Pelagic Fish Committee

ICES CM 1997/H:5



REPORT OF THE

# PLANNING GROUP FOR HERRING SURVEYS

Aberdeen, United Kingdom
24–28 February 1997

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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK-1261 Copenhagen K Denmark

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# 1 INTRODUCTION

## 1.1 Terms of reference

The planning group for herring surveys will meet in Aberdeen, UK, from 24 to 28 February 1997 to:

a) Coordinate the timing and area allocation of, and methodologies for, acoustic and larvae surveys for herring in the North Sea Divisions VIa and IIIa, and the Western Baltic;

b) Combine the survey data to provide estimates of abundance for the populations within the area;

c) Evaluate the usefulness of the herring acoustic time series with respect to North Sea assessment;

d) Discuss the outcome of studies of the consequences of reduced effort and area coverage for the herring larvae surveys;

e) Define future data processing needs for combining proposed acoustic and larvae surveys data from different countries and where this should be carried out over the next few years;

f) Develop a proposal for a survey plan for acoustic and larvae surveys which will provide data required for future North Sea assessments.

## 1.2 Participants

| | |
|---|---|
| Martin Bailey | United Kingdom |
| Bram Couperus | Netherlands |
| Paul Fernandes | United Kingdom |
| Eberhard Götze | Germany |
| Nils Håkansson | Sweden |
| Cornelius Hammer | Germany |
| Kenneth Patterson | United Kingdom |
| David Reid | United Kingdom |
| John Simmonds (Chairman) | United Kingdom |
| Karl-Johan Stæhr | Denmark |
| Reidar Toresen | Norway |
| Else Torstensen | Norway |

## 1.3 An outline of the problem in the assessment

North Sea herring stock assessments from 1990 onwards show a systematic overestimation of the spawning stock biomass (Anon, 1996a). During the years 1990 to 1995, the spawning stock biomass estimates (and consequent catch forecasts) have been revised successively downwards. The reasons for this were thought to be associated at least in part with anomalously low acoustic survey observations in 1987 and 1988, followed by relatively higher observations in the period 1989 to 1995. Revisions in the assessments are shown in Figure 1, which also shows the trend in acoustic survey stock size estimates for comparative purposes. After 1989, the acoustic survey biomass estimates are much higher than the assessment working group's population model estimates, whereas before 1988 the estimates are rather similar.

The assessment working group identified an increase in acoustic survey efficiency, and possible misreporting of catches as plausible factors as probable cause for this overestimation. In consequence, the assessment working group recommended improved provision of information on catches and on survey estimates of stock size.

# 2 REVIEW OF THE SURVEY TIME SERIES

Four studies were presented:

- A review of the amplitude distributions from the acoustic surveys in the Orkney-Shetland area from 1988 to 1996. The review is documented as Appendix A to the report;

- A review of the spatial distribution of abundance for the full sequence of acoustic surveys from 1984 to 1996. The data from all surveys has been entered as numbers and biomass at age and maturity by ICES statistical rectangle and is available as a series of Excel spreadsheets. The spawning stock abundance and biomass are documented in Appendix B to the report;
- A review of the acoustic survey time series age disaggregated index with reference to the IBTS age disaggregated index. This review is included as Appendix C to the report;
- A missing catch stock model was presented, this is included as Appendix D to the report.

## 2.1 Results of the studies

### 2.1.1 The review of amplitude distributions from Orkney-Shetland area

A number of conclusions were presented:

1. The ratio of the number of zero and minimum class values changed through the period of study; the number of zero values increased.
2. The skew factor for the distribution increased during the period of the study.
3. The number of zero rectangles was greater after 1990.

Items 1 and 3 are incompatible with an increase in abundance due to changes in data treatment or due to changes in the mean as an estimator of the stock abundance value. However, there is a possibility that item 2 may be caused by underestimation of the largest schools in the early years due to saturation of the highest signals in the electronics, this could explain a change in survey efficiency between 1990 and 1991.

### 2.1.2 The distribution of abundance from acoustic surveys

The distribution maps show important changes in distribution both across the North Sea and east and west of Shetland. The maps show that the survey in 1988 had substantial high values on the northern boundary and this may have given rise to a low estimate in this year due to a lack of coverage.

The distribution shows some year to year variation in the abundance in the area west of Orkney- Shetland and north of the Minch. There is uncertainty as to the correct allocation of these fish to the North Sea or west of Scotland stocks.

### 2.1.3 Comparison between acoustic survey and IBTS time series

The ratio of the acoustic index with the IBTS from 1987 to 1994 shows considerable fluctuation with a low point in 1988, resulting in a factor of 1.7 or 1.2 between observations at the ends of this period. The difference depends on the method used to combine the year classes. The differences over the full available time series from 1984 to 1994 indicates a factor between 1.4 to 0.7 from the mid 1980s to the early 1990s. The study also examined the precision for the estimates of year-class strength, these are not of high quality but do suggest that there is considerable overlap in the series and the acoustic series provides a more precise estimate of year-class strength at 2 to 4 ring.

### 2.1.4 Missing catch model

A population model similar in structure to the working group's assessment model, but excluding catch information, was used to investigate whether the perceptions of increasing catchability in the acoustic survey biomass estimate are dependent on using reported catches in a VPA-type model structure. Some estimates of the variability in different data series were calculated. Detailed methodology and results are reported in Appendix D.

The following inferences were drawn from the model fits:

1. The perception of increasing catchability with time for the acoustic survey biomass estimates (with respect to larvae surveys, to the IBTS index, or even to the acoustic survey age-structure alone) remained, even when reported catches, though not catch age structure, are excluded from the stock assessment model.

2. In terms of measures of variability in abundance estimates, the IBTS abundance index performs best, the acoustic survey abundance index performs worst, and the performance of the MLAI index is intermediate.

3. In terms of measures of between-year correlation in errors in abundance, which may be more important in terms of providing advice for management purposes, the IBTS survey is unlikely to have error correlation (P=0.97), the acoustic survey is very likely to have correlated errors (P=0.02) and the MLAI index is somewhat less likely to have correlated errors (P = 0.06).

4. In terms of estimating the age-structure of either the catch or the stock, the acoustic survey performs best, it has the largest effective sample size (smallest t2), the IBTS performs worst, it has the smallest effective samples size, and the sampling of commercial catches is intermediate.

Overall the model suggests that the most reliable sources of information are the acoustic survey estimates of age-structure and the IBTS spawning biomass estimates. These inferences are of course predicated on the assumptions detailed in Appendix D (Section 2.1), and rely on ignoring process errors (eg changes in selection pattern, changes in natural mortality, etc).

# 3 USE OF HERRING ACOUSTIC SURVEY IN ASSESSMENT

## 3.1 Remaining unanswered questions

a) Why is the age structure from the acoustic survey the most precise age index while the abundance index is the most divergent, when the abundance estimates are used to derive the age structure for a stock with spatially variable age structure?

b) Why does the IBTS abundance index perform best, during a period with changing adult age structure, when it is dominated by a single year class because it is derived from a survey with a fishing gear with a steep age selection function?

c) Why does the acoustic abundance index which shows the least year to year fluctuation give a stock trajectory that is different from other indices?

## 3.2 Conclusions from the studies

a) The problem of divergent indices is still present when the effect of the magnitude of unreported catch, with a linear increasing fishing mortality, is included in the analysis.

b) The acoustic survey and the IBTS survey indices may be more self consistent than all the indices combined.

c) There was a general increase in the frequency of zero values (2.5 Nm sample values) in the acoustic survey of the Orkney-Shetland area during the period 1987 to 1995. This would indicate a tendency to underestimate the population. The increase in skew in the amplitude distributions during this period could be caused by signal saturation for large schools, and thus could explain underestimation during this period.

# 4 ADVICE AND FUTURE WORK TO RESOLVE THE PROBLEMS

a) There is a need to investigate the importance in the survey time series of abundance changes to the west of Orkney-Shetland and north of the Minch. If these are important the age and length structure of herring should be investigated and these should be used to advise on the split between North Sea and west coast herring

b) An examination of the depth distribution of herring over the survey period should be carried out. These should be investigated in the light of the possible depth dependance of herring target strength, to estimate possible abundance changes over the survey period.

c) The use of General Additive Models (GAMs) on age disaggregated spatial distributions of herring from acoustic and IBTS surveys should be examined to see if these can be helpful.

d) Inferences drawn from the age structure and abundance indices may differ. This requires care when the indices are used in the assessment.

e) Perceptions of series divergence are dependant on the years, age ranges, and year class weighting given to different year classes.

f) There is a need to carry out studies of the implications of saturation in the electronics on surveys prior to 1991.

g) There is a need to increase confidence in the compatibility of multiple surveys used in the North Sea, Western Baltic and VIa. For this purpose it is proposed to include intercalibration during the survey, to exchange data on length and age distributions from hauls carried out during one year (1995) and to hold a workshop to study the interpretation stage of acoustic survey echo sounder output allocation to herring.

## 5 REVIEW OF LARVAE SURVEYS

The substantial decline in ship time and sampling effort allocated to the herring larvae surveys in recent years required a study of the effects on the estimates of larvae abundance and production derived from these surveys. The first step of this analysis was presented, considering a reduction in the number of subareas to be sampled and the required frequency of intermediate complete surveys (see Appendix E).

From the presentation and discussion of this study and comparison with results from a multiplicative model for the abundance index LAI, the following main conclusions can be drawn:

1. There is no long term stability in the relative importance of the different spawning areas and therefore the assumptions required for the multiplicative model used to overcome the problem of missing values in the data sets are not valid when based on extended time periods. The inclusion of interaction terms between survey areas may alleviate this problem.

2. For the calculation of abundance indices it would be prudent to concentrate effort on a few target areas rather than attempting to cover all spawning areas of the North Sea as has been done in the past. The precision of stock size estimates is not reduced when based on combined sampling results from Orkney-Shetland and Buchan or southern North Sea as compared to including all three areas or a complete coverage.

3. Complete coverage would nevertheless be required though less frequently, to observe long term trends in the relative importance of the different spawning areas and in the z/k values. From the multiplicative model there is evidence for temporal periodicity in the residuals of the larvae abundance values of the order of approximately 6-8 years. In order to study this periodicity, complete coverage would be required every three years.

4. The residuals in the multiplicative model for the abundance index (LAI) indicate that the results from different time periods within areas show differences similar to those between areas. It is thus not to be expected that a reduction in the survey frequency can be achieved without loss in precision of stock size estimates based on the LAI. For LPE one coverage may be sufficient, as has previously been suggested by the Herring Larvae Survey Working Group (Anon, 1990). This has to be reviewed, however, in the light of an additional reduction in the areas covered.

For the larvae surveys the Planning Group recommends:

1. Yearly surveys should focus on the southern North Sea as well as on the Orkney-Shetland and/or Buchan area. A more detailed analysis of the historical database is required to elucidate which of the two northern areas should receive a higher priority.

2. Efforts should be made to organise for a complete coverage every three years, out of phase with the mackerel egg survey, starting in 1999.

3. The effect of survey timing on larvae abundance indices and production estimates should be examined in more detail from the historical database, to confirm or disprove the indications so far available.

4. Reliability and changes of the z/k values should be studied as the LPE is especially sensitive to this parameter. A standard procedure to estimate z/k should be defined and the existing data series revised accordingly.

## 6 COORDINATION OF LARVAE SURVEYS

### 6.1 Surveys planned for 1997/98

| | | |
|---|---|---|
| Germany | 16-30 Sep 97 | Orkney-Shetland |
| Netherlands | 16-30 Sep 97 | Buchan |
| Netherlands | 01-15 Dec 97 | Southern North Sea |
| Germany | 01-15 Jan 98 | Southern North Sea |
| Netherlands | 16-31 Jan 98 | Southern North Sea |

### 6.2 Requirements for desired complete coverage in 1999/2000

| Area | Period | Stations | Time (days) |
|---|---|---|---|
| Orkney-Shetland | 01-15 Sep | 110 | *12 |
| | 16-30 Sep | 110 | 12 |
| Buchan | 01-15 Sep | 80 | *7 |
| | 16-30 Sep | 80 | *7 |
| Central North Sea | 01-15 Sep | 70 | *6 |
| | 16-30 Sep | 75 | *6 |
| | 01-15 Oct | 110 | *10 |
| | 16-31 Oct | 110 | *10 |
| Southern North Sea | 16-31 Dec | 60 | 5 |
| | 01-15 Jan | 90 | 8 |
| | 16-31 Jan | 90 | 8 |

Optimal complete coverage for calculating LAI and LPE would require a total of about 90 days survey time. The survey time required in addition to that presently available is indicated in the above table by * and amounts to about 58 days.

## 7 FUTURE DATA PROCESSING NEEDS FOR THE LARVAE SURVEYS

A copy of the herring larvae database has been successfully transferred and implemented in Rostock (Germany). An implementation in Kiel (Germany) is intended as soon as all required information has become available for rebuilding and checking the programmes for routine analyses of results from the yearly surveys. It is expected that the routine analysis and reporting can be provided from Kiel from 1999 onwards. At the 1997 ICES meeting it will be discussed and decided whether this task can be taken up at Kiel for the 1998/99 period.

## 8 COORDINATION OF ACOUSTIC SURVEYS

In 1997 the following surveys will be carried out in the North Sea and west of Scotland

| | | |
|---|---|---|
| Charter | 12 - 29 July | North of 56°30'N west of 3°W |
| Dana | 2 - 12 July | North of 57° east of 6°E |
| GO Sars | 28 June - 18 July | North of 57° east of 1°W with reduced effort east of 3°E |
| Scotia | 8 - 28 July | North of 58°30' between 4°W and 2°E |
| Tridens | 30 June - 18 July | South of 59°N west of 2°E |
| W Herwig | 23 June - 16 July | South of 57°N east of 2°E reduced effort between 2°-6°E |

The following survey will be carried out in the western Baltic.

| | | |
|---|---|---|
| Solea | 12 Sept - 2 Oct | ICES Sub-divisions 22, 23 and 24 |

## 9 FUTURE DATA PROCESSING NEEDS FOR ACOUSTIC SURVEYS

There are a number of developments requiring data processing, the need to deal more correctly with the herring abundance data, the need for a workshop on herring echogram scrutiny procedures and the need to exchange herring survey trawl data.

### 9.1 Herring abundance data

There is a need to reorganise the data collation in order to obtain better distribution maps and better overall combination of data. For this purpose, the planning group is organising the preparation of a herring survey database under an EU project ECHOHER.

For 1997, data on number and biomass of herring by ICES statistical rectangle and age/maturity proportion will be sent to John Simmonds in Aberdeen, Scotland. A blank Excel file will be provided. Data on Sprat will be sent to Else Torstensen in Arendal, Norway.

### 9.2 The workshop on scrutinising echograms

In undertaking a herring acoustic survey each country covers a separate area each with its specific characteristics, such as spatial distribution and bottom conditions. When analysing the data the scientist allocates acoustic signals to species (scrutinising). Thus decisions are made, based on experience gained by individual scientists during surveys in specific areas. This indicates a subjective input to the analysis process.

In order to improve data analysis, a synchronisation of the way data are interpreted is required. The planning group therefore recommends that a workshop on scrutinising be organised. It was suggested that this workshop should be held in Bergen, January 1998, during the next planning group for herring surveys meeting.

At this workshop every country participating in the international herring acoustic survey should bring national data for analysis. The data has to be the following:

- a data set, typical for the area, containing one survey day and an optional 12 hours of difficult problems;
- the paper output from the echosounder;
- the BI 500 files on tape (a scrutinised version and a blank version). These should be sent to IMR Bergen in August (8 mm Exabyte or QIC-150 format) for testing and control (contact Hans Peter Knudsen and Kaare A Hansen);
- the trawl data with the species composition (% in weight)*;
- weather conditions and notes on circumstances that may be relevant to the data.

*In areas where the bulk of the SA-values come from schools, the interpretation of the net-sounder traces in combination with actual trawl data are important, because the composition of the trawl may be different from the school composition. Here the interpretations of observations during the tow are subjective. Therefore detailed notes on trawl performance are required.

The different data sets will be analysed by a group of scientists from all countries involved and the results compared to provide a measure of the precision of the scrutinising process.

### 9.3 Intercalibration

It was decided by the planning group to utilise as many opportunities as possible for intercalibration during the 1997 surveys. In order to minimise the effect of spatial and temporal variability of herring abundance, the exercises are intended to be inter-ship calibrations, with the vessels running the same course at the same time. Since such an arrangement will require some extra time for cruising, which will inevitably reduce the coverage of the sampling area to some extent. This was judged to be acceptable.

The anticipated area for the first intercalibration is around 58°N and 0°E. The vessels scheduled to meet in the area are *GO Sars*, *Tridens* and *Walther Herwig III*. The *Walther Herwig* will leave port 23 June and will sail to its site for echo sounder calibration, presumably Kristiansand, Norway. After gear calibration she will sail to 58°N 02°E and will start surveying the area by covering transects in E-W direction up to 02°W. From then on she will cover transects 15 Nm apart in northern direction. Until the anticipated day of Intercalibration (1 July) *Walther Herwig* will have covered about eight statistical rectangles with probably relatively high fish abundance. The exact location of meeting for intercalibration will be determined after the area has been scrutinised and will be communicated to the other ships from *Walther Herwig* by radio. Radio contact will be established prior to the meeting at 10:30 UTC.

The vessels *Tridens* and *GO Sars* will attempt to reach the meeting point in the morning of 1 July. The Intercalibration will be carried out throughout the entire survey day, during which no fishing will take place.

A second calibration will be attempted between *Walther Herwig* and *Dana* after the completion of the first intercalibration. During 02 July *Walther Herwig* will sail eastward. Radio contact between *Walther Herwig* and *Dana* will be established 2 July UTC 1030 for agreement on the precise location of the meeting. This will be in the early morning of 3 July on the anticipated position 57°30'N and 06°00'E.

Further intercalibrations are anticipated between *GO Sars* and *Scotia* on/about 16 July and between *Scotia* and the west coast charter on/about 26 July. Details on timing and location will be arranged by radio contact between the two ships.

Details of various ships communications are provided in Appendix G.

#### 9.3.1 Procedure for the intercalibration of echosounders during the North Sea herring survey

The vessels should be positioned with one in front and the other 0.5 Nm behind at 5 on the starboard side. When three vessels take part simultaneously, the third vessel position will be 0.5 Nm behind the leading vessel, at 5 to the port side. In this situation the second and third vessel are steaming parallel.

The speed during the Intercalibration should be 10 knots or adapted to the vessel with the lowest practical integration speed. The integration should last for at least 12 hours. Due to the very limited time period, the intercalibration with *Dana* is restricted to 40 Nm.

The vessels take their relative positions and start sailing at the agreed speed and course. When the vessels are in a stable formation the, the leading vessel gives a start signal and starts his own logging. The other vessels start their logging after steaming 0.5 Nm. A synchronising signal should be given by the leading vessel every 5 Nm at which time all vessels should record their geographic position and annotate their echograms accordingly. The leading vessel should be changed frequently ensuring that each configuration is carried out at least twice during the procedure.

A sampling interval of 1 Nm should be used for integration. The integration should start at 10 m below water surface and the SA-values should preferably be stored by 10, 15, 20 or 25 metre layers depending on the intercalibration area so that 10 surface channels can be registered on one echogram. Threshold for the echogram should be set to -70 dB. Normal survey settings should be used for all other parameters.

### 9.4 Exchange of length and age data from trawl hauls

A study of the length frequency and age proportions of trawl hauls by different vessels in similar areas is to be undertaken. This study will take place in Aberdeen and results will be submitted to the HSPG meeting in January 1998. The data will be collated from all hauls which contained herring undertaken during the North Sea and VIa surveys of 1995. Each participating country will submit their data to Aberdeen by the end of April 1997. The format for exchange of data was discussed and is based on the exchange specifications for the IBTS data (Anon, 1996b). The agreed platform for data exchange was a spreadsheet in Microsoft Excel v5.0; a blank template spreadsheet was supplied to all participants (xxx_95tr.xls - participants should save data file as "ICES country code_95tr.xls"). A table detailing the entries of this spreadsheet is appended (Appendix F). The procedure for the analysis of the data will be determined in Aberdeen.

## 10 RECOMMENDATIONS

The planning group recommends that:

1. Due to inconclusive findings in an examination of the herring survey time series that further studies be carried out on:

   - the separation of west coast and North Sea herring stocks within the acoustic survey time series;
   - the depth related distribution of herring and its impact on the stock estimation;
   - the use of GAMs on acoustic and IBTS survey data;
   - an examination of pre-1991 surveys for possible under estimation due to signal saturation in the electronics.

2. The acoustic surveys should be continued with each participant covering the same general areas to maintain consistency and a number of steps be taken to improve quality assessment in the acoustic surveys:

   - surveys will include inter-ship calibration;
   - a study of variability of trawl performance between participants be carried out;
   - a workshop be held in Bergen in January 1998 to study variability in echogram scrutinising procedures between participants.

3. For the larvae surveys:

   a) Yearly surveys should focus on the southern North Sea as well as on the Orkney-Shetland and/or Buchan area. A more detailed analysis of the historical database is required to elucidate which of the two northern areas should receive a higher priority.

   b) Efforts should be made to organise for a complete coverage every three years, out of phase with the mackerel egg survey, starting in 1999.

   c) The effect of survey timing on larvae abundance indices and production estimates should be examined in more detail from the historical database, to confirm or disprove the indications so far available.

   d) Reliability and changes of the z/k values should be studied as the LPE is especially sensitive to this parameter. A standard procedure to estimate z/k should be defined and the existing data series revised accordingly.

4. The planning group for herring surveys should meet in Bergen, Norway from 19 to 23 January 1998 under the chairmanship of E J Simmonds to:

   a) Coordinate the timing and area allocation of and methodologies for acoustic and larvae surveys for herring in the North Sea Divisions VIa and IIIa and the Western Baltic;

b) Combine the survey data to provide estimates of abundance for the populations within the area;

c) Hold a workshop on acoustic echogram scrutiny;

d) Assess the results of studies on: the separation of west coast and North Sea herring stocks within the acoustic survey time series, the examination of pre-1991 surveys for possible under estimation due to signal saturation in the electronics, the inter-ship calibrations, study of variability of trawl performance between participants.

e) Review the results of the above studies and then report on the applicability of a further study of the herring survey time series.

## 11 REFERENCES


Anon, 1996a. Report of the Herring Assessment Working Group for the Area South of 62°N. ICES CM 1996/Assess:10.

Anon, 1996b. Manual for the International Bottom Trawl Surveys. Revision V. Addendum to ICES CM 1996/H:1.

Anon, 1990. Report of the Working Group on Herring Larvae Surveys South of 62°N. ICES CM 1990/H:32.

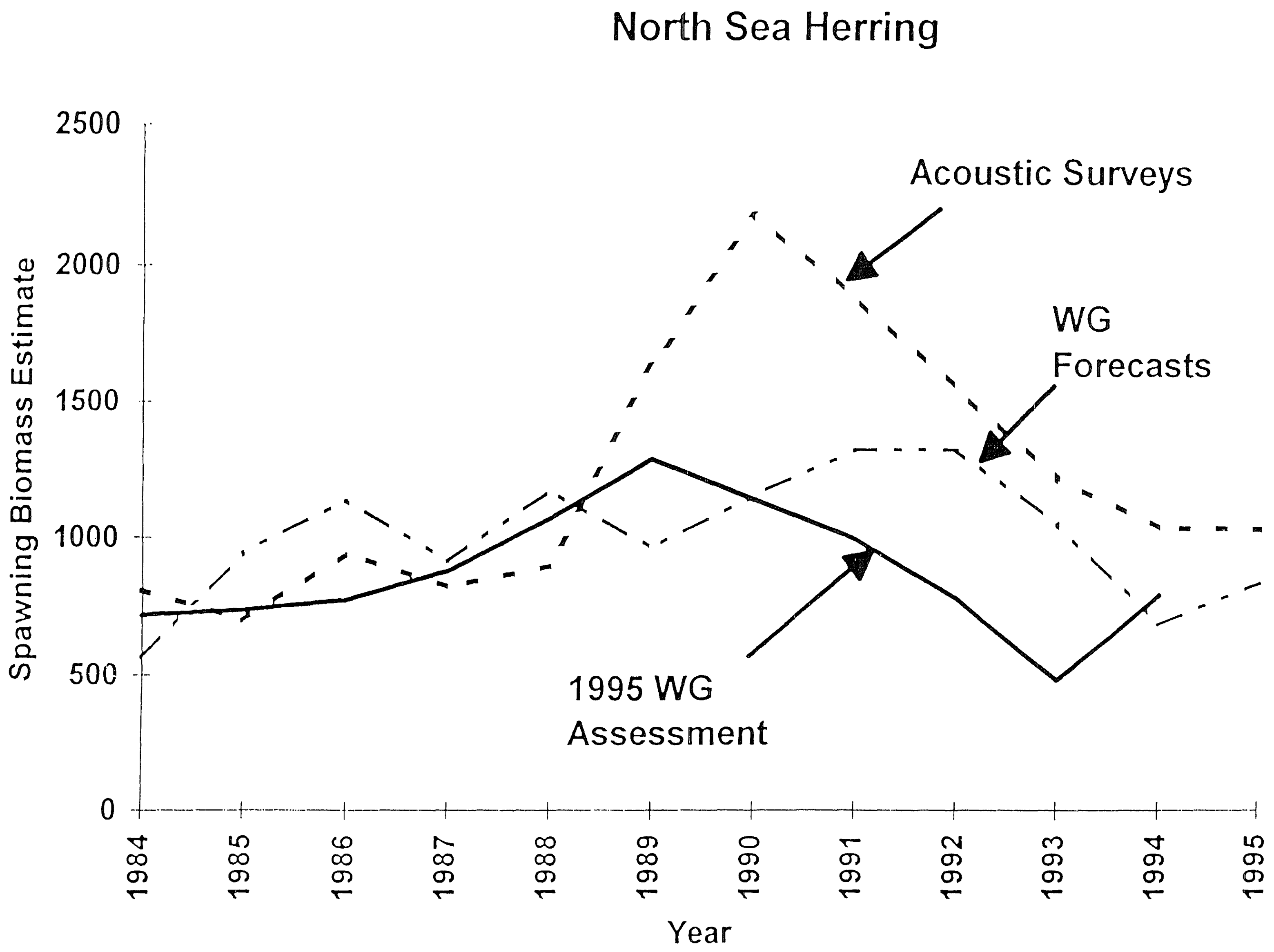



Figure 1 Discrepancy between the predicted and estimated spawning stock biomass. Solid line represents the spawning stock biomasses estimated at the 1995 Working Group meeting. The broken line "WG Forecasts" represent the forecasts made by the Herring Assessment Working Group from 1982-1993. The "Acoustic Surveys" have indicated a spawning stock biomasses over the period 1989-1995, which are double those calculated than those calculated by the assessment.

## 12 APPENDICES

A) Amplitude distributions for *Scotia* surveys in IVa 1987-1996.

B) Abundance, and Biomass of herring by ICES statistical rectangle from acoustic surveys 1984 to 1996.

C) Comparison of acoustic and IBTS times series by examination of relative cohort strength.

D) Perceptions of North Sea herring stock dynamics and survey variability that are robust to catch misreporting.

E) Effects of reduced sampling effort on abundance and production estimates from North Sea Herring Larvae Surveys.

F) Format for exchange of trawl sample herring age and length data.

G) Communication information for research vessels.

H) Planning Group for Herring Survey contact numbers.

## APPENDIX A

## AMPLITUDE DISTRIBUTIONS FOR *SCOTIA* SURVEYS IN IVA 1987-96

**Background**

The following analysis was designed to examine the amplitude distributions by both quarter ICES rectangle and Elementary Distance Sampling Unit (EDSU) for the time series of *Scotia* surveys in ICES area IVa. The aim was to determine if there had been any dramatic changes in the performance of the surveys which might explain the alleged discrepancy between the acoustic index and other indices used in the assessment

**Methods**

**Core area**

A core area for the *Scotia* surveys was designated, based on the 1991-1996 surveys. A quarter rectangle was included in the analysis only if it had been surveyed in all these years. Any rectangle missed in one or more years was deleted. The core area is illustrated in Figure 1. For surveys prior to 1991 rectangles were included only if they were within the core area. However for some of these surveys coverage of the core area was not complete. The EDSU data set was filtered in the same way to include only EDSU from within the core area to allow direct comparison between years. The result of this approach is that the biomass and abundance data presented are not exact matches for the figures reported for the survey in a particular year.

**Data sets**

The biomass and abundance for each rectangle and year were extracted from the ICES coordinated survey reports for the area or from individual survey reports prior to 1989. The EDSU data set are echo integrals per 15 minute sampling period and were extracted from digital data recorded during the surveys on *Scotia* and used in the subsequent analysis presented to the HAWG. Following extraction the integrals were corrected using the echosounder calibration data for each particular year.

**Analysis**

**Biomass and abundance by rectangle**

The data were sorted into bins (classes) for presentation as histograms. For abundance the bin size chosen was 10 million fish and included a zero bin and greater than 200 million fish category. For biomass the bin size was 5,000 tonnes and included a zero bin and greater than 100,000 tonne category. The data are presented as absolute numbers of rectangles in each class. It should be noted that the earlier surveys included fewer rectangles.

**Echo integral by EDSU**

The data were sorted into bins (classes) for presentation as histograms. The bin size chosen was 500 and included a zero bin and greater than 10,000 category.

**Results**

**Biomass and abundance by rectangle**

The histograms for the 10 years are presented for tonnes by rectangle (Fig. 2) and numbers by rectangle (Fig. 3). A number of changes can be seen over the 10 years. For numbers (Fig. 3) up to 1990 the frequency distributions were relatively flat with similar numbers of rectangles in most of the lower value bins, less than 10% of the rectangles surveyed contained no fish. Distributions were more skewed for the biomass data in these years. One possible conclusion is that a lot of the fish in the middle range abundance bins were relatively young and contributed less to the biomass values. Following 1990 the distributions were much more skewed, with the number of zero rectangles generally being between 20 and 30% of the total. It is interesting that in all years there were small numbers of rectangles with abundances greater the 200 million fish and that this did not seem to fluctuate much with any change in stock levels. To illustrate some of these trends the frequencies in the zero and lowest value biomass bins were plotted against year in Figure 4. The increasing numbers of zero rectangles can be seen, and a possible decrease in the number of rectangles with low biomass.

**Echo integral by EDSU**

The histograms for corrected integrator values are presented in Figure 5. Again as in the rectangle based data there is strong evidence of an increasing number of zero observation over the time period - between 30 and 45 up to 1990 and generally greater than 60% thereafter. Figure 6 illustrates these trends in more detail with the frequencies in the zero and lowest value bins plotted against year. Although there are some fluctuations there is clear evidence of an increase in zero samples over the period. However this is strongly mirrored by a decrease in the number of samples in the next bin. The most likely explanation for this is that over the years, the operator has attached less importance to very small fish schools on the echogram. This possibility is supported by the general perception that the most important element of the biomass is contained in the relatively few larger samples, and that it is not worth expending effort allocating very small traces to species. It should be noted that this would be expected to lead to a small underestimate, as some herring schools will be missed, however, it is unlikely to bias the stock estimate upwards. Figure 7 show the percentage of zero samples in each year plotted against the biomass in the core area in that year. Interestingly there is a possible trend of increasing percentage of zero samples with increasing biomass. However, this is likely to be seriously confounded with the observed change in operator practice noted above.

The same data are presented in a 3D plot in Figure 8. Apart from he increase in zero sample frequency, there is little obvious difference. It may be possible that there are more high value observations later in the period. To clarify this the percentage of high values against year is plotted in Figure 9. There is no clear overall trend. However, the level is fairly stable to 1990, a sharp dip between 1990 and 91, and following this a possible increasing numbers of high values from 1991 to 96. Figure 10 shows the percentage of high values plotted against biomass, and no clear relationship can be seen.

The final plot (Fig. 11) shows cumulative frequency distributions by year. The data have been normalised and only the last 200 points plotted representing the maximum number of non zero samples in the core area in any year. The only obvious pattern in this plot is that again, the years 1987-1990 are clearly separated from the later years, having generally shallower trajectories.

**Discussion**

The main conclusion from the study is that, at least for this survey area, no obvious explanation for the alleged change in survey performance over the last 10 years can be seen. There is some evidence of a change in the performance of the surveys between 1987-1990 and 1991-1996. The most likely explanation for this lies in the changeover from Simrad EK400 to EK500 echosounders. The dynamic range of the EK500 is significantly greater than the EK400, and it is possible that particularly dense schools resulted in saturation of the system. This would tend to reduce the amplitude of the high vales and may have resulted in a tendency to underestimate in these years. The perceived tendency for more zero samples over the period can largely be put down to operator changes, and would be expected to result in a slight underestimate of the stock.

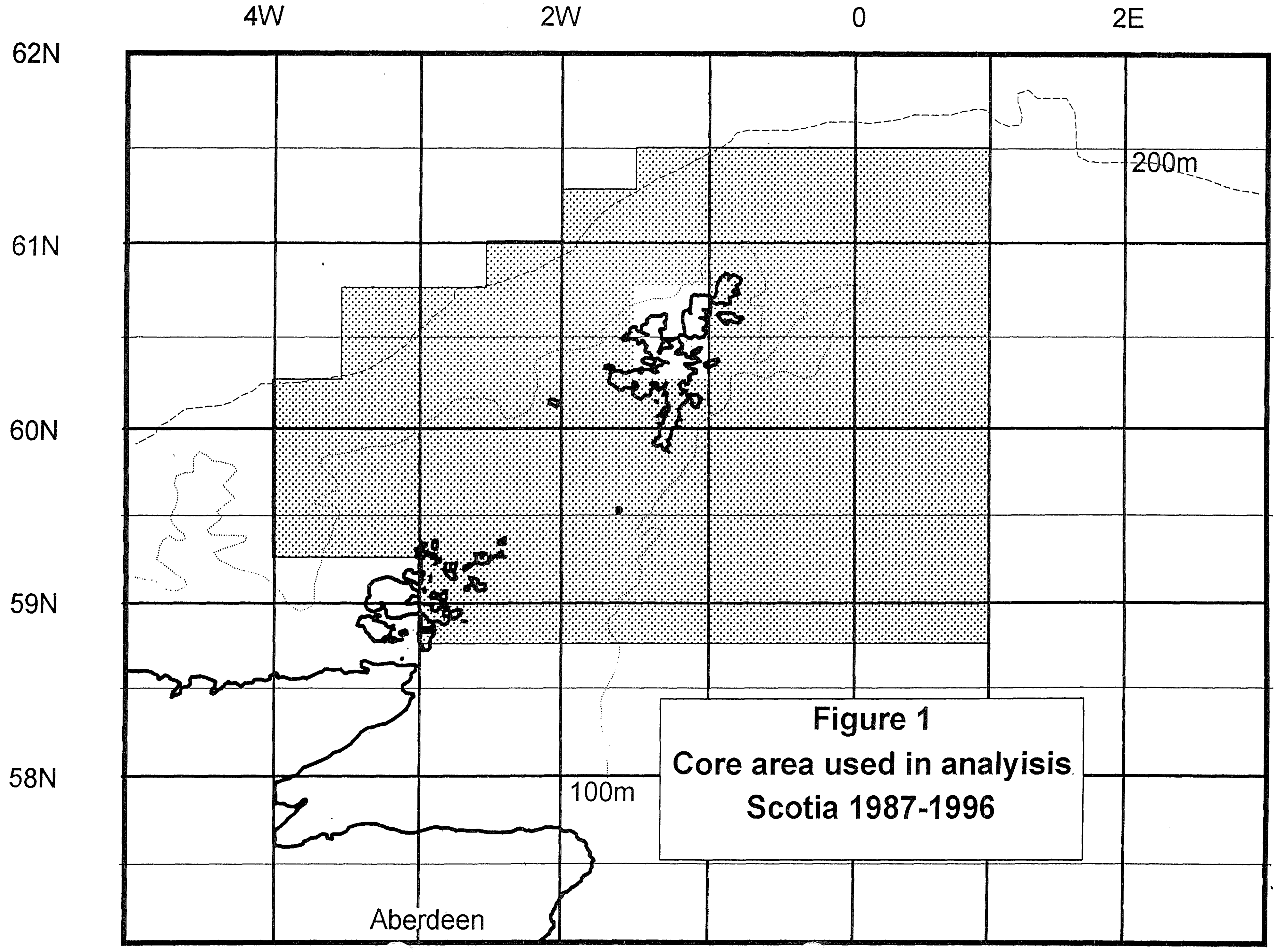



**Figure 1**
**Core area used in analyisis**
**Scotia 1987-1996**

# Figure 2. Numbers by rectangle
# Scotia 1987-96

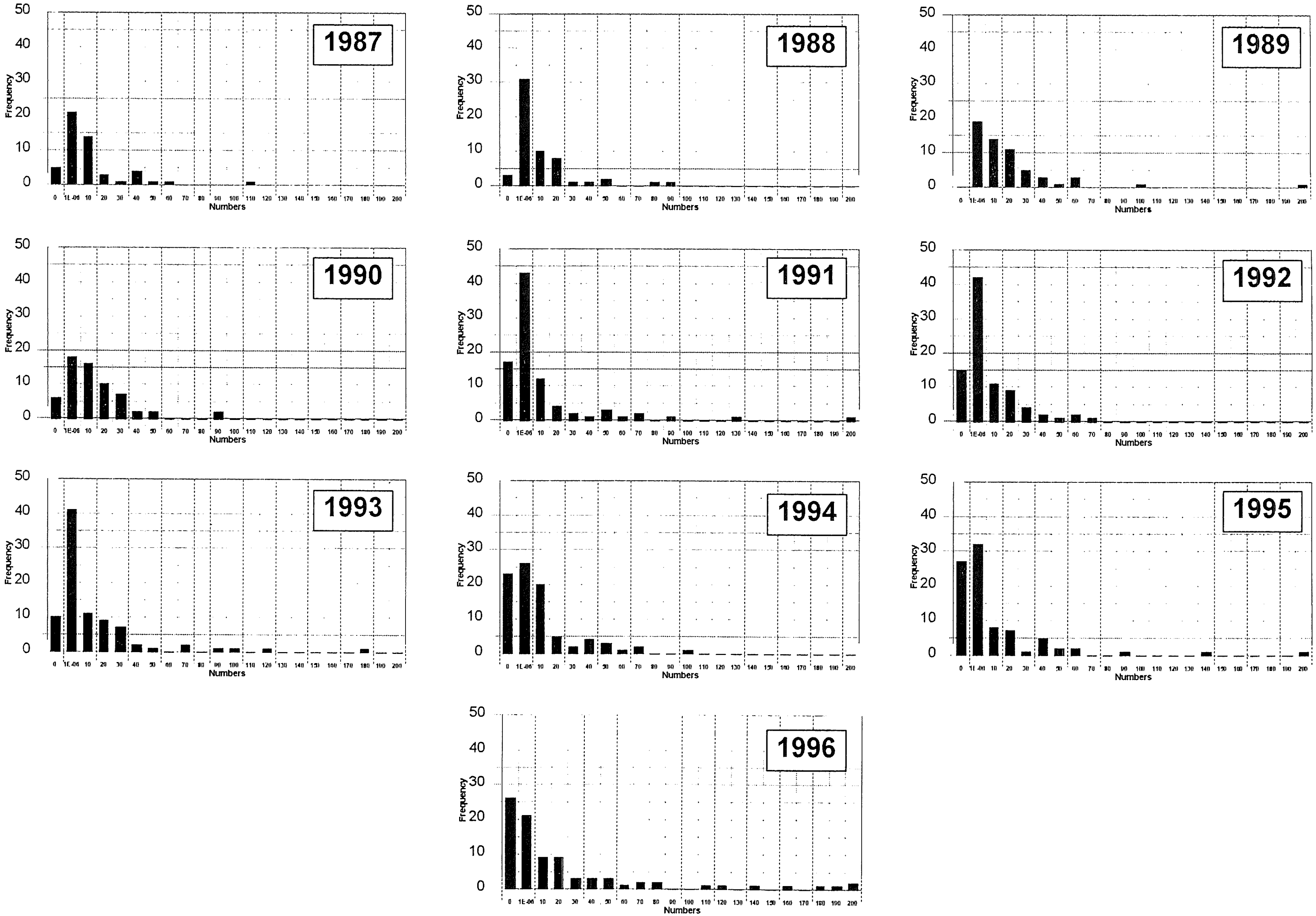


Figure 3. Numbers by rectangle
Scotia 1987-96

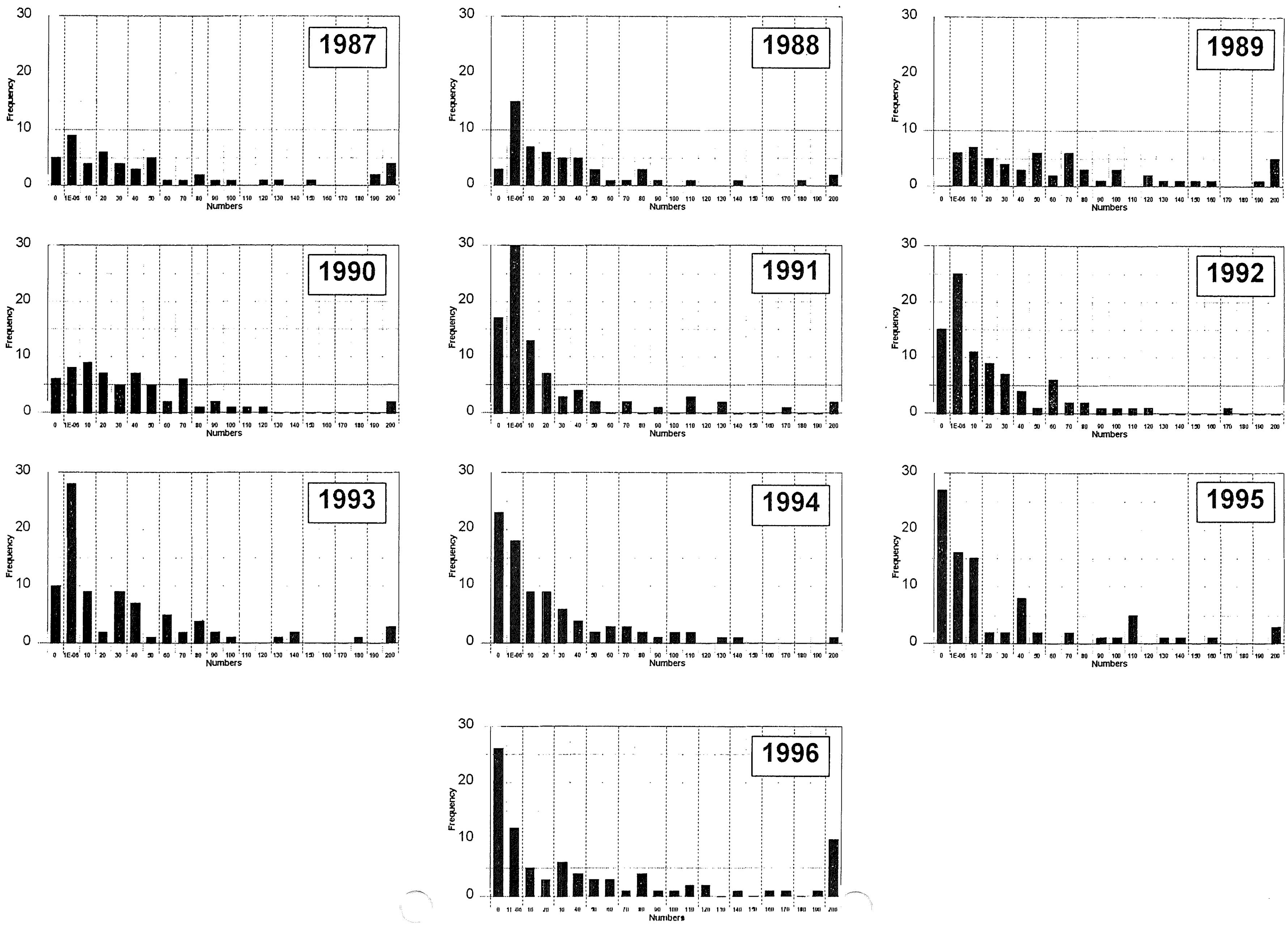
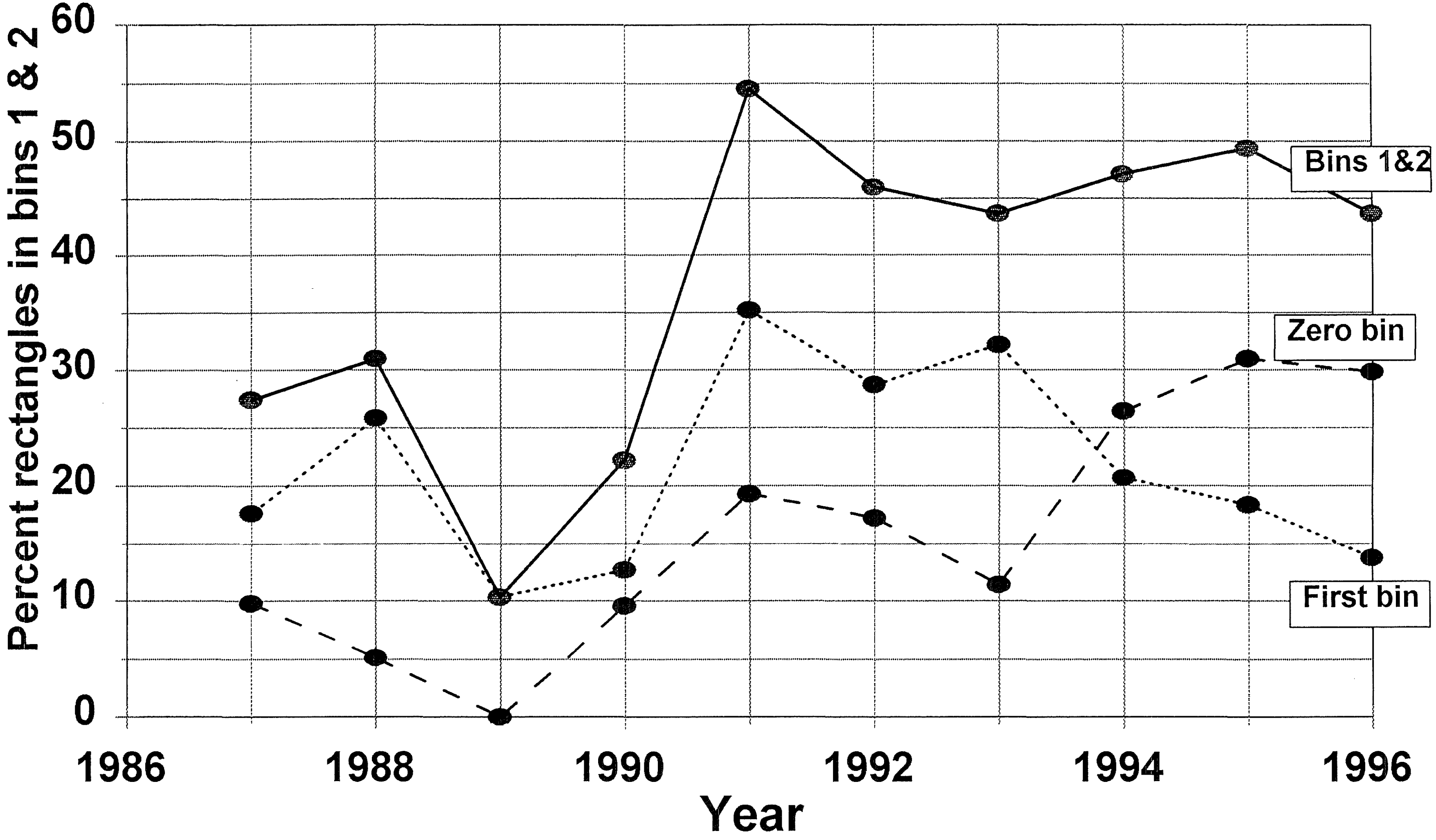


Figure 4. Percentage of rectangles in bins 1 & 2 Numbers - Scotia 1987-96



# Figure 5. Corrected Integrator frequencies
# Scotia 1987-96

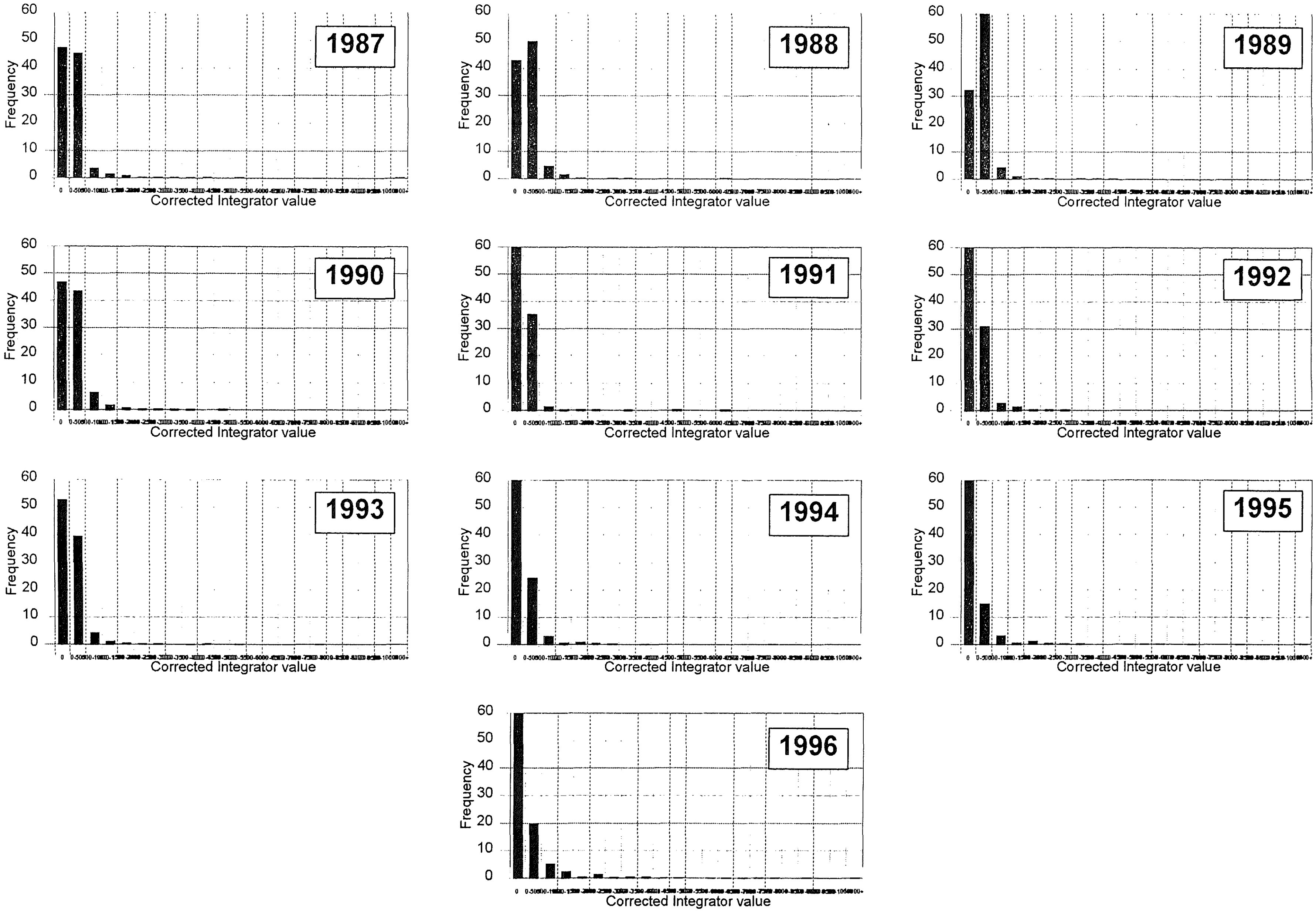


Figure 6. Percentages in first two bins Scotia 1987-96

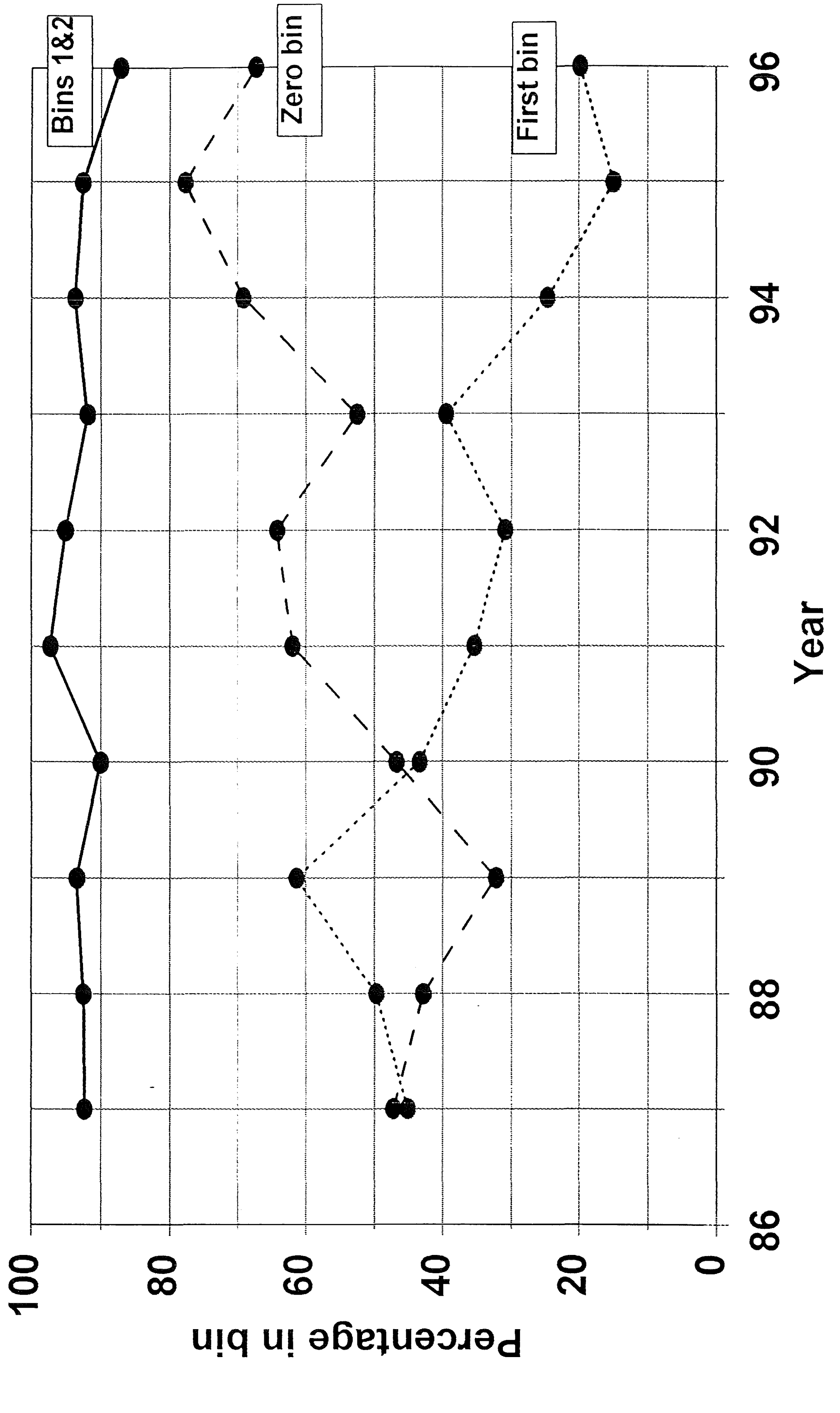
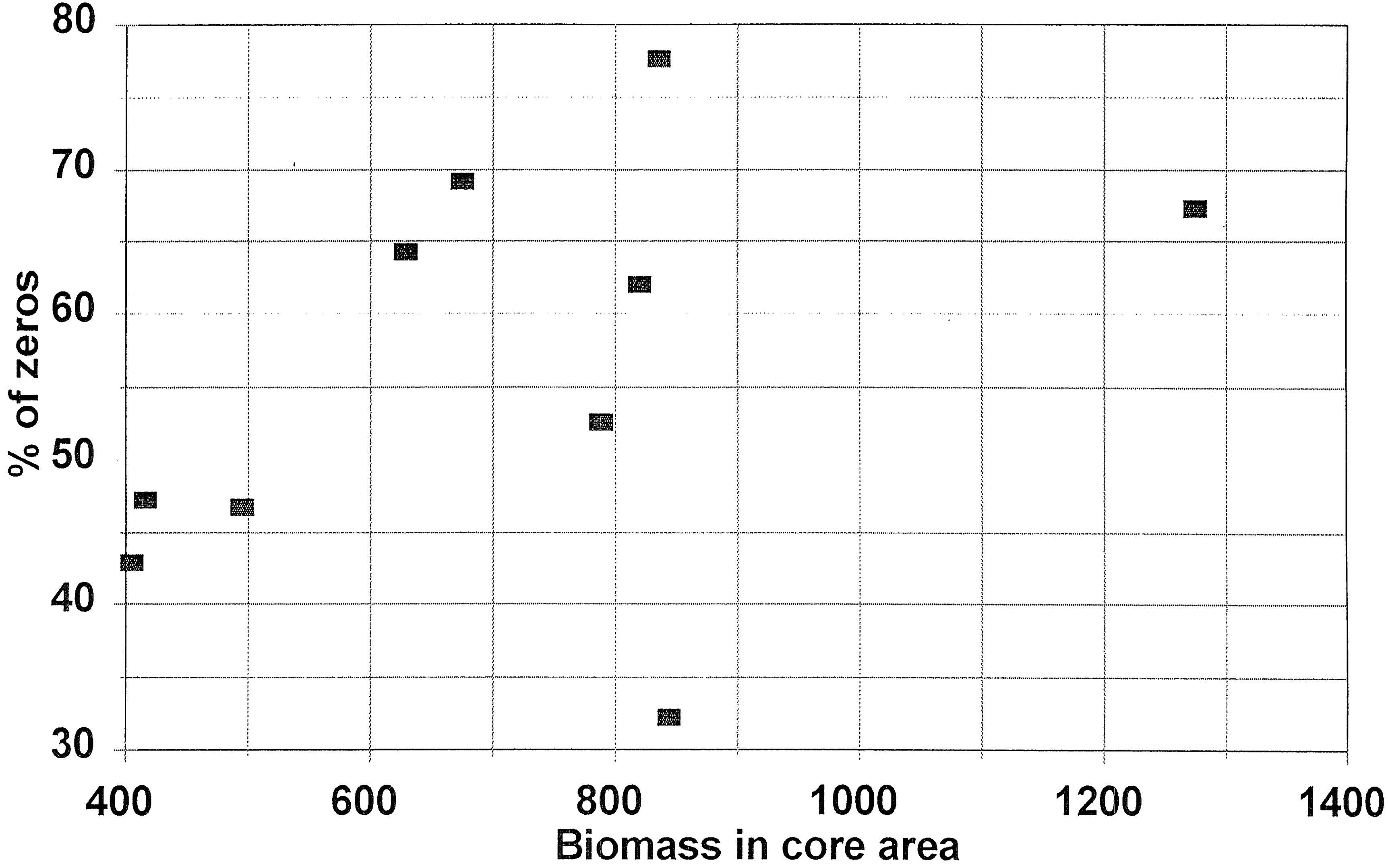
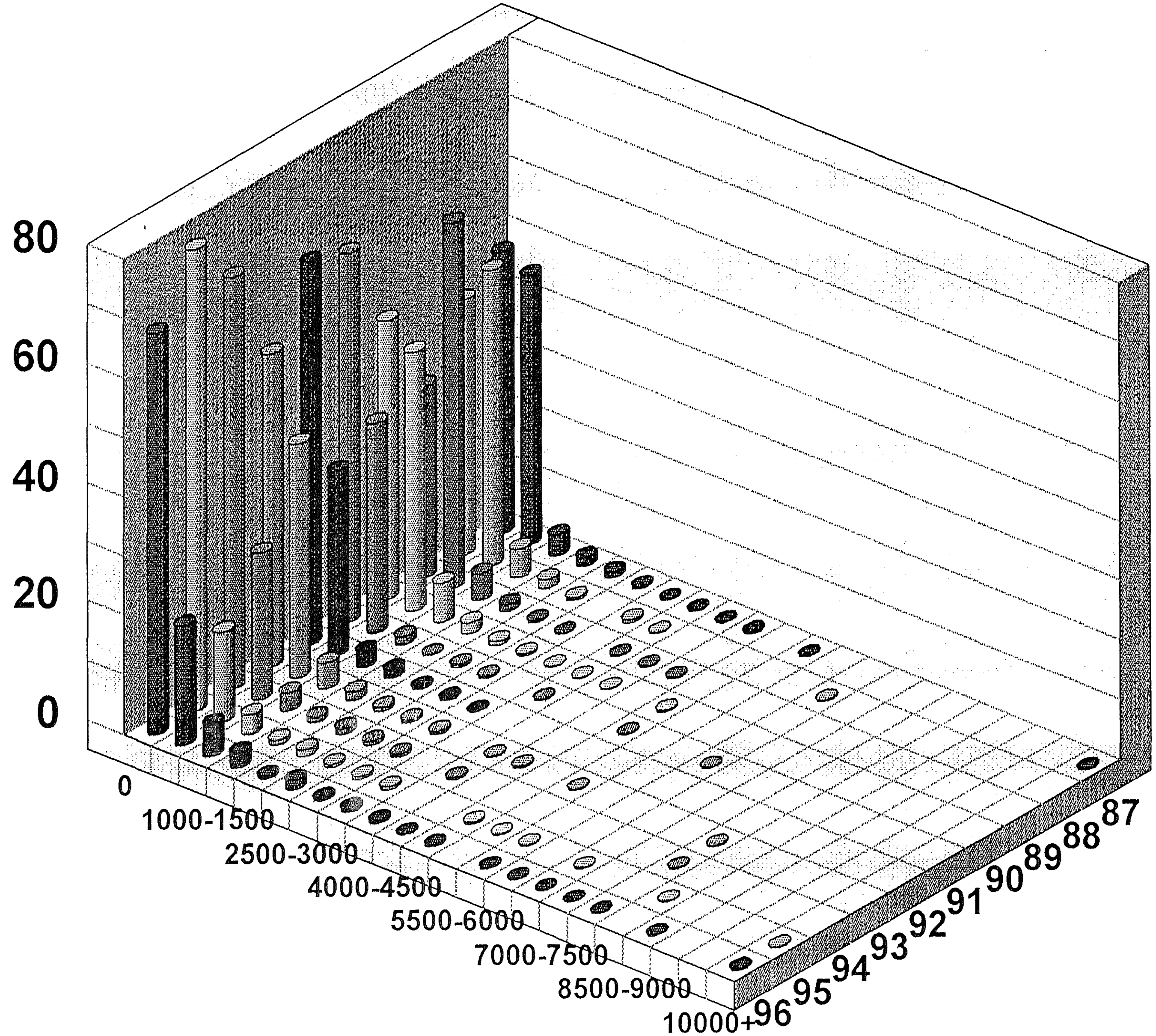


Figure 7. Percentage of zero samples against biomass in the core area 1987-96



## Figure 8. Percentage by class in core area 87-96



## Figure 9. Percentage of high values against year in the core area 1987-96

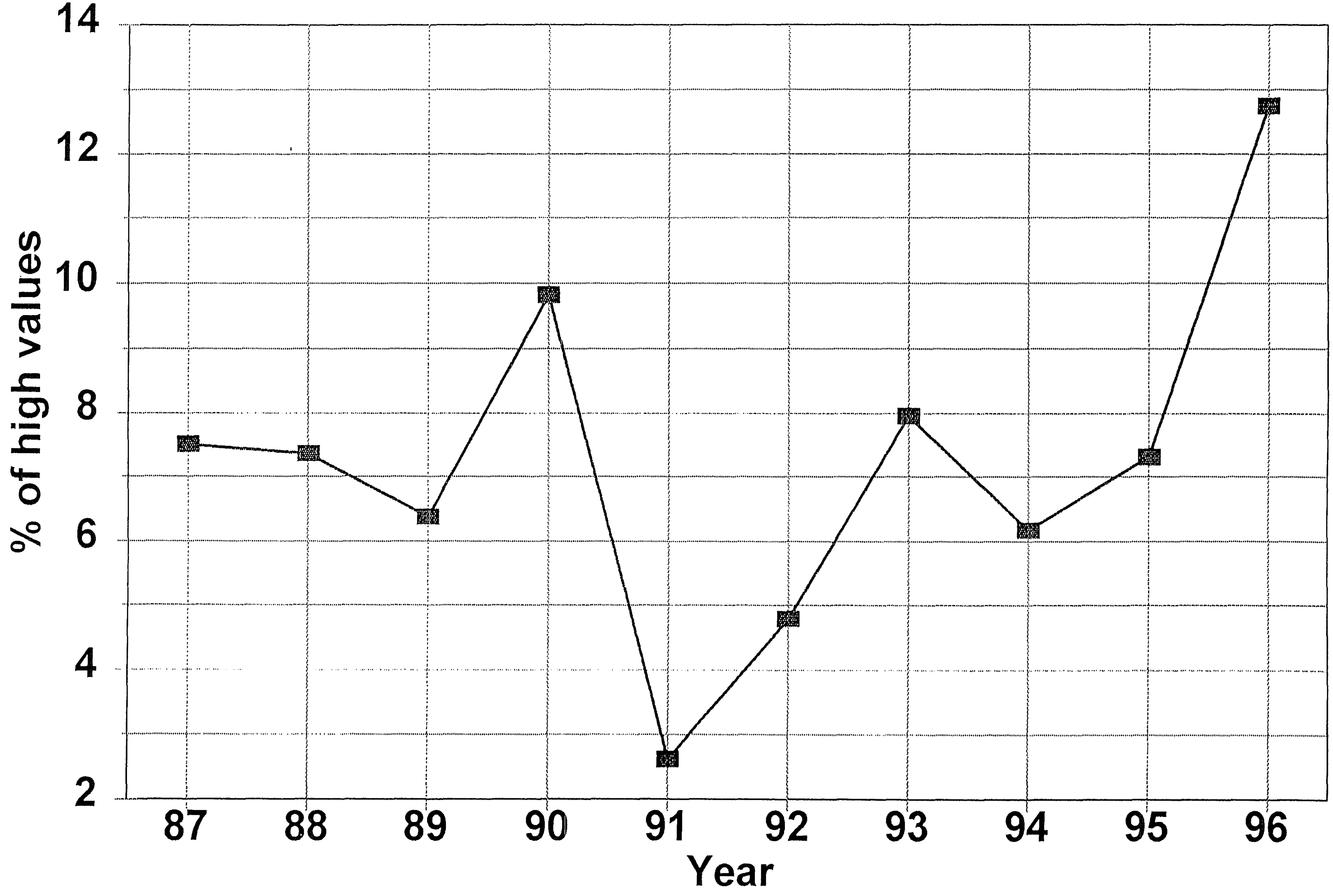


**Figure 10. Percentage of high values against biomass in the core area 1987-96**

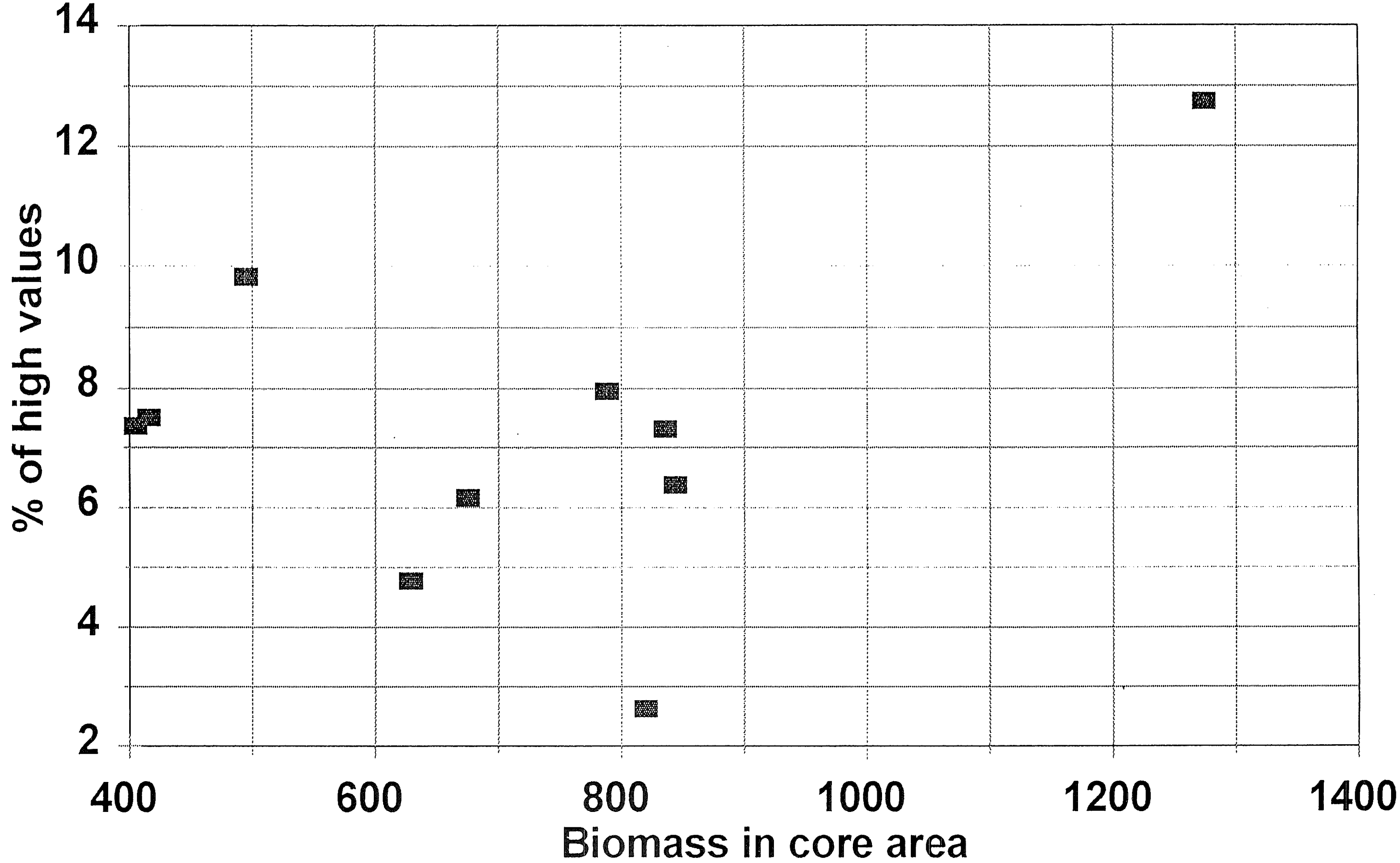
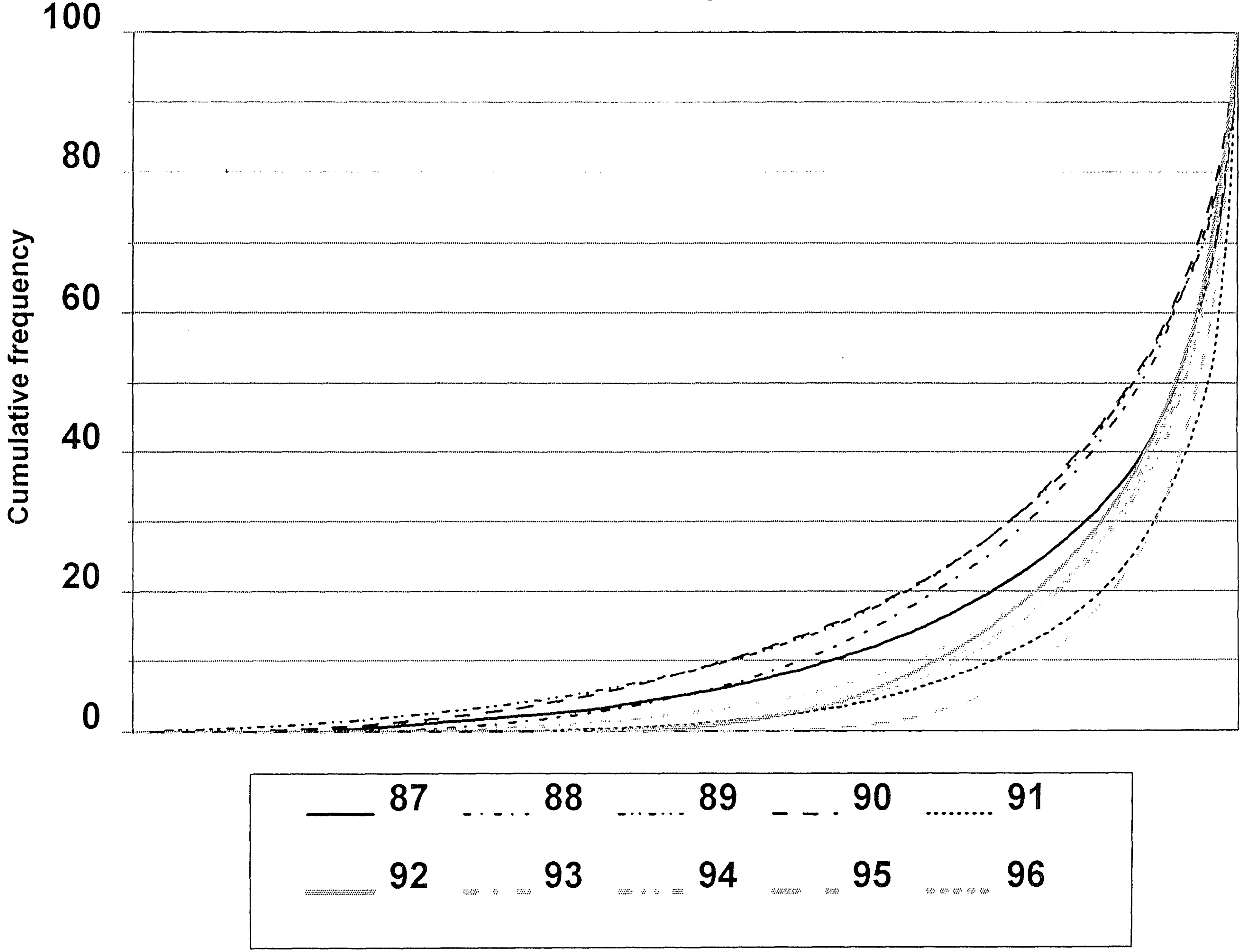


Figure 11. Cumulative Frequency plots by year
- last 200 points -



## APPENDIX B

## COMPILATION OF THE COORDINATED ACOUSTIC SURVEY TIME SERIES ESTIMATES FOR HERRING

Marked variability in the annual estimates of abundance and biomass of herring stocks in northern European waters has contributed to the requirement to review survey design and data analysis. One component of this review has been to construct a spreadsheet application which will provide estimates of abundance and biomass from the existing time series by age and ICES statistical square for both the North Sea autumn spawning stock and Baltic Sea spring spawning stock respectively. This was undertaken in October 1996 and has recently been completed.

Using the annual ICES reports for herring acoustic surveys, the proportions of abundance at age within each sub-group in each cruise were used to calculate abundance and biomass (incorporating mean weight at age) on the 30 mile ICES statistical square scale. The resulting abundance and biomass estimates were then checked against the estimates published in the annual survey reports and combined. For illustrative purposes the abundance (millions) and biomass ('000 tonnes) estimates for mature autumn spawning herring by year are given in Figures 1-13. The annual abundance data for mature autumn spawners are also presented as contour plots for each year from 1984 to 1996 (Figs 14-26).

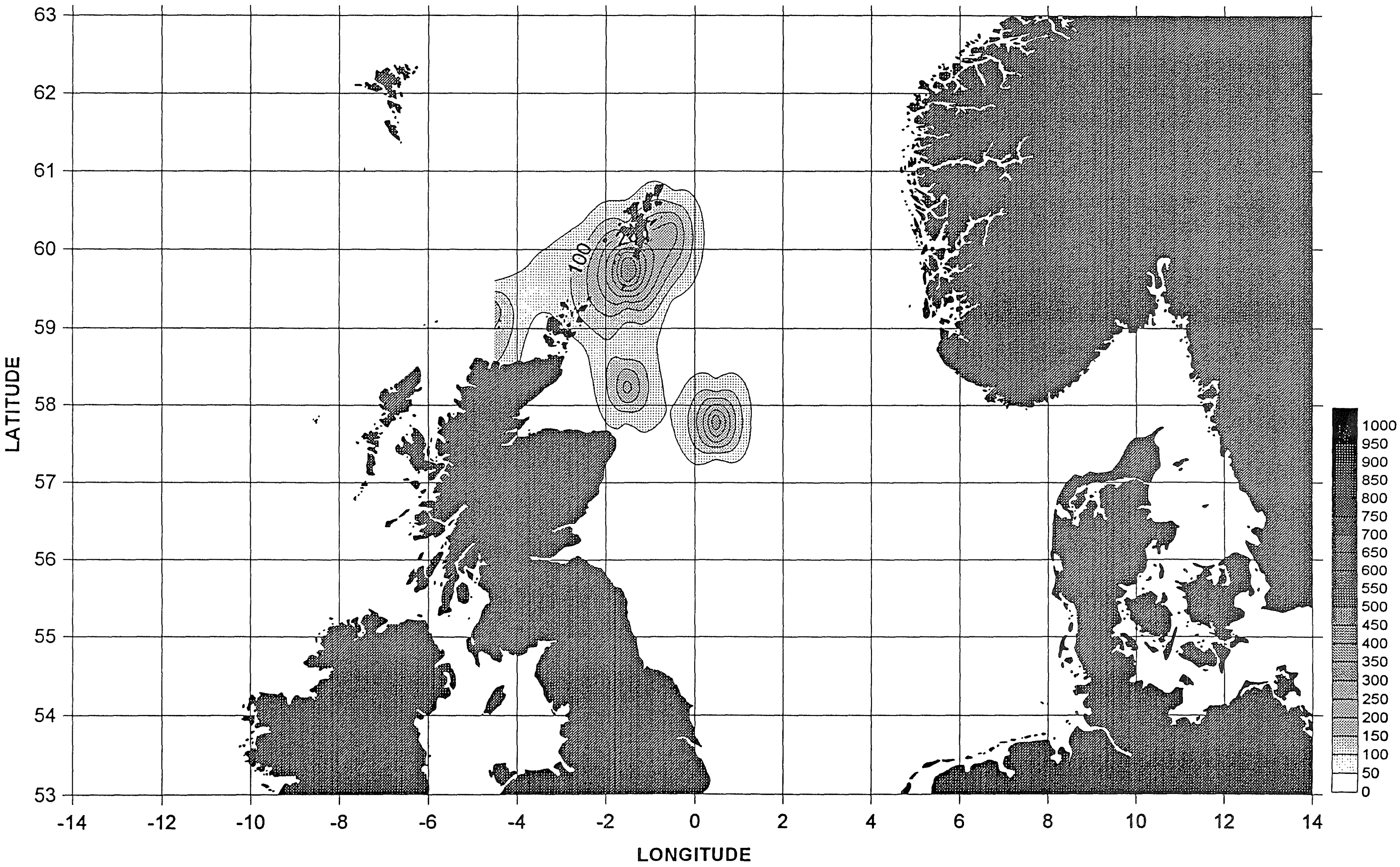
Compiling the individual reports from several participating nations was not straightforward. This was due to differences in format and presentation. In order that future surveys can be combined efficiently it would be helpful if participants could provide data in a standard format. Specifically, reports should include:

- A map of the cruise track overlaid with a grid corresponding to the ICES statistical rectangle scale. This should be appended with the number of 15 minute integrator runs in each rectangle.

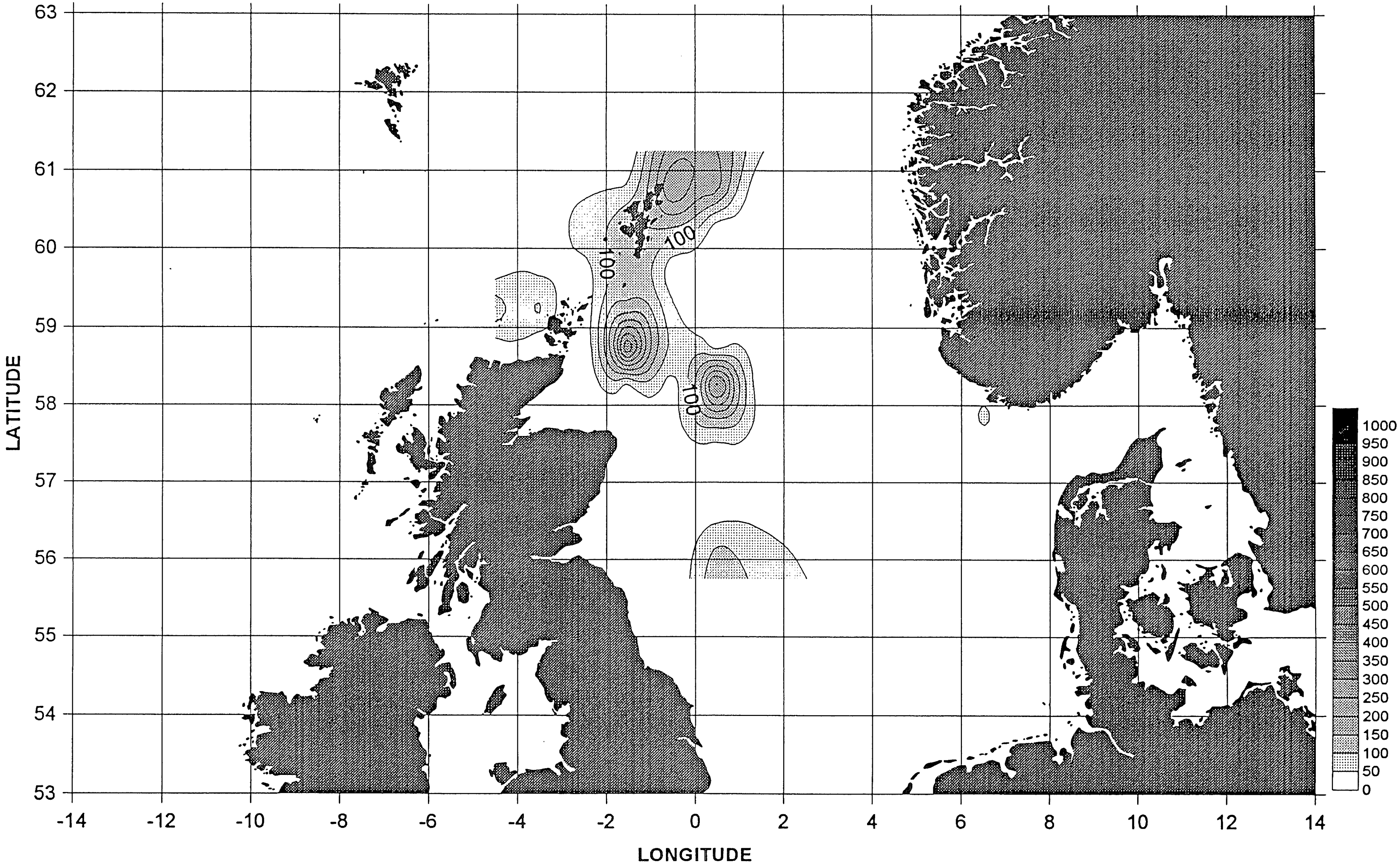
- A corresponding map showing abundance (millions) and biomass ('000 tonnes) together with the boundaries between the sub-areas (strata).

- Two tables giving herring abundance, mean weight and biomass by age (0 to 9+), maturity and sub-area for North Sea autumn spawners and Baltic spring spawners respectively.

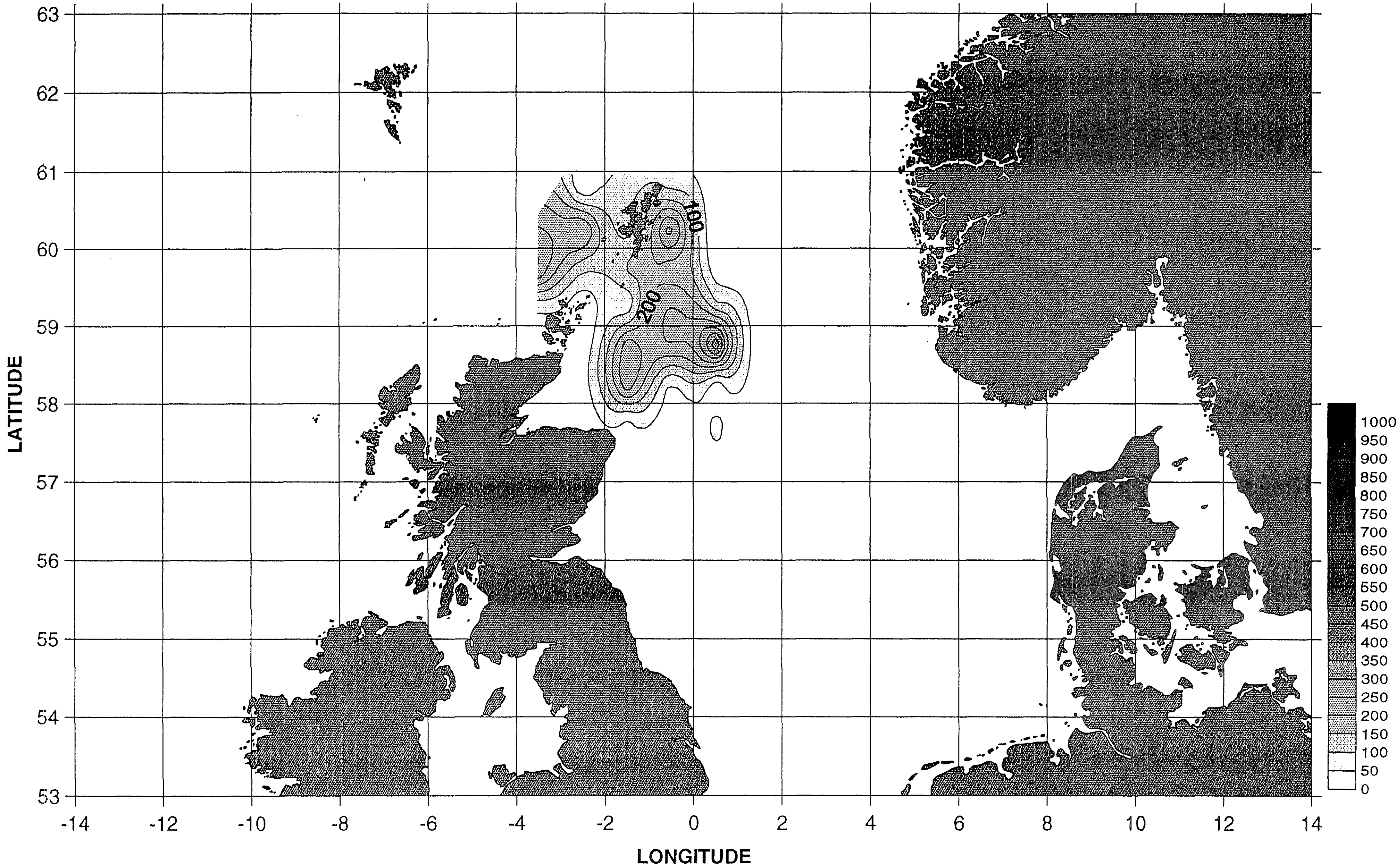
# Numbers (millions) of mature autumn spawners (1984).



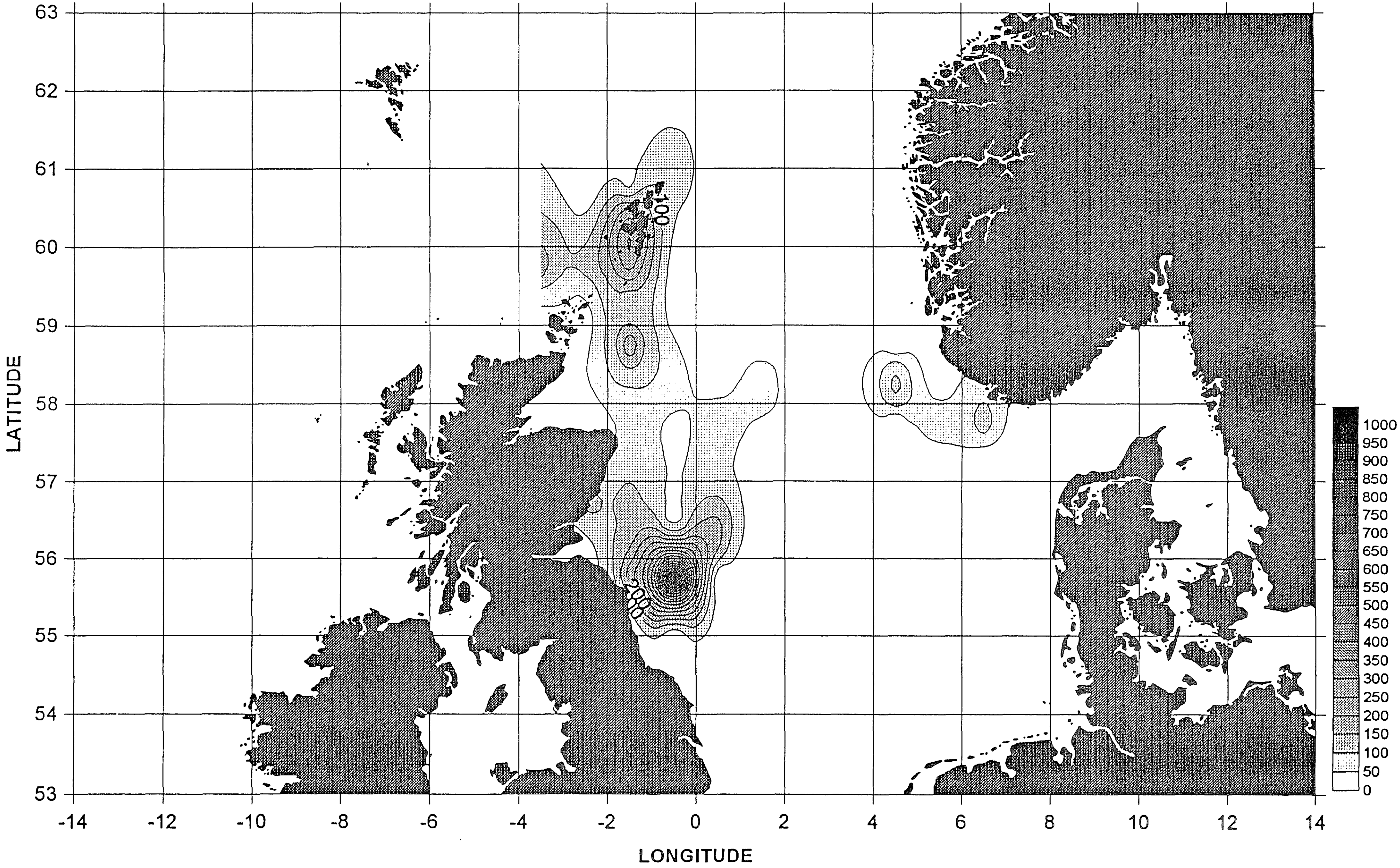
# Numbers (millions) of mature autumn spawners (1985).



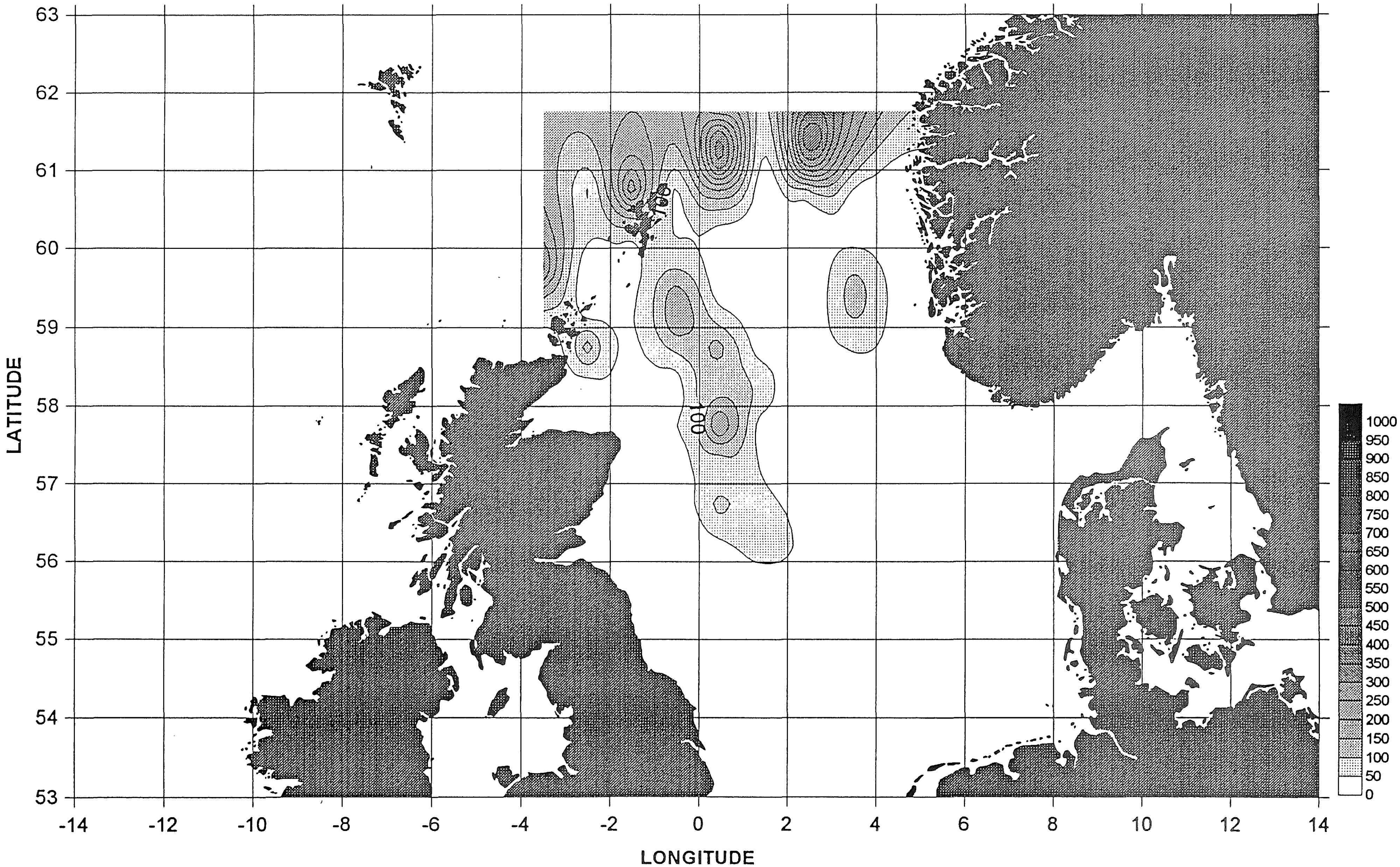
# Numbers (millions) of mature autumn spawners (1986).



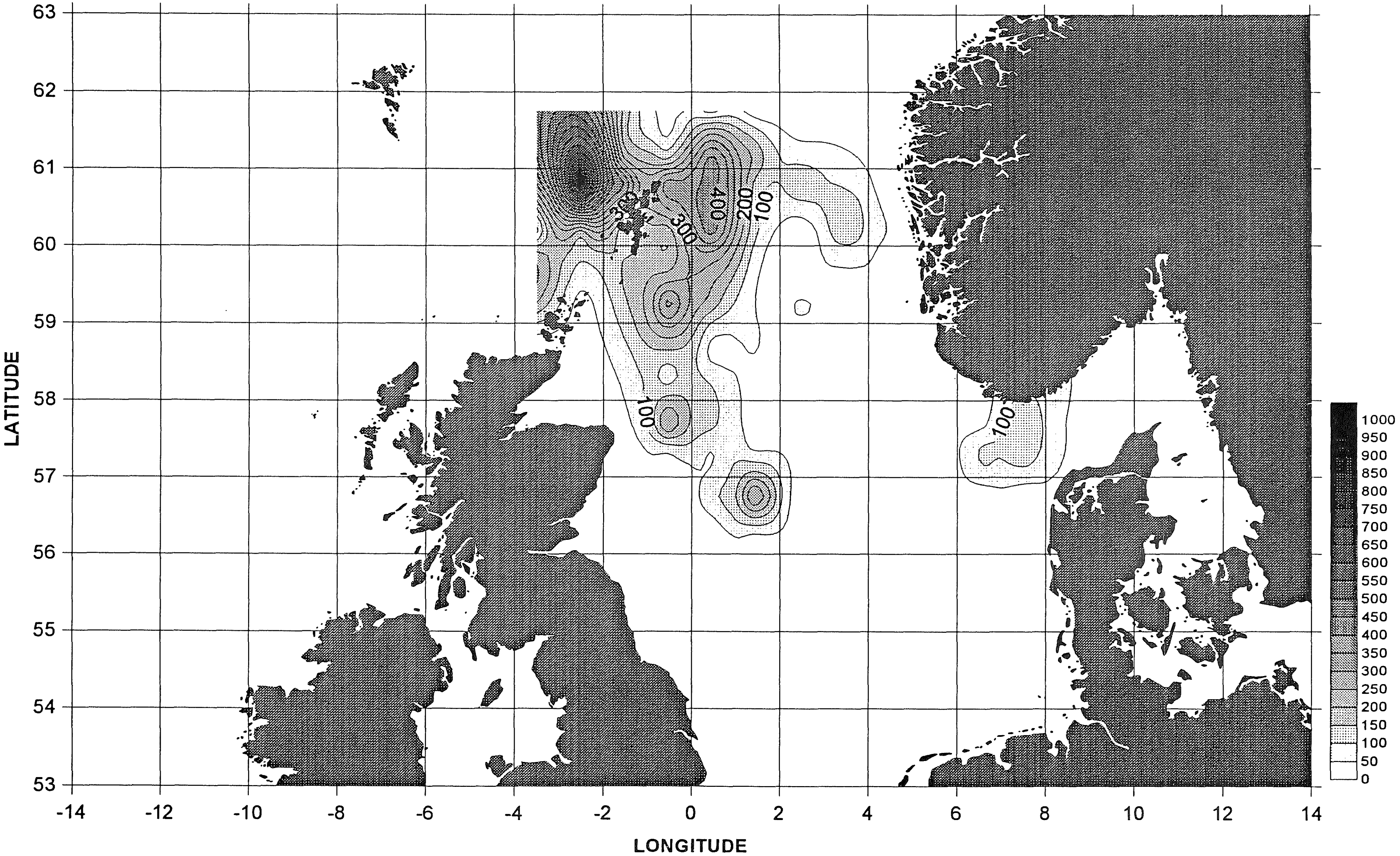
# Numbers (millions) of mature autumn spawners (1987).



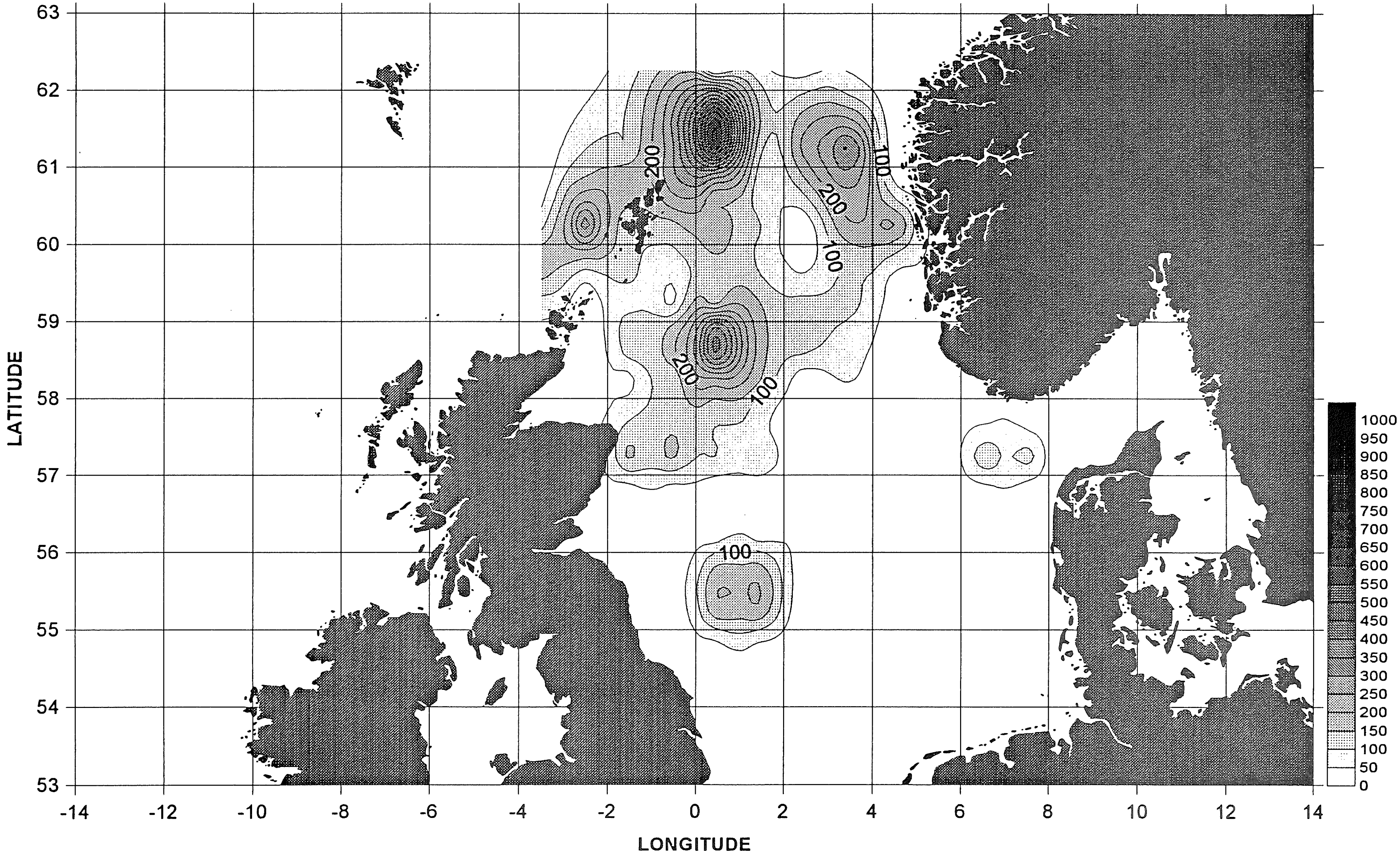
Numbers (millions) of mature autumn spawners (1988).



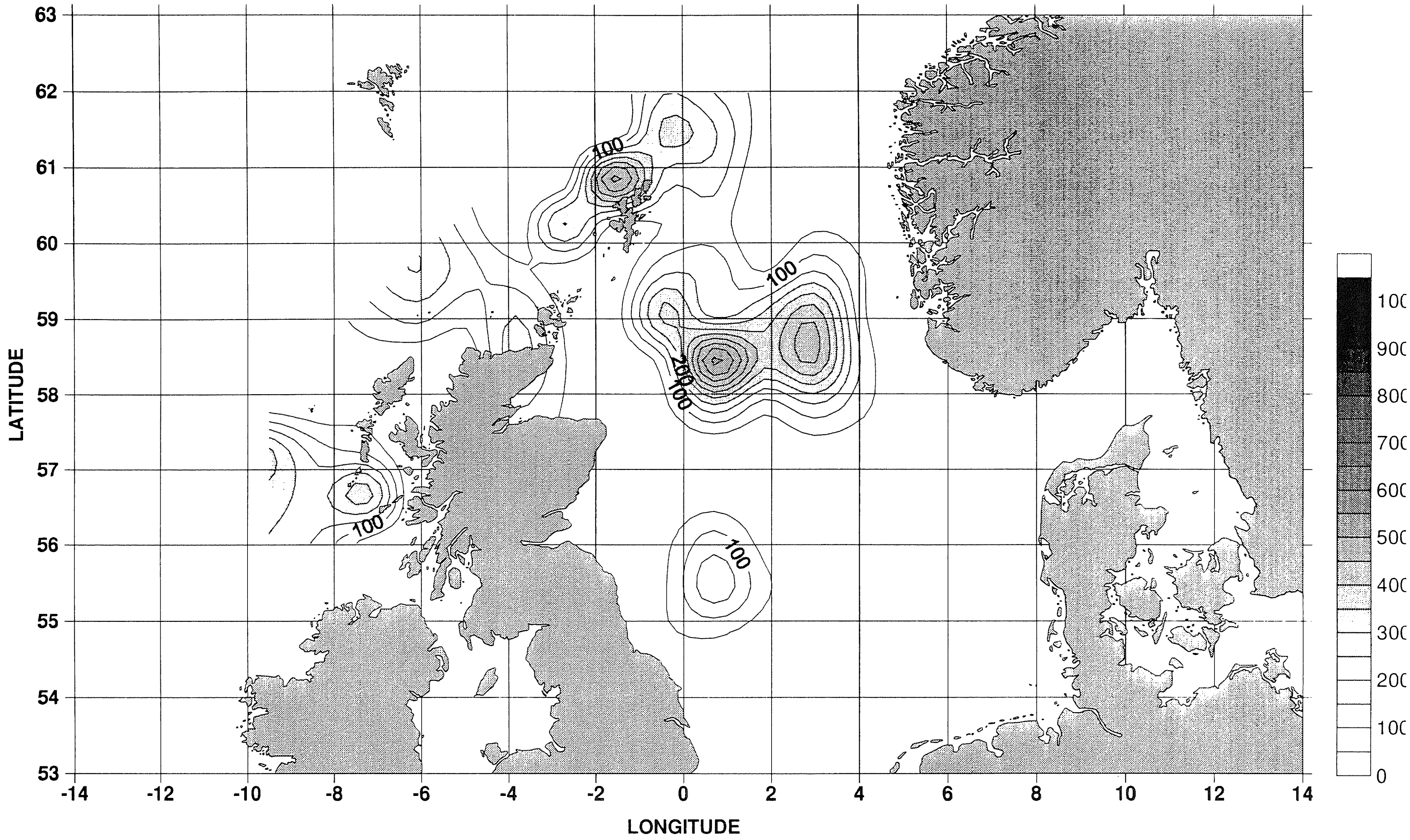
# Numbers (millions) of mature autumn spawners (1989).



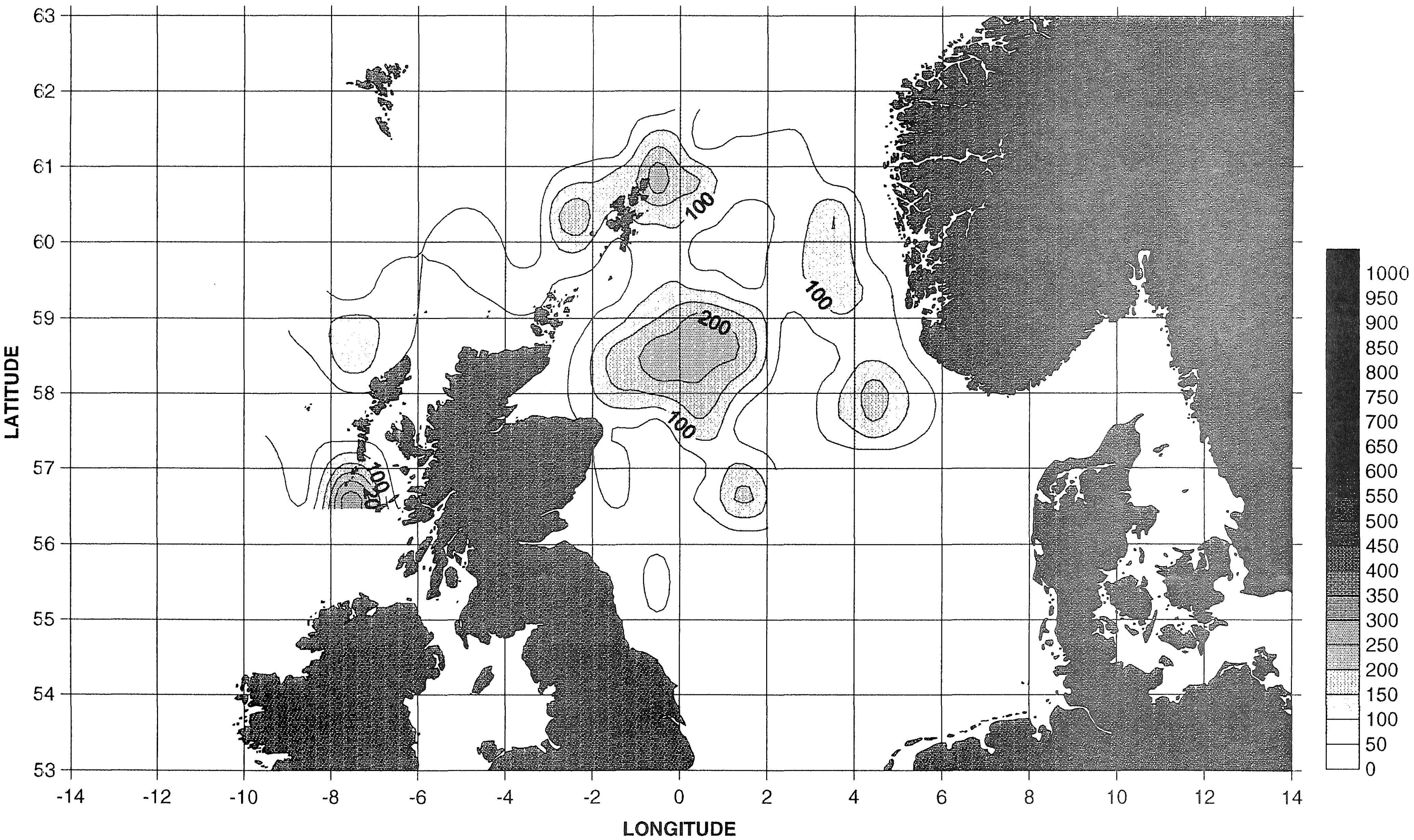
# Numbers (millions) of mature autumn spawners (1990).



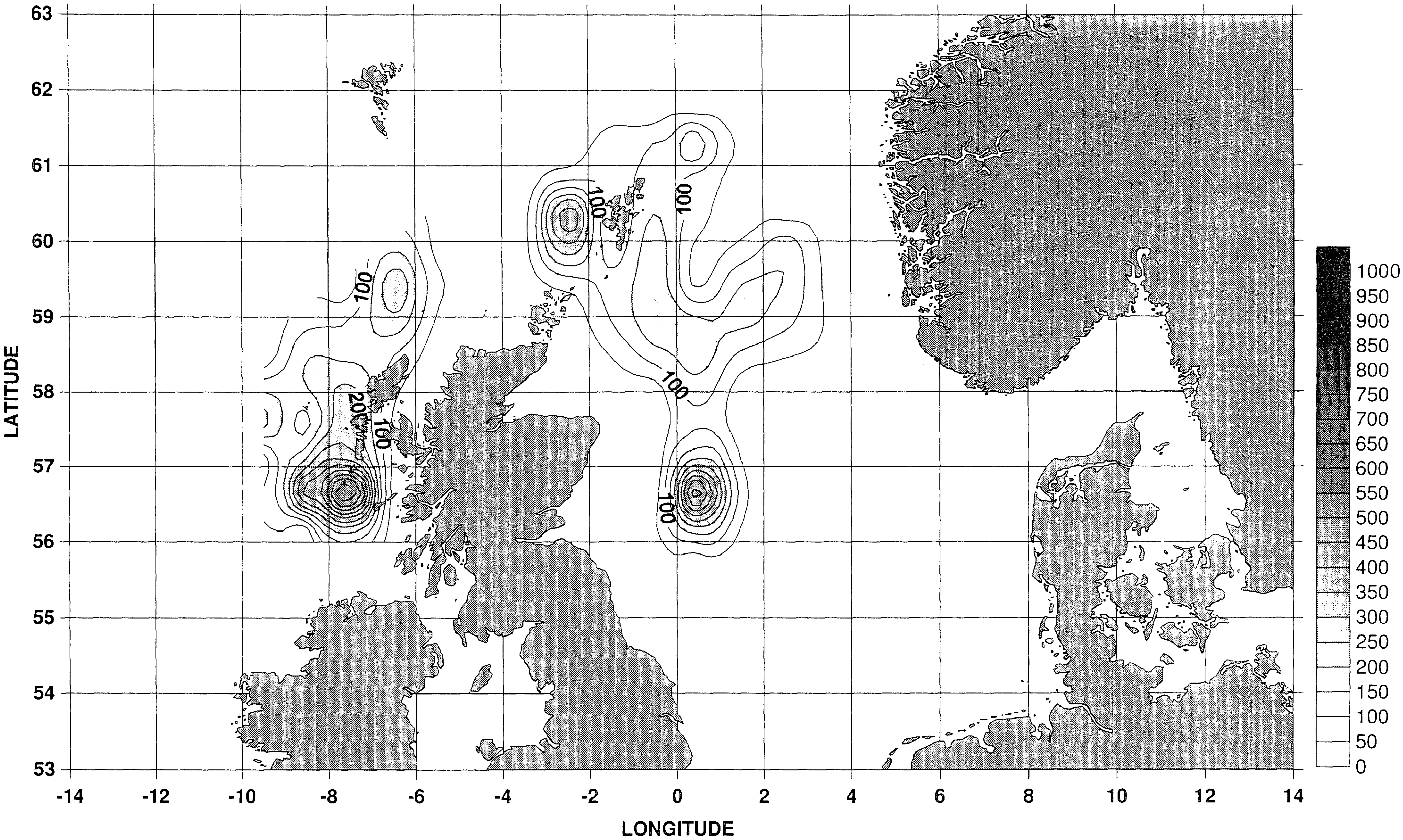
# Numbers (millions) of mature autumn spawners (1991).



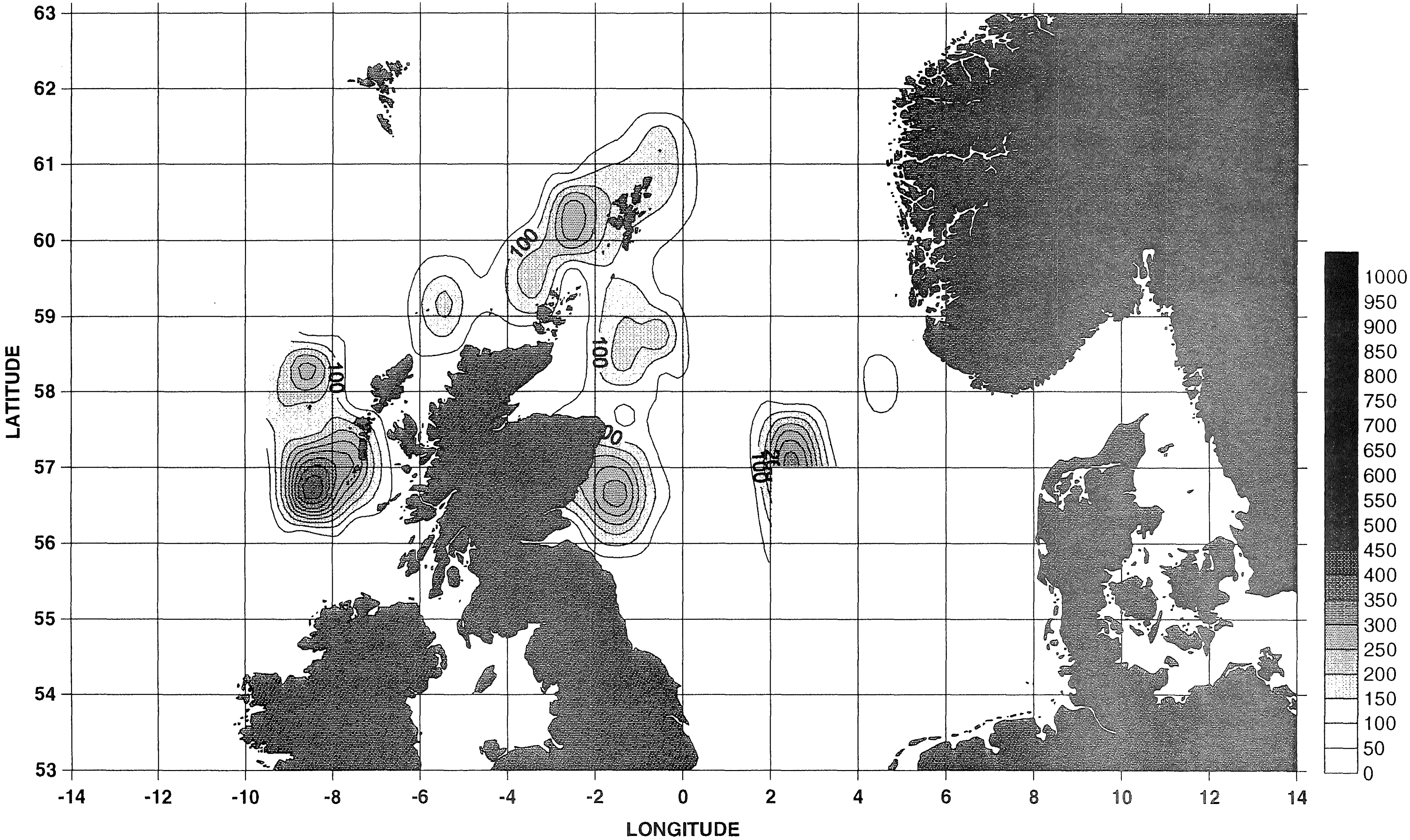
Numbers (millions) of mature autumn spawners (1992).



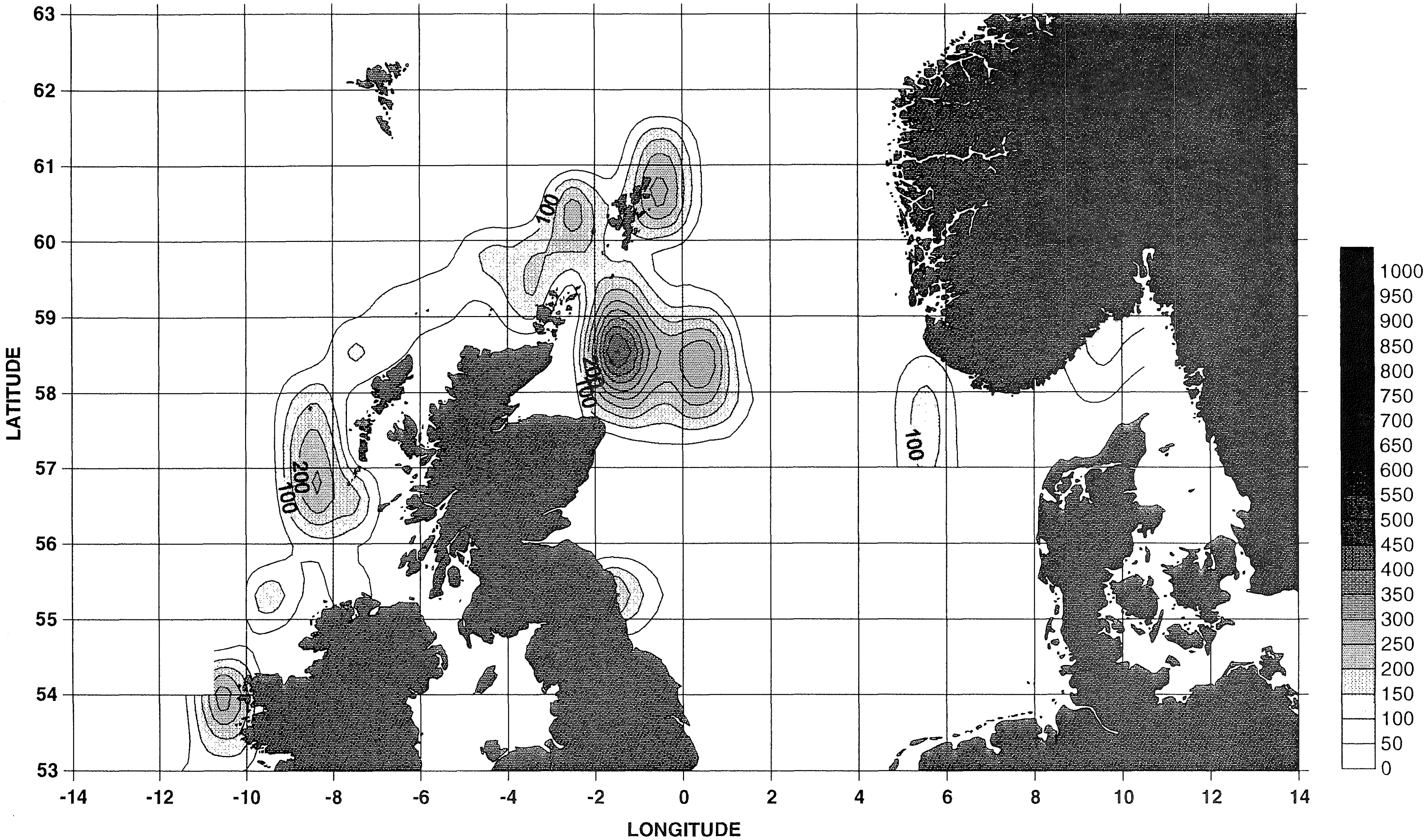
# Numbers (millions) of mature autumn spawners (1993).



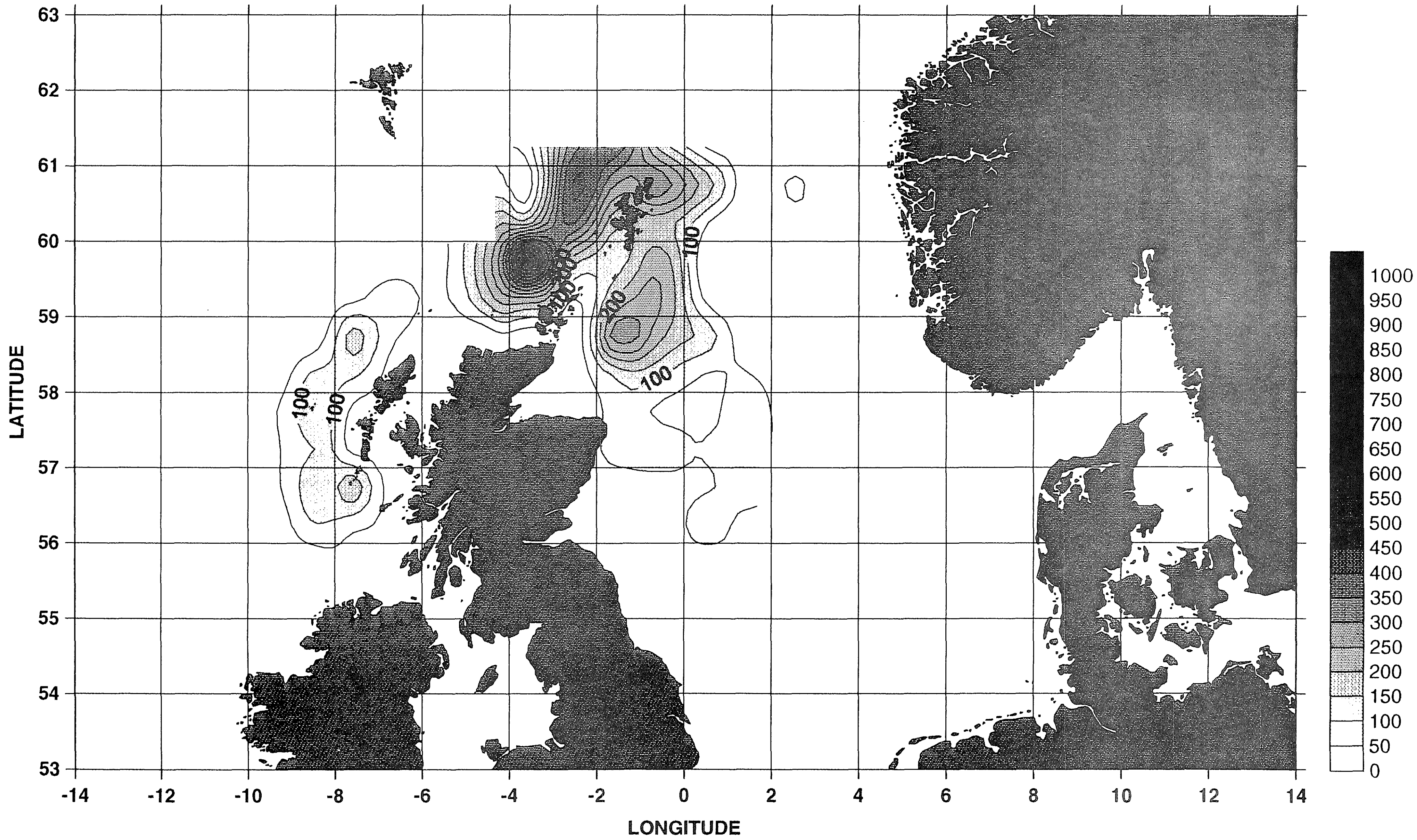
# Numbers (millions) of mature autumn spawners (1994).



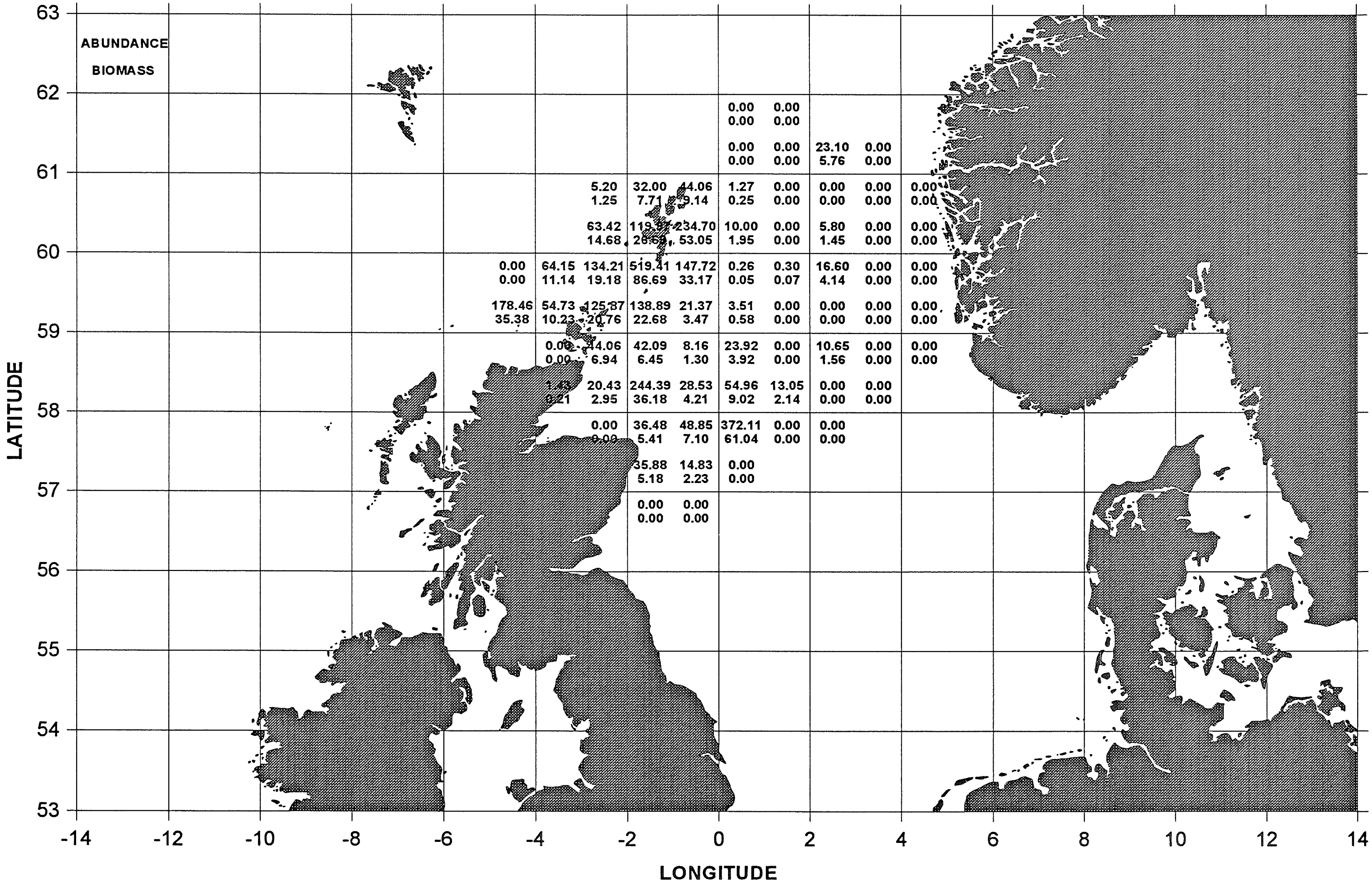
# Numbers (millions) of mature autumn spawners (1995).



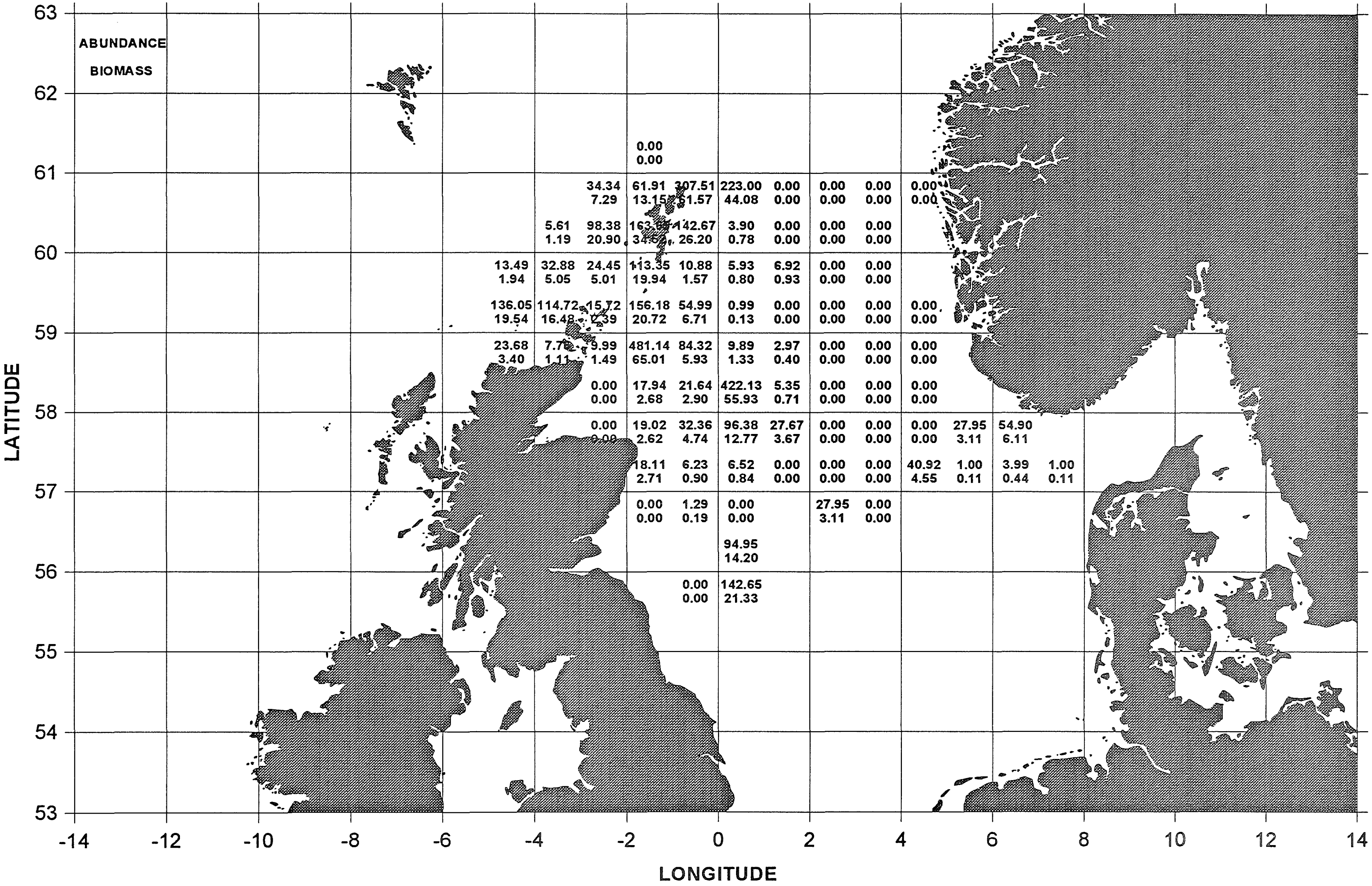
# Numbers (millions) of mature autumn spawners (1996).



# Mature autumn spawners (1984).



# Mature autumn spawners (1985).



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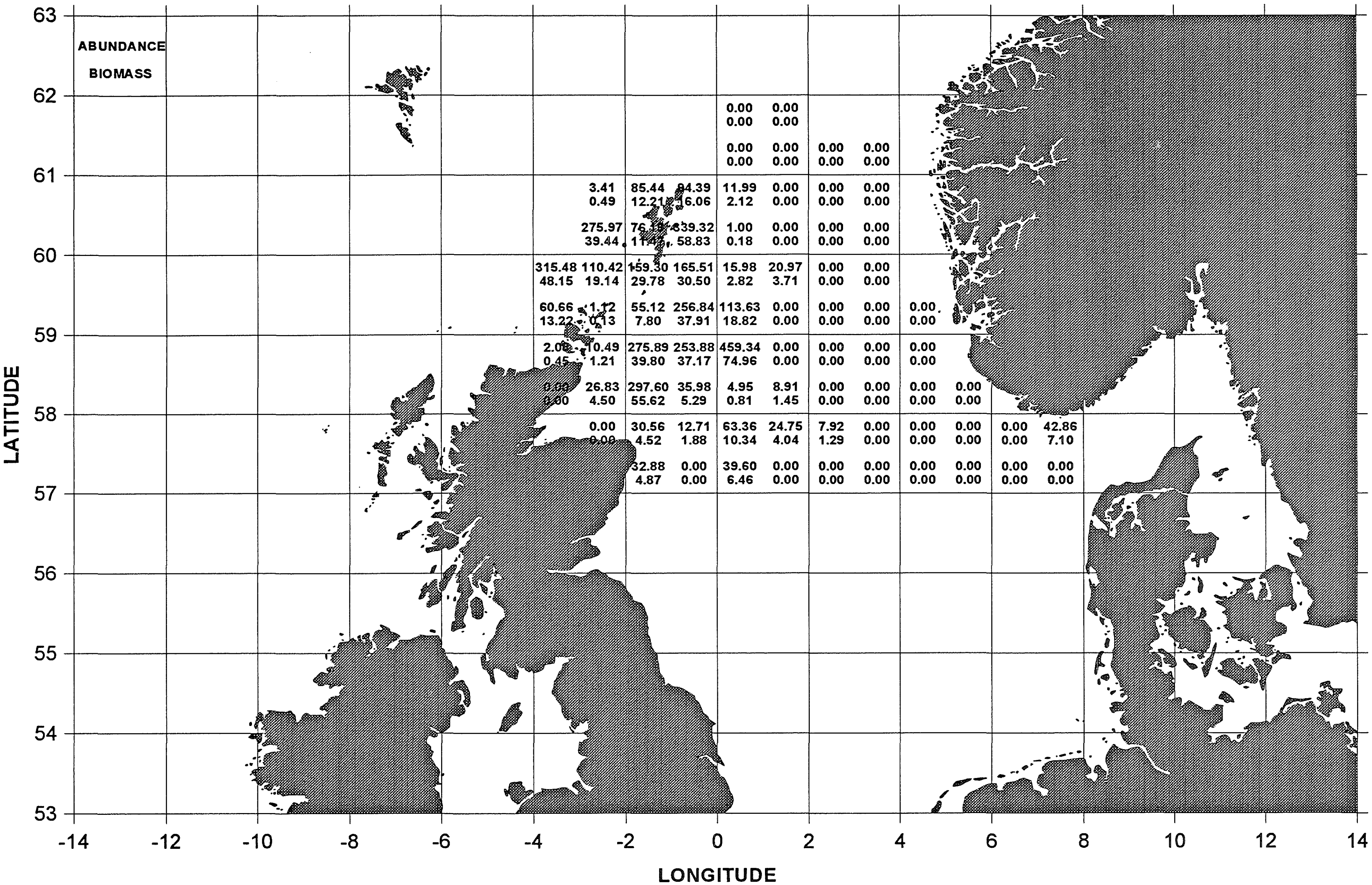
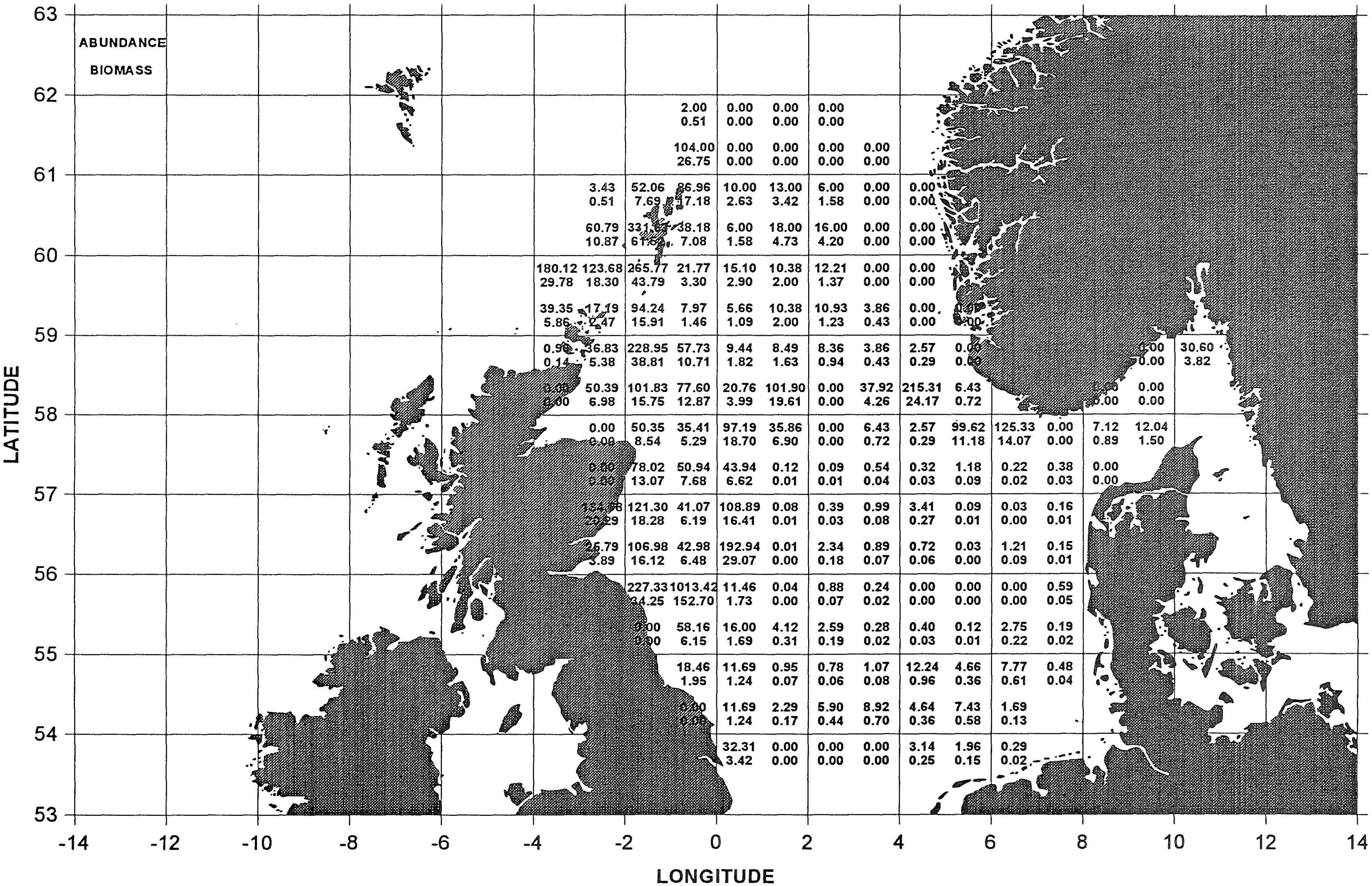
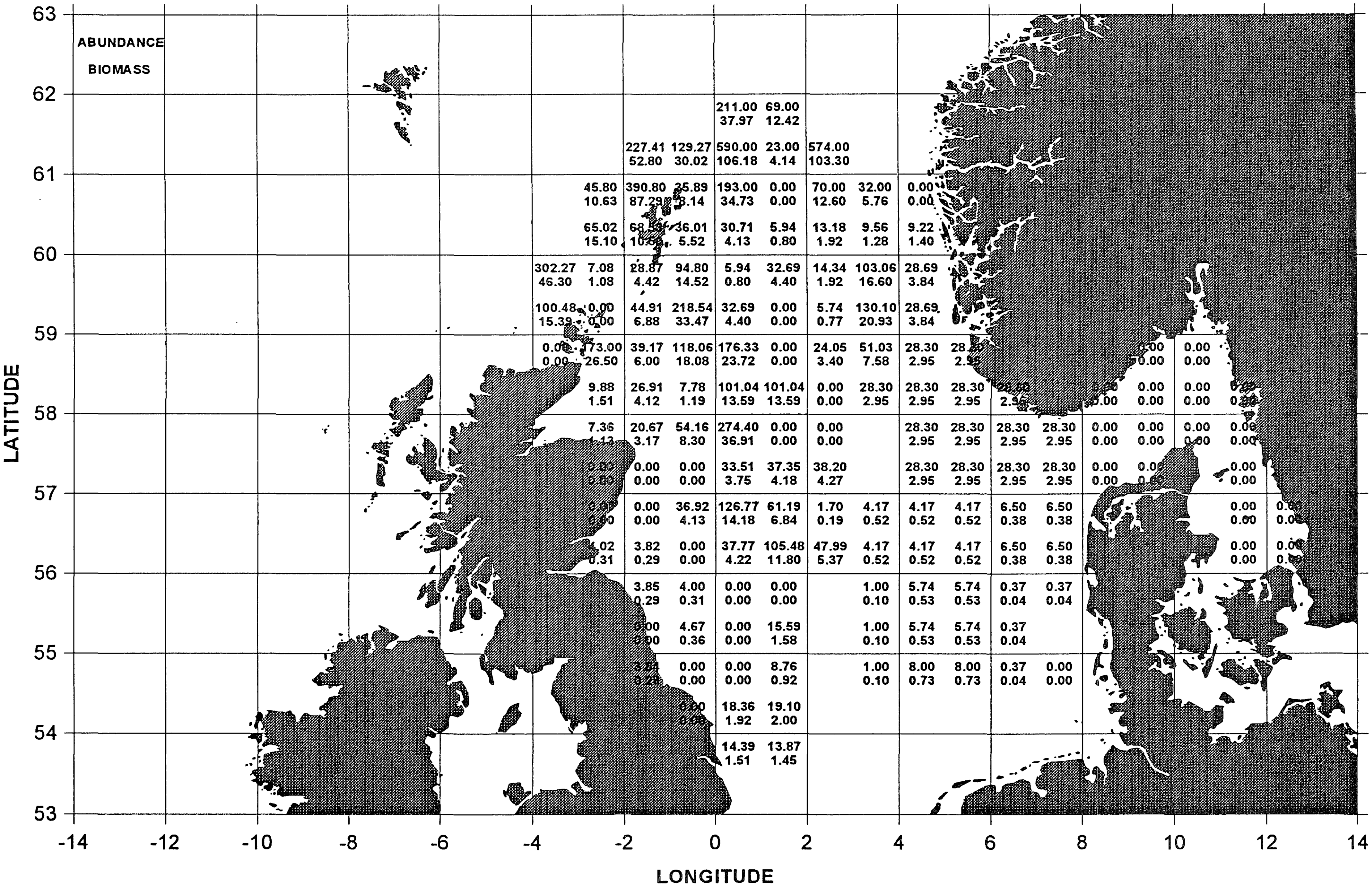


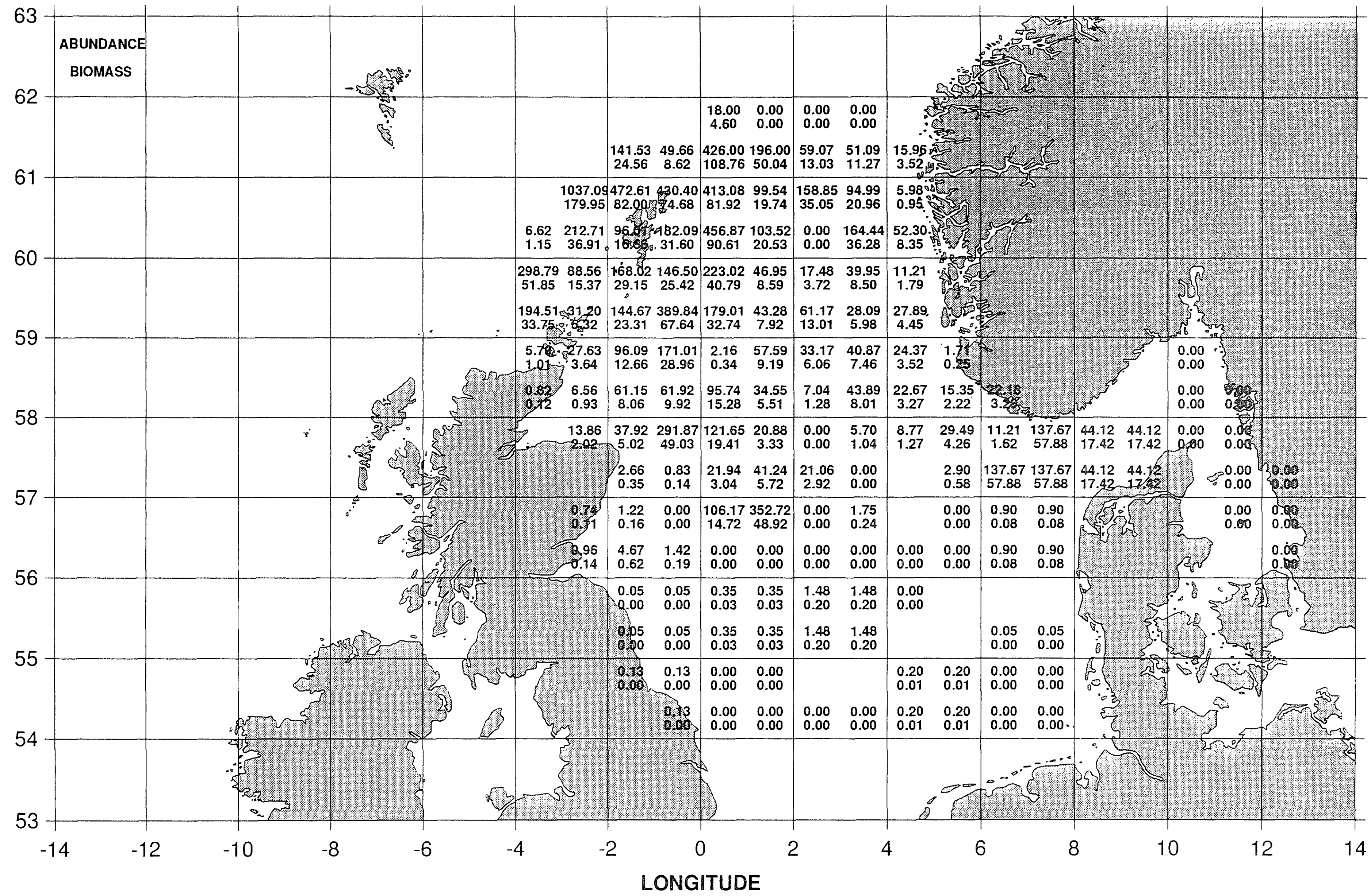
# Mature autumn spawners (1987).



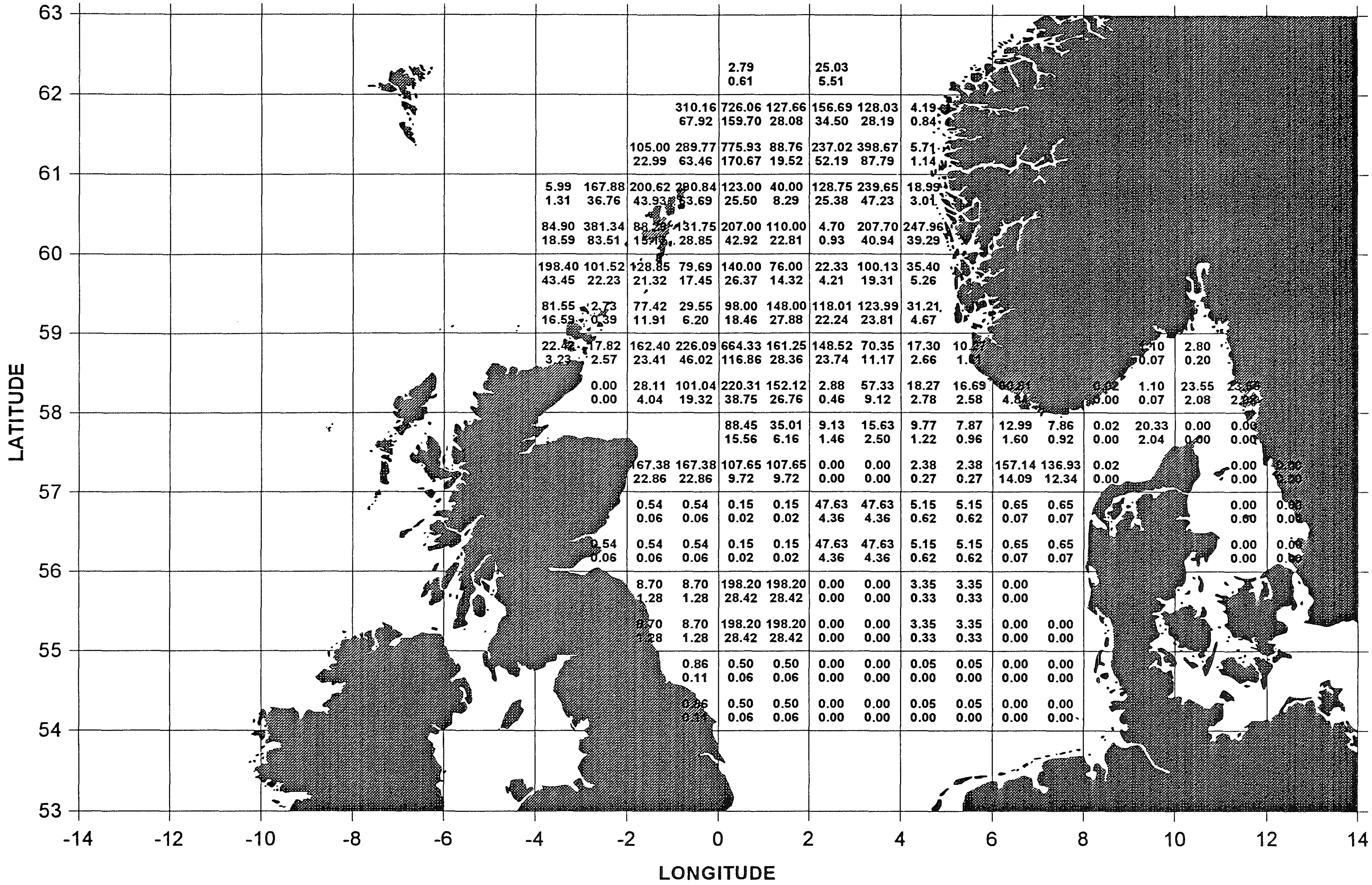
# Mature autumn spawners (1988).



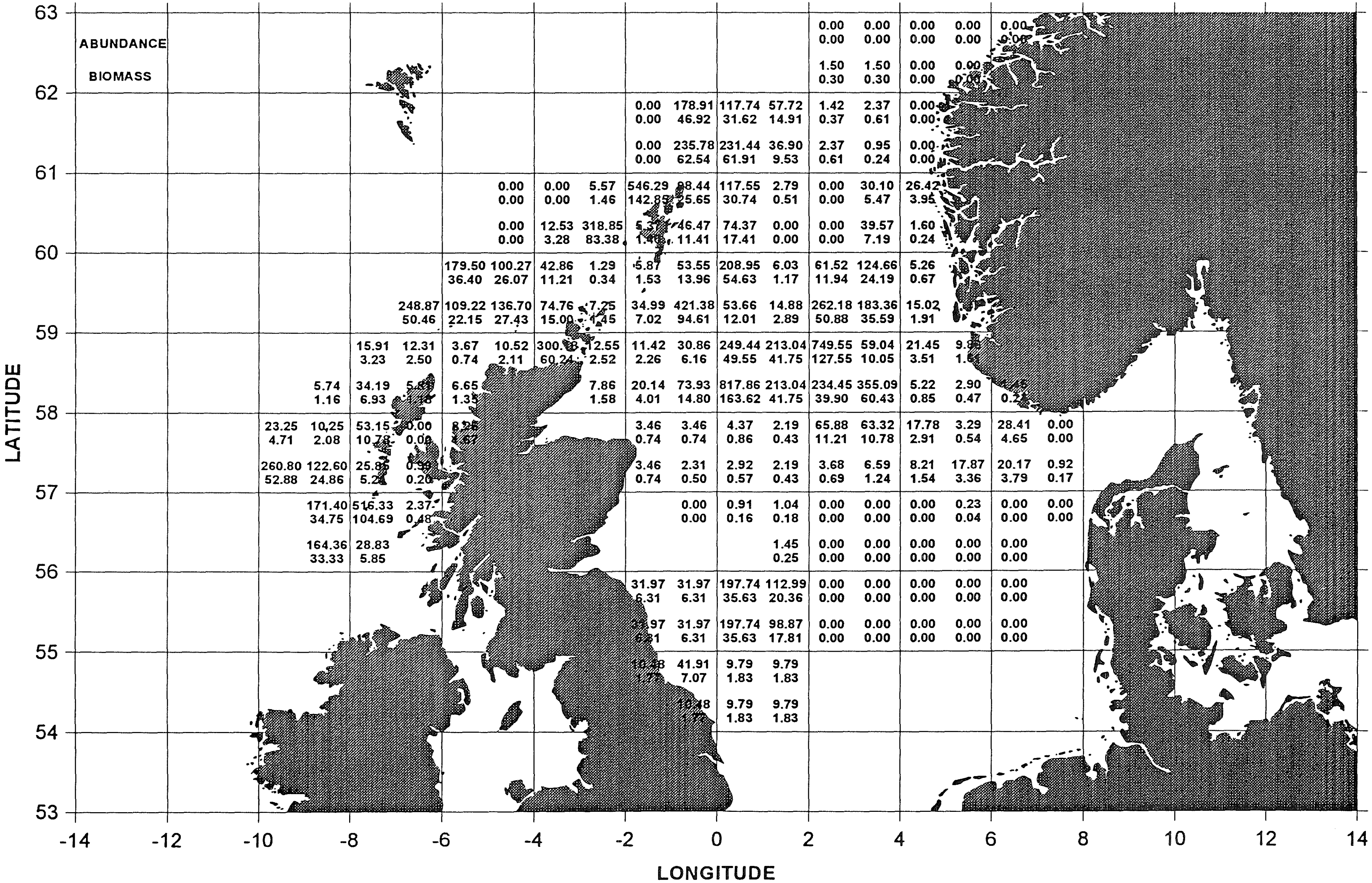
# Mature autumn spawners (1989).



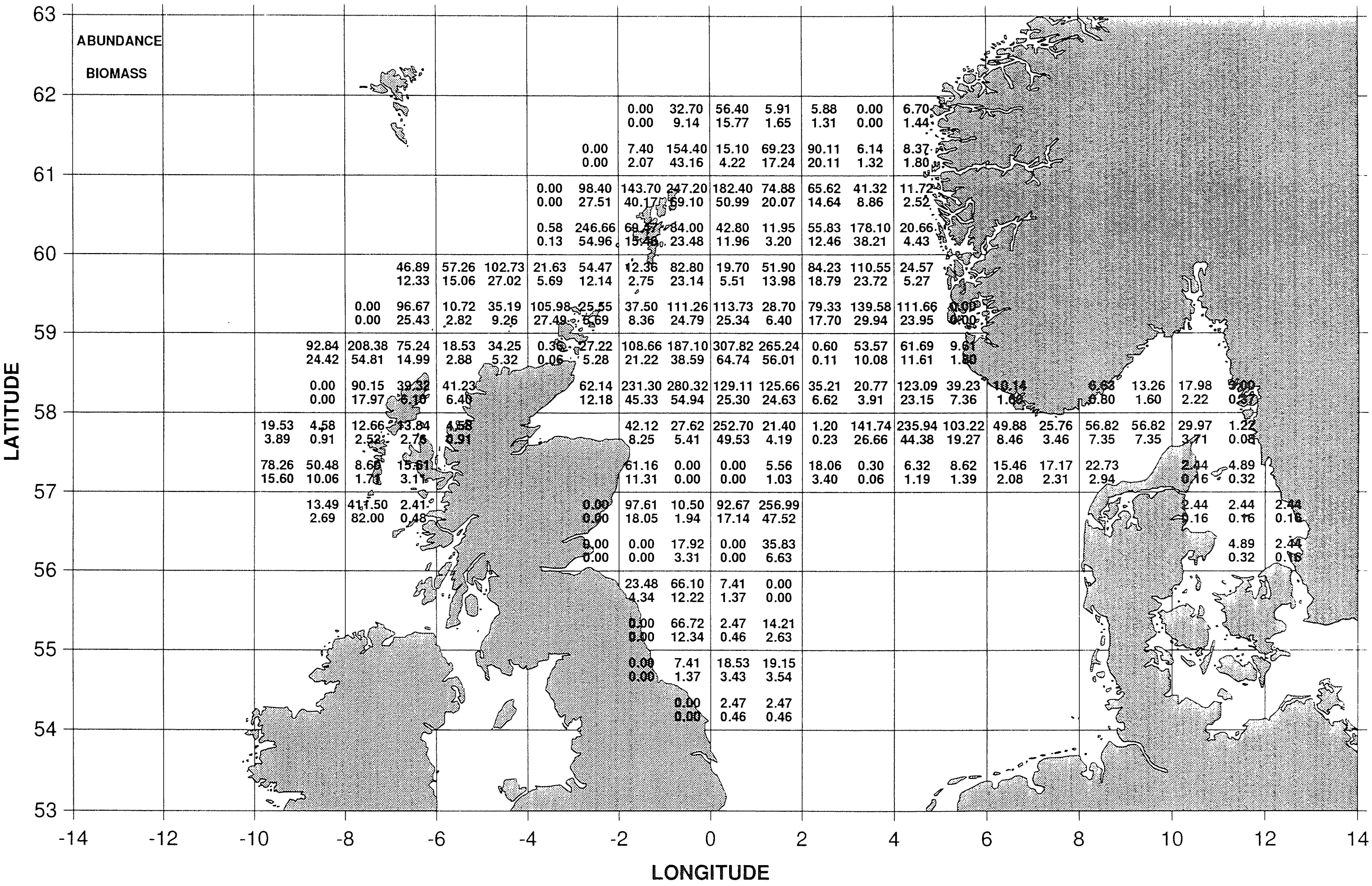
# Mature autumn spawners (1990).



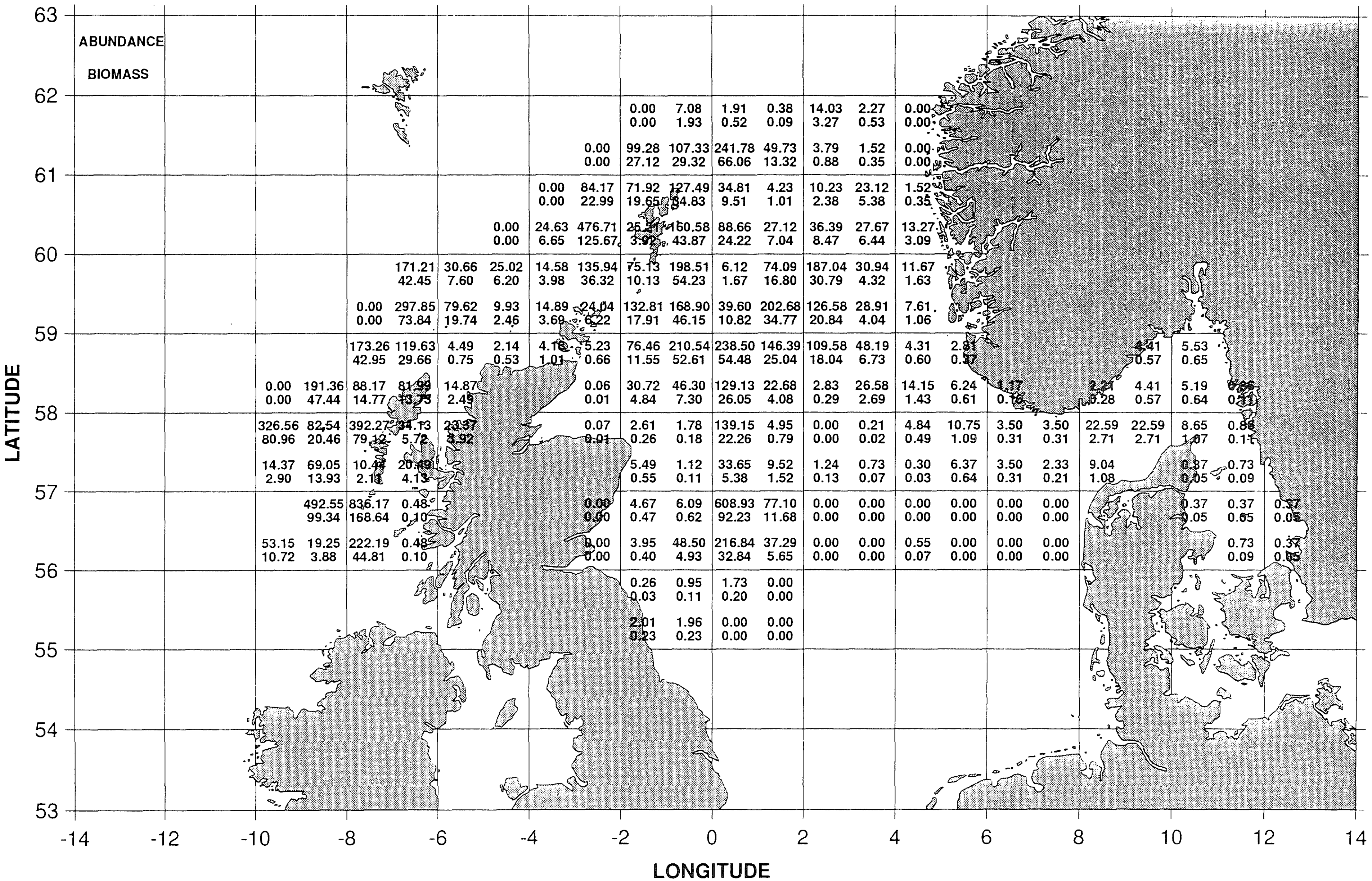
# Mature autumn spawners (1991).



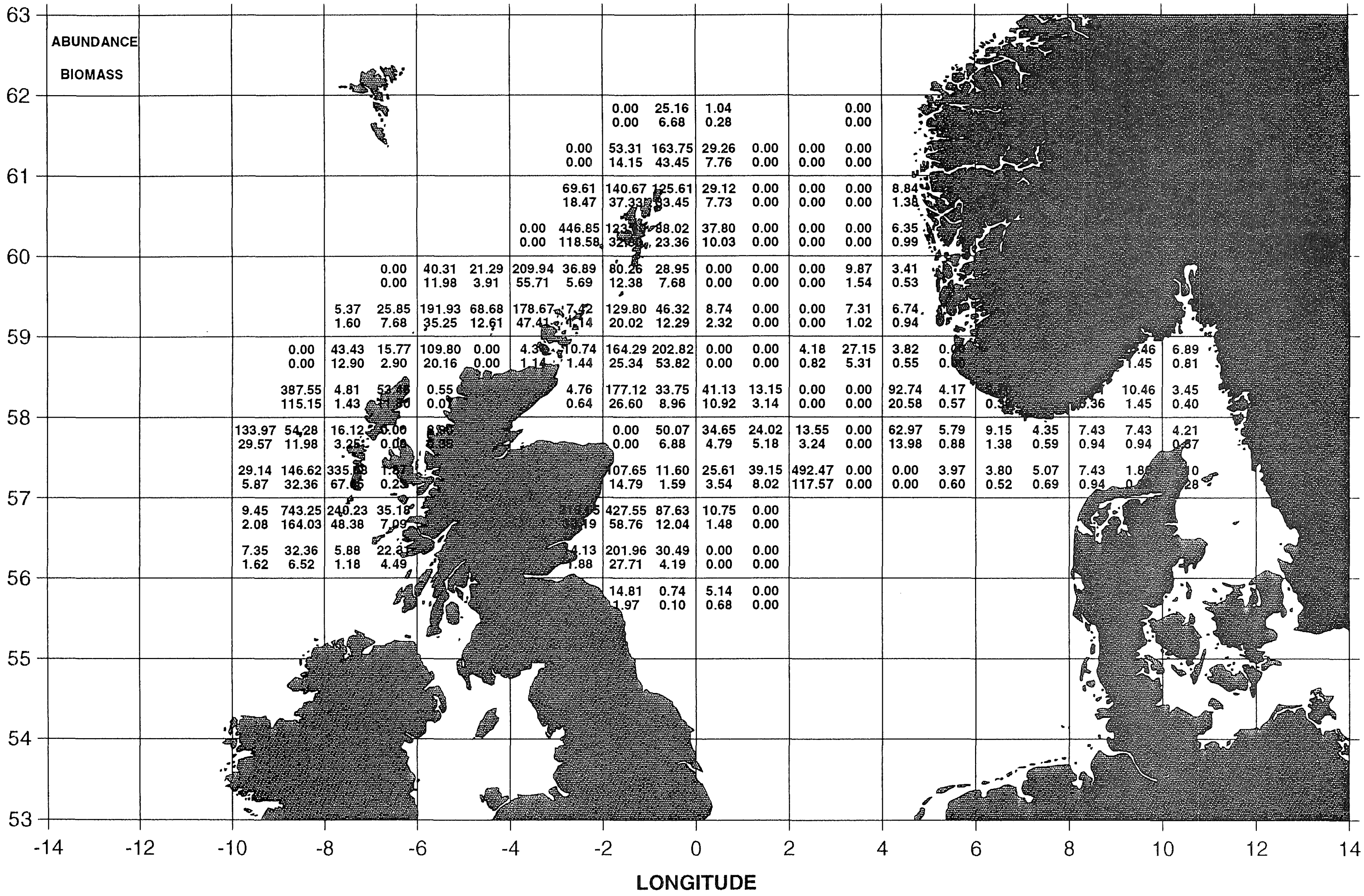
# Mature autumn spawners (1992).



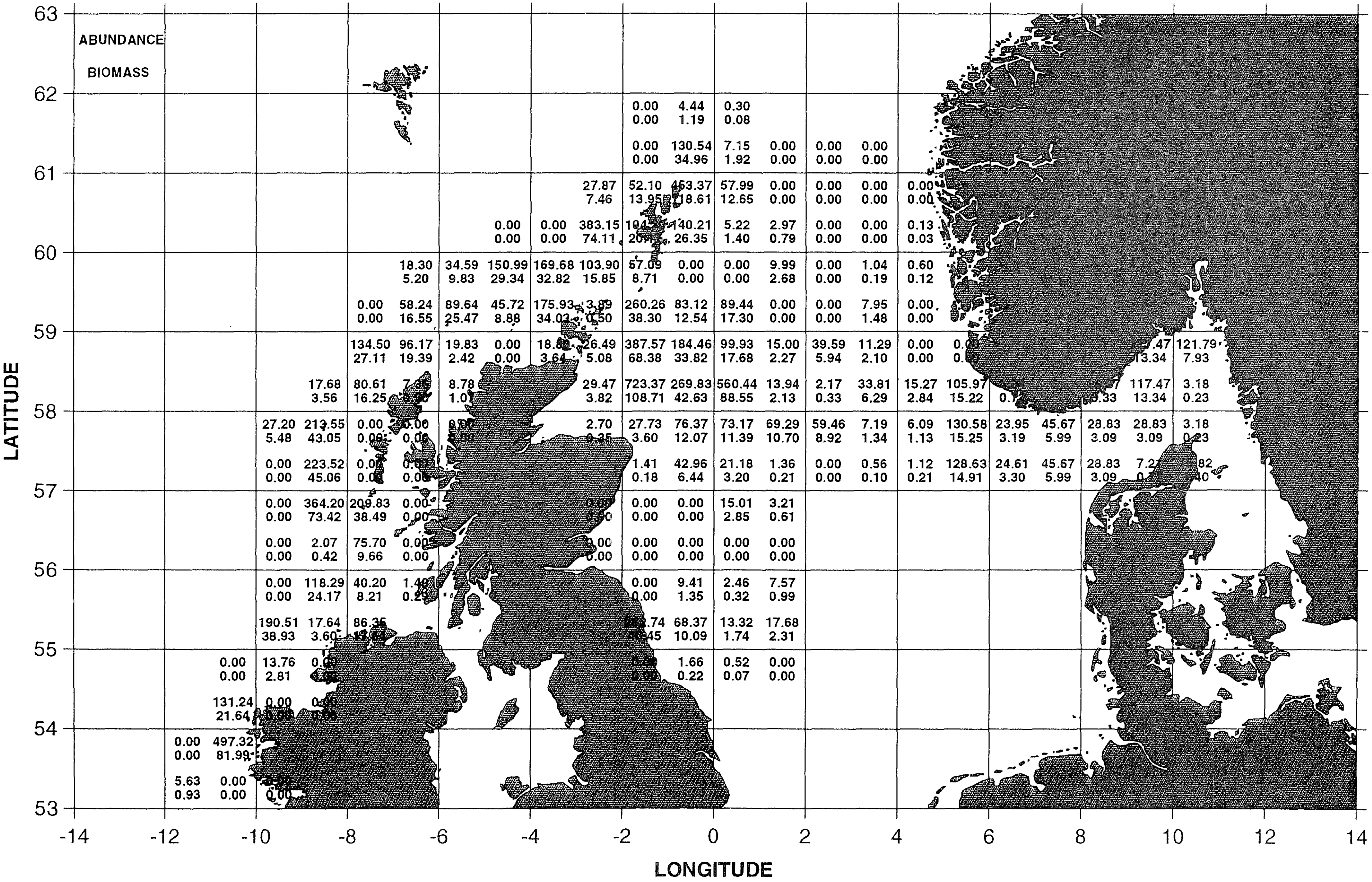
# Mature autumn spawners (1993).



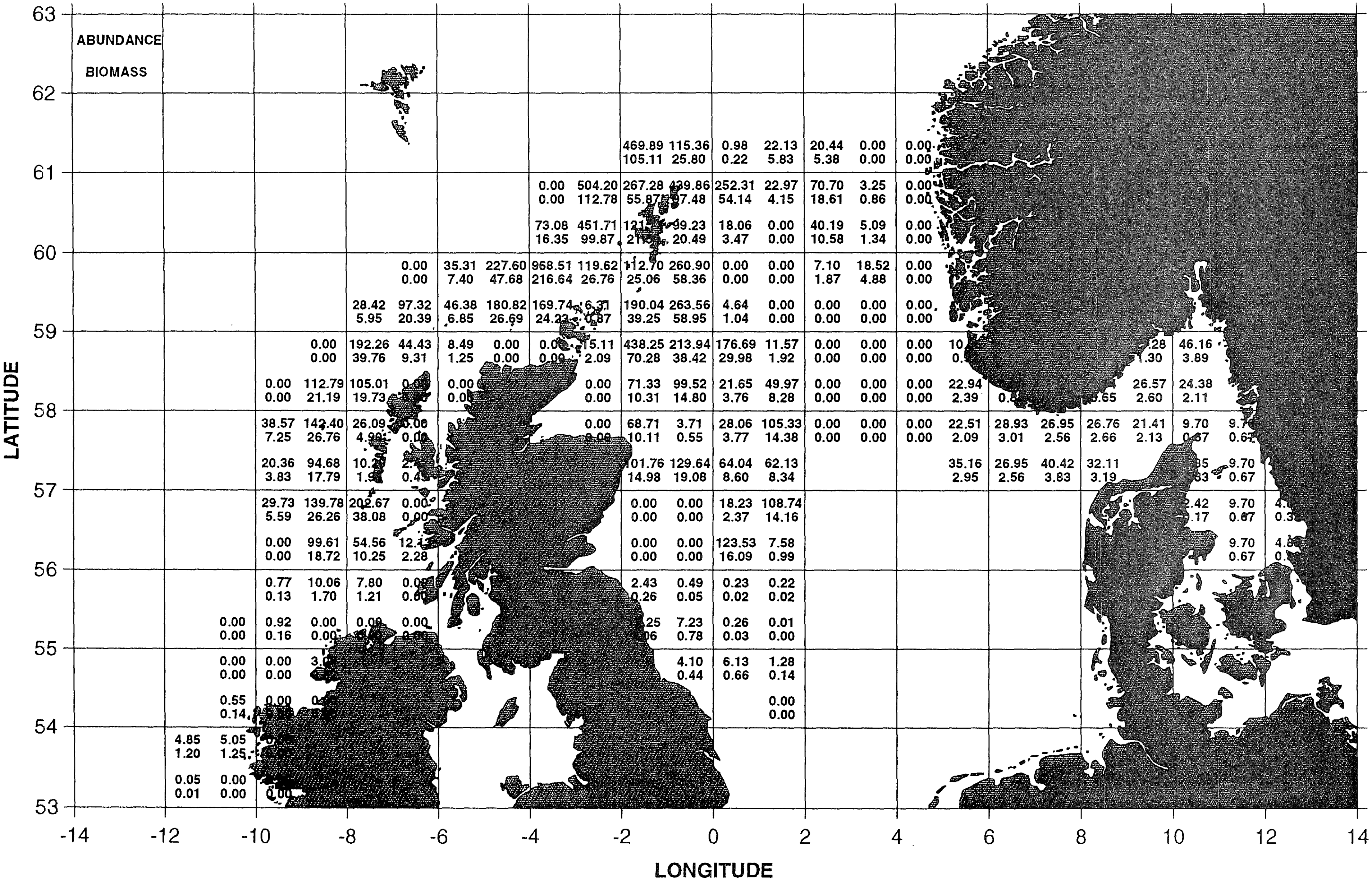
# Mature autumn spawners (1994).



# Mature autumn spawners (1995).



# Mature autumn spawners (1996).



## APPENDIX C

## A COMPARISON OF INDICES OF HERRING STOCK (INDEPENDENT OF THE ASSESSMENT MODEL)

John Simmonds, SOAEFD Marine Laboratory, PO Box 101
Victoria Road, Aberdeen - 13 December 1996

### Introduction

In order to get some information on relative trends in the abundance of herring described by different indices a simple analysis of acoustic and IBTS surveys was carried out. Both surveys provide age disaggregated indices of abundance which can be used to give indices of relative cohort strength recruiting to the adult stock. These indices can then be used as an indication of the relative performance of the two series over the period compared. The indices values used are those reported in the Herring Assessment WG Report (Anon, 1996).

### Methods

The year class strength measured by acoustic and IBTS surveys can be seen for years 1984 to 1996 in Figures 1 and 2 for the two surveys. The IBTS exhibits much steeper selection (faster apparent reduction of numbers at age) than the acoustic survey, but for each survey it may be assumed that the relative abundance at age in each year is an indication of year class strength. In order for the comparison to be independent of any changes in mortality between year class or between surveys only fully comparable year class strengths have been included in the analysis, thus for a comparison of the acoustic survey and the IBTS only the abundance of 2, 3, 4 and 5 ring fish have been included in the analysis. For some treatments the 5 ring class is not used as this is a +ring class in the IBTS.

The relative abundance of each cohort was estimated from the survey time series by two methods:

1. The abundance at each age weighted by their relative abundance in the survey; this assumes the errors are dependant on the abundance, then the relative cohort abundance is:

$$N_{1y} = \frac{N_{2(y+1)} + N_{3(y+2)} + N_{4(y+3)} + N_{5(y+4)}}{\sum_{y=1984}^{y=1996} \sum_{a=2}^{a=5} N_{ay} / \sum y}$$

   where N2(y+1) is the number of 2 ring fish in year y+1 and Sy is the number of years of data. Where the 5 ring observations are excluded these are removed from both top and bottom of the equation. These series are described as the weighted series.

2. Equal weight for each age, to remove the effects of selection which is known to be different in each index, in this case the relative cohort abundance is:

$$N_{1y} = \frac{N_{5(y+4)}}{\sum_{y=1984}^{y=1996} N_{5y}} + \frac{N_{4(y+3)}}{\sum_{y=1984}^{y=1996} N_{4y}} + \frac{N_{3(y+2)}}{\sum_{y=1984}^{y=1996} N_{3y}} + \frac{N_{2(y+1)}}{\sum_{y=1984}^{y=1996} N_{2y}}$$

This series is described as the normalised series.

### Results

The relative cohort abundances derived from IBTS and acoustic surveys are shown in Figure 3. The substantial peak in the IBTS in the weighted series is due to a single survey and year class observation; this can be seen in

Figure 1 as an unusually high value in the 1987 cohort occurring at age 2 ring in the 1988 survey. This cohort is not seen to the same extent at 1 ring in 1987 or as 3 ring in 1989. The normalised series are less sensitive to this value.

The ratio of the IBTS cohort indices and the acoustic survey cohort indices (from Fig. 3) is shown in Figure 4 for the 1 ring in 1983 to 1993. For clarity a three year running mean has been included on the plot. The mean recruitment ratio from the acoustic to IBTS surveys for the first four years of the period can be compared with the last four years of the period (these two ratios are independent of one another). The normalised series shows a relative increase of 35% in the acoustic index, the weighted index shows a 5% increase. It is possible to obtain an indication of the precision of the relative cohort indices using the three estimates of each cohort in the normalised series. The two normalised series +1 standard deviation can be seen in Figure 5. This analysis suggests that the long term relative performance change in these two surveys is much laee than that indicated by comparison of the assessment and the acoustic indices, and that the difference between these surveys may not be significant. It is also possible to estimate the mean CV for the acoustic and IBTS series. These are estimated as:

| | | |
|---|---|---|
| CV for relative IBTS normalised series | = | 0.43 |
| CV for relative acoustic normalised series | = | 0.25 |

**Figure 1. Cohort Abundance North Sea Herring from IBTS surveys (years are surveys)**

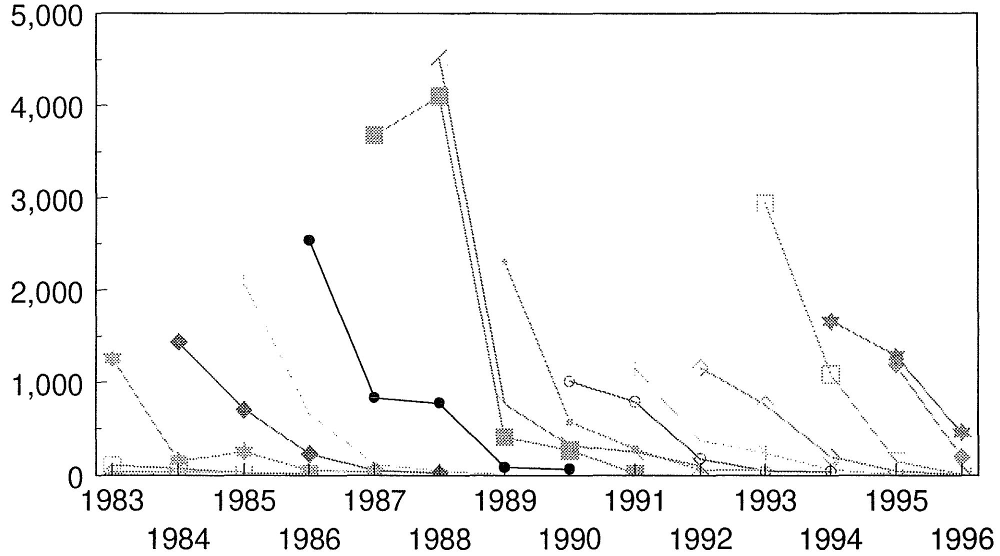



**Figure 2. Cohort Abundance North Sea Herring from Acoustic Surveys (years are surveys)**

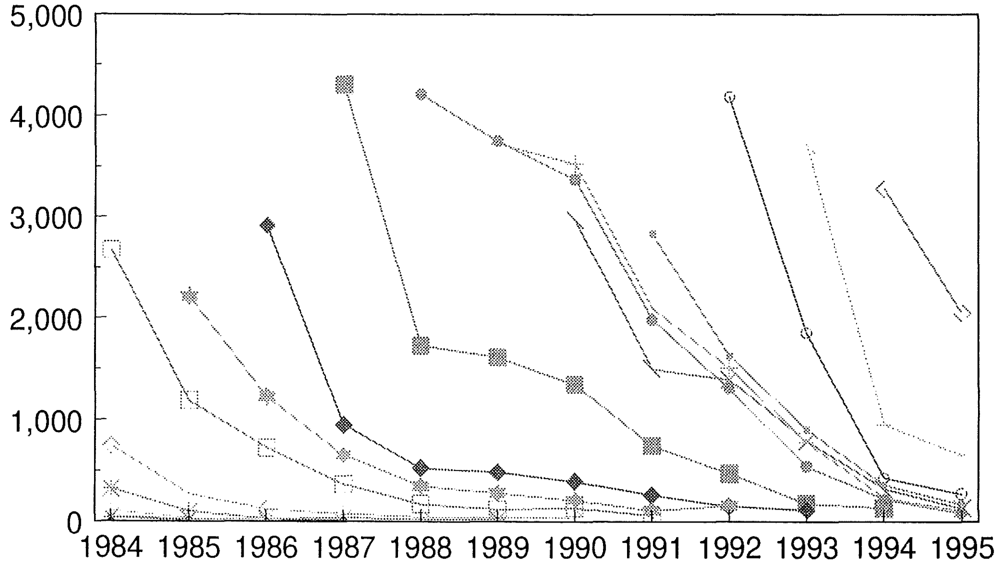


**Figure 3. Estimates of relative cohort strength (refered to 1 ring year) from 2 to 4 ring and 2 to 5 year age classes, weighted by survey abundance and weighted by equally.**

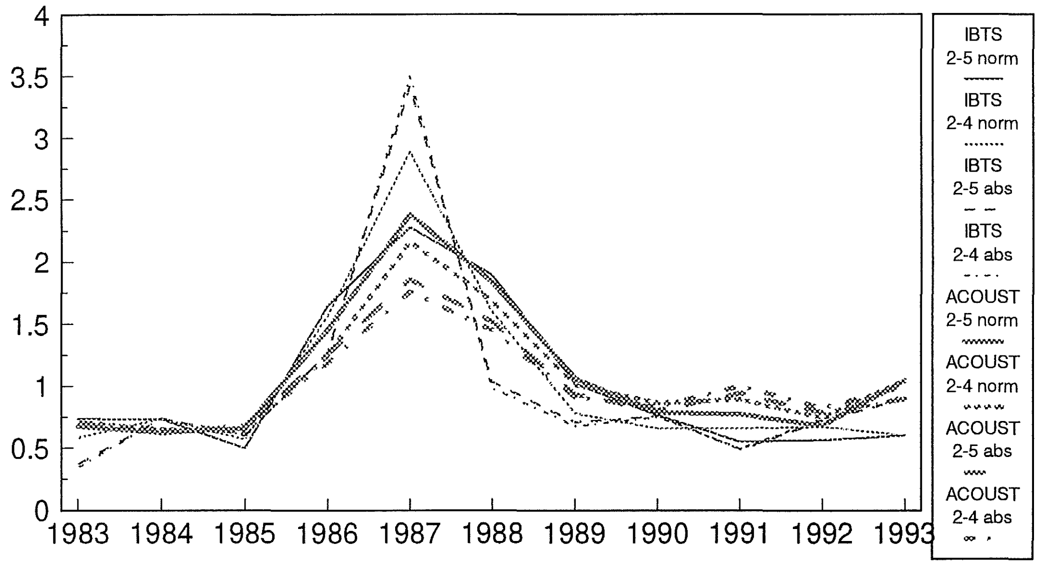



**Figure 4. Ratio of Relative Acoustic and IBTS Estimates of cohort strength (refered to 1 ring year )from 3 surveys (dotted)and smoothed (solid) using ages 2 to 4.**

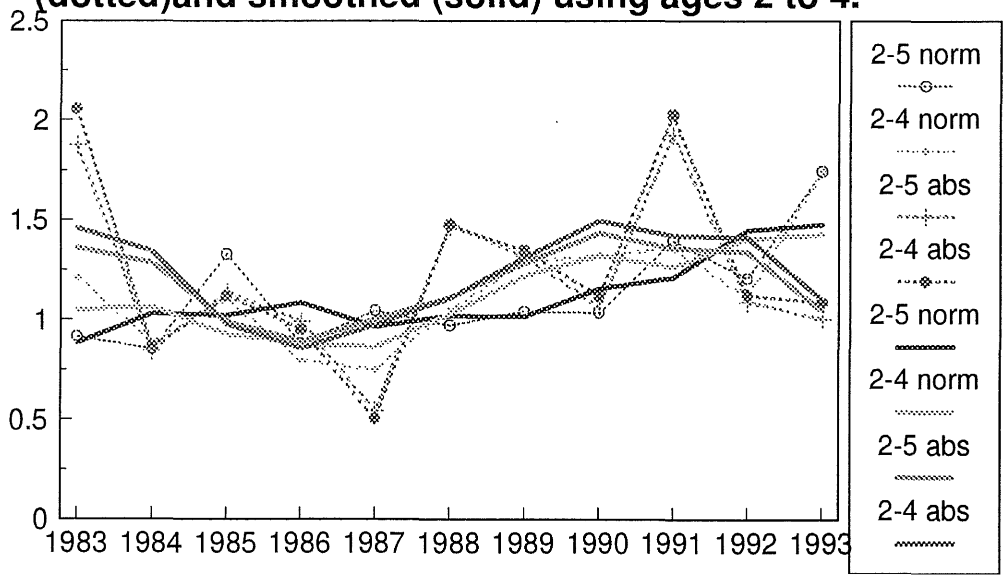
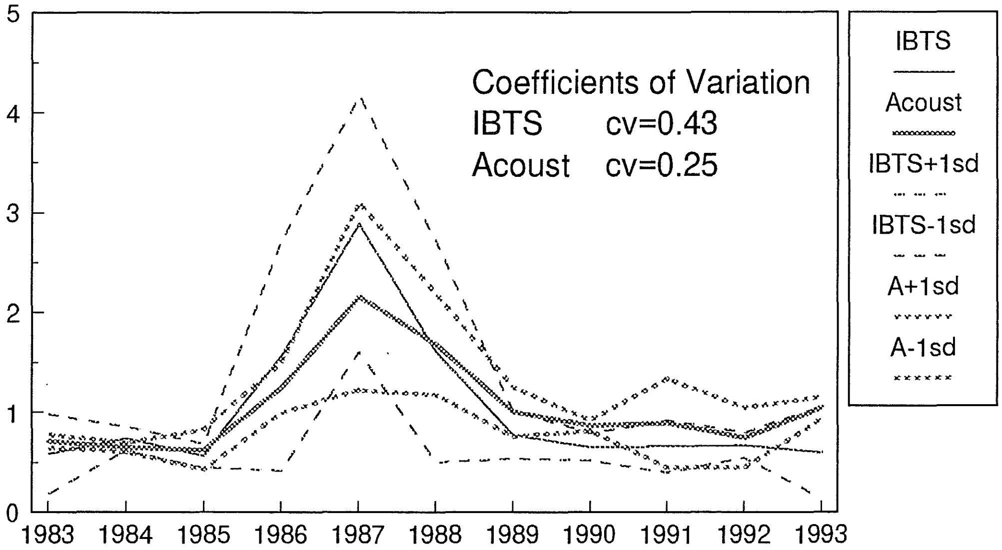


**Figure 5 Estimates of relative cohort strength ( refered to 1 ring year) from succesive surveys ±1 standard deviation IBTS 2-4 years Acoustic surveys 2-4 years**



APPENDIX D

# PERCEPTIONS OF NORTH SEA HERRING STOCK DYNAMICS AND SURVEY VARIABILITY THAT ARE ROBUST TO CATCH MISREPORTING

K R Patterson, SOAEFD Marine Laboratory
PO Box 101, Victoria Road, Aberdeen

## 1. Introduction

This note explores what change in perception of trends in stock size, fishing mortality, landings from the North Sea herring stock occurs when the assumption that catches are estimated without bias is relaxed to the assumption that catches are unknown. Variances with which the various survey indices estimate stock size and age-structure are estimated, together with a simple measure of time-series correlation in the errors in spawning biomass estimates.

## 2. The Model Described

The model used here is a derivative of models described by Patterson (1996) and Anonymous (1996). Familiarity with those documents will be assumed and only a brief description of the present application is provided here.

The model treats estimates of fish abundance separately from the estimates of age-structure, and ignores interdependence in the two sorts of information. This allows biological sampling of landings for age-structure to be used in the model while not using information on total catches, which is here considered a potential source of bias and is not used. Similarly, acoustic survey estimates of stock abundance (which are principally determined by echo-integration) can be treated separately from the estimates of the age-structure of the stock (which are derived from the accompanying trawl sampling). For consistency, the IBTS survey has been treated in a similar way, and overall herring abundance from that survey has been treated as being measured separately from the age-composition of the fish population. This treatment is consistent with the usual assumption that the greatest source of variability in surveys arises from variable catchabiltiy of the gear.

### 2.1 Assumptions

The model has been structured with the following assumptions:

- Catch data are assumed to be unreliable and are not used.
- Biological sampling of catches for age-structure information is assumed to be unaffected by misreporting of catches.
- Fish aged less than two years and more than eight years old are excluded from the animalysis.
- Random sampling for age is assumed in both catch and in surveys.
- Instead of attempting to estimate annual fishing mortalities, a polynomial trend in fishing mortality with time is fitted. This is a simple approach to smoothing, which is used because models of this type perform extremely poorly for estimating annual fishing mortalities or landings.
- Landings reported between 1975 and 1981 are assumed known precisely. Imposing this constraint allows a rescaling of the missing catch model for comparison with a conventional model.
- Selection is assumed to be uniform from ages 2 to 8.

### 2.2 Notation

Defining the following variables:

a,y - subscripts describing year and age
N - Population abundance
W- weight of fish at age and year
P - proportions of fish at age and year in the catches or in the surveys
U - index of abundance of spawning fish

Q - proportionality parameters ("catchabilities") relating the indices of abunance of the larvae and acoustic surveys to the fitted populations.
F - fishing mortality
$f_i$ - parameters of the fishing mortality trend in time, i =1,j
$T^2$ - effective sample size when sampling for proportions at age (see Haist *et al.*, 1993 for a detailed description of this parameter).
$\sigma^2$ - survey variance
$n_{pc}$, $n_u$ - number of observations of proportions in the catches and in the surveys respectively.
$\xi$ - estimates of the variances of the proportions of fish by age in the catches, calculated on the assumption of random sampling from a multinomial distribution. $\xi$ is calculated as $PC_{a,y}(1-PC_{a,y})+ 0.01$ (Haist *et al.*, 1993).
$\alpha$ - as $\xi$, for sampling for ages in acoustic surveys.

### 2.3 Structural assumptions

Fishing mortality and abundance estimates from historic VPA have been assumed to be known precisely up to 1981. Thereafter, fishing mortality is structured as

$$F_{a,y} = \sum_{i=1}^{i=j} f_i \cdot (y-1981)^{i-1} \qquad (1)$$

i.e., a simple polynomial-time model. Additional terms $f_i$ are added to the model until adding additional parameters results in no significant improvement to the model fit at the 0.05 probability level (terms are not included if the log-likelihood increases by less than 1.96).

The usual exponential mortality and catch equations are assumed to hold and are used as the structural model. As absolute estimates of stock size cannot be calculated when catches are not known, all abundance estimates are scaled to VPA-estimated values for the period between 1975 and 1981.

Spawning stock biomass is simply calculated as

$$SSB_y = \sum_a N_{a,y} W_{a,y} O_{a,y} \text{ maturity ogive} \qquad (2)$$

### 2.4 Information on age-structure

The model is fitted by finding a maximum in the joint log-likelihood term for age-structured information and for information about the indices of abundance of spawning biomass. Omitting subscripts showing the source of information (surveys, catch sampling, etc) the log-likelihood component is:

$$-\frac{1}{2}\sum_{a,y}\left( \ln(2\Pi\xi_{\alpha,\psi}T^2) + \frac{(P_{a,y} - \hat{P}_{a,y})^2}{T^2\xi_{a,y}} \right) \qquad (3)$$

where $\xi$ is given by

$$\xi_{a,y} = P_{a,y}(1-P_{a,y}) + 0.01 \qquad (4)$$

and $T^2$ is estimated iteratively as

$$T^2 = \sum_{a,y} \frac{(P_{a,y} - \hat{P}_{a,y})^2}{n_{pc}\xi_{a,y}} \qquad (5)$$

For surveys, the proportions P are proportions of fish by age in the samples. For commercial catches, they are proportions of fish by age in the sampled catches, with corresponding conventional structural assumptions.

## 2.5 Information on abundance of spawning biomass

These are treated conventionally assuming a simple proportionality of survey index to the spawning stock size from the structural model, and lognormal observation error:

$$-\frac{1}{2}\sum_{y}\left(\ln(2\Pi\sigma^{2})+\frac{\ln(Q\hat{B}_{y}/U_{y})^{2}}{\sigma^{2}}\right) \tag{6}$$

with variances iteratively recalculated as

$$\sigma^{2}=\sum_{y}\left(\frac{\ln(QB_{y}/U_{y})^{2}}{n_{u}}\right) \tag{7}$$

Separate estimates of $^{2}$ for each source of age-structured information were calculated, and separate estimates of $^{2}$ and of Q for each estimate of SSB were also calculated.

## 3. Data

The information used to estimate stock parameters was:

- Estimates of the proportion of total international catch by number in the adult (2+ stock), by year (1975 to 1996).
- Acoustic survey estimates of the abundance of spawning fish by year (1986 to 1996)
- Acoustic survey estimates of the proportion of fish by age in the adult stock (1986 to 1996)
- IBTS survey estimates of the biomass of fish (1983 to 1996)
- IBTS survey estimates of proportion of fish by age in the adult stock (1983 to 1996)
- The multiplicative larval abundance index (MLAI) from International Herring Larvae surveys

These data are given in Anon (1996), except for the 1996 acoustic larval survey estimate (Simmonds, pers. comm., 1997)

## 4. Model Fits and Parameter Estimates

Key population parameter estimates are given in Figure 1. This shows generally similar trends to those estimated in the conventional assessment model, except that:

- Recruitment between 1985 and 1990 is estimated as being much higher
- Catches in the period 1987 to 1991 are estiamted as being substantially higher than reported catches, almost reaching double reported levels from 1987 to 1990. However, as noted in Patterson (1996), the precision with which catches or fishing mortality can be estiamted with this type of model is very low.
- The model indicates that the spawning biomass of herring in the late 1980s may have reached much higher levels than indicated in the conventional model. According to estimates of accuracy in Patterson (1996), estimates of stock size from this type of model are expected to be quite good.

Details of the full model fit are given in the Appendix Tables.

Estimates of the variance of survey spawning biomass estimates are:

| Survey | Variance ($\sigma^2$) | Probability of no positive autocorrelation in errors (*) |
|---|---|---|
| Acoustic SSB | 0.32 | 0.02 |
| MLAI | 0.26 | 0.06 |
| IBTS SSB | 0.21 | 0.79 |

(*) Runs test, Draper and Smith (1981, p157)

Estimates of the $T^2$ parameter, indicating the effective sample size for estimating the proportions of fish by age are:

| Source of information | $T^2$ |
|---|---|
| Catch sampling | 0.0164 |
| Acoustic surveys | 0.0022 |
| IBTS age-structure | 0.232 |

The above model fit and associated estimates are obtained by using all available information, and making the assumption that the observation erorrs are independent. That however may not be the case, to the extent that different surveys may have different time-trends in residuals, which is indicated by the runs-test diagnostics. As a further data explotation exercise, the model fits were repeated but either fitting only to a) catch and acoustic survey data, b) catch and larval survey data, or c) catch and IBTS data. The same parameters were estimated, which allows a simple exploration of the dependence of perceptions of survey precision on making prior assumptions that each of the surveys in turn is "correct" with respect to the other two.

The perception that the age-structure of acoustic surveys is measured accurately contrasts with the perception that the accuracy of the spawning biomass estimate from the same survey is poor. To explore the consistency of the surveys further, the model was fitted to the commercial catch sampling proportions and to the acoustic survey age-structure alone. The resulting fit agrees well with the remaining sources of information, with the exception of the acoustic survey SSB estimate (Fig. 6).

| Data series | Fitted to acoustic SSB+ ages | Fitted to IBTS SSB+ages | Fitted to acoustic ages | Fitted to MLAI |
|---|---|---|---|---|
| Catch sampling ($T^2$) | 0.01644 | 0.01549 | 0.0164 | 0.01517 |
| Acoustic survey age structure ($T^2$) | 0.00215 | 0.00925 | 0.00215 | 0.00953 |
| IBTS age-structure ($T^2$) | 0.235 | 0.197 | 0.366 | 0.471 |
| Acoustic SSB ($\sigma^2$) | 0.0866 | 0.375 | 1.157 | 0.257 |
| IBTS SSB ($\sigma^2$) | 0.898 | 0.196 | 0.366 | 0.250 |
| MLAI ($\sigma^2$) | 1.44 | 0.376 | 0.336 | 0.257 |

## 5. Discussion

The following inferences could be drawn from the parameter estimates above:

1. In terms of measures of variability in abundance estimates, the IBTS abundance index performs best, the acoustic survey performs worst, and the performance of the MLAI index is intermediate.

2. In terms of measures of between-year correlation in errors in abundance, which may be more important in terms of providing advice for management purposes, the IBTS survey is unlikely to have error correlation(P=0.97), the Acoustic survey is very likely to have correlated errors (P=0.02) and the MLAI index is somewhat less likely to have correlated errors (P = 0.06).

3. In terms of estimating the age-structure of either the catch or the stock, the acoustic survey has the largest effective sample size, the IBTS has the smallest effective samples size, and the sampling of commercial catches is intermediate.

Overall the model suggests that the most reliable source of information are the acoustic survey estimates of age-structure and the IBTS spawning biomass estimates.

Such inferences are of course predicated on the assumptions made in Section 2.1, and rely on ignoring process errors (eg changes in selection pattern, changes in natural mortality,etc).

## 6. References


Anonymous. 1996. Herring assessment working group for the area South of 62 N. ICES CM Assess: 10.

Draper, N. and Smith, H. 1981. Applied regression analysis (second edition). John Wiley and Sons, 709pp.

Patterson, K.R. 1996. Assessing fish stocks when catches are misreported: model, simulation tests and application to cod, haddock and whiting in the ICES area. ICES CM 1996/D:7.

Appendix Table 1. North Sea Herring. Elements of the Missing Catch structural model

| | Relative Population abundance (Populations in 1975 = VPA estimates) | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
| 2 | 839 | 926 | 288 | 251 | 425 | 486 | 1406 | 1383 | 2674 | 5472 | 6135 | 6376 | 14209 | 19335 | 11644 | 5936 | 4383 | 4624 | 3967 | 5710 | 4792 | 3598 |
| 3 | 360 | 148 | 177 | 103 | 177 | 296 | 274 | 747 | 831 | 1558 | 3092 | 3362 | 3389 | 7325 | 9667 | 5646 | 2792 | 1999 | 2046 | 1702 | 2376 | 1934 |
| 4 | 198 | 70 | 31 | 70 | 80 | 136 | 185 | 161 | 496 | 535 | 973 | 1873 | 1975 | 1931 | 4047 | 5180 | 2935 | 1407 | 977 | 970 | 783 | 1060 |
| 5 | 71 | 43 | 16 | 14 | 60 | 68 | 94 | 120 | 118 | 353 | 369 | 651 | 1216 | 1243 | 1179 | 2397 | 2976 | 1635 | 760 | 512 | 493 | 386 |
| 6 | 23 | 15 | 10 | 7 | 12 | 51 | 47 | 61 | 88 | 84 | 243 | 247 | 423 | 765 | 759 | 698 | 1377 | 1658 | 883 | 398 | 260 | 243 |
| 7 | 11 | 5 | 4 | 4 | 6 | 10 | 35 | 31 | 45 | 63 | 58 | 163 | 160 | 266 | 467 | 450 | 401 | 767 | 896 | 463 | 203 | 128 |
| 8 | 4 | 2 | 1 | 2 | 4 | 5 | 7 | 23 | 22 | 32 | 43 | 39 | 106 | 101 | 163 | 277 | 258 | 223 | 414 | 469 | 235 | 100 |
| Sum 2-9 | 1506 | 1210 | 527 | 451 | 764 | 1054 | 2049 | 2526 | 4274 | 8096 | 10914 | 12711 | 21478 | 30966 | 27926 | 20584 | 15121 | 12314 | 9944 | 10224 | 9142 | 7449 |
| Relative | 1.00 | 0.80 | 0.35 | 0.30 | 0.51 | 0.70 | 1.36 | 1.68 | 2.84 | 5.38 | 7.25 | 8.44 | 14.26 | 20.56 | 18.54 | 13.67 | 10.04 | 8.18 | 6.60 | 6.79 | 6.07 | 4.95 |

| | Relative Spawning Biomass in the Population | | | | | | | | | | | | | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1975-80 |
| 2 | 107 | 118 | 37 | 32 | 54 | 62 | 179 | 176 | 340 | 675 | 633 | 669 | 1197 | 1670 | 1243 | 636 | 415 | 328 | 217 | 538 | 460 | 284 | |
| 3 | 67 | 28 | 33 | 19 | 33 | 55 | 51 | 140 | 155 | 294 | 587 | 634 | 605 | 1122 | 1595 | 1026 | 541 | 369 | 242 | 264 | 446 | 362 | |
| 4 | 44 | 16 | 7 | 16 | 18 | 30 | 41 | 36 | 111 | 120 | 219 | 419 | 434 | 416 | 855 | 1110 | 637 | 303 | 209 | 201 | 176 | 241 | |
| 5 | 17 | 10 | 4 | 3 | 14 | 16 | 22 | 29 | 28 | 85 | 90 | 161 | 297 | 307 | 285 | 577 | 705 | 384 | 182 | 115 | 116 | 88 | |
| 6 | 6 | 4 | 3 | 2 | 3 | 14 | 13 | 17 | 24 | 23 | 66 | 66 | 115 | 208 | 205 | 186 | 354 | 438 | 242 | 105 | 71 | 64 | |
| 7 | 3 | 1 | 1 | 1 | 2 | 3 | 11 | 9 | 13 | 19 | 17 | 47 | 45 | 75 | 132 | 127 | 111 | 213 | 261 | 134 | 60 | 37 | |
| 8 | 1 | 1 | 0 | 0 | 1 | 2 | 2 | 7 | 7 | 10 | 14 | 12 | 33 | 31 | 48 | 82 | 76 | 68 | 130 | 146 | 75 | 32 | |
| Sum 2-9 | 246 | 178 | 85 | 74 | 126 | 183 | 319 | 413 | 679 | 1226 | 1627 | 2010 | 2726 | 3829 | 4363 | 3745 | 2839 | 2102 | 1483 | 1504 | 1404 | 1107 | 148 |
| Relative | 1.66 | 1.20 | 0.57 | 0.50 | 0.85 | 1.23 | 2.15 | 2.78 | 4.57 | 8.26 | 10.96 | 13.54 | 18.36 | 25.79 | 29.39 | 25.22 | 19.12 | 14.16 | 9.99 | 10.13 | 9.46 | 7.46 | 1.00 |

| | Proportions in the Population by Age | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
| 2 | 0.56 | 0.77 | 0.55 | 0.56 | 0.56 | 0.46 | 0.69 | 0.55 | 0.63 | 0.68 | 0.56 | 0.50 | 0.66 | 0.62 | 0.42 | 0.29 | 0.29 | 0.38 | 0.40 | 0.56 | 0.52 | 0.48 |
| 3 | 0.24 | 0.12 | 0.34 | 0.23 | 0.23 | 0.28 | 0.13 | 0.30 | 0.19 | 0.19 | 0.28 | 0.26 | 0.16 | 0.24 | 0.35 | 0.27 | 0.18 | 0.16 | 0.21 | 0.17 | 0.26 | 0.26 |
| 4 | 0.13 | 0.06 | 0.06 | 0.16 | 0.11 | 0.13 | 0.09 | 0.06 | 0.12 | 0.07 | 0.09 | 0.15 | 0.09 | 0.06 | 0.14 | 0.25 | 0.19 | 0.11 | 0.10 | 0.09 | 0.09 | 0.14 |
| 5 | 0.05 | 0.04 | 0.03 | 0.03 | 0.08 | 0.06 | 0.05 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 | 0.06 | 0.04 | 0.04 | 0.12 | 0.20 | 0.13 | 0.08 | 0.05 | 0.05 | 0.05 |
| 6 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.09 | 0.13 | 0.09 | 0.04 | 0.03 | 0.03 |
| 7 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.06 | 0.09 | 0.05 | 0.02 | 0.02 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 | 0.05 | 0.03 | 0.01 |

| | Fishing Mortality Parameterisation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
| Years from start: | | | | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| WG Mortality est. | 1.434 | 1.355 | 0.728 | 0.048 | 0.061 | 0.272 | 0.333 | 0.550 | 0.481 | 0.424 | 0.273 | 0.436 | 0.315 | 0.226 | 0.168 | 0.261 | 0.247 | 0.180 | 0.189 | 0.164 | 0.164 |
| Fitted F | 1.434 | 1.355 | 0.728 | 0.048 | 0.061 | 0.272 | 0.333 | 0.210 | 0.240 | 0.271 | 0.301 | 0.332 | 0.363 | 0.393 | 0.424 | 0.454 | 0.485 | 0.516 | 0.546 | 0.577 | 0.607 |

# Appendix Table 1 (contd.) North Sea Herring. Elements of the 'MCM' structural model

| Catches in Number | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ages | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
| 2 | 571 | 613 | 131 | 10 | 22 | 101 | 347 | 227 | 497 | 1129 | 1390 | 1569 | 3768 | 5484 | 3512 | 1894 | 1473 | 1630 | 1462 | 2193 | 1913 |
| 3 | 254 | 102 | 84 | 4 | 9 | 64 | 71 | 128 | 161 | 337 | 733 | 866 | 940 | 2173 | 3048 | 1883 | 980 | 736 | 787 | 683 | 990 |
| 4 | 145 | 50 | 15 | 3 | 5 | 31 | 50 | 29 | 101 | 121 | 242 | 505 | 573 | 599 | 1335 | 1807 | 1078 | 542 | 393 | 406 | 341 |
| 5 | 52 | 30 | 8 | 1 | 3 | 16 | 25 | 22 | 24 | 80 | 92 | 176 | 353 | 386 | 389 | 836 | 1093 | 629 | 306 | 215 | 215 |
| 6 | 17 | 11 | 5 | 0 | 1 | 12 | 13 | 11 | 18 | 19 | 60 | 67 | 123 | 238 | 251 | 244 | 506 | 638 | 355 | 167 | 113 |
| 7 | 8 | 4 | 2 | 0 | 0 | 2 | 10 | 6 | 9 | 14 | 14 | 44 | 47 | 83 | 154 | 157 | 147 | 295 | 360 | 194 | 88 |
| 8 | 3 | 2 | 1 | 0 | 0 | 1 | 2 | 4 | 5 | 7 | 11 | 10 | 31 | 31 | 54 | 97 | 95 | 86 | 167 | 197 | 102 |
| SUM | 1051 | 812 | 246 | 19 | 40 | 227 | 517 | 427 | 815 | 1707 | 2542 | 3237 | 5834 | 8994 | 8743 | 6917 | 5371 | 4557 | 3831 | 4054 | 3763 |
| Rel. 1975 | 1.00 | 0.77 | 0.23 | 0.02 | 0.04 | 0.22 | 0.49 | 0.41 | 0.78 | 1.62 | 2.42 | 3.08 | 5.55 | 8.56 | 8.32 | 6.58 | 5.11 | 4.34 | 3.65 | 3.86 | 3.58 |

| Catches in Weight | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ages | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | Mean 1975-1980 |
| 2 | 72 | 77 | 16 | 1 | 3 | 13 | 41 | 27 | 59 | 133 | 178 | 190 | 373 | 609 | 404 | 216 | 191 | 168 | 168 | 285 | 318 | |
| 3 | 45 | 18 | 15 | 1 | 2 | 11 | 10 | 19 | 24 | 50 | 120 | 132 | 140 | 315 | 466 | 281 | 163 | 129 | 114 | 109 | 192 | |
| 4 | 31 | 11 | 3 | 1 | 1 | 7 | 9 | 5 | 18 | 22 | 47 | 92 | 103 | 104 | 231 | 320 | 198 | 102 | 74 | 74 | 70 | |
| 5 | 13 | 7 | 2 | 0 | 1 | 4 | 5 | 5 | 5 | 17 | 19 | 36 | 74 | 76 | 81 | 161 | 222 | 130 | 62 | 46 | 47 | |
| 6 | 4 | 3 | 1 | 0 | 0 | 3 | 3 | 3 | 4 | 5 | 13 | 15 | 29 | 51 | 58 | 56 | 110 | 142 | 81 | 40 | 27 | |
| 7 | 2 | 1 | 0 | 0 | 0 | 1 | 3 | 1 | 2 | 4 | 4 | 10 | 12 | 20 | 38 | 37 | 35 | 70 | 88 | 49 | 22 | |
| 8 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 3 | 9 | 8 | 14 | 24 | 25 | 21 | 43 | 54 | 27 | |
| Sum | 167 | 117 | 38 | 3 | 6 | 38 | 72 | 61 | 114 | 233 | 384 | 478 | 740 | 1183 | 1292 | 1095 | 943 | 763 | 631 | 656 | 702 | 61.7671 |
| Rel. 1980-1975 m | 2.71 | 1.90 | 0.62 | 0.05 | 0.10 | 0.62 | 1.16 | 0.99 | 1.84 | 3.77 | 6.22 | 7.75 | 11.98 | 19.15 | 20.92 | 17.72 | 15.27 | 12.36 | 10.21 | 10.63 | 11.36 | |

| Proportion in catches | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ages | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
| 2 | 0.54 | 0.76 | 0.53 | 0.54 | 0.54 | 0.44 | 0.67 | 0.53 | 0.61 | 0.66 | 0.55 | 0.48 | 0.65 | 0.61 | 0.40 | 0.27 | 0.27 | 0.36 | 0.38 | 0.54 | 0.51 |
| 3 | 0.24 | 0.13 | 0.34 | 0.23 | 0.24 | 0.28 | 0.14 | 0.30 | 0.20 | 0.20 | 0.29 | 0.27 | 0.16 | 0.24 | 0.35 | 0.27 | 0.18 | 0.16 | 0.21 | 0.17 | 0.26 |
| 4 | 0.14 | 0.06 | 0.06 | 0.17 | 0.11 | 0.14 | 0.10 | 0.07 | 0.12 | 0.07 | 0.10 | 0.16 | 0.10 | 0.07 | 0.15 | 0.26 | 0.20 | 0.12 | 0.10 | 0.10 | 0.09 |
| 5 | 0.05 | 0.04 | 0.03 | 0.03 | 0.08 | 0.07 | 0.05 | 0.05 | 0.03 | 0.05 | 0.04 | 0.05 | 0.06 | 0.04 | 0.04 | 0.12 | 0.20 | 0.14 | 0.08 | 0.05 | 0.06 |
| 6 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05 | 0.02 | 0.03 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | 0.09 | 0.14 | 0.09 | 0.04 | 0.03 |
| 7 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.06 | 0.09 | 0.05 | 0.02 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 | 0.05 | 0.03 |

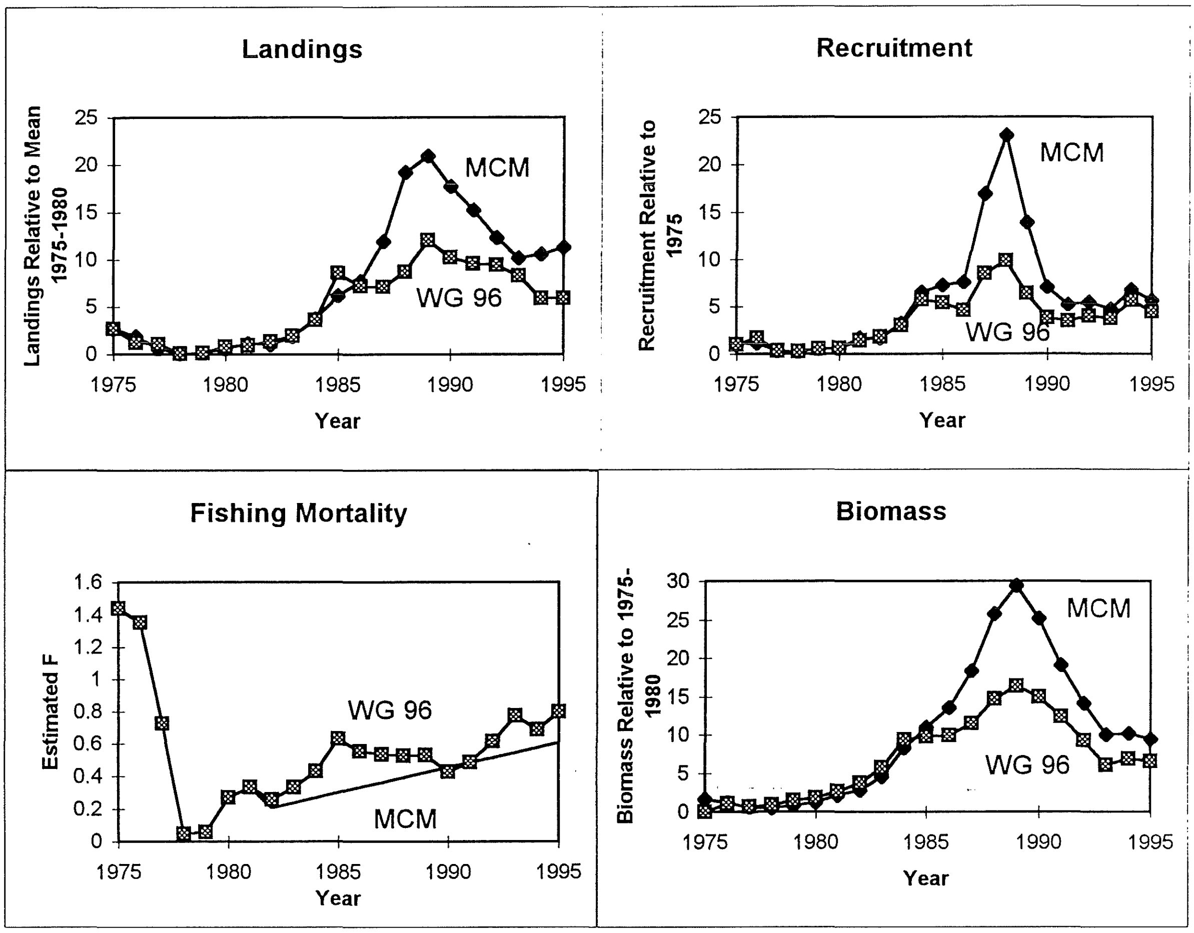



Figure 1. Summary of missing catch model fit compared with the assessment model fit given in Anon. (1996).

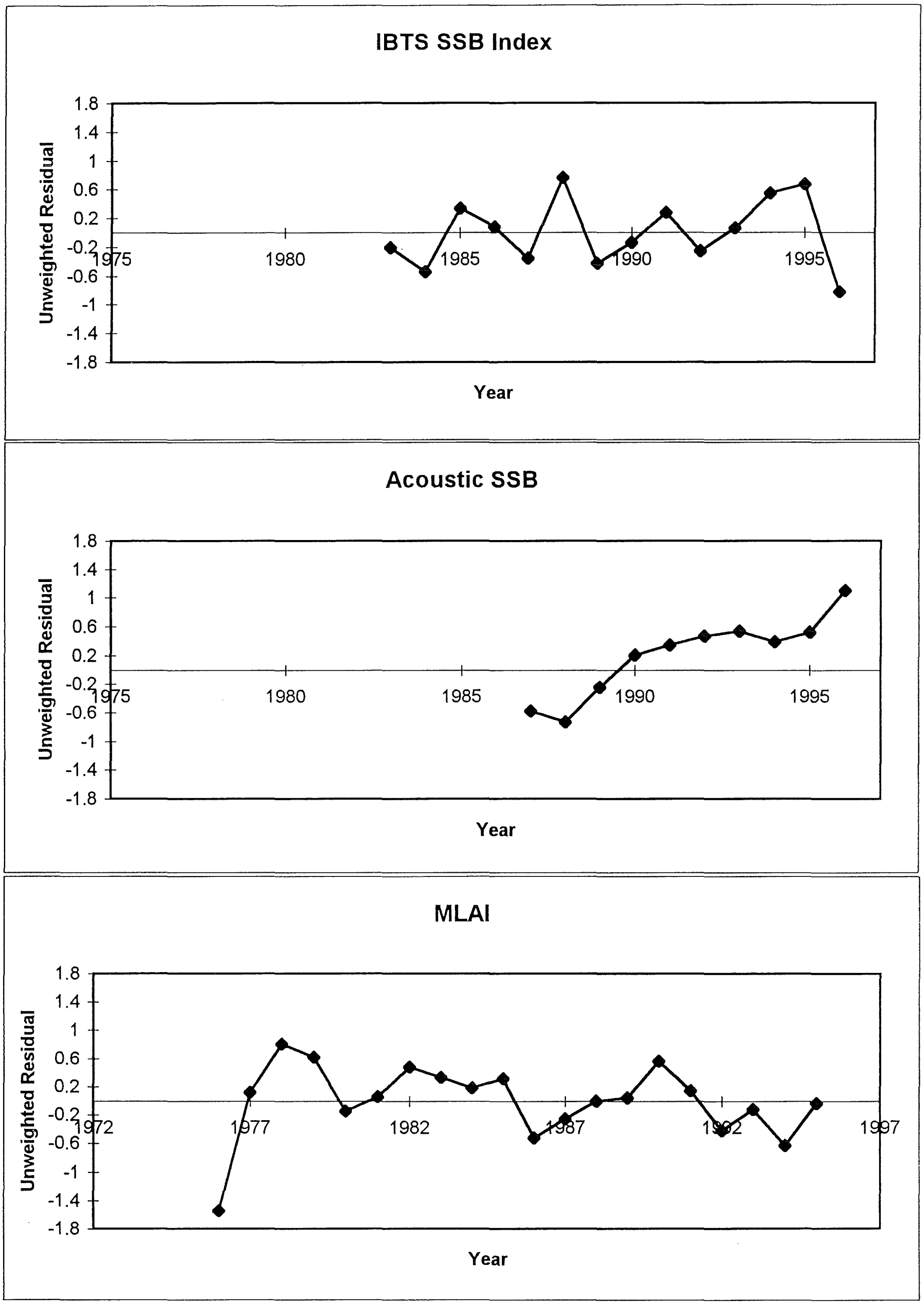



**Figure 2**. Residual-time plots for the three surveys giving information about Spawning Stock Biomass. Log residuals for the full model fit are plotted.

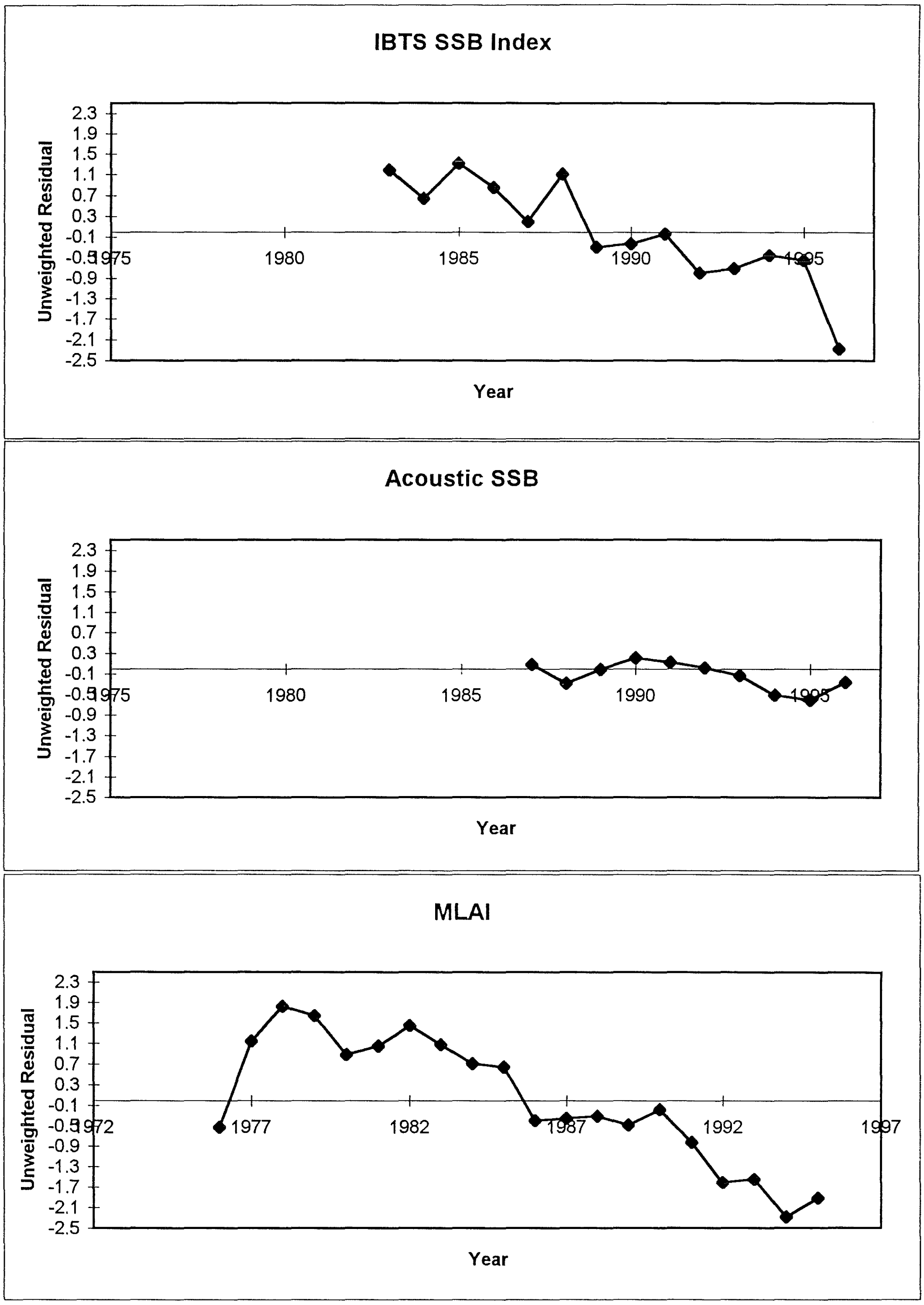



**Figure 3**. Residual-time plots for the three surveys giving information about Spawning Stock Biomass. Log residuals when fitting the population model to the acoustic survey and to the catches alone.

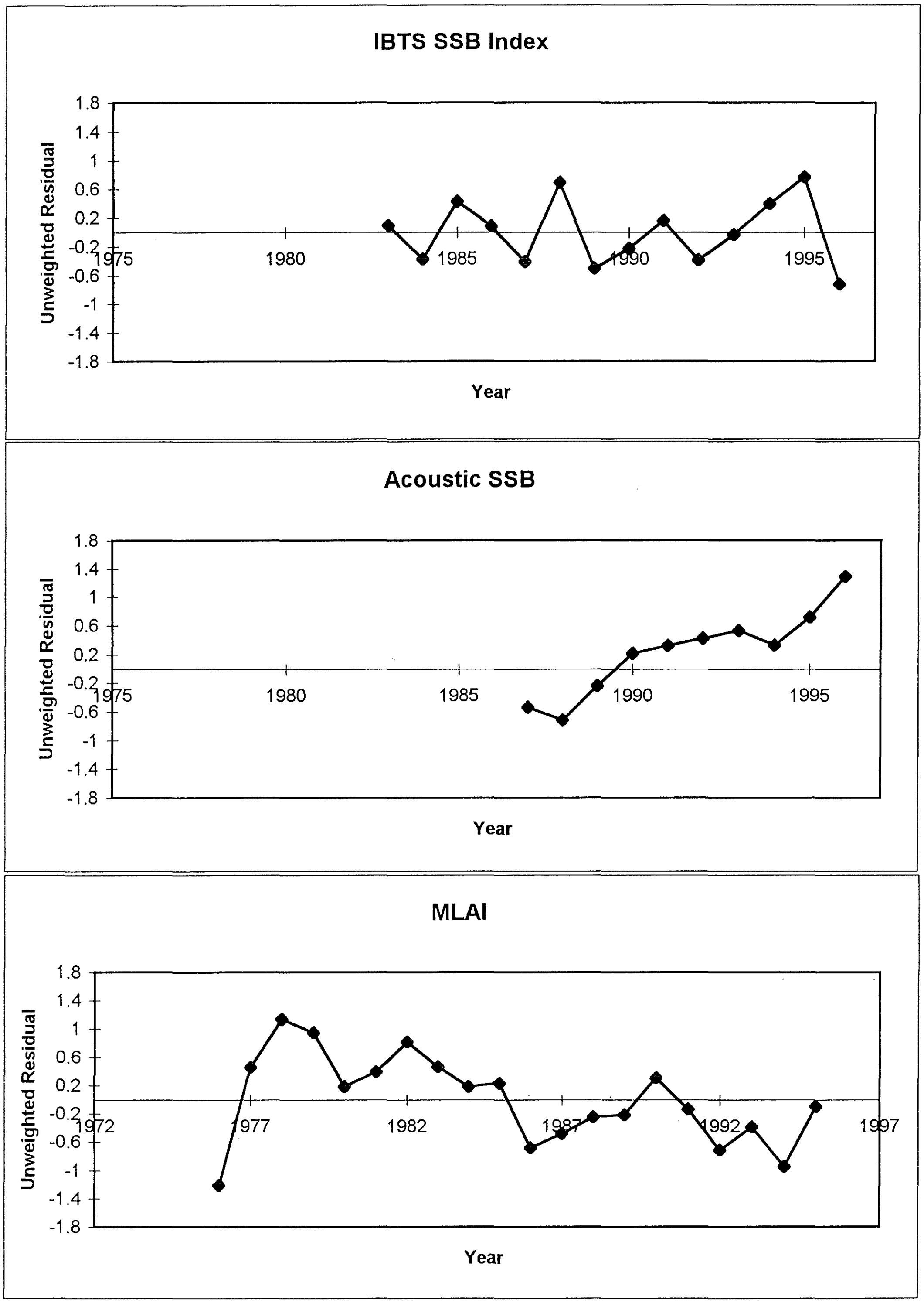



**Figure 4**. Residual-time plots for the three surveys giving information about Spawning Stock Biomass. Log residuals when fitting the population model to the IBTS and to the catch sampling data.

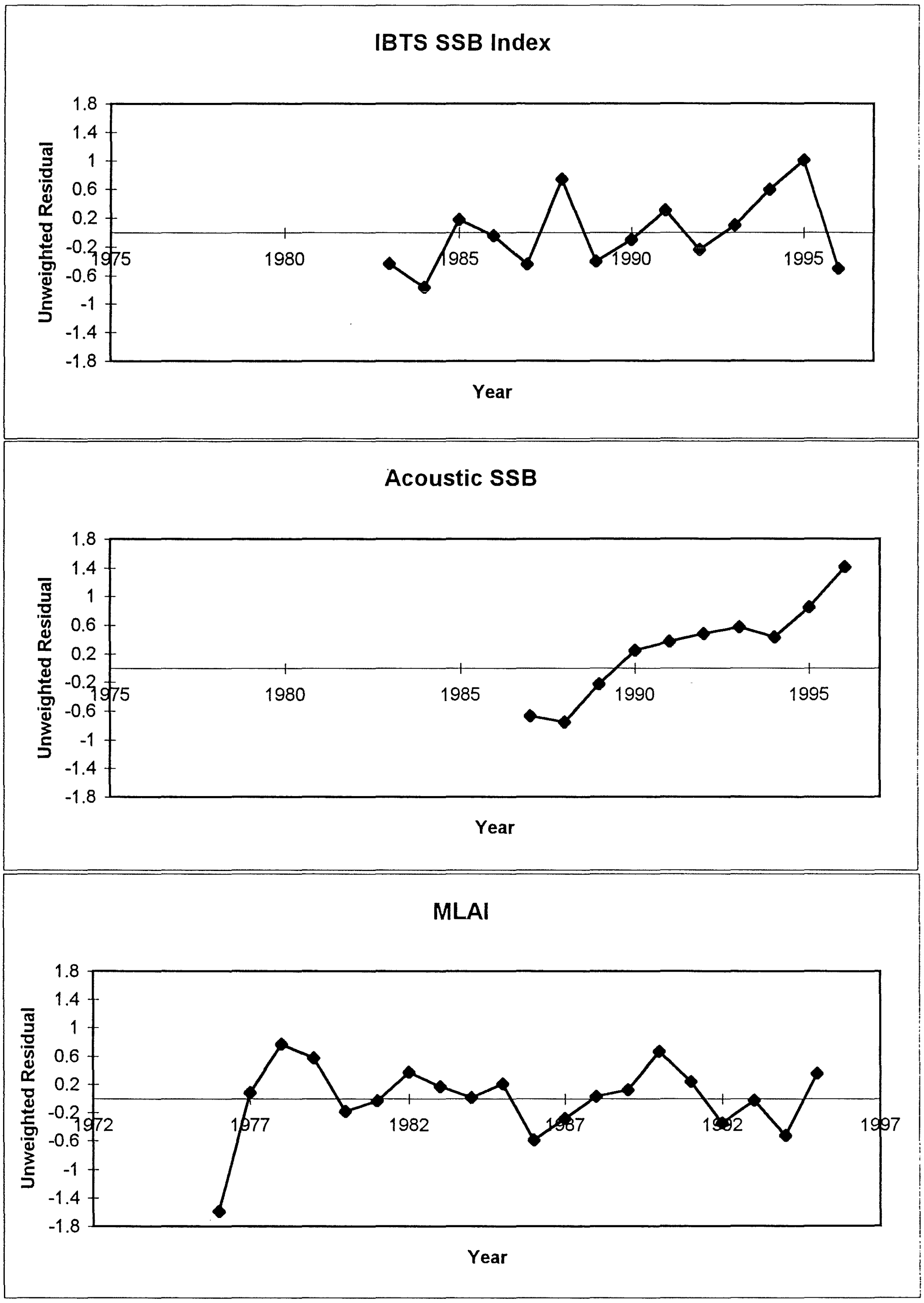



**Figure 5**. Residual-time plots for the three surveys giving information about Spawning Stock Biomass. Log residuals when fitting the population model to the MLAI larval index and to the catches alone.

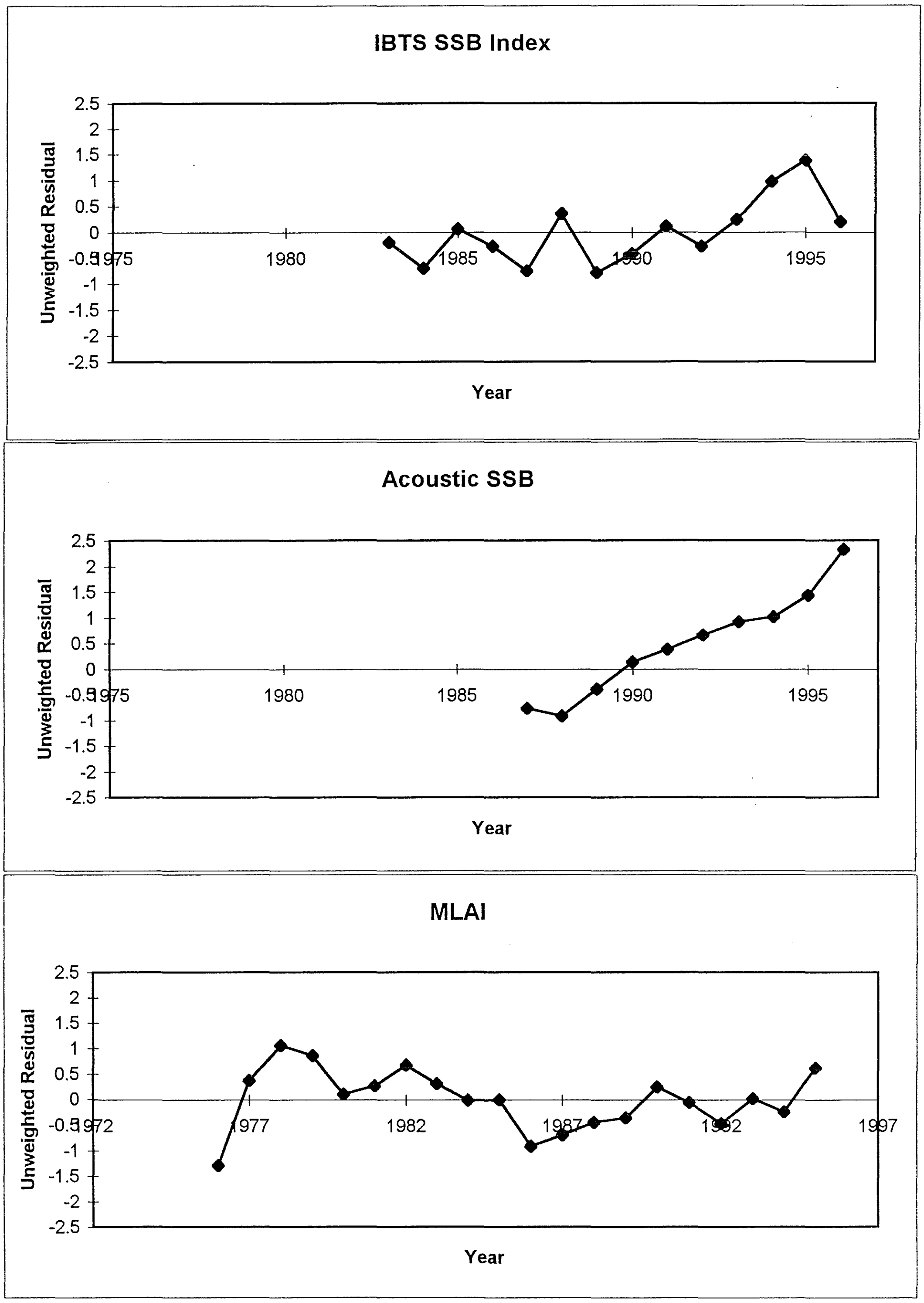



**Figure 6**. Residual-time plots for the three surveys giving information about Spawning Stock Biomass. Log residuals when fitting the population model to the catch sampling and acoustic survey age-structure information.

## APPENDIX E

# WORKING DOCUMENT TO THE PLANNING GROUP FOR HERRING SURVEYS - FEBRUARY 1997. EFFECTS OF REDUCED SAMPLING EFFORT ON ABUNDANCE AND PRODUCTION ESTIMATES FROM NORTH SEA HERRING LARVAE SURVEYS

J Gröger and D Schnack*
Institut für Ostseeforschung, An der Jägerbäk 2, D-18069 Rostock, Germany
*Institut für Meereskunde, Düsternbrooker Weg 20, D-24105 Kiel, Germany

### Introduction

Due to a substantial decline in ship time and sampling effort allocated to the Herring Larvae Surveys since the end of the 80s, it has been questioned, whether these surveys can still provide abundance and production indices (LAI and LPE) comparable to those of previous years and sufficiently reliable for the use as measure of stock size. Since 1992/3 a multiplicative model was used to fill in missing values (Patterson and Beveridge, 1994, 1995a) and for the period 1994/95 no traditional index was calculated, but the multiplicative model approach was used to analyse overall trends in the larval data series (Patterson and Beveridge, 1995b). This method assumes that larval production in each area and time unit defined for the traditional sampling schedule is a certain constant proportion of the total. In view of the urgent demand for reliable stock size estimates, the Herring Assessment Working Group requested to evaluate the validity of assumptions in the methods used and to define the minimum sampling effort required and possible survey strategies that could be achieved considering given restrictions in ship time.

The Planning Group for Herring Surveys recognised that it will not be possible to perform further detailed analyses and testing of survey strategies at Aberdeen and, thus, suggested to transfer the entire data set of the herring larvae surveys, presently located in Aberdeen (Scotland), to Kiel (Germany) and to update this set regularly. Maintenance of the data bank and standard analyses for assessment purposes, however, were still to be carried out at Aberdeen for the time being.

This working document summarises the present status of implementation of the data bank and standard analyses at Kiel and of the requested specific analyses.

### Implementation of Data Bank and Standard Analyses of Herring Larvae Surveys at Kiel (Germany)

A complete set of the herring larvae data has first been established in Rostock. The structure of the data bank has been clarified and the calculation routines for standard analyses of abundance indices have been established according to the definitions given in working group reports (Anon, 1985, 1986), manuals and summary presentations (Heath, 1992), and personal information obtained from Aberdeen. The calculation of both indices (LAI and LPE), however, include some final problems still to be solved:

The LPE value is critically depending on z/k estimates, obtained from the length distribution of larvae. The sampled larvae populations did not always provide a reasonable basis for calculating these values. Thus, they have frequently been estimated as some mean from previous surveys. The way this problem has been handled seem to differ between years and the values utilised are difficult to identify. It appears to be essential to define a standard procedure for estimating the z/k values.

For calculating the LAI there remain some uncertainties in the area values used to raise the mean abundance values per station, and these areas appear to differ from those used in the LPE.

Both these problems have to be solved before the indices can be calculated for individual successive time periods separately, within any of the standard areas in a way that they are comparable to the combined yearly values given for these areas. It is planned to transfer the system to Kiel after it has been completely established.

**Validity of Assumptions Made in the Multiplicative Model Approach**

It has already been mentioned by Patterson and Beveridge (1995b) that the assumption for this model approach may be invalid, as the distribution of herring spawning areas have undergone strong changes. Figure 1 compares the proportion of larvae abundance for the four traditional spawning areas in the North Sea. The LAI values for Shetland/Orkney are taken as standard and those from Buchan, Central North Sea and Southern North Sea are given as percentage compared to this standard. It is obvious that there are significant changes in the relative importance of the individual areas between extended periods: The large percentages for the compared areas in the 80s and mostly small values in the 70s and 90s up to now, do indicate a long-term trend, which is to some extend common among two or three areas but different from the Sheltland/Orkney area.

Due to this condition the present analyses did not consider the model in more detail but focused on evaluating the effect of using only two or three target areas on the relation between abundance or production index and spawning stock size as derived from VPA. The effect of timing of the surveys has not yet been analysed due to the above mentioned problem in recalculating the indices. The area effect could be studied by the available indices from the given data set.

**Effect of Reduced Sampling by Using Target Areas on the Reliability of Abundance Indices**

Area specific regressions of abundance indices on SSB and also Figure 1 indicate that it might be reasonable to use the Shetland/Orkney area and either the Buchan or the Southern North Sea or may be these three as target areas. The results from combining the LAIs and LPEs from these areas (two and three) have been compared to those from combining all areas including VIa north as there is a large scale advection from west of Scotland to the northern North Sea areas (Heath, 1992). The combination has been done by simply using the corresponding sums of the index values.

Figure 2 provides scatter plots for LAI and LPE comparing total coverage with the combination of Shetland/Orkney and Buchan. Including the southern North Sea results in an intermediate situation. The main question is whether the variance explained by regression is reduced by using the target areas or not and if so, whether it could be increased by adding complete coverage in certain intervals.

Figures 3 and 4 show for LAI and LPE respectively, the effect of an increasing distance between complete coverage on the slope, the residual variance (standard deviation = RMSE) and the percentage explained variance ($r^2$ = RSQ). The RSQ-value is a redefined value for a model excluding the effect of the intercept, which was in no case statistically significant. Thus, the absolute value of RSQ is higher than from the regular model. The last values for a 23 years distance includes no complete coverage in the given data series. The counting starts 1972, but due to missing values the data series includes a total of 18 data point (1976-1993).

The main result appears to be, that there is no substantial effect on the explained variance (RSQ) for both indices and both area combinations. The RMSE values for LAI are exceptionally high for one year and for 19 years distance of complete coverage. This is due to an exceptionally high and fairly uncertain value in the total LAI value for 1990, which is included in the data set only in these two instances. The values for LAI are fairly stable, whereas the LPE is more sensitive to the specific year included as complete coverage. But again the reduction to the target areas does not reduce the explained variation of the regression, and inclusion of complete coverage does not seem to provide any improvement.

The problem of defining the precision of the required inverse prediction of SSB from the larvae indices has not yet been sufficiently addressed. Some attempt, however, has been made to look for trends in the inverse prediction error by calculating the variance of the predicted SSB on the basis of a method described by Neter *et al.* (1985) for utilising calibration regressions. Figure 5 presents, as an example, prediction errors from a very low and a very high abundance index value for the different steps from complete to only target area coverage. The absolute values are not meaningful, as extremely low and high values have been used in comparison to see if this may have an effect on the trend. There may be some slight but not substantial increase in the prediction error towards the reduction to the target areas in case of LAI. For LPE this is not obvious within the range of variation of these values.

## Conclusion

The results lead to the general impression that restriction of the sampling to only two target areas, including Shetland/Orkney and Buchan or southern North Sea does not reduce the reliability of stock size estimates. As the southern stock component is managed separately, this area should be included in any case and it is to be expected that the combination of this area with Shetland/Orkney will provide comparable results to those obtained with the combinations presented as examples in this paper. This should be checked, however. Additional complete coverage do not seem to improve the results but could be required for other purposes, eg to check for changes in the system compared to the observed data series. If the problem of estimating reasonable z/k values for the LPE calculations is solved, this method might be favourable, as it is to be expected that only one coverage could be sufficient in each of only two target areas. The question of timing of the surveys has already been discussed in some detail by the Working Group on Herring Larvae Surveys (Anon, 1990). But after adequate standardisation of the calculation method, the effect of timing should again be studied for both indices in view of restriction to the target areas.

The present results do not indicate that estimation of stock size based on the regression with larval abundance indices for a combination of the two or three target areas mentioned here would be less reliable than base on a complete area coverage.

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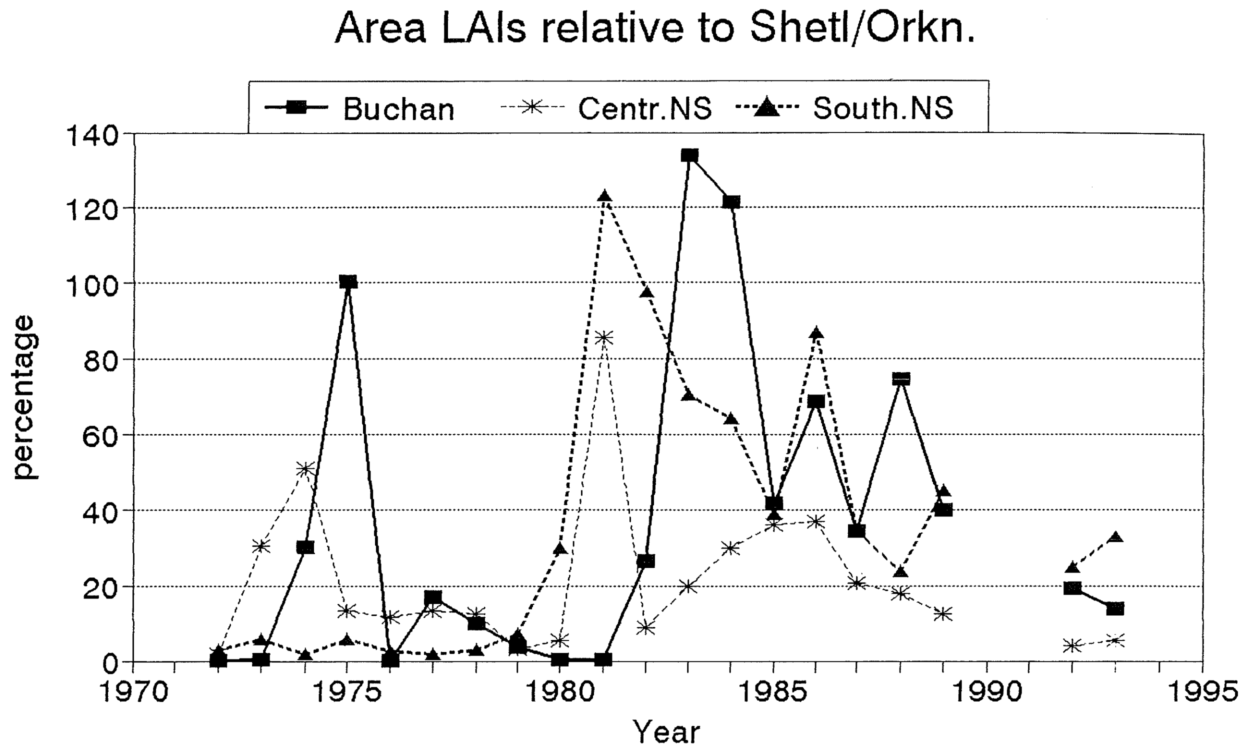
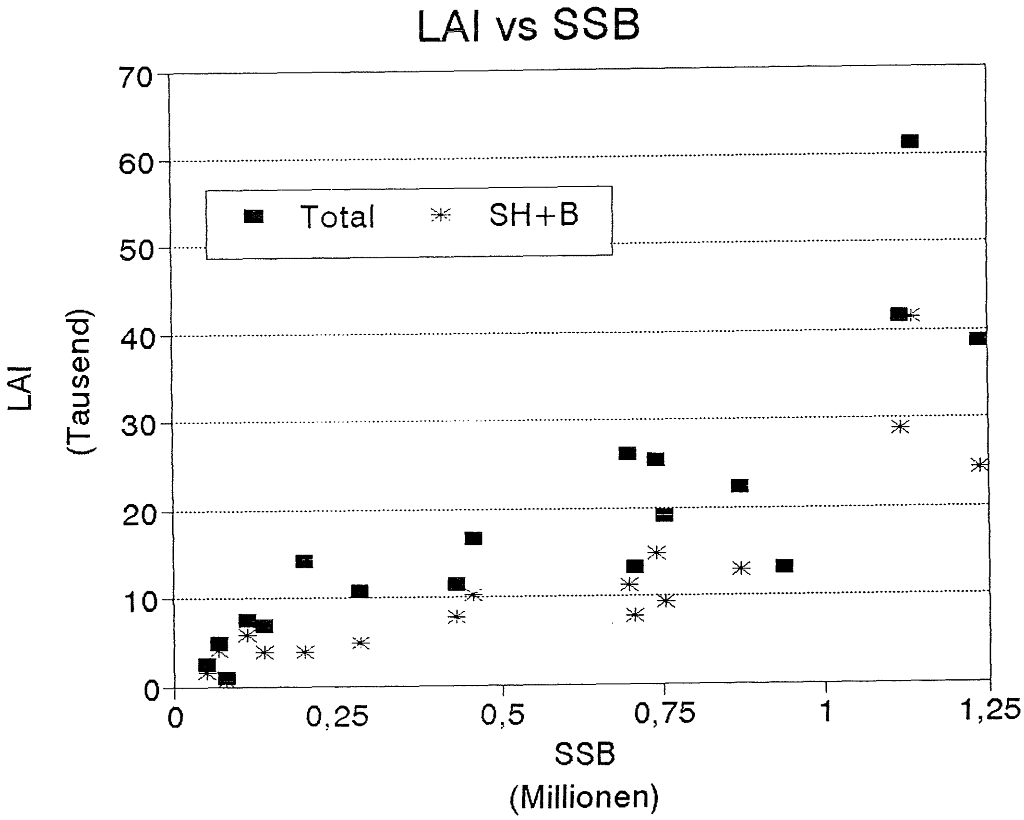



Figure 1 Trends in herring larvae abundance indices (LAI) for Buchan, Central North Sea and Southern North Sea as percentages of the value for the Shetland/Orkney area.



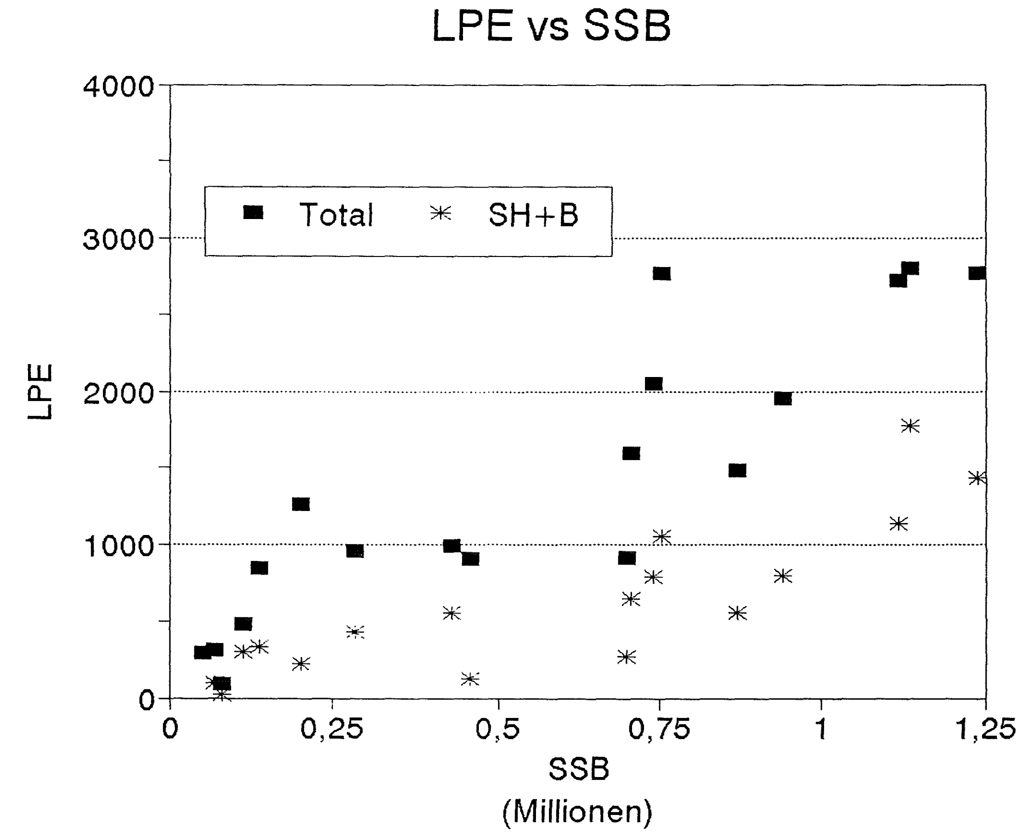
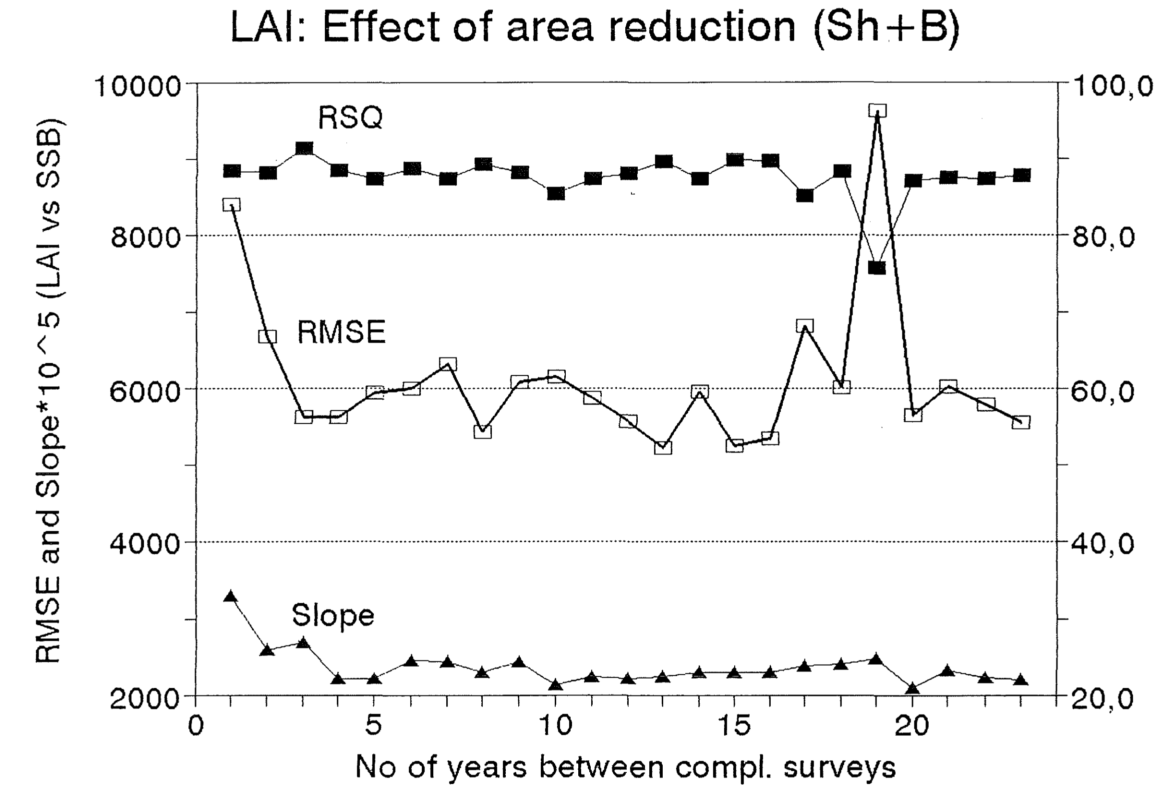




Figure 2 Scatterplots of herring larvae abundance index (LAI) and production estimate (LPE) versus spawning stock biomass (SSB) based on herring larvae survey data from all North Sea spawning areas including subarea VIa north (Total) compared to combined results from Shetland/Orkney and Buchan area only (SH+B).



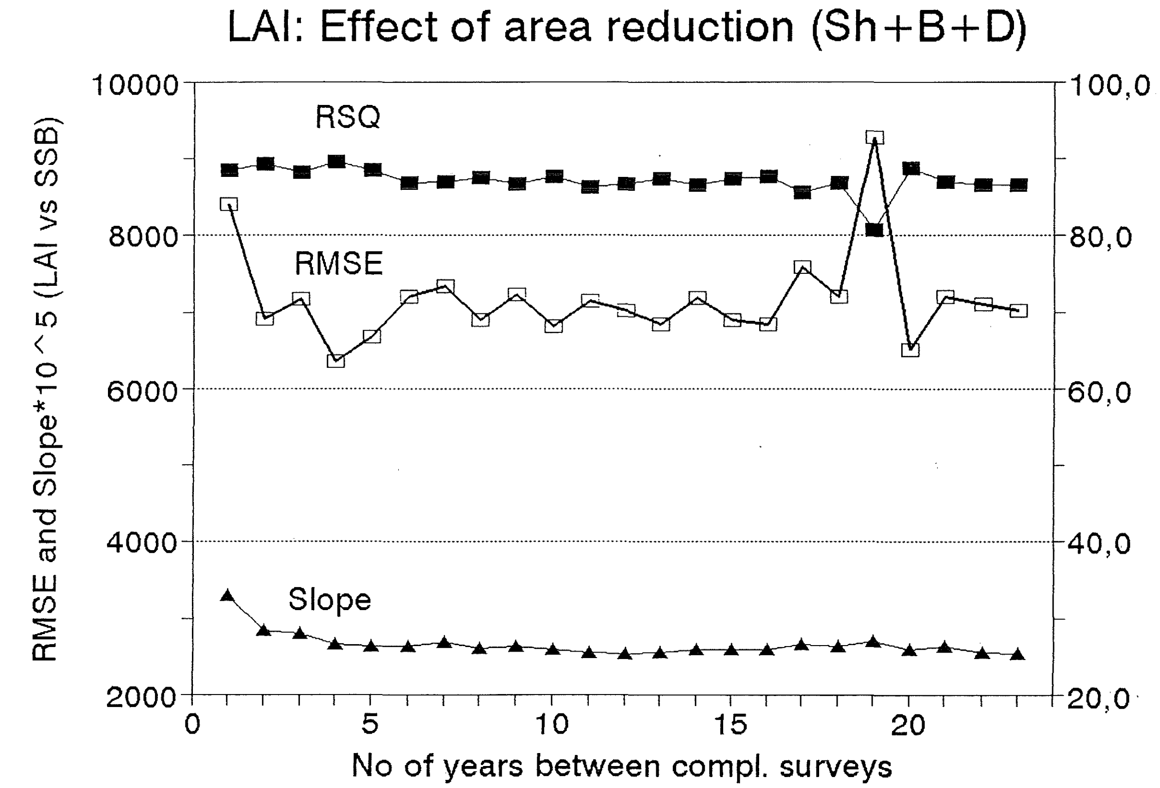
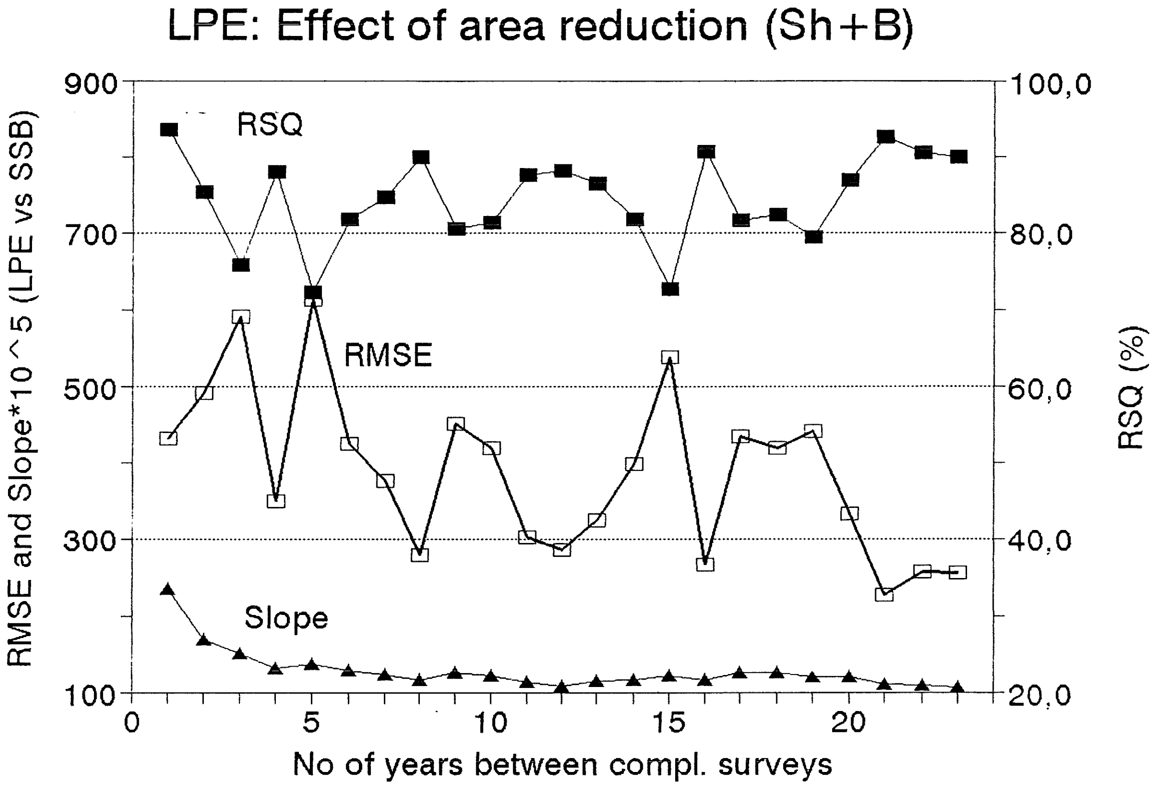




Figure 3 Regression of LAI on SSB: Effects of reduction in sampling effort by increasing the number of years between complete surveys (total area coverage) and sampling in between in two or three target areas only. SH+B: Shetland/Orkney and Buchan as target areas. Sh+B+D: Shetland/Orkney, Buchan and Downs (southern North Sea) as target areas. Regression parameters: Slope, Standard error of Residuals (Root Mean Square Error = RMSE), and $R^2$ (RSQ given as percentage).



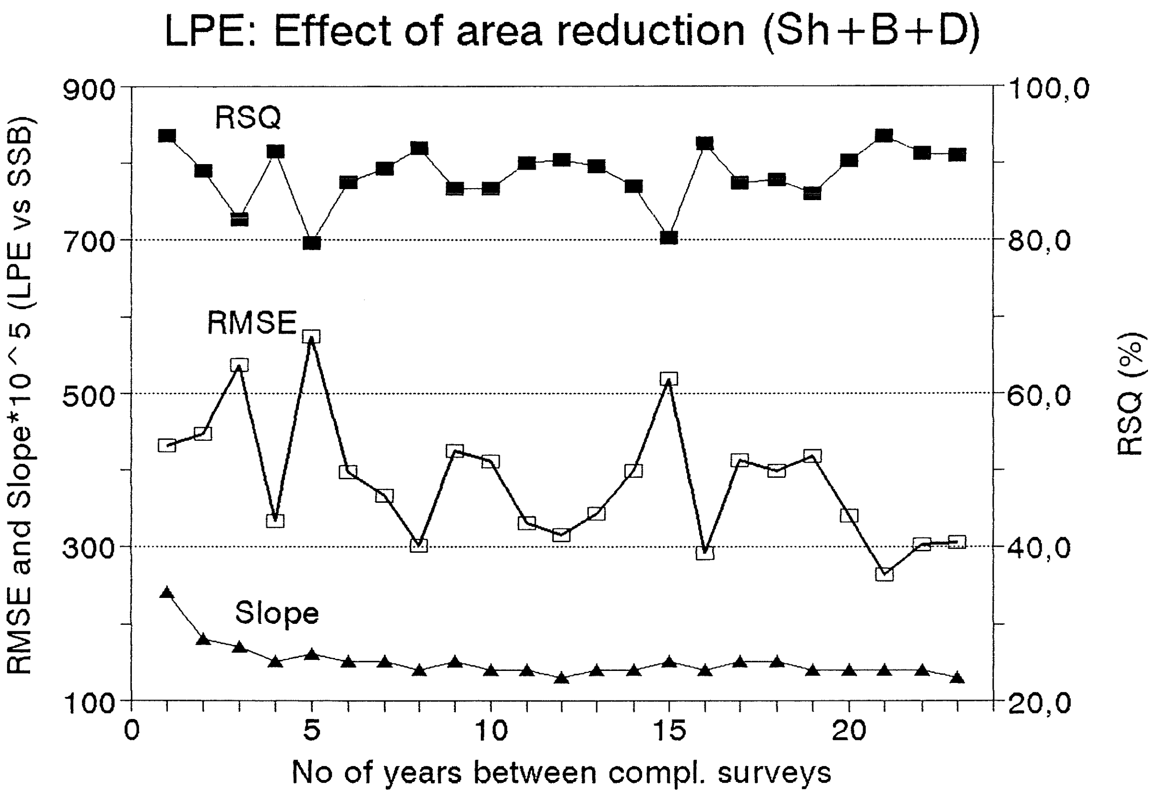
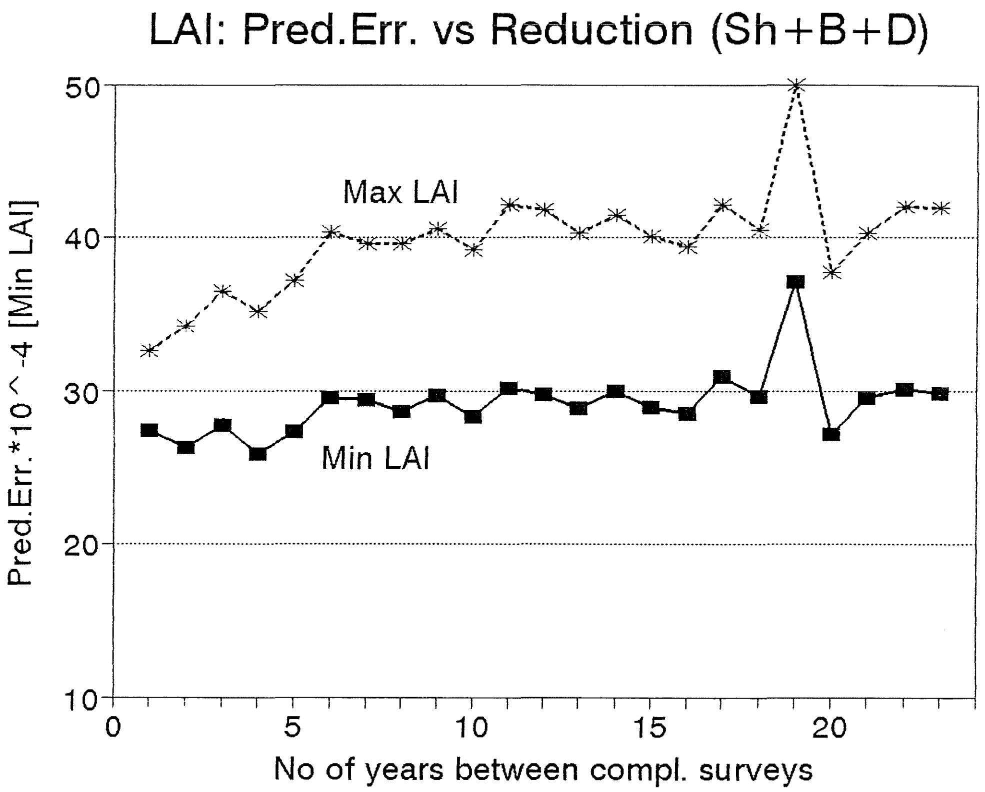




Figure 4 Regression of LPE on SSB: Effects of reduction in sampling effort by increasing the number of years between complete surveys (total area coverage) and sampling in between in two or three target areas only. SH+B: Shetland/Orkney and Buchan as target areas. Sh+B+D: Shetland/Orkney, Buchan and Downs (southern North Sea) as target areas. Regression parameters: Slope, Standard error of Residuals (Root Mean Square Error = RMSE), and $R^2$ (RSQ given as percentage).



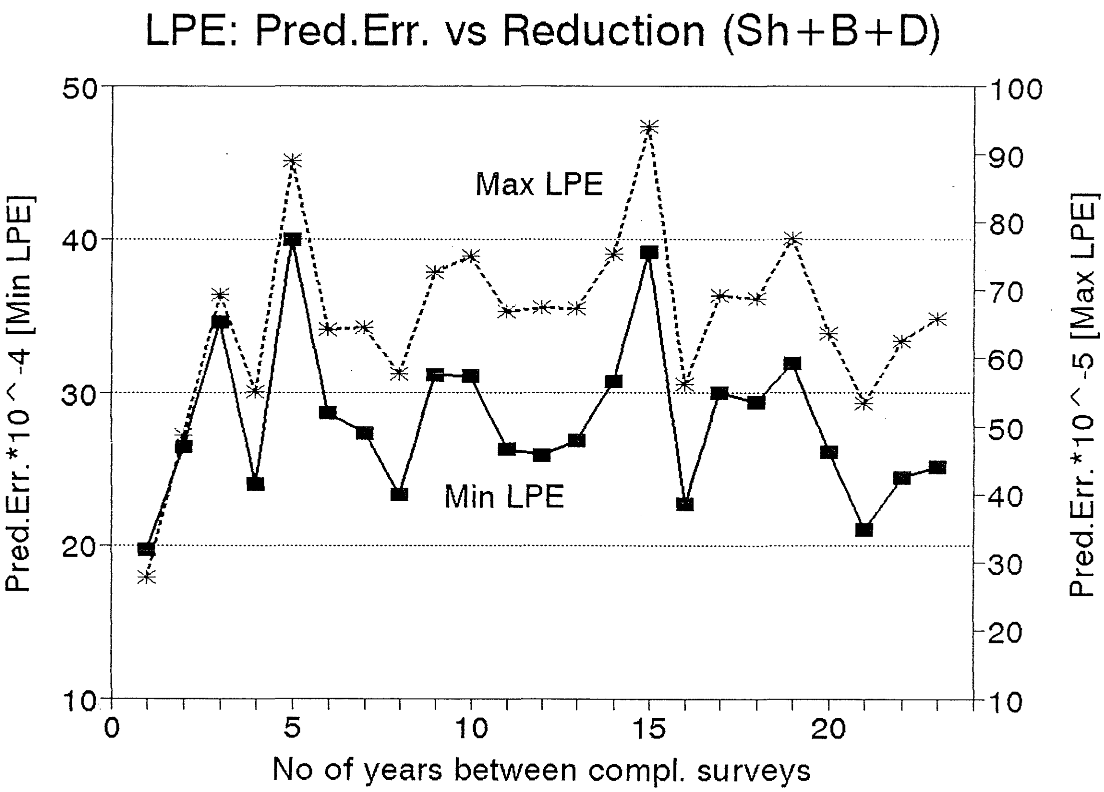




Figure 5 Inverse prediction error according to Neter *et al.* (1985) for SSB, estimated from extreme low (1) and high (61277) values of LAI and LPE. Effect of reduction in sampling effort by increasing the number of years between complete surveys (total area coverage) and sampling in between in three target areas only: Shetland/Orkney, Buchan and Downs area.

## APPENDIX F

| Data entry explanation | | | Structure derived from IBTS Manual Revision V ICES CM 1996/H:1 | |
|---|---|---|---|---|
| Column | Header | Field name | Range | Comments |
| A | | Country | See IBTS manual | ICES alpha code for countries - DEN, GFR, NED, NOR, SCO, SWE |
| B | | Ship | See IBTS manual | ICES alpha code for ships - DAN2, WAH, TRI2, GOS, SCO, ARG |
| C | | Gear type | See IBTS manual | ICES alpha code for gear |
| D | | Bot/Pel | B or P | Text entry: B = trawled on bottom; P = trawled pelagically |
| E | | Haul No | 1 to n | |
| F | | Year | 1995 | *Trawl location to be determined by user as most appropriate position of sampled fish |
| G | | Month | 6 to 8 | |
| H | | Day | 1 to 30/31 | |
| I | | Date | 01/06/95 to 31/08/95 | Excel date format dd/mm/yy |
| J | | Time shot | 00:00 to 24:00 | In UTC |
| K | | Duration | 5 to 180 | In minutes |
| L | Trawl | Longitude | -12.00 to 12.00 | *Decimalised longitude = degrees + (minutes/60) West = negative = -1x(degrees + (minutes/60)) |
| M | location | Latitude | 53.00 to 63.00 | *Decimalised latitude = degrees + (minutes/60) |
| N | Depth | Water | 0 to 1000 | Depth from surface to bottom in metres |
| O | Depth | Fishing | 0 to 1000 | Depth from surface to headrope of trawl in metres |
| P | | Validity | H, P, or M | Text entry: H = Hit target fish - successful trawl; M = Missed target fish - failed trawl; P = Partial success, eg caught some component of target fish |
| Q | | Total catch | 1 to n | Raised (total) catch of herring in numbers |
| R-CT | Length frequency (0.5 cm) | Length frequency | 1 to n | Numbers of herring caught at 0.5 cm length intervals (0 - 40 cm) |
| CU | Age data | Pooled ? | P or no entry | Enter P if age proportions are pooled from a number of trawls, otherwise LEAVE BLANK |
| CV-DG | | Age proportions - North Sea fish | 1 to n | Numbers of herring at age(ring)/maturity class for North Sea fish (0 - 9+) |
| DH-DS | | Age proportions - Baltic Sea fish | 1 to n | Numbers of herring at age(ring)/maturity class for Baltic Sea fish (0 - 9+) |
| DT-EE | | Mean weight at age - North Sea fish | 1 to n | Mean weight at age(ring)/maturity class for North Sea fish (0 - 9+) grams |
| EF-EQ | | Mean weight at age - Baltic Sea fish | 1 to n | Mean weight at age(ring)/maturity class for Baltic Sea fish (0 - 9+) grams |

## APPENDIX G

### COMMUNICATION INFORMATION FOR RESEARCH VESSELS

| Vessel | Telephone | | Telefax | | Telex | Radio call sign |
|---|---|---|---|---|---|---|
| | Mobile | Satellite | Mobile | Satellite | | |
| GO Sars | Bridge: +47 9455 6811<br>Mess: +47 9450 5071<br>GSM: +47 9119 3383 | +871 3257 15010<br>+871 3257 15011 | +47 9454 9900 | +871 3257 15012 | +581 4257 15010<br>+581 3257 15014 | LLZG |
| Scotia | +44 836 385 975 | +871 144 0552<br>+872 144 0552 | +44 836 385 975* | +871 144 0561<br>+872 144 0561 | | GOWS |
| Walter Herwig III | | +871 112 3217 | | +871 112 3221 | +581 112 3217<br>+581 4211 21550 | DBFR |
| Tridens | | | | | | |
| Dana | Scientist:+45 3028 6864<br>Bridge: +45 3020 0363 | +871 161 0205 | | +871 161 0207 | +581 161 0205 | OXBH |

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## APPENDIX H

### PLANNING GROUP FOR HERRING SURVEY - ABERDEEN 24-28 FEBRUARY 1997

| Name | Telephone No | Facsimile No | E-mail |
|---|---|---|---|
| Richard Aukland | +44 1224 295539 | +44 1224 295511 | auklandr@marlab.ac.uk |
| Martin Bailey | +44 1224 295539 | +44 1224 295511 | baileymc@marlab.ac.uk |
| Paul Fernandes | +44 1224 295403 | +44 1224 295511 | fernandespg@marlab.ac.uk |
| Eberhard Götze | +49 40 3890 5232 | +49 40 3890 5264 | |
| Nils Håkansson | +46 5231 8716 | +46 5231 3977 | n.hakansson@imr.se |
| Cornelius Hammer | +49 40 3890 5232 | +49 40 3890 5264 | nilshammer@aol.com |
| Kenneth Patterson | +44 1224 295507 | +44 1224 295511 | pattersonkr@marlab.ac.uk |
| Dave Reid | +44 1224 295363 | +44 1224 295511 | reiddg@marlab.ac.uk |
| Dietrich Schnack | | | dschnack@ifm.uni-kiel.de |
| J Simmonds (Chairman) | +44 1224 295366 | +44 1224 295511 | simmondsej@marlab.ac.uk |
| Karl-Johan Staehr | +45 3396 3200 | +45 3396 3260 | kjs@dfu.min.dk |
| Reidar Toresen | +47 5523 8500 | +44 5523 8532 | reidar@imr.no |
| Else Torstensen | +47 3705 9000 | +47 3705 9001 | else.torstensen@imr.no |