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# SOURCES OF VARIATION IN IYFS INDICES OF ABUNDANCE - A PRELIMINARY ANALYSIS

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## Abstract.

International young fish survey data for 1983, 1984 and 1985, made available in exchange tape format from the SIR data base at ICES headquarters, were submitted to a preliminary analysis of possible sources of variation in catch rates. A dual approach was followed. Firstly standard recruitment indices were calculated for various subsets: (1) excluding single countries; (2) splitting in even and uneven haul numbers; (3) sorting stations by depth, temperature and salinity bands. Secondly, a covariance analysis of intership variation was made based on rectangles fished by pairs of vessels. The effect of excluding single vessels on the index of abundance is generally relatively small and for untransformed catch data only in case of cod one vessel caught consistently significantly less fish than the others. When data were log transformed statistical sensitivity for differences appears to be enhanced, indicating anomalous performance of one other vessel for herring. For cod the discrepancy resulted largely from one particular year. Still, it appears that correction for differences in catch rates would only marginally affect overall indices of recruitment.

Subsets based on a split in even and uneven haul numbers yielded very similar answers, indicating that the overall coefficient of variation as affected by sampling intensity is small. Catch rates were, however, varying considerably with depth, temperature and salinity. These factors, which are interrelated, deserve further attention, because their affect on the ultimate index of abundance could be considerably larger than the effect of intership variation.

The results are presented as a contribution to the discussion on evaluation of survey results during the theme session. They do not pretend to give final answers on how alternative better indices could be derived.

## Introduction.

For over 20 years International Young Fish Surveys (IYFS) have been carried out annually in february in the North Sea to estimate year class strength of juvenile herring, cod, haddock, whiting, Norway pout, mackerel and sprat. Stock assessment working groups rely heavily upon the survey indices of most of these species for making catch predictions. Essentially, this type of use requires that the reliability of the index is at least not much less than the precision of recruitment estimate by means of VPA. However, estimation of statistical precision of a VPA recruitment figure is hardly possible and also for survey indices calculation of statistical precision requires making some largely untestable assumptions. Therefore, correlation techniques between the two independent estimators have been widely applied to give some guidance as to their reliability. If correlations are highly significant, the intrinsic reliability of each of the estimates becomes less important, because the confidence limits of the correlation may be used to evaluate the effect of the recruitment estimate from the survey on the prognosis. If correlations are not or poorly significant, the practical value of a survey index is virtually zero. However, this would not necessarily mean that the survey index is not a reliable estimate of abundance in the sea, because rather the problems may be caused by the VPA input data. In fact, in some cases independent survey estimates for a single year class as measured in different surveys were better correlated than any of these with VPA estimates (ANONYMOUS, 1985). In such cases it would seem likely that the VPA does not present the ultimate truth.

In the past adjustments in standard areas, transformations and a posteriori stratification procedures have been introduced at various occasions in calculating IYFS indices (ANONYMOUS, 1981, 1983). The main objective of these changes has been to improve the correlation coefficients with VPA estimates and the proces was more characterized by trial and error than by rigid statistical analysis. Such an approach can not be a very profitable one, because correlation coefficents have themselves distributional properties and a high coefficient for any particular index may simply result from chance. Realizing these problems the IYFS working group (ANONYMOUS, 1985) stressed the need to start an extensive statistical analysis of the various factors affecting variances of catch rates.

With the development of a computerized data base for these surveys at ICES headquarters (HANSEN et al, 1983) the possibilities for such an analysis have increased considerably. To date data tapes for three survey years have been exchanged and this paper describes the results of some preliminary analyses carried out on these data. The main aim is to explore various sources of variations and to evaluate the impact on the ultimate index in order to define further priorities.

The approach followed is twofold. Firstly, indices of abundance according to the defined standard procedures were calculated for separate subsets of the data base as characterized by specific ranges of parameter values. In this way one can easily obtain an overview of the impact that any particular factor has on the ultimate index. Secondly, a covariance analysis has been applied to address specifically intership variation. In an internationally coordinated survey differences in catch rate may be expected, which are entirely due to the use of different vessels, even when these operate standardized fishing gear. This problem was given first priority.

By no means the results presented here will be conclusive. Not only have we addressed only part of the factors possibly contributing to the variance, but also have amendments to the data exchanged earlier recently been circulated. Therefore, this contribution should be considered entirely as a discussion paper, meant to evoke further investigations.

Thanks are due to Willem Dekker for his continuous help in trying to solve the overwhelming statistical problems and for the multiple adaptations of his programs to our wishes.

## Material and Methods.

Exchange tapes according to the agreed format for the survey years 1983, 1984 and 1985 have been made available by ICES from the SIR data base. The age length keys were grouped by sampling areas and by means of these the length distributions in individual hauls were transposed in age distributions. The numbers per age group per haul were linked to the station data and this file presented the basis for all further calculations employing various selection procedures.

A. Comparison of indices.

In the standard analysis of recruitment indices for assessment purposes the hauls are stratified by statistical rectangles. Numbers per hour fishing in valid hauls are first averaged by rectangle and subsequently over all rectangles included in a species specific standard area. In calculating indices for various subsets the same stepwise procedure was followed. It should be noted that, because of this stepwise averaging procedure, the mean of two subsets differs from the standard index, because weighting factors for individual hauls change in an unpredictable way. The factors for each of the three years and for each of three species (cod, haddock and whiting) and two age groups considered were:

1. Country effect: by excluding one country at a time the overall effect of the contribution of a particular vessel was investigated.
2. Sample size: independent indices were calculated for even and uneven hauls to investigate to what extent variation may be ascribable to sample size.
3. Depth: hauls were grouped by 25 m depth bands.
4. Temperature: hauls were grouped by 1 degree C bands.
5. Salinity: hauls were grouped by 1‰ salinity bands.

Clearly, factors like depth, temperature and salinity are interrelated, but at this stage no effort was made to study this in more detail, because ICES has expressed some doubts as regards the quality of some of the hydrographical information in the survey data base. The main aim here is to investigate qualitatively what kind of patterns do emerge and how they may affect survey indices.

B. Intership covariance analysis.

A program, developed by Willem Dekker for a covariance analysis by means of multiple regression based on EDWARDS (1979) was chosen because it allows for a larger number of degrees of freedom than any of the standard packages available at the institute. These will be required, when ultimately other parameters will be included in the analysis. To minimize rounding errors the program uses Doolittle's method for solving a system of equations (BURDEN et al, 1981).

The main criterium for including hauls in the stepwise comparison of two vessels at a time has been that both vessels had been fishing in the same statistical rectangle. Only valid GOV hauls were selected. To get rid of a large number of zero values only squares in which one of the vessels caught at least one fish belonging to the species considered. It was reasoned that two vessels operating in an area with no fish do not yield significant information about their relative fishing power. If a vessel made more hauls within a rectangle the catches were averaged. This procedure means some loss of information, but circumvents the problem of one haul counting more than once in the analysis when it had to be compared with more than one haul made by another vessel.

One of the main problems in analyses of variance is related to distribution properties of the catch rates. A priori we assumed that these were normally distributed and most of the analyses were based on untransformed data. However, in a selected number of cases logarithmic transformations (adding 1) were also made. In addition this aspect was investigated by comparing standardized residual sums of squares for various power transformations (MONTGOMERY & PECK, 1982). The standarization procedure requires that the residual sums of squares are corrected by a factor

if q<>0 : $$\frac{1}{(q\,\dot{y}^{q-1})^2}$$

if q=0 : $$\dot{y}^2$$

where $\dot{y}$ is the geometric mean and q is the transformation factor.

The smallest value of the residual sums of squares is an indication of the best transformation procedure to normalize the data.

## Results.

A. Comparison of indices.

Tables 1-3 summarize the results of the various analyses for I- and II-group fish of each of the three species in each of the three years. In each column the standard index is given for comparison.

Omitting one country from the data set has in general a very small effect on the calculated index. The largest deviations observed in both directions and the country causing the deviation are summarized in the text table below.

| | Cod | | | | Haddock | | | | Whiting | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | | II | | I | | II | | I | | II | |
| 1983 | | | | | | | | | | | | |
| MIN | DEN | -25% | FRA | -20% | GFR | -13% | GFR | -17% | SCO | -16% | FRA | -8% |
| MAX | NOR | +19% | GFR | +15% | NOR | +12% | DEN | +13% | GFR | +13% | SCO | +9% |
| 1984 | | | | | | | | | | | | |
| MIN | DEN | -20% | NOR | -13% | FRA | -2% | DEN | -3% | SCO | -16% | SCO | -9% |
| MAX | GFR | +34% | GFR | +40% | GFR | +5% | GFR | +5% | ENG | +16% | GFR | +8% |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | |
| MIN | DEN | -10% | DEN | -12% | DEN | -8% | GFR | -13% | ENG | -21% | ENG | -16% |
| MAX | NOR | +10% | GFR | +14% | SCO | +15% | SCO | +9% | SCO | +5% | GFR | +14% |

Negative values resulting from omitting a particular country indicate that that country caught more fish than the others and similarly positive values indicate relative poor performance. From this table it is not obvious that any of the participating countries is consistently catching more or less fish for any of the species, except that GFR appears to be catching less cod than the others. For the remainder indeed most countries appear both at the top and bottom rows at various instances suggesting a chance distribution. In general the effect that any country has on the index of cod is higher than for the other two species.

A global comparison of the abundance indices derived from even and uneven hauls indicates that these are very similar to the standard index. The standard deviations (percentage of the mean) based on the two independent data sets are given in the text table below.

| | Cod | | Haddock | | Whiting | |
|---|---|---|---|---|---|---|
| | I | II | I | II | I | II |
| 1983 | ± 6 | ±36 | ± 5 | ± 7 | ± 5 | ±23 |
| 1984 | ± 7 | ±17 | ±17 | ± 6 | ±19 | ± 8 |
| 1985 | ±17 | ±12 | ±10 | ±28 | ± 8 | ±23 |

Only rarely do the standard deviations exceed 20%. From the general level it may be deduced that sampling intensity does not present a real problem. Possibly sampling intensity might even be allowed to drop by a significant amount below the present level.

The distributions of the various species age groups over the depth range vary widely. The highest densities of I-group cod are observed in shallow waters, but in 1985 when overall abundance was poor a relatively large proportion occurred up to 125 m. II-group cod are more evenly distributed throughout the total depth range with higher aggeregations in shallow water in 1983 and in waters deeper then 75 m in 1984. Apparently these patterns are highly variable. Haddock I- and II-group are consistently found in large numbers in waters between 50 and 200 m, but in this case most of the shallow regions of the North Sea have been omitted from the standard area for this specific reason. Whiting shows variable results in different years. In 1983 most of the juveniles were found within the 100 m depth range, whereas in 1984 they were evenly distributed up to 150 m. In 1985 no concentrations were observed in the nearshore zone and both age groups were particular abundant in the range between 50 and 100 m.

The abundances of cod and whiting by temperature and salinity largely reflect the distribution by depth zone. Typically, the maximum abundances of cod by temperature or salinity band are higher than by depth range, whereas for whiting the opposite is true. This is related to the fact that cod concentrations are largely restricted to the shallow areas along the continental coast, where the lowest temperatures and salinities occur, whereas whiting may also be abundant in other shallow areas along the British coast. The haddock avoid low temperature and salinity regions, but again these squares are not in their standard area.

B. Intership Covariance Analysis.

Tables 4-9 provide significance matrices of the F-statistic in comparing catch rates of two vessels fishing in the same squares. They should be read in such a way that if there are plusses the ship in the vertical column catches significantly more fish at the indicated level of significance than the ship in the horizontal row. One must be aware that, if ship A catches more than B and B more than C, it does not follow that in the table A catches also more than C, because different subsets are used in comparing each set of two countries. In general one also has to take into account that in producing such a large amount of statistical tests the appearance of any significant difference may simply result from chance. Therefore, one should not pay much attention to randomly occurring plusses or minusses. Only, when one ship is catching consistently less or more than some others, one should start worrying about a real difference. Of course, there is no virtue in one ship catching more than others, because this would equally indicate that a vessel is having standarization problems with its gear as when one is catching less!

Tables 4-7 refer to cod, haddock, whiting and herring respectively and provide information for the two youngest age groups separately. The cod matrices (table 1) indicate that both for I-group and II-group AND2 catches less than most of the others. ELD appears twice as catching less than two other vessels in I-group cod (table 1) and in II-group herring (table 4). For the remainder all significant differences appear to be randomly distributed among all vessels.

To investigate what kind of effects transformation procedures may have on levels of significance, a ln(N+1) transformation has been carried out for II-group cod and herring (table 8). In case of cod has not only the level of significance considerably increased for the poor performance of AND2, but also SCO2 appears to be catching less cod than 3 other vessels and THA more than 2 others. Apparently, in this case the number of significant differences has increased markedly. Also for herring there are indications that logtransformated data are statistically more sensitive, indicating that THA catches less than 4 other vessels. In other species no markedly different results were obtained between untransformed and transformed data. For that reason they have been excluded here.

So far the analyses refer to all three years combined. However, performance may change from year to year, particularly because in IYFS standarization of gear operations has been and is a gradual continuous proces. Also, ultimately we would wish to make adaptations to the index by year. Therefore the analysis has been repeated for the three years separately, but only for II-group cod (table 9). For 1983 no significant differences were observed. In 1984 AND2 caught less than 4 other vessels, but the significance was only at the 10% level. Only in 1985 highly significant differences between this vessel and most others are observed. Obviously the degrees of freedom are considerably reduced when analysing annual differences and this may well hamper detection of differences in performance.

To investigate what kind of transformation would be appropriate to improve the normal distribution properties of the catch rates a comparison was made between the standarized residual sums of squares for a range of transformation factors running from 1 (no transformation) through 0 (logarithmic transformation) to -1 (one divided by the number). These are plotted on a logarithmic scale against the transformation factor in fig 1. For all species and all sets of ships considered the smallest residual sums of squares were encountered close to zero. Although the minimum is sometimes slightly to the right or left, the difference in the actual value of the residual sums of squares is only marginal and for all practical purposes the logarithmic transformation would appear to be appropriate.

## Discussion.

The analysis presented here cannot be very conclusive. Firstly, the exchanged data were not yet completely free of errors and particular subsets have already been superseded. Secondly, the methods applied were probably not appropriate, because the analysis of the effect of various power transformations suggests that to study intership variance a logarithmic transformation should be applied. However, in those cases where both untransformed and transformed data were submitted to a covariance analysis generally similar results were obtained. Therefore, it cannot be expected that the logarithmic transformation would completely alter the results. In the present analysis we have only compared two vessels at a time. In the future it might be better to introduce a stepwise procedure, combining vessels which have lowest F-statistics and compare remaining individual ships against this larger set. Due to the increased degrees of freedom this approach should be more sensitive to detecting anomalies in vessel performance within years. Also one would end up with one correction factor for each vessel significantly deviating from the majority rather than having to apply separate raising factors for each group of rectangles where two vessels had been fishing together. At this stage this has not been pursued any further.

The ultimate aim of any kind of statistical analysis of the factors affecting the variance will be to do something about it in deriving a final index of recruitment. However, obtaining statistical evidence that one vessel catches more or less than another is one thing, but applying some kind of correction procedure is another. Not only will any type of statistically estimated adjustment factor probably have wide confidence limits, but also it has been suggested that at a total North Sea scale distributions are probably compound (ANONYMOUS, 1981). In this case logarithmic transformations could lead to highly unrealistic variances. Keeping such problems in mind, one wonders whether a detailed analysis of intership variance is worth proceeding any further. In fact within the three years considered problems resulting from intership variation in fishing power appear to be of minor importance only. They are largely restricted to one ship for one species in one year. Although the statistical evidence that AND2 was catching less is supported by the analysis of the effect of omitting that particular vessel from the data base, the overall effect of AND2 in 1985 could only have caused a discrepancy of 14% at maximum in the standard index. For other years and species much larger ship effects were found, but these were apparently not significant. The general conclusion seems justified that any correction procedure might only marginally affect the final index and that the survey is well enough buffered against possible intership variation.

The reduction of the total data base to two independent sets has a very limited effect on the actual indices, which can be commonly characterized by a mean standard deviation of approximately 15%. This suggests that the variance on the total data set as far as it is depending on sampling intensity is even less. This would mean that not much gain could be expected from increasing sampling effort any further and in fact there might be scope for some reduction.

The analysis of the three other factors considered indicate that differences in abundance are closely associated with depth, temperature and salinity. In particular the cod distribution over the salinity bands confirms earlier observations by BURD & PARNELL (1982). However, because these three factors are strongly interrelated, it is impossible at this stage to discriminate between primary and secondary factors. Moreover, because there are considerable differences within any species age group between years, it seems likely that there is an area effect superimposed on these factors. Although there are interesting features, without considering the area effect it would seem extremely difficult to define a posteriori an appropriate stratification procedure based on any of these parameters. Still, the variations related to these factors are relatively large in comparison with ship effects. Thus chance differences between years in the haul distributions over the depth ranges within squares might be expected to significantly affect the comparability of annual indices. These problems could clearly be overcome by establishing fixed stations and such a change might be considered for the future. Even then the possible additional effects of temperature and salinity would remain, because they vary from year to year. However, given the fact that these surveys have been carried out for 20 years largely on the basis of randomizing stations within statistical rectangles, a more elaborate analysis is required before major changes are introduced. It would seem that factors affecting the distribution of the fish over the sea deserve a higher priority than the intership variations, because the effect on the ultimate recruitment index appears to be very much larger.

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Table 1.
IYFS indices of abundance for various subsets of the 1983 data base within the standard species area (N = number of rectangles).

| | COD | | | HADDOCK | | | WHITING | | |
|---|---|---|---|---|---|---|---|---|---|
| Index | N | I | II | N | I | II | N | I | II |
| Standard | 136 | 3.88 | 16.60 | 105 | 307.2 | 400.2 | 140 | 128.0 | 126.4 |
| Omitting one country: | | | | | | | | | |
| - DEN | 135 | 2.93 | 14.39 | 104 | 337.6 | 452.0 | 139 | 129.6 | 127.3 |
| - ENG | 136 | 4.40 | 18.81 | 105 | 303.3 | 396.8 | 140 | 118.2 | 125.2 |
| - FRA | 136 | 3.16 | 13.31 | 105 | 296.4 | 385.7 | 140 | 138.3 | 116.3 |
| - GFR | 133 | 4.32 | 19.01 | 102 | 268.0 | 332.1 | 137 | 145.2 | 127.0 |
| - NET | 136 | 3.86 | 16.82 | 105 | 312.8 | 417.6 | 140 | 130.0 | 129.7 |
| - NOR | 136 | 4.63 | 14.91 | 105 | 344.3 | 420.5 | 140 | 132.5 | 127.5 |
| - SCO | 136 | 3.88 | 17.89 | 105 | 298.3 | 408.8 | 140 | 107.5 | 137.4 |
| Splitting hauls: | | | | | | | | | |
| EVEN | 116 | 4.55 | 14.86 | 86 | 317.9 | 398.7 | 120 | 135.6 | 111.7 |
| UNEVEN | 114 | 4.95 | 25.15 | 85 | 294.3 | 439.9 | 118 | 146.4 | 154.6 |
| Depth (m): | | | | | | | | | |
| 0- 25 | 11 | 25.84 | 64.52 | 2 | 10.7 | 168.8 | 15 | 86.0 | 139.8 |
| 25- 50 | 49 | 6.78 | 12.07 | 21 | 46.1 | 39.9 | 50 | 180.8 | 58.7 |
| 50- 75 | 43 | 4.44 | 6.64 | 40 | 145.3 | 218.6 | 43 | 211.8 | 113.0 |
| 75-100 | 37 | 1.17 | 18.25 | 36 | 386.1 | 700.1 | 37 | 200.7 | 356.3 |
| 100-125 | 21 | 0.26 | 24.06 | 21 | 532.5 | 749.8 | 21 | 8.8 | 140.5 |
| 125-150 | 19 | 0.67 | 15.90 | 19 | 423.7 | 599.8 | 19 | 8.4 | 97.1 |
| 150-175 | 9 | 0.11 | 5.54 | 9 | 548.3 | 196.7 | 9 | 16.1 | 33.7 |
| 175-200 | 4 | 0.00 | 7.28 | 4 | 621.0 | 183.2 | 4 | 0.3 | 0.8 |
| >=200 | 1 | 0.00 | 4.99 | 1 | 1414.4 | 54.0 | 1 | 0.0 | 0.0 |
| UNKNOWN | 8 | 11.88 | 71.69 | 1 | 0.0 | 0.0 | 10 | 42.2 | 8.4 |
| Temperature ($^{o}$C): | | | | | | | | | |
| 2 - 3 | 1 | 2.00 | 0.00 | - | | | 3 | 2.8 | 0.0 |
| 3 - 4 | 9 | 12.20 | 70.18 | 3 | 0.0 | 0.0 | 11 | 62.0 | 47.0 |
| 4 - 5 | 32 | 14.16 | 41.81 | 9 | 8.1 | 80.1 | 34 | 125.1 | 79.4 |
| 5 - 6 | 65 | 4.94 | 9.69 | 42 | 124.4 | 138.0 | 66 | 205.6 | 126.0 |
| 6 - 7 | 64 | 1.19 | 10.08 | 62 | 417.3 | 515.2 | 64 | 98.8 | 189.4 |
| 7 - 8 | 30 | 0.34 | 24.19 | 30 | 433.4 | 528.6 | 30 | 9.9 | 121.7 |
| UNKNOWN | 12 | 1.34 | 3.85 | 3 | 93.9 | 131.5 | 12 | 36.2 | 76.6 |
| Salinity (%o): | | | | | | | | | |
| 29 - 30 | - | | | - | | | 1 | 98.9 | 3.5 |
| 30 - 31 | - | | | - | | | 2 | 63.0 | 2.0 |
| 31 - 32 | 2 | 2.50 | 40.07 | - | | | 5 | 24.4 | 2.2 |
| 32 - 33 | 4 | 14.36 | 150.93 | - | | | 6 | 71.0 | 96.9 |
| 33 - 34 | 10 | 26.37 | 65.28 | 2 | 5.3 | 84.4 | 11 | 145.9 | 152.3 |
| 34 - 35 | 77 | 5.26 | 7.24 | 52 | 157.0 | 309.0 | 77 | 211.3 | 158.8 |
| 35 - 36 | 69 | 1.79 | 16.06 | 64 | 432.0 | 544.6 | 69 | 41.9 | 156.4 |
| UNKNOWN | 40 | 1.05 | 4.91 | 26 | 203.4 | 134.8 | 40 | 62.8 | 28.9 |

Table 2.
IYFS indices of abundance for various subsets of the 1984 data base within the standard species area (N = number of rectangles).

| | COD | | | HADDOCK | | | WHITING | | |
|---|---|---|---|---|---|---|---|---|---|
| Index | N | I | II | N | I | II | N | I | II |
| Standard | 138 | 15.20 | 8.01 | 106 | 1057.1 | 218.8 | 142 | 435.5 | 178.6 |
| Omitting one country: | | | | | | | | | |
| - DEN | 138 | 12.23 | 7.17 | 106 | 1046.1 | 212.8 | 142 | 412.9 | 177.0 |
| - ENG | 137 | 16.14 | 7.32 | 105 | 1038.5 | 214.1 | 141 | 504.1 | 182.2 |
| - FRA | 138 | 12.91 | 7.56 | 106 | 1035.7 | 220.8 | 142 | 411.1 | 173.5 |
| - GFR | 132 | 20.32 | 11.25 | 100 | 1110.4 | 229.5 | 136 | 486.2 | 192.6 |
| - NET | 138 | 19.74 | 8.37 | 106 | 1069.2 | 220.1 | 141 | 458.5 | 187.1 |
| - NOR | 137 | 12.92 | 6.96 | 105 | 1040.1 | 214.2 | 141 | 414.9 | 177.1 |
| - SCO | 134 | 15.65 | 7.63 | 102 | 1105.1 | 229.1 | 138 | 367.3 | 162.9 |
| Splitting hauls: | | | | | | | | | |
| EVEN | 108 | 18.07 | 7.06 | 79 | 1135.7 | 210.3 | 112 | 388.1 | 187.0 |
| UNEVEN | 109 | 16.30 | 9.01 | 79 | 889.0 | 227.9 | 113 | 507.8 | 167.0 |
| Depth (m): | | | | | | | | | |
| 0- 25 | 12 | 67.18 | 6.33 | 2 | 1470.6 | 1.9 | 16 | 751.4 | 113.9 |
| 25- 50 | 42 | 16.72 | 3.14 | 14 | 19.4 | 4.0 | 44 | 568.2 | 81.3 |
| 50- 75 | 44 | 20.31 | 2.20 | 40 | 1273.7 | 103.9 | 44 | 707.9 | 97.6 |
| 75-100 | 35 | 9.47 | 9.69 | 33 | 1355.3 | 255.7 | 35 | 431.8 | 451.1 |
| 100-125 | 28 | 3.72 | 12.52 | 28 | 1239.1 | 509.7 | 28 | 103.1 | 304.8 |
| 125-150 | 24 | 2.26 | 19.66 | 24 | 1084.8 | 218.6 | 24 | 28.4 | 134.1 |
| 150-175 | 6 | 3.75 | 7.50 | 6 | 625.4 | 82.2 | 6 | 13.7 | 13.6 |
| 175-200 | - | | | - | | | | | |
| >=200 | - | | | - | | | | | |
| UNKNOWN | 1 | 5.53 | 46.07 | 1 | 138.5 | 49.5 | 1 | 3.4 | 13.7 |
| Temperature (°C): | | | | | | | | | |
| 1 - 2 | - | | | - | | | 2 | 2577.2 | 134.7 |
| 2 - 3 | 1 | 0.00 | 0.00 | 1 | 0.0 | 0.0 | 3 | 551.3 | 52.7 |
| 3 - 4 | 9 | 83.43 | 5.80 | 2 | 50.6 | 2.2 | 12 | 1202.4 | 195.2 |
| 4 - 5 | 38 | 27.62 | 4.19 | 18 | 194.9 | 93.0 | 40 | 536.5 | 57.5 |
| 5 - 6 | 65 | 16.98 | 5.63 | 46 | 1037.0 | 142.3 | 65 | 620.7 | 170.7 |
| 6 - 7 | 63 | 12.14 | 11.49 | 59 | 1601.1 | 337.6 | 64 | 141.7 | 249.6 |
| 7 - 8 | 15 | 2.14 | 7.38 | 15 | 748.5 | 215.1 | 15 | 22.5 | 93.5 |
| UNKNOWN | 48 | 10.76 | 5.51 | 27 | 1200.0 | 187.5 | 52 | 420.0 | 142.8 |
| Salinity (‰): | | | | | | | | | |
| 28 - 30 | 1 | 267.09 | 3.90 | - | | | 1 | 716.3 | 354.4 |
| 29 - 30 | - | | | - | | | 1 | 3228.8 | 83.2 |
| 30 - 31 | - | | | - | | | 2 | 1420.0 | 96.5 |
| 31 - 32 | 1 | 298.98 | 30.46 | - | | | 3 | 1034.9 | 317.8 |
| 32 - 33 | 3 | 6.30 | 4.66 | 1 | 0.0 | 0.0 | 6 | 1904.1 | 149.2 |
| 33 - 34 | 6 | 100.80 | 8.65 | 3 | 215.9 | 0.5 | 8 | 673.6 | 137.8 |
| 34 - 35 | 81 | 16.12 | 4.59 | 53 | 1013.7 | 141.3 | 81 | 653.2 | 213.6 |
| 35 - 36 | 61 | 9.66 | 12.13 | 59 | 1164.9 | 339.0 | 61 | 57.8 | 172.1 |
| UNKNOWN | 49 | 10.60 | 5.57 | 28 | 1161.4 | 181.6 | 53 | 408.9 | 140.0 |

Table 3.
IYFS indices of abundance for various subsets of the 1985 data base within the standard species area (N = number of rectangles).

| | COD | | | HADDOCK | | | WHITING | | |
|---|---|---|---|---|---|---|---|---|---|
| Index | N | I | II | N | I | II | N | I | II |
| Standard | 139 | 0.91 | 17.64 | 107 | 228.6 | 828.5 | 142 | 340.9 | 358.8 |
| Omitting one country: | | | | | | | | | |
| - DEN | 138 | 0.82 | 15.58 | 106 | 211.6 | 834.4 | 141 | 354.1 | 361.5 |
| - ENG | 139 | 0.93 | 17.22 | 107 | 230.3 | 866.6 | 142 | 270.3 | 303.3 |
| - FRA | 139 | 0.91 | 17.34 | 107 | 223.0 | 800.4 | 142 | 355.7 | 329.8 |
| - GFR | 139 | 0.90 | 20.14 | 107 | 215.5 | 722.6 | 142 | 354.3 | 409.5 |
| - NET | 139 | 0.91 | 16.87 | 107 | 224.1 | 809.5 | 141 | 341.8 | 347.3 |
| - NOR | 139 | 1.00 | 16.36 | 107 | 226.1 | 863.2 | 142 | 346.3 | 374.1 |
| - SCO | 139 | 0.97 | 19.86 | 107 | 263.6 | 899.9 | 142 | 359.4 | 378.5 |
| Splitting hauls: | | | | | | | | | |
| EVEN | 126 | 1.10 | 15.65 | 95 | 221.3 | 972.6 | 129 | 336.3 | 406.4 |
| UNEVEN | 124 | 0.86 | 18.60 | 93 | 192.8 | 649.2 | 127 | 298.6 | 291.4 |
| Depth (m): | | | | | | | | | |
| 0- 25 | 14 | 0.48 | 10.16 | 1 | 0.0 | 0.0 | 17 | 13.3 | 91.9 |
| 25- 50 | 49 | 1.70 | 19.05 | 18 | 7.5 | 32.8 | 50 | 203.9 | 435.6 |
| 50- 75 | 51 | 2.06 | 18.95 | 46 | 160.6 | 593.4 | 51 | 1025.7 | 413.4 |
| 75-100 | 41 | 0.77 | 23.31 | 40 | 253.8 | 1678.3 | 41 | 561.0 | 782.2 |
| 100-125 | 26 | 1.19 | 19.78 | 26 | 338.8 | 880.8 | 26 | 118.9 | 338.3 |
| 125-150 | 23 | 0.10 | 13.33 | 23 | 285.0 | 473.9 | 23 | 103.8 | 353.9 |
| 150-175 | 9 | 0.00 | 14.49 | 9 | 406.1 | 123.1 | 9 | 10.7 | 21.1 |
| 175-200 | 1 | 0.00 | 3.65 | 1 | 163.7 | 16.8 | 1 | 0.0 | 0.0 |
| >=200 | - | | | | | | | | |
| UNKNOWN | - | | | | | | | | |
| Temperature (°C): | | | | | | | | | |
| 0 - 1 | 5 | 3.48 | 12.00 | - | | | 5 | 39.6 | 97.4 |
| 1 - 2 | 7 | 0.57 | 30.83 | 1 | 0.0 | 0.0 | 8 | 32.5 | 13.0 |
| 2 - 3 | 5 | 0.72 | 19.30 | - | | | 5 | 7.7 | 229.2 |
| 3 - 4 | 17 | 0.10 | 70.00 | 4 | 3.8 | 7.5 | 17 | 23.7 | 196.2 |
| 4 - 5 | 28 | 1.33 | 8.25 | 15 | 32.8 | 39.2 | 28 | 135.9 | 264.4 |
| 5 - 6 | 34 | 1.06 | 17.00 | 29 | 287.2 | 1138.6 | 34 | 448.8 | 242.1 |
| 6 - 7 | 54 | 0.34 | 25.67 | 54 | 293.2 | 1233.7 | 54 | 354.0 | 363.3 |
| 7 - 8 | 30 | 0.07 | 19.89 | 30 | 233.8 | 660.5 | 30 | 27.9 | 275.9 |
| 8 - 9 | 2 | 0.00 | 0.00 | 2 | 73.1 | 135.4 | 2 | 0.0 | 2.0 |
| UNKNOWN | 106 | 1.02 | 13.14 | 78 | 190.9 | 804.0 | 109 | 475.3 | 526.0 |
| Salinity (%o): | | | | | | | | | |
| 31 - 32 | 2 | 0.60 | 25.07 | - | | | 2 | 6.4 | 18.0 |
| 32 - 33 | 3 | 4.73 | 148.50 | - | | | 4 | 17.4 | 4.2 |
| 33 - 34 | 6 | 0.49 | 7.12 | 1 | 0.0 | 0.0 | 7 | 3.1 | 1.9 |
| 34 - 35 | 35 | 0.86 | 29.91 | 11 | 90.9 | 487.4 | 35 | 99.0 | 402.7 |
| 35 - 36 | 55 | 0.65 | 37.68 | 52 | 244.0 | 635.7 | 55 | 126.1 | 229.7 |
| UNKNOWN | 134 | 0.90 | 12.21 | 102 | 210.6 | 895.3 | 137 | 384.5 | 381.2 |

Table 4.
Significance matrix of intership variances for cod 1983-1985.

A. I-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | = | = | - | = | = |
| CIR | = | XXXXX | ++ | -- | = | = | = | = |
| THA | = | -- | XXXXX | = | = | = | = | = |
| AND2 | = | ++ | = | XXXXX | +++ | +++ | ++ | = |
| TRI | = | = | = | --- | XXXXX | ///// | = | - |
| ELD | + | = | = | --- | ///// | XXXXX | = | ++ |
| SCO2 | = | = | = | -- | = | = | XXXXX | ///// |
| EXP | = | = | = | = | + | -- | ///// | XXXXX |

B. II-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | -- | = | = | = | = |
| CIR | = | XXXXX | = | ----- | = | = | = | = |
| THA | = | = | XXXXX | --- | -- | = | = | = |
| AND2 | ++ | +++++ | +++ | XXXXX | + | ++++ | ++ | = |
| TRI | = | = | ++ | - | XXXXX | ///// | - | = |
| ELD | = | = | = | ---- | ///// | XXXXX | = | = |
| SCO2 | = | = | = | -- | + | = | XXXXX | ///// |
| EXP | = | = | = | = | = | = | ///// | XXXXX |

| | | | |
|---|---|---|---|
| - | or | + | $p < 0.100$ |
| -- | or | ++ | $p < 0.050$ |
| --- | or | +++ | $p < 0.025$ |
| ---- | or | ++++ | $p < 0.010$ |
| ----- | or | +++++ | $p < 0.005$ |

Table 5.
Significance matrix of intership variances for haddock 1983-1985.

A. I-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | = | = | = | ///// | = |
| CIR | = | XXXXX | = | = | = | = | ///// | = |
| THA | = | = | XXXXX | = | = | = | = | + |
| AND2 | = | = | = | XXXXX | = | = | = | = |
| TRI | = | = | = | = | XXXXX | = | = | = |
| ELD | = | = | = | = | = | XXXXX | = | + |
| SCO2 | ///// | ///// | = | = | = | = | XXXXX | ///// |
| EXP | = | = | - | = | = | - | ///// | XXXXX |

B. II-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | = | = | = | ///// | = |
| CIR | = | XXXXX | = | = | = | = | ///// | = |
| THA | = | = | XXXXX | = | = | = | = | = |
| AND2 | = | = | = | XXXXX | = | = | = | = |
| TRI | = | = | = | = | XXXXX | ///// | - | = |
| ELD | = | = | = | = | ///// | XXXXX | = | = |
| SCO2 | ///// | ///// | = | = | + | = | XXXXX | ///// |
| EXP | = | = | = | = | = | = | ///// | XXXXX |

- or + $p < 0.100$
-- or ++ $p < 0.050$
--- or +++ $p < 0.025$
---- or ++++ $p < 0.010$
----- or +++++ $p < 0.005$

Table 6.
Significance matrix of intership variances for whiting 1983-1985.

A. I-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | = | = | -- | ///// | = |
| CIR | = | XXXXX | = | = | = | = | = | = |
| THA | = | = | XXXXX | = | = | = | - | = |
| AND2 | = | = | = | XXXXX | = | + | = | = |
| TRI | = | = | = | = | XXXXX | = | = | = |
| ELD | = | = | = | - | = | XXXXX | = | +++ |
| SCO2 | ///// | = | + | = | = | = | XXXXX | ///// |
| EXP | = | = | = | = | = | --- | ///// | XXXXX |

B. II-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | = | = | = | ///// | = |
| CIR | = | XXXXX | + | -- | = | = | = | = |
| THA | = | - | XXXXX | = | = | = | = | - |
| AND2 | = | ++ | = | XXXXX | = | = | = | = |
| TRI | = | = | = | = | XXXXX | //// | = | = |
| ELD | = | = | = | = | ///// | XXXXX | = | +++ |
| SCO2 | ///// | = | = | = | = | = | XXXXX | ///// |
| EXP | = | = | + | = | = | --- | ///// | XXXXX |

- or + $p < 0.100$
-- or ++ $p < 0.050$
--- or +++ $p < 0.025$
---- or ++++ $p < 0.010$
----- or +++++ $p < 0.005$

Table 7.
Significance matrix of intership variances for herring 1983-1985.

A. II-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | = | = | = | = | No data |
| CIR | = | XXXXX | --- | = | = | = | = | No data |
| THA | = | +++ | XXXXX | = | = | = | + | No data |
| AND2 | = | = | = | XXXXX | = | -- | = | No data |
| TRI | = | = | = | = | XXXXX | ///// | = | No data |
| ELD | = | = | = | ++ | ///// | XXXXX | ++ | No data |
| SCO2 | = | = | - | = | = | -- | XXXXX | No data |
| EXP | No data | No data | No data | No data | No data | No data | No data | XXXXX |

B. III-group.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | -- | = | = | = | No data |
| CIR | = | XXXXX | = | = | = | = | = | No data |
| THA | = | = | XXXXX | = | = | = | ///// | No data |
| AND2 | ++ | = | = | XXXXX | = | = | = | No data |
| TRI | = | = | = | = | XXXXX | ///// | = | No data |
| ELD | = | = | = | = | ///// | XXXXX | = | No data |
| SCO2 | = | = | ///// | = | = | = | XXXXX | No data |
| EXP | No data | No data | No data | No data | No data | No data | No data | XXXXX |

| | | | |
|---|---|---|---|
| - | or | + | $p < 0.100$ |
| -- | or | ++ | $p < 0.050$ |
| --- | or | +++ | $p < 0.025$ |
| ---- | or | ++++ | $p < 0.010$ |
| ----- | or | +++++ | $p < 0.005$ |

Table 8.
Significance matrix of intership variances for ln+1 transformed data for II→group cod and herring 1983→1985.

A. Cod.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | →→ | = | →→ | = | = | = | = |
| CIR | ++ | XXXXX | = | →→→→→ | = | = | →→ | = |
| THA | = | = | XXXXX | →→→→ | →→→→→ | = | = | = |
| AND2 | ++ | +++++ | ++++ | XXXXX | +++++ | ++ | ++++ | = |
| TRI | = | = | +++++ | →→→→→ | XXXXX | ///// | →→→ | = |
| ELD | = | = | = | →→ | ///// | XXXXX | → | ++ |
| SCO2 | = | = | ++ | →→→→ | +++ | + | XXXXX | ///// |
| EXP | = | = | = | = | = | →→ | ///// | XXXXX |

B. Herring.

| | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | →→ | = | = | = | + | No data. |
| CIR | = | XXXXX | →→→→→ | = | = | = | = | No data. |
| THA | ++ | +++++ | XXXXX | = | ++ | = | ++ | No data. |
| AND2 | = | = | = | XXXXX | = | →→ | = | No data. |
| TRI | = | = | →→ | = | XXXXX | ///// | = | No data. |
| ELD | = | = | = | ++ | ///// | XXXXX | +++++ | No data. |
| SCO2 | → | = | →→ | = | = | →→→→→ | XXXXX | No data. |
| EXP | No data. | No data. | No data. | No data. | No data. | No data. | No data. | XXXXX |

| | | | |
|---|---|---|---|
| → | or | + | $p < 0.100$ |
| →→ | or | ++ | $p < 0.050$ |
| →→→ | or | +++ | $p < 0.025$ |
| →→→→ | or | ++++ | $p < 0.010$ |
| →→→→→ | or | +++++ | $p < 0.005$ |

Table 9.
Significance matrices of within-year intership variances for II-group cod.

| A.1983 | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | ///// | ///// | = | = | ///// | = |
| CIR | = | XXXXX | = | = | = | ///// | ///// | ///// |
| THA | ///// | = | XXXXX | ///// | = | ///// | ///// | = |
| AND2 | ///// | = | ///// | XXXXX | = | = | ///// | = |
| TRI | = | = | = | = | XXXXX | ///// | ///// | = |
| ELD | = | ///// | ///// | = | ///// | XXXXX | ///// | = |
| EXP | = | = | = | = | = | = | ///// | XXXXX |

| B.1984 | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | ///// | - | = | = | ///// | = |
| CIR | = | XXXXX | = | - | = | = | ///// | = |
| THA | ///// | = | XXXXX | - | --- | ///// | ///// | = |
| AND2 | + | + | + | XXXXX | = | + | ///// | = |
| TRI | = | = | +++ | = | XXXXX | ///// | ///// | = |
| ELD | = | = | ///// | - | ///// | XXXXX | ///// | ///// |
| EXP | = | = | = | = | = | = | ///// | XXXXX |

| C.1985 | DAN2 | CIR | THA | AND2 | TRI | ELD | SCO2 | EXP |
|---|---|---|---|---|---|---|---|---|
| DAN2 | XXXXX | = | = | = | = | = | = | ///// |
| CIR | = | XXXXX | = | ----- | = | = | = | ///// |
| THA | = | = | XXXXX | -- | = | = | = | ///// |
| AND2 | = | +++++ | ++ | XXXXX | +++ | + | ++ | ///// |
| TRI | = | = | = | --- | XXXXX | = | - | ///// |
| ELD | = | = | = | - | = | XXXXX | = | ///// |
| SCO2 | = | = | = | -- | + | = | XXXXX | ///// |

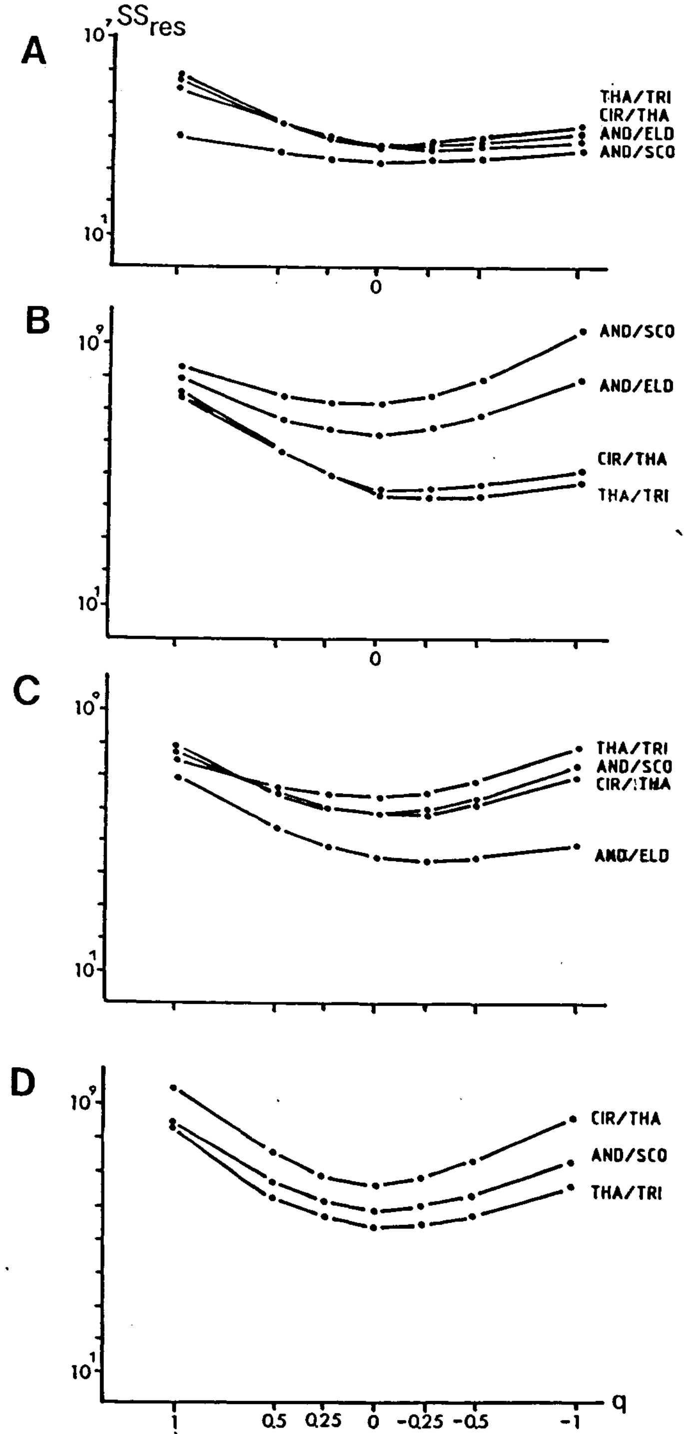


Figure 1.
Logarithmic plot of standardized residual sums of squares against transformation factor for individual intership comparisons.

A. Cod
B. Haddock
C. Whiting
D. Herring