On the Use of Meiofauna in Ecological Monitoring: Who Needs Taxonomy?

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Taxonomic problems have hindered the widespread use of meiobenthos for the purpose of pollution monitoring despite its potential usefulness. The question whether it is necessary to go down to species level in order to distinguish assemblages and stations was studied using data on meiofauna densities available from a GEEP-workshop held in Norway, August 1986.

Using the complete species list of harpacticoid copepod and nematode species, the six stations could be clearly separated by different multivariate techniques (TWINSPAN, DCA, MDS, Clustering). The abundance data of the genera, the families and even the orders (in the case of nematodes) still allowed a more or less clear separation of the stations, although their relative relationships were sometimes distorted. Thus, from a practical point of view, it may be sufficient to identify the animals to genus or family level.

It is proven that this result is not due to ecological similarities between congeneric or confamilial species. The species groups typifying the stations in the TWINSPAN analysis did not contain more confamilial species pairs than expected from random sorting. Randomly assembled 'families' allowed a separation of the stations as clear as that based on taxonomic groups.

We conclude that the information contained in species abundances was preserved, at least partially, when the species are grouped, even at random. The grouping in higher taxonomic categories was as good as any, and more convenient than all the others. However, within the (limited) range of habitats studied, ecological adaptation is achieved nearly exclusively on the species level.

During the last decade, the detection and description of pollution influence has become an increasingly important field of marine research. Among the different methods in use, ecological monitoring has a function mainly as a *post hoc* detection (Rapport *et al.*, 1985). Its importance lies also in the fact that a change in the existing communities is often the criterion by which to judge if a certain pollution load can be accepted.

In practice, ecological monitoring typically covers one or a few taxonomical groups (taxocenes). The choice of the taxocene depends on practical and theoretical considerations. The possibilities for sampling and the taxonomical expertise available in an institute or even country usually are important practical considerations. On the other hand, the sensitivity of the ecological monitoring depends on the range of stress conditions in which the taxocene can be found, on the array of responses that can be displayed by the taxocene in different conditions, and on the 'stability of the baseline', i.e. the predictability of the ecological structures under undisturbed circumstances (Herman & Heip, 1986).

Meiofauna and Pollution Monitoring

In almost all respects the meiobenthos has quite interesting features for monitoring work. Extensive arguments and references in favour of ecological monitoring with the meiobenthos are given by Heip, Warwick *et al.* (1988). In short, the meiofauna occupy all marine habitats, from severely stressed (both naturally and anthropogenically) sites to the most clean and

undisturbed ones, from the high beach to the hadal depths. The number of species that exists is high, so that a large number of quite different assemblages can be found in different sediment types. These assemblages are specific and typical for the circumstances in which they occur, and the diversity of meiofauna assemblages permits the recognition of many different circumstances. The density of the meiobenthos is high, in the order of $1 \times 10^6 \text{ m}^{-2}$, so that relatively small samples suffice. The predictability is reasonable, and generally better than in the macrofauna. When undisturbed, temporal variability is on time scales of one year or longer. On the other hand, short generation times (weeks to months) can yield a fast reaction to disturbances.

However, the meiobenthos presents major taxonomical problems to the inexperienced researcher. The experienced researcher still has to devote a considerable effort in the identification of species. Therefore the cost-effectiveness of monitoring the meiobenthos is generally considered relatively unfavourable.

The cost would be drastically reduced if it were possible to detect pollution effects by studying the meiobenthos at a higher taxonomic level, e.g. genus or family. Since the publication of Platt & Warwick's (1983) pictorial key to nematode genera, identification of these animals to genus level has become quite feasible (and even easier than direct identification to family level). For copepods, identification to family level may, in most instances, avoid the time-consuming dissections.

Results from the Oslo Workshop

The IOC/GEOP Biological Effects Workshop, held in Oslo in August 1986, was a good opportunity to study these possibilities. The aim of this workshop was to compare different methods of pollution detection and monitoring. Ecological monitoring of the meiobenthos was one of the methods used. The results of this exercise are extensively described by Heip, Warwick *et al.* (1988), where an account of the methods can also be found.

For the purpose of this note it is sufficient to state that six stations, A–F, along a supposed pollution gradient were sampled for meiofauna (Fig. 1). All copepod specimens in three replicates from each station were determined to species level. For nematodes, 200 specimens were determined in two replicates per station.

The results of the pollution monitoring exercise are discussed in Heip, Warwick *et al.* (1988). In general, it was not possible to detect the supposed pollution gradient. The same conclusion was reached with most other methods. On the other hand, it was shown that each station had a typical meiofauna assemblage. Differences in faunal composition were much larger between stations than between replicate samples within stations. Moreover, some stations (mainly station F) showed clear symptoms of stress. In the undisturbed to moderately stressed range, copepod assemblages differed more between stations than nematode assemblages. However, nematodes cover a broader range of

Fig. 1. Position of the six sampling stations (A–F) in Frierfjorden and Langesundfjorden, Norway. From Heip, Warwick *et al.* (1988).

stress conditions. In station F copepods were nearly absent.

Heip, Warwick *et al.* (1988) discuss at length the possibility of performing ecological monitoring without identifying the animals to the species level. They conclude that meaningful ecological monitoring is possible with higher taxonomical levels. The nematodes were less sensitive (compared with copepods) to the grouping of the species in genera, families and even sub-orders. This assertion was mainly based on the fact that, with different multivariate analyses and even with higher taxonomic levels, replicates from the same station were consistently sorted closer together than were the replicates from different stations, and that the relative positions of the stations in ordination diagrams did not change very much. Some changes did occur. In general the distinction between stations C and D became unclear with higher levels. With copepods, grouping from the genus level onwards changed the relative positions of stations A and E: although they still were distinct from each other, the distance in the ordination graphs was reduced.

The Hypothesis

The observation that stations are characterized by meiofauna genera and even families, leads to the hypothesis that species belonging to the same taxonomical group (congeneric, confamiliar) are consistently more similar in their ecological preferences to each other than to members of other groups.

The Tests

In a first test we created what we call 'random families' of copepods and nematodes, and tested how good they were in separating the stations. These random families were created by forming as many groups as there were taxonomic families in the species list (29 for

nematodes and 12 for copepods), and assigning each species at random to one of the groups. Afterwards these groups were treated in the same way as the taxonomic families.

The clustering of the stations on the basis of these random species groups was sometimes slightly better, and sometimes slightly worse than the clustering on the basis of the real families. Fig. 2 compares the clustering of the stations based on copepod species (Fig. 2a) and on the real, taxonomic copepod families (Fig. 2b) to two clusterings based on 'random family' groupings (Fig. 2c,d).

Detrended Correspondence Analysis and TWINS-SPAN analysis (Hill, 1979) showed the same qualitative result: the analyses with the 'random family' groupings are about as similar to the analysis based on species composition as is the analysis based on the real families.

The discrimination of the stations based on the real and 'random' families is poorer than that based on the species abundances. In a next step we show that this is not due to the relatively low number of groups (descriptors) used (12 and 29 for copepods and nematodes respectively). We performed a TWINS-SPAN classification of the species data. TWINS-SPAN gives a simultaneous classification of species and stations resulting in a table that shows a station clustering, with for each station group their associated group of species.

From these tables groups of ecologically related species were formed, and called 'optimal families'. The number of these 'optimal families' was the same as the number of real families: 12 for copepods and 29 for nematodes. They were then treated in the same way as the real and random families.

As an example Fig. 3 compares the results of the DCA of copepod species with the DCA of copepod 'optimal families'. Based on the latter, the discrimination between the stations is as good as, or even better, than the discrimination based on the individual species abundances. This comes as no surprise, in view of the relationship between the DCA and TWINS-SPAN methods. It proves, however, that the low number of descriptors *in itself* is no reason for the poorer discrimination. 12, with respect to 29 groups is enough for a good discrimination, if the groups are composed of ecologically similar species. Consequently, the fact that real families do not give a better discrimination of the stations is due to the fact that confamiliar species are not very similar in their ecological preferences.

We tested subsequently, if confamiliar species are ecologically more related to one another than any random pair of species. Both within nematodes and copepods, all species were classified in a two-way table according to taxonomic families on the one hand, and the 'optimal families' on the other hand. A G/q test of association (Sokal & Rohlf, 1981) showed no relationship between the two classifications, neither in copepods nor in nematodes. (For the purpose of this test groups with few species had to be lumped in one 'rest' group, as an excessive number of zeros in the table affects the efficiency of the test). However, we did find a significant association between feeding types of nematodes and the optimal families.

Fig. 2 Clustering of the station replicates (Bray-Curtis similarity, flexible sorting, $\beta = -.25$) based on: a. copepod species, b. copepod taxonomical families, c. and d. two runs of 'random families'. a. and b. from Heip, Warwick *et al.* (1988).

Fig. 3 First two axes of a detrended correspondence analysis of the station replicates, based on a. copepod species and b. 'optimal families'. a. from Heip, Warwick *et al.* (1988).

Conclusions

Our conclusions from this study are then:

1. Any grouping of the species allows a discrimination between the stations. Factors that influence the occurrence and abundance of species (both natural and pollution factors) will still be recognized from a monitoring based on species groups (e.g., based on higher taxonomical levels).

2. A taxonomical grouping is as good as any other, but not better. However, it is much more convenient. If grouping is envisaged for monitoring, a taxonomical grouping seems the most appropriate.

3. Within the copepods and nematodes, similarities in ecological preferences between species are not a consequence of the fact that they share a number of morphological features used in their classification.

Based on competitive exclusion theories, another result of the test of association could also have been expected. If closely related species exclude each other due to competition for shared resources, we would expect to find less confamilial species in any of the 'optimal families', than expected from random sorting. This was not the case. However, our data do not permit to judge the possibility of mutual exclusion on a smaller horizontal scale (mm to cm) or along the vertical dimension. On the scales covered by our sampling, we did not find any evidence of a closer ecological relation of whatever kind between confamilial species than between any randomly chosen pair.

In this study we only compared sediments with similar abiotic characteristics. Especially stations B, C, and D were very similar to each other with respect to sediment composition and depth, the two most important determining factors for the fauna. Our conclusions may be determined by this relative homogeneity. For some nematode and copepod groups, it is known that they are restricted to particular sediment types. Draconematoidea and Epsilonematidae, for example, are generally restricted to coarse sediments (e.g. Willems *et al.*, 1982). Interstitial families of copepods only occur in sediments where interstitial life is possible (median grain size larger than about 125 μ m). In a study including large differences in sediment structure, it can be expected that clear associations between these groups and the ecological preference groups would be found.

However, the purpose of any ecological survey

should not be to demonstrate that the fauna in a coarse gravel station is different from that in a fine silt sediment. Within groups of stations with similar abiotic conditions, we think our results are fairly general. Just how similar the stations should be is difficult to assess. Maybe the borderline between interstitial and non-interstitial life is of great importance.

By and large, it remains obscure what determines the often very high species diversities of meiofauna. We did not find evidence for similar ecological preferences in taxonomically related species. Nor could we demonstrate competitive exclusion between related species. It is known that the meiofauna finely tunes its vertical distribution (Joint *et al.*, 1982). Closely related species may sometimes avoid each other along the vertical axis (e.g. Boucher, 1972).

On the other hand, we did find some relation between feeding type and 'optimal families'. It seems likely that physiological differences between the species, either in their food preferences or in their tolerance to suboxic conditions, can provide some explanation of the high diversities. Many of these specialisations seem to occur only at species level. Thus, although ecological monitoring may do without specialised taxonomists, it is clear that taxonomy will continue to be of high importance for ecological studies of the meiofauna.

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