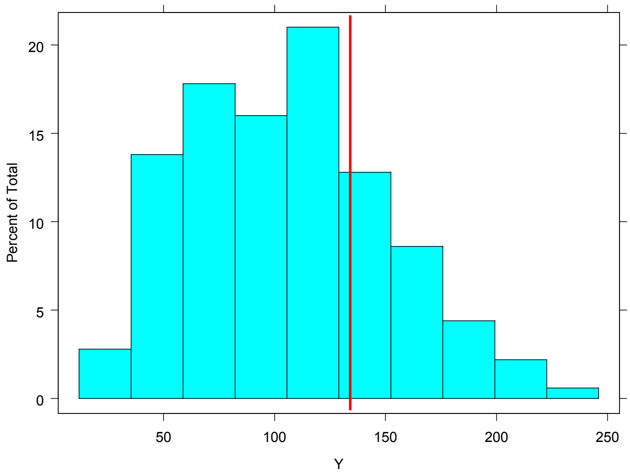
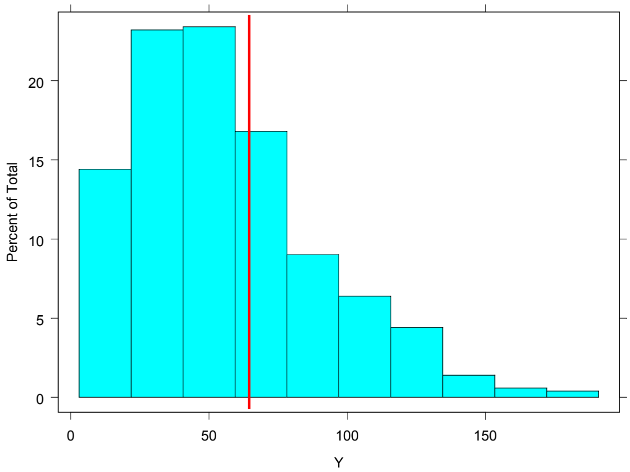


Fig 5.4.4b-g Histograms for remaining species showing 500 bootstrapped realisations of the null distribution of T with the observed value represented as a vertical solid line.

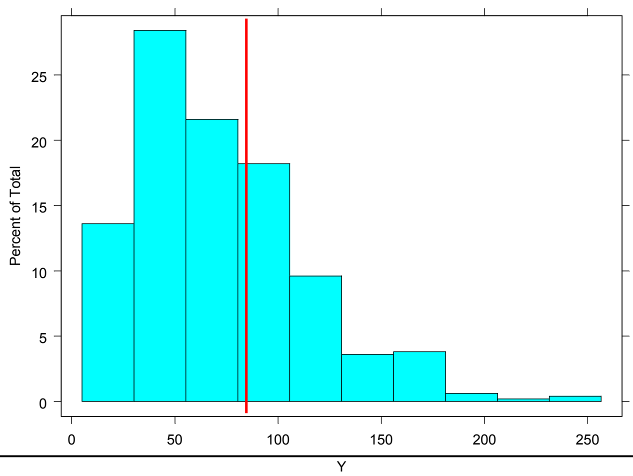
Haddock 2000: Observed diff 135.5669



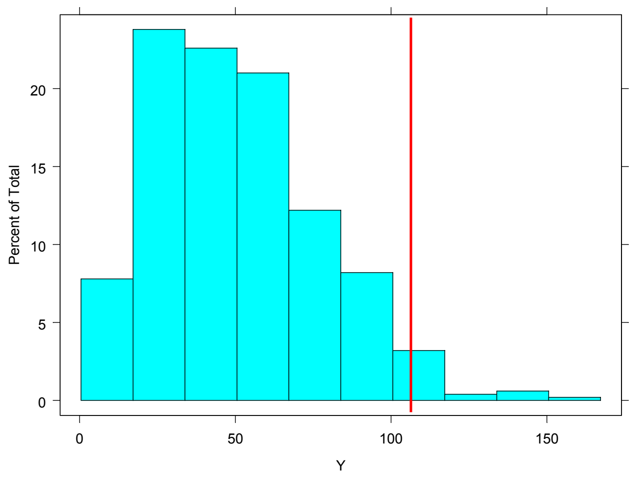

Norway pout 2000: Observed diff 71.34934



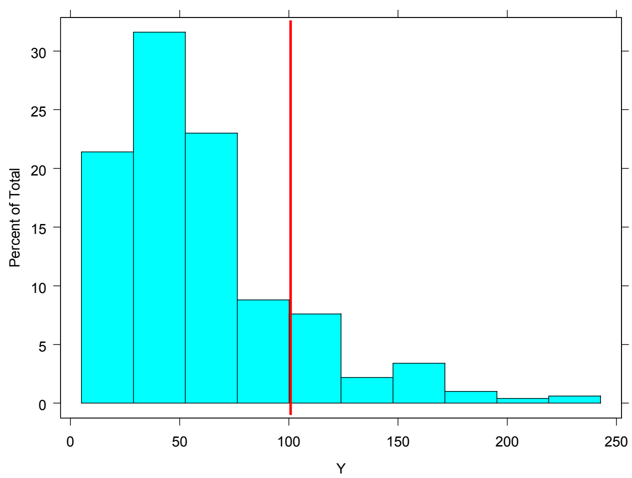

Poor cod 2000: Observed diff 77.01715



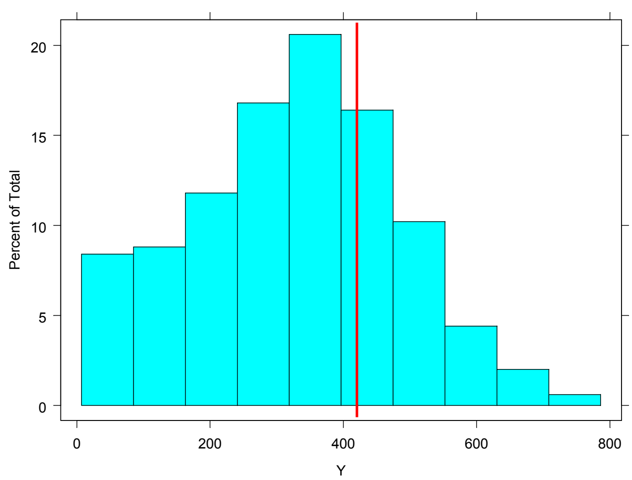
Herring 2000: Observed diff 108.493




Haddock 1999: Observed diff 100.8722




Whiting 1999: Observed diff 424.9275



## 5.5 Conclusion

From all the analysis carried out, there is only one species , namely herring, for which there is some evidence to reject a conversion factor of 1. However, as already mentioned, paired hauls with sufficient data were very few for this species. Thus caution must be exercised when interpreting this apparent trend in lower catches of herring for Celtic Voyager compared to Thalassa. Therefore, for the purpose of mapping distribution on a set by set basis it was decided that no conversion factors should be applied between Thalassa, Celtic Voyager and Scotia..

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Zuur, A.F. and Fryer, R.J. and Newton, A.W. (2001) The comparative fishing trial between Scotia II and Scotia III. FRS Marine Laboratory, Report No 03/01.

# 6 Surveys results

Given the conclusion of the intercalibration experiment (see section 5.5), no attempt was made to combine any surveys data to produce aggregated abundance indices for species whose stock areas are covered by more than one survey. Those time series of indices are therefore given by survey.

In order to visualise the distribution pattern of some of the most abundant species, distribution maps were produced including all survey data, even the West Coast Groundfish Surveys for which no intercalibration was carried for the reasons already stated. The maps provide valuable information on the distribution but should be regarded with caution for the area covered by the West Coast Groundfish Surveys (West coast of Ireland) with respect to relative abundance to other areas.

For Hake, Whiting Haddock, Herring and Mackerel, maps of abundance by age were also produced. The ALK's used to compute the distribution per set are given in table 6.1.

| Survey/year | EVHOE | | SCOTIA | | WCGFS | | ISCSGFS | |
|---|---|---|---|---|---|---|---|---|
| Species | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Hake | E-1999 | E-2000 | E-1999 | E-2000 | E-1999 | E-2000 | E-1999 | E-2000 |
| Whiting | E-1999 | E-2000 | S-1999 | S-2000 | W-1999 | W-2000 | I-1999 | I-2000 |
| Haddock | S-1999 | S-2000 | S-1999 | S-2000 | W-1999 | W-2000 | I-1999 | I-2000 |
| Herring | S-1999 | S-2000 | S-1999 | S-2000 | S-1999 | S-2000 | S-1999 | S-2000 |
| Mackerel | S-1999 | S-2000 | S-1999 | S-2000 | S-1999 | S-2000 | S-1999 | S-2000 |

Table 6.1 ALKs used for each survey data (E-EVHOE, S- SCOTIA, W-WCGFS, I-ISCSGFS)

## 6.1 Abundance and distribution patterns

### 6.1.1 Northern Hake

Northern Hake is distributed over almost the whole surveyed areas with the exception of the north of Scotland (fig. 6.1.1). Biomass and abundance were lower in 2000 than in 1999 in the whole area north of 48°N while in the Bay of Biscay, biomass and abundance have declined in the most southern part only. In the northern part of the Bay of Biscay ("Grande Vasière"), which is a major nursery area, abundance has somewhat increased from 1999 to 2000. This could indicate limited movement Between the Bay and Biscay and the most northern area of distribution.

The distribution patterns by age class (fig.6.1.2 and 6.1.3) indicate three nursery areas, the Northern Bay of Biscay, the centre of Celtic sea and western Ireland and a smaller area located west of Scotland. The decline in abundance from 1999 to 2000 is observed for all age groups in the area north of the 48$^{th}$ parallel with only a few patches of recruits in western Ireland. In the Bay of Biscay, a decline of abundance at age 1 is observed while the age 0 is showing an increase in the "Grande Vasière". However, a part of the "Grande Vasière" could not be sampled in 1999 due the oil pollution generated by the wreckage of the "ERIKA".

### 6.1.2 Whiting

The distribution area of Whiting is restricted to the British Isles, only few patches are found off the west coast of France (fig 6.1.4). From the distribution by age class (fig. 6.1.5 and 6.1.6) no particular nursery areas can be located. A decline of recruitment from 1999 to 2000 appears in the southern part of Ireland.

### 6.1.3 Haddock

Haddock is showing a similar distribution pattern as Whiting, with no individuals found south of the $48^{th}$ parallel (fig.6.1.8). The distributions per age class (fig. 6.1.8 and 6.1.9) show no particular nursery area and a decrease of age 0 and an increase of age 1 from 1999 to 2000.

### 6.1.4 Mackerel

Mackerel is distributed in three main areas, the Bay of Biscay, the north and west of Celtic Sea and the north of Ireland (fig 6.1.10). All age groups are evenly distributed in these areas and no particular change in abundance from 1999 to 2000 can be derived from the distribution figures (fig. 6.1.11 and 6.1.12).

### 6.1.5 Herring

Herring is found near the east coast of Ireland and from the north-west coast of Ireland up to the most northern part of the surveyed area (fig 6.1.13). A nursery area can be identified close to the east coast of Ireland (fig 6.1.14 and 6.1.15)

### 6.1.6 Cod

Cod is distributed around the British Isles and the Celtic Sea (fig.6.1.16). Given the low abundance generally observed, no distribution per age class was attempted.

### 6.1.7 Megrim

Megrim is found in deeper waters and the highest concentrations are located off the west and south-west coast of Ireland (fig.6.1.17). Given the difference in growth suspected between the northern and southern areas and the absence of ALKs for the northern area, no distribution per age class was attempted.

### 6.1.8 Plaice

Plaice is solely distributed around the British Isles. Highest concentrations are found mostly in shallow areas (fig. 6.1.18) . No particular change in biomass or abundance can be detected from the distribution figures from 1999 to 2000.

### 6.1.9 Lesser spotted dogfish

The species is widely distributed over the whole surveyed ares (fig. 6.1.19). Higher biomasses are found around the British Isles however. No particular change in biomass or abundance can be detected from the distribution figures from 1999 to 2000.

### 6.1.10 Norway pout

Norway pout's distribution is restricted to the British Isles (fig 6.1.20). No particular change in biomass or abundance can be detected from the distribution figures from 1999 to 2000.

### 6.1.11 Poor cod

The species is widely distributed over the whole surveyed ares (fig. 6.1.21). No particular change in biomass or abundance can be detected from the distribution figures from 1999 to 2000.

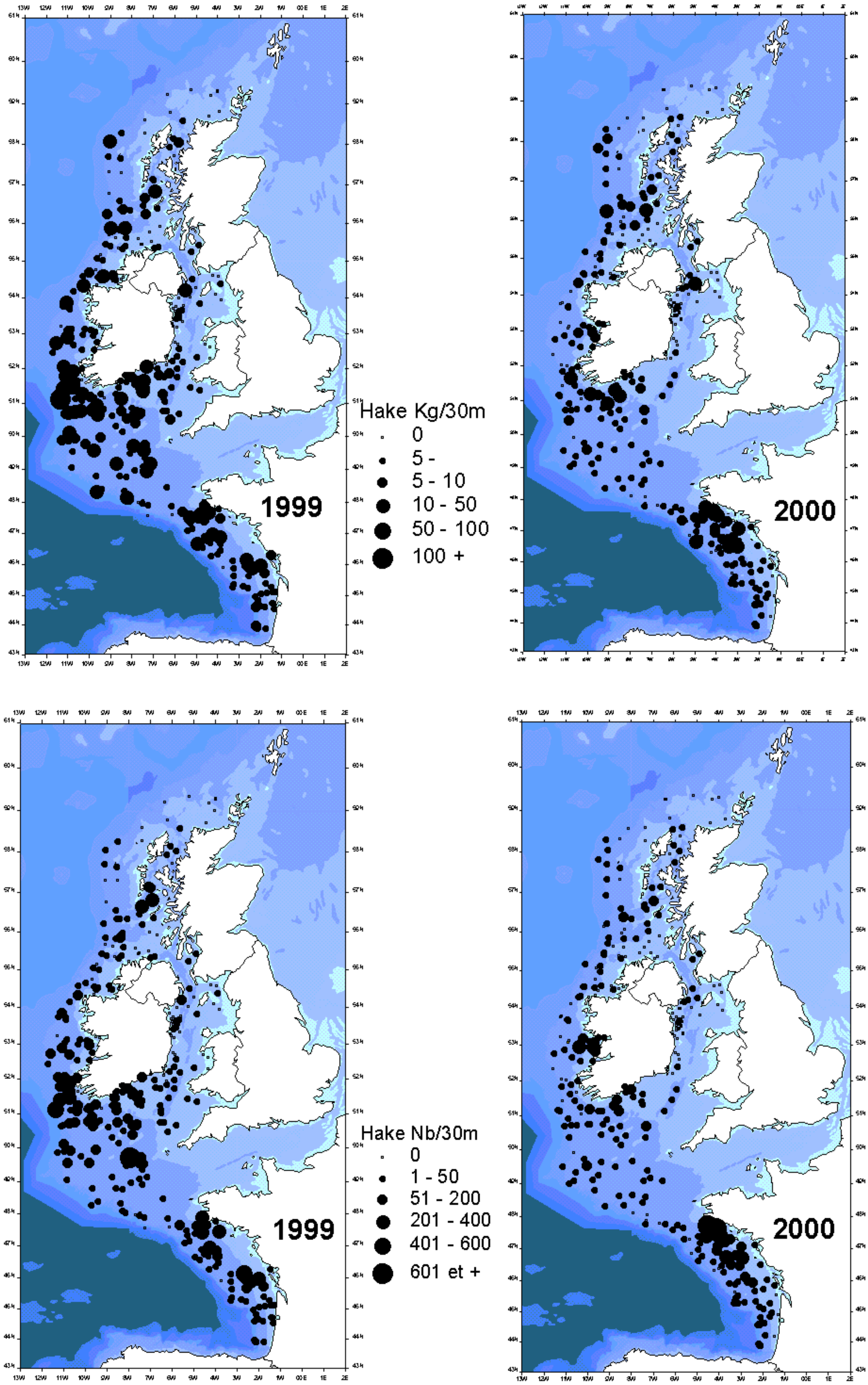


Figure 6.1.1 Abundance indices of Hake (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

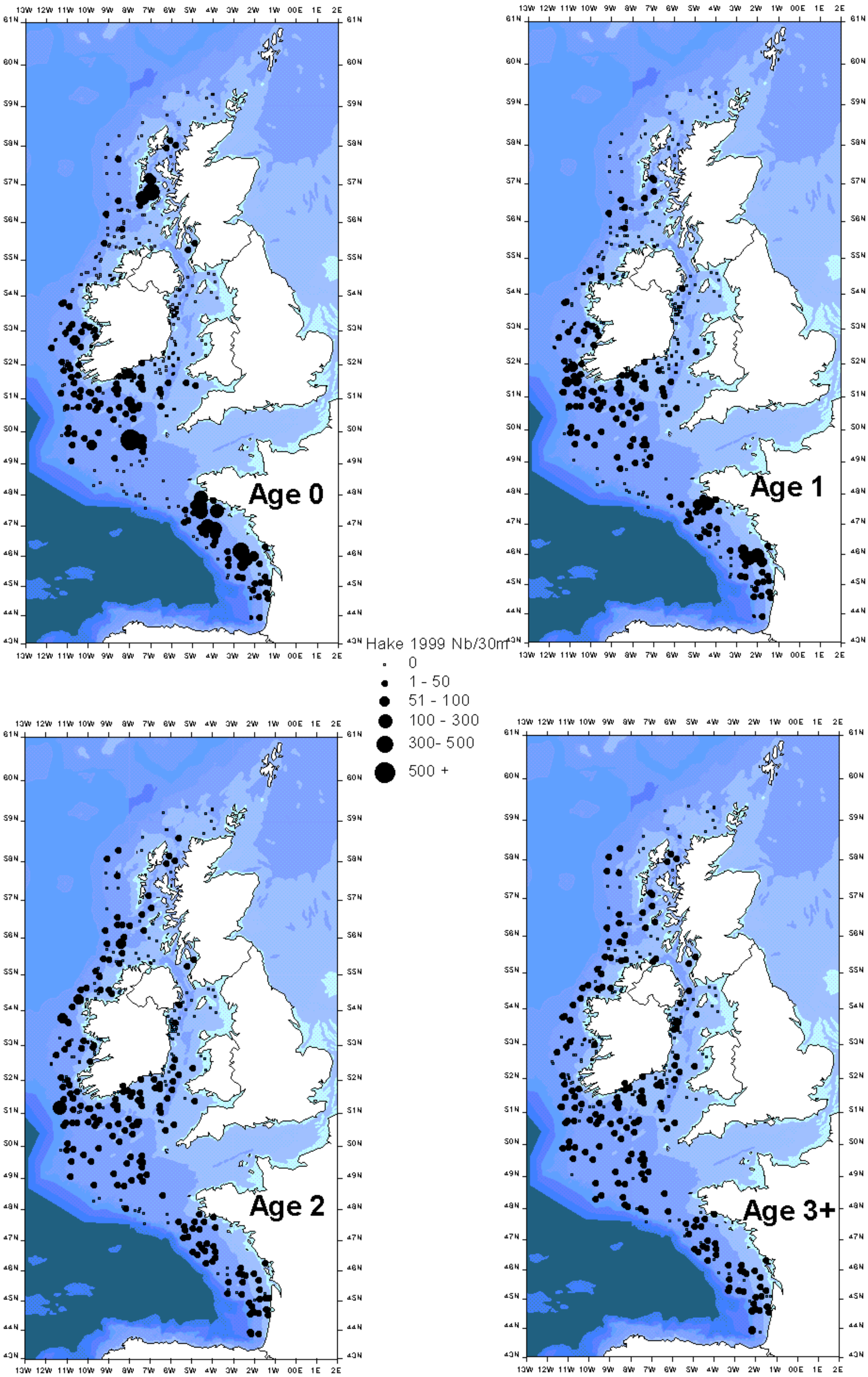


Figure 6.1.2 Abundance indices of Hake per age class (in Nb/ per 30 minutes tow) observed in the fall of 1999.

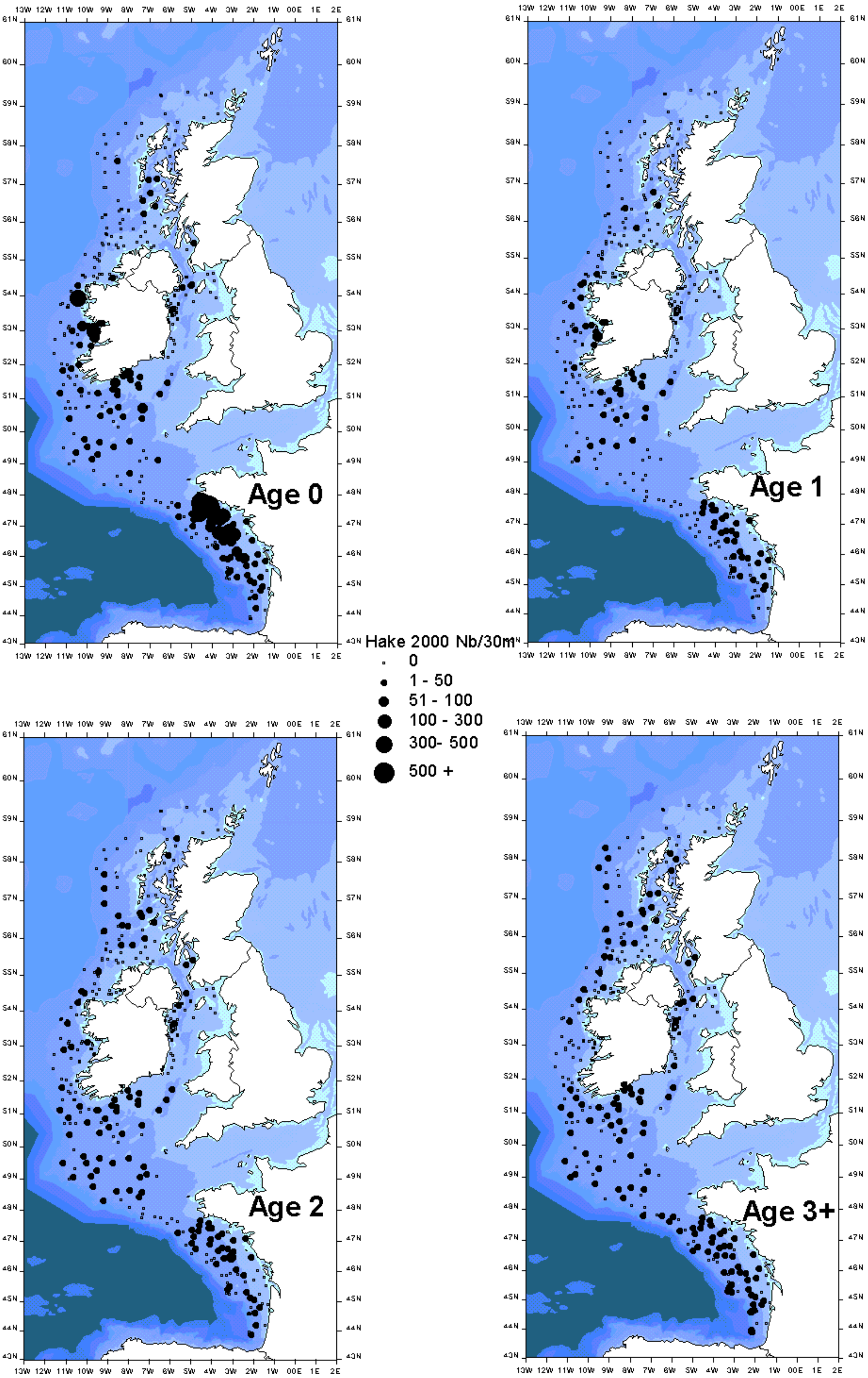


Figure 6.1.3 Abundance indices of Hake per age class (in Nb/ per 30 minutes tow) observed in the fall of 2000.

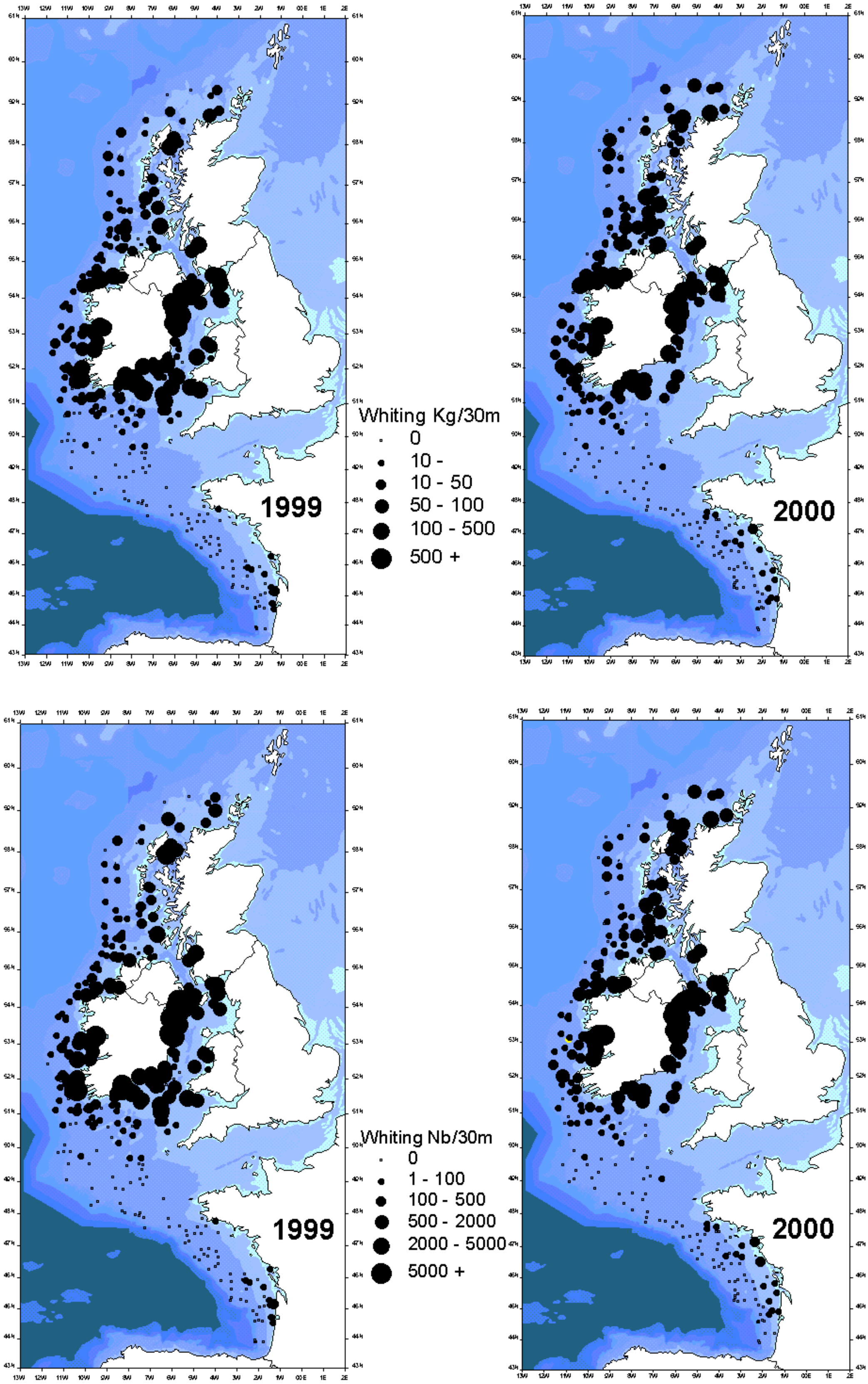


Figure 6.1.4 Abundance indices of Whiting (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

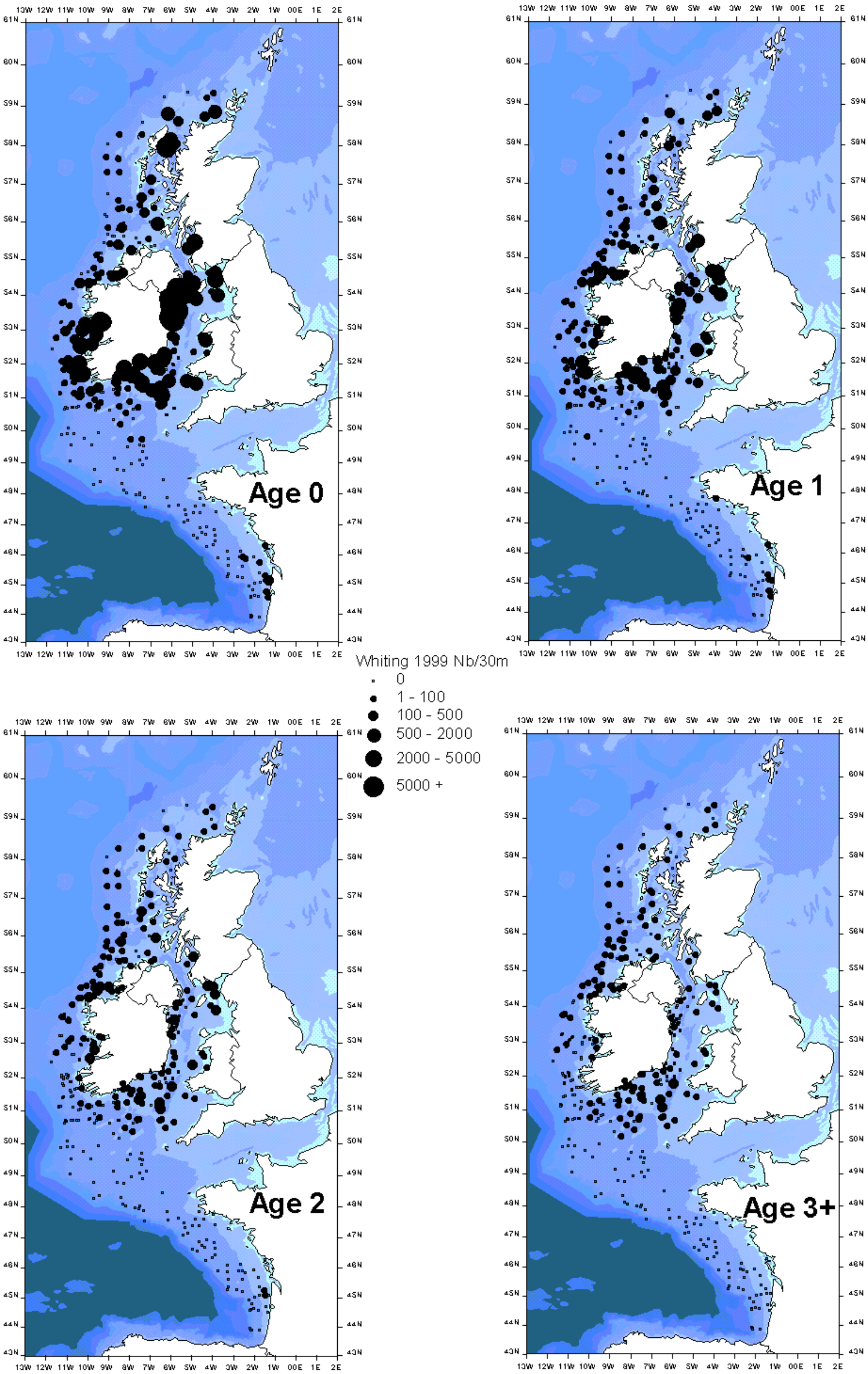


Figure 6.1.5 Abundance indices of Whiting per age class (in Nb/ per 30 minutes tow) observed in the fall of 1999.

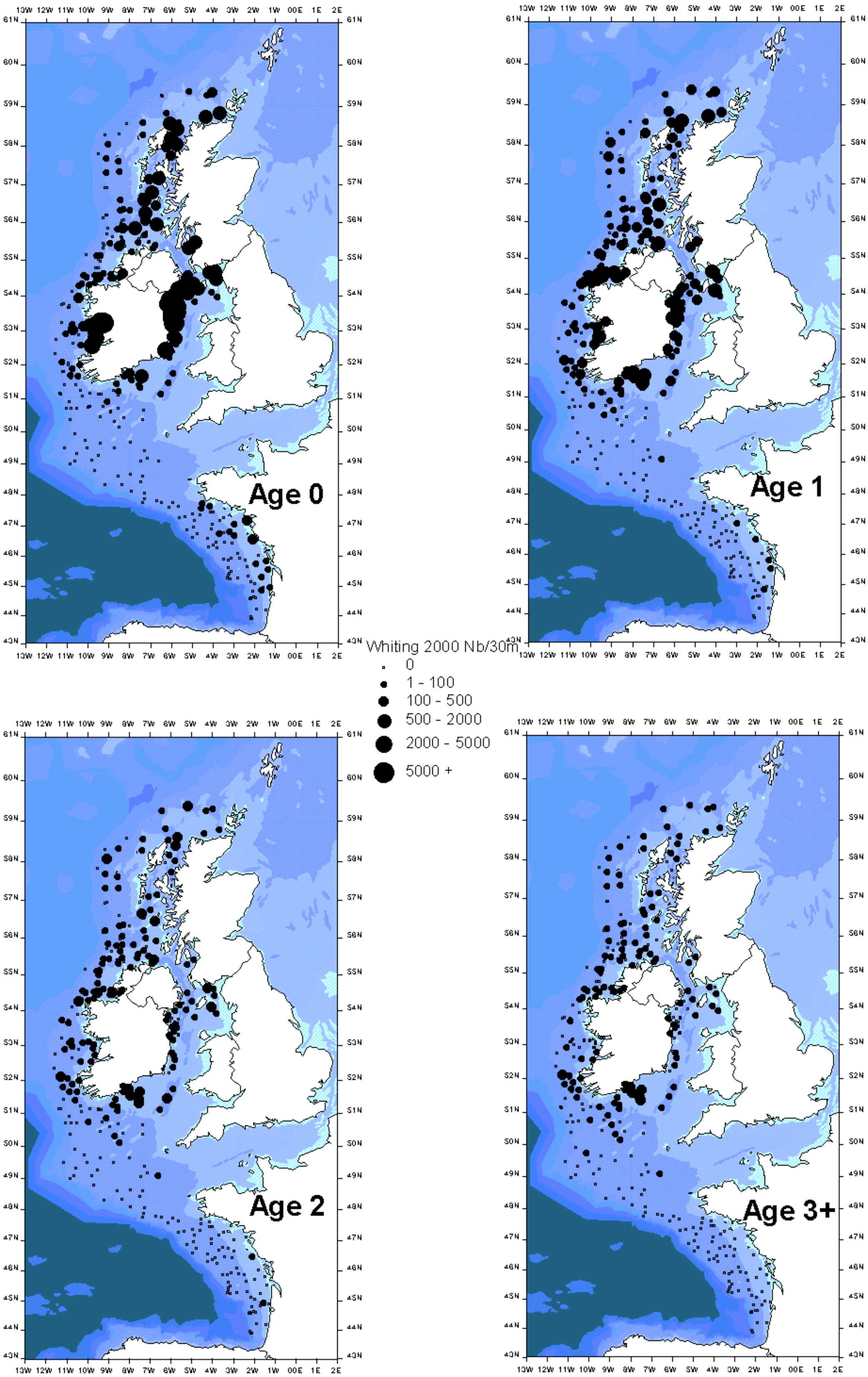


Figure 6.1.6 Abundance indices of Whiting per age class (in Nb/ per 30 minutes tow) observed in the fall of 2000.

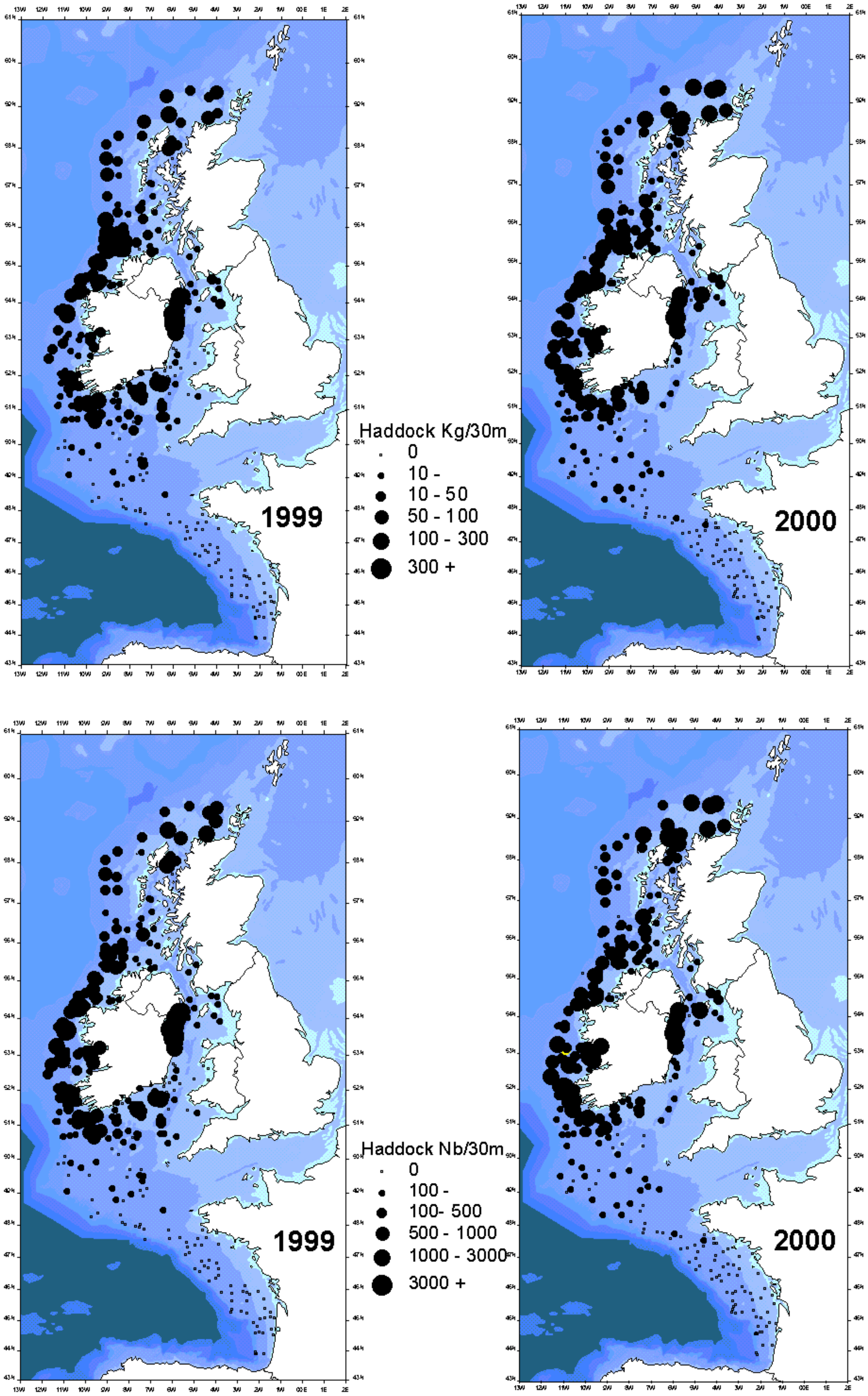


Figure 6.1.7 Abundance indices of Haddock (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

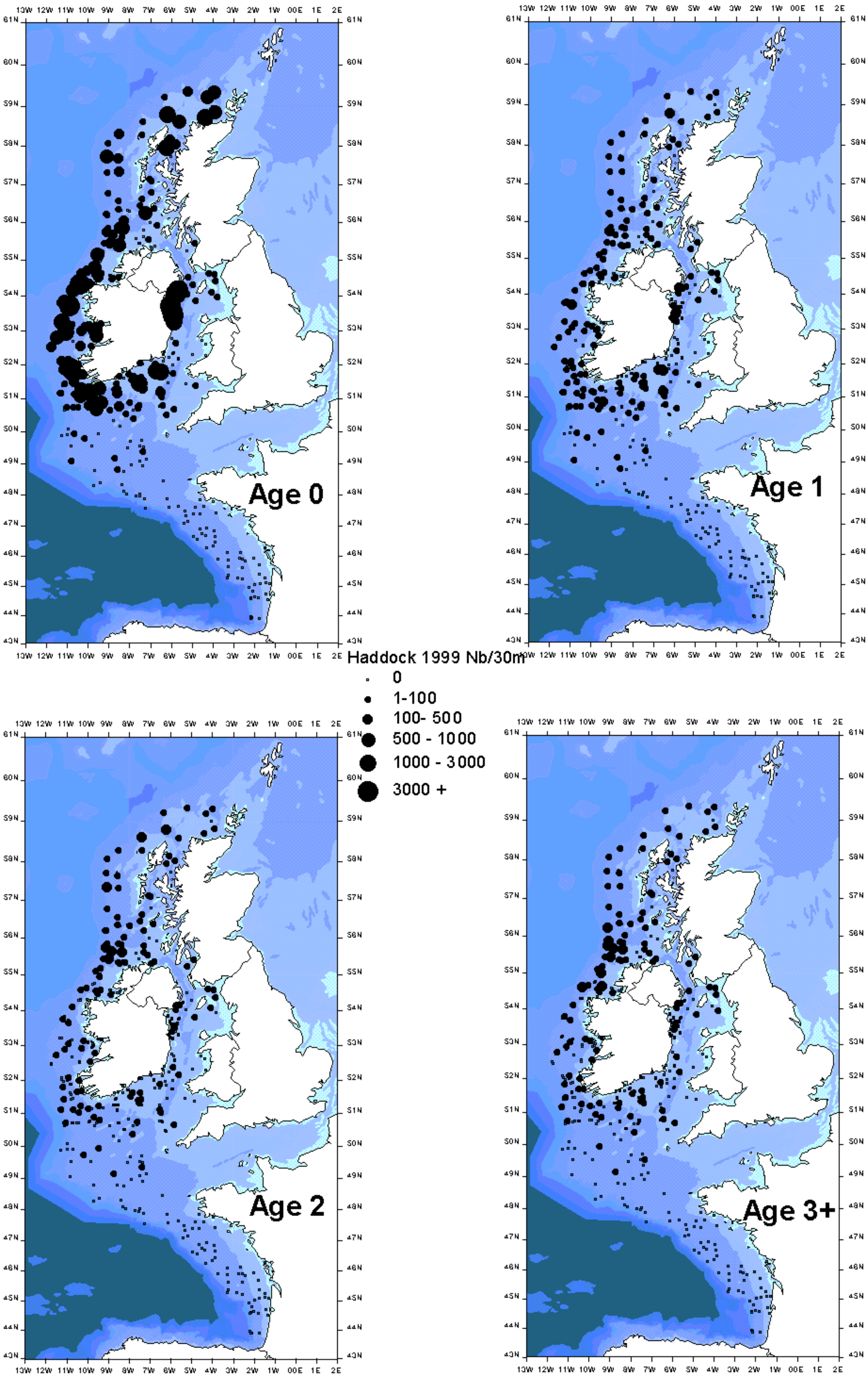


Figure 6.1.8 Abundance indices of Haddock per age class (in Nb/ per 30 minutes tow) observed in the fall of 1999.

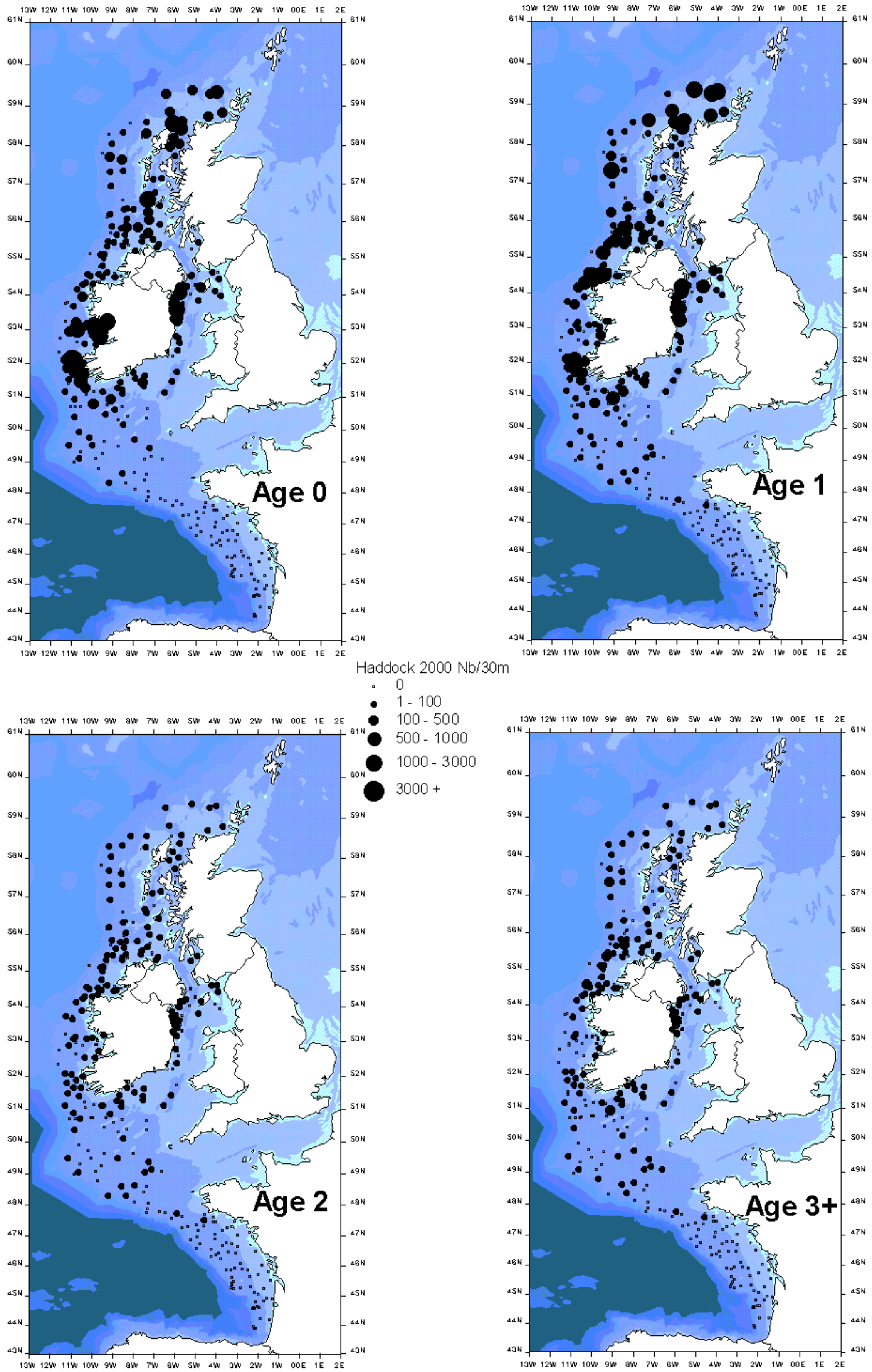


Figure 6.1.9 Abundance indices of Haddock per age class (in Nb/ per 30 minutes tow) observed in the fall of 2000.

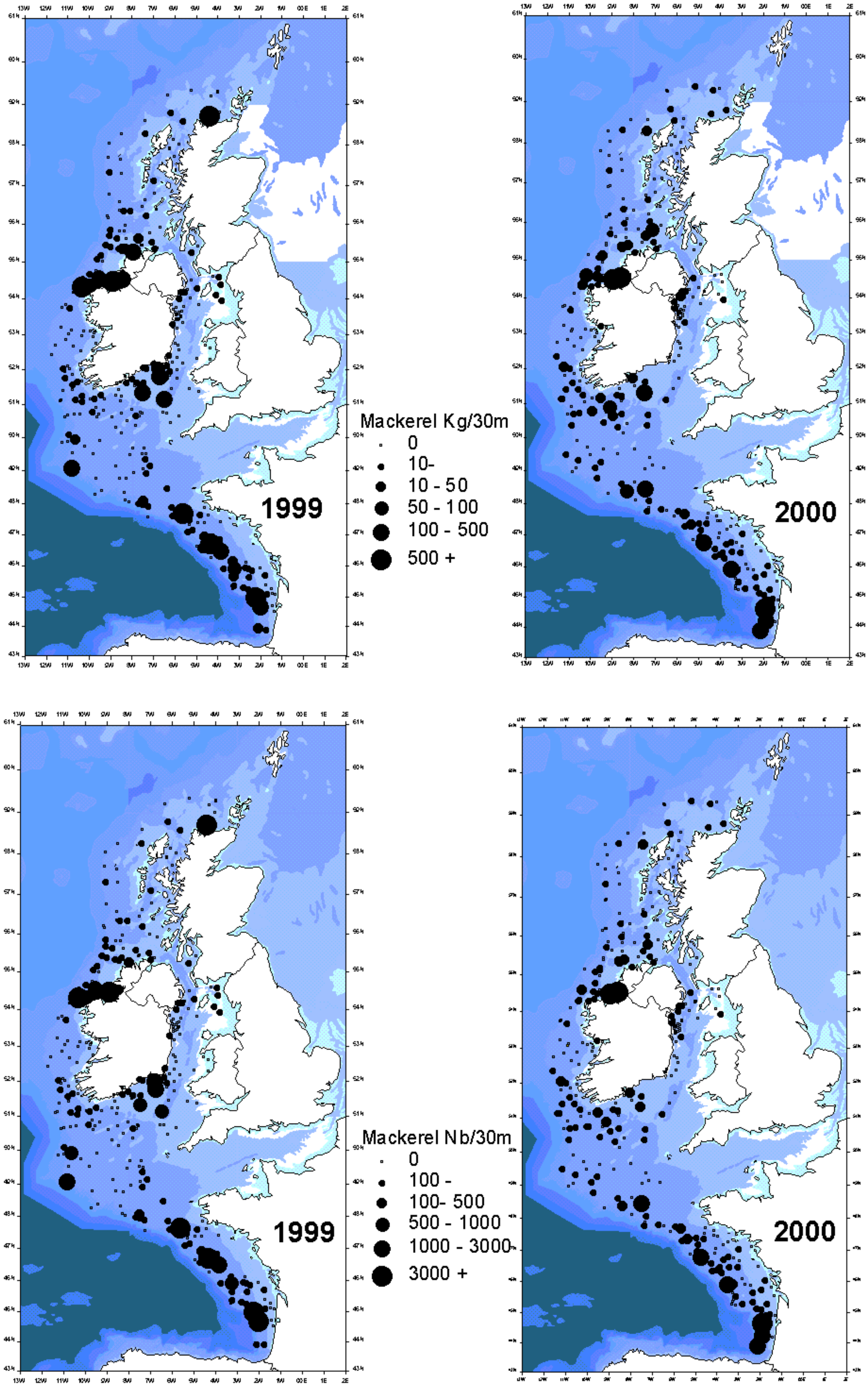


Figure 6.1.10 Abundance indices of Mackerel (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

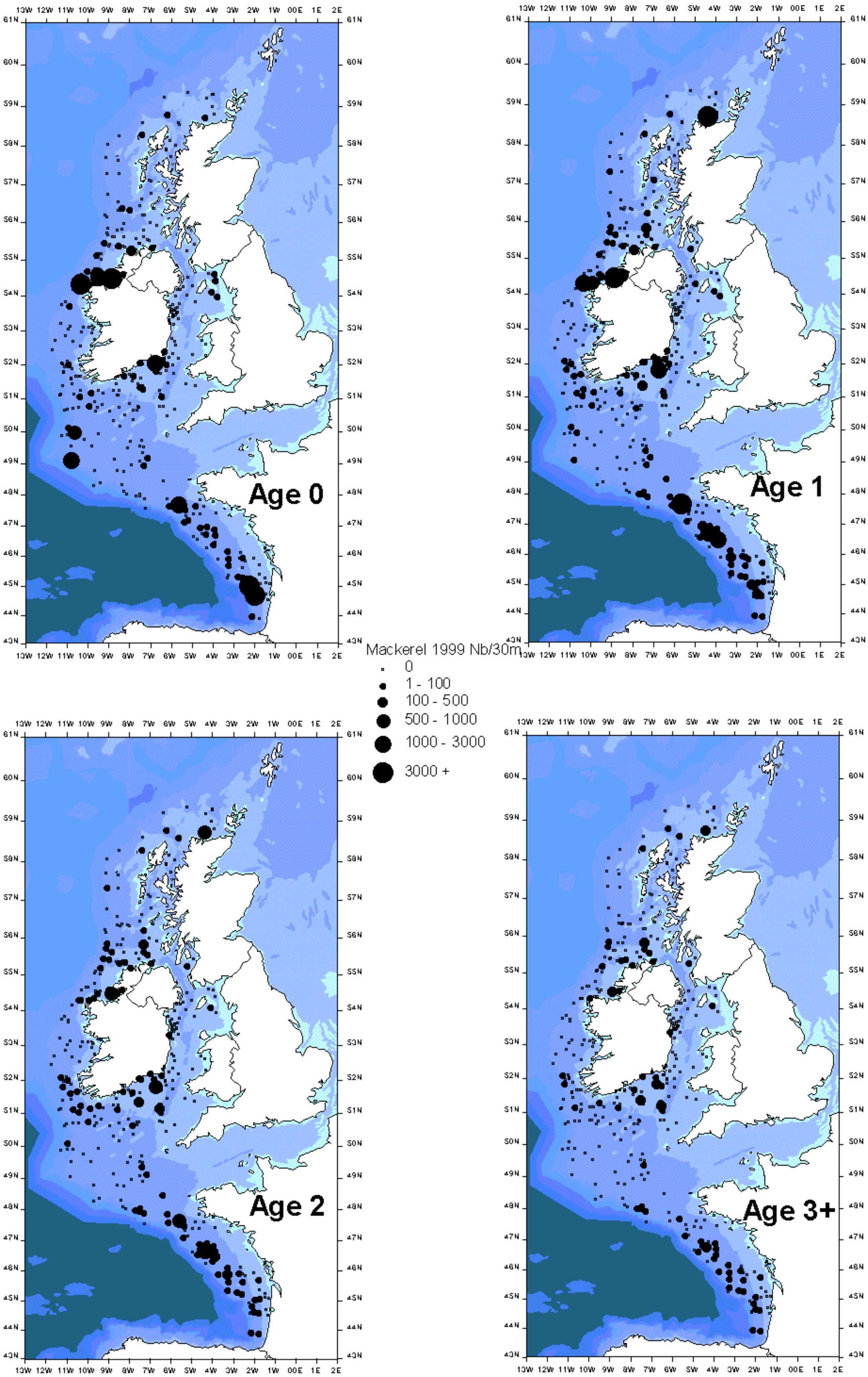


Figure 6.1.11 Abundance indices of Mackerel per age class (in Nb/ per 30 minutes tow) observed in the fall of 1999.

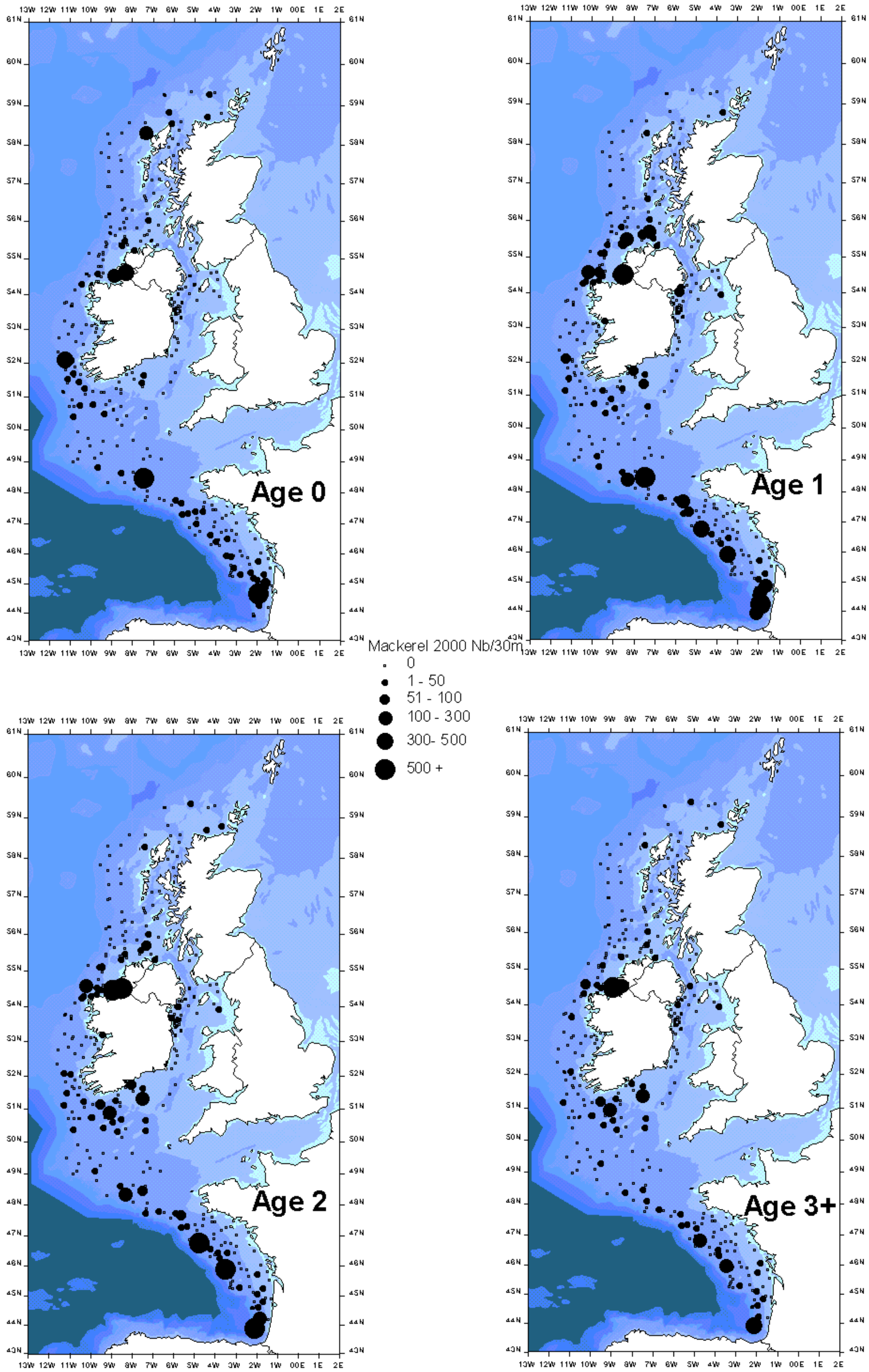


Figure 6.1.12 Abundance indices of Mackerel per age class (in Nb/ per 30 minutes tow) observed in the fall of 2000.

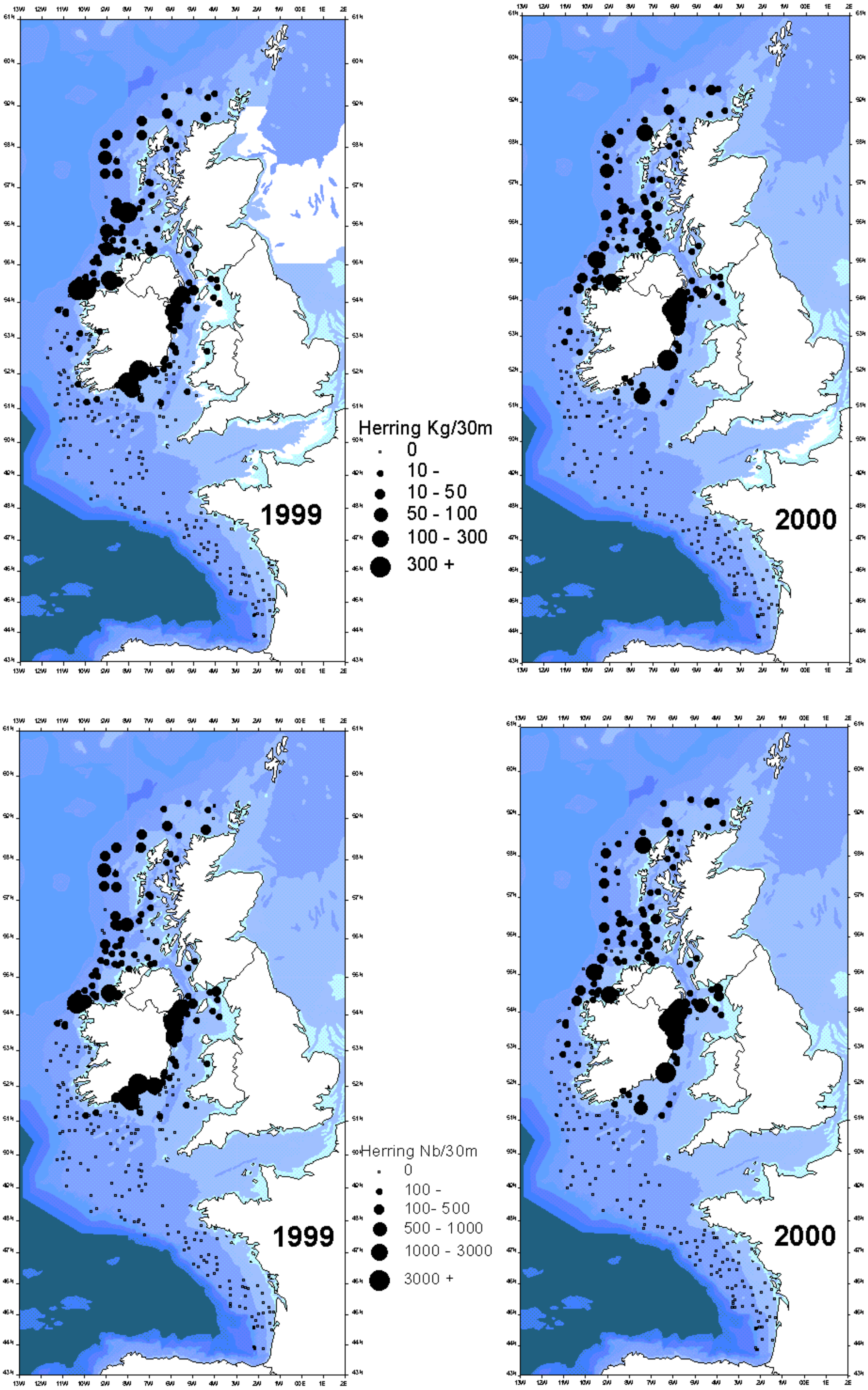


Figure 6.1.13 Abundance indices of Herring (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

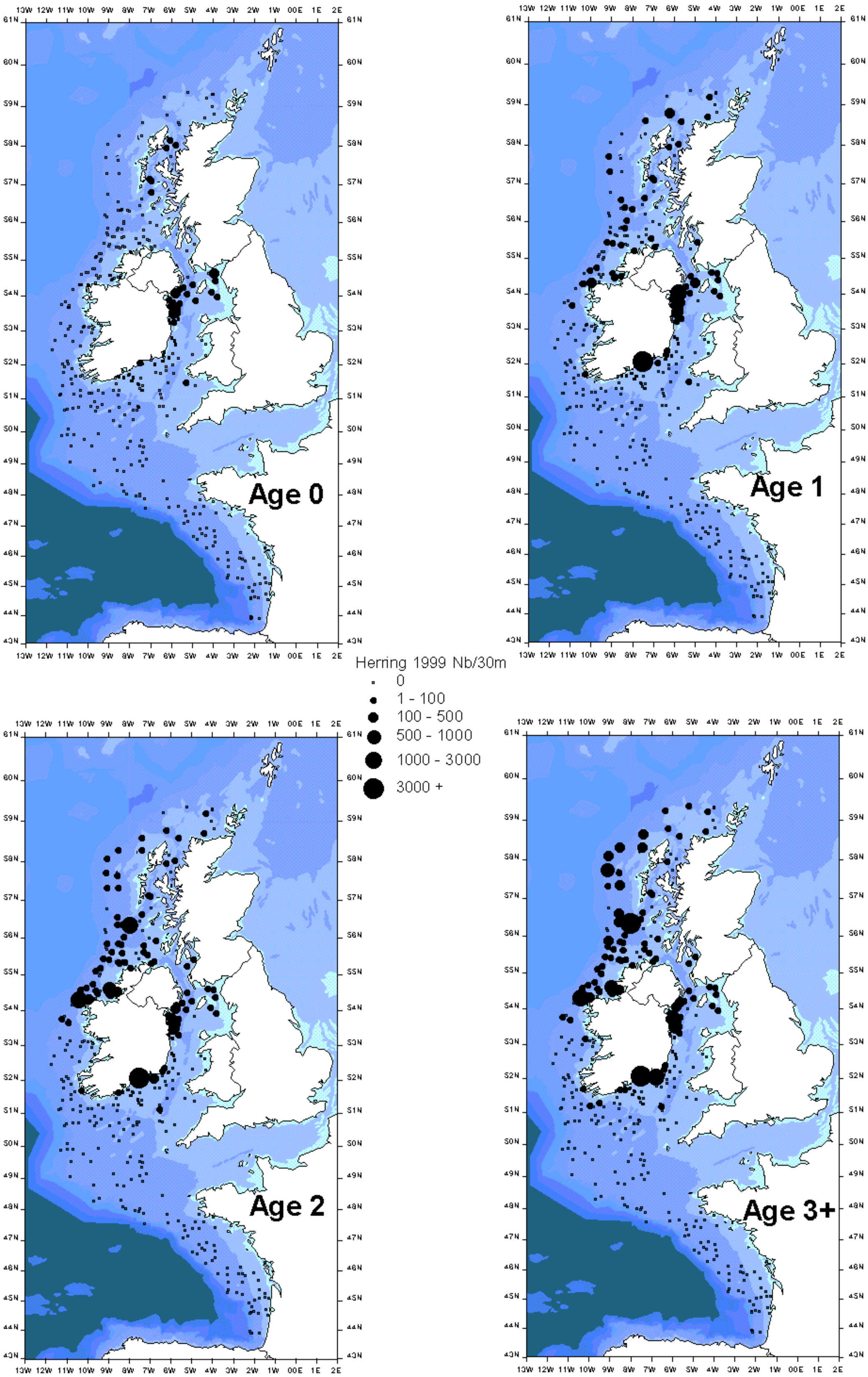


Figure 6.1.14 Abundance indices of Herring per age class (in Nb/ per 30 minutes tow) observed in the fall of 1999.

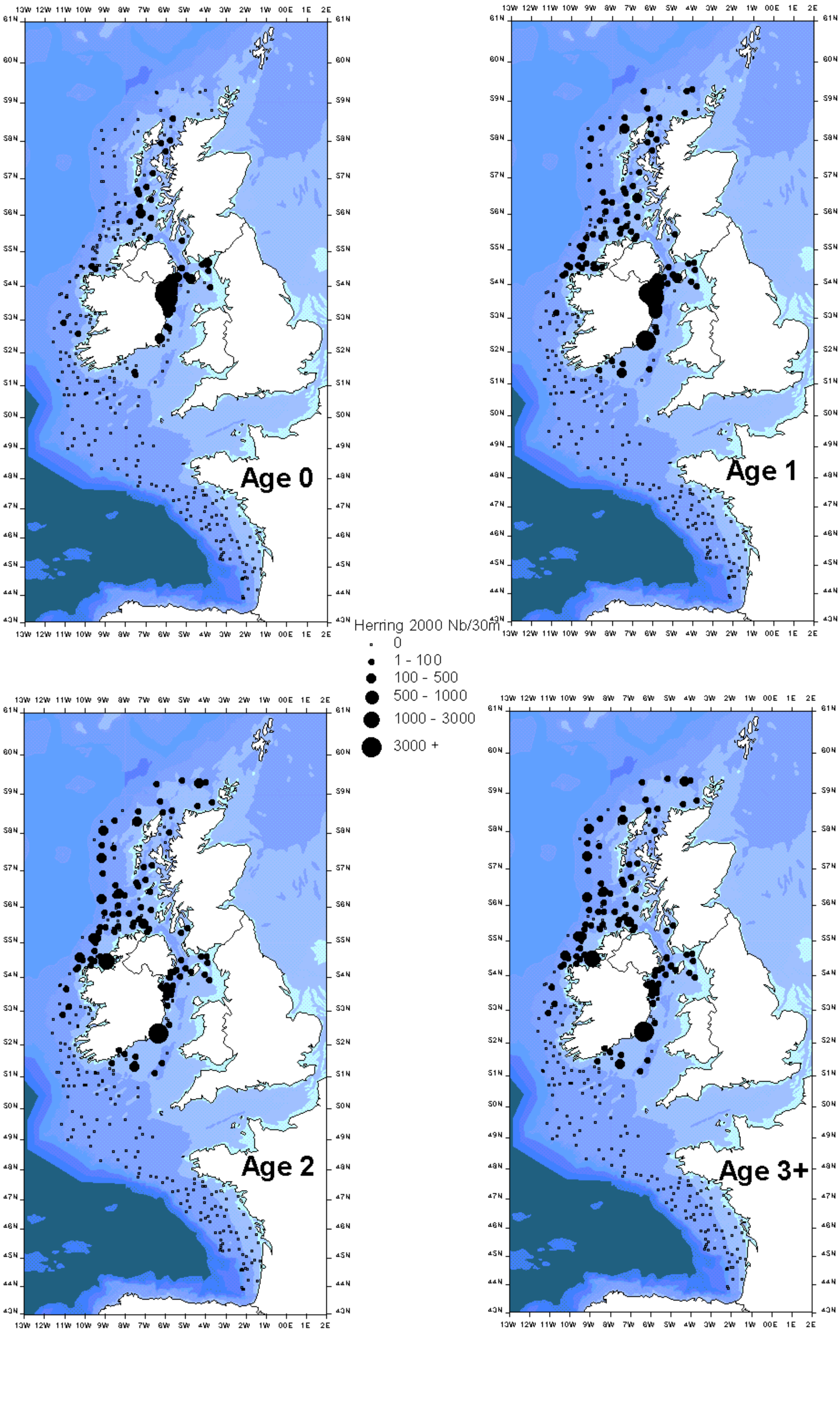


Figure 6.1.15 Abundance indices of Herring per age class (in Nb/ per 30 minutes tow) observed in the fall of 2000.

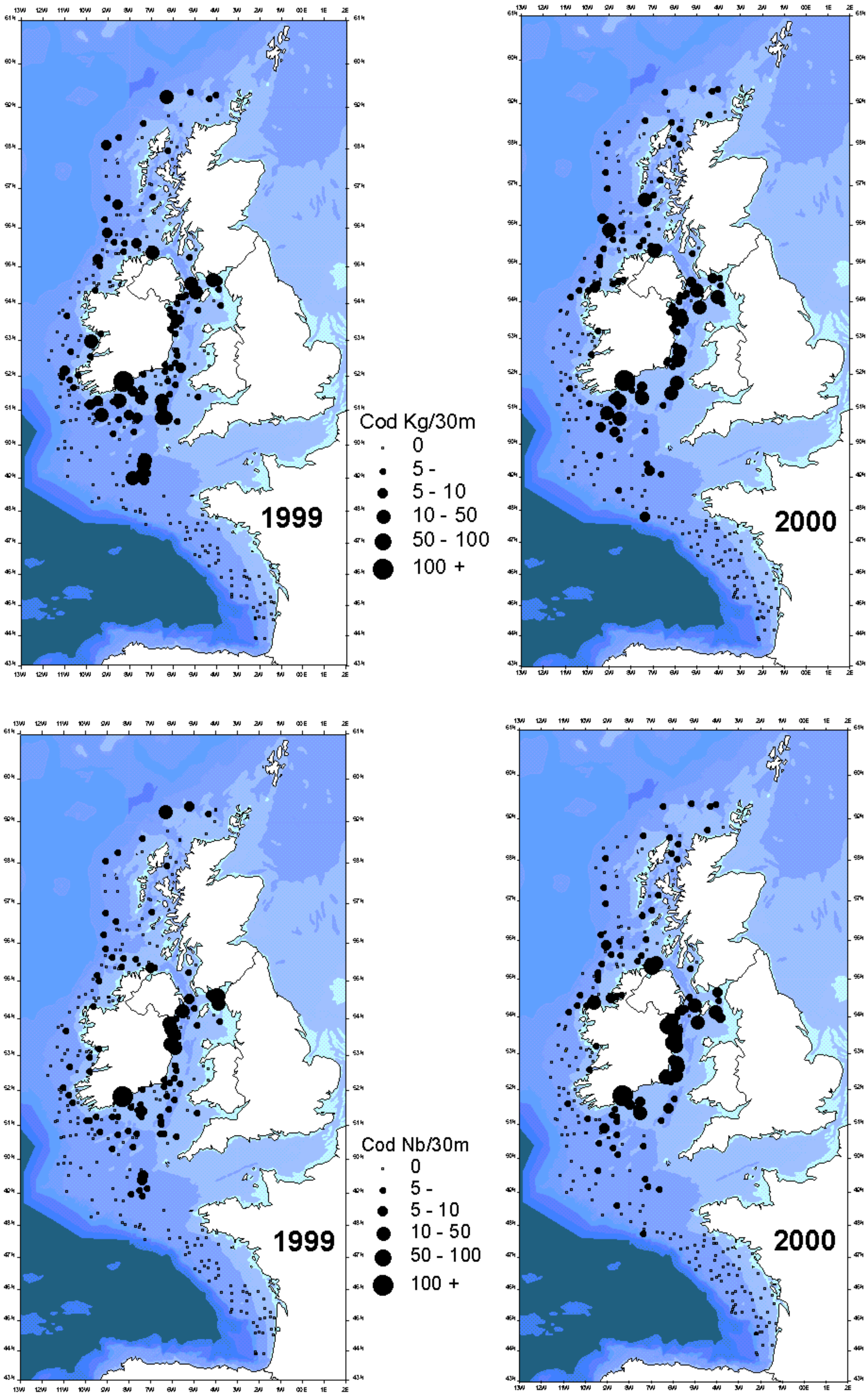


Figure 6.1.16 Abundance indices of Cod (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

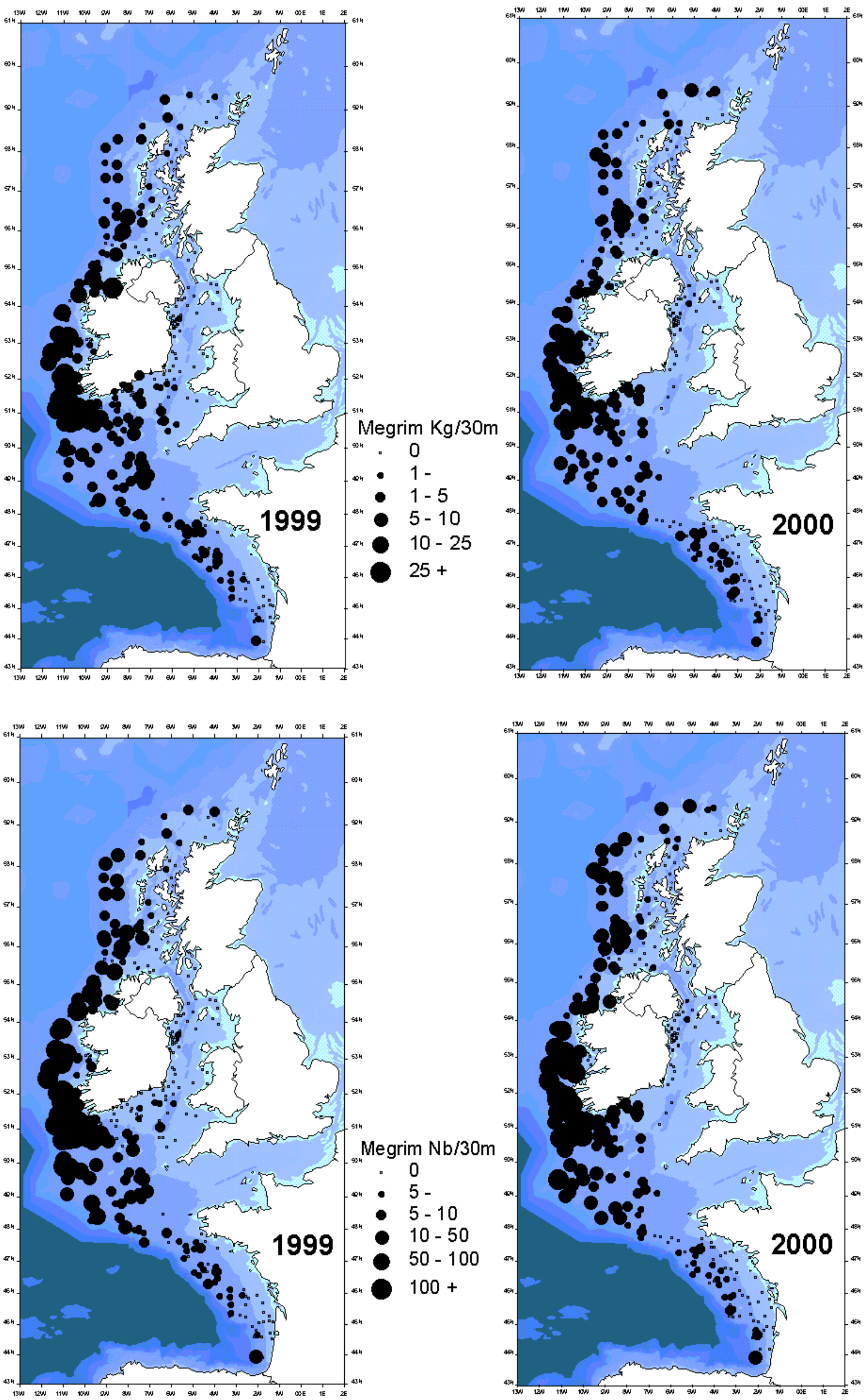


Figure 6.1.17 Abundance indices of Megrim (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

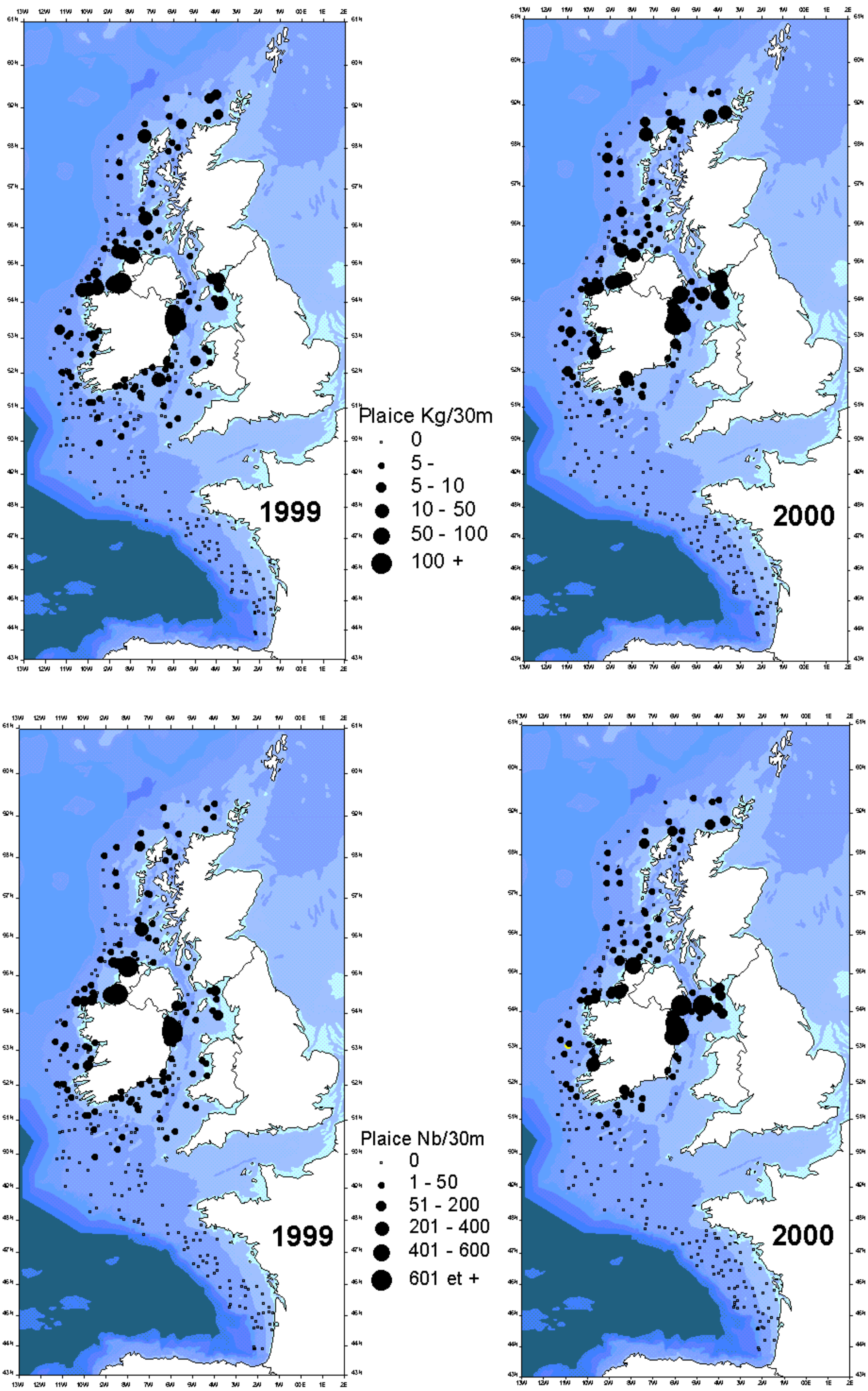


Figure 6.1.18 Abundance indices of Plaice (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

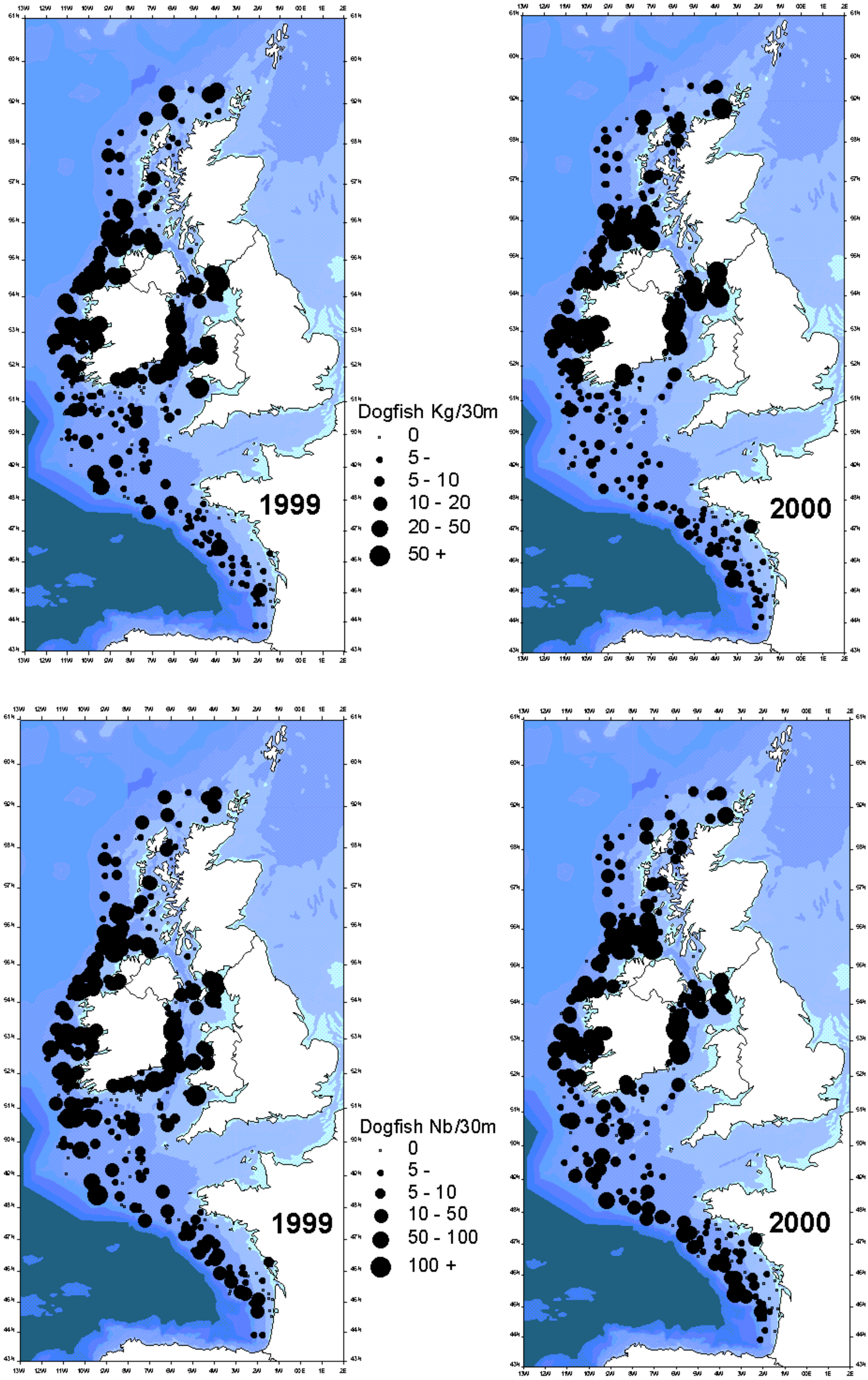


Figure 6.1.19 Abundance indices of Lesser spotted dogfish (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

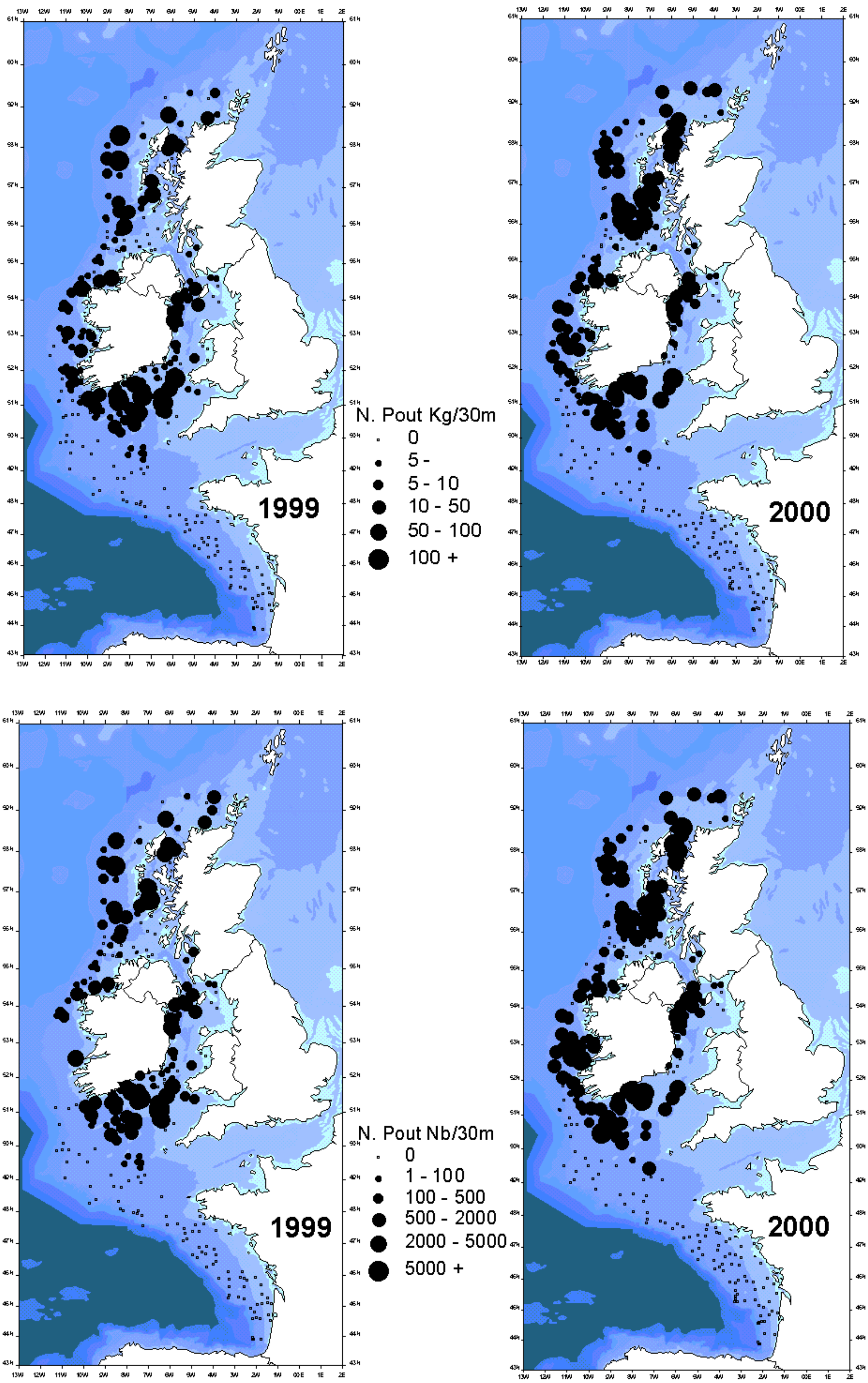


Figure 6.1.20 Abundance indices of Norway pout (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

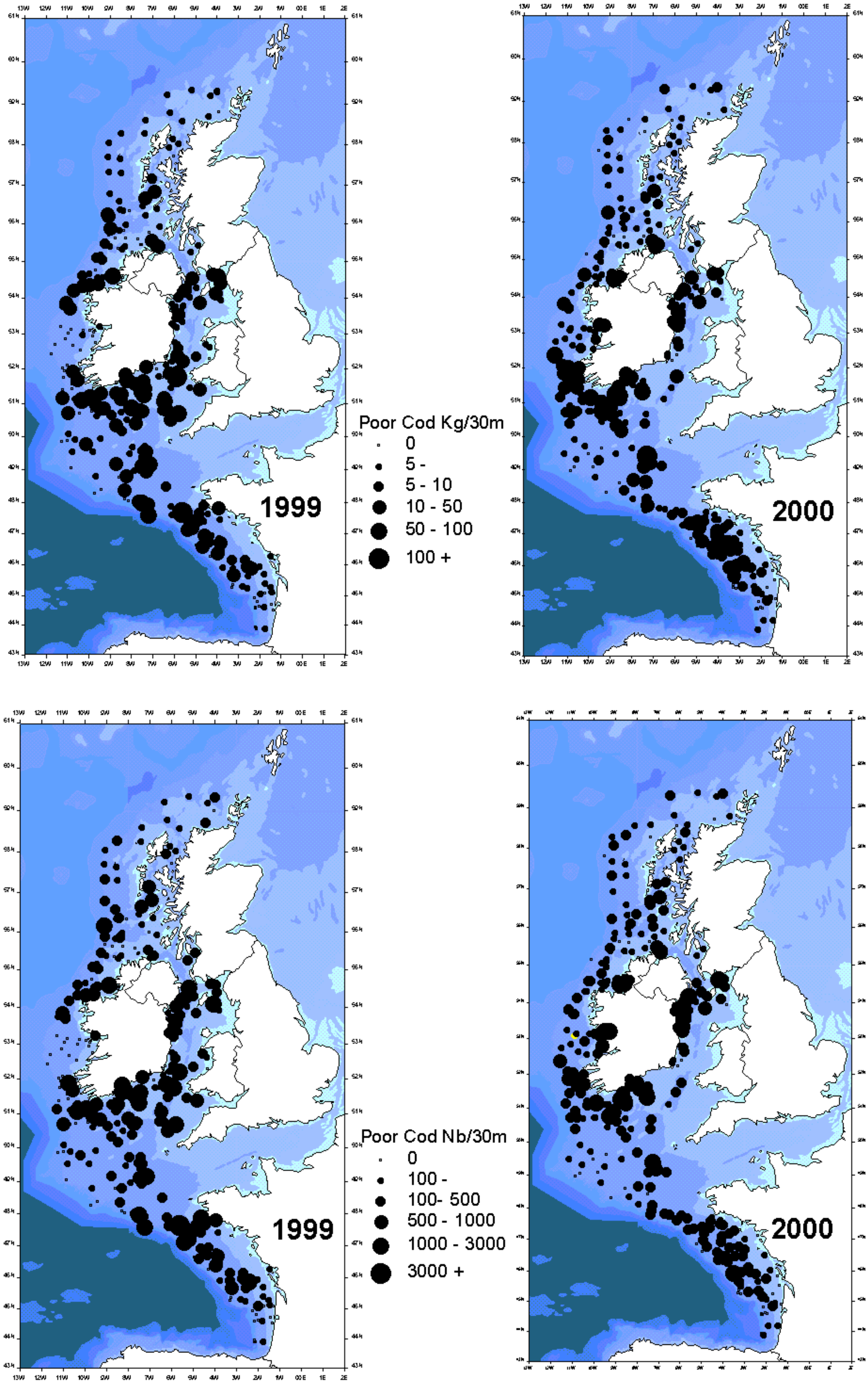


Figure 6.1.21 Abundance indices of Poor cod (in Kg and Nb/ per 30 minutes tow) observed in the fall of 1999 and 2000.

## 6.2 Trends in biomass and abundance indices

Data in this section are presented by survey and where more than two years of data are available. For each survey, species selection depends on data available in the time series. No attempt was made to combine any indices with respect to areas of stock units since survey designs differ substantially.

### 6.2.1 Scottish survey

Biomass indices are not available for the years 1997 and 1998 and the time series are not presented. Total abundance indices are given in figure 6.2.1 for four major species with 95% confidence intervals. For all those species (Haddock, Whiting, Norway pout, Herring and Hake), a drop of abundance is observed since 1998. This drop is not so pronounced for Haddock however.

Tables 6.2.1 to 6.2.7 give the abundance indices at age for the species for which ageing material is collected. Those indices are available to be used as tuning indices in stock assessments.

### 6.2.2 Irish surveys

Since the ISCSGFS only started in 1999, data are not presented for this survey.

Time series (from 1993 to 2000) of biomass and abundance indices for the WCGFS part A (covering area Via and north of VIIb) and WCGFS part b (covering areas VIIb and VIIj) are given in figures 6.2.2 to 6.2.5 for eight commercially important species (Cod, Haddock, Herring, Hake, Mackerel, Megrim, Plaice and Whiting). Cod and Hake are showing a downward trend in the biomass and abundance indices in both surveys and mostly in the latter part of the series. Megrim indices are somewhat higher in the most southern area covered by the WCGFS part b and have remained relatively stable over the last five years.

Tables 6.2.8 to 6.2.12 give the abundance indices at age and per ICES area for the species for which ageing material is collected. Those indices are available to be used as tuning indices in stock assessments.

### 6.2.3 French survey

Biomass and abundance indices of selected species are given in figure 6.2.6 for the whole area covered by the French EVHOE survey, for the Celtic Sea (figure 6.2.7) and Bay of Biscay (fig. 6.2.8). Hake, Anglerfishes and Megrim  are assessed based on a stock unit that covers both the Celtic Sea and the Bay of Biscay. Whiting and Cod are assessed considering the Celtic Sea as a stock unit. Megrim and Hake indices were computed for the whole area and for the Celtic Sea and Bay of Biscay to illustrate patterns or trends per area.

Within the four years of data available, Hake biomass indices for the whole area show a higher value in 1999 due to some catches of large individuals. The abundance indices show a slight dowward trend. If we consider the indices per area (fig 6.2.7 and 6.2.8), the trends are different in relation to area. The abundance indices show opposite trends in the Bay of Biscay and Celtic Sea. These patterns are driven mostly by recruitment as indicated in the abundance at age (table 6.2.13). This pattern is also to be considered in parallel with the distribution pattern discussed in section 6.1.1.

Megrim indices show downward trends from 1998 to 2000 in both areas.

White anglerfishes indices fluctuate with a higher value in biomass in 1998 and in abundance in 1999.

Black anglerfish indices show a decrease from 1997 to 1999 and an increase in 2000.

Tables 6.2.13 to 6.2.16 give the abundance indices at age and per area for the species for which ageing material is collected. Those indices are available to be used as tuning indices in stock assessments.

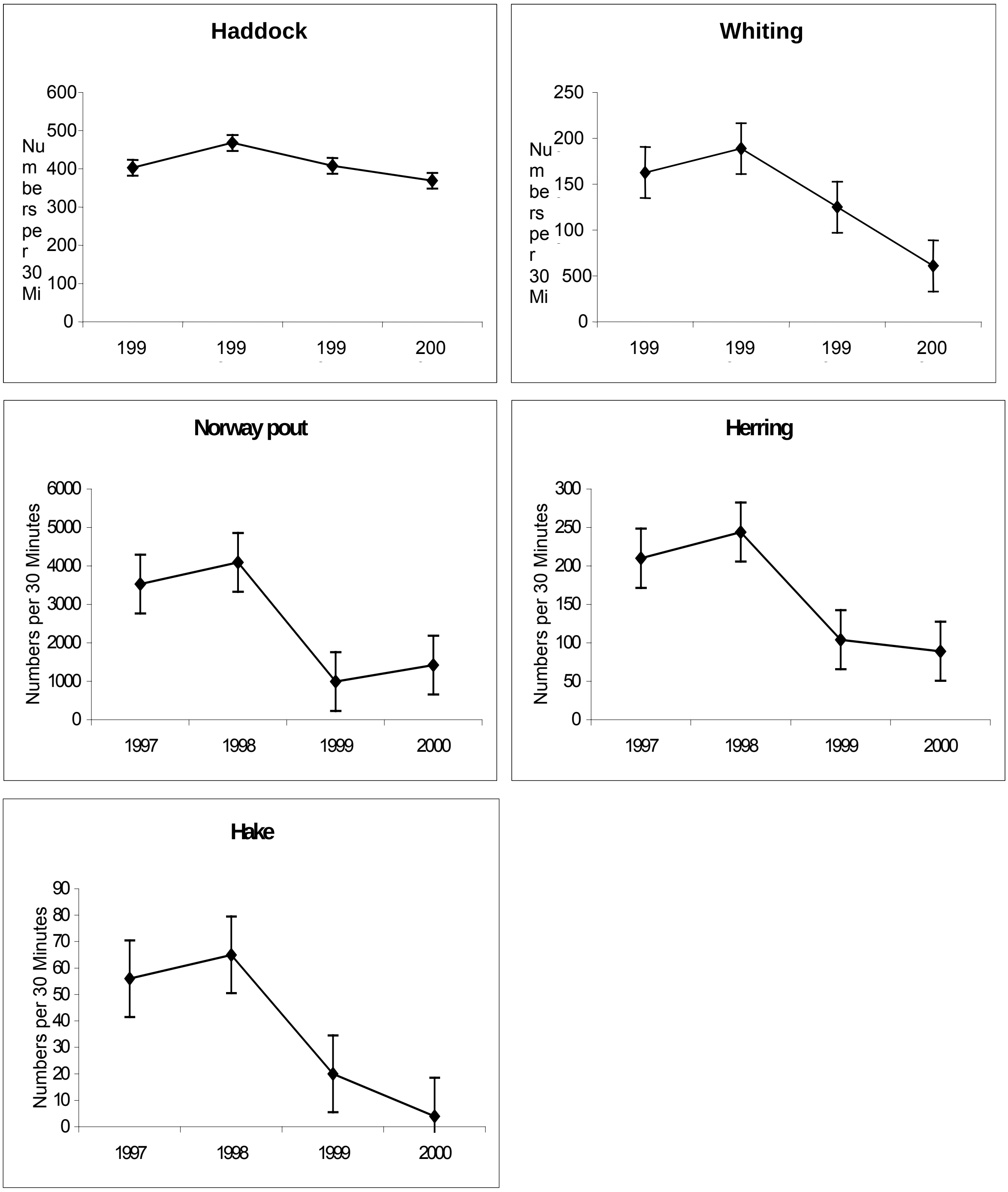


Figure 6.2.1 Total abundance indices of five commercially important species caught on the Scottish survey from 1997 to 2000.

| Table 6.2.1 Scottish Indices of Abundance for Cod (Nb/30m) – VIa | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age/Year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **1996** | 0.00 | 0.05 | 0.70 | 0.25 | 0.15 | 0.05 | 0.00 |
| **1997** | 0.05 | 0.55 | 0.10 | 0.05 | 0.05 | 0.05 | 0.00 |
| **1998** | 0.00 | 0.75 | 0.45 | 0.05 | 0.00 | 0.00 | 0.00 |
| **1999** | 0.10 | 0.20 | 0.30 | 0.45 | 0.05 | 0.00 | 0.00 |
| **2000** | 0.00 | 0.80 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 |

| Table 6.2.2 Scottish Indices of Abundance for Haddock (Nb/30m) – VIa | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age/Year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **1996** | 145.50 | 38.00 | 33.00 | 3.50 | 7.00 | 3.00 | 1.00 |
| **1997** | 185.50 | 68.00 | 14.00 | 7.50 | 1.00 | 1.50 | 0.50 |
| **1998** | 20.00 | 82.00 | 24.50 | 7.50 | 7.00 | 1.00 | 1.50 |
| **1999** | 233.50 | 18.50 | 28.50 | 13.50 | 4.50 | 3.50 | 0.50 |
| **2000** | 148.00 | 211.50 | 7.50 | 9.50 | 3.00 | 1.00 | 0.25 |

| Table 6.2.3 Scottish Indices of Abundance for Whiting (Nb/30m) – VIa | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age/Year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **1996** | 257.50 | 95.50 | 56.00 | 28.50 | 9.50 | 2.50 | 0.00 |
| **1997** | 400.00 | 43.50 | 47.50 | 16.00 | 8.00 | 2.50 | 0.60 |
| **1998** | 92.50 | 135.50 | 56.00 | 7.50 | 5.00 | 1.00 | 0.05 |
| **1999** | 410.00 | 117.00 | 29.00 | 7.00 | 1.50 | 1.00 | 0.05 |
| **2000** | 221.50 | 203.00 | 39.50 | 8.00 | 0.45 | 0.35 | 0.05 |

| Table 6.2.4 Scottish Indices of Abundance for Saithe (Nb/30m) – VIa | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age/Year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **1996** | 0.00 | 18.00 | 1.05 | 0.50 | 0.05 | 0.00 | 0.00 |
| **1997** | 0.00 | 0.00 | 0.05 | 0.15 | 0.05 | 0.05 | 0.00 |
| **1998** | 0.00 | 0.05 | 0.10 | 0.10 | 0.05 | 0.00 | 0.00 |
| **1999** | 0.00 | 0.00 | 1.60 | 0.35 | 0.00 | 0.00 | 0.00 |
| **2000** | 0.00 | 0.00 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 |

| Table 6.2.5 Scottish Indices of Abundance for Norway Pout (Nb/30m) – VIa | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age/Year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **1996** | 4197.00 | 824.00 | 530.50 | 2.50 | 0.00 | 0.00 | 0.00 |
| **1997** | 1186.50 | 479.50 | 56.50 | 40.50 | 0.00 | 0.00 | 0.00 |
| **1998** | 2560.50 | 393.50 | 211.50 | 0.50 | 0.50 | 0.00 | 0.00 |
| **1999** | 1039.00 | 115.00 | 15.00 | 7.00 | 0.00 | 0.00 | 0.00 |
| **2000** | 1265.50 | 299.00 | 108.50 | 15.00 | 1.00 | 0.00 | 0.00 |

| Table 6.2.6 Scottish Indices of Abundance for Herring (Nb/30mr) – VIa | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age/Year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **1996** | 0.50 | 25.00 | 57.00 | 81.00 | 24.50 | 20.00 | 8.00 |
| **1997** | 3.00 | 4.00 | 19.00 | 32.00 | 23.50 | 23.50 | 10.00 |
| **1998** | 4.50 | 3.00 | 17.50 | 26.00 | 26.50 | 31.00 | 13.00 |
| **1999** | 2.00 | 12.50 | 5.00 | 24.50 | 14.00 | 14.00 | 18.00 |
| **2000** | 7.50 | 10.50 | 12.00 | 5.50 | 16.50 | 8.50 | 7.50 |

| Table 6.2.7 Scottish Indices of Abundance for Mackerel (Nb/30m) – VIa | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age/Year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **1996** | 21.50 | 196.50 | 16.50 | 2.50 | 0.10 | 0.15 | 0.00 |
| **1997** | 43.50 | 5.00 | 1.00 | 0.20 | 0.20 | 0.05 | 0.05 |
| **1998** | 245.00 | 2.50 | 0.50 | 0.15 | 0.00 | 0.05 | 0.00 |
| **1999** | 27.50 | 181.50 | 22.50 | 5.00 | 0.15 | 2.00 | 0.05 |
| **2000** | 5.00 | 5.00 | 6.00 | 2.50 | 0.45 | 0.05 | 0.05 |

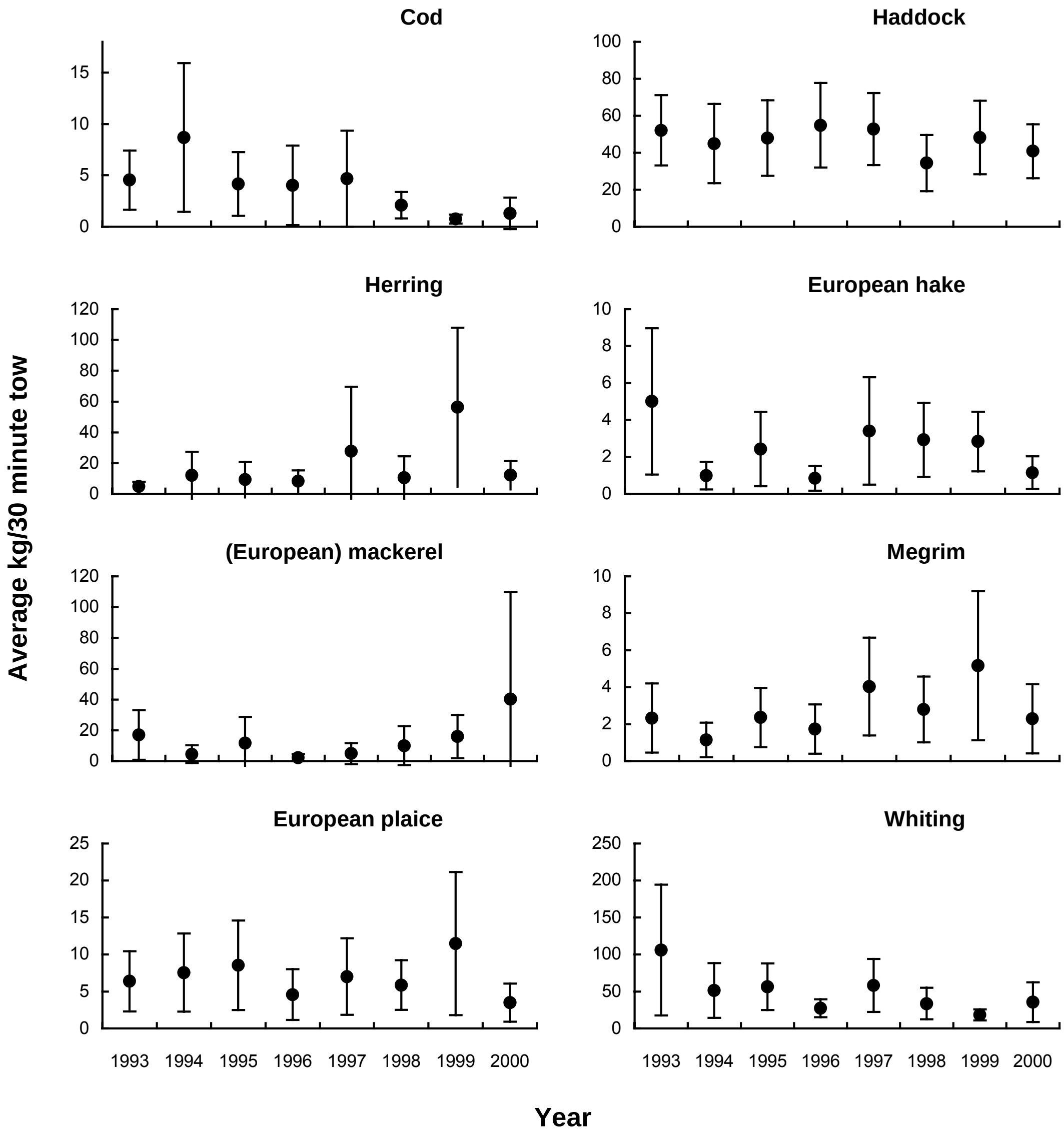


**Figure 6.2.2.** Abundance by weight (average kg/30 minute tow) of eight commercially important species caught on the Irish WCGFS Part A. Error bars indicate 95% confidence intervals.

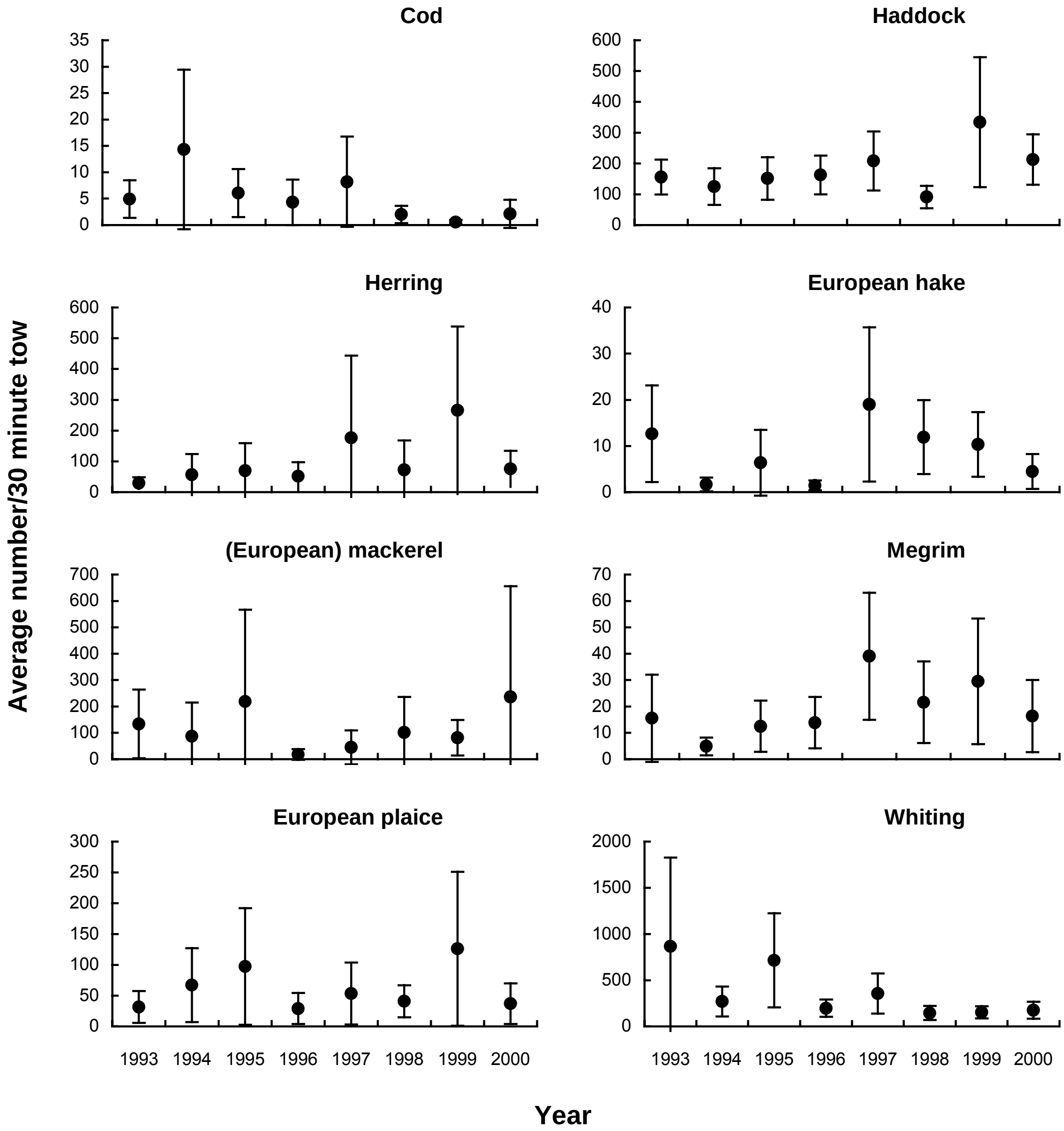


**Figure 6.2.3.** Abundance by number (average number/30 minute tow) of eight commercially important species caught on the Irish WCGFS Part A. Error bars indicate 95% confidence intervals.

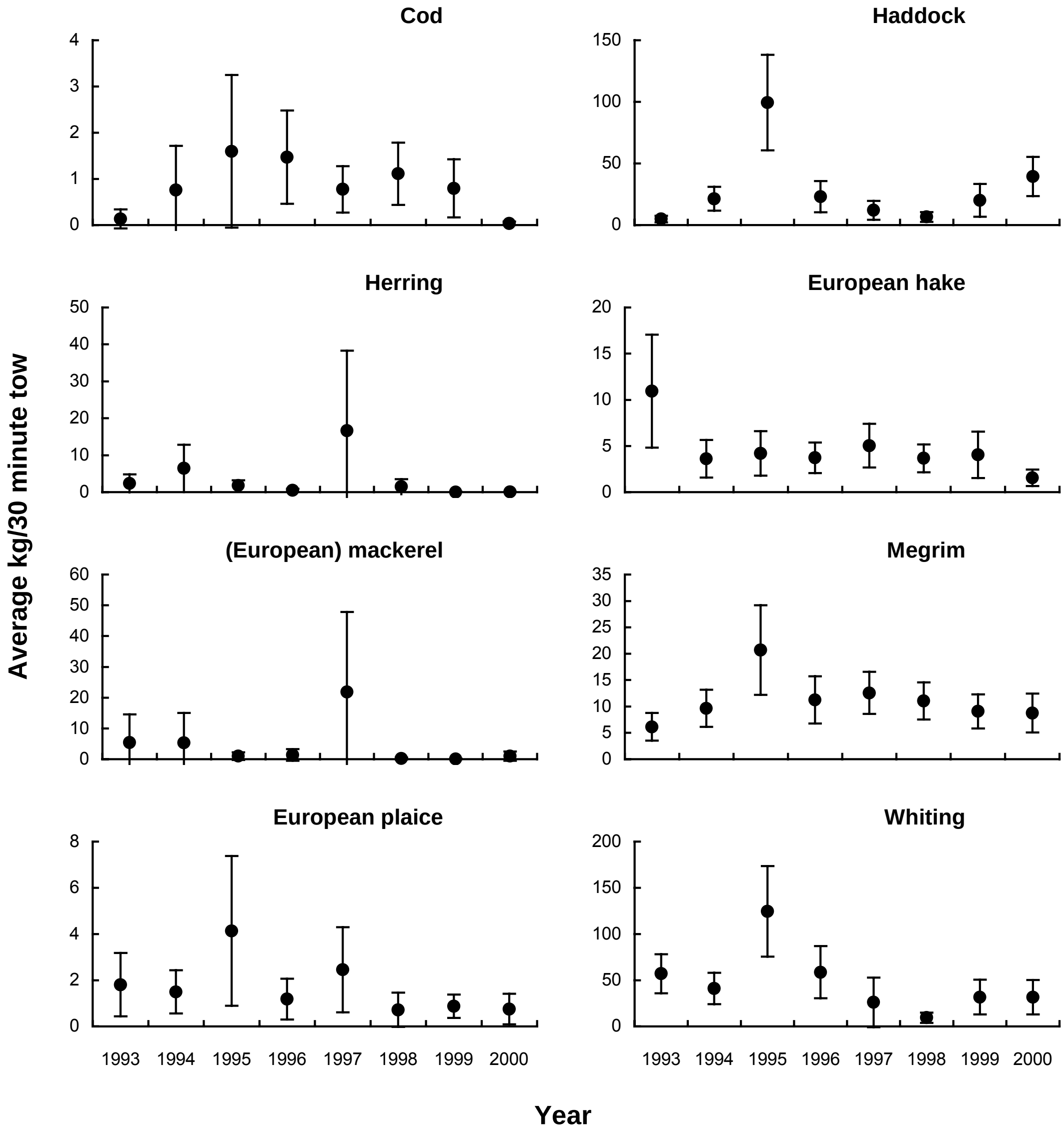


**Figure 6.2.4.** Abundance by weight (average kg/30 minute tow) of eight commercially important species caught on the Irish WCGFS Part B. Error bars indicate 95% confidence intervals.

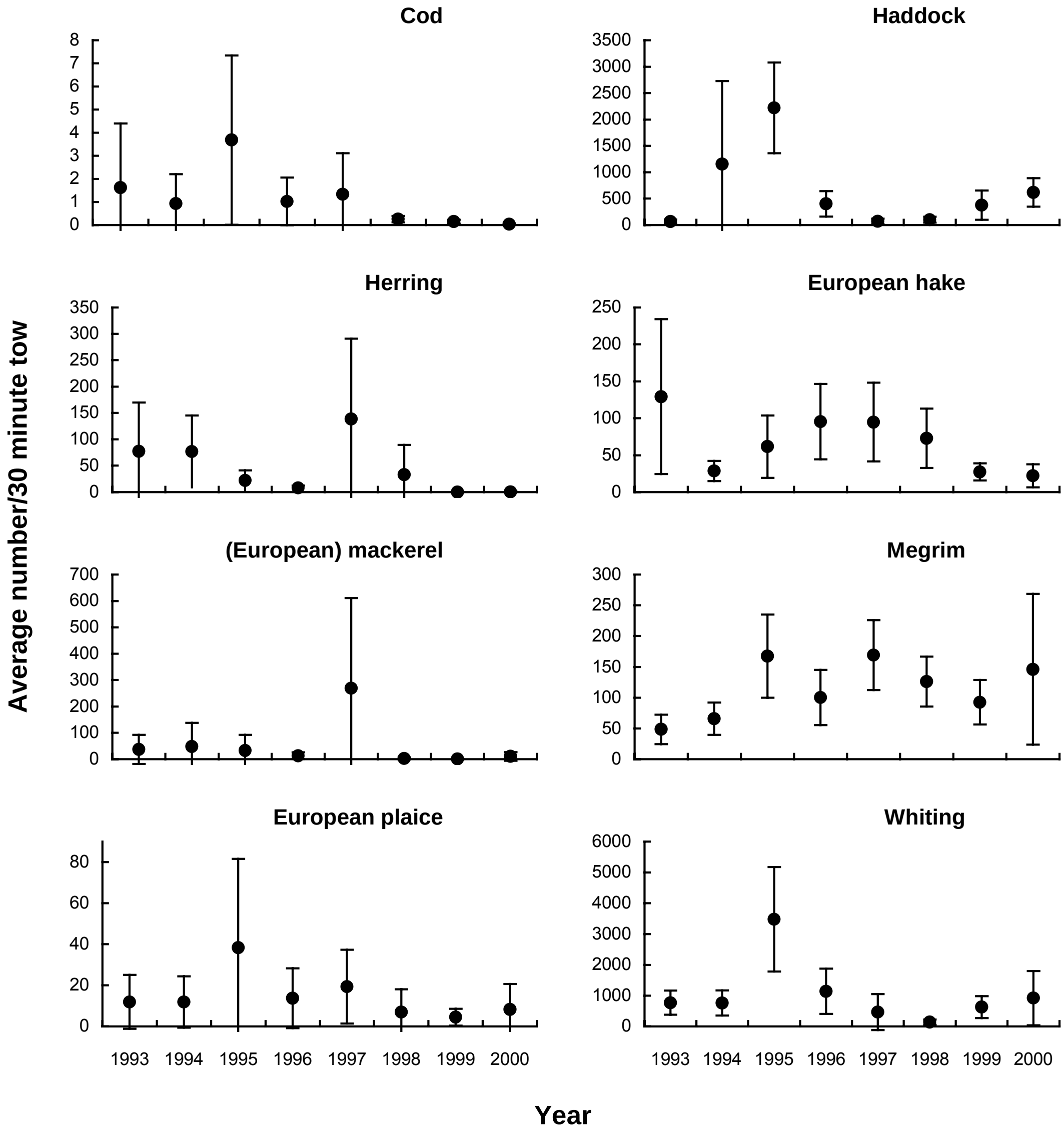


**Figure 6.2.5.** Abundance by number (average number/30 minute tow) of eight commercially important species caught on the Irish WCGFS Part B. Error bars indicate 95% confidence intervals.

| VIa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 |
| 1 | 0.38 | 0.48 | 0.00 | 0.73 | 1.25 | 0.25 | 0.28 | 1.63 |
| 2 | 0.07 | 0.16 | 0.00 | 0.08 | 0.20 | 0.57 | 0.24 | 0.07 |
| 3 | 0.00 | 0.02 | 0.00 | 0.00 | 0.07 | 0.05 | 0.06 | 0.00 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIb | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.66 | 0.84 | 0.00 | 0.05 | 0.05 | 0.00 |
| 1 | 0.02 | 0.00 | 0.11 | 0.16 | 0.00 | 0.03 | 0.02 | 0.64 |
| 2 | 0.00 | 0.00 | 0.08 | 0.09 | 0.00 | 0.10 | 0.02 | 0.00 |
| 3 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.10 | 0.00 | 0.00 |
| 4 | 0.00 | 0.00 | 0.08 | 0.02 | 0.00 | 0.08 | 0.00 | 0.00 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.07 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIj | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 |
| 1 | 0.00 | 0.00 | 3.41 | 0.14 | 0.11 | 0.17 | 0.02 | 0.23 |
| 2 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.06 | 0.07 | 0.03 |
| 3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.05 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.05 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.00 |

Table 6.2.8 Abundance at age for Cod (in Nb per 30 minutes) per ICES area covered by the WCGFS surveys.

| VIa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.18 | 0.00 | 0.00 | 0.00 | 0.90 | 0.63 | 0.00 | 0.53 |
| 1 | 1.03 | 0.57 | 0.17 | 0.00 | 0.72 | 0.34 | 0.00 | 1.38 |
| 2 | 1.50 | 0.84 | 0.57 | 0.00 | 0.42 | 0.54 | 0.00 | 0.48 |
| 3 | 0.63 | 0.71 | 0.24 | 0.00 | 0.10 | 0.48 | 0.00 | 0.07 |
| 4 | 0.22 | 0.09 | 0.10 | 0.00 | 0.07 | 0.18 | 0.00 | 0.08 |
| 5 | 0.02 | 0.04 | 0.02 | 0.00 | 0.02 | 0.04 | 0.00 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIb | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.54 | 1.63 | 0.90 | 1.64 | 1.87 | 1.58 | 2.20 | 2.39 |
| 1 | 0.25 | 0.43 | 0.58 | 1.29 | 0.13 | 0.20 | 1.45 | 2.36 |
| 2 | 0.02 | 0.09 | 0.34 | 0.05 | 0.00 | 0.35 | 0.77 | 1.14 |
| 3 | 0.00 | 0.09 | 0.11 | 0.02 | 0.00 | 0.15 | 0.09 | 0.50 |
| 4 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.03 | 0.02 | 0.39 |
| 5 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.09 | 0.08 |
| 6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIj | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 4.10 | 1.86 | 0.41 | 0.41 | 0.64 | 1.40 | 1.89 | 0.93 |
| 1 | 0.50 | 0.23 | 1.09 | 0.82 | 0.00 | 0.44 | 1.55 | 3.30 |
| 2 | 1.90 | 0.86 | 0.23 | 0.18 | 0.00 | 0.10 | 0.09 | 1.90 |
| 3 | 1.60 | 0.73 | 0.23 | 0.05 | 0.00 | 0.02 | 0.00 | 0.18 |
| 4 | 0.10 | 0.05 | 0.32 | 0.09 | 0.00 | 0.00 | 0.00 | 0.03 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 6.2.9 Abundance at age for Whiting (in Nb per 30 minutes) per ICES area covered by the WCGFS surveys.

| VIa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.58 | 0.02 | 0.00 | 0.17 | 0.70 | 0.36 | 1.37 | 0.55 |
| 1 | 0.92 | 0.16 | 0.69 | 0.63 | 1.23 | 0.64 | 0.98 | 1.60 |
| 2 | 2.07 | 0.77 | 0.24 | 0.45 | 0.08 | 0.14 | 0.98 | 0.43 |
| 3 | 0.77 | 0.91 | 0.64 | 0.07 | 0.07 | 0.16 | 0.96 | 0.62 |
| 4 | 0.37 | 0.16 | 0.50 | 0.00 | 0.08 | 0.09 | 0.59 | 0.60 |
| 5 | 0.03 | 0.05 | 0.03 | 0.00 | 0.13 | 0.07 | 0.41 | 0.32 |
| 6 | 0.08 | 0.00 | 0.02 | 0.00 | 0.03 | 0.11 | 0.13 | 0.07 |
| 7 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.11 | 0.03 |
| 8 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 | 0.04 | 0.00 |
| 9 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIb | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.45 | 0.44 | 0.82 | 1.10 | 0.00 | 1.13 | 1.48 | 1.14 |
| 1 | 0.27 | 0.00 | 0.53 | 1.19 | 1.18 | 0.28 | 0.20 | 2.47 |
| 2 | 0.00 | 0.00 | 0.03 | 0.00 | 0.08 | 0.30 | 0.02 | 0.19 |
| 3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.02 | 0.14 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.06 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.14 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIj | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | na | 0.27 | 2.05 | 0.09 | 0.75 | 1.77 | 1.63 |
| 1 | 0.00 | na | 1.05 | 1.23 | 0.61 | 0.17 | 0.39 | 4.75 |
| 2 | 0.00 | na | 0.00 | 0.18 | 0.00 | 0.06 | 0.00 | 0.20 |
| 3 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.06 | 0.02 | 0.00 |
| 4 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| 5 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| 6 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 0.00 | na | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 6.2.10 Abundance at age for Haddock (in Nb per 30 minutes) per ICES area covered by the WCGFS surveys.

| VIa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | na | 0.00 | 0.00 | 0.00 |
| 1 | 0.00 | 0.09 | 0.02 | 0.43 | na | 0.04 | 0.00 | 0.00 |
| 2 | 0.00 | 0.14 | 0.12 | 0.42 | na | 0.43 | 0.00 | 0.02 |
| 3 | 0.00 | 0.20 | 0.05 | 0.15 | na | 0.32 | 0.00 | 0.02 |
| 4 | 0.00 | 0.05 | 0.09 | 0.05 | na | 0.09 | 0.00 | 0.00 |
| 5 | 0.00 | 0.05 | 0.07 | 0.07 | na | 0.02 | 0.00 | 0.05 |
| 6 | 0.00 | 0.02 | 0.05 | 0.03 | na | 0.09 | 0.00 | 0.02 |
| 7 | 0.00 | 0.05 | 0.02 | 0.00 | na | 0.02 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.02 | 0.00 | na | 0.00 | 0.00 | 0.00 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | na | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 | na | 0.00 | 0.00 | 0.00 |

| VIIb | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 |
| 1 | 0.00 | 0.00 | 0.18 | 0.33 | 0.55 | 0.05 | 0.23 | 0.25 |
| 2 | 0.00 | 0.00 | 0.58 | 0.34 | 0.53 | 0.53 | 0.41 | 0.39 |
| 3 | 0.00 | 0.00 | 0.42 | 0.71 | 0.29 | 0.78 | 1.11 | 0.50 |
| 4 | 0.00 | 0.00 | 0.40 | 0.29 | 0.29 | 0.40 | 0.73 | 0.97 |
| 5 | 0.00 | 0.00 | 0.32 | 0.38 | 0.42 | 0.38 | 0.75 | 2.00 |
| 6 | 0.00 | 0.00 | 0.23 | 0.09 | 0.18 | 0.38 | 0.45 | 0.86 |
| 7 | 0.00 | 0.00 | 0.10 | 0.07 | 0.05 | 0.20 | 0.18 | 1.00 |
| 8 | 0.00 | 0.00 | 0.02 | 0.02 | 0.03 | 0.05 | 0.05 | 0.22 |
| 9 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 | 0.14 |
| 10 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |

| VIIj | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 |
| 1 | 0.00 | 0.00 | 1.18 | 0.32 | 0.50 | 0.31 | 0.00 | 0.45 |
| 2 | 0.00 | 0.00 | 1.64 | 1.95 | 0.30 | 0.46 | 0.00 | 0.48 |
| 3 | 0.00 | 0.00 | 0.64 | 1.32 | 0.32 | 0.65 | 0.25 | 1.45 |
| 4 | 0.00 | 0.00 | 0.86 | 0.95 | 0.25 | 0.33 | 0.82 | 0.65 |
| 5 | 0.00 | 0.00 | 0.64 | 0.59 | 0.18 | 0.08 | 0.66 | 0.83 |
| 6 | 0.00 | 0.00 | 0.36 | 0.18 | 0.09 | 0.02 | 0.45 | 0.48 |
| 7 | 0.00 | 0.00 | 0.09 | 0.09 | 0.02 | 0.02 | 0.18 | 0.23 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.05 | 0.05 |
| 9 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.02 | 0.02 | 0.03 |
| 10 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.03 |

Table 6.2.11 Abundance at age for Haddock (in Nb per 30 minutes) per ICES area covered by the WCGFS surveys.

| VIa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 |
| 1 | 0.27 | 0.77 | 0.38 | 0.83 | 0.33 | 0.80 | 0.74 | 0.52 |
| 2 | 0.53 | 0.57 | 0.50 | 1.17 | 0.52 | 0.41 | 1.26 | 0.57 |
| 3 | 0.17 | 0.45 | 0.12 | 0.18 | 0.18 | 0.20 | 0.57 | 0.10 |
| 4 | 0.10 | 0.21 | 0.05 | 0.03 | 0.28 | 0.09 | 0.33 | 0.08 |
| 5 | 0.03 | 0.11 | 0.05 | 0.00 | 0.10 | 0.04 | 0.04 | 0.07 |
| 6 | 0.02 | 0.07 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.05 |
| 7 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.04 | 0.02 | 0.02 |
| 8 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIb | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 0.11 | 0.00 | 0.35 | 0.79 | 0.55 | 0.23 | 0.00 | 0.61 |
| 2 | 0.34 | 0.00 | 0.52 | 0.69 | 0.68 | 0.75 | 0.00 | 1.22 |
| 3 | 0.07 | 0.00 | 0.13 | 0.76 | 0.03 | 0.73 | 0.00 | 0.31 |
| 4 | 0.00 | 0.00 | 0.10 | 0.19 | 0.00 | 0.20 | 0.00 | 0.36 |
| 5 | 0.00 | 0.00 | 0.03 | 0.07 | 0.00 | 0.05 | 0.00 | 0.11 |
| 6 | 0.00 | 0.00 | 0.03 | 0.02 | 0.00 | 0.00 | 0.00 | 0.03 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| VIIj | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age/year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 0.30 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.40 | 0.00 | 0.14 | 0.05 | 0.00 | 0.06 | 0.07 | 0.00 |
| 3 | 0.20 | 0.00 | 0.14 | 0.09 | 0.00 | 0.13 | 0.05 | 0.08 |
| 4 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.08 | 0.11 | 0.03 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.02 | 0.03 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 6.2.12 Abundance at age for Plaice (in Nb per 30 minutes) per ICES area covered by the WCGFS surveys.

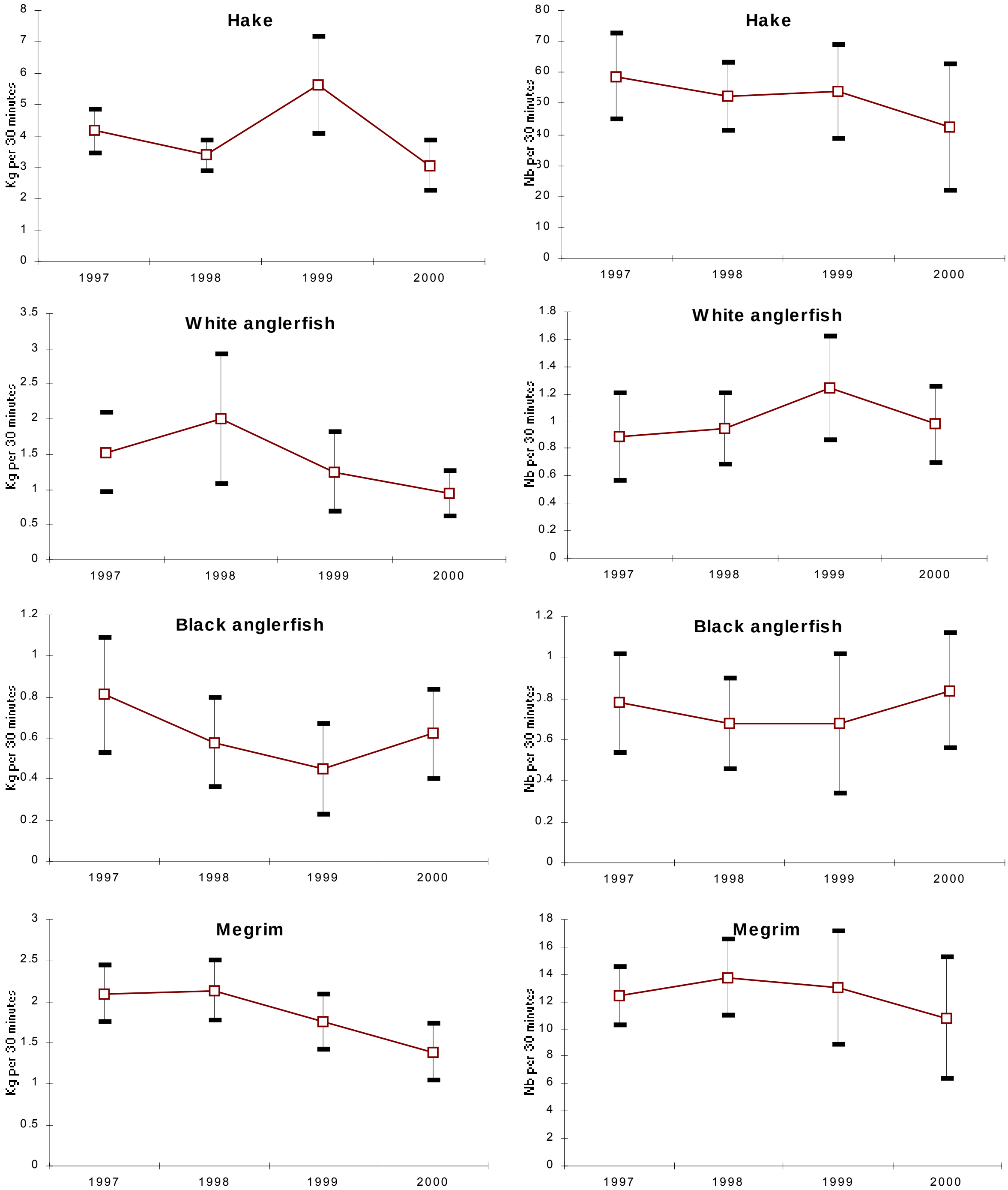


Figure 6.2.6 Biomass and abundance indices of Hake, White and Black anglerfish and Megrim for the whole area covered by the EVHOE survey (Divisions VIIgjh and VIIIab).

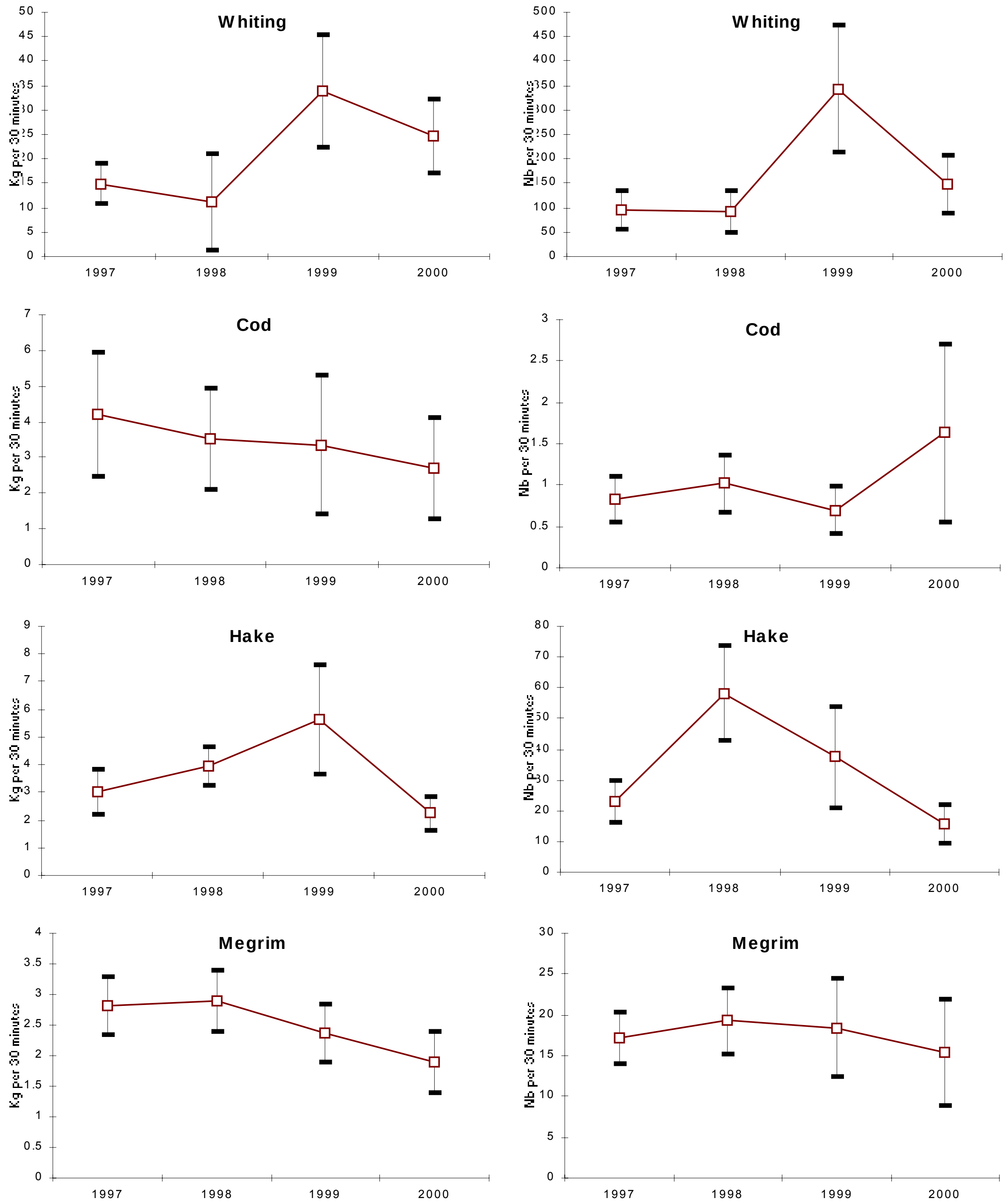


Figure 6.2.7 Biomass and abundance indices of Whiting, Cod, Hake and Megrim for the Celtic Sea area covered by the EVHOE survey (Divisions VIIgjh).

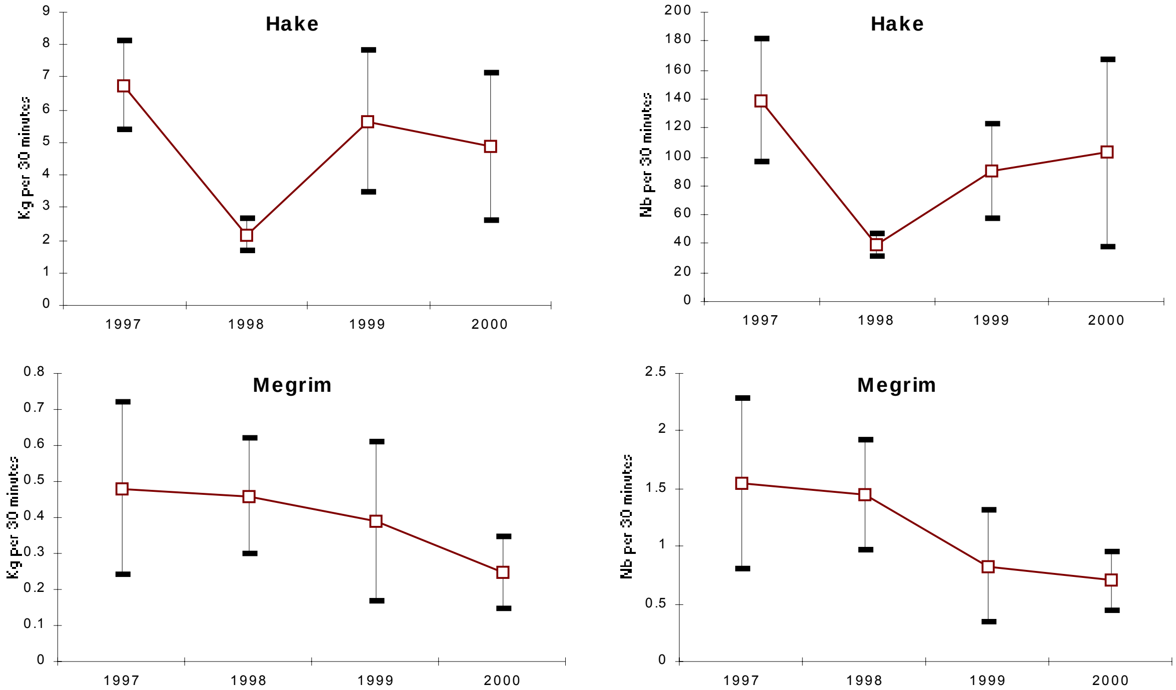


Figure 6.2.8 Biomass and abundance indices of Hake and Megrim for the Bay of Biscay area covered by the EVHOE survey (Divisions VIIIab).

| Total area | | | | |
|---|---|---|---|---|
| **Age** | **1997** | **1998** | **1999** | **2000** |
| **0** | 41.83 | 38.36 | 28.11 | 33.82 |
| **1** | 6.56 | 5.29 | 13.53 | 2.28 |
| **2** | 8.26 | 3.67 | 9.05 | 3.94 |
| **3** | 1.84 | 1.78 | 2.37 | 1.70 |
| **4** | 0.31 | 0.48 | 0.41 | 0.61 |
| **5** | 0.11 | 0.08 | 0.10 | 0.10 |
| **6** | 0.01 | 0.02 | 0.08 | 0.03 |
| **7** | 0.00 | 0.04 | 0.03 | 0.00 |
| **8** | 0.01 | 0.01 | 0.01 | 0.00 |
| **9** | 0.01 | 0.00 | 0.02 | 0.01 |
| **10** | 0.01 | 0.02 | 0.01 | 0.00 |
| **11** | 0.00 | 0.02 | 0.01 | 0.00 |
| **12** | 0.01 | 0.00 | 0.03 | 0.00 |
| **13** | 0.01 | 0.00 | 0.00 | 0.00 |

| Celtic Sea | | | | |
|---|---|---|---|---|
| **Age** | **1997** | **1998** | **1999** | **2000** |
| **0** | 9.98 | 40.89 | 16.54 | 8.36 |
| **1** | 3.56 | 6.36 | 6.15 | 1.47 |
| **2** | 7.55 | 4.58 | 10.97 | 4.15 |
| **3** | 1.36 | 1.99 | 2.91 | 1.26 |
| **4** | 0.14 | 0.50 | 0.36 | 0.52 |
| **5** | 0.05 | 0.07 | 0.14 | 0.12 |
| **6** | 0.01 | 0.01 | 0.11 | 0.03 |
| **7** | 0.00 | 0.03 | 0.04 | 0.00 |
| **8** | 0.01 | 0.02 | 0.01 | 0.00 |
| **9** | 0.00 | 0.00 | 0.02 | 0.01 |
| **10** | 0.02 | 0.03 | 0.01 | 0.00 |
| **11** | 0.00 | 0.03 | 0.00 | 0.00 |
| **12** | 0.02 | 0.00 | 0.04 | 0.00 |
| **13** | 0.00 | 0.00 | 0.00 | 0.00 |

| Bay of Biscay | | | | |
|---|---|---|---|---|
| **Age** | **1997** | **1998** | **1999** | **2000** |
| **0** | 113.13 | 32.67 | 54.02 | 90.83 |
| **1** | 13.28 | 2.90 | 30.06 | 4.10 |
| **2** | 9.85 | 1.62 | 4.76 | 3.48 |
| **3** | 2.93 | 1.30 | 1.15 | 2.70 |
| **4** | 0.69 | 0.44 | 0.52 | 0.81 |
| **5** | 0.24 | 0.08 | 0.00 | 0.06 |
| **6** | 0.01 | 0.03 | 0.01 | 0.04 |
| **7** | 0.01 | 0.04 | 0.01 | 0.01 |
| **8** | 0.02 | 0.00 | 0.01 | 0.01 |
| **9** | 0.03 | 0.00 | 0.03 | 0.00 |
| **10** | 0.00 | 0.00 | 0.00 | 0.00 |
| **11** | 0.00 | 0.00 | 0.03 | 0.00 |
| **12** | 0.00 | 0.00 | 0.00 | 0.00 |
| **13** | 0.00 | 0.00 | 0.00 | 0.00 |

Table 6.2.13 Abundance at age for Hake (in Nb per 30 minutes) for the total area covered by the EVHOE survey and for the Celtic Sea and Bay of Biscay

| Total area | | | | |
|---|---|---|---|---|
| Age | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.02 | 0.00 | 0.08 | 0.02 |
| 1 | 0.47 | 1.62 | 0.53 | 1.38 |
| 2 | 3.85 | 0.65 | 3.35 | 2.62 |
| 3 | 2.71 | 4.35 | 0.68 | 2.52 |
| 4 | 1.55 | 3.06 | 2.06 | 1.36 |
| 5 | 1.40 | 1.49 | 3.30 | 1.20 |
| 6 | 1.11 | 0.98 | 1.61 | 0.73 |
| 7 | 0.62 | 0.78 | 0.67 | 0.41 |
| 8 | 0.35 | 0.40 | 0.29 | 0.28 |
| 9 | 0.18 | 0.13 | 0.25 | 0.14 |
| 10 | 0.07 | 0.06 | 0.14 | 0.13 |
| 11 | 0.02 | 0.00 | 0.01 | 0.03 |
| 12 | 0.00 | 0.09 | 0.01 | 0.01 |
| 13 | 0.00 | 0.01 | 0.01 | 0.00 |

Table 6.2.14 Abundance at age for Megrim (in Nb per 30 minutes) for the total area covered by the EVHOE survey.

| Celtic Sea | | | | |
|---|---|---|---|---|
| Age | 1997 | 1998 | 1999 | 2000 |
| 0 | 0.10 | 0.00 | 0.02 | 0.35 |
| 1 | 0.23 | 0.22 | 0.17 | 1.04 |
| 2 | 0.12 | 0.49 | 0.17 | 0.04 |
| 3 | 0.05 | 0.22 | 0.27 | 0.11 |
| 4 | 0.00 | 0.04 | 0.01 | 0.07 |
| 5 | 0.00 | 0.04 | 0.03 | 0.01 |
| 6 | 0.03 | 0.00 | 0.01 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9 | 0.81 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 6.2.15 Abundance at age for Cod (in Nb per 30 minutes) for the Celtic Sea area covered by the EVHOE survey.

| Celtic Sea | | | | |
|---|---|---|---|---|
| Age | 1997 | 1998 | 1999 | 2000 |
| 0 | 37.15 | 57.83 | 257.79 | 35.91 |
| 1 | 27.80 | 17.60 | 59.60 | 83.15 |
| 2 | 9.60 | 8.30 | 16.61 | 24.10 |
| 3 | 8.70 | 1.29 | 4.77 | 2.77 |
| 4 | 10.39 | 1.73 | 1.80 | 1.19 |
| 5 | 1.87 | 0.57 | 1.57 | 0.31 |
| 6 | 0.24 | 0.15 | 1.11 | 0.18 |
| 7 | 0.00 | 0.02 | 0.14 | 0.46 |
| 8 | 0.00 | 0.00 | 0.12 | 0.06 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 6.2.16 Abundance at age for Whiting (in Nb per 30 minutes) for the Celtic Sea area covered by the EVHOE survey.

# 7. Task 4 – Hydrological data

## 7.1 Data collected

Hydrological data were collected during the French EVHOE survey in 1999 (119 CTD profiles) and in 2000 (123 CTD profiles), the UK Scotland SCOTIA surveys in 1999 and 2000 and during the Irish ISCSGFS in 2000. However, due to technical problems with the probe, the Irish data could not be validated. Fig 7.1 shows the position of the stations occupied in 1999 and 2000.

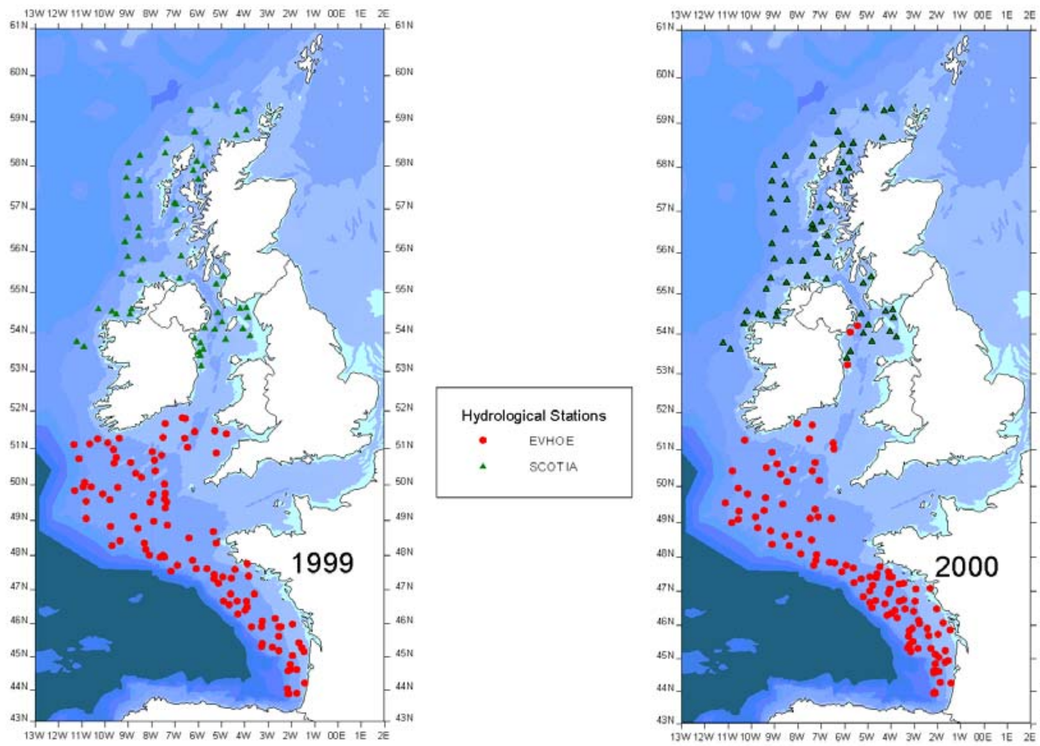


Figure 7.1 – Position of hydrological stations occupied in the IPROSTS area in 1999 and 2000 from the Scottish R/V SCOTIA and French R/V THALASSA.

## 7.2 General observations

The important phenomenon to keep in mind is the development of a seasonal thermocline due to the summer warming of the surface water layer. In the fall, there is a well marked stratification of the water column. This stratification disappears following the mixing induced by the windy conditions at the end of fall/the start of early winter. This phenomenon is general to our latitudes but the effect decreases from South to North.

In the Bay of Biscay, residuals currents are very weak and the hydrodynamic is driven by tidal currents, wind and freshwater derived from rivers. Below 100m depth, a cold residual water (11 – 11.5°C) known as the “Cold Layer” extends from the Gironde estuary to the area off Brittany.

In the Celtic Sea, the hydrodynamic is stronger and it is common to observe a uniform temperature profile from surface to bottom. This explains the similarity observed in the bottom and surface temperature illustrated in fig. 7.2.

### 7.3 Hydrological conditions in 1999 and 2000

Maps of surface and bottom temperature are presented in fig. 7.2. The interpolation method used for grid construction is an inverse distance weighting over a 90 nautical mile radius.

For logistic reasons due to a revised re-scheduling of R/V Thalassa's surveys in 1999, the EVHOE Survey was delayed by one month in this year. It was then decided that in order to benefit from maximum daylight the timing of the survey should be reversed , and that it should start from the North to the South instead of from the Bay of Biscay to the Celtic Sea which is the usual pattern. Therefore the 1999 surface water condition in the Bay of Biscay mainly reflects this operational shift rather than a year effect. The Celtic Sea was covered at the usual period.

In the Celtic Sea and northern area of the British Isles, the surface and bottom waters were colder in 2000 than in 1999.

In the Bay of Biscay, while the timing problem already mentioned exaggerates the difference, surface waters, and to a lesser extent bottom water, show opposite trends between the two years. The situation in 2000 for the bottom water is close to the generally observed pattern, a well marked gradient from the shore to the "Grande Vasière". This is due to the fact that the thermocline lies around the 50m isobar, warmer water therefore covering the shallower depth along the coast The colder conditions observed in 1999 somewhat reflects the wind effect on the mixing of the water column.

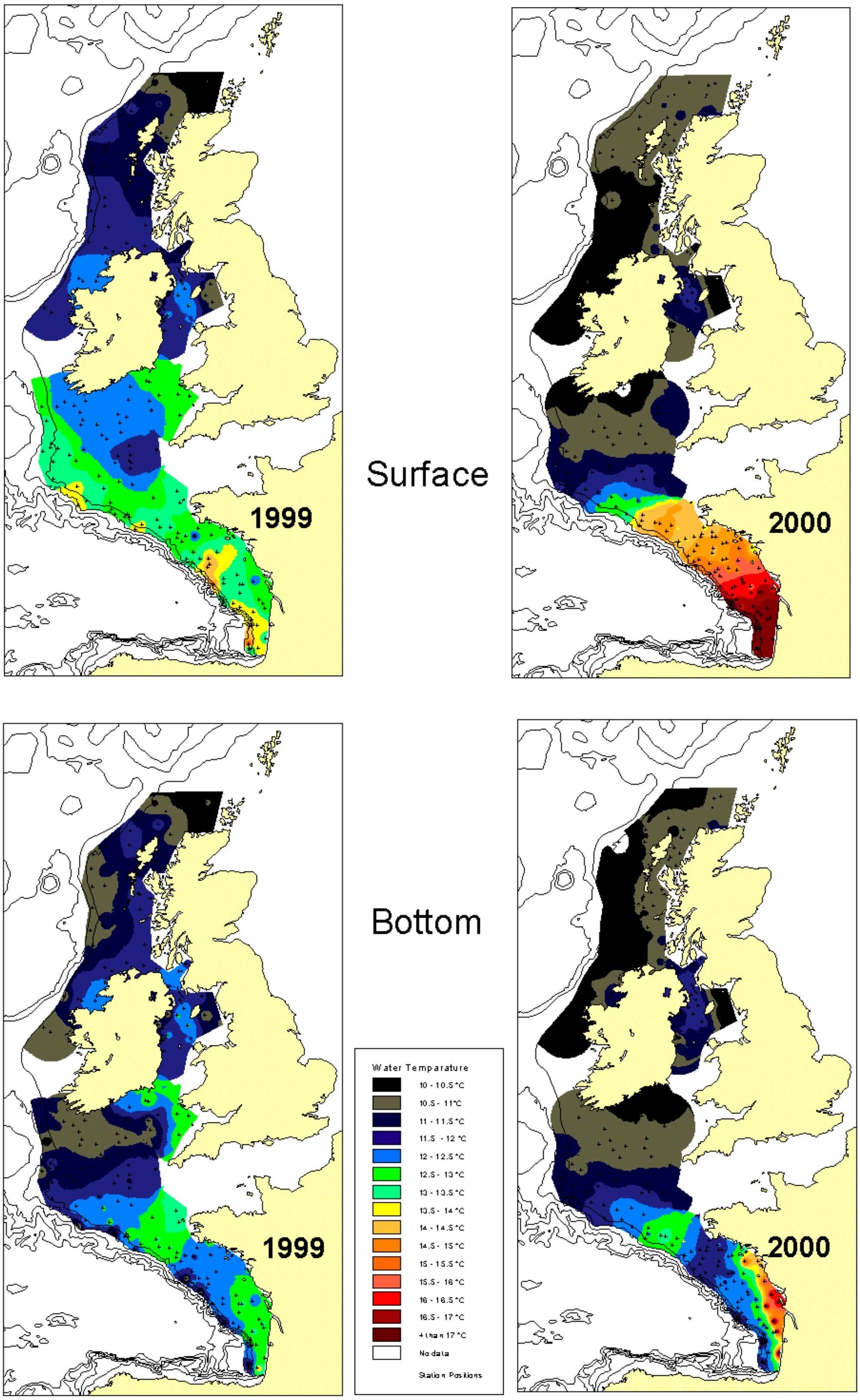


Figure 7.2 – Surface and bottom water temperature observed in the IPROST area in 1999 and 2000.

# 8. Storage of data

Each institute has its own database format and it was planned to define an agreed database format for exchange. This task was to benefit from the results of the SESITS program that came into an end in 1999. In view of the SESITS program's conclusion, it was decided to maintain each institute's database in their own format and to develop exchange formats compatible with the format of the new ICES IBTS database that will be developed in the near future under the recently approved DATRAS project (No QLRT-2001-00025).

## 9. Conclusions and recommendations

- This project has allowed survey data gathered by three different institutes working in North-western European waters to be amalgamated for the first time.
- This has allowed a more coherent approach to be initiated in reviewing trawl survey data from the western division.
- Significant progress has been made towards standardising protocols for the collection and analysis of trawl survey data in the western division
- An innovative statistical analysis has been applied to two sets of comparative fishing experiments.
- This study found that important information could be gleaned on inter-vessel variability using similar gear despite a limited number of paired tows.
- No conversion factors were adopted between the vessels as there was no conclusive evidence that such factors were required for the mapping of distribution and abundance.
- It was concluded that the vessels fished similarly for the six species analysed in detail.
- Basic mapping of numbers and weights of abundance undertaken within this project has provided a valuable insight into the distribution of species from the Orkney Isles to the Bay of Biscay
- Spatial and temporal patterns of abundance identified appear to be useful for stock discrimination
- The establishment of an inter-calibrated, spatially extended time series of trawl survey data offers new opportunities to the Northern and Southern Shelf Working Groups to tune VPAs for major commercial species.
- The project has provided a framework for improved co-ordination in the western division. If resources permit, areas of investigation for future years should include:

    - Depth stratification of the surveys
    - An analysis of the need for a standardised gear for the western division
    - An agreement on standardised protocols for sampling
    - An extension of the inter-calibration exercise for different areas, vessels and species

# Annex I

# Quantifying variability in Gear Performance on IBTS surveys: Swept area and volume with depth

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## ABSTRACT

The International Bottom Trawl Surveys (IBTS) on the western shelf represent an important source of fisheries independent data on the abundance and distribution of many important commercial species. Trawl hauls on these surveys are standardised to thirty minutes and four knots. It is thus assumed that they will generally take equivalent samples. We examined trawl surveillance data on; headline height, wing spread, door spread, swept area and swept volume for recent surveys by Scotland, France and Ireland. The study showed that there was substantial variability in all these parameters, and of particular importance, swept area and headline height. There was also good evidence that both these parameters varied systematically with the depth of the trawl haul, although this varied in pattern between the three different national surveys examined.

The implications of these findings for catch rates were examined using linear modelling with haddock catches on the Scottish surveys as a test case. The analysis was complicated by the fact that both the net performance parameters and the haddock abundance appear to be well correlated with depth. This made it difficult to isolate the net parameters as sources of variance. However, the analysis clearly suggested, for this species and in this location, that variation in headline height has an impact on catch rates. The significance of these findings and of the variability in the gear performance in general is discussed.

## INTRODUCTION

The major fishery independent tool for assessing demersal fish stocks is the stratified random bottom trawl survey (Pennington & Brown 1981). Such surveys are particularly important in the North Sea and adjacent areas where a series of international collaborative surveys (IBTS – ICES coordinated International Bottom Trawl Surveys) have been carried over many years (Heessen et al 1997). Considerable efforts are made to ensure that these surveys are carried out in a standard and consistent way. A manual has been produced describing the construction of the standard net (the GOV – Grande Ouverture Vertical), and standard rigging, deployment and data collection protocols are produced as an IBTS manual (Anon 1996). When new vessels are introduced into the survey, inter-calibration exercises are carried out (Pelletier 1998, Zuur et al 2001). Notwithstanding these efforts, it is still necessary to make some assumptions about the way the gear actually performs.

One such assumption is that the standard trawl, towed at a standard speed for a set period will sweep a fixed area of seabed (Forrest & Minnet 1981). However, this assumption does not necessarily hold true. It is known that swept area increases with depth as a result of the greater length of warp (Carrothers 1981; Godø & Engås 1989, Engås 1994, Rose & Nunnallee 1997). Godø & Engås (1989) suggested that this might well affect the efficiency of the gear. Godø & Engås showed that the increase in swept area was due to an increase in the spread of the wings and doors. As a corollary to this, the height of the headline reduced with depth, so effectively the net becomes wider and shallower with depth. It is reasonable to assume that either or both these factors (swept area or headline height) are likely to have an impact on the amounts of fish caught. Increase in swept area is likely to result in more fish captured. Decrease in headline height may reduce the amount captured, in that more may be lost over the headline.

Godø & Engås (1989) examined trawl surveys in the Svalbard area off Spitsbergen, where depths varied between 20 and 600m. In the North Sea and adjacent waters the surveys are usually restricted to 200m, although in the shelf area to the west of Europe surveys go down to 500m. As part of an EU funded project (IPROSTS Study Contract) we set out to determine the variability in trawl performance with depth on a number of IBTS surveys carried out on the west coast of Scotland. In addition we examined whether there was any evidence from these surveys that any swept area differences found might have an impact on catch rate of two common fish species: haddock (*Melanogramus aeglefinus*) and whiting (*Merlangius merlangus*).

# MATERIALS

## The Surveys

### Scotland

Trawl data from two Scottish west coast IBTS surveys were used in this analysis (November 1998 and 1999 carried out from FRV *Scotia*). These surveys were initially selected as they fell within the western area remit of IPROSTS. These surveys use the same, rectangle stratified, sampling design as the North Sea IBTS, but due to the nature of the western Scottish shelf, they tend to cover a wider depth range. Additionally, recent proposal to harmonise these surveys with those further south would require the depth limit to be extended to 500m, where the impact of gear performance changes may be even more important.

The trawl used was a standard GOV fitted with a heavy ground gear (ground gear C) to cope with the more difficult seabed found in this area. The trawl was fitted with ScanMar sensors to provide; headline height (HH), wing spread (WS) and door spread (DS). The sensors were interfaced to a PC for data logging using in-house software. For each haul, the software provide mean HH, WS & DS as well as mean swept areas between the wing ends (Net Swept Area - NSA) and the doors (Gear Swept Area - GSA). NSA and GSA were integrated from recordings of distance traveled and WS/DS every 30 seconds through the operation. Recordings were not started until the gear had settled and was fishing correctly, and were stopped as soon as the gear began to be recovered. The surveys used the current standard 30-minute tow, with the vessel speed maintained at 4 knots.

The surveillance data from 107 valid fishing operations were collected for the analysis. In approximately 5% of operations, the sensor data were corrupted or incorrect and these tows were discarded.

### France

Trawl surveillance and catch data were available from the EVHOE 1999 survey by IFREMER on FRV *Thallasa*, carried out in the Bay of Biscay and Celtic Sea in November 1999. The survey design used a depth stratified approach although the stations were carried out as standard IBTS half-hour tows. The trawl used was a standard GOV, although headline floats were substituted for the standard kite. Two different sweep lengths were used; 60m from 0 to 125m depth and 110m thereafter. The trawl was fitted with ScanMar sensors to provide; headline height (HH), wing spread (WS) and door spread (DS). Swept areas were calculated from these data and from the distance towed.

The surveillance data from 105 valid fishing operations were collected for the analysis.

**Ireland**

Trawl surveillance and catch data were available from the Irish Sea and Celtic Sea Ground Fish Survey (ISCSGFS) carried out by the Marine Institute, Abbotstown on FRV *Celtic Voyager*, in November 1999. The survey design used a rectangle-stratified approach and the stations were carried out as standard IBTS half-hour tows. The trawl used was a modified (reduced horsepower) GOV. One sweep length of 50m was used. The trawl was fitted with ScanMar sensors to provide; headline height (HH) and door spread (DS). Swept area was calculated from these data and from the distance towed.

The surveillance data from 53 valid fishing operations were collected for the analysis.

# METHODS AND RESULTS

## Depth dependence in trawl performance parameters

### Scotland

The basic trawl performance data for the two Scottish surveys are presented against water depth in Figures 1a to f. Calculated Regressions, $R^2$ values, values at 25 and 200m and differences are given in table 1.

Figure 1a shows the change in headline height. There is a clear decrease in this factor with water depth. The calculated headline height goes from 5m to 3.6m, a percentage change of 39.7%. Figure 1b & 1c show the change in wing and door spread with depth. Again there are clear changes with depth particularly in the case of wing spread. Figure 1d shows the variability in the distance towed. Most tows are between 1.8 and 2 n.mi., a variation of around 10%. These data are also used to generate the swept area values, which are shown for the net – calculated using wing spread, and for the whole gear - calculated using door spread in figures 1e and 1f respectively. In all cases there are obvious and substantial changes in gear performance with depth.

### France

The French survey uses a similar GOV gear to the Scottish surveys but with differences in rigging described above

The main trawl performance data for the French survey are presented in figure 2, and the details summarised in Table 2. Using the short sweeps, the French net showed very similar patterns to the Scottish net. The calculated headline height varied from about 4.5 to 3.5m over 100m depth range. Wing spread, door spread and net swept area all varied in a similar fashion to that seen on the Scottish surveys. However, with the long sweeps there was very little change at all with depth.

### Ireland

The Irish survey uses a scaled down version of the GOV suitable to a smaller vessel.
The main trawl performance data for the Irish survey are presented in figures 12 to 15, and the details are summarised in Table 3. No wing spread data and, hence, net swept area, information were available for this survey. The depth range in this survey was also less (maximum depth of 120m) than the other two surveys. The important points to note are that there was very little variation in the headline height across the depth range but that door spread varied by around 35%.

## Analysis of catch rates in relation to trawl performance

It was clear from the above that there were substantial changes in the performance of the gear across the normal depth range of the surveys. The next question was whether this could be shown to have had any impact on the trawl results. We decided to concentrate on the two most abundant species encountered, haddock and whiting. For this analysis we used only numbers caught irrespective of age or length.

Firstly, haddock and whiting abundance data were log-transformed to normalise the error structure. Histograms and qq-plots confirmed there was acceptable symmetry in the log abundances.

The second step was to investigate whether there might be important variations between the two survey years. Haddock and whiting abundance were plotted against six variables (Time of day, Bottom depth, Headline Height, Net swept area, Gear swept area and Net swept volume). See Figs 1 and 2.

**Haddock: 1998 survey v. 1999 survey**
Haddock abundance was higher in 1999 than 1998 (Fig. 1). The range of some gear parameters, e.g., headline height and gear swept area were very different between the two surveys. In 1999 headline heights ranged between 4-5.5m whereas in 1998 they ranged between 3 and 5.25m.

**Whiting: 1998 survey v. 1999 survey**
The differences in average whiting catches between the two surveys were not as pronounced as for haddock (Figure 2) although the differences between years in the ranges of gear parameters are, naturally, the same.

These figures suggested that it would be better to treat the 1998 and 1999 data separately

## Multiple Pair-wise plots of the 1998 and 1999 data

The next step was to determine the best approach to modeling the dependencies in the data. Figures 3 and 4 show multiple pair-wise comparisons between all the variables. They suggest broadly similar patterns of dependency for both the 1998 and 1999 datasets. Haddock abundance increased with bottom depth, gear swept area, net swept area, and net swept volume while it decreased with headline height and whiting abundance. Whiting showed almost the opposite pattern.

## Separating the effects of each predictor

The variables we were most interested in (depth, headline height, net swept area, gear swept area, and net swept volume) were generally correlated with each other. For the purposes of this work we wanted to quantify the variation due to each of these variables separately. The normal way to do this would be to use multiple regression and model haddock and whiting abundances as functions of depth, headline height etc. Unfortunately, for regression coefficients to have an unambiguous interpretation, it is necessary that the covariates be uncorrelated. In Figs 3 and 4 the positive relationships between depth, net swept area and gear swept area are very clear, as is the negative correlation between depth and headline height. This correlation also means that the effects are confounded. If interest, for example, focuses on separating the effect of bottom depth and trawl headline height we need shallow-water observations at low headline heights and deep-water observations at high headline heights. The negative correlation between the two variables (Figs 3 and 4) meant that this rarely happened.

## Reducing the correlation/confounding problem by sub-setting the data

Study of the raw data suggested that it would be possible to get a reasonable spread over all the covariates by using subsets of the data. This involved removing stations close to the maximum and minimum depth values, and which also had correlated values in the other net parameters. This then left us with data covering a range of depths associated with a range of, say, headline heights. The subsetted data were then re-plotted in multiple pair-wise comparisons (see Figs 5 & 6). This process reduced some of the correlation between the variables, although some remains between some of the covariates.

## Investigation of the subsetted data

The next step was to determine the relationships between the net surveillance parameters and the fish abundance using linear models.

**Haddock 1998**

The subset of the 1998 data was produced using only data with a net swept area >60000, collected at depths of between 60m and 160m.

A range of nested linear models, using all or some of the net parameters, were then fitted to the log-transformed haddock abundance data. The most complex model to come out of this process [log(Haddock)=Depth+HLHeight+Nswarea+natural spline(Time,2)] was then passed to the S-plus function "step" to select the most economic subset. This process indicated that only depth and headline height were important as predictors of herring abundance, although headline height did not come out as significant.

| Coefficients | Value | Std Error | t | P (>\|t\|) | Sig. |
|---|---|---|---|---|---|
| Intercept | -7.4626 | 5.6134 | -1.3294 | 0.1934 | |
| Depth | 0.0287 | 0.0121 | 2.3711 | 0.0241 | Sig. |
| HL Height | 1.6550 | 1.0663 | 1.5521 | 0.1308 | N Sig. |
| Residual standard error: 1.719 on 31 d.f. | | | Multiple R-Squared: 0.1594 | | |
| F-statistic: 2.938 on 2 and 31 d.f. | | | p-value is 0.06784 .. not significant | | |

**Haddock 1999**

The same process was followed for the 1999 data for haddock. In this case only depth was found to be important as a predictor.

| Coefficients | Value | Std Error | t | P (>\|t\|) | Sig. |
|---|---|---|---|---|---|
| Intercept | 0.2988 | 2.1908 | 0.1364 | 0.8931 | |
| Depth | 0.0385 | 0.0169 | 2.2751 | 0.0361 | Sig. |
| HL Height | na | na | na | Na | |
| Residual standard error: 1.68 on 17 d.f. | | | Multiple R-Squared: 0.2334 | | |
| F-statistic: 5.176 on 1 and 17 d.f. | | | p-value is 0.03613 .. significant | | |

**Whiting**

The same process was followed for the both years for whiting. In both cases only depth was again found to be important as a predictor. No further analysis was carried out on the whiting data.

## Partial Regression analysis

The final step was to investigate what dependencies remained in the data after the influence of the main factor, depth, was modelled out. This was done with the aid of partial regression plots (Figs 7 & 8). Residuals from the model (log(haddock)=Depth) for both 1998 and 1999 datasets were plotted against four of the gear parameters (net swept area, headline height, gear swept area and net swept volume). A linear model was then fitted to the data to summarise any gradient. The horizontal dotted line is the mean of the residuals. In theory, the plots summarise dependency on the other predictors after the effect of depth has been removed. Net swept area, gear swept area and net swept volume tended to have slight negative gradients. If this were a real effect, catches would be expected to increase when these parameters decrease at any given depth. Thus increase in sampling area or volume would be expected to result in a decrease in catch. This is counterintuitive, although it should be emphasised that these effects were not significant. Headline height showed the opposite effect. Greater headline height related to increased catch rates, at any given depth.

## DISCUSSION

The first important point to note is that the water depth at a trawl station had a dramatic impact on the performance of the gear. This effect has been well known for some time (Carrothers 1981,Godø & Engås 1989, Engås 1994). A number of approaches have been suggested to control this effect. One suggested remedy was to vary warp length to keep the door spread constant (Koeller 1991, Walsh & McCallum 1997). Another possibility, which has been widely adopted, is to use a rope between the warps to constrain door spread (Engås & Ona 1991). The IBTS manual requires the use of two different sweep lengths at different depths (50m sweeps down to 75m depths and 100m sweeps thereafter). How widely this is practiced is unknown. The data from the French surveys reported here suggests that this may go some of the way to ameliorating the situation.

The second point is, therefore, that the assumption that the standard trawl, towed at a standard speed for a set period will sweep a fixed area of seabed (Forrest & Minnet 1981) is clearly untrue. It is not unreasonable to assume that if there is a variation in the swept area there should be a variation in the catch taken. As the headline height also decreases with depth, there might be expected to be an impact of this change also. The problem we faced in determining whether this was happening was two fold.

Firstly, it is well known that the catch rates from bottom trawl surveys have a very high variability (Zuur et al 2001). The potential for isolating variability due to a single factor can be limited. Zuur et al were attempting to determine if there was a vessel effect between the new FRV *Scotia* and its predecessor. The data collection programme was designed to reduce as many other sources of variability as possible, however, the remaining variability made it impossible to determine any significant differences between the two vessels.

The second problem we faced was probably specific to the west of Scotland area. There was a clear pattern evident in these data of increasing haddock abundance with depth. As all the gear performance parameters also varied with depth, it became extremely difficult to isolate these from the depth signal. This confounding meant that high headlines and narrow spreads were mostly found in shallow waters and the opposite in deep waters. There were no sample data with high headlines in the deeper waters for instance. The use of subsets of the data over a restricted depth range was designed to give a more representative range of gear parameters at any given depth. However, this process itself gave rise to further problems. Firstly, the number of valid stations was reduced, and secondly, it was not possible to remove the effects of depth completely. The outcome of the analyses should be viewed in the light of these observations.

The model selection process applied to the 1998 haddock data suggested that headline height, along with depth, was an important predictor of haddock catch rate. This was borne out by the pattern of the residuals from a depth only model. Neither effect was statistically significant, but may, nonetheless, be considered as important. The model selection process did not include headline height for 1999, only depth was important. Also headline height showed only as a weak trend in the residual plots for 1999. The range of headline heights for 1999 was much less than for 1998 (4 to 5.5m in 1999 against 3 to 5.25m in 1998). Also the total number of samples in the subset was less in 1999. Either or both factors may have contributed to the failure to detect a clear signal for the 1999 data. Of course, it must be conceded that there may, in fact, be no detectable signal in 1999.

The conclusions from this study are clear. There was compelling evidence of systematic changes in gear geometry with increasing depth. Deeper tows were characterised by wider spread and lower headline height. There were indications from the analysis that headline height at least was important in one of the years as an explanatory variable for haddock abundance. This analysis represents a preliminary approach to this area of study. We used the actual calculated swept area in these analyses; however, this factor itself incorporates variability in wing spread AND distance towed. Inclusion of both these in the modelling may be more revealing. The combination of a small data set and a large depth variation militated against successful partitioning of the variance. One possibility would be to repeat this study using data from the IBTS in the North Sea where more data would be available over a wider and with less depth variation. Given the assumptions involved in swept area surveys these findings must give reason for disquiet and encourage further research.

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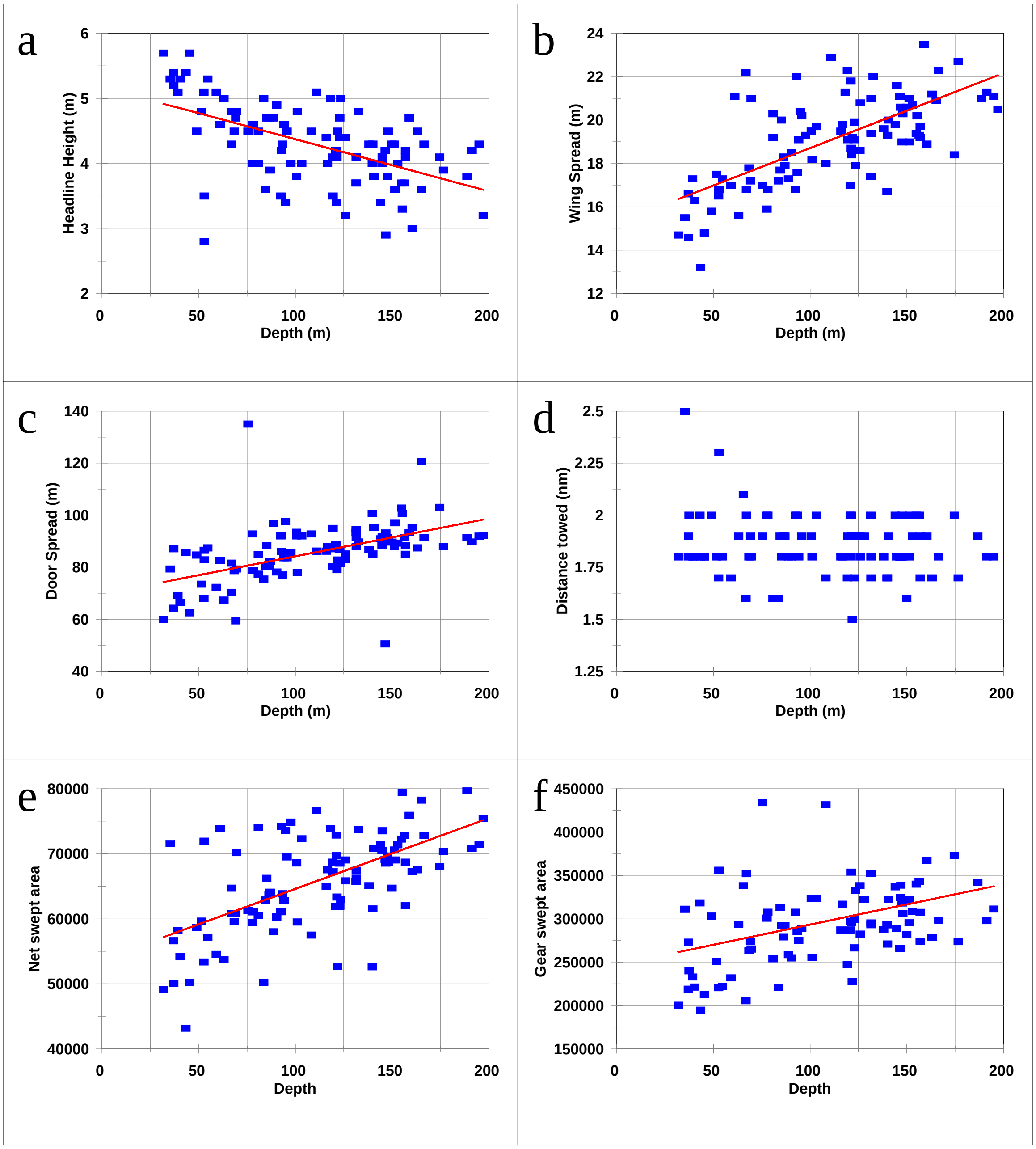


**Figure 1. Scatter plots and regressions for the six main gear parameters recorded on the two Scottish surveys. a. Headline height b. Wing spread c. Door spread d. Distance towed e. Net swept area & f. Gear swept area.**

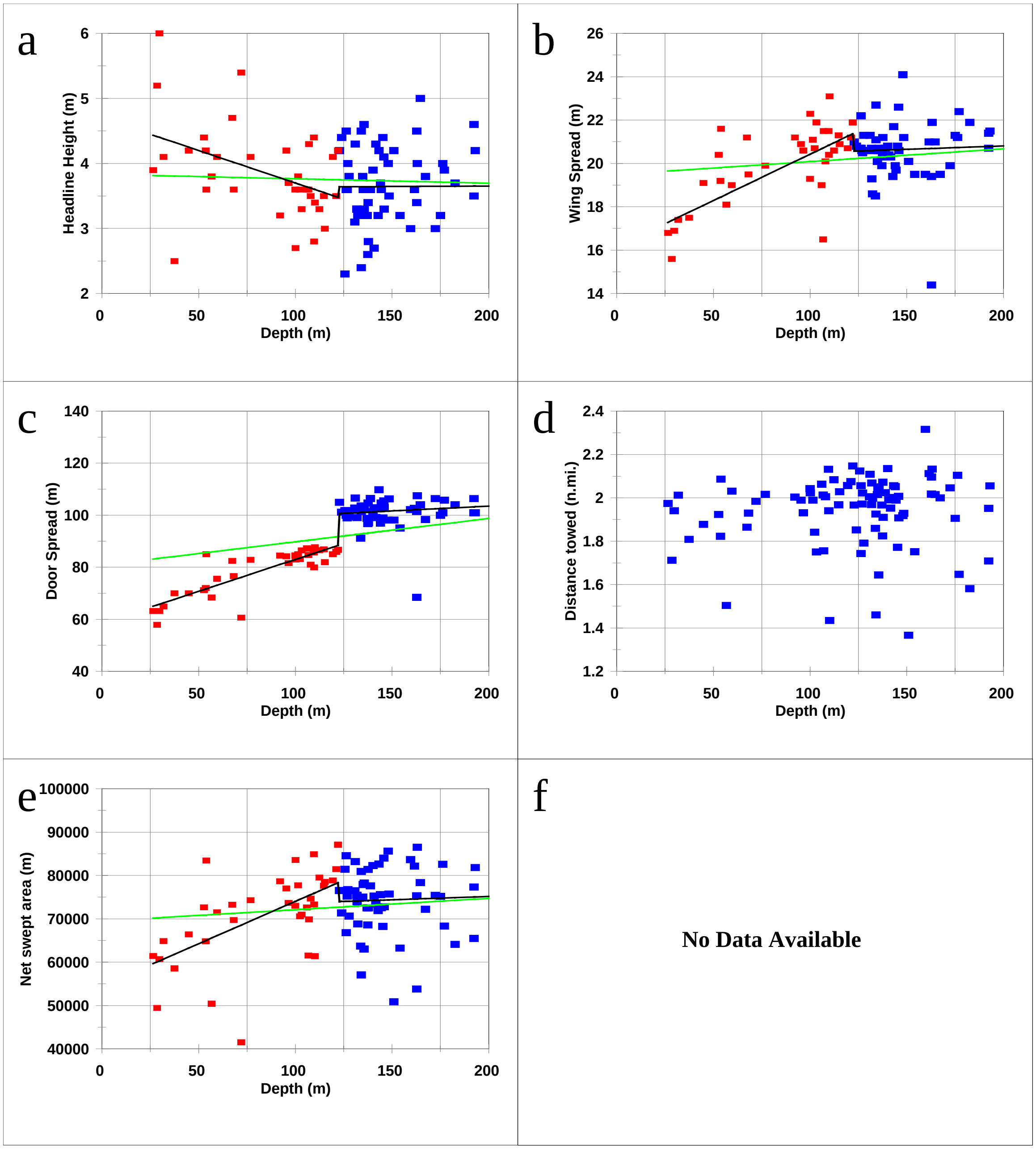


**Figure 2. Scatter plots and regressions for the six main gear parameters recorded on the French survey. a. Headline height b. Wing spread c. Door spread d. Distance towed e. Net swept area & f. Gear swept area.**

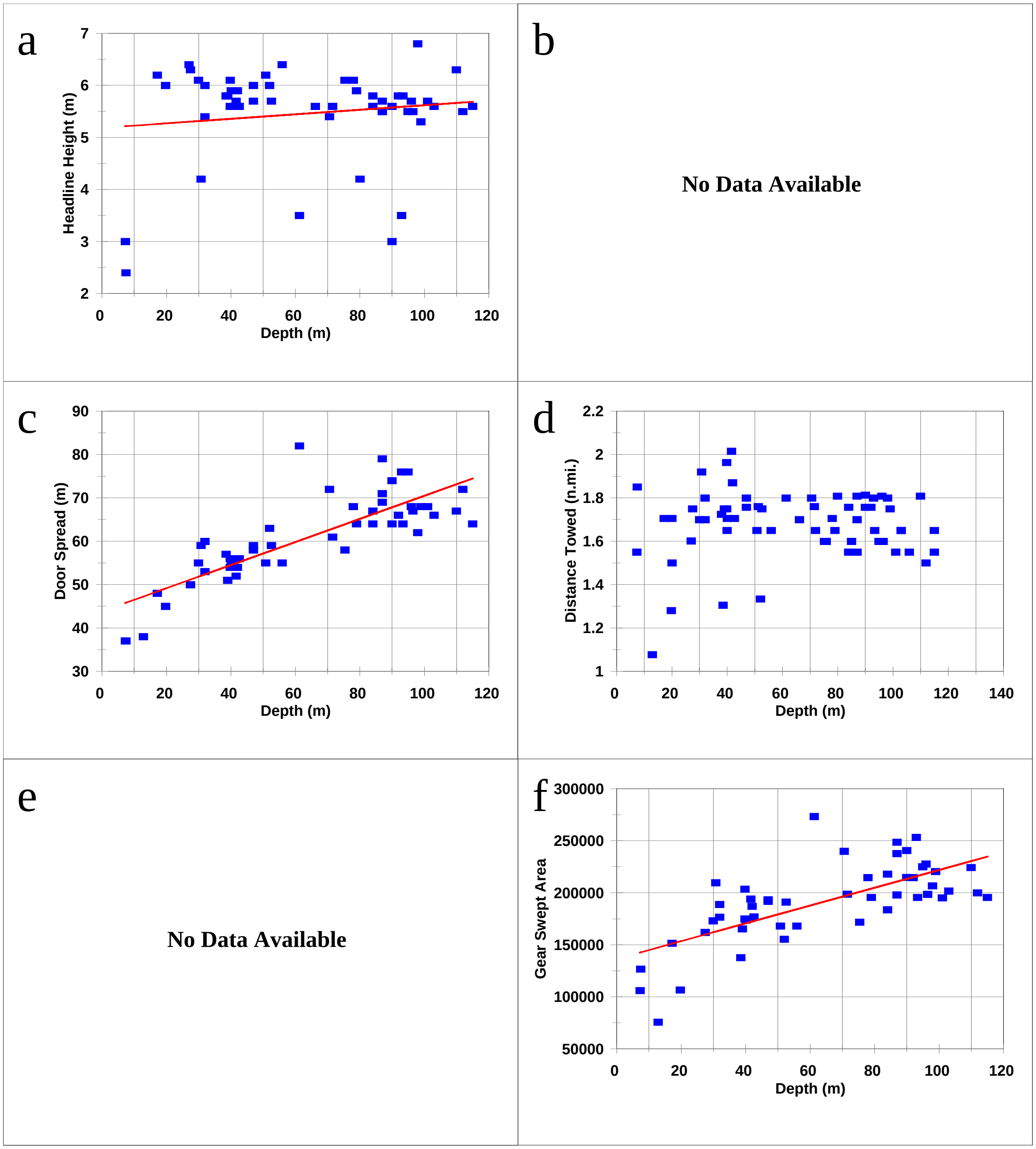


**Figure 3. Scatter plots and regressions for the six main gear parameters recorded on the Irish survey. a. Headline height b. Wing spread c. Door spread d. Distance towed e. Net swept area & f. Gear swept area.**

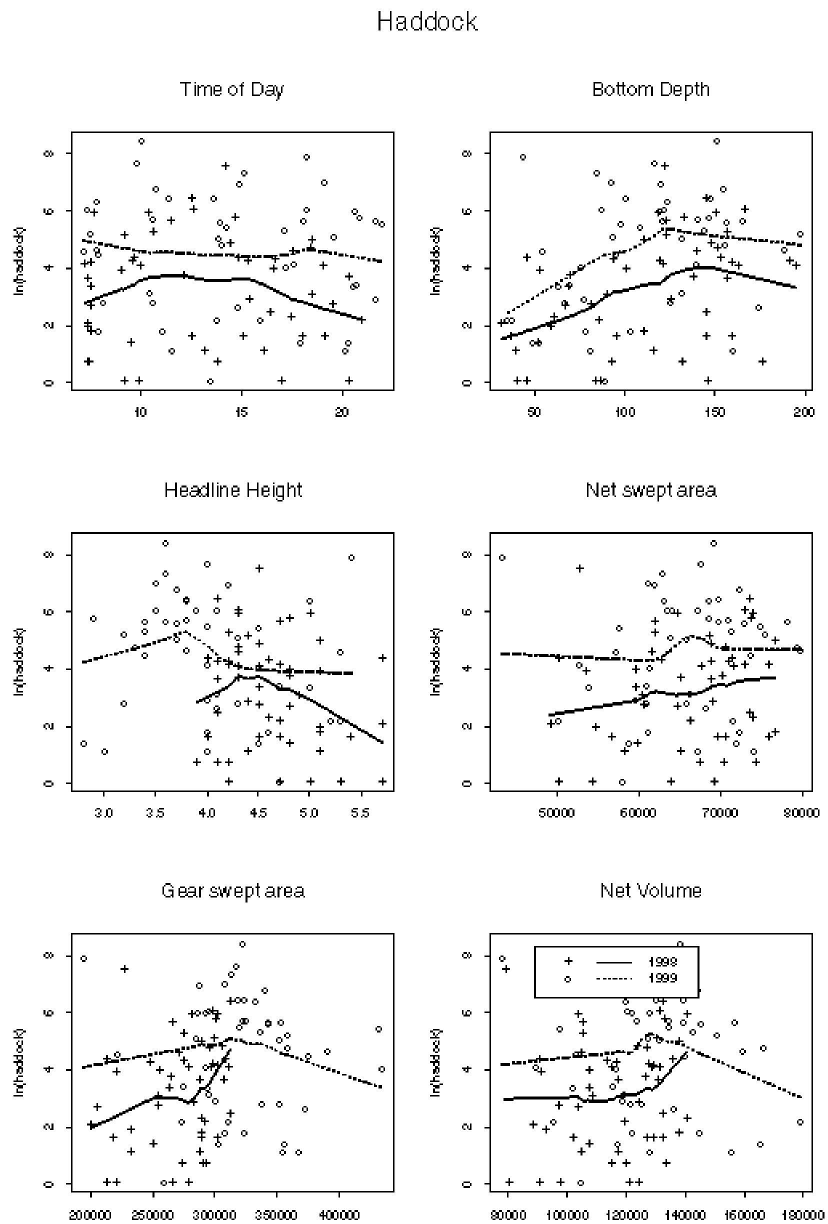


**Figure 4. Haddock catch rates in 1998 and 1999 as a function of six covariates**

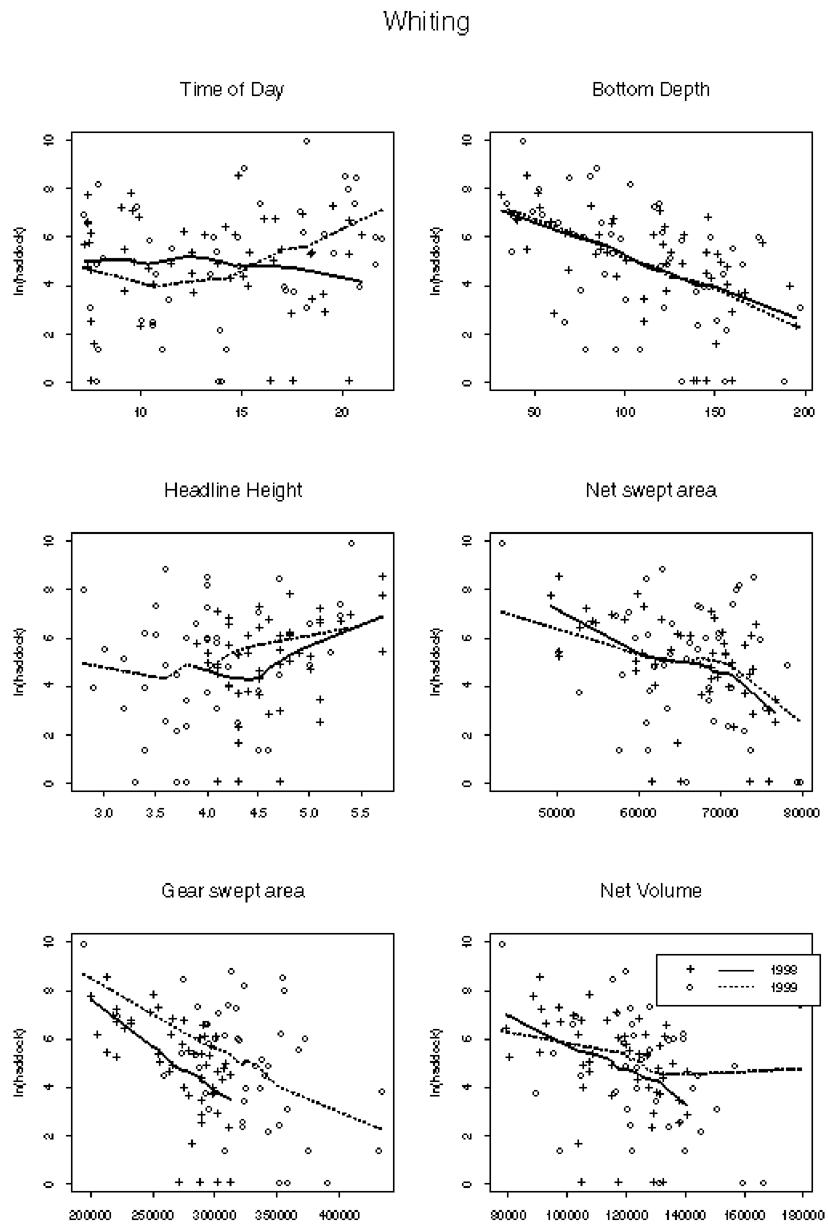


**Figure 5. Whiting catch rates in 1998 and 1999 as a function of six covariates**

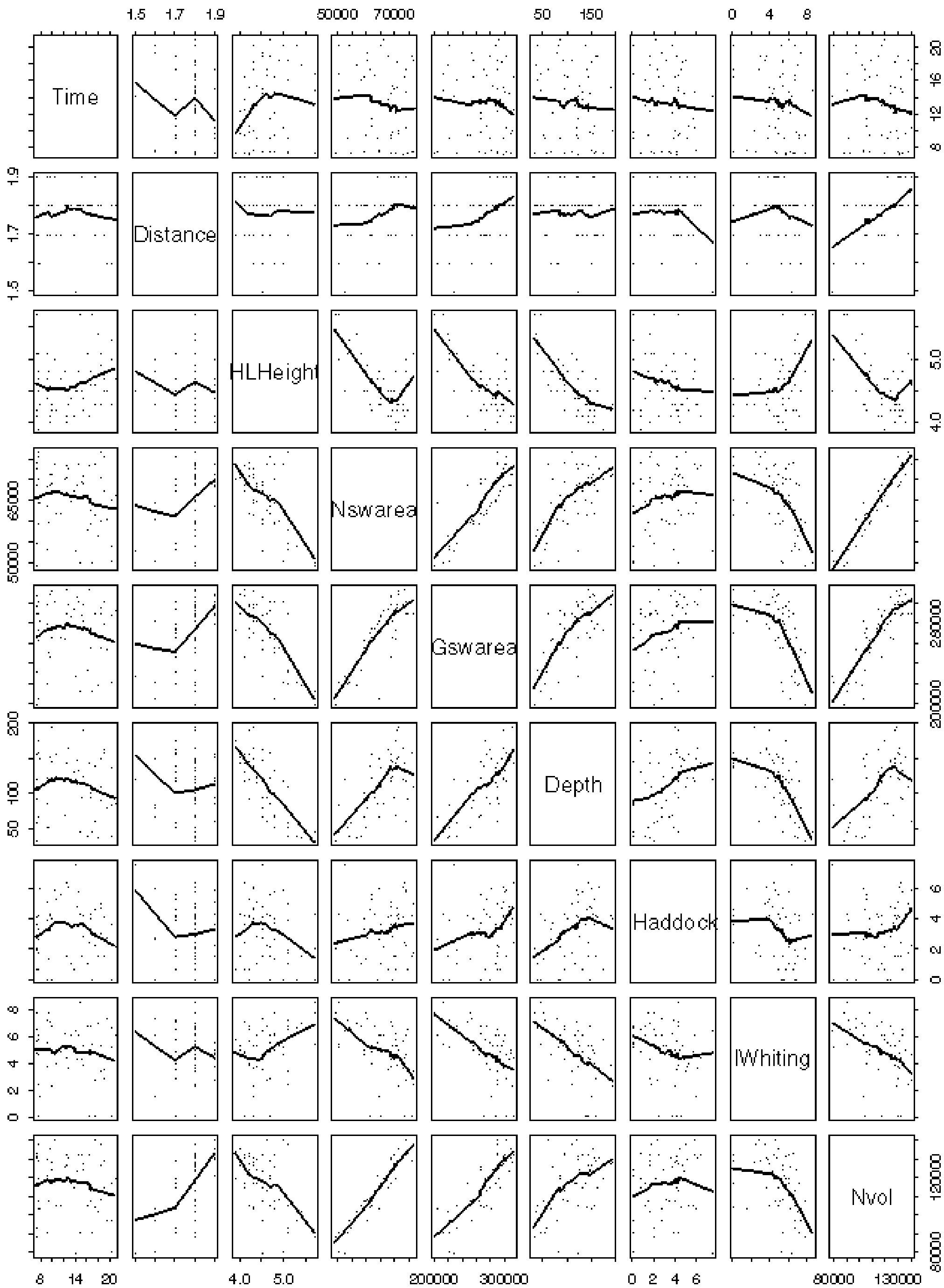


**Figure 6. Multiple pair-wise plots of all variables for the 1998 data with smooths**

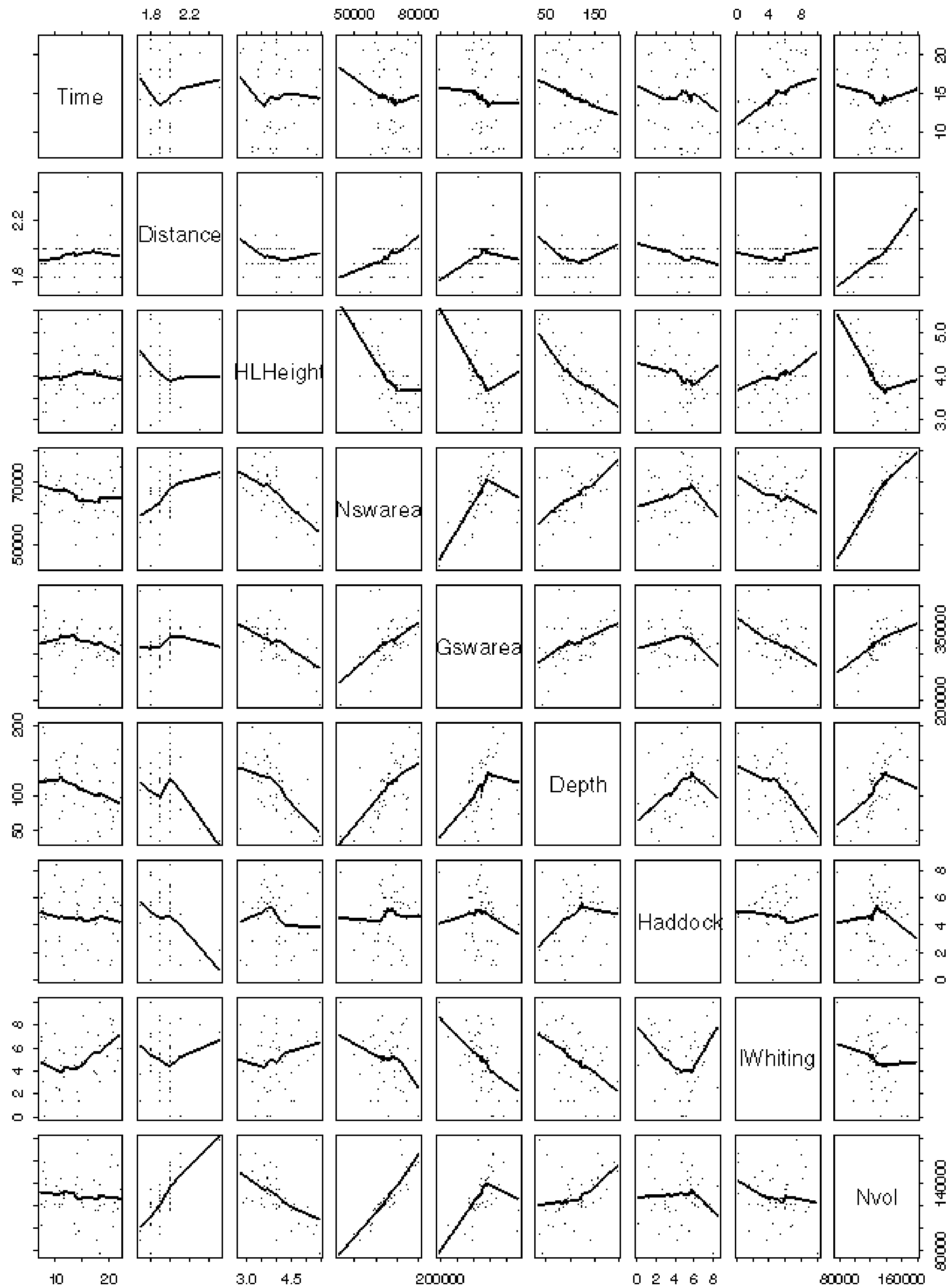


**Figure 7. Multiple pair-wise plots of all variables for the 1999 data with smooths**

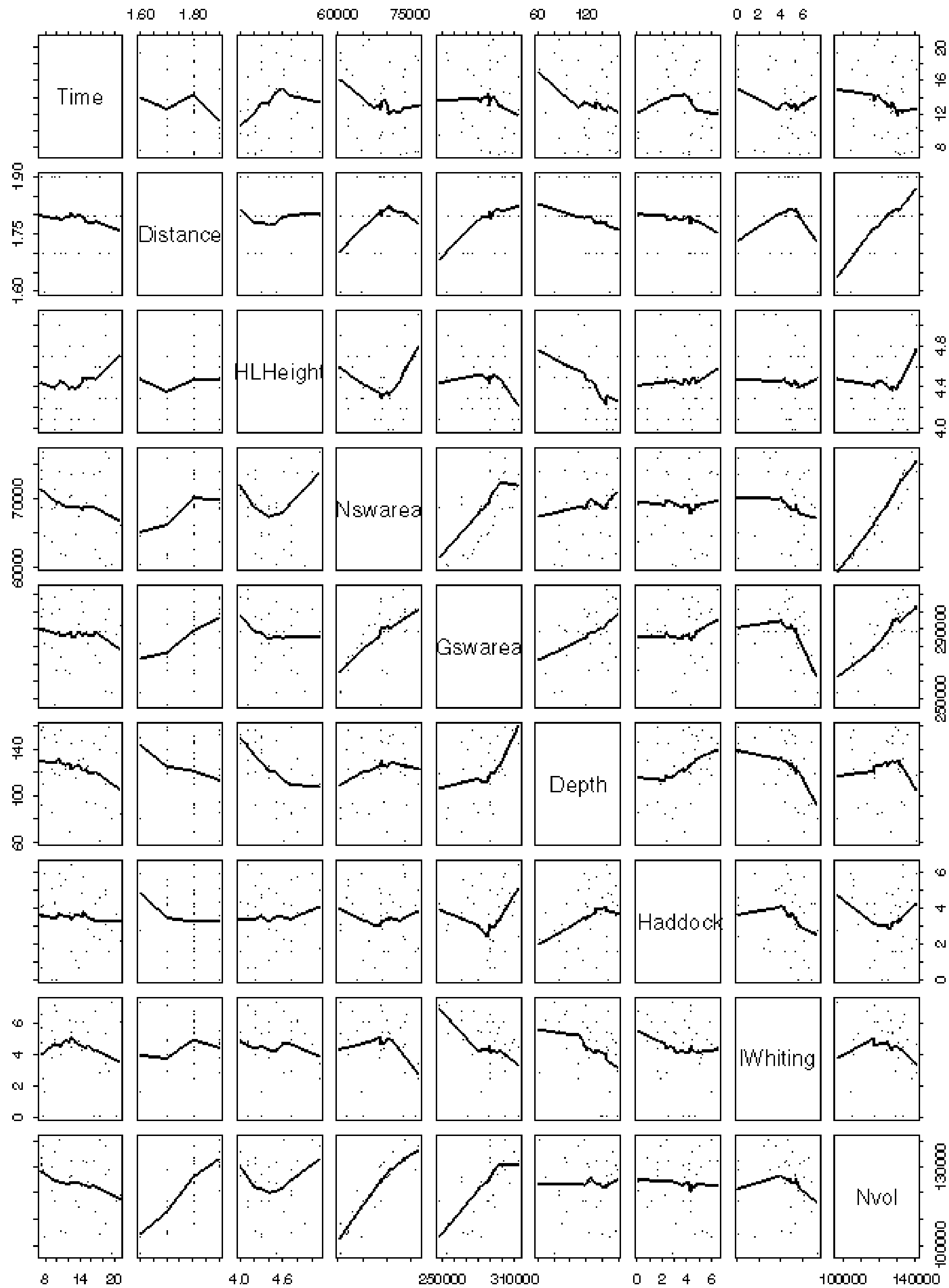


**Figure 8. Multiple pair-wise plots of all variables for the 1998 subset data with smooths**

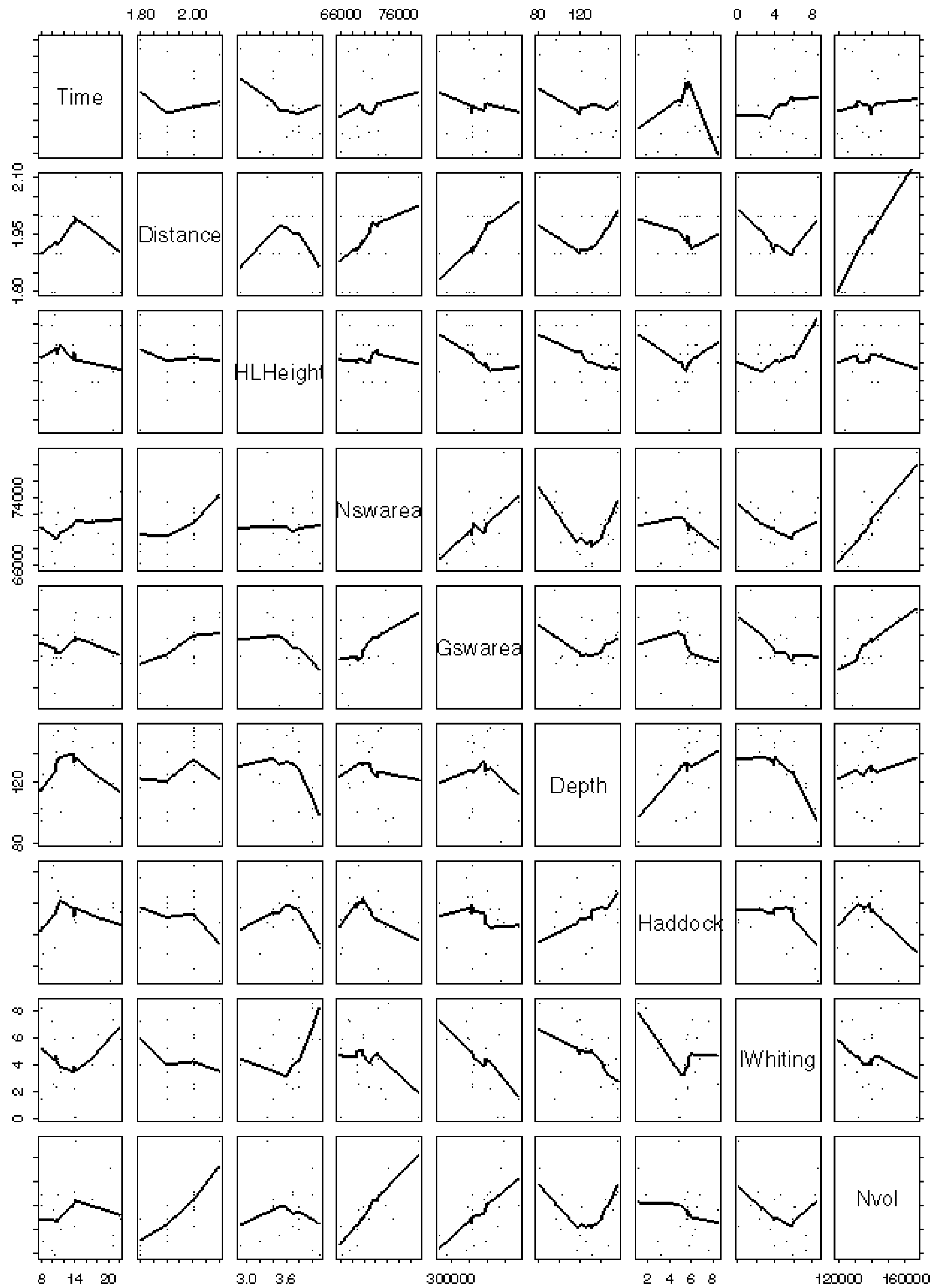


**Figure 9. Multiple pair-wise plots of all variables for the 1999 subset data with smooths**

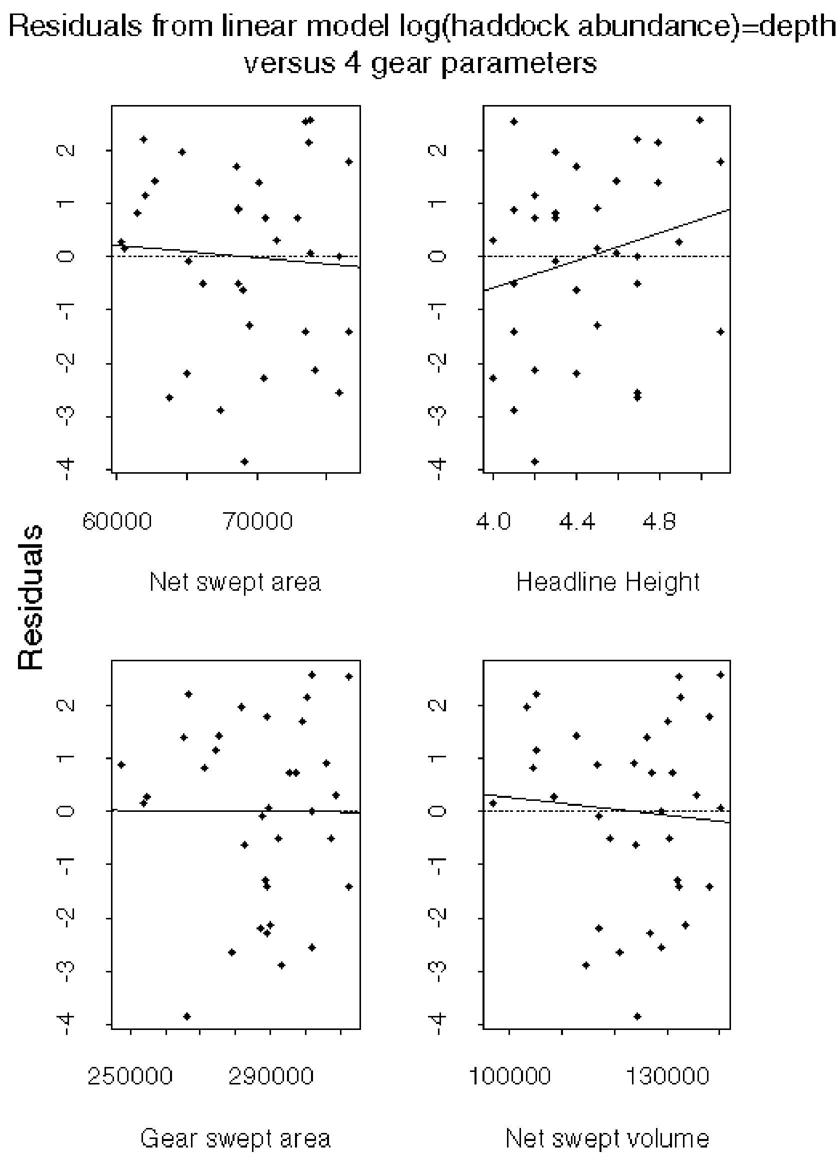


**Figure 10. Partial regressions of depth model residuals against gear parameters for the 1998 data. Horizontal lines represent the mean of the data, sloped lines are the partial regressions**

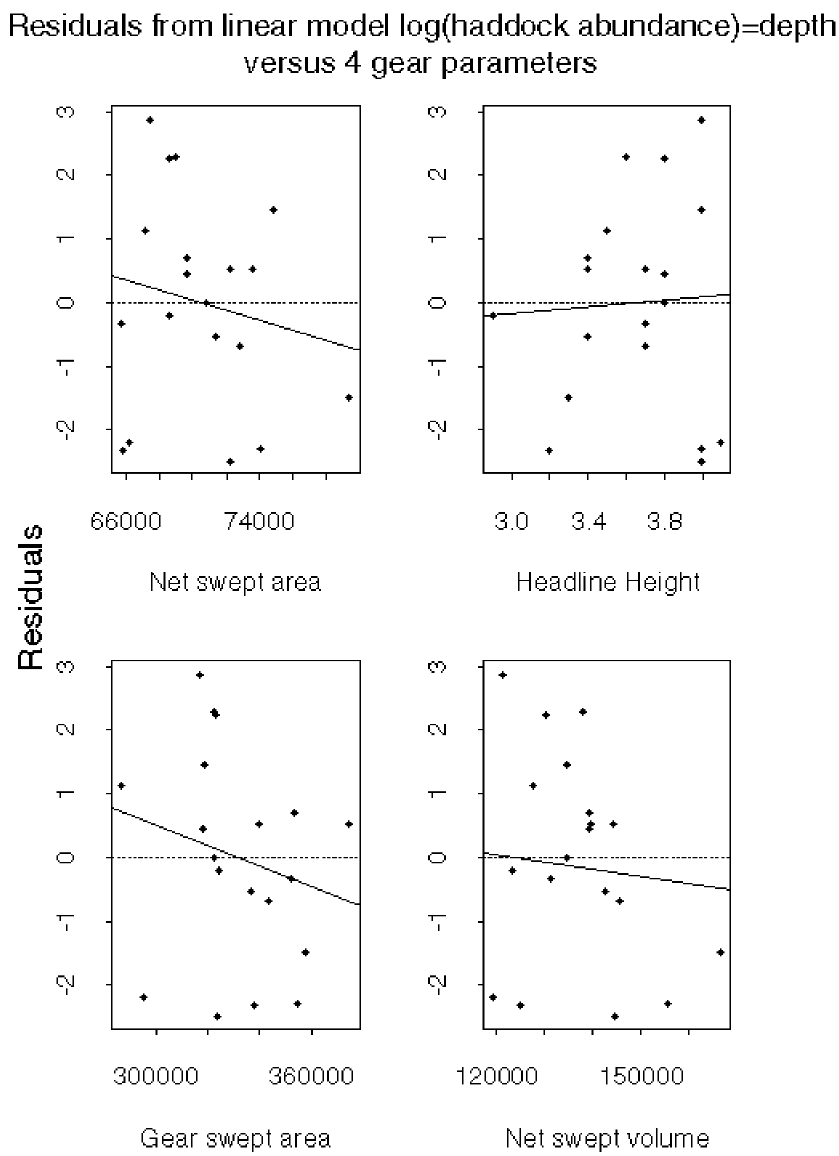


**Figure 11. Partial regressions of depth model residuals against gear parameters for the 1999 data. Horizontal lines represent the mean of the data, sloped lines are the partial regressions**

Table 1. Summary of trawl surveillance data for the two Scottish surveys (pooled data).

| Parameter | $R^2$ | Slope | Value at 25m | Value at 200m | Change | Change % |
|---|---|---|---|---|---|---|
| **Headline Height** | 0.210 | -0.008 | 5.00 | 3.58 | 1.42 | 39.7 |
| **Wing Spread** | 0.444 | 0.035 | 16.13 | 22.25 | 6.12 | 27.5 |
| **Door Spread** | 0.293 | 0.145 | 73.34 | 98.72 | 25.38 | 25.7 |
| **Net Swept Area** | 0.362 | 108.74 | 56450 | 75480 | 19030 | 25.2 |
| **Gear Swept Area** | 0.192 | 465.91 | 258433 | 339966 | 81533 | 31.55 |

Table 2. Summary of trawl surveillance data for the French survey.

| Parameter | $R^2$ | Slope | Value at 25m | Value at 125m | Change | Change % |
|---|---|---|---|---|---|---|
| | **Short sweeps – depths < 125m** | | | | | |
| **Headline Height** | 0.184 | -0.01 | 4.45 | 3.45 | 1.00 | 28.99 |
| **Wing Spread** | 0329 | 0.043 | 17.22 | 21.52 | 4.30 | 19.98 |
| **Door Spread** | 0.731 | 0.245 | 64.63 | 89.08 | 24.45 | 27.45 |
| **Net Swept Area** | .0344 | 195.07 | 59381 | 78888 | 19507 | 24.73 |
| **Gear Swept Area** | na | na | na | na | na | na |
| | **$R^2$** | **Slope** | **Value at 125m** | **Value at 200m** | **Change** | **Change %** |
| | **Long sweeps – depths > 125m** | | | | | |
| **Headline Height** | .001 | 0.001 | 3.64 | 3.66 | 0.02 | 0.55 |
| **Wing Spread** | 0.069 | 0.003 | 20.58 | 20.82 | 0.24 | 1.15 |
| **Door Spread** | 0.349 | 0.037 | 100.93 | 103.88 | 2.95 | 2.84 |
| **Net Swept Area** | 0.044 | 15.15 | 74092 | 75304 | 1212 | 1.61 |
| **Gear Swept Area** | na | na | na | na | na | na |

Table 3. Summary of trawl surveillance data for the Irish survey.

| Parameter | $R^2$ | Slope | Value at 25m | Value at 125m | Change | Change % |
|---|---|---|---|---|---|---|
| **Headline Height** | 0.015 | 0.004 | 5.29 | 5.73 | 0.44 | 7.68 |
| **Wing Spread** | na | na | na | na | na | na |
| **Door Spread** | 0.661 | 0.267 | 50.50 | 77.15 | 26.65 | 34.54 |
| **Net Swept Area** | na | na | na | na | na | na |
| **Gear Swept Area** | 0.480 | 854.06 | 157874 | 243280 | 85406 | 35.11 |

# Annex II

## Appendix II. Species codes identified in the study and their scientific and English common names.

| IFREMER code | Code | Scientific name | English common name |
|---|---|---|---|
| ACAN-PAL | SRW | *Acantholabrus palloni* | Scale-rayed wrasse |
| AGON-CAT | POG | *Agonus cataphractus* | Pogge (Armed bullhead) |
| ALLO-TEZ | ATS | *Alloteuthis subulata* | |
| AMMO-TOB | TSE | *Ammodytes tobianus* | Sandeel |
| ARGE-SPH | ARG | *Argentinidae* | Argentines |
| ARNO-IMP | ISF | *Arnoglossus imperialis* | Imperial scaldfish |
| ARNO-LAT | SDF | *Arnoglossus laterna* | Scald fish |
| ASPI-CUC | GUR | *Aspitrigla cuculus* | Red gurnard |
| BUGL-LUT | SOT | *Buglossidium luteum* | Solenette |
| CALL-LYR | CDT | *Callionymus lyra* | Common dragonet |
| CALL-MAC | SDT | *Callionymus maculatus* | Spotted dragonet |
| CANC-PAG | CRE | *Cancer pagurus* | Edible crab |
| CAPR-APE | BOF | *Capros aper* | Boar fish |
| CEPO-RUB | RPF | *Cepola rubescens* | Red bandfish |
| CLAM-OPE | QSC | *Chlamys opercularis* | Queen scallop |
| CLUP-HAR | HER | *Clupea harengus* | Herring |
| CONG-CON | COE | *Conger conger* | European conger eel |
| ECHI-VIP | WEL | *Trachinus (echiichthys) vipera* | Lesser weever fish |
| ELED-CIR | EDC | *Eledone cirrosa* | Curled octopus |
| ENCH-CIM | FRR | *Enchelyopus cimbrius* | Four-bearded rockling |
| ENGR-ENC | ANE | *Engraulis encrasicolus* | European anchovy |
| EUTR-GUR | GUG | *Eutrigla gurnardus* | Grey gurnard |
| GADU-MOR | COD | *Gadus morhua* | Cod |
| GAID-VUL | TBR | *Gaidropsarus vulgaris* | Three-bearded rockling |
| GALE-GAL | GAG | *Galeorhinus galeus* | Tope shark |
| GLYP-CYN | WIT | *Glyptocephalus cynoglossus* | Witch |
| HELI-DAC | RBM | *Helicolenus dactylopterus* | Blue-mouth redfish |
| HIPP-PLA | PLA | *Hippoglossoides platessoides* | Long rough dab (American plaice) |
| ILLE-COI | | *Illex coindetti* | Squid |
| LEPI-WHI | MEG | *Lepidorhombus whiffiagonis* | Megrim |
| LESU-FRI | | *Lesueurogobius friesii* | |
| LIMA-LIM | DAB | *Limanda limanda* | Dab |
| LOLI-FOR | NSQ | *Loligo forbesi* | Northern squid |
| LOPH-BUD | WAF | *Lophius budegassa* | Black-bellied anglerfish |
| LOPH-PIS | MON | *Lophius piscatorius* | Anglerfish (Monk) |
| MACR-PUB | MLP | *Macropipus (liocarcinus) puber* | Velvet swimming crab |
| MAJA-SQU | SCR | *Maia squinado* | Spiny spider crab |
| MELA-AEG | HAD | *Melanogrammus aeglefinus* | Haddock |
| MERL-MCC | HKE | *Merluccius merluccius* | European hake |

**Appendix II (continued).** Species codes identified in the study and their scientific and English common names.

| IFREMER code | Code | Scientific name | English common name |
|---|---|---|---|
| MERL-MNG | WHG | *Merlangius merlangus* | Whiting |
| MICR-KIT | LEM | *Microstomus kitt* | Lemon sole |
| MICR-POU | WHB | *Micromesistius poutassou* | Blue whiting |
| MICR-VAR | TBS | *Microchirus variegatus* | Thickback sole |
| MOLV-MOL | LIN | *Molva molva* | Common ling |
| MULL-SUR | MUR | *Mullus surmuletus* | Red mullet |
| NEPH-NOR | NEP | *Nephrops norvegicus* | Norway lobster |
| PECT-MAX | SCE | *Pecten maximus* | Escallop |
| PHRY-NOR | KT | *Phrynorhombus norvegicus* | |
| PHYC-BLE | GFB | *Phycis blennoides* | Greater forkbeard |
| PLAT-FLE | FLE | *Platichthys flesus* | Flounder (European) |
| PLEU-PLA | PLE | *Pleuronectes platessa* | European plaice |
| POMA-MIN | SDG | *Pomatoschistus minutus* | Sand goby |
| PSET-MAX | TUR | *Scophthalmus maximus* | Turbot |
| RAJA-BRA | BLR | *Raja brachyura* | Blonde ray |
| RAJA-CLA | THR | *Raja clavata* | Thornback ray (Roker) |
| RAJA-FUL | SHR | *Raja fullonica* | Shagreen ray |
| RAJA-MON | SDR | *Raja montagui* | Spotted ray |
| RAJA-NAE | CUR | *Raja naevus* | Cuckoo ray |
| ROSS-MAC | ROM | *Rossia macrosoma* | |
| SCOM-SCO | MAC | *Scomber scombrus* | (European) mackerel |
| SCOP-RHO | BLL | *Scophthalmus rhombus* | Brill |
| SCYL-CAN | LSD | *Scyliorhinus canicula* | Lesser spotted dogfish (Rough hound) |
| SCYL-STE | DGN | *Scyliorhinus stellaris* | Nurse hound |
| SEPI-ELE | SEE | *Sepia elegans* | Cuttle-fish |
| SEPI-OLZ | SEP | *Styela partita* | |
| SOLE-VUL | SOL | *Solea solea (S. vulgaris)* | Sole (Dover sole) |
| SPRA-SPR | SPR | *Sprattus (clupea) sprattus* | Sprat |
| SQUA-ACA | DGS | *Squalus acanthias* | Spurdog |
| SYNG-ACU | GPF | *Syngnathus acus* | Great pipefish |
| TODA-EBL | OME | *Ommastrephes (todaropsis) eblanae* | |
| TRAC-TRU | HOM | *Trachurus trachurus* | Horse-mackerel (Scad) |
| TRIG-LAS | GUS | *Trigloporus lastoviza* | Streaked gurnard |
| TRIG-LUC | TUB | *Trigla lucerna* | Tub gurnard |
| TRIG-LYR | PIP | *Trigla lyra* | Piper |
| TRIS-ESM | NOP | *Trisopterus esmarki* | Norway pout |
| TRIS-LUS | BIB | *Trisopterus luscus* | Whiting-pout (Bib) |
| TRIS-MIN | POD | *Trisopterus minutus* | Poor cod |
| ZEUS-FAB | JOD | *Zeus faber* | John dory |