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Exploration of the Sea

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REPORT OF THE PLANNING GROUP FOR HERRING SURVEYS

Bergen, 24 - 27 May 1994

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1 TERMS OF REFERENCE

At the 81th Statutory Meeting it was resolved (C.Res. 2:37) that a "Planning Group for Herring Surveys" should meet in Bergen, Norway from 24-27 May 1994 to:

- a) investigate and define procedures for species allocation of acoustic records;
- b) examine procedures for combining disaggregated length and age data from individual stations;
- c) coordinate the methods used on acoustic surveys for herring in the Northeast Atlantic and Baltic.

2 PARTICIPANTS

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N. Håkansson	Sweden
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3 SPECIES ALLOCATION OF ACOUSTIC RECORDS

Different methods of species allocation are being used in the various areas. The method used depends largely upon the schooling behaviour of the herring and the mixing with other species. In the North Sea and Division VIa the species allocation is based mainly on the identification of individual schools on the echogramme. In Skagerrak-Kattegat and Baltic the identification is based on composition of trawl catches. Both methods are described in more detail below.

3.1 North Sea and Division VIa

At the time of the survey most of the herring occur in well-defined schools, often of a characteristic shape. Integration values referring to the schools can be read directly from the increment of the integrator line on the echogramme, or from boxes drawn around the school with the BEI (BI 500). Information on bottom depth and bottom type may assist in identifying schools on the echogramme. Regular trawl hauls are made to check the identification of schools made from the echogramme, and to establish the identity of schools that can not be identified on the basis of their appearance.

Sometimes herring occur mixed with other species in aggregations of smaller schools. In this case, species allocation is based on the composition of trawl catches.

3.2 Skagerrak, Kattegat and Baltic

In most cases, herring cannot be distinguished from other species by visual inspection of the echogramme. Both herring and sprat tend to be distributed in scattering layers or in pelagic layers of small schools, and it is not possible to ascribe integrator values to typical herring schools.

Species allocation is based entirely upon trawl catch composition. Trawl catches considered representative for the fish recordings within each stratum are combined to give an average species and length composition of the catch. The mean back-scattering cross section of one fish in the average trawl catch is calculated using the appropriate length-TS relationship for each species. S_A -values attributable to fish are extracted from the echogramme by deducting plankton, bottom, and noise contributions from the total S_A values. Mean densities of fish are found by dividing S_A -values by the mean back-scattering cross section of one fish. These estimates of total fish density are then allocated to species and length groups according to the average trawl catch composition in that stratum.

4. COMBINATION OF DATA FROM INDIVIDUAL TRAWL STATIONS

During the surveys trawl sampling is carried out to identify and provide biological samples from the population. An examination of the data suggests very strongly that the survey area is heterogeneous both in length/age composition and the species composition of the mixed layers discussed in section 3. Samples are taken in an opportunistic manner and are not the result of an organised regime of either random or systematic design. Thus the samples cannot be attributed equally to the whole area, but must be associated appropriately with the heterogeneous abundance distribution. The problem is to determine the appropriate spatial allocation of data from the hauls. While substantial differences are found between some hauls others are more similar. The requirement is to determine how much of the variability can be attributed to real changes in distribution, and how much is the result of small scale variability in catch or distribution. For example does a trawl providing a catch from one or two schools accurately reflect the length of all the local schools close by or is some combination of two similar but statistically independent trawls 10 or 15 nautical miles apart more representative of the combined larger area. This section addresses this problem both with regard to length/age combination of herring and estimation of species proportion.

4.1 Stratification for estimating species composition.

The stratification for estimating species composition is made in four different ways in the total area from the North Sea to the Baltic and the different methods are connected to the areas North sea, Division IIIa, Sub-division 22 and the Baltic.

North Sea:

In the North Sea the species allocation is not done in a stratified way but based on the appearance of the fish on the echogram. Only in areas with mixed species stratification on areas is made. Here ICES rectangles are used.

Division IIIa:

In IIIa the overall key in stratification for species composition is the bottom depth and as the second parameter divided into geographic area (Fig. 1). For each geographic area, trawl hauls for estimation of species composition are made in each depth stratum.

Sub-division 22:

ICES Sub-division 22 is a heterogeneous area in respect to habitats and the area is therefore divided into four strata based on the species communities. In each of these four strata the depth is used for defining substrata.

Baltic Sea:

For the Baltic Sea a stratification for estimation of the species composition is based on ICES rectangles.

4.2 Stratification for estimating length and age distribution

Over the survey area a number of trawl hauls provide length and age information. This information is used to disaggregate the herring abundance by age and to obtain mean target strength values for abundance estimation. Four methods of stratification have been applied to trawl haul data; two methods of fixed strata based on statistical rectangles and depth strata, and two methods of area aggregation based on examination of length samples to establish statistical rectangle or quarter statistical rectangle based strata. Predefined strata remove the problem of correctly establishing strata from the data, but leave more severe problems of aggregating data within the strata. The problems of combination within strata are discussed in more detail in section 4.3. Selection of areas of homogeneity from the data is dealt with here.

The problem is to evaluate whether it is more appropriate to use the trawl hauls directly on the local echointegrator data, or to average some of the hauls. In examining the trawls it is possible to see that some fish traces have completely different length compositions from others, while some are quite similar. The questions of which hauls may be combined and which dealt with separately must be addressed. The length composition by trawl haul is examined to see if there are regions of homogeneity within the survey area. This can be done visually or using the Kolmogorov-Smirnov (KS) test and the geographical proximity of similar hauls. The section on the use of the KS test is taken from MacLennan and Simmonds 1991.

The Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov (KS) test compares two samples to determine whether they have been drawn from populations with different probability distributions. The test is sensitive to differences in the mean, variance and number of modes. Length frequency data from trawl samples can differ in all these features. A good description of the test and its limitations will be found in Campbell (1974).

The test statistic is D_{\max} , defined as the maximum difference between the two cumulative probability distributions. If the two samples comprise N_1 and N_2 fish and the numbers in length class j are n_{j1} and n_{j2} respectively, the cumulative frequencies are:

$$\begin{aligned} f_{i1} &= \sum_{j=1}^i n_{j1}/N_1 \\ f_{i2} &= \sum_{j=1}^i n_{j2}/N_2 \end{aligned} \quad (1)$$

D_{\max} is the largest value of $|f_{i1}-f_{i2}|$. On the null hypothesis that the samples have been drawn randomly from the same population, there is a small probability that D_{\max} will be larger than

$$D_p = A_p \sqrt{(N_1+N_2)/(N_1N_2)} \quad (2)$$

The factor A_p is 1.36, 1.63 or 1.95 for $P = 0.05, 0.01$ or 0.001 respectively.

Figure 2 shows the length frequencies of herring samples collected at three trawl stations in the Orkney Shetland area of the North Sea, along with the corresponding cumulative probability distributions. N is close to 150 in each case. A separate test is done for each pair of stations with the following results.

Stations 1 and 2, $D_{\max} = 0.13$

Stations 1 and 3, $D_{\max} = 0.81$

Stations 2 and 3, $D_{\max} = 0.86$

D_p is 0.24 for $P = 0.001$, so it is almost beyond any doubt that the population at station 3 is different from the others, while those at stations 1 and 2 are probably from the same size distribution.

The trawl samples are normally analyzed in a manner which is incompatible with the strict rules of the KS test. In particular, the interval between length classes is required to be small so that no more than seven observations occur in any class. In the example illustrated in Figure 2, there are 16 fish in the most frequent class. This results in D_{\max} being under-estimated by about 0.05 at the 5% probability level. Because of this uncertainty, it is not suggested that the KS test should be used as a completely objective procedure for classifying trawl samples in similarity groups defined by a pre-determined value of P . Instead, D_{\max} is considered as an index of similarity and no more than that. Each sample is compared with all the others and the resulting values of D_{\max} are displayed in a triangular matrix whose rows and columns are ordered by the station numbers. This matrix is examined for associations by comparing D_{\max} with a threshold D_c . Samples from

neighbouring stations for which $D_{\max} < D_t$ are considered to represent the same population. D_t is set between 0.1 and 0.4, at a level where the associations are least sensitive to changes in the threshold. For the three samples described above, the two groups, (1, 2) and (3), are confirmed since they are consistently identified by any threshold between 0.13 and 0.81.

Selection of areas

For trawl hauls which are found to be grouped, by visual or numerical examination, the groups are checked to see if they occur separately in space. If this occurs then the groups of hauls are used to define strata (on a 15' latitude by 30' longitude or 30' latitude 1° longitude grid) for the survey area. Figure 3 shows the distribution of KS test values found comparing multiple samples from 22 hauls and the distribution of values between the 22 hauls. An example of the KS test applied to survey data is shown in Table 1 which contains the grouping for different levels of the KS test and Figure 4 the geographical distribution of the hauls from Scotia 1993 survey of the Orkney and Shetland area. Figure 4 also shows the final choice of areas.

4.3 Combining length samples

This problem has been addressed in Simmonds et al 1992. The usual procedure is to average the length distributions obtained within strata of convenient size. The strata might be the fixed statistical rectangles, depth strata or any combination of these, or areas defined from the geographical distribution of different size groups.

Assume that within a strata there are n samples containing herring are obtained. The average fraction (f_i) of length group i is then calculated as:-

$$f_i = \frac{1}{\sum a_j} \sum_{j=1}^n a_j f_{ij} \quad (3)$$

where f_{ij} is the fraction of length group i in sample j and a_j is the weighting factor for sample j .

The weighting factors depend on how the trawl catches are considered.

Three main cases may occur:

1. Catch rates assumed proportional to abundance: Each sample weighted according to the catch rate of the species.
2. Catch rates poorly related to abundance: Equal weight to all samples, possibly with exclusion of small samples.
3. Catch rates poorly related to abundance: Weight proportional to neighbouring echo integrator values of the herring.

Case 1 is not used in these herring surveys as the catch rate from pelagic gear is not

regarded as either a reliable indicator of local abundance or of the quality of the length sample. Small catches may be regarded as rather unrepresentative.

In case 2 the a_j in equation 3 are equal to 1. Small samples (too few measurements to have a good length distribution) may require special treatment. A simple procedure is just to exclude them. Then there is a risk that significant additional information is excluded, particularly if the number of good samples in the stratum is low. Where the data are used to define the strata as in the KS test above a small sample may be excluded from the equal weighted mean for the area but still used to define the area boundary. In this procedure a_j takes the value 1 for all length samples greater than $n=c$ (the sample size cut off) and 0 for all samples with $n<c$. In practice c has been set between 50 to 100 depending on the number of samples and the range of classes in the length distribution. This procedure is most commonly used when the strata are defined from the trawl data. Here intra-strata variability is regarded as sampling error. Inter-strata variability is used to describe systematic variation in length/age distribution over the whole survey area.

Case 3 is used where the within strata length and abundance data are heterogeneous. The weighting factors a_j are defined as the mean echointegrator values in the vicinity of the hauls. The section of track used in averaging is selected subjectively and extends to the limits of similar fish traces. In this case the age composition is regarded as having a spatial variability similar to the abundance and the hauls reflect accurately the local length/age composition. This method is used mostly where the strata are predefined.

4.4 Testing the precision of age class proportions.

The impact of the use of trawl haul data on the precision of the age disaggregation process has been examined using a Jackknife technique (Efron and Tibrishani 1992). Each haul is removed in turn and the abundance age and length data analysed to obtain a new estimate of abundance at age. This includes a re-evaluation of age proportion, target strength and strata boundaries. The impact of trawl information on the assignment of echointegrals to species is not included within the analysis. The series of estimates are used to estimate the precision of the abundance estimation of each age class. An example is given from Scotia 1993 survey, Table 2 shows the abundance estimates by age class when each trawl haul is removed sequentially. The coefficient of variation (CV) shown at the base of the table (presented as a percentage) is calculated from the Jackknife estimate of standard error and the mean abundance. The abundance estimates at age 1 and age 2 are more variable and are particularly sensitive to one haul each, 295 and 330 respectively. Ages 3 and above are estimated with good precision. The overall abundance is not significantly affected by the variability in the trawl data.

5 COORDINATING METHODS IN DIFFERENT AREAS

5.1 Coordination of acoustic surveys in Division IIIa and the Western Baltic

The Herring Assessment Working Group has raised the question of synchronisation of the hydroacoustic coverage in Division IIIa and the western Baltic.

Presently, the Division IIIa is covered in July as a part of the international acoustic survey for herring in the North Sea, while the western Baltic Sea is covered during the international hydroacoustic survey for herring and sprat in the Baltic Proper (Sub-divisions 24-29) in October.

The reason for choosing July for the coverage of IIIa was to avoid the problems with the double counting of the "Rügen Herring", which is migrating rapidly through the Skagerrak and Kattegat during the month of August. In July, the migration from the North Sea is just at the beginning and the "Rügen herring" will be found just at the border between the North Sea and the Skagerrak.

The survey in the Baltic proper is performed in October because this has been shown as the best time to cover both the herring and the sprat stocks, since the major part of the stocks can be found in the open sea.

The coverage of IIIa and the western Baltic is thus connected to the coverage of two different larger areas.

If one should change the timing of the cruises, it would be appropriate to do it so that one of the international coordinated surveys is undisturbed.

A change in time for the coverage of the western Baltic Sea from October to July is not recommended, since the 0- and 1-group of herring and sprat at this time of the year are found in very shallow waters, where they cannot be covered, neither by echo sounding nor trawling. Furthermore, it is uncertain whether the adult "Rügen herring" at this time really is appearing in Division IIIa or if some part still stays in the Divisions IVa/IVb.

Performing the IIIa survey in October could be a better solution, since all the "Rügen herring" will be inside IIIa and the western Baltic.

Unfortunately, there is a likelihood for serious underestimation of the adult 2+ herring, since the major part of the adults is concentrated in Öresund in October. Special investigations made in connection with the planned fixed link between Sealand and Sweden have shown that the large herring are located in very dense layers along the steep slopes in the Sound, where it cannot be covered by big vessels like Argos and Solea.

The conclusion is that there is no gain in aligning the timing of the surveys in the North Sea and the Baltic.

5.2 Exchange and storage of data

The exchange of data after the acoustic survey has been restricted to processed data on final results and estimates from the respective areas covered by each country. The results have, in recent years, been sent to Aberdeen where they are combined and a total estimate of herring divided in autumn and spring spawners by ICES Divisions is obtained.

It is required that each country provide estimates in terms of number and biomass per age group per rectangle (1/2 degree latitude by 1 degree longitude) in the area covered. It is

also required that the estimate is divided in mature and immature parts per agegroup. This is to facilitate the estimation of the spawning stock of autumn spawners. One further requirement is to divide the number in the respective areas in spring- and autumnspawners.

So far, there has been no common guidelines for storing data collected from these surveys. Some members of the group expressed their wish of having a common database which could contain necessary data for future research and provide researchers for data in a convenient way. However, to establish a database that works properly for the users require thorough planning, and the group agreed that for now we should store the data on a local basis. However, some kind of standardization can be done, e.g. by storing the estimated number of fish by agegroup by rectangle, and the group agreed that this be done from now on.

The coordinator of the surveys is responsible for storing the annual estimates by ICES rectangle, and the participating Laboratories are asked to store all original trawl data and acoustic data on their own. Thereby it will be possible to make a common data base in the future. The resolution of the original acoustic data should at least be at the Elementary Distance Sampling Unit used for the survey (in the order of 1 to 5 nautical miles).

6 EVALUATIONS OF EARLIER SURVEYS

6.1 Causes of variability in acoustic stock estimate for ICES area VIa(N)

Two acoustic surveys were carried out in area VIa(N) in July 1992 and 1993. The stock estimates for the two years were 428,600 and 893,600 tonnes respectively. It does not appear likely that the stock had actually increased by this amount. There was no evidence from the age structures in the two years of strong recruitment or substantial immigration. The survey procedures including integral allocation to species and calibration procedures were examined intensively, and no errors were identified. Although the survey area had expanded slightly this could only account for a maximum of 10% of the stock.

A frequency histogram analysis was carried out comparing the distributions of both the 15 minute echo integrals assigned to herring and the tonnages by rectangle for 1992 and 1993 in VIa(N) and in IVa for comparison. The frequency distributions for tonnage by rectangle are very similar for both areas in both years. All are highly skewed with large numbers of low observations. However, there are marked differences between the areas in the frequency distributions for 15 minute echo integrals (Figure 5). Again the distributions are highly skewed, but substantially more so in VIa(N) compared to IVa. In VIa(N) more than 70% of the observations are zero, in IVa less than 60 % are zero. The proportion of very large values was twice as great in both years in VIa(N) than in IVa. It is concluded therefore, that the stock in VIa(N) shows a more contagious distribution than IVa, with herring found in fewer but larger concentrations. This will, inevitably, lead to an increase in the sampling variability, and could explain the discrepancy in the two stock estimates. The bulk of the fish have been concentrated in two areas of VIa(N) in both years; south of the Hebrides around 56.30N and along the shelf break NW of the Hebrides. It is therefore suggested that greater effort be allocated to these areas, and that, if this pattern persists, a

different survey strategy could be adopted which concentrates on these known areas of aggregation.

6.2 Fish migration relative to the direction of survey progress

The migration of herring schools during the 1991 acoustic survey, has been studied by use of sonar (Hafsteinsson 1994). There seemed to be a quite consistent trend of southerly migration throughout the area investigated (Division IVa, east of 1 degree west). A similar pattern was observed along the western edge of the Norwegian Deeps just after the herring survey in 1992. The migration pattern reported is likely to bias the survey estimate. The magnitude of such a bias is highly dependent on the direction of survey progress relative to the swimming direction of the schools (MacLennan and Simmonds 1991). In case of a steady southerly migration the bias would be minimized by working the transects north-south. Most surveys so far have applied east-west transects because the density (and depth) gradients tend to be largest in that direction. A change in survey directions has implications for the sharing of areas, which cannot be altered radically for the 1994 surveys. It would be useful to analyze data on school migration from more years to examine the consistency between years.

7 PLANS FOR THE 1994 AND 1995 SURVEY

1994

Participating vessels, areas and scheduled periods are shown in Figure 6. "Walter Herwig III" and "Dana" make a nearly parallel coverage in Skagerrak as this is the first year "Walter Herwig III" participates. The coverage by "Tridens" is somewhat earlier than the recommended period, and the period is too short to make a reasonable coverage of the whole area indicated. Therefore "Scotia" and "G.O. Sars" will work some supplementary transects in the northern part of that area. This year Division VIa south will also be covered during July.

1995

The current coverage of the North Sea by the Herring Acoustic Survey does not include the central and eastern parts of Division IV b. The Planning Group wants to include these areas in the survey to ensure a full coverage of the herring stock, including the 1-ringers.

The question of including sprat in the herring acoustic survey was raised by the group. Data presented to the Herring Assessment Working Group have shown an increasing trend in the IBTS sprat indices for age groups 1-3 and the total since 1990 (Anon. 1994). An increase in total landings are also indicated. The current acoustic coverage of the North Sea does not include the southern and eastern parts of Division IV b which are the main distribution areas of 1- and 2-group sprat besides the traditional sprat areas along the east coast of England and Scotland.

The IBTS-index is considered to be an imprecise estimate for the sprat stock. Therefore, an additional acoustic estimate would be desirable for the stock assessment. This implies

a coverage of the central and eastern areas of Division IVb. This would require additional survey effort which can not be provided by the present participants. The current survey in the western central North Sea will be extended to include Moray Firth and Firth of Forth.

8 RECOMMENDATIONS

The Planning Group recommends that:

- a) additional effort should be allocated to cover the Eastern Central North Sea off the German and Danish coast and the Moray Firth and the Firth of Forth in order to obtain an estimate of 1-ringed herring.
- b) with this enlarged coverage the surveys should provide an acoustic estimate of the North Sea sprat stock.
- c) all participants use the standard length/ target strength relationships given in Appendix.
- d) Laboratories participating in the surveys in Divisions IIIa, IV and VIa are asked to provide the data required for making a combined estimate of numbers of fish by age by ICES-rectangle. For partly recruited age groups separate estimates should be provided for the mature and immature component. The coordinator for the surveys is responsible for having this data set properly stored each year.
- e) the surveys in Divisions IIIa, IV and VIa are performed within the period 1-20 July, plus or minus one week.
- f) neither of the surveys should be moved to synchronize the coverage in the Baltic with those in other areas.
- g) more studies are made on the migration pattern of herring relative to the direction of survey progress.

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Table 1. Groupings of hauls against KS test value for Scotia 1993 Survey of Orkney Shetland Area. Note the stability of the chosen groups between KS threshold values 0.2-0.3 inclusive.

Pass	1	2	3	4	5	6	7	Groups Chosen
Threshold	0.1	0.15	0.2	0.25	0.3	0.4	0.5	
AREA I	295	295	295	295	295	295	295	295
AREA II			329 331	327 329 331	298 327 329 331	291 292 293	291 292 293	298 327 329 331
AREA III	294 309	294 309	291 294 299 300 306 307 309 310 311 312 313 315 316 318 319 320 324 325 326 310 311 313 319 320 330	291 292 293 294 298 299 300 306 304 307 309 310 311 312 313 315 316 318 319 320 324 325 326 325 326 330 332	291 292 293 294 298 299 300 306 304 307 308 309 310 311 312 313 315 316 318 319 320 324 325 326 330 332	291 292 293 294 298 299 300 306 304 307 308 309 310 311 312 313 315 316 318 319 320 324 325 326 330 332	291 292 293 294 298 299 300 306 304 307 308 309 310 311 312 313 315 316 318 319 320 324 325 326 330 332	291 292 293 294 298 299 300 306 298 299 300 306 304 307 308 309 310 311 312 313 315 316 318 319 320 324 325 326 330 332

Table 2. Results of Jackknife analysis of age class estimation from Scotia 1993

Trawl no	1A	2I	2M	2A	3I	3M	3A	4A	5A	6A	7A	8A	9+	TOTAL
291	491	209	560	769	151	464	614	347	403	683	437	140	109	3993
292	487	206	558	763	150	458	608	352	412	684	433	140	109	3987
293	491	212	581	793	156	462	618	343	397	678	431	140	110	4000
294	491	213	578	791	158	475	633	353	402	667	423	138	109	4007
295	68	286	696	982	191	496	687	374	402	674	425	135	106	3852
297	566	184	541	725	156	470	626	360	404	677	426	136	106	4027
298	491	214	587	801	159	485	643	351	395	671	421	132	107	4012
299	491	212	579	791	160	484	644	351	393	670	422	141	108	4012
300	494	225	587	811	158	449	607	355	406	674	424	132	107	4011
301	464	183	586	769	173	483	656	368	403	673	424	135	106	3998
304	491	208	527	735	153	455	607	365	412	689	436	140	109	3985
306	491	213	533	746	153	455	608	353	409	697	437	141	110	3991
307	491	213	581	795	154	479	633	355	405	669	416	139	110	4012
309	491	211	573	784	155	475	630	358	393	673	431	137	109	4006
310	491	213	587	800	159	484	643	364	399	675	423	127	100	4022
311	491	214	587	801	159	485	644	360	400	670	421	129	103	4020
312	491	212	575	787	154	455	609	367	405	677	428	138	103	4004
313	491	214	587	800	160	482	642	363	391	674	419	136	104	4019
315	491	214	588	802	160	491	651	365	408	670	410	130	97	4024
316	491	214	589	803	160	493	653	364	406	668	415	130	98	4028
318	491	214	589	802	159	492	652	365	401	666	414	130	103	4024
319	491	214	589	802	160	494	653	370	401	658	414	131	100	4021
320	491	214	587	801	159	482	640	372	392	664	423	134	104	4020
322	491	214	590	804	147	463	610	367	398	685	418	133	101	4007
324	491	211	563	773	148	458	605	367	408	683	429	137	103	3997
325	491	209	558	767	153	452	605	363	401	685	434	138	109	3994
326	491	214	581	794	156	473	629	370	402	659	421	137	108	4012
328	505	226	579	805	120	484	604	349	402	674	424	135	106	4003
329	502	207	577	784	156	466	622	364	402	674	424	135	106	4014
330	529	362	772	1135	210	472	682	346	362	575	374	117	90	4210
331	491	226	548	774	165	465	630	361	405	678	426	136	106	4008
332	498	241	594	835	171	485	655	370	399	643	405	134	107	4046
All	491	212	574	786	156	474	630	361	402	673	424	135	106	4008
Aver	481	219	585	804	159	474	633	360	401	671	422	135	105	4011
CV(%)	15.52	13.66	7.29	8.81	8.56	2.85	3.40	2.23	2.15	2.90	2.67	3.54	4.17	1.15

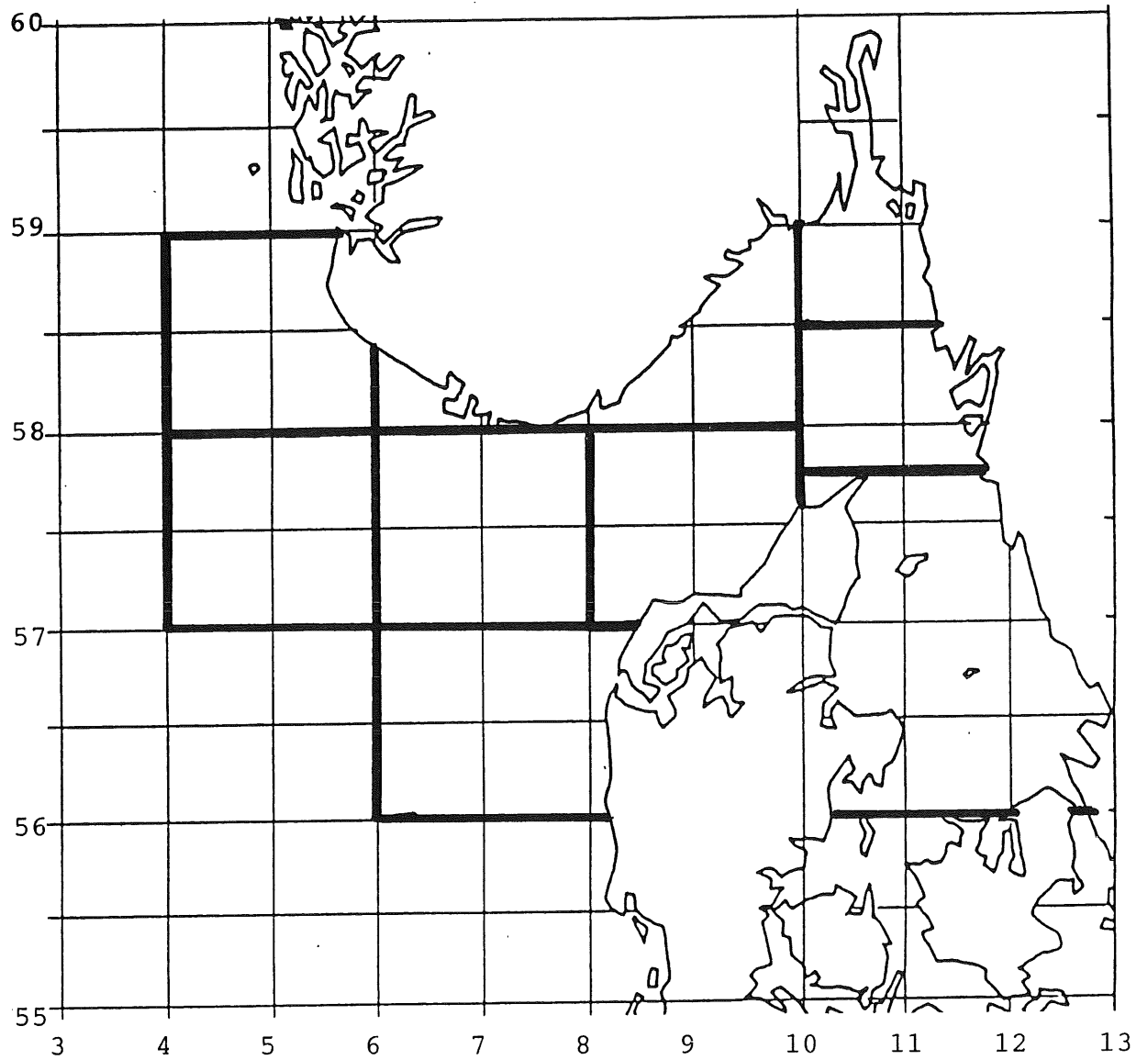


Figure 1. Geographical areas used as strata. Within each area the following depth strata are used: 0-20 m, 20-40 m, 40-60 m, 60-100 m, 100-200 m, 200-300 m and >300 m.

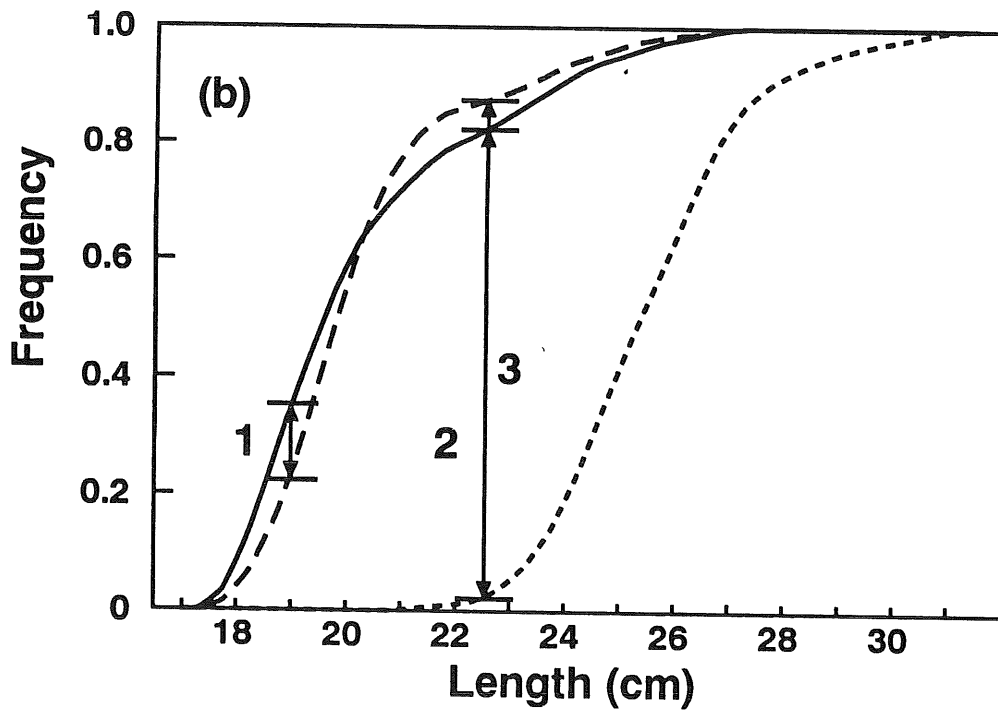
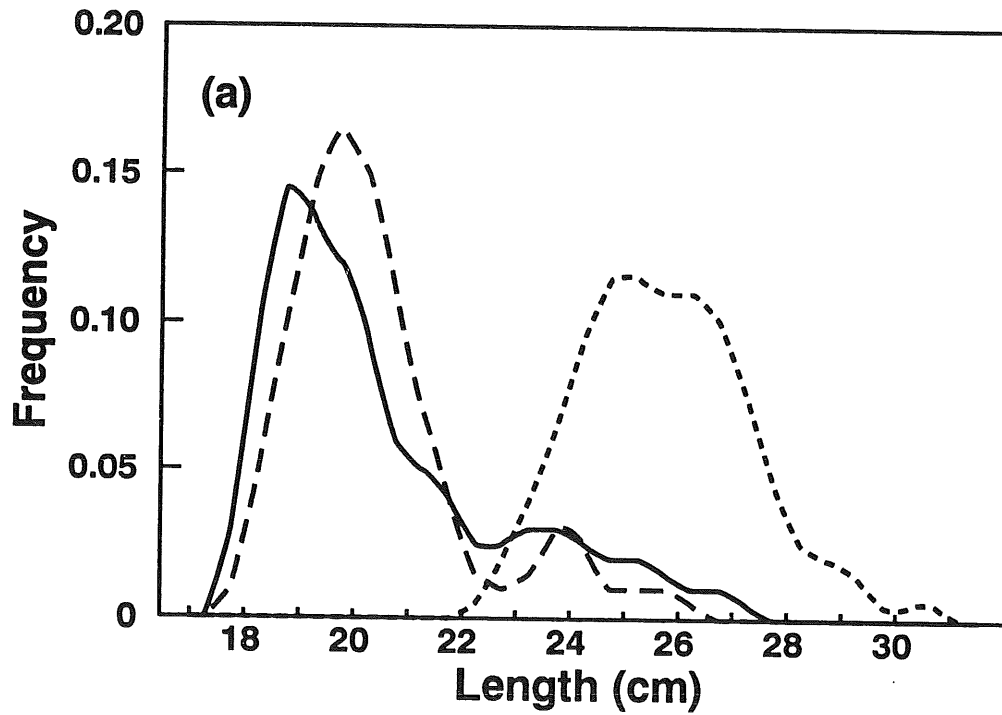


Figure 2. Length frequency distribution (a) and cumulative distribution (b) of herring at three different trawl stations. —:station 1, - - -:station 2, - - - -:station 3. The maximum differences are indicated on the cumulative graphs.

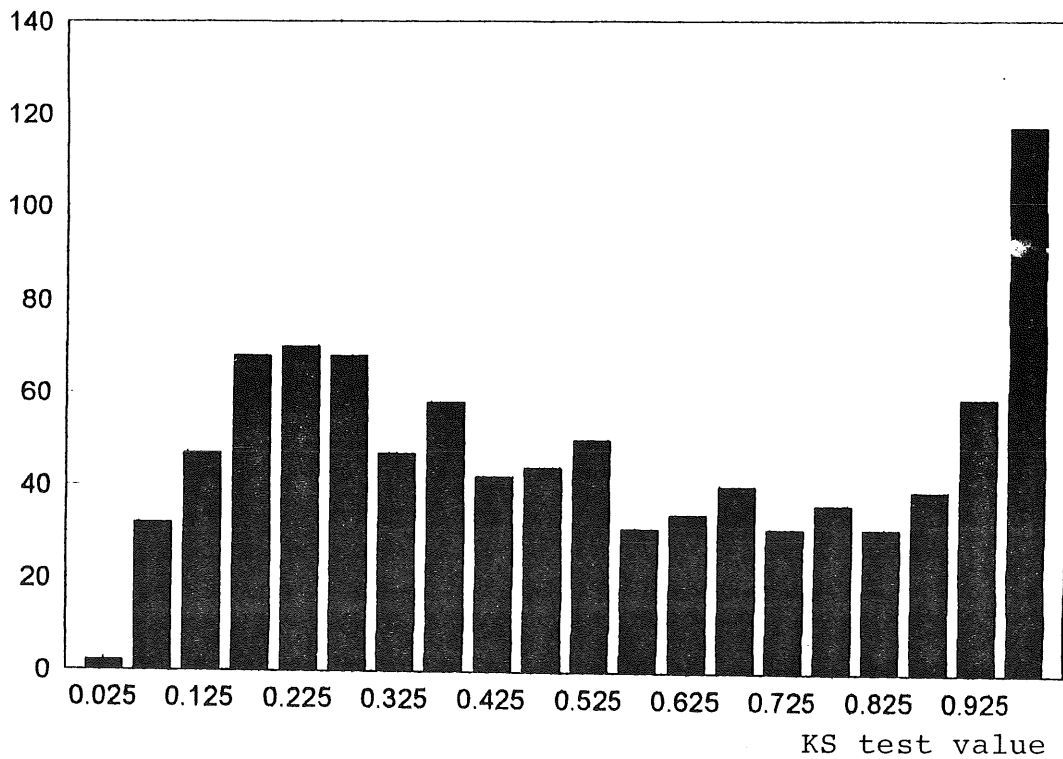
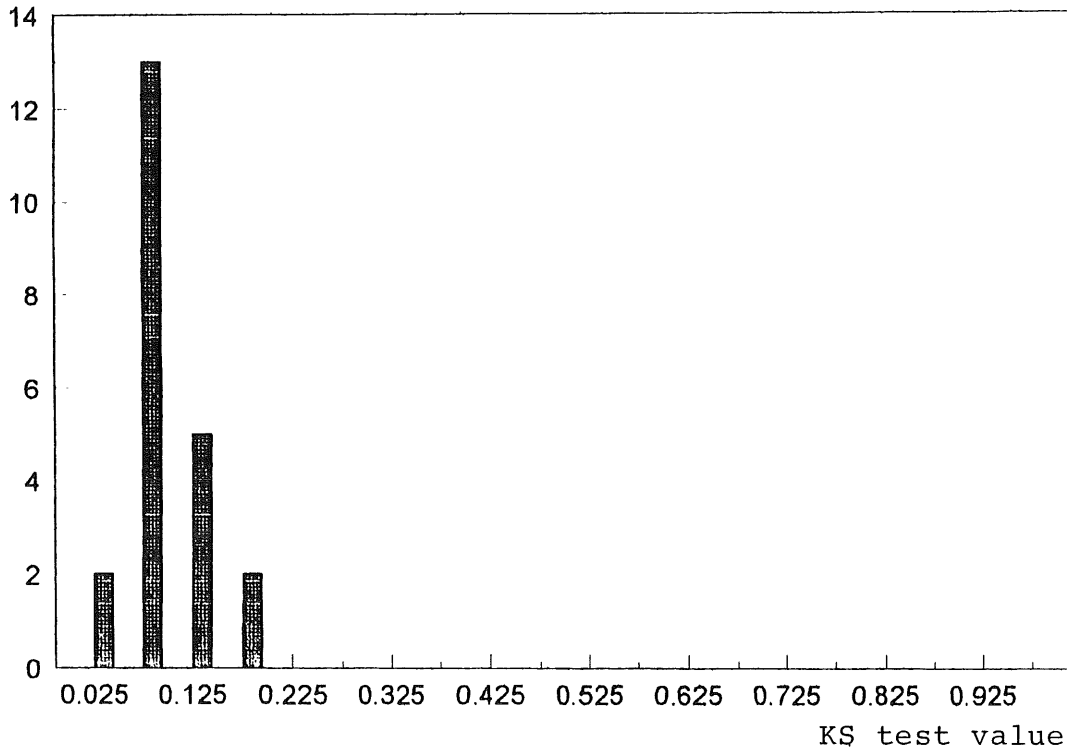


Figure 3. Distribution of KS test values. Upper histogram represents multiple samples of the same catch. Lower histogram represents samples from 22 different catches.

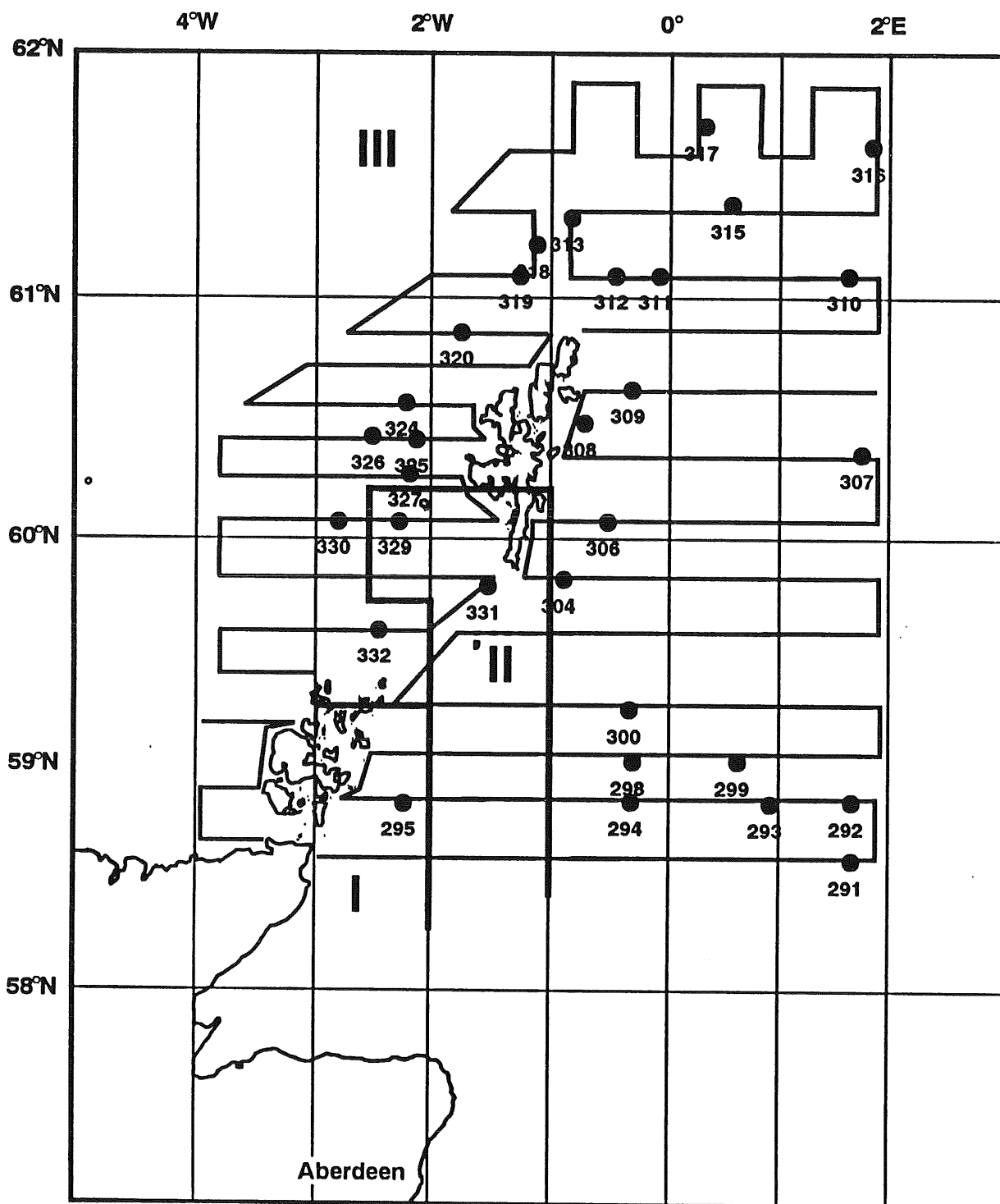


Figure 4. Geographical distribution of the trawl stations listed in Tables 1 and 2 (Scotia July 1993). The borders between areas I, II and III are determined from Table 1.

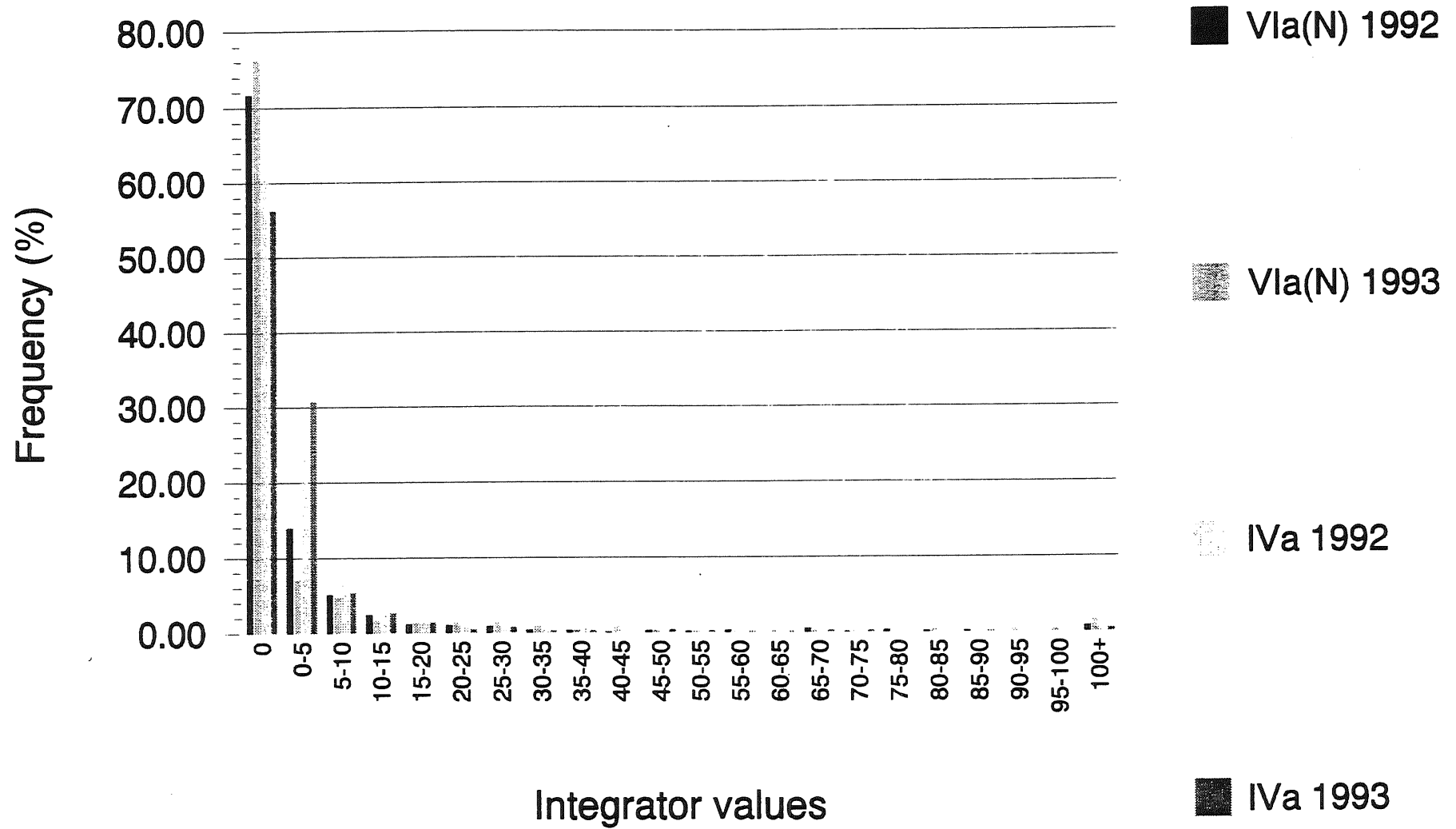


Figure 5. Frequency histogram of herring integrator values for acoustic surveys of areas IVa and VIa(N) in 1992 and 1993.

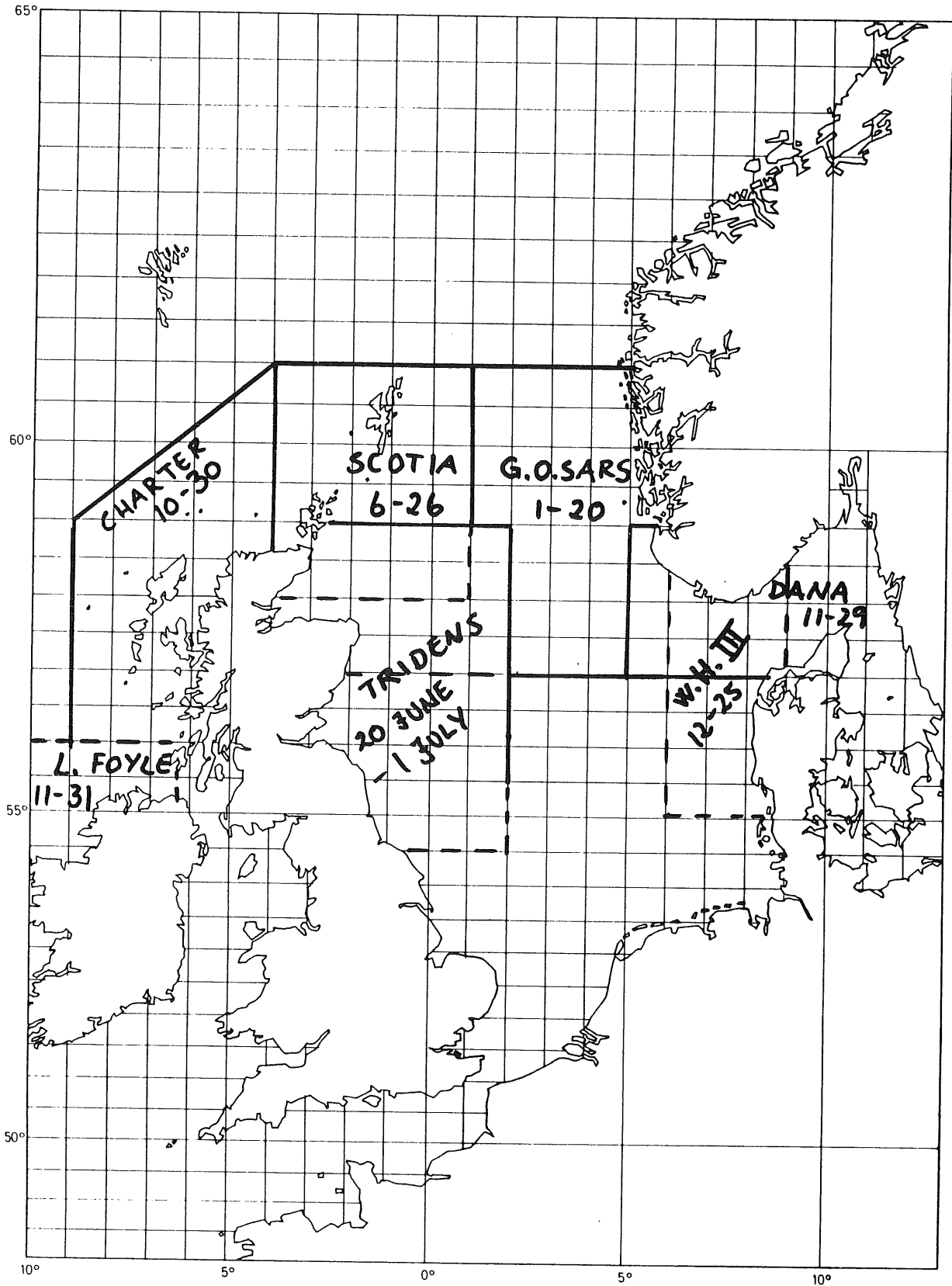


Figure 6. Participating vessels, areas and dates scheduled for the 1994 summer acoustic herring surveys. (Where the month is not mentioned, the dates are within July)

APPENDIX

MANUAL FOR HERRING ACOUSTIC SURVEYS IN ICES DIVISIONS III, IV AND VI

1. Transducer and calibration

The standard frequency used for the survey is 38 kHz. Both hull mounted transducers and towed body transducers are used in the surveys.

A calibration of the transducer is conducted at least once during the survey. If possible, the transducer is calibrated both at the beginning and the end of the survey, and the mean value is applied to the data obtained during the survey. If a new calibration differs by more than 0.4 dB, the system should be thoroughly inspected. Calibration procedures are described in Foote *et al.* (1987) and in the EK 500 manual.

Minimum target range for calibration is 10 meters. With hull mounted transducers, centering of the target below the transducer is facilitated if the target is suspended at a greater depth (about 20 meters) below the transducer.

2. Instrument settings during the survey (for SIMRAD EK-500)

For most settings the default values from the manufacturer may be used, or alternatively the operator can choose his own settings depending on the circumstances. It is recommended that each year the same settings are used for the printer in order to facilitate comparison of echogrammes.

Critical settings that affect the calibration should not be changed during the survey. These are the following settings:

Tranceiver menu:

- absorption coeff
- max power
- 2-way beam angle
- Sv transducer gain
- Ts transducer gain

The following settings may affect the integration values obtained, irrespective of the calibration of the transducer:

Bottom detection menu:

The minimum detection level depends on water depth and bottom type. At depths < 100 meter and hard bottoms, the threshold level may be set at -30dB. This will enable the instrument to detect dense schools close to the bottom. At depths > 100 meter or soft bottoms, the threshold has to be lowered, otherwise the upper layer

of the bottom will be counted as fish as well.

Layer menu:

A bottom margin of the order of 0.5 m is recommended. In shallow areas (<100 m) it can be somewhat reduced.

The Sv-minimum for echo integration and presentation of echogramme is set at -70dB. Increasing the Sv-minimum will reduce the integration values if the herring occur in scattering layers or in loose aggregations.

3. Survey design

Transects are spaced at a maximum distance of 15 nautical miles.

Two aspects are considered in choosing the direction of the transects. The transects should preferably run perpendicular to the greatest gradients in fish density, which is often related to the gradients in bottom topography and hydrography. This means that the transects will normally run perpendicular to the coast. The second aspect considers the direction in which the fish are migrating. If there is evidence of rapid displacement of the fish throughout the survey area, it is advisable to run the transects parallel to the direction of the migration. This survey design will minimize the bias caused by migration.

Ship's speed during the survey is typically between 10-12 knots. At higher speeds, problems are encountered with engine noise or propeller cavitation. These problems, however, depend on the vessel. In rough weather, the ship's speed may be reduced in order to avoid problems with air bubbles under the ship.

If species identification depends on recognition of schools on the echogramme, the survey will have to be interrupted during periods of the day when the schools disperse. This occurs during the hours of darkness, depending on the area. When schools disperse during darkness, some of the herring may rise to the surface and get above the transducer. It is recommended - if time permits during the survey - to study the diurnal behaviour of the fish schools, in order to determine at what time of the day the fish may not be visible on the echo sounder.

4. Species allocation of acoustic records

Different methods of species allocation are being used in the various areas. The method used depends largely upon the schooling behaviour of the herring and the mixing with other species. In the North Sea and Division VIa the species allocation is based mainly on the identification of individual schools on the echogramme. In Skagerrak-Kattegat and Baltic the identification is based on composition of trawl catches. Both methods are described in more detail below.

In the North Sea and Division VIa most of the herring occur in well-defined schools, often of a characteristic shape. Integration values referring to these schools can be read directly from the increment of the integrator line on the echogramme.

Sometimes herring occur mixed with other species in aggregations of smaller schools. In this case, species allocation is based on the composition of trawl catches.

In Skagerrak, Kattegat and Baltic, herring normally cannot be distinguished from other species by visual inspection of the echogramme. Both herring and sprat tend to be distributed in scattering layers or in pelagic layers of small schools, and it is not possible to ascribe integrator values to typical herring schools.

Species allocation is then based entirely upon trawl catch composition. Trawl catches within each stratum are combined to give an average species and length composition of the catch. Each trawl catch is given equal weight, unless it is decided that a catch is not representative for the fish concentration sampled. In this case, the catch is not used. The mean back-scattering cross section of one fish in the average trawl catch is calculated using the appropriate length-TS relationship for each species. S_A -values attributable to fish are extracted from the echogramme by deducting plankton, bottom, and noise contributions from the total S_A values. Mean densities of fish are found by dividing S_A -values by the mean back-scattering cross section of one fish. These estimates of total fish density are then allocated to species and length groups according to the average trawl catch composition in that stratum.

5. Data analysis

This section describes the calculation of numbers and biomass by species from the echo-integrator data, and trawl data. Most of this section is taken from Simmonds et al 1992.

The symbols used in this section are defined in the text but for completeness they have been collated and are given below:-

F_i	estimated area density of species i
K	equipment physical calibration factor
$\langle\sigma_i\rangle$	mean acoustic cross-section of species i
E_i	partitioned echo-integral for species i
E_m	echo-integral of a species mixture
c_i	echo-integrator conversion factor for species i
TS	target strength
TS_n	target strength of one fish
TS_w	target strength of unit weight of fish
a_i, b_i	constants in the target strength to fish length formula
a_n, b_n	constants in formula relating TS_n to fish length
a_w, b_w	constants in formula relating TS_w to fish length
a_f, b_f	constants in the fish weight-length formula
L	fish length
W	weight
L_j	fish length at midpoint of size class j
f_{ij}	relative length frequency for size class j of species i
w_i	proportion of species i in trawl catches
A_k	area of the elementary statistical sampling rectangle k
Q	total biomass

Q_i total biomass for species i

The objective is to estimate the density of targets from the observed echo-integrals. This may be done using the following equation from Foote et al 1987:-

$$F_i = (K / \langle \sigma_i \rangle) E_i \quad (4)$$

The subscript i refers to one species or category of target. K is a calibration factor, $\langle \sigma_i \rangle$ is the mean acoustic cross-section of species i , E_i is the mean echo-integral after partitioning and F_i is the estimated area density of species i . The quantity is the number or weight of species i , depending on whether σ_i is the mean cross-section per fish or per unit weight. $c_i = (K / \langle \sigma_i \rangle)$ is the echo-integrator conversion factor, which may be different for each species. Furthermore, c_i depends upon the size-distribution of the insonified targets, and if this differs over the whole surveyed area, the calculated conversion factors must take the regional variation into account.

K is determined from the physical calibration of the equipment, which is described in detail in Foote (1987) for an EK500 the sounder may be set so K becomes a constant (see EK500 manual). K does not depend upon the species or biological parameters. Several calibrations may be performed during a survey. The measured values of K or the settings of the EK500 may be different but they should be within 10% of one another. If two successive measurements are very different the cause should be investigated since the equipment may be malfunctioning. Otherwise, K should be taken as the average of the two measurements before and after the relevant part of the survey.

Conversion factors for a single species

The mean cross-section $\langle \sigma \rangle$ should be derived from a function which describes the length-dependence of the target-strength, normally expressed in the form:-

$$TS = a_i + b_i \text{Log}_{10}(L) \quad (5)$$

where a_i and b_i are constants for the i 'th species, which by agreement with the other participants in the survey are given in Table 4.1.

The equivalent formula for the cross-section is:-

$$\sigma_i = 4\pi 10^{((a_i + b_i \text{Log}(L))/10)} \quad (6)$$

The mean cross-section is calculated as the σ average over the size-distribution of the insonified fish. Thus:-

L_j is the mid-point of the j 'th size-class and f_{ij} is the corresponding frequency as deduced from the fishing samples by the method described earlier. The echo-integrator conversion factor is $c_i = K / \langle \sigma_i \rangle$. The calculation may be repeated for any species with a target-

$$\langle \sigma_i \rangle = 4\pi \sum_j f_{ij} 10^{((a_i + b_i \text{Log}(L_j))/10)} \quad (7)$$

strength function.

Table 4.1 The Recommended Target Strength Relationships for herring surveys in the North Sea and adjacent waters.

Species	Target Strength Equation Coefficients	
	b_i	a_i
herring	20	-71.2
sprat	20	-71.2
gadoids	20	-67.5
mackerel	20	-84.9
horse mackerel	20	-71.2

Note that it is the cross-section that is averaged, not the target-strength. The arithmetic average of the target-strengths gives a geometric mean, which is incorrect. The term "mean target-strength" may be encountered in the literature, but this is normally the target-strength equivalent to $\langle \sigma_i \rangle$, calculated as $10 \log_{10}(\langle \sigma_i \rangle / 4\pi)$. Some authors refer to TS as $10 \log(\sigma_{bs})$ the definition of σ is different from σ_{bs} and should not be confused.

Conversion factors for mixed species layers or categories

Sometimes several species are found in mixed concentrations such that the marks on the echogram due to each species cannot be distinguished. From inspection of the echogram, the echo-integrals can be partitioned to provide data for the mixture as one category, but not for the individual species. However, further partitioning to species level is possible by reference to the composition of the trawl catches (Nakken and Dommasnes, 1975). Suppose E_m is the echo-integral of the mixture, and w_i is the proportion of the i 'th species, calculated from fishing data. It is necessary to know the target-strength or the acoustic cross-section, which may be determined in the same manner as single species above. The fish density contributed by each species is proportional to w_i . Thus the partitioned fish densities are:-

$$F_i = \frac{w_i K}{\sum_i w_i \langle \sigma_i \rangle} E_m \quad (8)$$

The w_i may be expressed as the proportional number or weight of each species, according to the units used for $\langle \sigma_i \rangle$ and c_i . Consistent units must be used throughout the analysis, but the principles are the same whether it is the number of individuals or the total weight that is to be estimated.

Using Weight-length relationships

The abundance is expressed either as the total weight or the number of fish in the stock. When considering the structure of the stock, it is convenient to work with the numbers at each age. However, an assessment of the commercial fishing opportunities would normally be expressed as the weight of stock yield. Consistent units must be used throughout the analysis. Thus if the abundance is required as a weight while the target-strength function is given for individual fish, the latter must be converted to compatible units. This may be done by reference to the weight-length relationship for the species in question.

For a fish of length L , the weight W is variable but the mean relationship is given by an equation of the form:-

$$W = a_f L^{b_f} \quad (9)$$

Where a_f and b_f are taken as constants for one species. However, a_f and b_f could be considered as variables varying differently with stock and time of year as well as species. Suppose the target-strength of one fish is given as:-

$$TS_n = a_n + b_n \log_{10}(L) \quad (10)$$

The corresponding function TS_w , the target-strength of unit weight of fish has the same form with different constants:-

$$TS_w = a_w + b_w \log_{10}(L) \quad (11)$$

The number of individuals in a unit weight of fish is $(1/W)$, so the constant coefficients are related by the formulae:-

$$b_w = b_n - 10b_f \quad (12)$$

$$a_w = a_n - 10 \log_{10}(a_f) \quad (13)$$

Abundance Estimation

So far the analysis has produced an estimate of the mean density of the insonified fish, for each part of the area surveyed, and for each species considered. The next step is to determine the total abundance in the surveyed area. The abundance is calculated independently for each species or category of target for which data have been obtained by partitioning the echo-integrals. The calculations are the same for each category:-

$$Q_i = \sum_{k=1}^n A_k F_i \quad (14)$$

The total biomass for all species is:-

$$Q = \sum_i Q_i \quad (15)$$

The F_i are the mean densities (section 4.3) and A_k are the elements of area that have been selected for spatial averaging in section 4.2. These may be calculated from the shape of an area or measured, depending upon the complexity of the area. The presence of land should be taken into account, possibly by measuring the proportions of land and sea.

6. Data exchange

For coordinated surveys a joint report is produced that contains charts with the following results:

- number of 1-ringed herring per rectangle
- number of 2-ringed herring per rectangle
- number of 3+ringed herring per rectangle
- total number and total biomass of herring per rectangle (excluding 0-ringers)

In order for the coordinator to prepare this report, the following data should be supplied by each participant:

- a chart giving the total number of herring per rectangle (excluding 0-ringers)

- a chart showing the stratification for age keys and mean weights per age
- for each stratum an age/length key and the mean weight by age group. The age groups (in winter rings) to be used are:

1,2 immature (maturity stage 1 or 2), 2 mature (maturity stage 3+), 3 immature, 3 mature, 4, 5, 6, 7, 8, 9+.

7. References

Foote, K.G., Knudsen, H.P., Vestnes, G., MacLennan, D.N. and Simmonds, E.J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. Int. Coun. Explor. Sea Coop. Res. Rep. 144, 57pp.

Nakken, O. and Dommasnes, A. 1975. The application of an echo integration system in investigations of the stock strength of the Barents Sea capelin 1971-1974. Int. Coun. Explor. Sea CM 1975/B:25, 20pp (mimeo).

Simmonds, E. J., Williamson, N. J., Gerolotto, F. and Aglen, A. 1992 Acoustic Survey Design and Analysis Procedures: A Comprehensive Review of Current Practice. ICES Coop. Res. Rep. 187: 130pp.

