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THE SCOTTISH HERRING SAMPLING PROGRAMME AND ITS RELIABILITY

by

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Summary

1. Scottish sampling of herring from the Shetland area is based on daily samples of 50 fish from the catches of each gear type during the fish season.

2. Over the three years 1971-73 this has resulted in 400-950 fish sampled per 1000 tons landed by the drift-net fishery and 80-200 fish per 1000 tons landed by the purse-seine fishery.

3. Analysis of purse-seine samples suggests the variance on estimates of the age composition within a month and statistical square is rather high. There would appear to be little evidence of significant differences in age composition between statistical squares over the area fished by the Scottish fleet.

4. The number of samples required to give relative errors in age composition have been roughly estimated. This suggests that the current Scottish sampling system is likely to give errors of around the 10% level.

Introduction

At the 61st Statutory Meeting of the Council a resolution was passed asking for a report on the results of a statistical evaluation of the adequacy of the number and size of samples taken from individual fisheries. This paper is an attempt to provide such a report for the Scottish North Sea herring fishery. Some information is also provided on the sampling systems in force for other Scottish herring fisheries, but an evaluation of their adequacy will be reported at a subsequent meeting.

The Scottish sampling system

Before 1951 sampling of the herring stocks landed at Scottish ports was carried out by buying herring from the ports at irregular intervals, depending on the state of the fishing. The quantity purchased was normally a box (or basket) amounting to 250-350 herring. From these herring, data were collected for length, maturity, age, and meristic characters.

In 1951 a new method of sampling was introduced for the Scottish summer fishery in the North Sea. A random sample of 50 fish was collected each day from any one of the boats landing at each of the major herring ports (at that time Lerwick, Fraserburgh and Peterhead) and sent to the laboratory for examination. From these herring, length, maturity and age data were collected, and from as many as possible, meristic data also. Sampling of the stocks on the west coast of Scotland and from other ports on the east coast was still carried out by purchasing boxes of herring as desired from the ports. The system of sampling by random samples of 50 fish was later extended to Aberdeen on the east coast and later still to Stornoway and Mallaig on the west coast of Scotland.

When the Buchan fishery failed there were no regular landings of herring at Fraserburgh Peterhead and Aberdeen, and the collection of daily samples of herring was discontinued at these ports.

The methods used in recent years for sampling the major Scottish fisheries are described below.

a) Shetland fishery

Random samples of 50 herring are collected daily from the landings by each method of fishing at Lerwick, supplemented as required by the purchase of boxes of herring landed at other ports from the Shetland grounds.

b) Minch winter fishery

Random samples of 50 herring are collected daily at Mallaig and Stornoway from the landings of each fishing gear supplemented by occasional samples from Ullapool.

c) Minch summer fishery

Random samples of 50 herring collected daily at Mallaig (the only port with regular landings) supplemented by occasional samples from Stornoway and Ullapool).

d) Clyde fishery

A box of herring is purchased every week from Ayr. The sampling of spasmodic landings at other ports has been carried out by purchasing boxes of herring at the port of landing.

The samples of herring are examined for length, weight, sex, maturity, V.S. and K_2: otoliths are taken for age and type and scales for growth calculations. When it is not possible to sample for all of these characters meristic characters and scales are omitted.

In 1974 this sampling system has been extended by taking regular length measurements of catches landed at the major ports. Age-length keys are compiled from the random samples delivered to the laboratory under the system described above and from samples bought specifically to fill gaps in the age-length keys.

The Distribution of Sampling between Gears, Months and Areas

In the Scottish herring fishery in the Shetland area drift-net and purse-seine are the only fishing methods which land appreciable catches. In the text table below are given the number of fish sampled per metric ton of fish landed by these methods subdivided by month for the three peak months of the Scottish fishing season and the annual totals for these three months.

Number of fish sampled in Shetland area per tonne landed by month and gear type

YEAR	JUNE		JULY		AUGUST		ANNUAL TOTALS					
							DRIFT			PURSE		
	DRIFT NO. M.TON	PURSE NO. M.TON	DRIFT NO. M.TON	PURSE NO. M.TON	DRIFT NO. M.TON	PURSE NO. M.TON	CATCH (M.TONS)	NO. OF FISH SAMPLED	FISH SAMPLED / M.TONNE	CATCH (M.TONS)	NO. OF FISH SAMPLED	FISH SAMPLED / M.TONNE
1971	0.362	0.076	0.809	0.079	0.311	0.077	3126.4	1283	0.410	17057.3	1319	0.077
1972	1.165	0.112	0.362	0.094	0.633	0.162	3445.0	2362	0.686	10640.5	1267	0.119
1973	1.703	0.139	0.360	0.242	1.174	0.216	954.5	897	0.940	9699.8	1949	0.201

In total during these three months Scotland has in the years 1971-73 sampled 2.6 - 3.6 x 10^3 herring from the Shetland area with the number sampled per 1000 m. tonnes ranging from 129-260. The distribution of sampling between gears however has been rather less satisfactory; the rate of sampling per tonne landed has been about 5 times higher for drift-net than for purse-seine. This disparity has arisen from the sampling system not being adapted quickly enough to the changes in the relative importance of these two methods of fishing over the past five years.

The same feature of a disproportionate emphasis on sampling of drift-net catches is, of course, also evident in the monthly figures for the number of fish sampled per tonne landed. The sampling between months within gear types however is as consistent as could be expected from a system which must be rather rigidly defined in view of the distance of the landing port from the laboratory.

In view of the much greater importance of the purse-seine fishery in the Scottish landings from the Shetland area in recent years the analysis of sampling in relation to area and time of fishing has been confined to samples taken from catches by that gear. In Table 1 for each of the years 1971-73 the landings by that method of fishing are given by month for each statistical square together with the number of fish sampled in that month from that statistical square. Although there are some disparities in the number of fish sampled per weight of fish landed between statistical squares, in general the distribution of sampling over areas is reasonably well related to the weight of fish landed from the areas. The very high and very low ratios of fish sampled to fish landed are in respect of statistical squares from which the weight of fish landed was small and where the options are to sample either at a high ratio or not at all. The general impression given by Table 1 is that in respect of sub-areas the samples are reasonably randomly distributed in relation to the distribution of fishing by the Scottish fleet.

The Reliability of the Sampling as an Index of Age Composition of the Catch

It can be seen from Table 1 that there are rather few cases within a year and a month when sufficient samples have been taken from a single statistical square to give a reliable measure of within square variability with which to test the significance of between square variability in age composition. Analyses of variance have, however, been carried out using the statistical squares, within months and years, in which the data give the best distribution for measuring the within square variance. As the age composition is measured as proportions, with the entire range from 0 to 1 potentially available, some variance stabilising transformation is necessary. Following

Lassen et al (1973) an arc sine transformation (arcsin $\sqrt{p}$) has been used which makes the variance independent of the value of p. Independent analyses of variance have been done for 2 ringers and 3 ringers which together have made up over 80% of the Scottish herring catches from this area in the years under consideration. In Tables 2a and 3a the transformed mean proportions in the years, months, and squares used in the analysis of variance are given, together with the residual mean square of the transformed values obtained from the analysis of variance. These residual mean squares are fairly homogeneous for each age group so a pooled mean square has been calculated and used to determine the 95% confidence limits on each mean. The mean values and their 95% confidence limits transformed back to the original scale are given in Tables 2b and 3b. Of the 9 analyses of variance done, for each of these two age groups, the between squares difference was significant in one case for the 2 ringers and in 3 cases for the 3 ringers.

These data are not very satisfactory for answering the question as to whether there are significant differences in age composition between statistical squares within the area at Shetland fished by the Scottish fleet. To do so on an adequate statistical basis would demand setting up a sampling experiment specifically for this purpose and is probably beyond the resources of most laboratories, whilst continuing to maintain their normal sampling programme. The data given here however would tend to suggest that within the area fished by the Scottish fleet the age composition of the catch is reasonably homogeneous and that little may be gained in the accuracy of the estimated age composition by attempting to distribute the sampling over the area fished in proportion to the distribution of the catch. The other factor which should be considered is the time variation in age composition of the catches during the season fished by the Scottish fleet. In view of the fact that the evidence presented above suggests that there may be little significant difference in age composition over the area fished this has been tested by taking all samples within a month as equally valid estimates of the age composition of the total catch in that month and testing the significance of the differences in the monthly means within years on arc-sine transformed data. The results are presented in Table 4. These show that, in the three years considered there were significant differences between months in the proportion of 3 ringed fish in the Scottish catch in the Shetland area but not in 2 ringed fish. The differences would appear to have been in 1971 when the proportion of 3 year olds in June was high in comparison with the following months and in August 1972 when it was very low in relation to the proceeding and following months.

Discussion

Because of logisitic difficulties in sampling a fishery, where practically all of the landings are made at a port remote from the laboratory, the system currently used for sampling the Scottish herring catches at Shetland falls somewhat short of the ideal in that the distribution of sampling over the sub-areas is not very closely related to the size of the landings from the sub-areas. In the present state of the fishery, however, where the catch is largely composed of only two age groups, this would appear to have had little effect on the reliability of the estimate of the overall age composition of the catch. In the years 1971-73 there was little evidence of any significant differences in the age composition of the catches between statistical squares fished by the Scottish fleet. This is, perhaps, hardly surprising in view of the fact that the catch in the area, as a result of over-exploitation, has during these years been very largely composed of only two age-groups. It is also true that the variance in the estimates of the proportion of an age-group in samples taken in the same statistical square and the same month is rather large as shown in Table 2. This means that area differences would have to be large to be

statistically significant. In this situation it would appear that, although there could be some advantage in distributing sampling more proportionately in relation to catch over the area, the greatest gain in precision is likely to be achieved by increasing the overall sampling intensity. In future Scottish sampling in this area it is hoped that an improvement in both these respects can be achieved by carrying out more regular market sampling by laboratory staff at Lerwick, and by striking a better balance between samples of drift-net and purse-seine catches consigned to the laboratory.

If one accepts the evidence presented earlier that there are no significant differences between sub-areas one can calculate, from the residual variances given in Table 4, the number of samples required to estimate the proportion of an age group in the catch with any required degree of precision. This has been done independently for both 2 ringers and 3 ringers. The results suggest that to get estimates accurate with 10% one would require for both age groups about 40 samples; to increase the accuracy to 5% would require about 160 samples.

References

Lassen, H., Morek-Larsen, B., Elkarachily, A.F.I. 1973 "A method of obtaining estimates of catch composition in a mixed fishery". ICES C.M. 1973, Pelagic Fish Northern Cttee. Doc. no. H:18.

TABLE 1 CATCH BY SCOTTISH PURSE-SEINERS AND NUMBER OF FISH SAMPLED FROM SHETLAND AREA BY STATISTICAL SQUARE AND MONTH, 1971-73

Stat square	1971 Total catch (m. ton)	1971 No. of fish sampled	1971 No. of samples	1971 No. of fish sampled per m. ton	1972 Total catch (m. ton)	1972 No. of fish sampled	1972 No. of samples	1972 No. of fish sampled per m. ton	1973 Total catch (m. ton)	1973 No. of fish sampled	1973 No. of samples	1973 No. of fish sampled per m. ton
JUNE												
21B	-	-	-	-	67.6	0	0	0.0	-	-	-	-
21D	-	-	-	-	109.2	50	1	0.458	523.7	0	0	0.0
20B	647.1	0	0	0.0	56.0	0	0	0.0	55.1	0	0	0.0
20C	1069.4	174	4	0.162	31.8	0	0	0.0	380.4	178	4	0.468
20D	2998.8	149	3	0.050	1754.6	99	2	0.056	777.3	149	3	0.192
19B	758.9	0	0	0.0	-	-	-	-	1200.7	88	2	0.073
19C	69.2	99	2	1.431	-	-	-	-	55.0	0	0	0.0
19D	-	-	-	-	624.3	150	3	0.240	-	-	-	-
18A	32.4	0	0	0.0	14.2	0	0	0.0	-	-	-	-
18D	-	-	-	-	22.7	0	0	0.0	-	-	-	-
Total	5575.8	422	9	0.076	2680.4	299	6	0.112	2992.2	415	9	0.139
JULY												
21C	35.7	0	0	0.0	1.4	0	0	0.0	171.0	98	2	0.573
21D	-	-	-	-	105.4	49	1	0.465	67.3	38	1	0.565
20B	193.4	0	0	0.0	31.6	0	0	0.0	48.6	50	1	1.029
20C	248.9	0	0	0.0	273.7	94	2	0.343	1133.4	69	2	0.061
20D	5492.3	447	10	0.081	1771.1	99	2	0.056	100.4	0	0	0.0
19B	104.7	0	0	0.0	19.5	50	1	2.564	1147.0	151	4	0.132
19C	761.3	94	2	0.123	-	-	-	-	10.0	50	1	5.000
19D	-	-	-	-	1743.7	49	1	0.028	-	-	-	-
18A	-	-	-	-	166.8	0	0	0.0	145.4	38	1	0.261
18B	-	-	-	-	-	-	-	-	44.7	0	0	0.0
18C	-	-	-	-	221.7	49	1	0.221	-	-	-	-
18D	-	-	-	-	350.0	49	1	0.140	-	-	-	-
17A	-	-	-	-	-	-	-	-	417.1	300	6	0.719
Total	6836.3	541	12	0.079	4684.9	439	9	0.094	3284.9	794	18	0.242
AUGUST												
21D	-	-	-	-	17.3	0	0	0.0	330.8	123	4	0.372
20B	84.0	39	1	0.464	-	-	-	-	19.1	0	0	0.0
20C	143.3	0	0	0.0	-	-	-	-	400.1	177	4	0.442
20D	1167.1	99	2	0.085	1366.0	248	5	0.182	209.1	52	3	0.249
20E	-	-	-	-	-	-	-	-	15.0	0	0	0.0
19B	869.6	0	0	0.0	-	-	-	-	861.7	177	4	0.205
19C	1094.4	80	2	0.073	19.0	0	0	0.0	-	-	-	-
19D	107.4	89	2	0.829	209.7	0	0	0.0	524.8	81	2	0.154
18A	-	-	-	-	45.7	0	0	0.0	-	-	-	-
18B	-	-	-	-	-	-	-	-	35.8	0	0	0.0
18C	94.1	0	0	0.0	109.4	0	0	0.0	-	-	-	-
18D	1085.3	49	1	0.045	-	-	-	-	126.6	50	1	0.395
18E	-	-	-	-	-	-	-	-	112.0	0	0	0.0
17A	-	-	-	-	423.1	0	0	0.0	32.4	0	0	0.0
17B	-	-	-	-	120.2	0	0	0.0	-	-	-	-
17C	-	-	-	-	684.4	235	5	0.343	425.3	0	0	0.0
17D	-	-	-	-	-	-	-	-	330.0	80	2	0.242
16D	-	-	-	-	280.4	46	1	0.164	-	-	-	-
Total	4645.2	356	8	0.077	3275.2	529	11	0.162	3422.7	740	20	0.216

TABLE 2a ARC SINE TRANSFORMED MEAN PROPORTIONS OF 2 RINGERS IN SCOTTISH PURSE-SEINE SAMPLES FROM STATISTICAL SQUARES USED IN ANALYSIS OF VARIANCE. NUMBER OF OBSERVATIONS IN PARENTHESES

Year	Stat. square / Month	17A	17C	17D	18C	18D	19B	19C	19D	20C	20D	21C	21D	Res. M.S.	df.
1971	June	-	-	-	-	-	-	-	-	0.509(4)	0.825(3)	-	-	0.0293	5
	November	-	-	-	-	0.776(5)	-	0.602(5)	0.769(3)	-	-	-	-	0.0149	10
1972	June	-	-	-	-	-	-	-	1.066(3)	-	0.974(2)	-	-	0.0237	3
	August	-	0.822(5)	-	-	-	-	-	-	-	1.002(5)	-	-	0.0326	8
	September	-	-	-	1.010(2)	1.097(9)	-	-	1.011(5)	-	-	-	-	0.0182	13
1973	June	-	-	-	-	-	0.741(2)	-	-	0.670(4)	0.820(3)	-	-	0.0308	6
	July	0.494(6)	-	-	-	-	0.555(4)	-	-	0.676(2)	-	0.452(2)	-	0.0026	10
	August	-	-	0.941(2)	-	-	0.716(4)	-	0.794(2)	0.615(4)	-	-	0.595(4)	0.0332	11
	September	-	-	-	-	0.967(4)	-	-	-	0.616(8)	-	-	-	0.0245	10

TABLE 2b THE MEAN VALUES FROM TABLE 2a, AND THEIR 95% CONFIDENCE LIMITS, TRANSFORMED BACK TO ORIGINAL SCALE

Year	Stat. square / Month	17A	17C	17D	18C	18D	19B	19C	19D	20C	20D	21C	21D
1971	June	-	-	-	-	-	-	-	-	0.237 (0.12-0.38)	0.540 (0.37-0.71)	-	-
	November	-	-	-	-	0.491 (0.36-0.62)	-	0.321 (0.20-0.45)	0.484 (0.31-0.66)	-	-	-	-
1972	June	-	-	-	-	-	-	-	0.766 (0.60-0.90)	-	0.684 (0.48-0.86)	-	-
	August	-	0.539 (0.40-0.67)	-	-	-	-	-	-	-	0.710 (0.58-0.82)	-	-
	September	-	-	-	0.717 (0.51-0.88)	0.792 (0.70-0.87)	-	-	0.718 (0.59-0.83)	-	-	-	-
1973	June	-	-	-	-	-	0.456 (0.25-0.67)	-	-	0.386 (0.24-0.54)	0.535 (0.36-0.70)	-	-
	July	0.225 (0.13-0.34)	-	-	-	-	0.278 (0.15-0.42)	-	-	0.391 (0.20-0.60)	-	0.191 (0.06-0.38)	-
	August	-	-	0.653 (0.44-0.84)	-	-	0.431 (0.29-0.58)	-	0.509 (0.30-0.72)	0.333 (0.20-0.48)	-	-	0.315 (0.18-0.46)
	September	-	-	-	-	0.678 (0.53-0.81)	-	-	-	0.334 (0.24-0.44)	-	-	-

TABLE 3a. ARC SINE TRANSFORMED MEAN PROPORTIONS OF 3 RINGERS IN SCOTTISH PURSE-SEINE SAMPLES FROM STATISTICAL SQUARES USED IN ANALYSIS OF VARIANCE. NUMBER OF OBSERVATIONS IN PARENTHESES

Year	Month \ Stat. square	17A	17C	17D	18C	18D	19B	19C	19D	20C	20D	21C	21D	Res. M.S.	df.
1971	June	-	-	-	-	-	-	-	-	0.758(4)	0.341(3)	-	-	0.0145	5
	November	-	-	-	-	0.386(5)	-	0.288(5)	0.512(3)	-	-	-	-	0.0089	10
1972	June	-	-	-	-	-	-	-	0.250(3)	-	0.414(2)	-	-	0.0353	3
	August	-	0.172(5)	-	-	-	-	-	-	-	0.225(5)	-	-	0.0089	8
	September	-	-	-	0.332(2)	0.352(9)	-	-	0.402(5)	-	-	-	-	0.0139	13
1973	June	-	-	-	-	-	0.782(2)	-	-	0.734(4)	0.663(3)	-	-	0.0156	6
	July	0.745(6)	-	-	-	-	0.780(4)	-	-	0.664(2)	-	0.787(2)	-	0.0048	10
	August	-	-	0.560(2)	-	-	0.678(4)	-	0.655(2)	0.735(4)	-	-	0.727(4)	0.0211	11
	September	-	-	-	-	0.516(4)	-	-	-	0.801(8)	-	-	-	0.0100	10

TABLE 3b THE MEAN VALUES FROM TABLE 3a, AND THEIR 95% CONFIDENCE LIMITS, TRANSFORMED BACK TO ORIGINAL SCALE

Year	Month \ Stat. square	17A	17C	17D	18C	18D	19B	19C	19D	20C	20D	21C	21D
1971	June	-	-	-	-	-	-	-	-	0.473 (0.36-0.59)	0.112 (0.04-0.31)	-	-
	November	-	-	-	-	0.142 (0.08-0.22)	-	0.081 (0.03-0.15)	0.240 (0.14-0.36)	-	-	-	-
1972	June	-	-	-	-	-	-	-	0.062 (0.01-0.14)	-	0.162 (0.06-0.30)	-	-
	August	-	0.029 (0.005-0.07)	-	-	-	-	-	-	-	0.046 (0.02-0.10)	-	-
	September	-	-	-	0.106 (0.03-0.22)	0.119 (0.07-0.17)	-	-	0.153 (0.09-0.23)	-	-	-	-
1973	June	-	-	-	-	-	0.497 (0.34-0.66)	-	-	0.449 (0.34-0.56)	0.379 (0.26-0.51)	-	-
	July	0.460 (0.37-0.55)	-	-	-	-	0.495 (0.38-0.61)	-	-	0.380 (0.23-0.54)	-	0.512 (0.35-0.67)	-
	August	-	-	0.283 (0.15-0.44)	-	-	0.393 (0.29-0.51)	-	0.372 (0.22-0.53)	0.450 (0.34-0.56)	-	-	0.442 (0.33-0.56)
	September	-	-	-	-	0.243 (0.15-0.35)	-	-	-	0.516 (0.44-0.60)	-	-	-

Table 4 Analysis of variance for differences between months in Scottish purse-seine age compositions from Shetland area.

3 Ringers	D.F.	M.S.	V.R.
Between Years	2	2.2014	130.7788
Between Months	4	0.0556	3.3051 x
Interaction	7	0.0324	1.9274
Residual	131	0.0168	
2 Ringers			
Between Years	2	1.1775	44.4117
Between Months	4	0.0336	1.2686 N.S.
Interaction	6	0.1142	4.3059
Residual	129	0.0265	

x = Significant at 5% level.
N.S. = Not significant.