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<u>An evaluation of different methods for the determination of food composition of fish</u>

by
Sture Hansson

ABSTRACT

Using data on stomach contents in <u>Perca fluviatilis</u>, <u>Rutilis rutilus</u>, <u>Myoxocephalus quadricornis</u> and <u>Coregonus nasus</u>, five methods for food composition determination are compared. Comparisons between calculated food compositions and similarity indexes between the food compositions of entire samples and subsamples are made. From these, it is concluded that the percent method is least biased and requires fewer samples than the other methods to describe the food composition of fish populations. It is also recommended that all fishes,independent of their stomach fullness should be included in the analysis.

Askölaboratory and
Department of Zoology
University of Stockholm
Box 6801
S-113 86 Stockholm
SWEDEN

1. INTRODUCTION

Knowledge of the diet composition of different organisms plays an important role in ecological investigations. Unfortunately the methods used often differ and may produce significantly different diets, which creates difficulties when data from different studies are compared. In the present paper, five methods for the analysis of the quantitative food composition of fish are compared with regard to their capacity to accurately describe diet compositions.

2. MATERIAL AND METHODS

During 1975-1977 ecological investigations were carried out in the archipelago of Luleå (Bothnian Bay, 65°30' N, 22°15'E). Within these investigations the fish fauna was studied by use of gill nets. Stomachs (in roach the anterior third of the digestion channel) from subsamples of the catches were preserved in 4% formaldehyde. The volume of each stomach content was measured using the displacement method and the composition examined under a stereo microscope (Wild M5). The percentage contribution from different food items was determined subjectively.

In the present paper the stomach content of four of the most abundant demersal fish species (perch - Perca fluviatilis L., fourhorn sculpin - Myoxocephalus quadricornis L., roach - Rutilus rutilus L., whitefish - Coregonus nasus Pallas) are analysed using five different methods:

The occurrence method: The occurrence frequencies of all food items are summed and the frequencies are then divided by this sum and multiplied by 100 to obtain the percentage composition in the diet.

The percent method: The ratios (in %) of each food item are summed separately for all the stomachs studied. These sums are then divided by the number of stomachs examined to give the percentage composition in the diet.

The volume method: The total volume of each type of food is divided by the total food volume. These ratios are then recalculated to give the food composition (in %).

The point method: Hynes (1950) described a point method in which stomachs influenced the results proportionate to their fullness. The point method used in the present paper is a modification of this method. First the fullness index of a stomach is calculated (see formula below) and then each food item is allotted a fraction of this index proportionate to their share of the content. The fractions for each seaparate item are then summed for all stomachs and the percentage composition in the diet determined relative to these sums.

The CFI (Comparative Feeding Index) *method:* This method, described by Christensen (1978), is a combination of the point and occurrence method. The ratio of each food item in the diet according to the two methods is multiplied and the products are scaled to give the percentage composition in the diet.

Formula used in the calculations of the fullness indexes

$$\text{Fullness index} = \frac{V \times 100}{W}$$

V = volume of food (in ml) in the stomach
W = the theoretical weight of the fish as calculated from its length and the species specific length-weight relationship ($W = k_1 \times l^{k_2}$) found in the area (Hansson, unpubl).

For each species, the diet analysis, using the five methods presented above, was carried out in two steps. Calculations were first made using the total number of stomachs and then using 135 different subsamples (5, 10, 15, 20, 30, 40 or 50 fish in each, Table 1) selected randomly from the total number.

In some of the calculations all stomachs with content were used, in others only those exceeding a predetermined minimum fullness index. The similarity in food composition between the entire sample and each subsample were calculated using the Sanders index (Sanders 1960, 100% similarity when samples are identical and 0% when totally disimilar). In these calculations only data derived by using the same method and minimum fullness index were used. From sets of subsamples, with the same number of fish in each, mean similarity indexes and standard deviations were calculated. The diversity of the food composition was calculated using the Shannon index (Odum 1971, p. 144).

Subsampling and calculations were carried out on a Tektronix 4051 computer and a Tektronix 4907 File Manager.

3. RESULTS

3.1. The analysis of the total number of stomachs

A comparison of the methods clearly shows that they may give substantially different results (Fig. 1). The occurrence and percent methods generally emphasize small food organisms to a greater extent than the other methods. When the diversity in food composition is high (perch and whitefish), these methods give similar results, while when it is very low (fourhorn sculpin) they deviate considerably from each other. When the diets are calculated using the volume, point or CFI method fewer important food items are registered. The diversity in food is always lower when calculated from diets obtained by the CFI method than by any of the others.

In perch the exclusion of low fullness indexes strongly influences the diet compositions, increasing the importance of fish in the diet (Fig. 2).

3.2. Comparisons between subsamples and the entire samples.

The similarity in diet composition between subsamples and the entire sets of stomachs generally decreases as the diversity in the diet increases. The CFI method shows higher similarity indexes than the other methods when the diversity in food composition is low (fourhorm sculpin and roach, Fig. 3 and 6) while, when the diversity is higher, the similarity decreases dramatically. In species with a relatively high diversity in food composition (perch and whitefish, Fig. 4 and 5) the occurrence method displays higher similarity indexes than any of the others. The percent method frequently yeilds results among the highest similarity indexes, while the volume and point methods generally demonstrate lower indexes than the other methods.

When only stomachs exceeding a minimum fullness index are considered, the similarity between subsample and entire sample generally increases (Fig. 7). The variation in similarity indexes claculated form equal sized subsamples is shown in Fig. 8. These results clearly show thar the occurrence and the percent methods generally results in a less variable similarity than the other methods. It can also be seen that there is no obvious correlation between minimum fullness index and standard deviation.

4. DISCUSSION

As the entire sample consisted of fish of different sizes, caught at different stations and seasons, this artificially created a greater diversity than normal and may have resulted in diets of little biological relevance. The diets of perch, for example, were calculated using data from both small and large specimens despite the fact that these are known to have significantly different feeding habits. However, as the aim of this paper is to compare methods rather than to describe diets, this will not affect the possibilities of making general conclusions from the results.

All stomach data used was derived from fish caught in gill nets. As they may very well have been trapped 8-10 hours before they were killed, differences in digestion rate between food items may have severely biased the results. Fish which, when caught, had only easily digestible items in the stomach would have a lower stomach fullness than those containing items which remain for a considerable time in the stomach. The use of minimum fullness indexes will then further bias the results in favour of slowly digested items.

When the food composition is analysed using the volume method the stomach content of large fish will influence the results comparatively more due to their larger stomach content compared to small fish. In the point method, the volume differences due to fish size is compensated for by the use of a fullness index. Despite this, stomachs with slowly digestible food items will be over emphasized as they may be expected to show greater fullness than others. Even if food items have the same evacuation rate and only fish within a narrow size range are considered, the volume and point methods seem to be unrealistic. For example, fish which have been caught for a long time and which therefore may have less stomach content are assigned less importance. The CFI method often results in diets similar to the volume and point methods, but with fewer important food items (lower diversity). The weak point in this method and in others which combine diets calculated using the results from other methods (e.g. the IRI method, Pinkas _et al._, 1971) is that the division of the food contents into separate components may affect the results significantly (see example in Table 2).

The discussed difference in digestion rates does, of course, also influence the diets calculated by the occurrence and percent method. However, both these methods account more for small, usually easily digested animals than do the others. One disadvantage of the occurrence, compared to the percent method, is that the former assigns the same value to a food item independent of its fraction of the stomach content. This means that if two items occur with the same frequency, but one always contibutes a much larger fraction of the stomach content than the other, the occurrence method assigns both items the same value in the diet. This method may also overemphasize items with slowly digested components (e.g. spines, shells) with a long retention time in the stomach. This type of bias is probably the reason why the occurrence method differs from all the others in the analysis of the food composition of fourhorn sculpin.

One advantage in using the occurrence compared to the percent method, is that it does not require determinations of the quantitative composition of the stomach content. Such determinations are either carried out subjectively or require measurements which are very time consuming, especially when the diversity in food is high. In some cases it can be impossible to separate different food items for volume/weight determinations. The results presented indicate, however, that the occurrence and percent methods deviate significantly from each other only when the diversity in diets is low. Under such circumstances either subjective determinations can be made fairly accurately or only few measurements are needed. When diversity is high, the methods give similar results, indicating that the errors in the subjective determinations have only slight effects on the results.

In most investigations on food composition, limited numbers of stomach analyses are used to describe the diet of parts or of entire populations. In this respect the determination of diets from subsamples drawn from large samples of stomachs could be considered to simulate such investigations. Consequently, from comparisons of the similarity indexes displayed, conclusiong can be drawn about which methods need the smallest sample to describe the diet of populations.

Such comparisons clearly show that the volume and point methods need larger samples (= displays lower similarity indexes) than the others. Of the remaining three methods, the CFI results in low similarity indexes when the diversity is high and the occurrence method when it is low. Only the percent method results in comparatively high similarities for all species investigated.

The use of minimum fullness indexes generally increase the similarity between subsamples and the entire sample. The use of such discrimations do, however, decrease the number of observations and in the present investigation these effects tended to rule each other out.

As already pointed out, the use of minimum fullness indexes have no effect on the standard deviations calculated for the similarity indexes. The lower standard deviations obtained with the occurrence and percent methods indicate that these are less sensitive to single deviating specimens than the other methods.

5. CONCLUSIONS

When calculating food compositions from gill-net catches

a) the percent method is considered the most suitable

b) minimum stomach fullness shall not be used to eliminate stomachs from the analysis.

6. REFERENCES

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Table 1. The number of different sized subsamples taken randomly from the entire samples of the different species.

No. of obs. per subsample	No. of Subsamples
5	25
10	25
15	25
20	25
30	15
40	10
50	10

Table 2: Effects of different divisions of stomach food contents into separate components on diets, as calculated by the CFI method.

Food composition a)

Calculation method:	Occurrence	Point	CFI
Food:			
Mysis relicta	10%	10%	2%
M. Mixta	10%	10%	2%
Neomysis vulgaris	10%	10%	2%
Other items	70%	70%	94%

Food composition b)

Calculation method:	Occurrence	Point	CFI
Food:			
Mysids	30%	30%	16%
Other items	70%	70%	84%

Note that according to a), Mysids contribute 6% of the food and in b) to 16%.

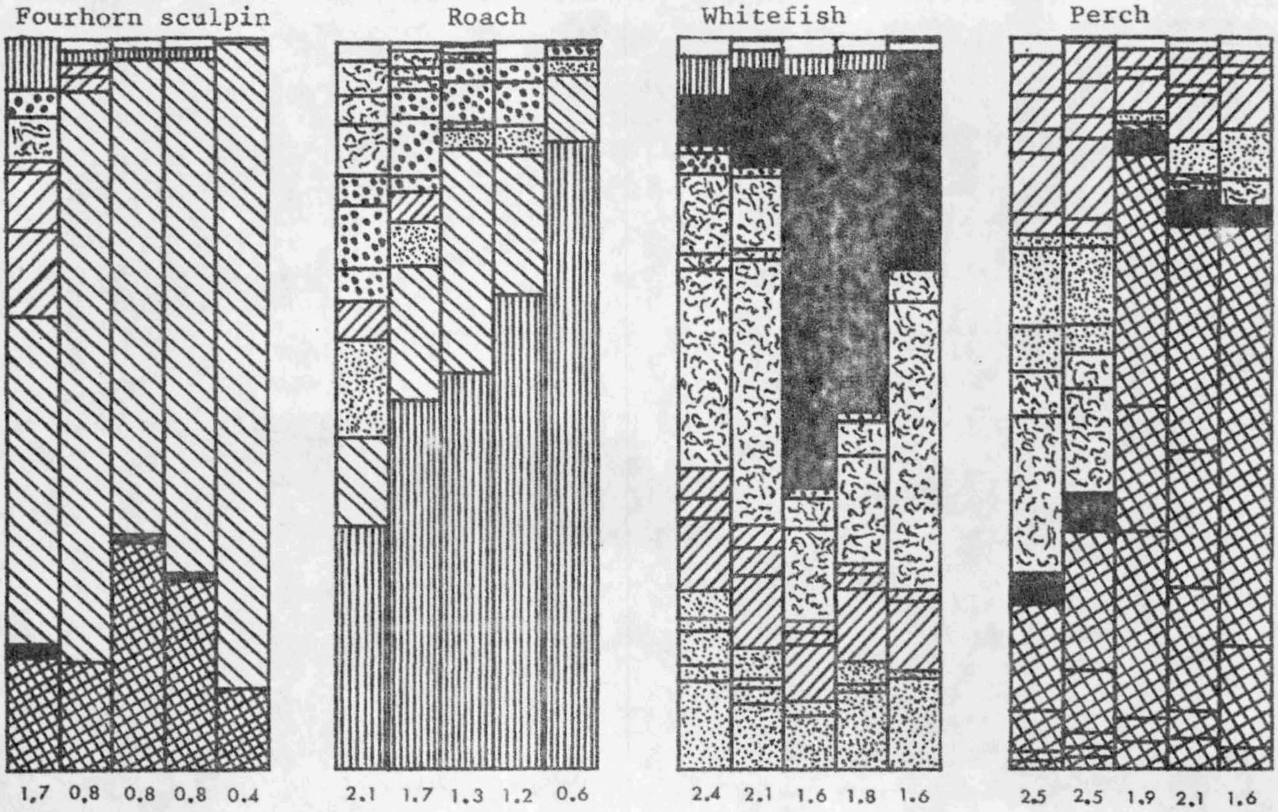


Fig. 1: Food composition of the investigated species calculated using the different methods. All fish, independent of stomach fullness considered. Methods from left to right: occurrence, percent, volume, point and CFI. Diversity in food composition indicated below figures.

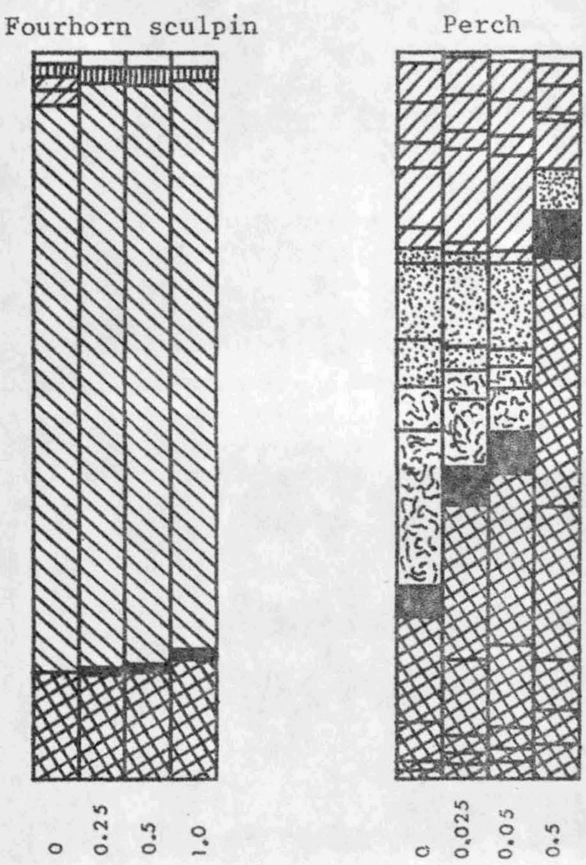
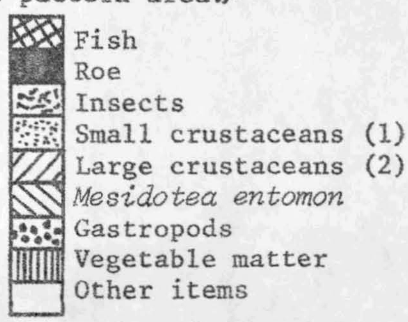


Fig. 2: Food composition of fourhorn sculpin and perch calculated by the pernent method and using different minimum fullness indexes (indicated below figures).

To make the figures clearer only nine patterns have been used. In the calculations however, the number of different items were considerably higher (as indicated by the horizontal bars separating different items within the same pattern area.)



(1): copepods, cladocerans, ostracods
(2): mysids, amphipods and isopods except for *M. entomon*.

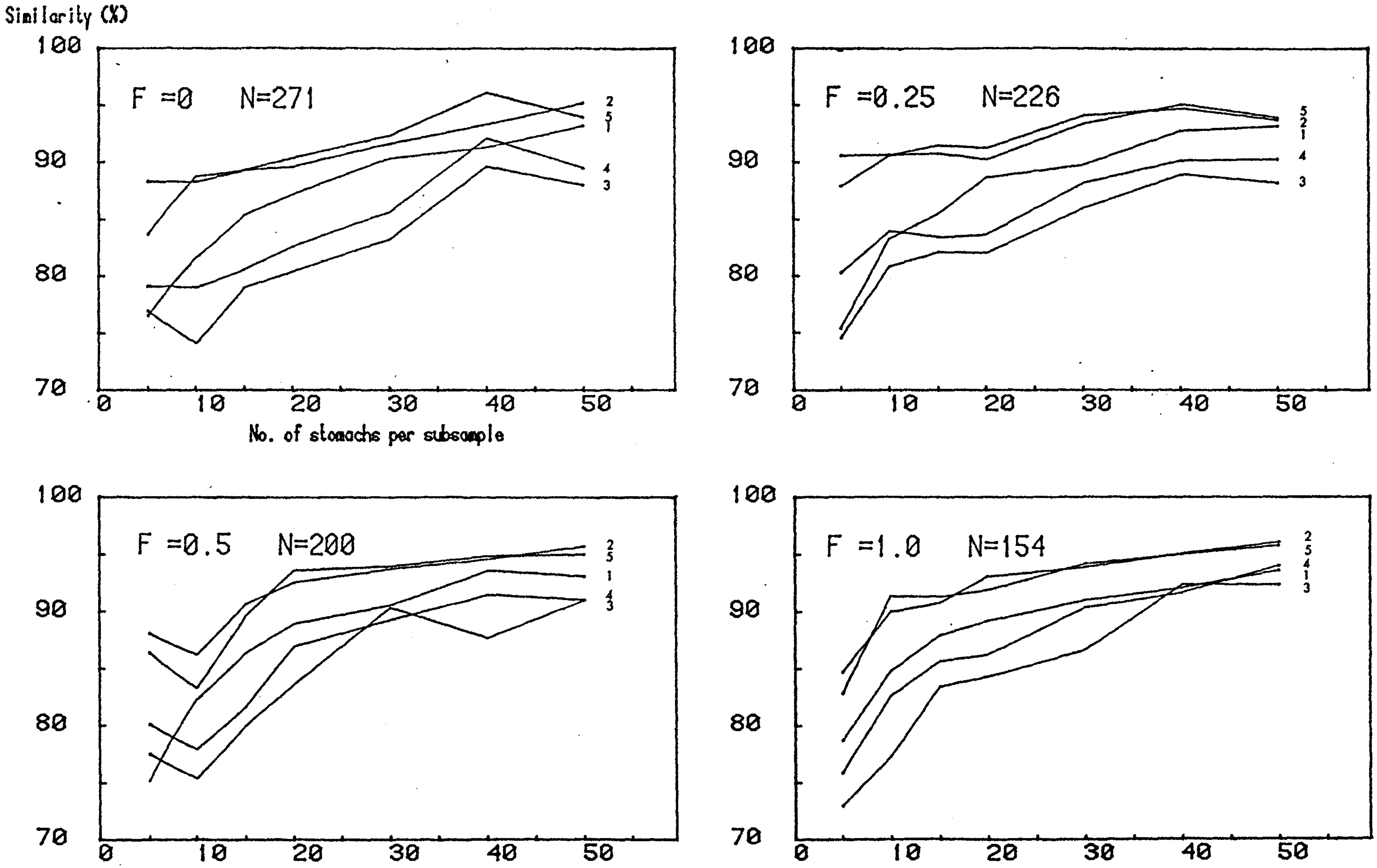
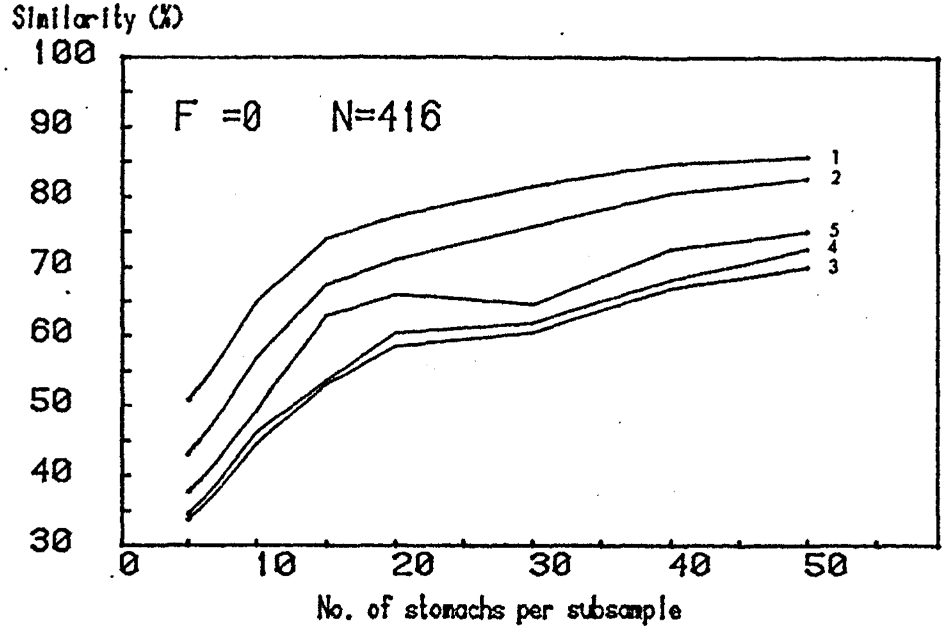


Fig. 3: Mean similarity in food composition between different sized subsamples and the total numbers of fourhorn sculpin analysed. See Table 1 for the numbers of subsamples per set. Figures at curves denote analysis method, 1 = occurrence method, 2 = percent m., 3 = volume m., 4 = point m. and 5 = CFI m. F = minimum fullness index, N = the total number of specimens at or above this index.



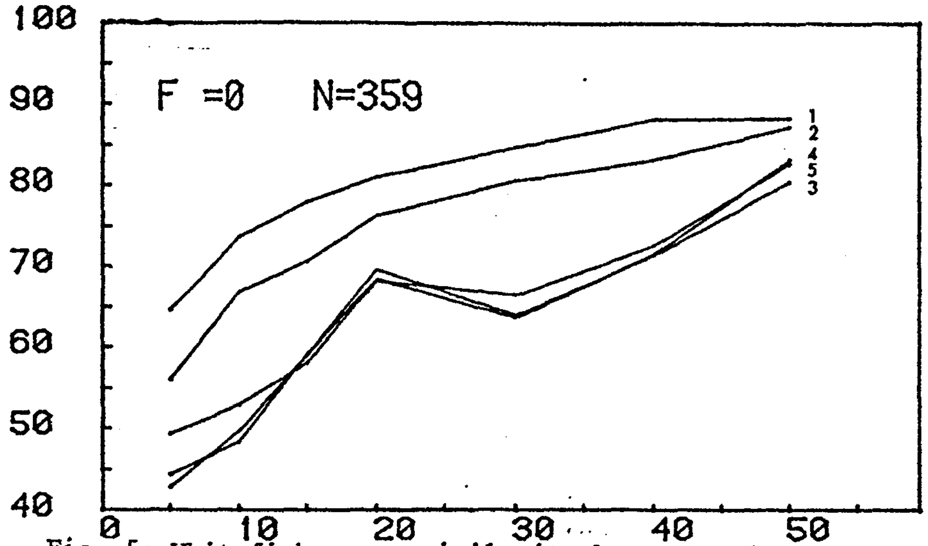


Fig. 5: Whitefish, mean similarity between subsamples and the total number of stomachs analysed. Explanations in Fig. 3.

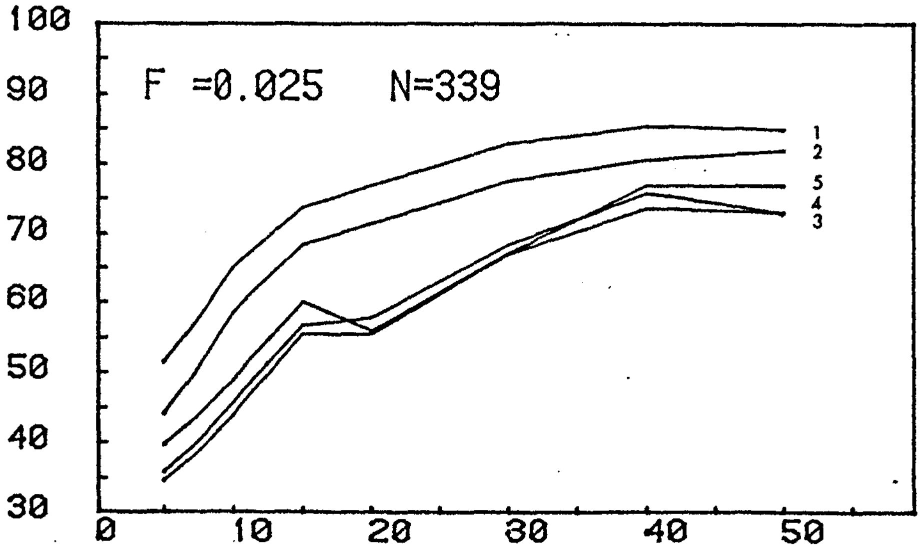


Fig. 4: Perch, mean similarity between subsamples and the total numbers of stomachs analysed. Explanations in Fig. 3.

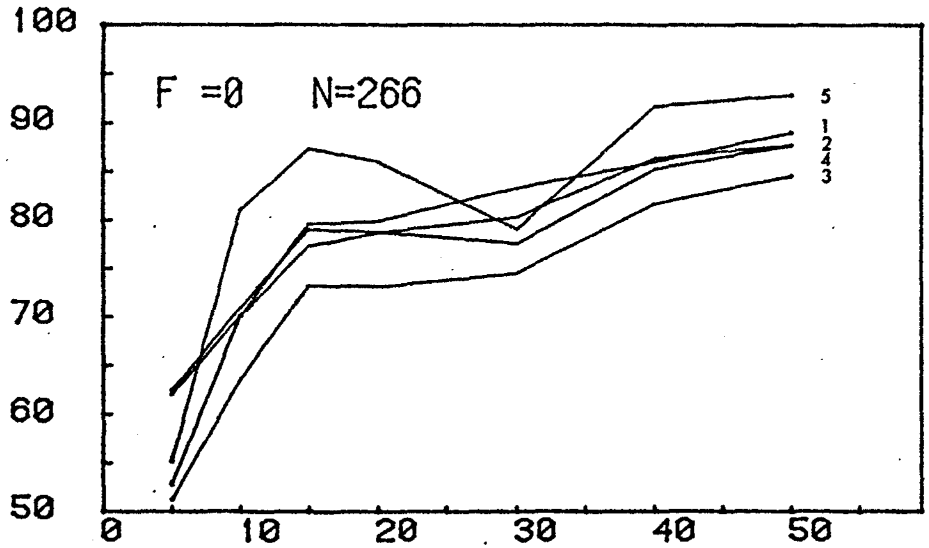


Fig. 6: Roach, mean similarity between subsamples and the total number of stomachs analysed. Explanations in Fig. 3.

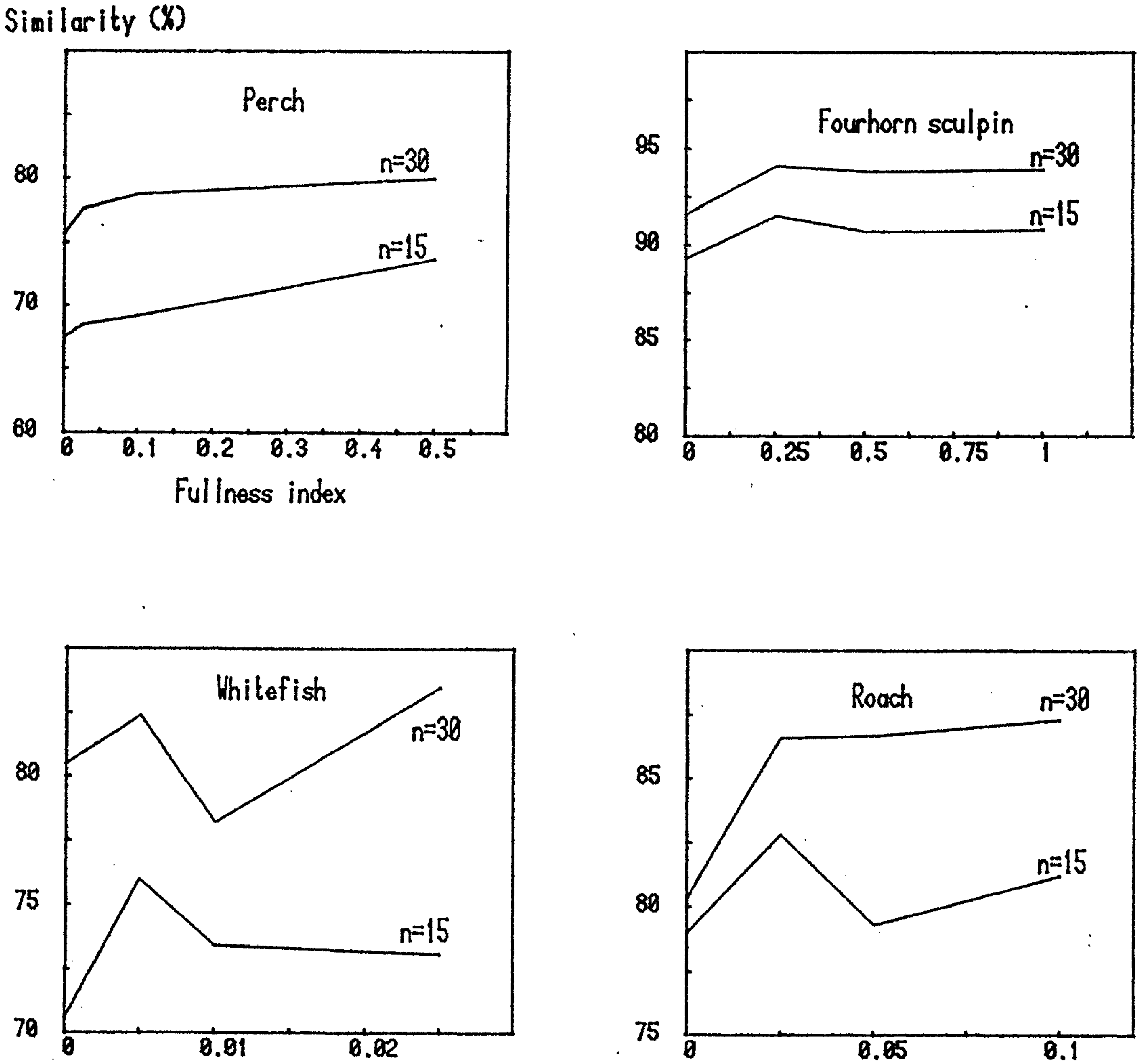


Fig. 7: The effect of different minimum fullness indexes on the mean similarity between subsamples and entire samples. n = number of stomach analysed per sample.

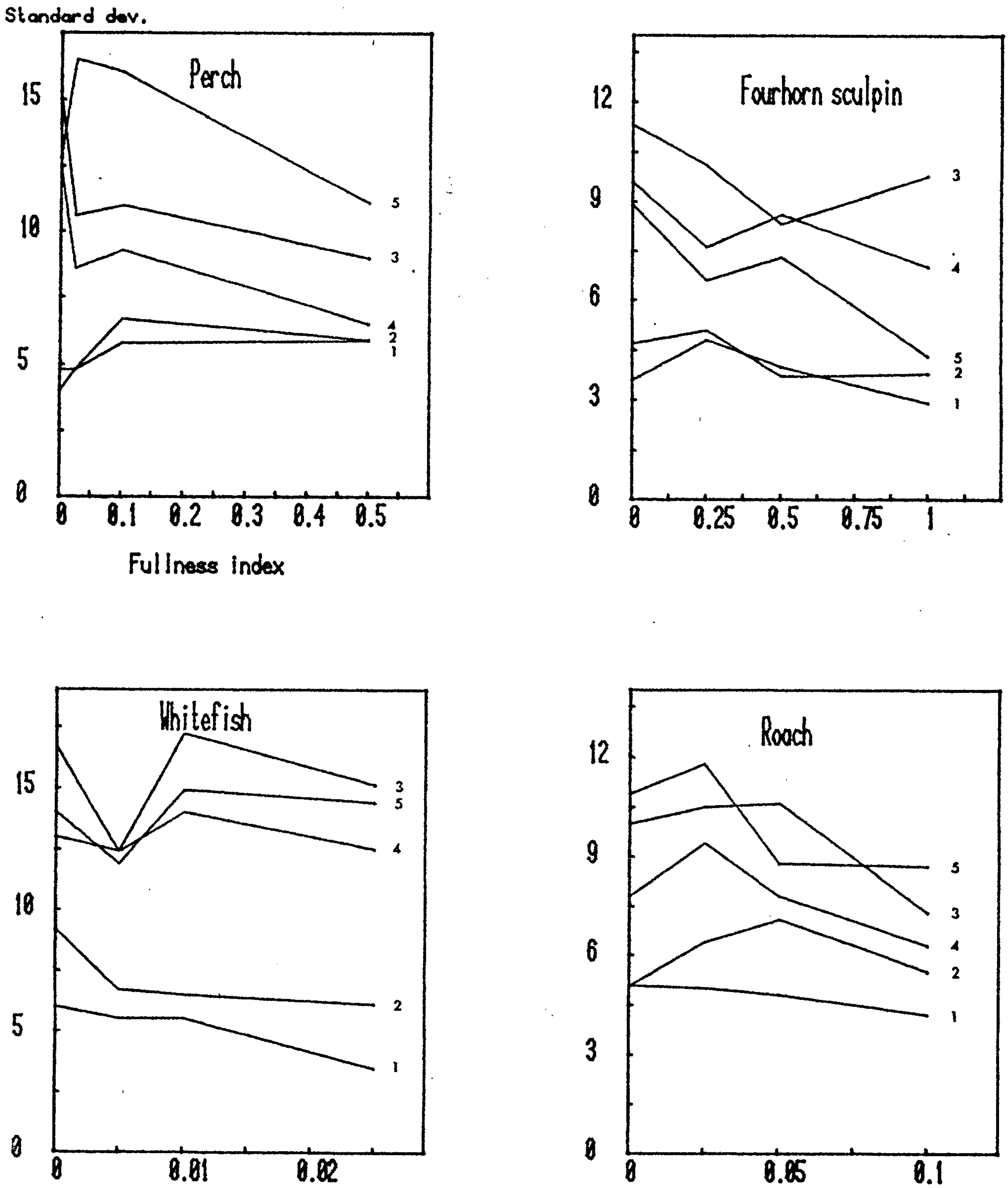


Fig. 8: The effect of different minimum fullness indexes on standard deviations in similarity indexes calculated from subsamples of 15 analyses in each. Figures at curves denote the analysis method, 1 = occurrence method, 2 = percent m., 3 = volum m., 4 = point m. and 5 = CFI m.