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# Errors in Sampling

by

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During the deliberations of the 1961 and 1962 Herring Working Group, all data submitted on length, age and meristic characters were taken at their face value. Equal weight was given to data whether collected from 1,000 or 100 observations. Indeed there is no reason why a sample of 100 fish or less should not give as good an estimate of the growth and meristic characters of the population from which it came as a bigger sample. However, when differences occur between two such estimates the question arises as to what level do such differences become significant.

## 1. Sampling for Length

In 1955 a full analysis was made of the sampling method in the East Anglian fishery. It was found that the 95% confidence limits on the seasonal mean length were ± 3.0 mm. These limits were based on the biggest component of variance between samples and was that related to area of fishing. At any time in the season the largest fish tended to be in the north and east. In comparing the mean length of a sample of herring with the seasonal mean only a difference greater than ± 3 mm would need to be considered to be possibly significantly different.

herring Using the 1961 data the variation in mean length of three year old East Anglian / has been analysed. In East Anglia the fish taken for age determination are selected by length so that in the scale sample there are proportionately many more larger fish than in the market measurements. This is so that a good age/length key for the older fish may be obtained. Market measurements are made from English and Scottish vessels at Lowestoft and Yarmouth and the age/length key is used to raise the four sets of data separately. Though the Scots use slightly smaller nets, the length distribution of three year olds is well within the retention lengths of the nets used and no bias due to net selection is likely. The length measurements are grouped by three-day periods and means were calculated for the three year old fish. Comparing the English and Scottish means at Lowestoft and Yarmouth there is no significant difference between them. The 1961 seasonal mean for three year old fish was 24.35 cm with 95% confidence limits of ± 3.4 mm. These are very similar to the limits on the mean of all ages in 1955.

Thus from two different years' data confidence limits on the seasonal mean of about ± 3 mm have been calculated. This is the same order of difference as that found at the 1961 Working Group between the means within the Southern Bight fisheries. Buchan spawners are on average 12 mm bigger than fish in the Southern Bight. A similar difference in means is seen between the Whitby spawning fish (part of the Bank stock) and the Downs herring. The mean differences between known Bank and Downs samples lie outside the confidence limits of the seasonal means within the fisheries on Downs herring.

The confidence limits discussed above are derived from three-day period means and between area differences. Between individual measurements within a three-day period or area the variation may be much greater than the limits on the seasonal mean. In East Anglia the 95% confidence limits of individual means is ± 8 mm on the seasonal mean. The sources of such variation may be either artificial, due to mesh selection or biassed sampling on the market, or may be real, due to true differences in the stock in, say, the places where the boats fished.

For a fishery lasting over several months it is clear that the best form of sampling for length consists of a series of length measurements taken regularly over the whole period of the fishery. Occasional research vessel samples of periodic market measurements might give length distributions very different from the true population. For instance, the research vessel sample might come from an area away from the main fishing concentration, and even in taking an occasional market sample errors of this sort might occur. An example of the difference which can occur is taken from the East Anglian data for the week ending 25th October, 1959. The length distributions of samples from two areas not twenty miles apart are given:-

East Anglia length distribution - Percentage

| cm / Area | 2o | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 3o | 31 | $\bar{X}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | o.1 | 2.7 | 19.5 | 53.2 | 21.4 | 1o.5 | 7.5 | 4.o | o.9 | o.2 | - | | 23.61 |
| B | o.1 | 2.o | 1o.2 | 19.3 | 15.8 | 15.5 | 18.2 | 11.4 | 4.6 | 1.7 | 1.o | o.2 | 24.74 |

It is obvious that age distributions derived from these two sets of data would be very different. A research vessel or a single market sample might have resulted in fish from either A or B being taken as representative of the fishery. As presented, both sets of data are given equal weighting, that from area A might, however, consist of a single sample of 1oo fish while that from B consists of some thousands. In this situation one might be inclined to accept the larger sample. Just because the length distribution is comprised of ten times as many measurements as that of A, this is no reason for claiming it to be a better representative sample of the fishery, for it is only a better sample of the catch from which it came. If, however, the larger sample consisted of a series of many smaller samples from a series of catches in the area then some justification for regarding it as a better estimate of the population might be made.

Again, the larger sample might have been taken from an area in which very little or no fishing was taking place, the smaller sample being a market sample from the fishery. In this situation more weight might be placed on the latter sample if the purpose of the measurements is to describe the population of fish in the fishery.

Thus, before the significance of such differences in means can be discussed some essential background data is needed on how the sampling was made and how the area of this sampling was related to the commercial fishery at the time.

In the case in point the length distributions are both derived from many sets of market measurements. Those from area A totalled some 2,3oo fish while those from B numbered 4,6oo fish. The distributions may be considered as adequate samples of the fishing in the areas from which they came. During the period in question 732 crans were taken in area A and 3,157 crans in area B. The respective catches per shot were 1o.2 crans and 36.7 crans. The best estimate of length distribution for the East Anglian catch from these two areas during this period would be the mean length distribution weighted by the area catches per effort. However, this would not represent the length distribution of the fishery at that time for a further 2,955 crans were landed in a third area and in obtaining a length distribution representative of the fish in the catches, length data from this area would also have to be incorporated.

In the above example, the case has been taken where a single observation made in either area A or B and not related to the distribution of fishing at the time might lead to considerable error in describing the length distribution of the stock in the fishery. A second problem of interpretation can be illustrated from the "Statistical Newsletter", No.9 for 1959. In the Stock Records both Scottish and Polish length distributions are given for Statistical Square E.16 for May. The percentage distributions are as follows:-

Length in cm

| cm | 2o | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 3o | 31 | 32 | No. | $\bar{X}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Polish | o.2 | 1.1 | 5.7 | 12.9 | 18.3 | 24.o | 21.3 | 1o.7 | 3.1 | 1.3 | o.7 | o.5 | o.2 | 2,231 | 24.99 |
| Scottish | | | | | 7.o | 23.o | 37.o | 19.o | 6.o | 5.o | 2.o | 1.o | | 1oo | 26.22 |

The Polish data is from trawl-caught herring while the Scots data is drift-net caught. A simple explanation for the difference can be that of gear, a comparatively non-selective trawl and a selective drift net. But this is most unlikely unless the Scots vessel was using an unusually large-sized fleet of drift nets. The Polish data based on 2,231 fish should present a more reliable estimate of the trawlable fish if the measurements have been spread out during the fishing. There is no indication whether these fish comprise one sample or many. Neither can the catch data help to give weight to one or other length distribution as being the best sample

of the fish in the area. 379 tons were caught by drift net and 372 tons by trawlers, in the main Polish. Thus, in this area we have two length distributions which differ by more than the between area difference in the previous example. With the data, as presented, both could be taken as equally good, or bad, estimates of the available stock.

In both the previous examples, we have been able to make a comparison of two length distributions and discuss their relative merits as adequate estimates of stock. There remains the problematical question of how much weight can be placed on single samples taken over the North Sea at long intervals in space and time.

In publication of Stock Records I would suggest that length data should be considered in two categories:- (a) those data composed of multiple samples taken from commercial catches or research vessel catches working within the commercial fleet, and (b) individual samples taken at random in time or space from the commercial catches or research vessel hauls away from commercial fisheries. The former could be referred to, in publication, as:-

'Length distribution of the ..... fishery';

the latter might be referred to as:-

'Length distribution of samples from .....', giving the area either as a statistical square or fishing ground.

In this way distinction would be clear between a systematic fishery sampling technique and random sampling.

The utility of small samples becomes apparent when all the data collected on the Recruit Surveys is put together. But such background is essential if individual sample means are to be interpreted satisfactorily.

c. Sampling for Age

The estimate of age distribution of the fish in a fishery can be no better than the data from which the age material is collected. Thus before any variation may be introduced from the method of selecting fish for age analysis, any original variance on length distribution of the sampled catch will be inherent in the age data. In the analysis of the East Anglian sampling method in 1955 it was found that due to the variance on length between areas the 95% confidence limits on the estimate of abundance of three year olds were ± 11%. These were maximum estimates due to the method of calculation and in practice it is most unlikely that the limits would be so wide. In this section it is intended to discuss, merely, the techniques used in taking fish for age determination.

At the English ports herring are landed mainly in 1/6 cran boxes or in some cases $\frac{1}{4}$ cran baskets. Depending on the mean length of the fish these units consist of between 2oo and 3oo fish. With a fish whose length range in the fishery is rarely over 1o cm and with a standard deviation of about 1 cm about the mean, it would seem quite unnecessary to measure 2oo-3oo fish to get an adequate estimate of the length distribution of the fish in a box and hence catch of the boat. In practice it is almost impossible to take 1oo fish from a box without some selection taking place. This is illustrated in the following table where the measurements of the first hundred fish taken from a box were recorded separately:-

| Sample No. | Mean lengths in cm of: | | Difference |
|---|---|---|---|
| | First 1oo | Remainder | |
| 1 | 25.49 | 24.96 (164) | +o.53 |
| 2 | 25.55 | 25.o2 (19o) | +o.53 |
| 3 | 26.o5 | 25.57 (194) | +o.48 |
| 4 | 24.95 | 24.65 (2o6) | +o.3o |
| 5 | 25.37 | 24.71 (198) | +o.66 |

Thus it is seen that in just taking, at random, 1oo fish from $\frac{1}{4}$ cran boxes of herring on Lowestoft market a bias can be introduced into any age distribution based on these fish alone. In this example the fish were not being taken for scale taking; when this occurs a further error may be introduced in that fish with few scales are rejected. An example of this type of bias is shown in the following table, where the mean lengths of the scale samples of fish are compared with those of the remainder of the

| Sample No. | Mean lengths in cm of: | | Difference |
|---|---|---|---|
| | Sample | Remainder | |
| 1 | 24.87 | 24.36 (185) | +o.51 |
| 2 | 25.13 | 24.3o (164) | +o.83 |
| 3 | 24.36 | 23.87 (1o5) | +o.89 |
| 4 | 25.16 | 24.27 (94) | +o.89 |
| 5 | 24.56 | 23.24 (67) | +1.32 |
| 6 | 28.25 | 27.68 (87) | +o.57 |

The full effects of this type of bias on the estimate for age of the sample, or boats catch from which the samples came, can be illustrated from data from North Shields. Two samples were taken during the week, consisting of a total of half a cran of fish. All the fish were measured and 1oo fish for scale taking were taken from each box. Age/length keys were made from the two scale samples and these were then raised by the total length distribution to give an estimate of the age distribution in the ships catches, from which the samples were taken. The age distributions for: (a) the scale sample, and (b) the raised samples are given below:-

| Age | | 3 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| A | No. | 44 | 83 | 55 | 7 | 8 | 1 |
| B | No. | 29o | 222 | 111 | 14 | 13 | 1 |

It is seen that when the total length samples are used that the relative abundances of two and three year olds are reversed. It is also seen that proportionately far more older fish are taken in the scale samples than those in the younger age groups. The use of an age/length key enables a better estimate of age distribution to be made in data where an extensive age analysis would not be possible.

In the previous section the case of differing length distributions within an area was discussed. The age distributions for this same area are also given in the Statistical Newsletter. The Scottish length distribution is evidently based on the same fish as the age distribution, as there are 1oo observations in each. However, in the Polish data, though some 2.231 length observations were made only 146 fish provided information for the age distribution. By using an age/length key from this age sample full opportunity could be taken for improving the reliability of the age distribution.

For July 1959, two length distributions were published by Schubert (Ann. Biol., 1961) for the Fladen Ground. These have means of 24.32 and 25.87 cm; the samples numbered 7o7 and 1,515 respectively. In Table 42 which gives the ‰ age compositions of all samples for July only one age distribution is given based on 387 fish. The length data is from trawl catches and it is well known that fish from such sources are rather devoid of scales. If the age sample is from those fish having scales, then there may be bias in the distribution. But again if it represents a sub-sampling of one of the larger length samples some improvement in the data could be made by using the full length distribution via an age/length key.

Because of the variations in the length of samples taken from a fishery, there will be an inherent sampling variance for age. C ly by minimising this variance in the initial sampling technique can it be minimised in the age data.

However, we can ensure that our age sample is the best that can be obtained from the available material. Biasses due to selection of fish for scale taking may be eliminated by using an age/length key to raise the scaled sample to the full length sample. If otoliths are used then this type of bias is eliminated but there still remains the bias of taking fish from a greater number as was illustrated above. Again, age/length data can eliminate this error.

With the publication of Stock Records often there may be occasions when more length data is available but is not published for lack of age data to accompany it. Such data when processed with an age/length key for the area from which it came, could give valuable additional information on stock abundance.

In publication of age data a similar distinction to that suggested in the previous section could be made. Those age distributions obtained from many age samples or based on extensive length measurements, and taken from the commercial fishery might be termed 'Age Distribution of the ..... fishery'. Similarly all other data could be referred to as 'Age Distribution from .....', again giving the area or ground.

## 3. Sampling for Growth and Meristic Characters

### (a) Growth data

More often than not such data as $l_1$ and other growth data, which have been obtained directly from the scale samples, are accepted as representative of the fish in the fishery. However, if the sample taken for age is biassed then, in consequence, the $l_1$ distribution for the fishery must also carry this bias. $l_1$ is correlated with total length, therefore if there has been selection so that the smaller fish are missing from the young age groups, then these will give $l_1$ distributions with too high values. In systematic sampling from a fishery as opposed to research vessels or occasional sampling, this error rarely occurs. When this error does occur it tends to underestimate the numbers of low $l_1$ in the stock.

### (b) Maturity

The following table shows the relation between the maturity stages of four year old fish in June, 1961, at North Shields.

Four year olds, North Shields, June 1961

| cm \ Mat. | I | I-II | II | II-III | III | III-IV | IV | IV-V | V | VI | VII | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2o | | | | | | | | | | | | |
| 21 | 16 | | | | | | | | | | | 16 |
| 22 | 49 | 62 | | | | | | | | | | 111 |
| 23 | 26 | 1o9 | | 7 | | | | | | | | 142 |
| 24 | | 95 | 16 | 19 | 18 | | | | | | | 148 |
| 25 | | 39 | | 55 | 9 | 6 | 2 | 13 | | | | 124 |
| 26 | | 9 | 3 | 22 | 12 | 28 | 7 | 3 | 3 | | | 87 |
| 27 | | | | 5 | | 9 | | 4 | | | | 18 |
| 28 | | | | | | 5 | | | | | | 5 |
| 29 | | | | | | | | | | | | |
| 3o | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | |
| Total | 91 | 314 | 19 | 1o8 | 39 | 48 | 9 | 2o | 3 | | | 651 |

It is seen that there is a clear correlation between length and maturity stage. Any bias which may occur from the method of obtaining the fish resulting in an unrepresentative length distribution, for example, will thus be imposed on the maturity distribution. This distribution, far from representing that of the fishery, will only be representative of the biassed sample from which it was derived.

This table illustrates a second point. It is clear that the fish in low maturity stages have a lower mean length than those in the higher stages, and by this method it is possible in the feeding fisheries of the northern North Sea to separate Bank and Downs components.

For example, using maturity/length keys in the Whitby and 'Haisborough' fisheries, it was possible to separate Bank and Downs components in the 1961 season. The mean lengths for age are given on page 6:-

| Maturity | Area | Age in years | | |
|---|---|---|---|---|
| | | 3 | 4 | 5 |
| Spawners | Whitby | 25.71 | 27.06 | 27.55 |
| | 'Haisborough' | 25.43 | 26.55 | 27.58 |
| < IV | Whitby | 24.17 | 24.79 | 27.48 |
| < V | 'Haisborough' | 24.76 | 25.35 | 26.84 |
| | East Anglia | 24.38 | 25.89 | 27.07 |

The low maturity fish at Whitby and Haisborough have the same mean length and meristic characters as the East Anglian samples.

In the feeding fisheries of the northern North Sea similar techniques would enable further light to be brought on the relative abundances of Bank and Downs stocks in those fisheries.

However, while this type of analysis can be performed on any samples to describe the maturity distribution of the fishery, it is necessary to remove any sampling bias if possible. This may be improved by raising the maturity distribution by the total length distribution obtained from the area. The effect of such a raising may be illustrated from a North Shields sample:-

Percentage in Maturity Stages

| | I | I/III | II | II/III | III | III/IV | IV | IV/V | V | VI | VII |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | 1 | 6 | 2 | 1 | 29 | 9 | 23 | 16 | 13 | - | - |
| Raised | 2 | 25 | 2 | 1 | 35 | 9 | 12 | 9 | 6 | - | - |

It is clear that the maturity distribution of the sample bears only small similarity to that in the fishery.

(c) Vert.S.

It is generally accepted that the vertebral number is determined in the egg at an early stage in development. No clear correlations have been demonstrated between vertebral number and length or any other growth character in the North Sea fisheries. In part this may be due to the limited vertebral range. Zijlstra (1961) has showed that in the central North Sea recruit herrings there was a gradual decrease in vertebral count with time on the spawning ground. In the Southern Bight the reverse appeared to be the case.

As mean vertebral counts in Bank and Downs spawning stocks are consistently different, then the conventional method of presenting mean vertebral count by maturity stage by age groups would appear to be the best possible method of presentation.

Discussion

Sampling for age and meristic characters is a time-consuming operation, one whose very nature tends to preclude any one country adequately sampling more than a limited number of fisheries.

At this time when reliable estimates of total mortality and effort on the different stocks are badly needed it seems natural that full advantage should be taken of whatever data is collected from the fisheries. This paper has pointed out how, even at this present level of sampling, some improvement might be made in age and length data by fully using the available information. If full stock data from

market sampling were available from each major fishery for each month then how much more valuable would be the research vessel samples when viewed against this background. Are we still too far from the time when each major catching country is internationally responsible for providing stock data from at least one of its fisheries?

## References

Zijlstra, J. J. 1961 "On the recruitment mechanism in the North Sea herring". ICES Herring Symposium, Doc.No.29.

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