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Species richness of macrozoobenthos, especially chironomid communities, in the littoral zone of some Finnish lakes

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The species richness increased with the area sampled and the number of individuals studied in the oligotrophic, clear-water Lakes Pääjärvi and Inarijärvi, while five lakes sampled by the same methods showed a strong correlation between the abundance of individuals and species richness and between biomass and species richness. Total phosphorus and water colour seem not to explain the variation in species richness. The results regarding the whole macrofauna and the chironomids alone were parallel.

1. Introduction

Though the term diversity is in common use, the concept is not easy to define. In many papers species diversity is synonymous with species richness or else species richness is at least considered one of several possible measures of species diversity (Magurran 1988). Species richness indicates how many species based on the estimate obtained from the sample occur in the study area. Hurlbert (1971) also used the term "species density" in this case. Species richness is especially influenced by the number of rare species. Indices based on the proportional abundances of species seek to crystallize richness and evenness into a single figure. These indices have been strongly criticized (see Hurlbert 1971), for although species diversity and species richness are often positively correlated (Paasivirta 1976, Smith et al. 1979, Magurran 1988), this is not a necessity (see Hurlbert 1971).

When comparing the richness of communities we need to eliminate differences arising from sample size. The number of species increases in relation to the area sampled (Kempton 1979, Magurran 1988), often on account of the increasing number of microhabitats (e.g. Sarvala 1986). The number of species is also related to the number of individuals studied or to the population density, and a true comparison of the communities may be obscured if the diversity estimators are biased (Kempton 1979). Many researchers have presented relationships between species diversity (or richness) and biomass (or productivity) (e.g. Grime 1973, Huston 1979, Rex 1981, Tilman 1982, Sousa 1984, Huston 1985), but the ultimate mechanism is not clear, because new species can not appear from the biomass.

The aim here is to study the relations between the area sampled, abundance, biomass and the species richness of the whole macrozoobenthos and that of chironomid taxa, and the influence of the standardizing of several factors affecting the habitat structure of lake littoral (see Palomäki 1992) on the species richness.

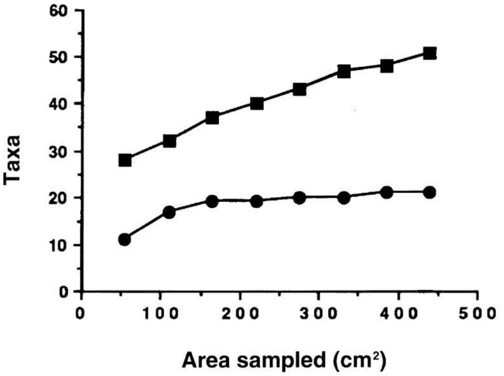

Fig. 1. Relation between the number of taxa in the whole macrozoobenthos (squares) or the chironomids alone (circles) and the area sampled on 27 Aug. 1973 in the soft bottom of Lake Pääjärvi at a depth of two metres. Samples taken with a tube sampler. Order of the samples random in the figure.

2. Material and methods

Since the mesh size of the sieve, the sampler type and the person who picked out and identified the animals can all influence the number of species in a sample (see Sanders 1968), we sampled with two different methods, and analyzed the data separately. The animals in the first group, obtained with a tube sampler (random sampling, 5–8 replicates per station, Table 1) were sorted under a binocular microscope, while those in the second, sampled with an Ekman-Birge grab, (random sampling, Lake Pyhäjärvi: 5 replicates per station, others: 3) were sorted under a loupe. The mesh size of the sieves was 0.4 mm and the sampled depths were 0.5, 1 and 2 m. Samples were not taken at the shallowest station in Lake Pääjärvi (0.5 m). All the samples were preserved in ethanol or formaldehyde (except those from Lake Sarmijärvi and Lake Sarmilompolo, which were sorted alive). The animals were identified to species or larval types as far as possible. The biomasses (ash free dry weight) of all animals

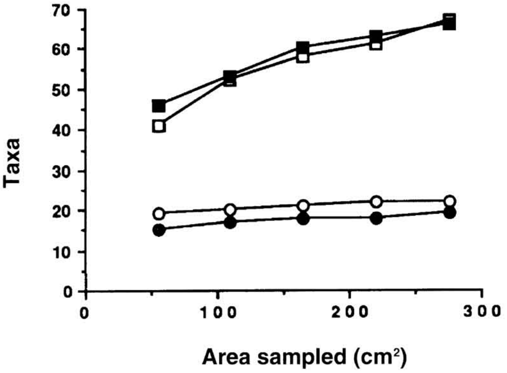

Fig. 2. Relation between the number of taxa in the whole macrozoobenthos (squares) or the chironomids alone (circles) and the area sampled on two dates (open symbols 8 Aug. and filled symbols 27 Aug. 1973) in the soft bottom of Lake Pääjärvi at the depth of one metre. Samples taken with a tube sampler. Order of the samples random in the figure.

Table 1. Dates of sampling in the various lakes and methods used.

Lake, coordinates	Date	Samples
Tube sampler, 55 cm²		
Lake Pääjärvi, 61°04′N, 25°08′E	08.08.1973	5
Lake Pääjärvi	24.08.1973	13
Ekman sampler, 289 cm²		
Lake Inarijärvi, 68°58′N, 27°52′E	19.06.1977	18
Lake Inarijärvi	8.08.1977	18
Lake Sarmijärvi, 68°47′N, 28°11′E	20.07.1978	18
Lake Sarmilompolo, 68°47′N, 28°07′E	8.08.1978	18
Lake Pyhäjärvi, 63°36′N, 26°02′E	18.08.1979	30
Lake Alajärvi, 68°00′N, 23°52′E	4.09.1986	9

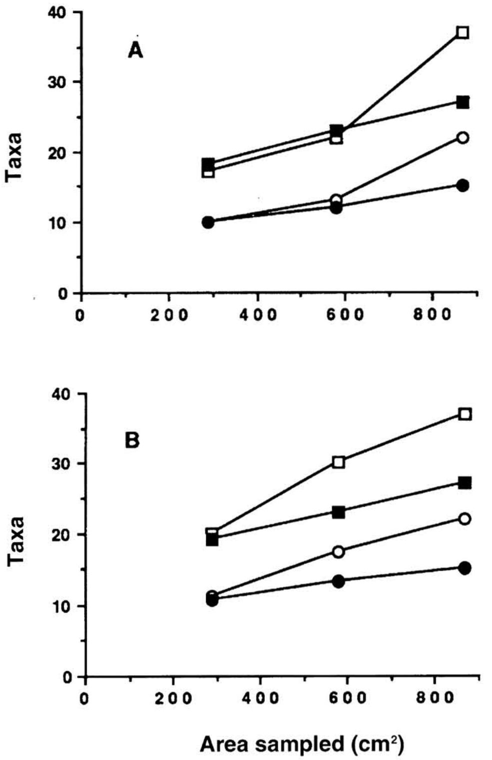

Fig. 3. Relation between the number of taxa in the whole macrozoobenthos (squares) or the chironomids alone (circles) and the area sampled in two seasons (open symbols 9 June, filled symbols 8 Aug. 1977) in the soft bottom of Lake Inarijärvi at a depth of two metres. Samples taken with an Ekman grab. Order of the samples random in the figure (A) or relations calculated by a jacknife method (B).

were estimated from length measurements using the relationships between length and biomass for the various taxa (Holopainen & Paasivirta, unpubl.).

The habitats studied were situated in sheltered bays with sand or detritus bottoms. More exact descriptions of the lakes in group 2 have been published in an earlier paper (Palomäki 1989), in which the dominant chironomid taxa are presented. A summary of macrozoobenthos investigations at Lake Pääjärvi has been presented earlier (Sarvala et al. 1981). The limnological data was obtained from the Finnish National Board of Waters and Environment.

The relations between the variables were evaluated by a standard regression technique and the slopes tested with the *F*-test. The relation between the number of taxa and the area sampled was descriped to draw lots a random order of the samples or with a jackknife method (Efron 1982).

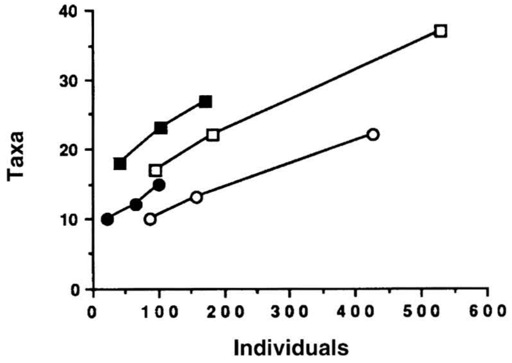

Fig. 4. Relation between the number of taxa in the whole macrozoobenthos (squares) or the chironomids alone (circles) and the number of individuals studied in Lake Inarijärvi. The material is the same as in Fig. 3 and the order of the samples as in Fig 3A.

3. Results

3.1. Relation between number of taxa and sampled area

The numbers of taxa in the whole macrozoobenthos of Lake Pääjärvi and among the Chironomidae seem to increase with the area sampled (Fig. 1). The increase in total macrozoobenthos seemed to be roughly similar on two occasions in August (Fig. 2) and the same applied to the chironomids, although the number of taxa was a little lower on 27 Aug. than on 8 Aug. (Fig. 2).

The number of taxa in the whole macrozoobenthos and among the chironomids in Lake Inarijärvi also increased with increasing sample area (Fig. 3A), but not so evenly as in Lake Pääjärvi. The evenness seems to be better, when the data was treated with a jackknife method, but the increases have not a same direction in two seasons (Fig. 3B). The increase in the number of taxa seems to be much even, however, when the explanatory factor was the number of individuals in the same material (Fig. 4), i.e. the factor in which the sample area was taken account, too.

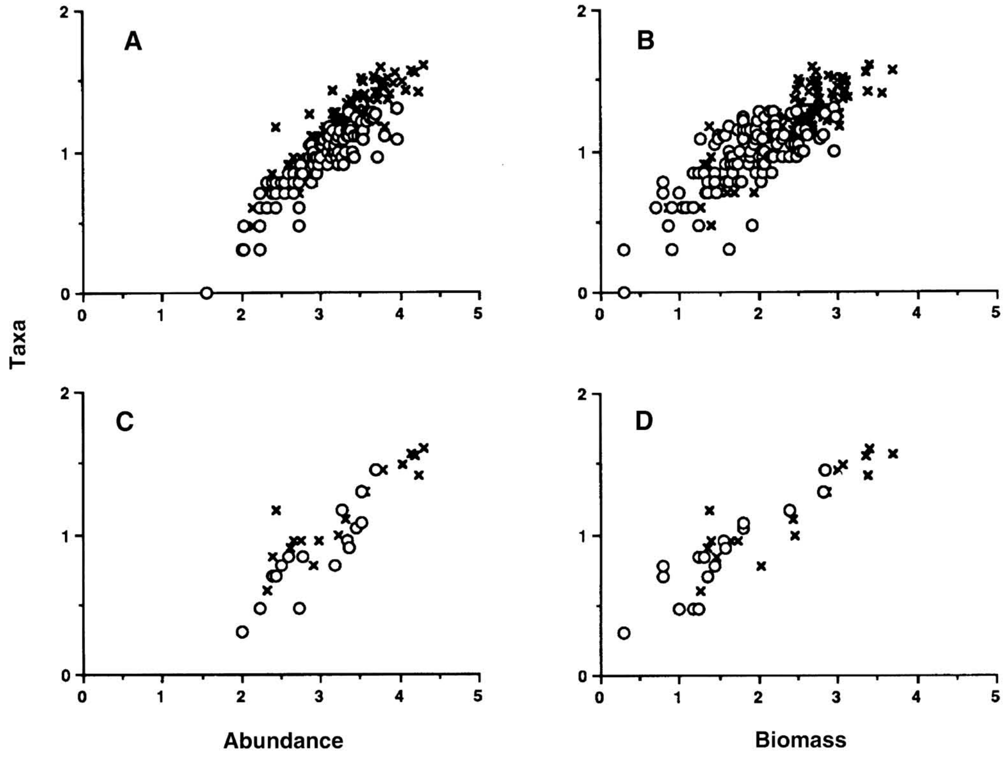

Fig. 5. Log-log plot of the numbers of taxa in the whole macrozoobenthos (x) and among the chironomids (o) against their abundance (ind./m^2) and biomass (mg/m^2) in all Ekman samples (A and B) and samples from sandy bottom at 1 m depth (C and D). — Regressions (whole macrozoobenthos = MZB, chironomids = CH): A: $\log y = 0.453 \log x - 0.293$, $r^2 = 0.77$, $n = 111$, $P < 0.001$ (MZB), $\log y = 0.454 \log x - 0.423$, $r^2 = 0.80$, $n = 111$, $P < 0.001$ (CH). B: $\log y = 0.37 \log x + 0.288$, $r^2 = 0.69$ $n = 111$, $P < 0.001$ (MZB) and $\log y = 0.313 \log x + 0.364$, $r^2 = 0.51$, $n = 111$, $P < 0.001$ (CH). C: $\log y = 0.389 \log x - 0.151$, $r^2 = 0.83$, $P < 0.001$, $n = 17$ (MZB) and $\log y = 0.503 \log x - 0.615$, $r^2 = 0.78$, $n = 17$, $P < 0.001$ (CH). D: $\log y = 0.322 \log x + 0.401$, $r^2 = 0.79$, $P < 0.001$, $n = 17$ (MZB) and $\log y = 0.407 \log x + 0.233$, $r^2 = 0.81$, $n = 17$, $P < 0.001$ (CH).

3.2. Relation between number of taxa, abundance and biomass

The numbers of taxa in the whole macrozoobenthos and among the chironomids (Fig. 5A) were closely related to abundance. The slope of the relation between the number of chironomid taxa and their total abundance (0.453 log x) was about the same as that for the total macrozoobenthos (0.454 log x). The number of taxa also had a close relationship to biomass (Fig. 5B). The chironomids showed slightly more variation than the whole macrozoobenthos in the relationship between their number of taxa and biomass.

Our data comprised only sheltered habitats, and to examine the habitat effect more closely, we chose only samples which had been taken at the same depth, 1 metre, and from bottoms of the same quality, sand. This standardization of the habitats only lowered the variation in the relationship between the number of taxa and the abundance or biomass of the whole macrozoobenthos slightly, however (Fig. 5C, D). In contrast, the coefficient of determination of the regression increased considerably in the chironomids, especially in relation to biomass.

3.3. Effect of the vertical scale sampled in littoral zone and water quality

When the results of the "Ekman scale" (Fig. 5A, B) were compared with those applying to the whole littoral (3 depths, Table 2), the trends were parallel. Neither water colour nor total phosphorus content could explain the number of taxa in the whole macrofauna or among the chironomids in the lake littoral (Table 3).

4. Discussion

Species richness is the easiest way of measuring diversity in a community. If communities are to

Table 2. Total numbers of taxa in the whole macrozoobenthos and among the chironomids, their average abundance (ind./m^2) and average biomass (AFDW mg/m^2) in the littoral (0.5, 1 + 2 m, altogether 9 Ekman samples/transect). — S = sandy shore, D = soft bottom, detritus shore. The total phosphorus content (µg/l) and colour of the water (mg Pt/l) are also given.

Lake	Habitat type	Number of taxa	Average abundance	Average biomass	Total phosphorus	Colour
Whole macrozoobenthos						
Pyhäjärvi	S	63	8200	1300	15	20
Sarmijärvi	S	55	4100	500	5	10
Inarijärvi, VIII	S	36	2700	300	5	10
Inarijärvi, VI	S	36	2000	300	5	10
Alajärvi	S	32	700	60	55	150
Sarmilompolo	D	66	2400	700	10	10
Pyhäjärvi	D	61	3700	500	15	20
Sarmilompolo	D	51	1900	400	10	10
Inarijärvi, VIII	D	46	5400	500	5	10
Sarmijärvi	D	46	3400	400	5	10
Inarijärvi, VI	D	43	3300	600	5	10
Chironomidae						
Pyhäjärvi	S	28	4000	50	15	20
Sarmijärvi	S	26	3500	300	5	10
Inarijärvi, VI	S	17	600	30	5	10
Inarijärvi, VIII	S	16	500	30	5	10
Alajärvi	S	16	500	30	55	150
Inarijärvi, VI	D	28	2400	300	5	10
Sarmilompolo	D	27	1500	90	10	10
Sarmijärvi	D	25	3000	300	5	10
Sarmilompolo	D	24	1500	80	10	10
Pyhäjärvi	D	23	2600	60	15	20
Inarijärvi, VIII	D	23	4300	140	5	10

Table 3. Regression of (y) the number of whole macrozoobenthos or chironomid taxa in the whole littoral (0–2 m, see table 2) on (x) abundance, biomass, phosphorus content of water and colour of water. $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

	Whole macrozoobenthos	r^2	Chironomidae	r^2
Abundance (Ind./m^2)	$\log y = 1.649 \log x + 0.695$	0.39^{*}	$\log y = 3.235 \log x - 1.142$	0.74^{***}
Biomass (mg/m^2)	$\log y = 2.468 \log x - 1.524$	0.61^{**}	$\log y = 3.121 \log x - 2.278$	0.52^{*}
Phosphorus (µg/l)	$\log y = -0.111 \log x + 1.121$	0.00	$\log y = -0.819 \log x + 2.043$	0.05
Colour (mg Pt/l)	$\log y = -1.149 \log x + 3.087$	0.12	$\log y = -1.598 \log x + 3.324$	0.18

be compared, the sampling methods must be the same and the stations sampled must belong to the same habitat type. Similar areas are hard to find, however (Simberloff & Abele 1982), and therefore no large bodies of material for comparisons have been available. In this study, however, the standardization of the sheltered habitat (depth and bottom quality) had not a markedly influence on the results.

Many workers (e.g. Connell 1978, Huston 1979) have stressed that disturbance is one of the most important factors affecting species diversity. Palomäki (manuscript) has observed mostly in the same lakes as here that the light disturbance and water level fluctuation together affect the biomass of macrozoobenthos in the lake littoral, and we also found here close relation between the biomass and species richness. The results regarding the whole macrofauna and the chironomids alone were parallel. Thus, if disturbance has a direct effect on all components of a community (abundance, biomass and species number), disturbance evaluations could produce clues to the problem of species diversity.

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