Living Resources Committee

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REPORT OF THE

PLANNING GROUP FOR HERRING SURVEYS

Hirtshals, Denmark
2–4 February 1999

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK-1261 Copenhagen K Denmark

Table of Contents

Section **Page**

1 TERMS OF REFERENCE

According to C.Res 1998/2:51 the Planning Group for Herring Surveys (Co-Chairs: E. Torstensen, Norway and K.-J. Stæhr, Denmark) met in Hirtshals, Denmark from 2–4 February 1999 to:

a) coordinate the timing, area allocation and methodologies for acoustic and larval surveys for herring in the North Sea, Division VIa and IIIa and the Western Baltic;

b) combine the survey data to provide estimates of abundance for the population within the area;

c) review the existing manual of the North Sea acoustic survey (Doc. ICES C.M. 1994/H:3), taking into consideration recent developments in methodology and the results of the scrutiny workshop;

d) plan for a further echogram scrutiny workshop to be held in 2000;

e) for the historical database of larvae surveys, complete the analysis of the effect of reduced sampling effort, in order to improve the basis for a final decision on the index and the target sampling units to be used;

f) provide a revised MLAI with explanation of any differences between this and the MLAI presented in Patterson *et al.* (1997);

g) investigate the methodological problem related to estimation of larval indices when very high numbers are caught in single hauls;

h) develop and coordinate an international survey to be carried out by Denmark, Germany and Sweden which should cover the whole area where Western Baltic spring-spawner herring are distributed;

i) obtain peer review of the Planning Group report from the appropriate Assessment Working Group prior to the 1999 Annual Science Conference;

j) comment on the draft objectives and activities in the Living Resources Committee component of the ICES Five-Year Strategic Plan, and specify how the purpose of the Working Group contributes to it.

Some of the above Terms of Reference are set up to provide ACFM with the information required to respond to requests for advice/information from NEAFC, IBSFC and EC DGXIV.

PGHERS will report to HAWG and to the Resource Management and Living Resources Committees at the 1999 Annual Science Conference.

2 PARTICIPANTS

Frederik Arrhenius (part-time)	Sweden
Bram Couperus	The Netherlands
Paul Fernandes	UK (Scotland)
Joachim Gröger	Germany
Eberhard Götze	Germany
Nils Håkansson (part-time)	Sweden
Jens Pedersen	Denmark
Norbert Rohlf	Germany
John Simmonds	UK (Scotland)
Dietrich Schnack	Germany
Karl-Johan Stæhr (co-chair)	Denmark
Else Torstensen (co-chair)	Norway
Christopher Zimmermann	Germany

3 HERRING LARVAL SURVEY

3.1 Review of Larvae Surveys

3.1.1 North Sea

Seven units and time periods have been covered in the North Sea during the 1998 surveys.

Area / Period	1–15 September	16–30 September	1–15 October
Orkney / Shetland	--	Germany	--
Buchan	--	Netherlands	--
Central North Sea	Germany	Netherlands	--
	16–31 December	**1–15 January**	**16–31 January**
Southern North Sea	Netherlands	Germany	Netherlands

The measurements necessary for the calculation of larval abundance are not yet complete, but will be ready for the Herring Assessment Working Group (HAWG) meeting in March 1999. Preliminary analyses indicate that there may be a recovery in stock size, particularly in the Southern North Sea (SNS). This would verify the results from the 1997 surveys in the SNS.

3.1.2 Western Baltic

Survey activity has concentrated on the "Greifswalder Bodden" area, which may be regarded as one of the most important spawning habitats for spring spawning herring in the Western Baltic. Sampling has taken place every year since 1977 from March/April to June. The principal objective of the sampling strategy last year was to establish a recruitment forecast based on larval abundance. These data may also be useful for stock abundance estimates, therefore, the data series should be made available to the HAWG. The Planning Group for Herring Surveys should review the survey strategy.

3.2 Coordination of Larvae Surveys for 1999/2000

The surveys planned for the 1999/2000 period are presented in the following table:

Area / Period	1–15 September	16–30 September	1–15 October
Orkney / Shetland	Norway*	Germany	--
Buchan	Norway*	Netherlands	--
Central North Sea	--	Netherlands	Germany
	16–31 December	**1–15 January**	**16–31 January**
Southern North Sea	Netherlands	Germany	Netherlands

* Tentative participation

The participation of Norway is recommended, but will depend on the availability of ship time. The attempted complete coverage would require one additional survey in the first period in the Central North Sea. Survey results, including hydrographic data, should be sent, in the standard format, to IfM Kiel for inclusion into the IHLS database. IfM Kiel will report the summarised results and the updated series of MLAI-values to the HAWG.

4 HERRING LARVAE SURVEY METHODOLOGY

The ICES Herring Larvae database was transferred from Aberdeen to Kiel in 1997 and larval index calculations have been done in cooperation with the BFA-Fi (Hamburg and Rostock). The programs previously used for calculating these indices could not be transferred successfully, because they included several locally installed sub-routines, which were not readily accessible. Consequently, the calculation routine had to be re-established on the basis of documentation and information received from Aberdeen. However, the documentation was incomplete in certain details and included some inconsistencies introduced by several steps of development in the calculation procedure. The reported data series of index values could not, therefore, be reconstructed to correspond exactly. One of the major problems was the area definition: in the abundance index (LAI) and production index (LPE), independent area definition files had been used, and some mixing of station grids for the two indices had occurred.

A single area definition file has now been established, based primarily on the 1985 manual (Anon. 1985). LAI estimates have been computed for the three length classes which have been traditionally used (total length (TL) <10mm; 10–15mm; >10mm). A detailed description of the calculation procedure is given in Rohlf *et al.* (1998) and in a Working Document 4.1 presented to the current meeting (Appendix 1). The problem of missing stations had previously been addressed by employing different interpolation methods. In order to find a more consistent objective method, no correction is currently made for any missing value. However, for inclusion into the multiplicative model and calculation of MLAI-values (Patterson & Beveridge 1995), a weighting factor is applied to LAI values for individual sampling units, the weight being proportional to the degree of coverage of each sampling unit and the inverse coefficient of variance within this unit. This will down-weight hauls with an exceptionally high amount of larvae, as appeared last year in one survey in the Southern North Sea.

The refined calculation procedure now produces LAI values that show no discrepancies to those reported since 1981. Some minor differences are still apparent for the earlier period, where uncertainties with regard to the utilised area definitions and interpolation methods could not be solved completely. The MLAI values derived with the refined procedure from the complete data set, do not therefore, correspond exactly to those obtained from the calculation routine at Aberdeen; but the fit appears to be very reasonable, leaving only 3% unexplained variance. Since one of the basics for MLAI calculation is a linear relationship to SSB, this should be equal for both when a good relationship is evident between their regression parameters. For comparison, Figure 4.1 shows this regression plot of refined against previous MLAI and Figure 4.2 the residual plot. The corresponding $r^2 = 0.962$. It should be pointed out that the remaining differences are mainly due to the weighting procedure as opposed to using some interpolation method for missing values. Remaining differences, which did occur in some years when plotting the MLAIs over the time period (Figure 4.3), may also be explained by the weighting procedure, which will smooth the new calculated MLAI to some degree.

The influence of reduced survey effort has been tested by simulating the reduction through systematic elimination of single survey units or complete areas from the MLAI calculation procedure.

These calculations were done:

- for the three length classes mentioned above;
- for the complete time series from 1972 to 1997;
- for a reduced time series window (1981 to 1991) with mostly complete sampling in all areas and time periods;
- with and without weighting by the degree of coverage and by the inverse variance within the sampling unit.

The model fits for the different combinations of sampling units, were characterised by several statistical values (e.g. r^2, RMSE, IPE) as given in the Working Document 4.1 (Appendix 1).

The main results can be summarised as follows:

- In general the new calculation procedure generated LAI-values which are comparable to the former ones; differences are apparent only for the first years of this survey program and are of minor importance.
- Larval abundance for length class TL < 10 mm had the best relationship to SSB.
- Introduction of a weighting factor improved the model fit reducing the variance by up to 5%.
- The best relationship between MLAI and SSB was obtained in surveys with complete standard coverage, i.e. when all sampling units were considered.
- Reduction in survey effort resulted in some loss of information, but when excluding the Central North Sea sampling units, the explained variance of relationship of MLAI to SSB remained in the range of 70–90%, depending on the combination of survey areas selected.
- Among the different combinations of sampling units, Orkney/Shetland (15/9–30/9), Buchan area (1/9–15/9) and Southern North Sea (15/12–31/12 and 15/1–31/1) represented the selection which provided the best relationship of MLAI to SSB.
- Surveys in the Central North Sea appear to be of minor importance and may be considered to have lower priority.

MLAI comparison: refined estimates vs previous estimates:

Year	Refined estimates	previous estimates
73	0.32537	0.4011
74	-0.15655	-0.1103
75	-1.25399	-0.7665
76	-1.35538	-1.2330
77	-0.44818	-0.3026
78	-0.24572	0.2413
79	0.47727	0.5813
80	0.12017	0.1979
81	0.52471	0.9598
82	0.86344	1.6320
83	1.11997	1.9870
84	1.70911	2.4300
85	2.12151	2.8440
86	1.46709	2.2200
87	2.03311	2.7900
88	2.71536	3.3780
89	2.67812	3.5530
90	2.92118	3.9300
91	2.27148	3.2320
92	1.53926	2.3680
93	1.19128	2.3110
94	0.84287	1.8180
95	1.03135	2.3460
96	1.69655	.
97	2.75185	.

The minimum input for MLAI calculations would require survey effort to concentrate on the areas and time periods mentioned above as the best selection for representing the total variance in SSB. A more complete or full coverage of the whole spawning area should be introduced as far as possible. This should be realised at least on a three-year schedule in order to become aware of possible shifts in spawning time and location, and to test the validity of the present results from a 10-year period. The calculation of MLAI has to be based on the complete set of available data, until a more stable data set builds up over some years.

The present effort for the herring larvae program includes the survey activity of Germany and The Netherlands. This is sufficient to provide the minimum requirement effort. Additional input is required for years with more complete or full coverage. For this, additional vessel time in the range of about 40 days in total is to be envisaged for the period September/October.

5 ACOUSTIC SURVEYS

5.1 Review of Acoustic Surveys in 1998

5.1.1 North Sea and west of Scotland

Six acoustic surveys were carried out during late June and July covering most of the continental shelf north of 54°N in the North Sea and Ireland, to the west of Scotland, to a northern limit of 62°N. The eastern limits of the survey area were bounded by the Norwegian and Danish coasts, and western limits by the shelf-edge between 200 and 400 m depth. The surveys are reported individually, and a combined report has been prepared from the data from all surveys (Simmonds *et al.* 1999). The combined survey results provide spatial distributions of herring abundance by number and biomass at age by statistical rectangle.

The survey areas for each vessel are given in Figure 5.1.1.1. The results for the six surveys have been combined. Procedures and TS values are the same as for the 1997 surveys (Simmonds *et al.* 1998). Stock estimates have been calculated by age and maturity stage by ICES statistical rectangle for the whole survey area. The combined data gives estimates of immature and mature (spawning) herring for ICES areas VIa_{north}, IVa, and IVb separately and parts of IIIa. The data from all areas have been split between autumn spawners, in the North Sea and West of Scotland, and spring spawning Baltic stocks. The total SSB of autumn-spawning herring from the North Sea was 1 920 000 t, for IVa_{north} 375 000 t. The SSB for Baltic spring spawners was 224 000 t. Where the survey areas for individual vessels overlap, the effort weighted mean estimates by age and maturity stage for each overlapping rectangle have been used. Stock estimates by number and biomass are shown in Tables 5.1.1.1 and 5.1.1.2 respectively for areas VIa_{north}, IVa, IVa and IVb separately; mean weights at age are shown in Table 5.1.1.3. Stock estimates for Baltic herring by number and biomass are shown in Tables 5.1.1.4 and 5.1.1.5 respectively for ICES areas IIIa, IVa and IVb; mean weights at age for Baltic herring are shown in Table 5.1.1.6. The results of the surveys, (numbers, biomass, mean weight and maturity at age) are summarised by stock in Table 5.1.1.7. Figure 5.1.1.2 shows the distribution of abundance (numbers and biomass) of mature autumn spawning herring for all areas surveyed. Figure 5.1.1.3 shows the distribution split by age of 1 ring, 2 ring and 3 ring and older herring. Estimates of '0' group have been omitted in all plots. Figure 5.1.1.4 shows the density distribution of numbers of adult autumn spawning herring as a contour plot and Figure 5.1.1.5 shows the distribution for all 1 ring and older.

The numbers of fish infected with Ichthyophonus have increased in the RV "Scotia" survey from 5 in 1997, to 30 in 1998, although no Ichthyophonus were detected in any of the other surveys. The split by age is shown in Table 5.1.1.8.

5.1.2 Western Baltic

A joint German-Danish acoustic survey was carried out with R/V "Solea" from 2–19 October 1998 in the Western Baltic. The survey covered ICES Sub-divisions 22, 23, 24 and the southern part of the Kattegat. All investigations were performed during night-time as in previous years.

The acoustic equipment used was an EK500 Echo sounder connected to the BI500 Bergen-Integrator. A 38kHz transducer 38-26 was deployed in a towed body. The towed body had a lateral distance of about 30 m to reduce escape reactions of fish.

The length of the cruise track was 930 n.mi. which was somewhat shorter than in previous years because of bad weather conditions. A total of 48 trawl hauls were carried out for target identification. From each haul samples were taken for the determination of length, weight and age of fish. The hydrographic conditions were recorded after the haul using a CTD probe.

The measured S_A values for each stratum were converted into fish numbers using the TS-length regressions:

Clupeids	TS= 20 log L [cm] –71.2 [dB]
Gadoids	TS= 20 log L [cm] –67.5 [dB]

The estimations of abundance and biomass are presented in Tables 5.1.2.1 and 5.1.2.2. Cruise track and trawl positions are given in Figure 5.1.2.

The abundance of herring was 12% lower than in the year before but similar to the abundance in 1996.

The sprat abundance was reduced to 44% of the 1997 estimate. The main reason for these reductions was the low abundance in Sub-division 24 where very few young sprat were observed.

5.1.3 Other surveys in the area

Western Baltic spring-spawning herring migrating through the Sound in ICES Sub-division 23 have been surveyed in both autumn and spring in connection with an environmental impact monitoring programme carried out during the construction of a fixed link across the Sound. The aim of the monitoring programme was to examine if the construction work would disturb the migration pattern.

Monitoring first took place in the period prior to the initiation of construction work (Nielsen 1996); these were considered as base-line investigations with which to compare subsequent observations. The herring will then be monitored in the autumn and in the spring to examine whether they are coming from the feeding grounds to the Sound in autumn in the same proportion as during the baseline investigations, and then migrate south in the spring to the spawning grounds in the western Baltic.

Biomass estimates from the environmental impact-monitoring program were higher from the surveys conducted during the 1996/97 and 1997/98 migration period compared to the 1995/96 migration period (Nielsen *et al.* 1998). This higher biomass seems to be due to the recruitment of a strong 1994 year class of Western Baltic herring. This strong 1994 year class can be followed in the 1996/97 migration through the Sound as 2–3 year-old herring, in the fishery at the spawning ground in 1997 as 3 year-old herring, and in the Sound in November 1997 as 3–4 year-old herring in the 1997/98 migration period.

5.1.4 Sprat

Data on sprat were available from RV "Tridens", RV "Dana" and RV "Walther Herwig III". No catches of sprat were reported from RV "Scotia" and RV "G.O. Sars". In the 39 statistical rectangles which were covered by more than one ship (Figure 5.1.4.1), abundance was calculated from a weighted mean (weighted by the number of transects conducted in the respective rectangle).

Sprat was only found in 28 out of 146 investigated rectangles in the North Sea, Skagerrak and Kattegat. Values of up to 2.8 billion fish per statistical rectangle were detected and the abundance was higher than 100 million fish in 13 rectangles. Highest abundance of sprat was found at the southern edge of the investigation area, in rectangles 41E7 to 41E9 and 38F3 to 38F6. From these results it is obvious that the northern distribution limit of the sprat stock was reached during the surveys. In 1999, it is planned to extend the survey area southwards in order to cover the southern edge also.

The Netherlands and Germany provided otolith samples. As in the previous year, some problems in ageing were experienced. An exchange of otoliths will take place in 1999 between Norway, Sweden, Denmark, the Netherlands and Germany to examine some of the problems associated with the 1998 age readings.

5.2 Coordination of the 1999 Acoustic Surveys

Acoustic surveys in the North Sea and west of Scotland in 1999 will be carried out in the periods and areas given in the following Table and in Figure 5.2.1.

Vessel	Period	Area
Charter	10–28 July	North of 56°30'N, west of 3°W
G.O. Sars	29 June–19 July	North of 57°N, east of 1°W, incl. Skagerrak
Scotia	1–24 July	North of 58°15'N, between 4°W and 2°E
Solea	26 June–13 July	South of 57°N, east of 2°E
Tridens	21 June–16 July	South of 58°15'N, west of 2°E
Celtic Voyager	5–23 July	Celtic Sea and Division VIIj

In the western Baltic, the following survey will be carried out:

Vessel	Period	Area
Solea	25 September–16 October	ICES Sub-divisions 21 south, 22–24

The results from the national acoustic surveys in June–July 1999 will be collected and the result of the entire survey will be presented to the Herring Assessment Working Group. Survey results for sprat should be sent to Else Torstensen, Norway. The survey results for herring should be sent to John Simmonds, Aberdeen, preferably on Excel spread sheets, which will be prepared and distributed by 1 May 1999. Completed spreadsheets should be returned to John Simmonds by 1 December 1999.

5.3 Area Coverage for Acoustic Surveys of the North Sea and IIIa

The biomass of herring is not distributed evenly over the North Sea, with the area to the east of 2° E containing only a small percentage of stock biomass in 1997 and 1998. Currently the herring stock is recovering from low numbers: the assessment Working Group estimated that the SSB in 1997 was 745 000 t and projected to rise to 1 140 000 t in 1998. The acoustic survey in 1998 shows an increase in SSB; however, this increase is only about 10% from 1997 to 1998. The state of the spawning stock in 1998 compares well with the state of the stock as it was in 1987. The current spatial distribution of autumn-spawning herring can be seen in Figures 5.1.1.3 and 5.1.1.4. This can be compared to the historical time series of spatial distribution, which is documented in Bailey, Maravelias and Simmonds (1998). For convenience the distributions of 2 ring, 3 ring and 4+ ring are reproduced from this paper for the period 1984 to 1990 (Figure 5.3.1). The spatial distributions and SSB in 1997 and 1998 are comparable with the distributions in 1986 and 1987. The subsequent distributions in 1988 to 1990, as the stock increased in size, are much more extensive than the distributions seen in 1985 to 1987. If the stock were to follow the same pattern of area expansion as it exhibited from 1987 to 1990 (as it increased in biomass) it would again extend over much of the northern North Sea in July. Consequently, full coverage of the North Sea, particularly to the area east of 2°E, is essential if the survey is to ensure sufficient coverage of the stock.

July surveys for North Sea and Baltic herring have been extended into IIIa since 1989. The main abundance of 0 and 1 ring North Sea autumn spawning herring is located in IIIa during the summer. During this time a substantial part of the Baltic spring spawning herring is also located in IIIa, Sub-area IVa and IVb. In the past 10 years large variations in the distribution of both populations have been observed. Therefore, complete coverage of these divisions is needed for a proper coverage of the two populations.

While the influence of the IIIa survey on estimates of North Sea SSB is negligible, the estimates of North Sea 1 ring and to some extent 2 ring herring are significant. However, the survey has a significant influence on the assessment of Baltic spring spawning herring. In 1998 60% of the Baltic Spring spawning herring covered by the North Sea survey was within IIIa. The best estimate of the state of the Baltic spring spawning stock was derived using the ICA assessment model with the two acoustic surveys, the North Sea acoustic survey in July and the October acoustic survey in Sub-Division 22–24 (ICES CM 1998/ACFM:14). The fit between the reported catch and the North Sea acoustic survey provided the best agreement and had a minimum sum of squares that was half the value for the fit to the October survey. Therefore, if an assessment of this stock is to be achieved it is more than likely that the North Sea survey will give the best fit. Failure to continue this survey until any new survey is established will almost certainly guarantee failure to provide an assessment for Baltic spring spawning herring in the next 4 to 5 years.

Therefore, the Planning Group can not recommend stopping the complete coverage of IIIa before a new and better coordinated survey can replace the July acoustic survey. In the near future this will require two acoustic surveys in IIIa: one in July and one in October.

6 PLAN FOR INTERNATIONAL SURVEYS FOR WESTERN BALTIC SPRING-SPAWNING HERRING

For a synoptic and area limited survey of the Western Baltic spring spawning herring (WBSS) there are three time windows: spring, summer and autumn.

Spring:
During the winter and early spring the hibernating population from the Sound (Sub-division 23) move to the Arkona Basin (Sub-division 24) in different groups to the spawning ground. Then later the adult stock migrates to the shallow water spawning areas and cannot be investigated by means of acoustic surveys.

Summer:
During summertime the adult herring (age 3+ and some age 2) of the WBSS is dispersed throughout Division IIIa and in the NE of part of Division IVb and the south east of IVa. At this time the WBSS stock is mixed with the autumn spawner stock of the North Sea and small local herring stocks.

The young herring of the WBSS remains in the southern part of the Western Baltic in very shallow waters and can not be investigated by acoustic or trawl surveys. Therefore the investigation of the total WBSS stock during summertime can not be recommended.

Autumn:
In late summer the adult herring starts to migrate south. This is an unpredictable situation with unknown behaviour of the stock. The situation stabilises again in September/October where a main part of the WBSS stock resides in the Sound (Sub-division 23). At this time the young herring is also concentrated in the deeper waters of the south-western Baltic. This period seems to be the best period to survey the whole WBSS stock. It should be noted that an important part of the WBSS might still be in Division IIIa until the late autumn. Therefore this area must be covered as well as the Sound to obtain a total coverage of the WBSS stock in one survey.

The investigations of the Sound (Sub-division 23) should be intensified. R/V "Solea" will cover this area for 2–3 days with extensive trawl sampling in addition to an acoustic survey by the Danish R/V "Havfisken" for 4–5 days which will include the shallow waters during the same period. For the coverage of the northern part of Kattegat and Skagerrak additional ship time for at least one week with a larger research vessel (e.g. "Dana" or "Argos") is needed.

7 REVISION OF THE MANUAL

The manual for acoustic surveys in ICES Divisions II, IV and VI (appended to ICES CM 1994/H:3) describes some of the standard operational and analytical procedures which should be carried out during the ICES North Sea herring acoustic survey. The Planning Group discussed which parts of the manual should be revised and identified individuals who should be responsible for the revision of certain sections. Bram Couperus will undertake editorial control and overall coordination of the revision. The following revised structure was adopted (reviewers in brackets):

1. Transducer and calibration (P. Fernandes and J. Simmonds)
2. Instrument setting during the survey (P. Fernandes and J. Simmonds)
3. Survey design
4. Species allocation of acoustic records (J. Pedersen and C. Zimmermann)
    4.1 Allocation to classified schools
    4.2 Allocation to school mixtures and/or scattering layers
    4.3 Scrutinising using computer software
5. Trawling and sampling (B. Couperus)
    5.1 Trawl-types
    5.2 Trawling
    5.3 Sampling
6. Data analysis (no changes)
7. Data exchange (K.-J. Stæhr and J. Simmonds)
    7.1 Data output for combined survey abundance estimation
    7.2 Data output to the international database
8. References

Section 1 and 2 need only minor revision, although some details may be dealt with more extensively. The Group agreed Section 3 is adequate for the purposes of abundance estimation. Survey design is currently under development and may incorporate elements of stock motion within design. This Section should only be reviewed when the results of this work have been evaluated. The methods for allocating species contained in Section 4 need to be elucidated. A detailed description of the scrutinizing procedure for each national survey should be included in Section 4.3. This description should conform to a standard which will be prepared in the form of a template by Jens Pedersen and Chris Zimmermann. A template and an example will be sent to other participants before 1 October 1999. Section 5.1 should contain a list of trawl gear presently in use by the participants including a number of dimensions. Although the trawling strategy is very much dependent on subjective decisions, it was considered important to describe some general rules in Section 5.2. The sampling-methods (5.3) are presently being reviewed as part of an EU-funded market-sampling project. The results coming from this project should be included or refereed to in the manual. Section 7 should deal with the formats needed for data exchange for both abundance estimation of the combined survey and for the forthcoming database.

Draft versions of the revised Sections should be sent to Bram Couperus before 1 December 1999 so that a complete draft version of the manual is available for the Planning Group meeting in 2000 where a complete revised version will be prepared.

8 PLAN FOR ECHOGRAM SCRUTINY WORKSHOP IN 2000

One major part of the analysis of the results of acoustic surveys is the visual examination of the echogram and the allocation of the calculated Echo-integral into species and categories. This part of the data analysis (scrutiny) is essentially subjective and requires an experienced operator. With no objective analysis technique available, this scrutinisation process remains important in the data analysis.

In order to improve data analysis, a Workshop on Echogram Scrutiny was held in 1998 (Reid *et al.* 1998). The experiences gained during the Workshop were invaluable but the exercise did not provide a statistically valid evaluation of the process and it will, therefore, be repeated in 2000. This will be combined with the next PGHERS meeting, to be held in Bergen in February 2000.

At the Workshop every country participating in the acoustic herring surveys should bring national data for analysis. The data has to be the following:

- a data set for the area. Exact instructions on how the data set should be sampled, will be distributed by David Reid by the end of April 1999. The selection procedure will be structured to enable a thorough statistical analysis of the scrutiny exercise;
- the respective paper output from the echosounder;
- the integrator files on tape (one scrutinised and one blank version). These should be sent to IMR Bergen by August (8 mm Exabyte or QIC-150 format) for testing and control. Contacts in IMR are Hans Petter Knudsen and Kaare A. Hansen;
- the trawl data with species composition (% by weight)*;

- weather conditions and notes that may be relevant to the data.

* In areas where the bulk of the s_A values comes from schools, the interpretation of net-sounder traces in combination with actual trawl data is important. In these areas the composition of the trawl catch may be different from the actual school composition because the intended school targets may not have been successfully fished. Therefore detailed notes on trawl performance are required.

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

9 INTER-SHIP CALIBRATION

Intercalibration between RV "Dana" and RV "Walther Herwig".

On the morning the 29 June 1998 the RV "Walther Herwig III" and RV "Dana" met at the ICES rectangle 42F7 for the inter-ship calibration of acoustic equipment. "Walther Herwig III" was in front of "Dana" for the first part of the track, travelling north to east for 30 n.mi. "Dana" led during the second half travelling east for approximately 20 n.mi. The wind was a strong breeze to a moderate gale, which reduced ship speed to approximately 8 knots. Fish concentrations were mostly made up of small schools in mid water or mixed with dense layers of plankton. The integration interval was 0.5 n.mi. and the S_V threshold was –70 dB.

The aligned sequence of s_A values is shown in Figure 9.1. Figure 9.2 shows the full data set and the two simple linear regressions (Dana on "Walther Herwig" and "Walther Herwig" on "Dana") and the mean of these which provides a good approximation to a maximum likelihood regression. Values of s_A range from between 50 to 1000 with the exception of a single large value which results from a single school in the upper 50 m of the water column; this school was seen much more clearly on RV "Walther Herwig III" than on RV "Dana". As this is a single observation it does not provide a useful observation for regression and can be considered as an outlier to be excluded from the regression (Figure 9.3). The exclusion of these points influences the mean value by 3% which is not significant. The slope of the regression is much closer to 1 and the intercept is reduced from 80 to 21 (Table 9.1). This intercalibration does not show significant difference from a 1:1 relationship between RV "Dana" and RV "Walther Herwig III".

10 PGHERS WITHIN THE ICES FIVE-YEAR STRATEGIC PLAN

Contrary to what was expected, no ICES Five-Year Strategic Plan was available at the time of the Planning Group meeting.

11 PEER REVIEW OF THE PLANNING GROUP REPORT PRIOR TO THE 1999 ANNUAL SCIENCE CONFERENCE

At the Annual Science Conference in Portugal 1998 the Living Resources Committee requested that all Working Groups should arrange peer review of Working Group reports prior to the following Annual Science Conference in 1999.

The Planning Group for Herring Surveys recommends that its report should be reviewed by the Herring Assessment Working Group (HAWG). HAWG is the recipient of PGHERS output products and as such is the most appropriate peer to carry out the review.

12 RECOMMENDATIONS

The Herring Survey Planning Group recommends that:

General:

- the Planning Group report should be peer reviewed by the Herring Assessment Working Group before the 1999 Annual Science Conference;

- the Planning Group for Herring Surveys should meet in Bergen, Norway, from 1 to 4 February 2000 (co-chairs: Karl-Johan Stæhr, Denmark and Else Torstensen, Norway) to:

a) coordinate the timing, area allocation and methodologies for acoustic and larval surveys for herring in the North Sea , Division VIa and IIIa and the Western Baltic;

b) combine the survey data to provide estimates of abundance for the population within the area;

c) complete the revision of the existing manual of the North Sea Acoustic Survey (Doc. ICES C.M.1994/H:3);

d) hold a workshop on echogram scrutiny.

For acoustic surveys:

The Planning Group recommends that present acoustic international surveys for Western Baltic spring-spawning herring in October should be intensified in the Sound (Sub-division 23) and extended to the whole Division IIIa to achieve a complete coverage of the total spawning stock in one survey.

The Planning Group recommends that both the annual acoustic survey in July and the new survey in October should continue for the present time until the new survey can provide data for the assessment. These surveys should focus on the Baltic spring-spawning herring and the immature North Sea herring in IIIa. This will require participation by Denmark.

For larvae surveys:

- the North Sea Herring Larvae Surveys should be continued with concentration on the following units: Orkney/Shetland (15/9–30/9), Buchan area (1/9–15/9) and Southern North Sea (15/12–31/12 and 15/1–31/1);

- for the year 2000 and subsequently every three years, attempts should be made to achieve complete coverage with the following sampling units included: Orkney/Shetland (1–15/9 and 16–30/9), Buchan (1–15/9 and 16–30/9), Central North Sea (1–15/9, 16–30/9 and 1–15/10) and Southern North Sea (15–31/12, 1–15/1 and 16–31/1);

- MLAI values should be calculated according to the refined procedure explained above;

- herring larvae survey activities in the Western Baltic should be reviewed with regard to their potential for supporting spawning stock size estimates.

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14 WORKING DOCUMENT

Gröger, J., D. Schnack and N. Rohlf. A revised survey and calculation strategy for the International Herring Larval Survey in the North Sea.

Table 5.1.1.1 Numbers (millions) of autumn-spawning herring by ICES area in the North Sea and VIaN.

	IIIa	IVa	IVb	VIaN
0	493.46	0.00	0.00	0.00
1	1978.98	514.61	2286.15	1221.70
2i	195.68	1650.04	504.63	117.95
2m	34.23	2695.23	2723.79	676.69
3i	5.58	268.42	2.68	19.56
3m	30.86	2133.17	170.70	647.22
4	1.14	1597.10	59.69	471.07
5	0.37	980.65	2.10	179.05
6	0.19	444.82	0.17	79.27
7	0.00	170.31	0.00	28.05
8	3.87	41.28	0.02	13.85
9+	0.00	121.39	0.00	36.77
Immature	2673.70	2433.07	2793.45	1359.21
Mature	70.66	8183.95	2956.48	2131.98
Total	2744.36	10617.02	5749.93	3491.18

Table 5.1.1.2 Biomass (thousands of tonnes) of autumn-spawning herring by ICES area in the North Sea and VIaN.

	IIIa	IVa	IVb	VIaN
0	4.45	0.00	0.00	0.00
1	120.26	33.09	75.30	80.05
2I	17.19	152.22	29.95	14.47
2m	3.01	342.38	208.18	95.06
3I	0.58	45.95	0.31	3.19
3m	3.32	439.91	19.56	114.33
4	0.16	382.61	8.78	91.36
5	0.06	270.22	0.43	38.35
6	0.04	136.50	0.04	17.93
7	0.00	49.21	0.00	6.58
8	0.49	13.41	0.00	3.12
9+	0.00	44.04	0.00	9.16
Immature	138.04	231.26	105.55	97.71
Mature	7.08	1678.28	236.99	375.89
Total	149.56	1909.54	342.54	473.60

Table 5.1.1.3 Mean weight of autumn-spawning herring (g) by ICES area in the North Sea and VIaN.

	IIIa	IVa	IVb	VIaN
0	9.02			
1	60.77	64.29	32.94	65.53
2i	87.85	92.25	59.34	122.64
2m	87.90	127.03	76.43	140.48
3i	104.77	171.20	114.06	163.10
3m	107.63	206.22	114.59	176.65
4	140.38	239.57	147.16	193.94
5	152.70	275.55	203.54	214.20
6	216.50	306.86	216.50	226.18
7		288.93		234.49
8	126.30	324.94	126.30	225.04
9+		362.78		249.07
Mean (i)	84.46	109.25	68.78	117.09
Mean (m)	138.57	266.49	147.42	207.51
Mean (all)	109.38	223.60	121.21	182.85

Table 5.1.1.4 Number of Baltic spring-spawning herring (millions) by ICES area.

	IIIa	IVa	IVb
0	0.00	0.00	0.00
1	102.83	4.90	29.97
2I	1221.92	113.27	88.01
2m	216.33	25.20	17.04
3I	111.40	15.42	12.91
3m	628.39	66.49	66.12
4	172.41	82.00	27.92
5	76.02	27.85	6.66
6	29.82	12.98	7.85
7	19.53	8.80	2.24
8	23.93	6.98	6.61
9+	6.83	4.94	3.70
Immature	1436.15	133.58	130.89
Mature	1173.24	235.25	138.15
Total	2609.39	368.83	269.04

Table 5.1.1.5 Biomass of Baltic spring-spawning herring (thousands of tonnes) by ICES area.

	IIIa	IVa	IVb
0	0.00	0.00	0.00
1	5.55	0.31	1.28
2I	97.25	10.24	7.19
2m	17.21	2.79	1.43
3I	10.07	1.71	1.30
3m	56.81	8.04	6.84
4	18.37	13.31	3.52
5	7.83	4.38	0.91
6	3.34	2.35	1.19
7	2.73	1.69	0.35
8	3.67	1.36	1.14
9+	1.12	0.89	0.77
Immature	112.87	12.26	9.77
Mature	111.09	34.82	16.15
Total	223.96	47.07	25.93

Table 5.1.1.6 Mean weight of Baltic spring spawning herring (g) by ICES area

	IIIa	IVa	IVb
0			
1	53.99	62.73	42.69
2i	79.59	90.45	81.70
2m	79.56	110.64	84.06
3i	90.36	110.61	100.94
3m	90.41	120.92	103.48
4	106.55	162.32	125.95
5	102.99	157.42	136.34
6	111.90	181.10	152.09
7	139.97	192.48	156.92
8	153.34	194.48	172.32
9+	164.69	180.03	207.60
Mean (i)	74.65	87.93	75.11
Mean (m)	118.68	162.42	142.34
Mean (all)	106.67	142.11	124.01

Table 5.1.1.7 Numbers (millions), biomass (thousands of tonnes), maturity ogive and mean weight (g) for North Sea autumn spawning, Baltic spring spawning and West Scotland autumn spawning herring by age group. (Four-year and older are assumed 100% mature).

North Sea	Numbers	Biomass	Maturity	x weight(g)	Baltic	Numbers	Biomass	Maturity	x weight(g)	West Scot	Numbers	Biomass	Maturity	x weight(g)
0	493.46	4.45	0.00	9.02	0	0.00	0.00	0.00		0	0.00	0.00	0.00	
1	4779.74	228.65	0.00	47.84	1	137.70	7.14	0.00	51.84	1	1221.70	80.05	0.00	65.53
2	7803.61	752.93	0.70	96.48	2	1681.76	136.12	0.15	80.94	2	794.63	109.53	0.85	137.83
3	2611.40	509.63	0.89	195.16	3	900.72	84.77	0.84	94.11	3	666.78	117.52	0.97	176.25
4	1657.92	391.55	1.00	236.17	4	282.33	35.20	1.00	124.67	4	471.07	91.36	1.00	193.94
5	983.12	270.71	1.00	275.35	5	110.53	13.12	1.00	118.71	5	179.05	38.35	1.00	214.20
6	445.18	136.58	1.00	306.79	6	50.66	6.88	1.00	135.87	6	79.27	17.93	1.00	226.18
7	170.31	49.21	1.00	288.93	7	30.57	4.78	1.00	156.33	7	28.05	6.58	1.00	234.49
8	45.17	13.90	1.00	307.82	8	37.52	6.17	1.00	164.34	8	13.85	3.12	1.00	225.04
9+	121.39	44.04	1.00	362.78	9+	15.47	2.78	1.00	179.85	9+	36.77	9.16	1.00	249.07
Immature	7900.23	474.85			Immature	1700.61	134.90			Immature	1359.21	97.71		
Mature	11211.09	1922.35			Mature	1546.64	162.05			Mature	2131.98	375.89		
Total	19111.31	2401.65			Total	3247.26	296.95			Total	3491.18	473.60		

Table 5.1.1.8 Percentage of Ichthyophonus infected herring found on survey by FRV Scotia.

Age/ Maturity	1	2I	2M	3I	3M	4	5	6	7	8	9+	Total
% Infected	0.0	0.0	0.0	0.0	0.6	1.7	2.5	2.4	1.3	5.8	3.9	1.4

Table 5.1.2.1 Herring number (million) per age group and Stratum/Sub-division in October 1998

Sub-division	Stratum	Age groups 0	1	2	3	4	5	6	7	8+	Sum
21	4156	1.88	2.30	0.98	0.62	0.17	0.00	0.00	0.00	0.00	5.95
21	4157	39.51	29.32	8.23	2.93	0.81	0.49	0.24	0.00	0.00	81.54
21	4256	1.41	331.86	114.22	22.09	0.00	0.00	0.00	0.00	0.00	469.59
21	Total	42.79	363.48	123.43	25.65	0.98	0.49	0.24	0.00	0.00	557.07
			Sum 3+ group:		27.36						
22	22a	134.70	203.42	35.14	7.81	7.81	1.56	0.00	0.39	0.00	390.82
22	22b	62.81	49.23	5.94	1.46	1.70	0.00	0.00	0.00	0.00	121.13
22	22c	333.39	125.93	13.03	3.38	3.86	2.89	0.00	0.00	0.00	482.48
22	22d	597.63	109.38	11.59	3.62	2.17	0.00	0.00	0.00	0.00	724.40
22	Total	1128.53	487.96	65.70	16.26	15.54	4.46	0.00	0.39	0.00	1718.83
			Sum 3+ group:		36.65						
23	4057	1.68	16.28	202.04	150.97	115.61	36.48	17.96	11.22	8.98	561.21
23	4157	6.18	40.75	74.16	31.40	12.19	1.84	0.17	0.33	0.17	167.19
23	Total	7.86	57.03	276.19	182.36	127.80	38.32	18.13	11.56	9.15	728.39
			Sum 3+ group:		387.31						
24	3857	232.38	16.28	48.83	25.97	12.81	5.54	2.77	2.08	0.00	346.66
24	3858	1774.58	152.52	193.68	138.00	77.47	46.00	31.47	7.26	0.00	2420.98
24	3859	53.11	29.01	24.38	10.89	8.44	7.08	2.45	0.82	0.00	136.18
24	3957	345.03	3.68	8.47	5.52	3.31	1.10	0.00	0.74	0.00	367.86
24	3958	53.59	14.64	6.48	5.41	4.97	2.40	0.98	0.35	0.00	88.81
24	3959	35.49	47.32	33.09	18.22	13.75	7.35	3.84	0.80	0.00	159.86
24	Total	2494.18	263.45	314.92	204.02	120.76	69.48	41.51	12.05	0.00	3520.36
			Sum 3+ group:		448						
22-24	Total	3630.57	808.43	656.81	402.65	264.10	112.25	59.63	24.00	9.15	5967.59
			Sum 3+ group:		871.78						
21-24	Total	3673.37	1171.91	780.24	428.30	265.08	112.74	59.88	24.00	9.15	6524.66
			Sum 3+ group:		899.14						

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Table 5.1.2.2 Herring total biomass (t) per age group and Sub-division/Stratum and the overall mean weight (g) in October 1998

Sub-division	Stratum	Age groups 0	1	2	3	4	5	6	7	8+	Sum
21	4156	31.9	130.7	74.8	75.3	31.2	0.0	0.0	0.0	0.0	343.9
21	4157	489.9	1636.2	573.4	302.3	107.8	85.5	45.7	0.0	0.0	3240.9
21	4256	49.5	21272.2	8281.2	1621.6	0.0	0.0	0.0	0.0	0.0	31224.6
21	Total	571.3	23039.2	8929.4	1999.2	139.0	85.5	45.7	0.0	0.0	34809.4
				Sum 3+ group:	2269.5						
22	22a	2141.7	10638.7	2045.1	467.0	501.3	177.4	0.0	49.6	0.0	16020.7
22	22b	854.2	2220.2	290.5	77.4	82.0	0.0	0.0	0.0	0.0	3524.3
22	22c	3800.7	4936.4	622.7	173.9	203.8	273.6	0.0	0.0	0.0	10011.0
22	22d	6992.2	4364.4	540.1	195.2	115.4	0.0	0.0	0.0	0.0	12207.4
22	Total	13788.9	22159.6	3498.4	913.5	902.5	451.0	0.0	49.6	0.0	41763.5
				Sum 3+ group:	2316.6						
23	4057	12.6	1012.3	17233.6	15338.1	18243.1	6664.6	3557.6	2199.9	2098.5	66360.4
23	4157	61.2	2017.2	5198.3	2584.2	1287.5	271.5	27.1	59.0	34.5	11540.5
23	Total	73.8	3029.6	22431.9	17922.2	19530.6	6936.2	3584.7	2258.9	2133.0	77900.9
				Sum 3+ group:	52365.6						
24	3857	2068.2	703.2	3457.2	2277.9	1319.8	471.0	219.1	178.9	0.0	10695.3
24	3858	14551.6	5323.0	13286.4	11495.1	6375.9	3546.5	2382.5	869.4	0.0	57830.3
24	3859	478.0	1000.7	1538.2	725.6	393.5	367.5	146.3	69.4	0.0	4719.2
24	3957	3277.8	150.6	622.5	509.3	438.8	86.4	0.0	85.1	0.0	5170.4
24	3958	535.9	445.0	395.1	373.4	413.4	93.4	46.7	27.3	0.0	2330.2
24	3959	404.6	1608.9	2015.3	1177.3	680.5	366.9	214.5	77.9	0.0	6545.9
24	Total	21316.0	9231.4	21314.6	16558.5	9621.9	4931.8	3009.2	1308.0	0.0	87291.3
				Sum 3+ group:	35429.3						
22-24	Total	35178.6	34420.6	47244.9	35394.3	30055.0	12318.9	6593.9	3616.5	2133.0	206955.7
				Sum 3+ group:	90111.5						
21-24	Total	35750.0	57459.8	56174.4	37393.5	30194.0	12404.5	6639.6	3616.5	2133.0	241765.1
				Sum 3+ group:	92381.0						
mean weight		9.7	49.0	72.0	87.3	113.9	110.0	110.9	150.7	233.2	37.1

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Table 9.1 Comparison or regression factors for full data set and single pair removed.

	Ratio	Intercept	Coefficient
Complete Data	0.98	86.08	0.80
1 point pair removed	0.95	21.33	1.00

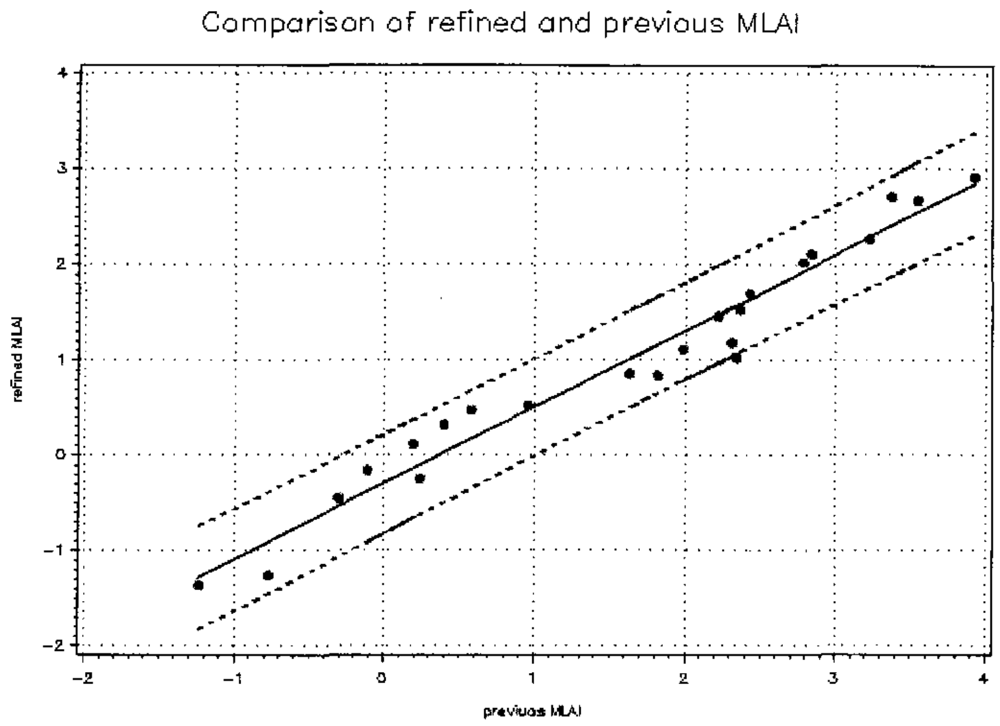

Figure 4.1 Regression of refined against previous MLAI.

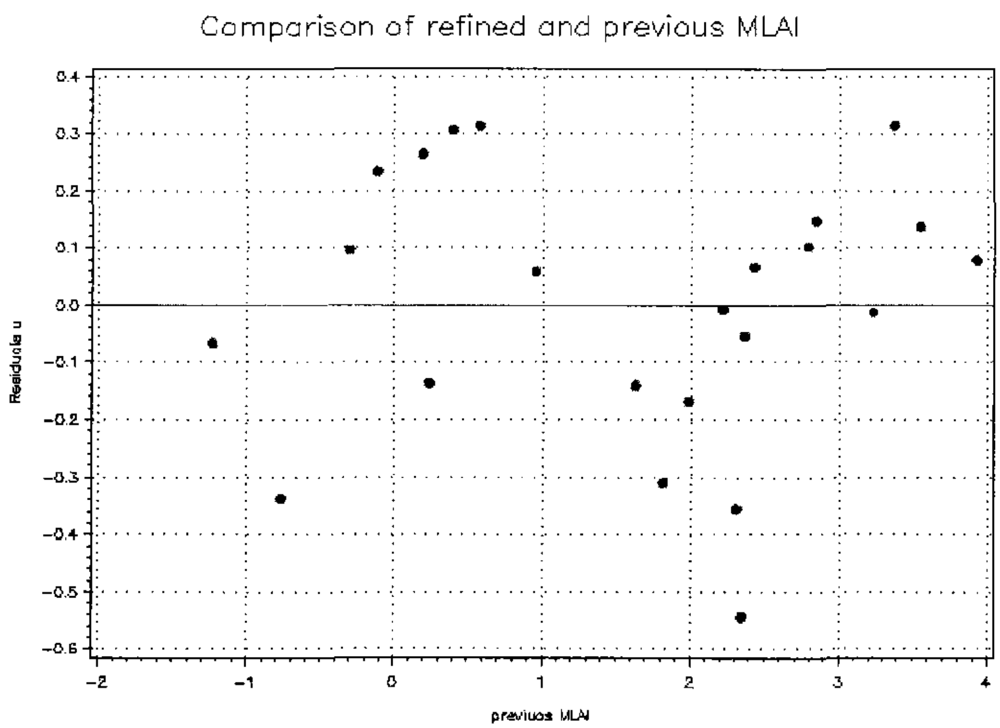

Figure 4.2 Residual plot of refined against previous MLAI.

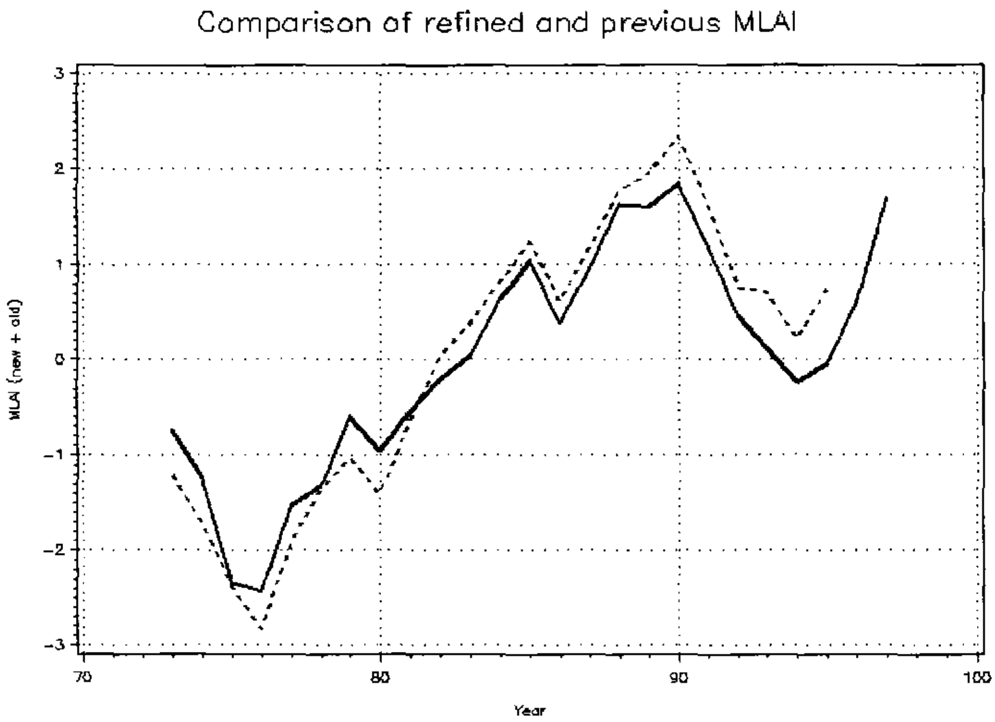

Figure 4.3 Comparison of MLAI over time.

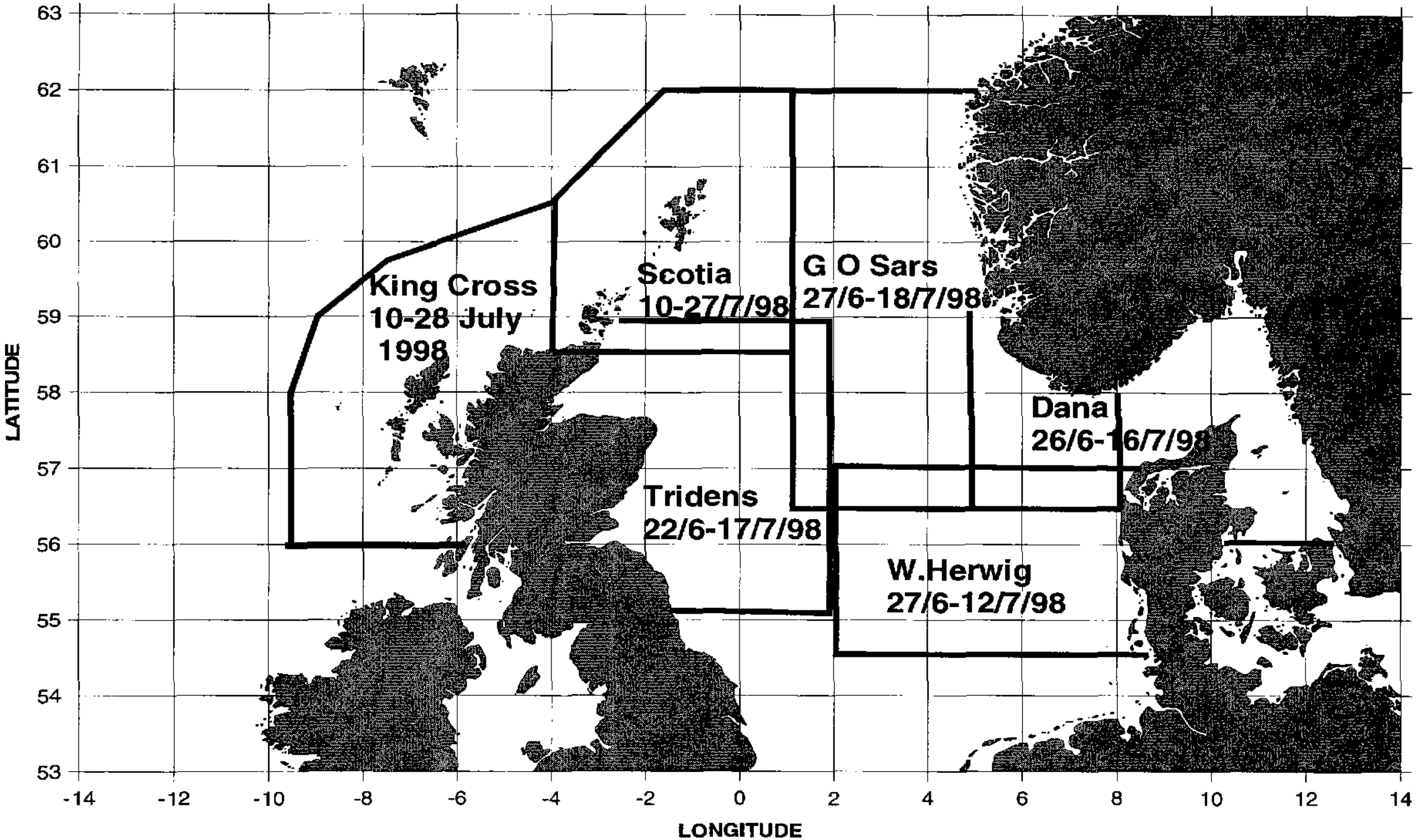

Figure 5.1.1.1 Survey dates and areas for combined acoustic survey.

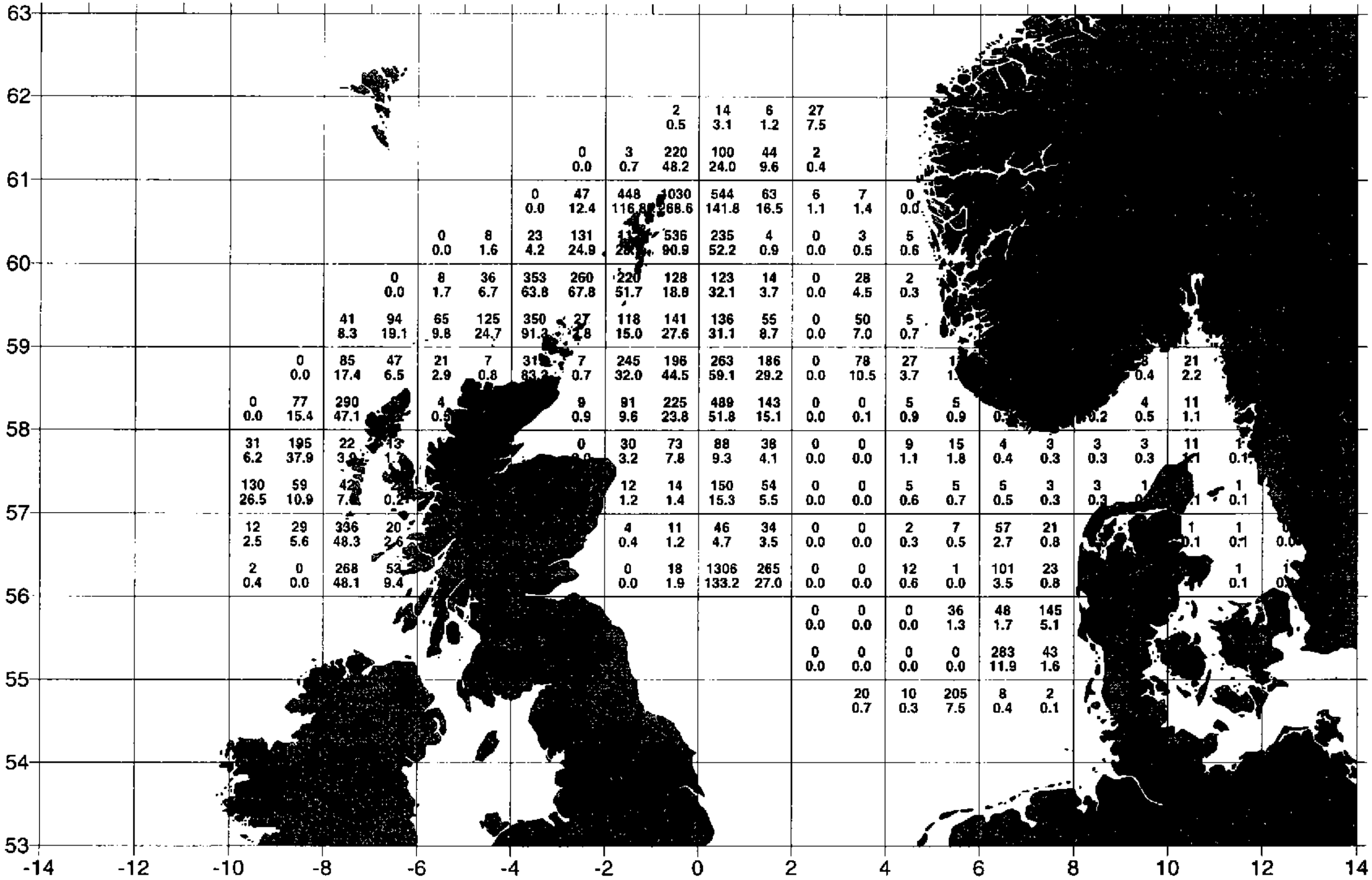

Figure 5.1.1.2 Numbers (millions) and biomass ('000 tonnes) of mature autumn spawning herring (1998).

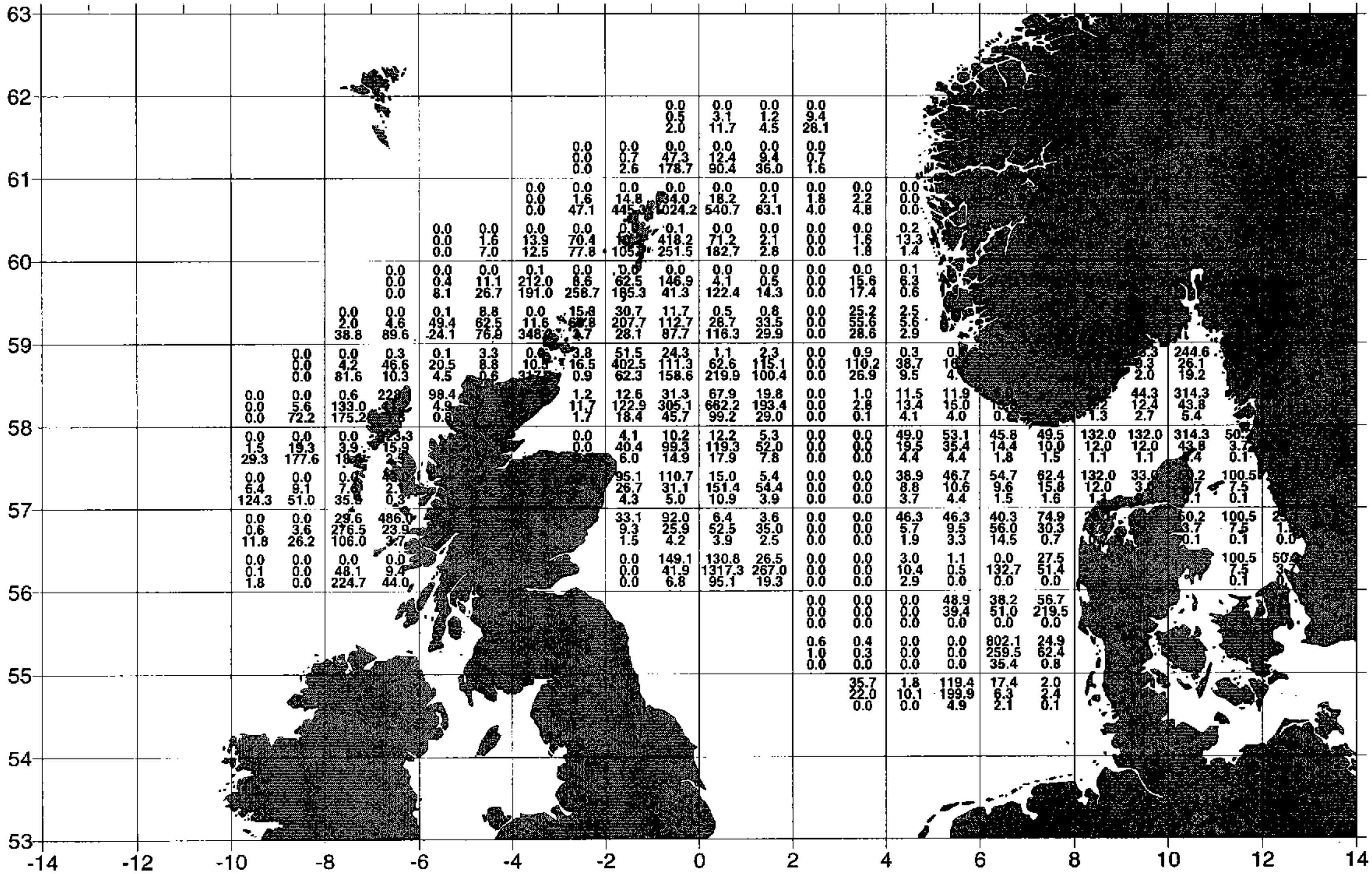

Figure 5.1.1.3 Numbers (millions) of autumn-spawning herring from combined survey in 1998; 1, 2 and 3+ groups.

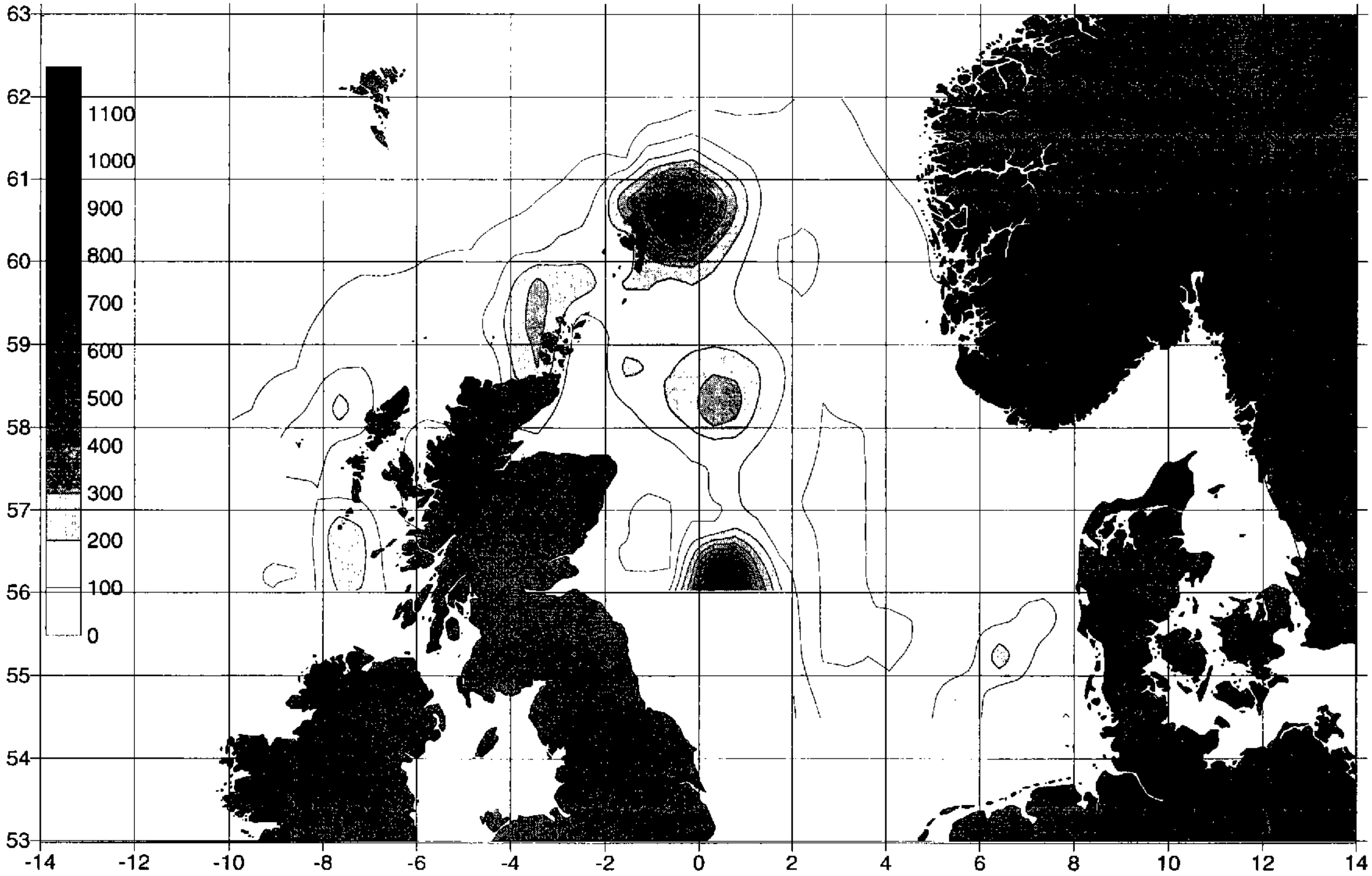

Figure 5.1.1.4 Numbers (millions) of mature autumn-spawning herring (1998).

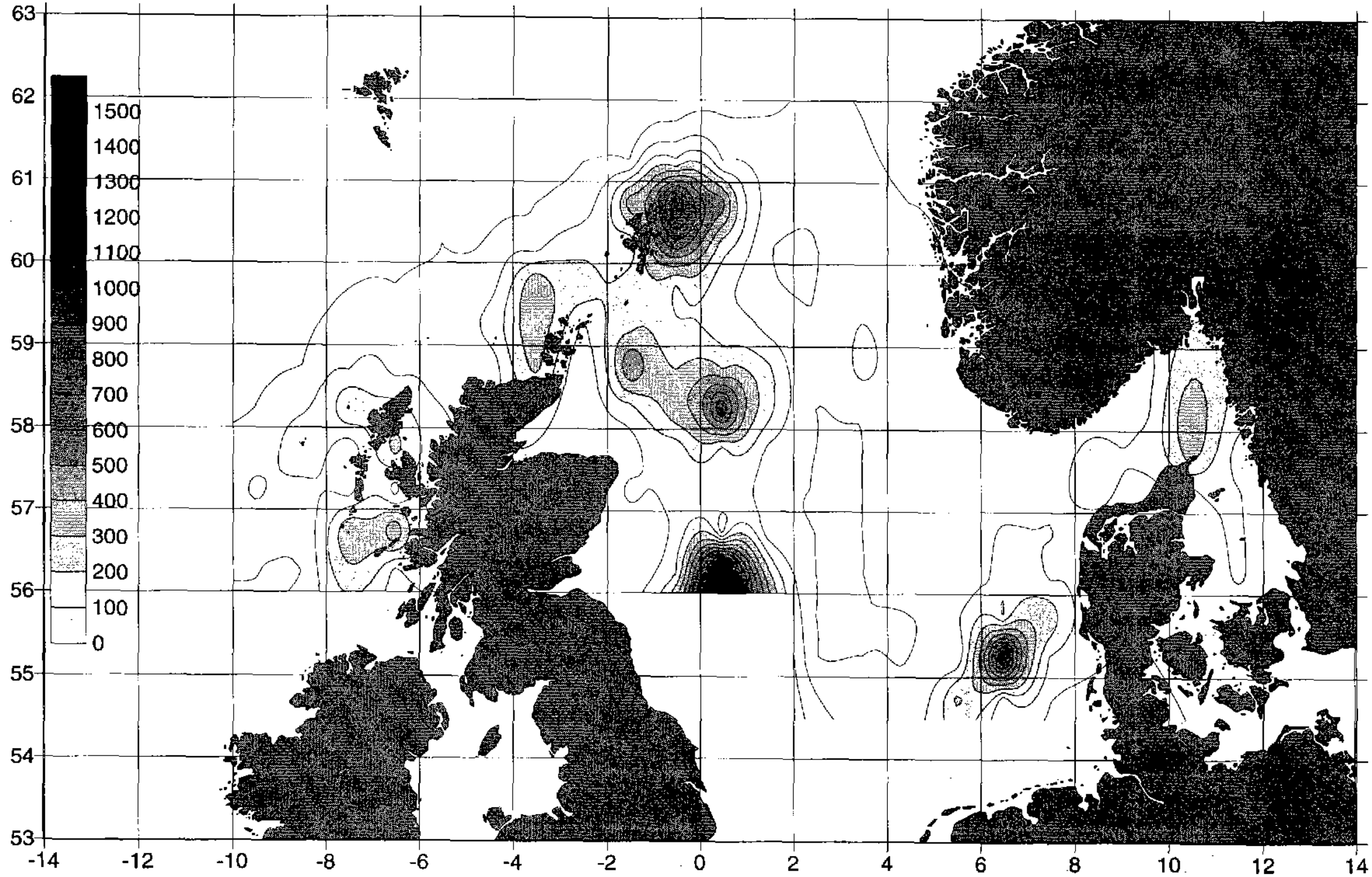

Figure 5.1.1.5 Numbers (millions) of autumn-spawning herring (1998).

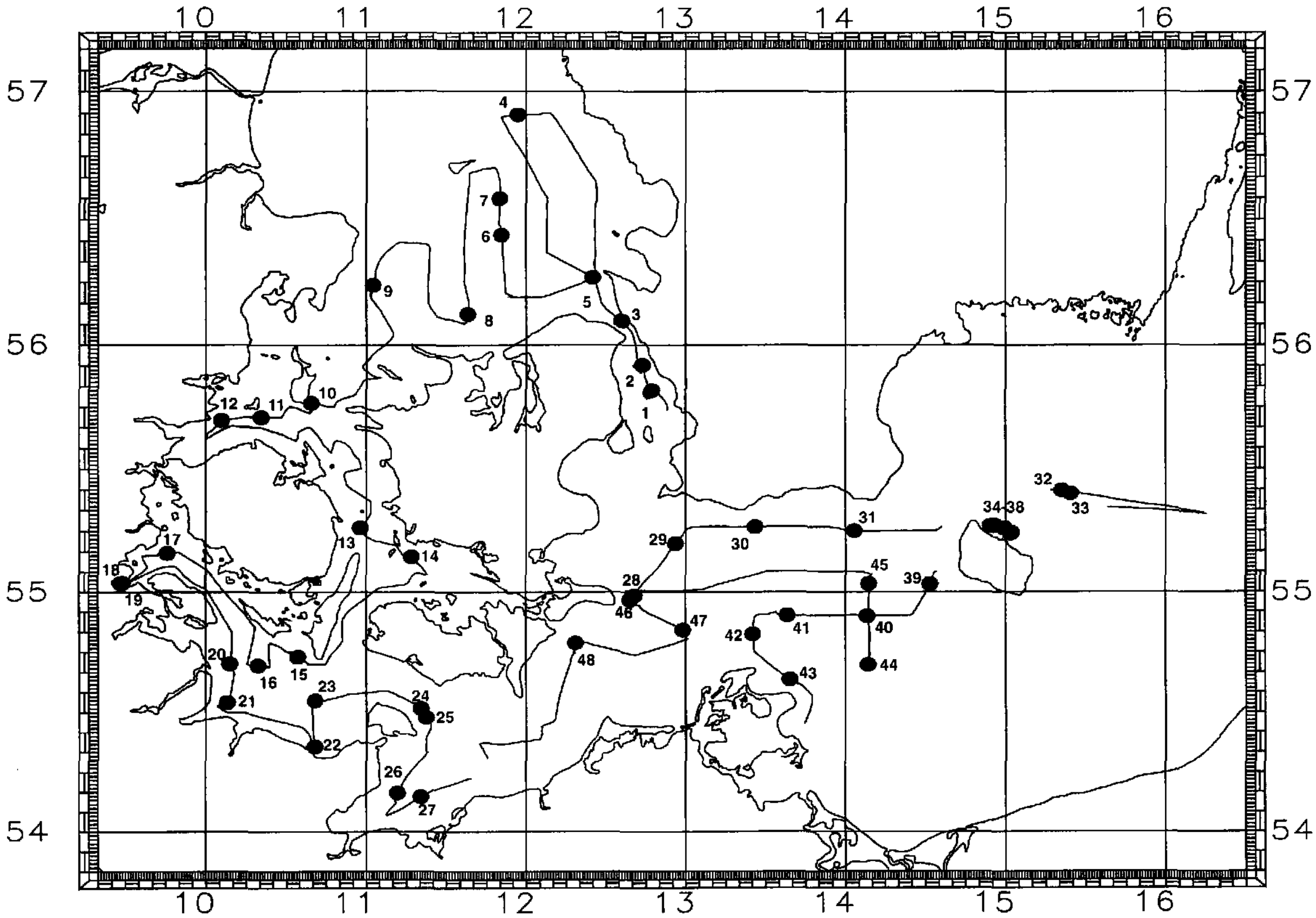

Figure 5.1.2.1 Cruise track and trawl positions, R/V "Solea", 2–19 October 1998.

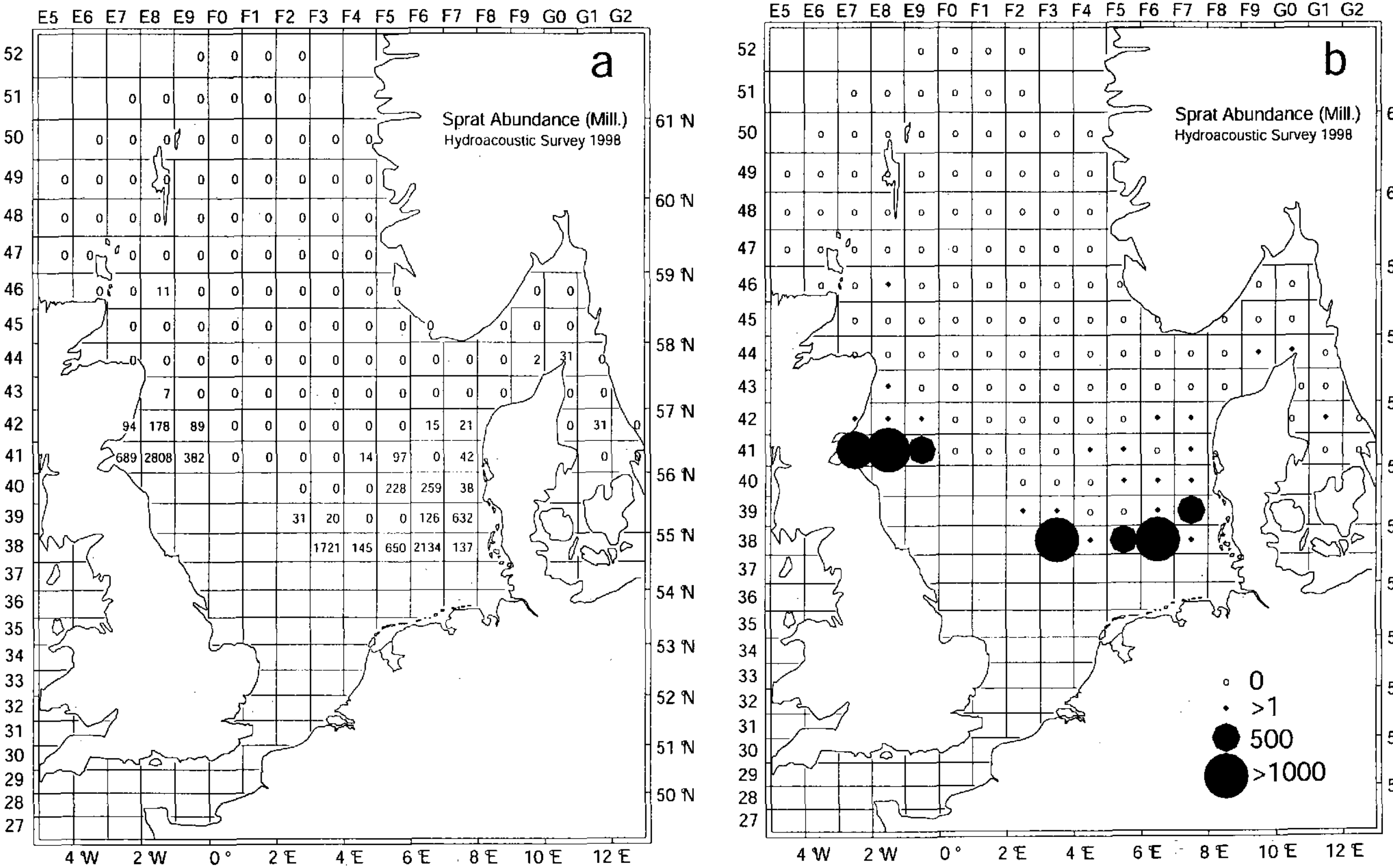

Figure 5.1.4.1 Abundance of sprat in the North Sea as obtained from the 1998 herring hydroacoustic surveys. Left panel: mean number in millions. Right panel: circle area is proportional to sprat abundance.

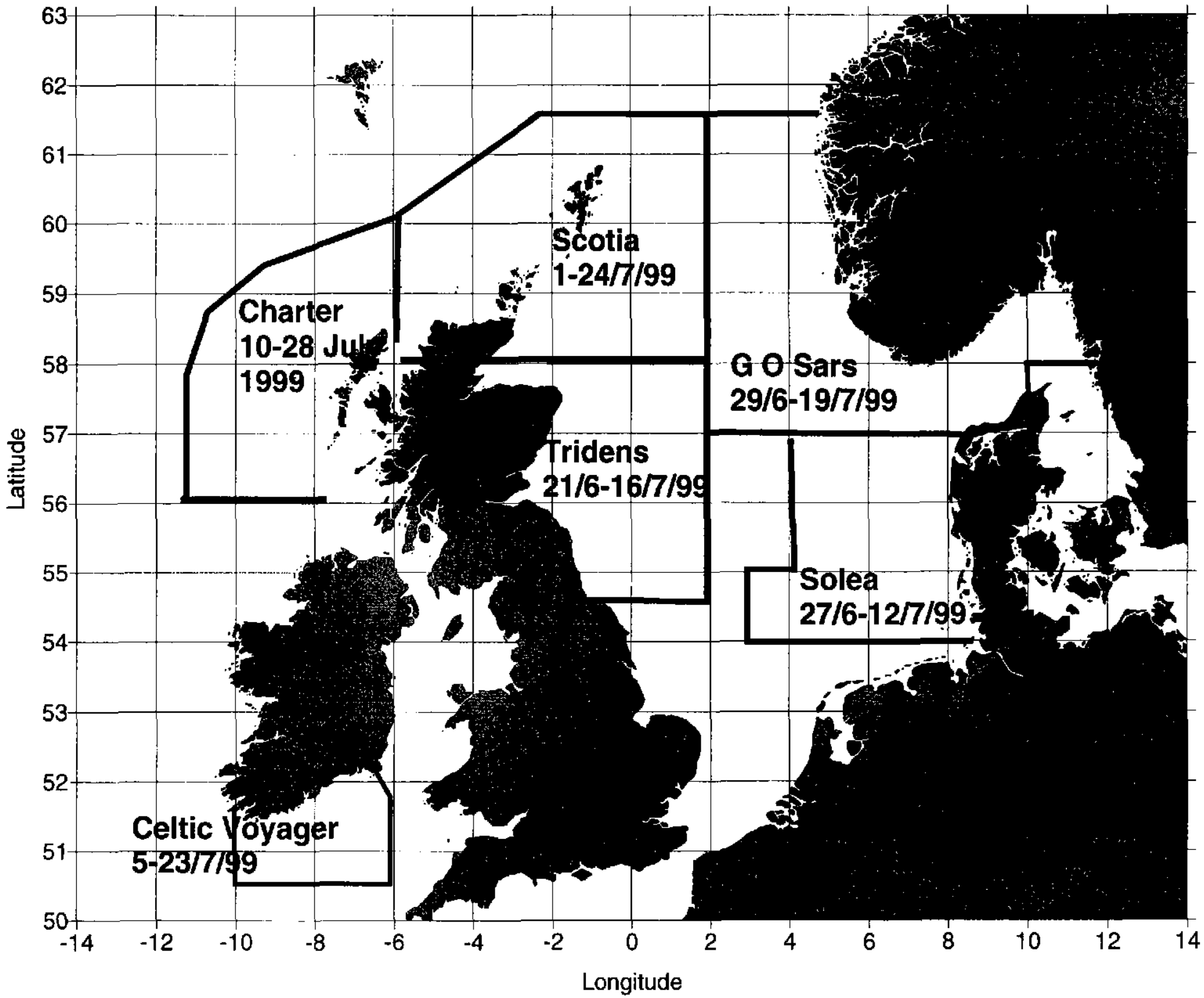

Figure 5.2.1 Layout and dates of survey areas for all participating vessels 1999.

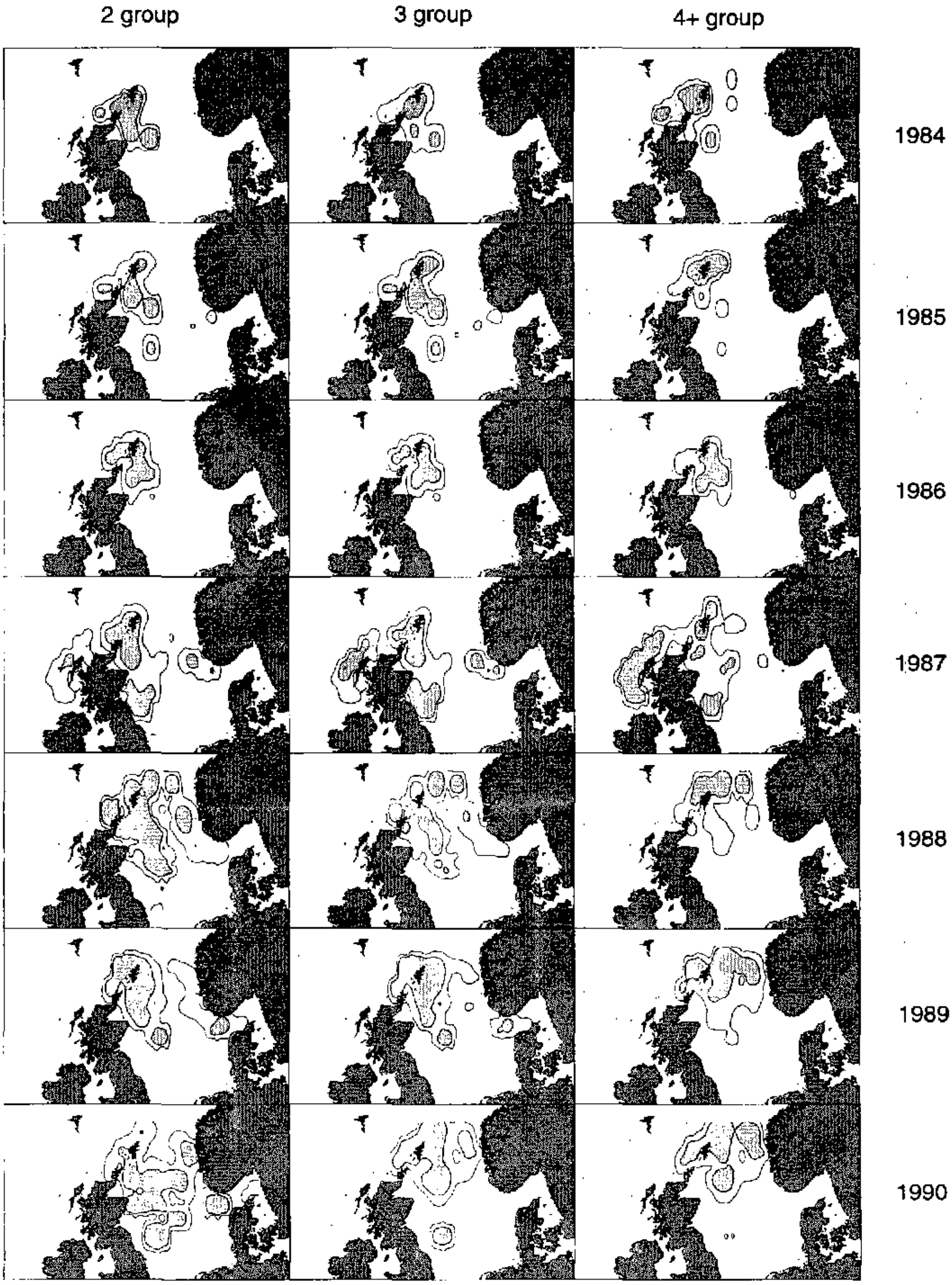

Figure 5.3.1 Relative distributions of autumn-spawning herring (dark grey 90%, light grey 75%) for 2 ring, 3 ring and 4+ ring groups of herring from 1984 to 1990 showing the change in distribution as the stock increases. Data derived from combined acoustic surveys in June–July 1984 to 1990.

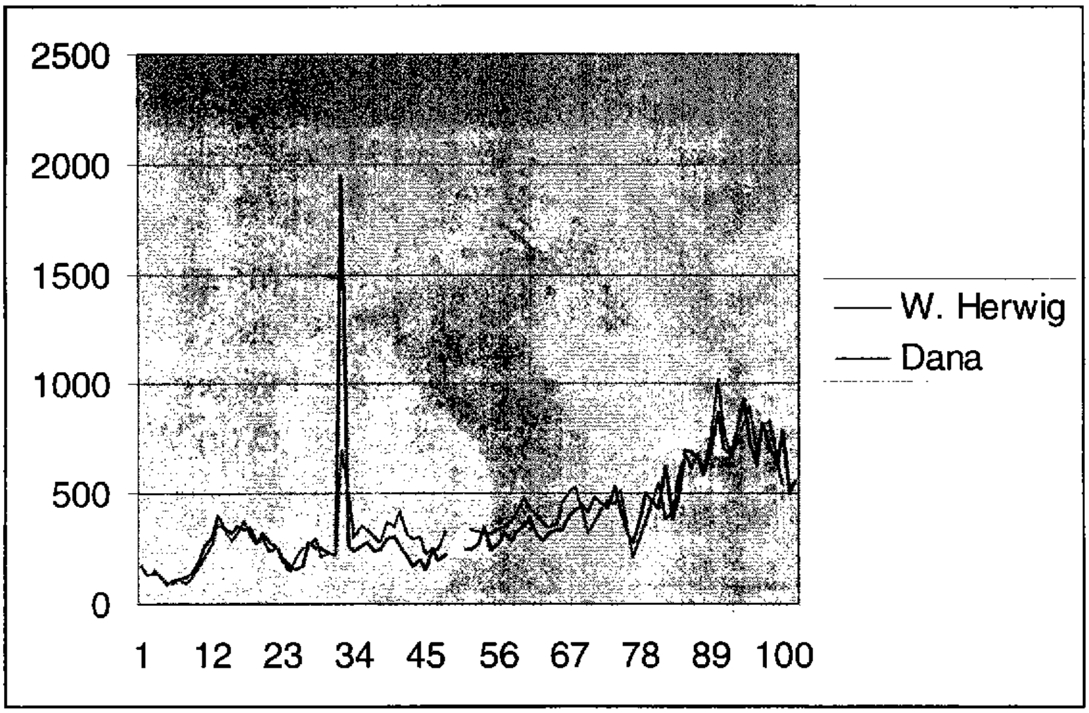

Figure 9.1 Time or Log sequence of integrator values during the acoustic intercalibration between RV "Dana" and RV "Walther Herwig III" (July 1998).

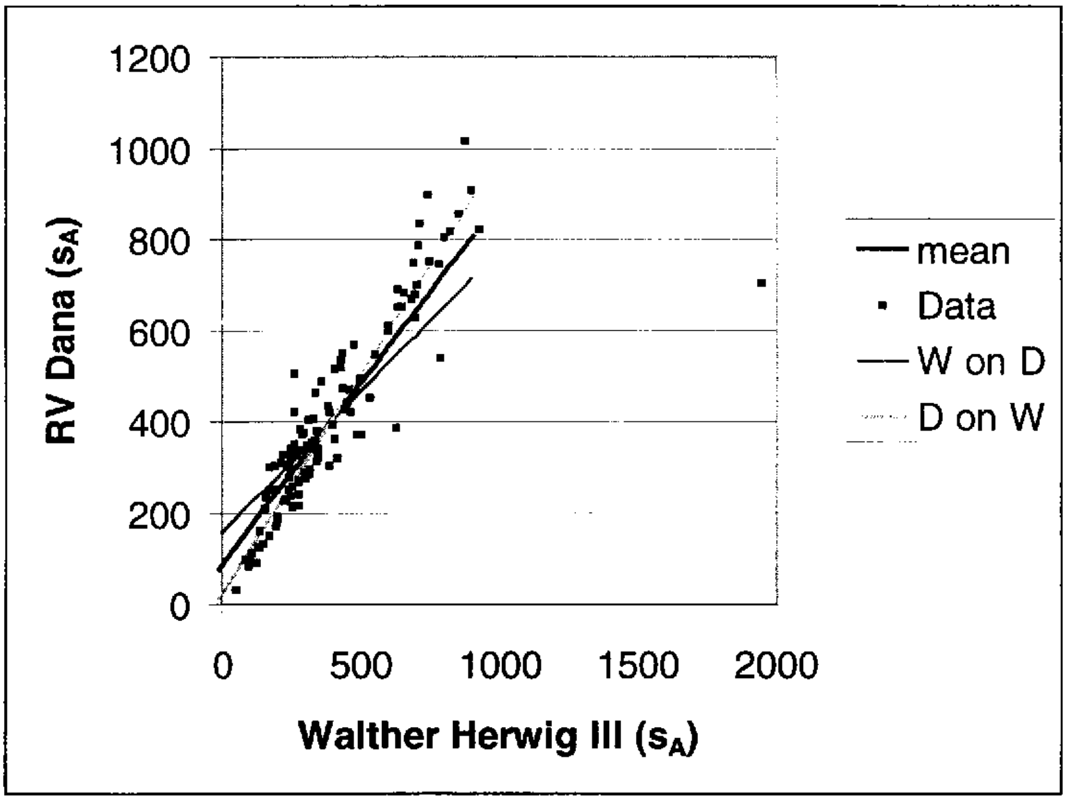

Figure 9.2 Scatterplot of integrator values from RV "Dana" (D) and RV "Walther Herwig III" (W). Showing data values and regressions.

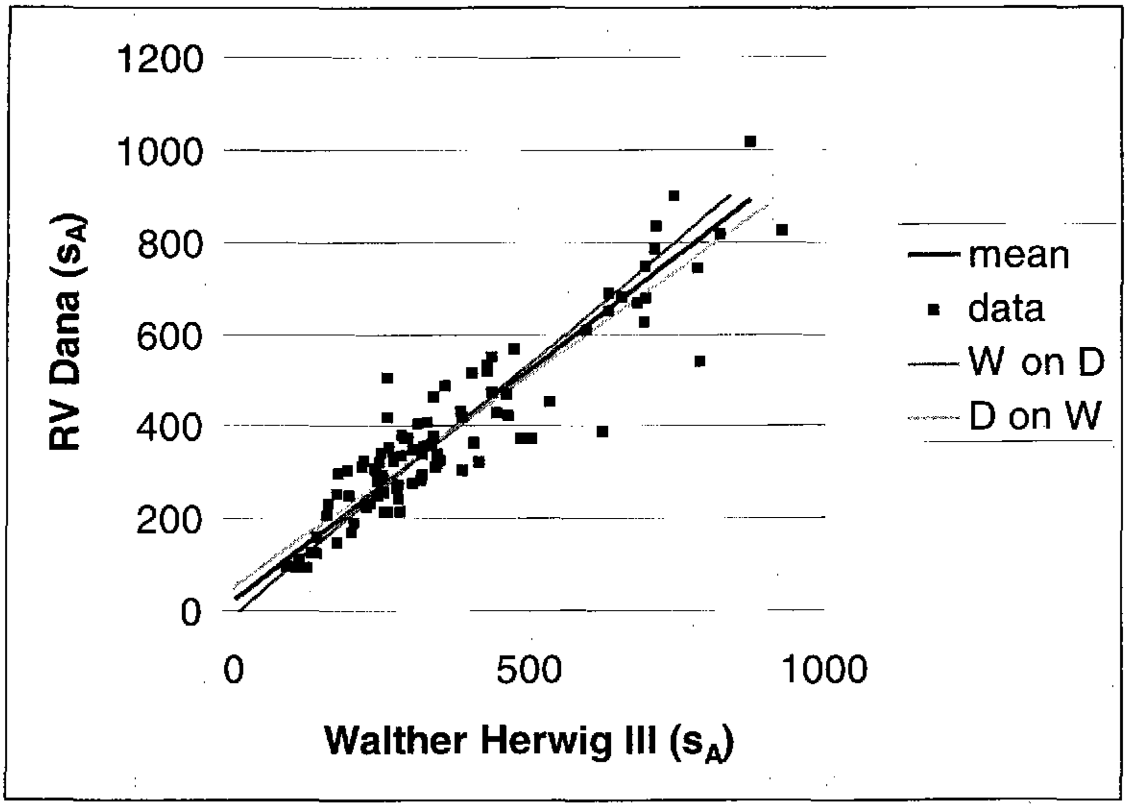

Figure 9.3 Scatterplot of Integrator values from RV "Dana" (D) and RV "Walther Herwig III" (W). Showing data values and regressions with single point pair removed.

A revised survey and calculation strategy for the International Herring Larval Survey in the North Sea

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The database from the International Herring Larvae Survey Program (IHLS) has been transferred from Aberdeen to Kiel and it has been agreed that the Institut für Meereskunde Kiel should continue to maintain this database and provide the abundance indices to be utilized by the Herring Assessment Working Group as one of the means for assessing the state of the herring stock in the North Sea. Calculation procedures for the abundance indices have been changed in some steps since the initiation of this programme. For establishing the calculation procedure at Kiel, it was necessary to decide on some specific details, which remained unclear so far in the most recently used procedure or which include subjective decisions. These details will be shortly explained and the differences in results depending on the specific decisions made will be discussed.

Due to a substantial decline in ship time and sampling effort allocated to the Herring Larvae Surveys since the end of the 80's, it may be questioned, whether these surveys can still provide abundance and production indices (LAI, LPE) comparable to those of previous years and sufficiently reliable for the use as measure of stock size. Using the historical herring larvae data base, the effects of this decline in effort, and the required total effort and allocation of sampling in space and time will be evaluated on the basis of the MLAI introduced in 1996.

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Introduction

The ICES program of international herring larval survey in the North Sea and adjacent areas has been in operation since 1967. Surveys were carried out in specific time periods and area, following the autumn/winter spawning activity of herring from north to south. Data of catches were reported to the ICES IHLS database and information of e.g. survey vessel, surveyed area and time, date and haul position, sampler and bottom depth, total number of larvae per haul and length distribution of larvae were archived since 1972. The main purpose is to provide quantitative estimates of the abundance of herring larvae, which have been used as a relative index of changes of spawning stock size.

A drastic decline in survey effort occurred since the end of the 80th. The traditional LAI and LPE, which rely on a complete coverage of the survey area, could not be estimated any longer due to the loss of information on larval abundance.

Instead, a multiplicative model was introduced for calculation of larval abundance index (MLAI, Patterson and Beveridge, 1995) from 1994 onwards. In this approach, the larvae abundances are calculated for a series of sampling units, defined by spawning area and sampling period; the total time series of data is used to estimate the year and the sampling unit effects on the abundance values and the unit effects are used to fill the sampling gaps so that a comparable abundance index (MLAI) can be estimated for each year.

In 1997, the IHLS database has been transferred to Kiel and the Institut für Meereskunde should continue to maintain this database and provide the abundance indices utilized by the Herring Assessment Working Group as one of the means for assessing the state of the herring stock in the North Sea.

However, when trying to recalculate the reported LAI values of previous years, it became obvious that several procedures have been changed since the initiation of the program and that not all steps necessary could be identified in detail. Therefore results were not comparable in all cases. Consequently, the information on relevant calculation procedures documented in several working group reports and manuals were collected and re-examined to establish a procedure which follows the historical methods as far as possible and produces results comparable with the traditional LAI. The software used by the database was completely re-written and SAS (Version 6.12) was introduced to the system instead of the former used Fortran and Basic versions.

Using this re-calculated data set, the impact of the decline in effort was evaluated by simulating different scenarios of survey coverage in space and time.

Data and methods

Some remarks on the calculation procedure concerning the larval abundance index (MLAI)

The complete calculation procedure is described in detail in Rohlf et al. (1998). But it should be mentioned here, that other positions than the standard positions (see area definition file of year 1985) are generally ignored within the current analysis. Four spawning areas are distinguished here and two to four sampling periods per area. The standard areas, fortnights and LAI units (= units of area by survey period) used here are

Standard area	(Code)	Fortnight	LAI unit code
Orkney/Shetland (abbreviated: Or/Sh)	B	30th August - 15th September	B1
		16th - 30th September	B2
Buchan	C	1st - 15th September	C1
		16th - 30th September	C2
Central North Sea (abbreviated: CNS)	D	1st - 15th September	D1
		16th - 30th September	D2
		1st - 15th October	D3
		16th - 31st October	D4
Southern North	E	15th - 31st December	E6

(abbreviated: SNS)	1st - 15th January	E7
	16th - 31st January	E8

In order to determine how complete the LAI units per each year have been sampled, a „coverage" value is defined and expressed as percentage standard positions sampled within each LAI unit and year:

$$Coverage_{Year,\ LAI\ unit} = \frac{sampled\ positions_{Year,\ LAI\ unit}}{standard\ positions\ in\ the\ area\ definition\ file_{LAI\ unit}} \times 100 \qquad (1)$$

This area coverage is later used as the first weighting factor component in the calculation of MLAI values (MLAI = year effect parameter estimates) with the multiplicative model (Patterson et al., 1997).

For comparison reasons, per each year and standard position the measured larvae will be aggregated into the following three length frequency classes (LFCs)

- 5mm ≤ larvae < 10mm (5 ≤ larvae < 11mm south of 5330 North)
- 10mm ≤ larvae ≤ 15mm (11 ≤ larvae ≤ 16 mm south of 5330 North)
- 10mm ≤ larvae ≤ 24mm (11 ≤ larvae ≤ 24 mm south of 5330 North).

These will be used later as three different larvae categories for the MLAI calculation in order to test which of these will show the closest relationship to the SSB. Correspondingly, in order to measure and reduce the LFC specific variance heterogeneity, per each LFC coefficients of variance (CVs) will be calculated by LAI unit and year, i.e.

$$CV(LAI_{Year,\ LAI\ unit}) = \frac{\sigma(LAI_{Year,\ LAI\ unit})}{\overline{LAI_{Year,\ LAI\ unit}}} \times 100 \qquad (2)$$

where $\sigma(LAI_{Year,\ LAI\ unit})$ is the standard deviation and $\overline{LAI_{Year,\ LAI\ unit}}$ the mean LAI calculated per each year and LAI unit. The CVs are used in a further step as the second of two weighting factor components for the computation of a weighted MLAI index by the multiplicative model of Patterson et al. (1995).

Evaluation procedure for testing survey strategies

All following considerations concerning the evaluation of the IHLS survey strategy (effort reduction in terms of time and space) are based on LAI calculations as described in Rohlf et al. (1998) as well as in principle on MLAI computations as defined in Patterson et al. (1997).

It should be mentioned that the way used here differs in one point from that described in the IHLS documentation (see Anon. 1995): no missing value correction has been included for standard positions which have not been sampled.

The first (intuitive) reason is that we want to investigate the effect of reduced sampling effort on the quality of the MLAI computations measured in terms of prediction performance for the spawning stock biomass (SSB). The second (statistical) reason is that only 5 to 10% (at maximum) of missing values are reliable to be filled in without loss in the statistical quality of the data (see Hand 1989). From the coverage values calculated according to step 1 of the previous paragraph (results see Annex) it can easily be seen that especially in the last years the amount of missing value stations overexceeded the 5% limit sometimes by far.

On the other hand, from the authors point of view it does not appear reasonable to completely exclude LAI units with incomplete coverage; the available expensive information should be utilized as far as possible. Thus, per each LAI unit two weigthing components are computed, one is the area coverage itself (in %) and the other the LAI variation in terms of the above mentioned CV (also in %). The idea is that the coverage is expected to be representative for and to be proportional to a prospectively inherent sampling error, assuming the lower the coverage the higher may be the sampling error induced by smaller sample sizes. The implementation of the CV as a second component of the weighting factor assumes that the higher the variation, the higher the uncertainties about the calculated LAI values for the associated LAI unit. I.e. the lower is their representativity. Both factors combined are balancing out some distortions, which might be included by using only one factor alone. It could well be the case that sampling results from few stations with a low variation are as representative as results from many stations with a high variation. Hence, the following weighting factor is introduced

$$Weight_{Year,\ LAI\ unit} = Coverage_{Year,\ LAI\ unit} \times \frac{1}{CV(LAI_{Year,\ LAI\ unit})} \tag{3}$$

This weighting factor is used when calculating the MLAIs per year and LAI unit in the multiplicative model. In such a case the least-squares estimators (LSQEs) are weigthed by a weighting matrix W, i.e.

$$\hat{\beta} = (X'WX)^{-1}\ X'Wy \tag{4}$$

where W contains the individual values $Weight_{Year,\ LAI\ unit}$ on its diagonal. This has the effect that a weighted residual sum of squares (WLSQ) is minimized, i.e.

$$WLSQ = \sum\left[Weight_{Year,\ LAI\ unit} \times (LAI_{Year,\ LAI\ unit} - \hat{LAI}_{Year,\ LAI\ unit})\right] \rightarrow Min. \tag{5}$$

$\hat{LAI}_{Year,\ LAI\ unit}$ means the estimated LAI values from the multiplicative model. As long as the weights for the LAIs are proportional to the reciprocals of the error variances then the weighted least-squares estimators (WLSQEs) are unbiased (see Anon. 1989). Taking all these considerations into account the basic idea is to vary as well as reduce the combination of LAI units included into the calculation of the MLAI in order to see which combination results in the best relationship between MLAI and SSB (spawning stock biomass) in terms of SSB prediction power. This is done by regressing the estimated MLAI values of the multiplicative model (regressand, y axis) on SSB values (regressor, x axis). The construction of the causal relationship within this regression approach is based on the assumption that the SSB produces the larvae (larvae abundances, LAIs, MLAIs). Hence in order to predict the SSB (given a new MLAI) this regression must be inverted leading formally to an inverse prediction of the SSB. Thus, the prediction power is measured by means of the inverse prediction error (IPE). Since the size of the prediction error as well as the inverse prediction error depends on the size of the SSB for which it is calculated, a specific position must be determined which should be kept the same for all related LAI unit exclusion experiments.

For the evaluation procedure some basic assumptions have been made here. It will be assumed that per construction both indices (MLAI and SSB) are linearly independent of each other despite the fact that the SSB estimate comes from the ICA. The reasons for this are:

1. Historical ICA-SSB-estimates incorporate LPE information in an unlinear manner.

2. ICA utilizes LPE indices as one out of three external calibration sources (hydro-acoustic plus IBTS data).

3. The LPE calculation is basically a backcalculation procedure via a nonlinear mortality model including some crucial assumptions about a mortality and a growth parameter. Hence, the calculation idea is principally different from that for the LAI or MLAI.

4. In contrast to LAI or MLAI calculations LPE calculations are using different standard positions from a different area definition file.

5. LPE calculations are based on a different spectrum of larval length classes.

6. Numerical pre-experiments based on SSB estimates from a VPA for the years 1981 to 1990 carried out completely independent of any larval index shows that only a slight increase of 2% percent points at maximum of the explained part of the variance (i.e. from 88% to 90%) could be possibly addressed to larval information artificially incorporated into a SSB estimation via ICA.

Hence, it can be concluded that any test of the survey strategy on the basis of the above stated linear MLAI-SSB-relationship is not trying to identify a relevant amount of an artificially constructed linear dependence. But even if it would be so it actually does not matter, since the various survey strategies to be contrasted in terms of included and excluded LAI units are compared relatively to each other meaning that any error-nous methodological assumption would be cancelled down. This also means, that any improvement of the survey strategy is evaluated by means of a criterion for what the larval index was constructed earlier. In fact, the highest improvement of the survey procedure could also improve the usefulness of the MLAI for ICA calibration purposes which is a wanted side effect.

It is known that in case of a normal regession the regression line always goes through the centre of the sample, i.e. through the point defined by the mean MLAI and the mean SSB. At this point the inverse prediction is smallest. Exactly this point is taken as that fixpoint for what all inverse prediction errors are calculated and compared with eachother. For the present purpose the centre of the samples, i.e. the mean value of SSB, has been used as the standard position for comparing the inverse prediction errors. Following the common definition of Neter et a. (1985) the inverse prediction error (IPE) is

$$s^2(SSB_{new}) = \frac{SSE}{\hat{b}^2\,(n-2)}\left[1 + \frac{1}{n} + \frac{(S\hat{S}B_{new} - \overline{SSB})^2}{\sum_{year}(SSB_{year} - \overline{SSB})^2}\right]$$

$$= \frac{SSE}{\hat{b}^2\,(n-2)}\left[1 + \frac{1}{n}\right] = IPE^2 \qquad (6)$$

$$SSE = \sum_{year} u^2_{year} = \sum_{year}(MLAI_{year} - M\hat{L}AI_{year})^2 .$$

where in this special case SSB_{new} will be replaced by the mean SSB which simplifies equation (6) a bit. In order to make the IPE somewhat easier interpretable within comparisions it will be expressed here as percentage of the mean SSB

$$IPE\text{-}\% = \frac{\sqrt{IPE^2}}{\overline{SSB}} \times 100 \qquad (7)$$

Furthermore, also the coefficient of determination r^2 together with some other statistical measures are computed to indicate the degree of explained variance. The two principal steps of the evaluation analysis can be summarized as follows:

1. Calculation of the linearized multiplicative model after Patterson et al. (1997)

$$\ln(LAI_{year,\,LAI\ unit}) = MLAI_{year} + MLAI_{LAI\ unit} + u_{year,\,LAI\ unit} \qquad (8)$$

   where $\ln(LAI_{year,\,LAI\ unit})$ is splitted into a year effect $MLAI_{year}$ (= regression parameter estimates concerning year as factor levels) and a LAI unit effect $MLAI_{LAI\ unit}$ (= regression parameter estimates concerning LAI units as factor levels). The $u_{year,\,LAI\ unit}$ are the corresponding residuals. These calculations were performed with and without weighting (see above). Reference year was 1981, reference LAI unit was B1. If B1 was excluded during the numerical experiments B2 was taken as the alternative reference LAI unit which left the year effect $MLAI_{year}$ uninfluenced.

2. Regression of the estimated $MLAI_{year}$ values of step 1 against SSB, i.e.

$$MLAI_{year} = a + b \times SSB_{year} + u_{year} \tag{9}$$

and calculations of r^2, of the root of the mean square error (RMSE) and of the inverse prediction error (IPE) as measure of the quality of the fit.

Both steps are carried out for different combinations of LAI units which are systematically reduced. The best result is choosen to be that combination of LAI units which leads to the smallest inverse prediction error. This should also show the highest degree of explained variance in terms of the coefficient of determination. Step 2 is separately performed with weighted and with unweighted MLAIs.

For comparative reasons both steps are separately carried out for the three different LFCs in order to see which of the different larvae length groups has (or have) the closest relationship to the SSB. Furthermore, it is also done for two different time periods where period 1 are the years 1981 to 1991 and period 2 is the complete IHLS period of the years 1972 to 1997 with sometimes relatively low coverage of the standard areas. Period 1 is assumed to give more unbiased results since the coverage is consistently high for all these years whereas especially the coverage especially during the period from 1992 onwards has largely been reduced.

Results

Results of the MLAI calculation

The step by step analysis of previously employed procedures for the estimation of LAI values was finally successful. Accordingly recalculated LAI values are highly comparable with the previously reported values on LAI unit level. Some minor differences occur especially for the years 1972 to 1979, but can be neglected for practical purposes. The estimations for the period from 1980 onwards fit exactly in most cases. The calculated values are presented per year and LAI unit in table 1 for LFC group 5-9mm. Accompanying information on percent coverage and the variation of data (also per year and LAI unit for LFC 5-9m) is included in table 2 as well table 3. The remaining small differences and discrepancies between the historical and the current versions of the LAI calculation on year and LAI unit level may be due to rounding errors, the use of another (now verified) area definition file, no correction for missing values in the present case and the use of different programming tools probably with differently installed platform options (precision etc.). Due to some inconsistensies and inconformities in the (national) area coding between survey data file and area definition file all area codes of the survey data file were totally ignored. Merging the area definition file with the survey data file is therefore done by year, fortnight and standard position. The SAS system (Version 6.12) was used as well for data management purposes as for all LAI and other statistical calculations.

Tab. 1 LAI values calculated per LAI unit and year for 5-9mm larvae. The used time window 1981-1991 is indicated by the bold lines. For further explanations see text.

Year	Number larvae (5 – 9 mm)										
	Buchan		CNS				Or/Sh		SNS		
	01-15Sep	16-31Sep	01-15Sep	16-30Sep	01-15Oct	16-31Oct	01-15Sep	16-30Sep	16-31Dec	01-15Jan	16-31Jan
72	30		165	88	134	22	1133	4583	2	46	
73	3	4	492	830	1213	152	2029	822			1
74	101	284	81		1184		758	421		10	
75	312			90	77	6	371	50	1	2	
76		1	64	108		10	545	81		3	
77	124	32	520	262	89	3	1133	221	1		
78		162	1406	81	269	2	3047	50	33	3	
79	197	10	662	131	507	7	2882	2362		111	89
80	21	1	317	188	9	13	3534	720	247	129	40
81	3	12	903	235	119		3667	277	1456		70
82	340	257	86	64	1077	23	2353	1116	710	275	54
83	3647	768	1459	281	63		2579	812	71	243	58
84	2327	1853	688	2404	824	433	1795	1912	523	185	39
85	2521	1812	130	13039	1794	215	5632	3432	1851	407	38
86	3278	341	1611	6112	188	36	3529	1842	780	123	18
87	2551	670	799	4927	1992	113	7409	1848	934	297	146
88	5812	5248	5533	3808	1960	205	7538	8832	1679	162	112
89	5879	592	1442	5010	2354	2	11477	5725	1515	2120	512
90	4590	2045	19955	1239	975			10144	2552	1204	
91		2032	4823	2110	1249		1021	2397	4400	873	
92		822	10	165	163		189	4917	176	1616	
93		174		685	85			66	1358	1103	
94				1464	44		26	1179	537	595	
95					43			8688	74	230	164
96		184		564				809	337	675	691
97		24						6717	2898390	1033	2164

Tab. 2 The percentage coverage after equation (1), calculated per LAI unit and year for 5-9mm larvae. The used time window 1981-1991 is indicated by the bold lines. For further explanations see text.

Year	Number larvae (5 – 9 mm)										
	Buchan		CNS				Or/Sh		SNS		
	01-15Sep	16-31Sep	01-15Sep	16-30Sep	01-15Oct	16-31Oct	01-15Sep	16-30Sep	16-31Dec	01-15Jan	16-31Jan
72	70	57	77	90	83	94	94	83	12	96	88
73	91	37	92	90	66	88	97	62	29		90
74	97	49	94		69		98	82		97	33
75	61			100	89	93	82	96	28	42	73
76	66	84	98	96	68	91	88	80		73	
77	34	100	84	87	92	66	99	94	81	62	43
78		91	84	100	95	87	100	39	83	51	
79	63	52	97	96	91	46	97	98	33	64	85
80	85	40	83	100	4	95	100	88	72	80	96
81	67	45	81	93	70	95	97	97	56		99
82	97	57	75	75	68	14	96	100	57	99	51
83	99	87	63	91	86		97	98	10	84	67
84	70	96	69	84	86	37	96	100	91	100	93
85	100	99	95	97	91	91	97	100	97	77	90
86	96	91	94	100	64	55	97	98	83	100	89
87	87	97	97	100	72	100	95	97	62	81	64
88	99	90	88	85	88	74	96	100	88	95	68
89	97	99	97	100	90	39	95	99	69	93	50
90	76	25	73	70	87			92	97	88	
91		70	80	100	86		39	44	90	97	
92		60	42	60	52		13	82	10	85	
93		69		99	59			40	90	88	
94				100	63		15	80	47	88	
95					34			96	98	100	35
96		96		48				49	91	88	62
97		70						96	83	88	94

The reason to base the entire evaluation procedure on time window 1981-1991 is to avoid data inconsistencies. These could have been caused due to the following data implications:

1. For this period the investigated all LAI units are sampled and covered in a more balanced way.

2. Since 1981 important flowmeter calibration information has been included in the dataset by which the larval abundance estimates have been standardized.

3. During the modelling process based on equation (9) no autocorrelation have been observed within this time window which vice versa would have occurred when taking all data from period 1972-1997.

In tables 1 – 3 the time window 1981-1991 is indicated though bold lines. Based on these considerations the MLAI values could be estimated as year effects from the multiplicative model of equation (8) explaining 72.81% ($R^2_{adjusted}$) of the variance. The related marginal significance level

Tab.3 Coefficients of variation after equation (2), calculated per LAI unit and year for 5-9mm larvae. The used time window 1981-1991 is indicated by the bold lines. For further explanations see text.

	Coefficients of variance in %										
	Buchan		CNS				Or/Sh		SNS		
year	C1	C2	D1	D2	D3	D4	B1	B2	E6	E7	E8
72	573		620	349	592	569	399	267	265	202	872
73	443	390	348	282	211	815	233	228			
74	488	473	352		320		322	323		388	
75	403			300	444		198	368	400	557	
76		748	324	266		647	290	312		544	
77	422	356	350	394	710	854	203	347	686		
78		322	309	410	564	985	471	141	651	454	
79	394	249	660	340	465	326	250	579		600	294
80	455	520	456	523	128	650	313	312	401	349	333
81	495	345	387	408	372		257	455	212		211
82	251	347	291	427	411	167	159	194	206	177	178
83	569	244	256	460	287		196	291	132	143	234
84	241	212	237	403	497	162	224	313	239	213	271
85	252	191	234	255	252	293	212	259	290	159	197
86	269	215	546	282	312	250	312	239	280	172	297
87	302	241	535	428	167	595	186	144	389	142	204
88	294	143	508	192	209	295	286	145	291	187	159
89	405	248	381	192	339	458	261	132	259	222	165
90	255	122	335	205	259			119	366	132	
91		187	457	345	392		148	125	696	288	
92		321	376	318	291		188	193	245	169	
93		291		219	184			267	221	209	
94				556	270		140	162	393	195	
95					183			278	256	165	182
96		378		402				264	376	249	239
97		219						289	690	205	473

Tab. 4 Results of the LAI unit exclusion experiment for the selected time window 1981-1991. 840380 t is the SSB average calculated from single ICA-SSB values (rounded to the nearest integer) which is used as fixpoint for IPE-% (*1.textblock*: LFC selection with unweighted MLAI values based on the complete LAI unit set, *2.textblock*: LFC selection with weighted MLAI values based on the complete LAI unit set, *3.textblock*: sucessive LAI unit reduction with weighted MLAI values). For further explanations see text.

LFC	a	b	R^2	BIC	AIC	RMSE	IPE-%	Re.Year	Re.LAI unit	Weight	LAI unit selection
5-9mm	0.26	0.0000021	0.859	-20.981	-23.856	0.28	15.93	81	B1	-	C1,C2,B1,B2,D1,D2,D3,D4,E6,E7,E8
10-15mm	-0.18	0.0000014	0.674	-18.328	-21.203	0.32	27.34	81	B1	-	C1,C2,B1,B2,D1,D2,D3,D4,E6,E7,E8
10-24mm	-0.57	0.0000013	0.623	-17.571	-20.446	0.33	30.55	81	B1	-	C1,C2,B1,B2,D1,D2,D3,D4,E6,E7,E8
5-9mm	-0.34	0.0000021	*0.907*	-25.827	-28.602	0.22	*12.56*	81	B1	+	*C1,C2,B1,B2,D1,D2,D3,D4,E6,E7,E8*
10-15mm	-0.14	0.0000012	0.738	-24.242	-27.117	0.24	23.39	81	B1	+	C1,C2,B1,B2,D1,D2,D3,D4,E6,E7,E8
10-24mm	-0.32	0.0000011	0.688	-23.273	-26.148	0.25	26.43	81	B1	+	C1,C2,B1,B2,D1,D2,D3,D4,E6,E7,E8
5-9mm	-0.24	0.0000019	0.806	-18.697	-21.572	0.31	19.33	81	B1	+	C1,C2,B1,B2,E6,E7,E8
5-9mm	-0.72	0.0000019	0.723	-14.665	-17.540	0.38	24.41	81	B1	+	C2,B1,B2,E6,E7,E8
5-9mm	-0.60	0.0000020	0.786	-16.955	-19.830	0.34	20.58	81	B1	+	C1,B1,B2,E6,E7,E8
5-9mm	-0.29	0.0000018	0.790	-19.029	-21.904	0.31	20.35	81	B1	+	C1,C2,B1,E6,E7,E8
5-9mm	0.11	0.0000020	0.786	-16.957	-19.832	0.34	20.58	81	B2	+	C1,C2,B2,E6,E7,E8
5-9mm	-0.72	0.0000019	0.722	-14.810	-17.685	0.38	24.51	81	B1	+	C1,B1,E6,E7,E8
5-9mm	-0.32	0.0000021	0.792	-16.494	-19.369	0.35	20.25	81	B2	+	C1,B2,E6,E7,E8
5-9mm	-0.85	0.0000017	0.670	-14.064	-16.939	0.39	27.75	81	B1	+	C2,B1,E6,E7,E8
5-9mm	-0.50	0.0000018	0.688	-12.625	-15.500	0.42	28.57	81	B2	+	C2,B2,E6,E7,E8
5-9mm	-0.15	0.0000019	0.799	-18.108	-20.983	0.32	19.83	81	B1	+	C1,B1,B2,E6,E7
5-9mm	-0.70	0.0000021	0.798	-16.860	-19.735	0.34	19.86	81	B1	+	C1,B1,B2,E6,E8
5-9mm	-0.34	0.0000020	0.758	-14.925	-17.800	0.38	22.33	81	B1	+	C1,B1,B2,E7,E8
5-9mm	-0.37	0.0000018	0.716	-14.793	-17.668	0.38	24.89	81	B1	+	C2,B1,B2,E6,E7
5-9mm	-0.81	0.0000019	0.750	-15.222	-18.097	0.37	22.83	81	B1	+	C2,B1,B2,E6,E8
5-9mm	-0.51	0.0000019	0.706	-13.453	-16.328	0.40	25.62	81	B1	+	C2,B1,B2,E7,E8
5-9mm	-0.27	0.0000021	0.781	-15.872	-18.747	0.36	20.95	81	B1	+	C1,B1,B2,E6
5-9mm	0.43	0.0000020	0.780	-16.538	-19.413	0.35	21.05	81	B1	+	C1,B1,B2,E7
5-9mm	-0.47	0.0000021	0.711	-11.576	-14.451	0.44	25.26	81	B1	+	C1,B1,B2,E8
5-9mm	-0.46	0.0000019	0.711	-13.469	-16.344	0.40	25.23	81	B1	+	C2,B1,B2,E6
5-9mm	0.12	0.0000019	0.705	-13.957	-16.832	0.39	25.61	81	B1	+	C2,B1,B2,E7
5-9mm	-0.61	0.0000020	0.715	-12.920	-15.795	0.42	24.97	81	B1	+	C2,B1,B2,E8
5-9mm	-0.49	0.0000022	*0.905*	-24.112	-26.987	0.24	*12.86*	81	B2	+	*C1,B2,E6,E8*
5-9mm	0.59	0.0000020	0.808	-18.059	-20.934	0.32	19.28	81	B2	+	C1,B2,E6,E7
5-9mm	0.16	0.0000021	0.788	-15.769	-18.644	0.36	20.54	81	B2	+	C1,B2,E7,E8
5-9mm	0.21	0.0000018	0.665	-12.294	-15.169	0.43	28.06	81	B2	+	C2,B2,E6,E7
5-9mm	-0.64	0.0000020	0.735	-13.602	-16.477	0.40	23.75	81	B2	+	C2,B2,E6,E8
5-9mm	-0.09	0.0000019	0.676	-11.718	-14.593	0.44	27.43	81	B2	+	C2,B2,E7,E8
5-9mm	-0.29	0.0000018	0.698	-14.484	-17.359	0.38	26.14	81	B1	+	C1,B1,E6
5-9mm	0.45	0.0000018	0.684	-13.146	-16.021	0.41	27.04	81	B1	+	C1,B1,E7
5-9mm	-0.56	0.0000019	0.434	-2.549	-5.424	0.70	45.47	81	B1	+	C1,B1,E8
5-9mm	0.38	0.0000022	0.872	-20.679	-23.554	0.28	15.21	81	B2	+	C1,B2,E6
5-9mm	2.36	0.0000020	0.823	-18.768	-21.643	0.31	18.41	81	B2	+	C1,B2,E7
5-9mm	-0.04	0.0000023	0.874	-20.372	-23.247	0.29	15.12	81	B2	+	C1,B2,E8
5-9mm	-0.52	0.0000016	0.638	-14.304	-17.179	0.39	29.91	81	B1	+	C2,B1,E6
5-9mm	0.01	0.0000016	0.639	-13.506	-16.381	0.40	29.87	81	B1	+	C2,B1,E7
5-9mm	-0.65	0.0000016	0.640	-13.557	-16.432	0.40	29.84	81	B1	+	C2,B1,E8
5-9mm	0.03	0.0000020	0.660	-10.158	-13.033	0.48	28.50	81	B2	+	C2,B2,E6
5-9mm	1.68	0.0000018	0.654	-11.744	-14.619	0.44	28.90	81	B2	+	C2,B2,E7
5-9mm	-0.26	0.0000021	0.713	-11.906	-14.781	0.44	25.19	81	B2	+	C2,B2,E8

is p=0.0001 (F=9.241) indicating a high significance of the model. Since many binary coded class variables are included into the model the adjusted coefficient of determination ($R^2_{adjusted}$) has been taken here and not the usual R^2. Table 4 summarizes all results of the complete evaluation procedure. The header shows different statistical measures. These are from left to right: Selected length aggregations (1. column), estimated regressions parameters a and b (2. + 3. column), various measures of fit (coefficient of determination, Bayes' information criterion, Akaike's information criterion, 4.-6. column), root of the mean squared error (7. column), inverse prediction error (8. column), relative year (9. column), relative LAI unit (10. column), weighting indicator (11. column) and selected LAI unit combination (12. column). The first and second textblocks are related to specific results based on the complete LAI unit set, the third textblock contains the results of the LAI unit exclusions experiment with successive LAI unit reduction and recombination.

Results of the LFC selection

Calculating abundance estimates for several selected length classes (LFCs) in years with a relatively complete coverage (1981 - 1991) under inclusion of all LAI units and comparing the resulting MLAIs (unweighted case) with the SSB revealed that the abundance of small larvae (5 < 10 mm) represents the best index in relation to the SSB. The inverse prediction error of SSB indicates the best model fit also for small larvae in terms of prediction power. Thios cna be inferred when comparing the first 3 rows of textblock 1 in table 4 (unweigthed MLAI calculation, entire LAI unit set) with eachother. This shows that LFC 5-9mm gives the smallest IPE-% (ca. 16%) explaining about 86% of the variance. In case of the two other LFCs the IPE-% is nearly double as high as of LFC 5-9mm, their explained variance is about 19 to 23% lower than that of LFC 5-9mm. A similar picture is created for the weighted MLAI calculation based on the entire LAI unit set. Hence, all following analyses and calculations are done on the basis of LFC 5-9mm.

Results concerning the weighting aspect

Inspecting table 2 shows that the coverage is partly extremely low, especially for years before 1981 and after 1991. It also can be inferred from this table that the coverage varied strongly over time, also in the more completely covered period 1981 to 1991. A view on the CVs in table 3 shows that also the variation differs drastically between years as well as LAI units and this on a high level of usually some hundred percent of the related mean. This alone makes it plausible that some weighting may help to reduce the negative effects of both factors.

A comparison of textblock 1 with textblock 2 of table 4 indicates that weighting the LAI values within the multiplicative model gives year effects which result in a better fit of the linear relationship MLA vs SSB than in the unweigthed case. The IPE-% will be decreased by 3 to 4 percent points through weigthing, te explained part of the variance will by increased by up to 5 percent points. Hence, all following analyses and

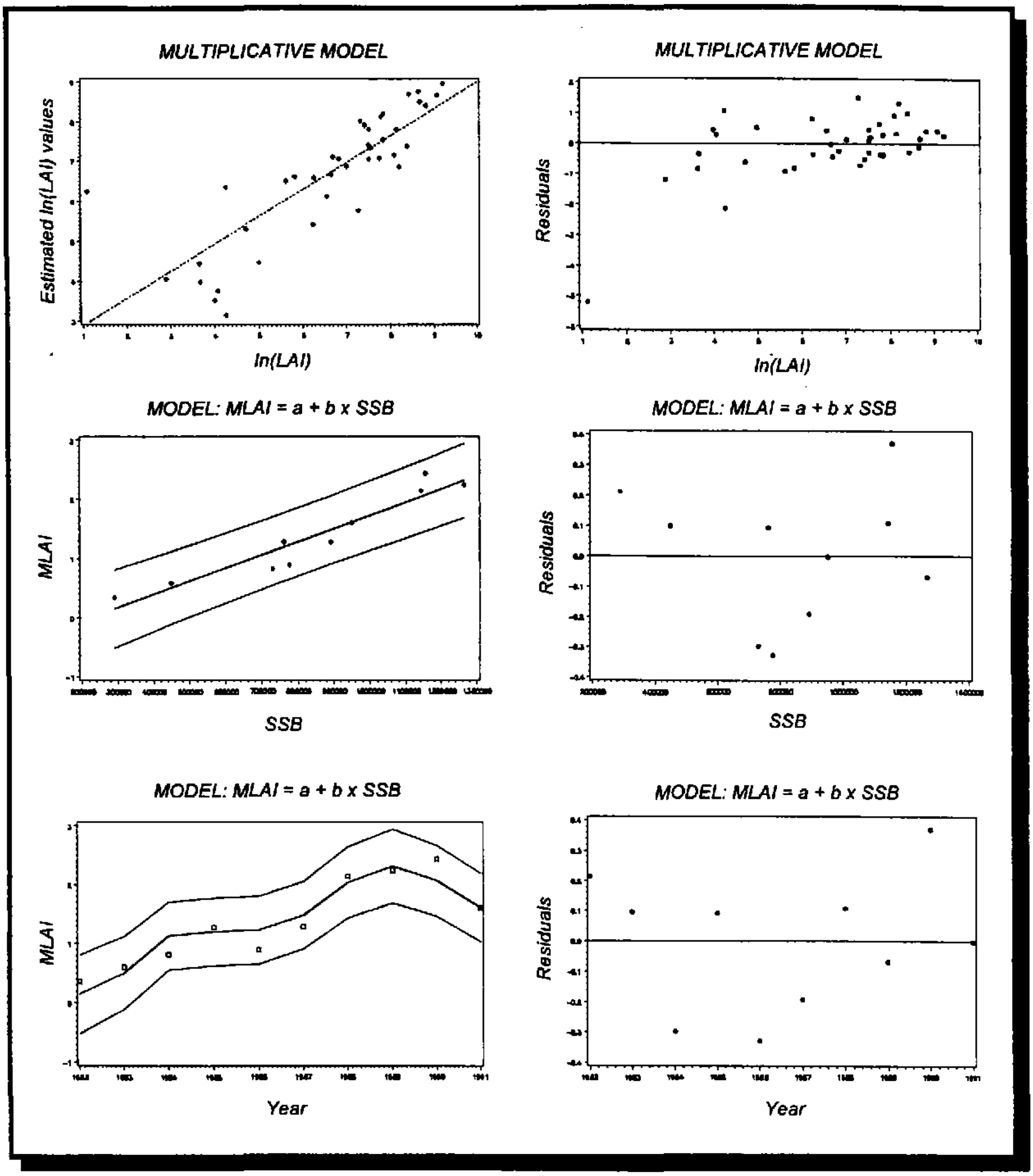

Fig. 1 Diagnosis diagrams: the two above plots are related to the multiplicative model, the four lower plots to the MLAI-SSB regression within time window 1981-1991 of the optimal LAI unit combination C1, B2, E6, E8 in terms of the IPE-% of LFC 5-9mm (*upper left*: plot of observed ln(LAI) values against estimated ln(LAI) values from the multiplicative model; *upper right*: plot of residuals from upper left ln(LAI) plot vs estimated ln(LAI) values; *centre left*: plot of MLAI values from the multiplicative model (year effects) vs SSB values with estimated regression line and 95% prediction interval for the individual MLAI value; *centre right*: plot of residuals from centre left MLAI plot vs SSB values; *lower left*: plot of observed and estimated MLAI values from model centre left with estimated 95% prediction interval for the individual MLAI value vs time; *lower right*: plot of residuals from the MLAI plot centre left vs time). For further explanations see text.

calculations will be carried out on the basis of weighted MLAI values.

Results concerning the controlled, sucessive LAI unit reduction

When simulating reduced survey effort and calculating the corresponding weighted MLAI values for larval lengths below 10 mm and period 1981 to 1991 the relative importance of specific units for the survey purpose became evident. The starting point is the complete LAI unit set with an IPE-% of 12.56% as well as an R^2 of 0.907. The exclusion of the CNS results in a decline of the coefficient of determination of about 10 percent points and an increase of the IPE-% of about 10 percent points, explaining only 81% instead of 91% of the total variance. Other reductions and combinations let decrease the explained part of the total variance down to 43% with a corresponding IPE-% of 45.47%. The best result is reached for LAI unit combination C1, B2, E6, E8 with R^2 = 0.905 and IPE-%=12.86% meaning that this result is neglectibly worse than that for the complete LAI unit set. The correspondingly estimated prediction model for this LAI unit combination is

$$M\hat{LAI}_{Year} = -0.49 + 0.0000022 \times S\hat{S}B_{Year} \qquad \textbf{(10)}$$

The associated diagrams are presented by figure 1. The two upper plots are related to the multiplicative model and the MLAI estimation. Since this modelling approach is similar to a two-factor ANOVA where only the endogenous variable is continuous, the estimated ln(LAI) values are plotted against the expected ln(LAI) values. A good fit is graphically indicated if all points lie nearby a thought line as shown in the upper left diagram of figure 1. The related adjusted coefficient of determination confirms this observation ($R^2_{adjusted}$ = 0.7281) and the associated diagnosis plot of residuals does not indicate any further systematics which would mark any model deterioration. The two diagrams in the central and lower left parts of figure 1 show that all MLAI values lie within the 95% prediction interval for the individual value. The residuals in the two central and lower right diagnosis diagrams does not indicate any model violation. Furthermore, the Durbin/Watson test results in a value near 2 (d_1 = 2.1581) which does not lead to a rejection of the null hypothesis of no first order autocorrelation as the marginal significance level confirms (p = 0.4564). Variance homogeneity could be intuitively expected as a direct consequence of the weighting process during the MLAI calculation. This expectation was confirmed by a related Lagrange/Multiplier test of order q (LM(q) test) which was carried out up to a maximum order of q=11: the marginal significance levels (p values) which were in all cases larger than 0.05 indicate that the nullhypothesis of homoscedasticity could not be rejected for any order.

Discussion

When trying to analyse and reproduce the traditional procedure used for calculating LAI values, a complete identification of all details turned out to be difficult. This is due to the fact that the methods have evolved in the course of time and changes have been made in calibration procedures, handling of the missing value problem, definition and coding of standard areas, the way of merging information from different co-existing area files with those from the survey files etc. It is thus strongly suggested to decide on a new standard definition of the calculation procedure for LAI's per sampling unit and per year, and we propose the procedure described in this paper as the basis for any further discussion in the corresponding planning and working groups of ICES.

The results presented here for different size groups of larvae, indicate that the MLAI values for the group of smallest larvae (< 10 mm) show the best relation to the spawning stock biomass (SSB) of the same year (i.e. without any time lag). This is intuitively plausible as the abundance of older larvae should depend to a larger extend on varying environmental influences.

The comparison of results obtained from different sampling effort have in general confirmed that, LAI values based on reduced effort lead to a reduced precision of SSB estimates. This can already be seen from the 5-10% better fit obtained when using the less extended but more completely covered time period 1981 to 1991 compared to using the entire data set (1972 to 1997), with less consistent sampling and largely reduced effort during the last years (compare Rohlf et al. 1998). The MLAI values obtained from systematically varied subsets of sampling units also lead to weaker relationships with SSB in general. The differences, however, were not very substantial. In a few cases even a slight increase in percentage of explained variance was obtained compared to the complete coverage. This may be expected by chance in case of generally similar values.

The latter effect may also be related to some degree to the use of a weighting factor which is inversely proportional to the variation. Such a factor leads to a harmonized MLAI data set. I.e., it is reducing not only the internal but also the external LAI unit variation. Furthermore, the use of such a weighting factor provides not only a helpful tool but also a more objective instrument to balance out extreme values (as for instance in case of the extremely high larvae numbers of the southern North Sea in 1997). The alternative of leaving out extreme values from the entire analysis does not only mean dropping valuable information but also biasing the results in an arbitrary way. Furthermore, the fact that the combined weighting factor used here also includes a coverage component makes it unnecessary to stick on an arbitrary missing value elimination, by which information is lost, or correction procedure, which may bias the results. The data fit could actually be improved this way.

The effect of reduced sampling effort is obviously depending on the sampling units selected. When using larvae smaller than 10 mm the optimum choice for minimum sampling effort appears to be given when surveying the units C1, B2, E6, E8. This suggests that the surveys in CNS are of less importance and thus may be omitted if necessary. It has to be considered, however, that these results are based on a data set obtained from complete coverage over a limited period of time. In future periods the variation in spawning time and area may differ from variations so far observed. Thus, the survey strategy should aim for at least occasional, exploratory coverages to allow the identification of possible general trends in the spawning behaviour and success of the herring groups in the North Sea.

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Appendix 2

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