BIOLOGICAL RESEARCH REPORTS FROM THE UNIVERSITY OF JYVÄSKYLÄ

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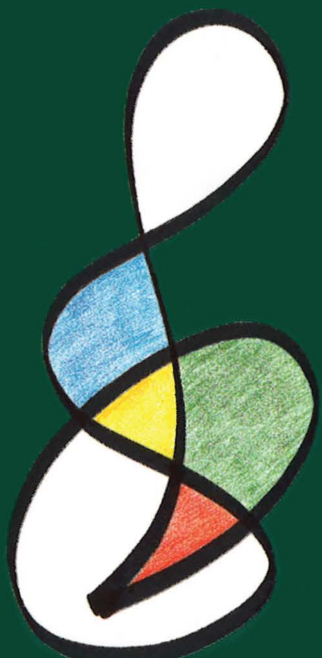
Risto Palomäki

Biomass and Diversity of Macrozoobenthos in the Lake Littoral in Relation to Environmental Characteristics



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Editors
Jukka Särkkä
Department of Biological and Environmental Science, University of Jyväskylä
Kaarina Nieminen
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To Annu, Emilia and Pyry

ABSTRACT

Palomäki, Risto
Biomass and diversity of macrozoobenthos in the lake littoral in relation to environmental characteristics
Jyväskylä: University of Jyväskylä, 1996, 27 p.
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Yhteenveto: Järven ranta-alueen pohjaeläimistön biomassaan ja monimuotoisuuteen vaikuttavien ympäristömuuttujien erittely
Diss.

Partly due to the spatially and temporally heterogeneous lake shores there are only a few macrozoobenthos (MZ) studies that have tried to develop methods for studying the littoral MZ and identifying the most important factors structuring the littoral habitats. The present study describes some crucial factors affecting the ecology of the littoral MZ, especially the large invertebrates that are important as fish food. This information is necessary, for example, for constructing a model of the littoral systems and for reconditioning littoral habitats or restoring food webs in lakes.

It was found that bottom freezing caused by water level regulation also notably affected the abundance, biomass and species richness of the littoral macrozoobenthos. Bottom freezing was spatially very restricted, however, and macrofauna survived better when organic content of the sediment was high. A strong relationship was found to exist between the MZ abundance and the species richness or between the MZ biomass and the species richness. The phosphorus content or colour of the water did not seem to explain the variation in species richness. The standardization of the habitats and varying vertical sampling scales had no clear effect on the results. As for the MZ biomass, the most important factors characterizing the structure of the shore habitats within lakes were the water content of the sediment and the exposure. The disturbance caused by water level fluctuation was another significant habitat variable affecting the MZ biomass. However, water level fluctuation is not a clearly defined factor. The MZ biomass was best explained by an index related to the extent of the illuminated littoral that was disturbed by the water level fluctuation. Water transparency is thus also a very important variable in this process. Predation by whitefish seemed to affect the total MZ abundance only slightly. However, diet shifts of fish were caused by decreased abundance or size of the key prey species.

Key words: Lake littoral; habitat structure; macrozoobenthos; biomass; species richness; water level fluctuation; bottom freezing; fish predation.

R. Palomäki, Central Finland Regional Environment Centre,
P.O. BOX 110, FIN-40101 Jyväskylä, Finland.
E-mail address: Risto.Palomaki@vyh.fi

CONTENTS

List of original publications

This thesis is based on the following articles, which will be referred to by their Roman numerals:

I Palomäki, R. & Koskenniemi, E. 1993: Effects of bottom freezing on macrozoobenthos in the regulated Lake Pyhäjärvi. -Arch. Hydrobiol. 128: 73-90.

II Palomäki, R. & Paasivirta, L. 1993: Species richness of macrozoobenthos, especially chironomid communities, in the littoral zone of some Finnish lakes. -Ann. Zool. Fennici 30: 209-214.

III Palomäki, R. 1994: Response by macrozoobenthos biomass to water level regulation in some Finnish lake littoral zones. -Hydrobiologia 286: 17-26.

IV Palomäki, R. & Hellsten, S.: Littoral macrozoobenthos biomass in a continuous habitat series (manuscript)

V Palomäki, R., Jokela, J., Vuori, K-M. & Puro, A. 1992: Prey preference and timing of the diet shifts of Coregonus pidschian and C. lavaretus: Preliminary results of a field experiment. -Pol. Arch. Hydrobiol. 39: 351-359.

1 INTRODUCTION

The land-water interface region has been emphasized as a very important area in the lake (Wetzel 1992). The littoral was defined here in accordance with Thienemann (1928) as the part of the lake close to the shore. The terms and classifications found in the literature approach the lake shore from various viewpoints (including geography, limnology and biology), which are usually incompatible and the littoral has perhaps been more clearly defined in classical limnology than in hydrobiology or geography (see Brinkhurst 1974). No classification based on the animals has ever been attempted, because the animals are mobile and therefore a more difficult basis for classifying zones than e.g. the shore vegetation (Hutchinson 1993). According to Thienemann's (1928) simple definition the littoral consists of a beach and a subaquatic part of the shore. The littoral is bordered by the terrestrial area above the high water level and by the profundal area characterized by the absence of photosynthetic forms. The lower part of the littoral is called the sublittoral zone, a transitional area towards the profundal of the lake.

In his review Brinkhurst (1974) describes the biomass, density, species composition and diversity of the littoral macrozoobenthos and the general differences between the lakes studied. Although attempts have been made for more than 70 years to classify the benthic communities (and especially the chironomids) on the basis of ecological factors, the classification still seems laden with many problems (see Orendt 1993). In the littoral the dominant species generally consist of eurytopic species, and it is very hard to identify the correct dimensions of the species niche studied.

The themes appearing in this dissertation have been frequently discussed in the literature but less studied in the littoral environment (Southwood 1988). Grimås (1961) argued that bottom freezing may have a great importance for the abundance and community structure of the littoral benthos. Especially the abundance of fish food animals (large insects) decreases due to bottom freezing in regulated lakes. Rex (1981) studied the benthos in the marine environment and observed a relationship between the diversity and biomass of the deep-sea benthos. The diversity of the littoral benthos was insufficiently studied, due to a lack of representative materials. Rasmussen (1988) was the first to try to outline in more general terms the factors affecting the biomass of the littoral benthos by using multidimensional statistical analyses. Within the lakes the most important factors in his model were the exposure and the littoral slope. Between lakes the most important factor was the chlorophyll-a content of the water, reflecting the general productivity level of the lake. Based on the litterature Thorp (1986) maintained that the effects of fish predation on the prey are not well known, but that predation may have some long-run effects on the ecosystems.

The environmental variables measured either directly or indirectly in the present study can be divided into four groups: climatic factors, morpho-edaphic factors , biotic factors and human impact (Fig. 1). The aims of this thesis are

1. Description of the effects of bottom freezing on the littoral macrozoobenthos.
2. Description of the relationship between the macrozoobenthos (MZ) abundance, MZ biomass, some environmental factors and the species richness of MZ.
3. Identification of the role of several environmental factors, including human impact (water level regulation), affecting the MZ biomass.
4. Description of the effect of fish predation on the MZ.

The results of this research can be used, for example, in reconditioning shore areas or restoring food webs. The knowledge can also be used to construct a model describing the benthic food biomass for fishes in the lake littoral (see Hanson & Leggett 1982, Boisclair & Leggett 1985) and it is already being used to develop a model for exploring the effects of water level regulation on the whitefish stocks in regulated lakes (Frisk et al. 1988, Marttunen 1989, Marttunen & Virtanen 1991, Kaatra & Marttunen 1993).

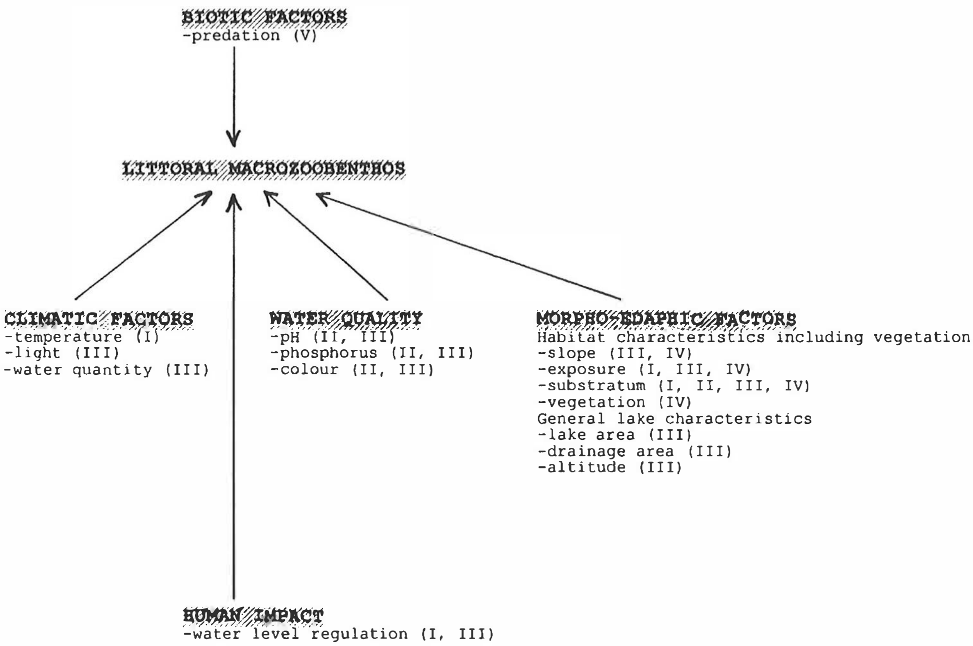

FIGURE 1 Simplified scheme of the setup used. The Roman numerals refer to the articles of this thesis.

2 DESCRIPTION OF THE LAKES STUDIED

This study material consists of data collected from 13 lakes. The lakes are situated from the southern Ostrobothnia to Lapland (Fig. 2). Most of the study objects are oligotrophic and clear-water lakes. The water level is regulated in some of the lakes, but usually very slightly (total amplitude <2 m).

FIGURE 2 The lakes included in this study. 1-2. Lake Inarijärvi, Sarmijärvi and Sarmilompolo; 3. Lake Pyhäjärvi (O.l.); 4. Lake Pääjärvi; 5. Lake Pyhäjärvi (T.l.); 6. Lake Kultsjön; 7. Lake Oulujärvi; 8. Lake Lentua; 9. Lake Ontojärvi; 10-13. Lake Konnevesi: 14. Lake Alajärvi. Lake Vuokalanjärvi is situated east from Lake Konnevesi (no 10-13).

3 MATERIAL AND METHODS

3.1 Macrozoobenthos and bottom freezing

The effects of bottom freezing on the macrozoobenthos (MZ) was studied in several littoral habitats of Lake Pyhäjärvi (O.l.) in Western Finland (I). The frozen and unfrozen shores were studied in the autumn, winter and spring in 1979-1983. Samples were taken with an Ekman sampler (sampling area 289 cm^2) or pump (82 cm^2) in hard bottoms or by a hand net (SFS 5077). The winter samples were taken by using a power saw, an ice pick and a hand net. All the samples were sieved through a 0.4 mm mesh and preserved in 70 % ethanol (except some winter samples). The biomasses (ODW) of the taxa were calculated according to a length-mass regression developed by Holopainen and Paasivirta (unpubl.). Effects of bottom freezing on MZ mortality was studied on the basis of the winter samples. After slow thawing of the samples, the sorted animals were kept in petri dishes in lake water at room temperature, and their mortality was checked over three days. The paired t-test was used in the statistical analyses of the vertical distribution and seasonal variation of MZ.

3.2 Macrozoobenthos diversity

Diversity in the macrozoobenthos (MZ) and chironomid communities was studied on the basis of data from the littoral habitats in several lakes (II). The results are highly affected by sampling methods, sampling area and also by sorting methods and the level of identification. Two sampling methods (tube and Ekman) were used in the littoral samplings and the data were analyzed separately. Both data sets were collected from sheltered bays in the study lakes. The tube material was collected from Lake Pääjärvi at the depths of 1 and 2 metres in August 1973. The Ekman material was collected from five lakes (Lake Inarijärvi, Sarmijärvi, Sarmilompolo, Pyhäjärvi (O.l.) and Alajärvi) at the depths of 0.5, 1 and 2 metres in 1977-1986.

All samples were sieved through a 0.4 mm mesh and preserved in 70 % ethanol, except the samples from lakes Sarmijärvi and Sarmilompolo, from which the samples were sorted out alive. The identification of the animals and biomass calculations were done with the same methods as in Lake Pyhäjärvi (see I).

The relationships between the species richness in the whole MZ or chironomid communities and the independent variables were studied by using a standard regression technique. The water quality data were obtained from the data register of the Finnish National Board of Waters and Environment.

3.3 Macrozoobenthos biomass

The relationship between macrozoobenthos (MZ) biomass and various abiotic variables was studied with data collected from several published investigations (III). Most of the study localities chosen were oligotrophic, clear-water lakes in Finland. The shore areas studied were situated in sheltered bays, which usually opened to the offshore at an angle of <90°. The samples had usually been taken in autumn with an Ekman sampler or a tube and then sieved through a 0.4-0.6 mm mesh. The independent variables consisted of factors varying both within the lakes and between the lakes. One of the most interesting factors was water level fluctuation. It was assessed with several alternative methods emphasizing the critical seasons, the intervals and relationships between the water level fluctuation and the depth of the illuminated littoral. The water level data were obtained from the data register of the Finnish National Board of Waters and Environment. The relationships between the littoral MZ biomass and the independent variables were studied with the correlation analysis (Pearson's correlation coefficient) and the standard regression technique.

The relationships between the factors structuring the littoral habitats (altogether 27 sampling stations) and the MZ biomass were studied intensively in Lake Inari in the autumn of 1993 (IV). The variation in water quality and illumination were eliminated by taking the samples from a limited area and at the same depth. The sampling procedure was the same as in Lake Pyhäjärvi (see I), but the samples were sieved through a 1.0 mm mesh and the biomass was measured as wet weight. Apart from this, it was tested how much MZ biomass was lost when using only a 1.0 mm mesh. The difference in effectiveness between the Ekman sampler and the pump in collecting benthic animals was also tested. Nine independent variables (IV, Table 2) were measured in all the habitats simultaneously with the MZ sampling. The relationship between the MZ biomass and the independent variables was studied by the correlation analysis (Pearson's correlation coefficient), the standard regression technique and stepwise regression analysis.

3.4 Macrozoobenthos and fish predation

Prey preference, timing of the diet shifts, and the relationship between the abundance of macrozoobenthos (and zooplankton) and whitefish predation were studied in a field experiment in the oligotrophic Lake Vuokalanjärvi (Eastern Finland) (V). This study concentrates on a biotic factor (predation), and the experimental method is therefore a better alternative than the classical, observational methods. Two net cages (a 100 m^2) were placed into the sandy littoral and one hundred immature whitefish were released into each on Oct. 14, 1989. A benthos-feeder, *Coregonus pidschian* (Gmelin), and a plankton-feeder, *C. lavaretus* (L.), were stocked into their own cages. Thus the initial mean density was 0.1 fish m^{-2} in each cage. The experiment took 29 days.

Stomach (gillnets), benthos (Ekman sampler, 1.0 mm mesh) and plankton samples (draw net, 0.2 mm mesh) were taken regularly from the cages during the experiment and from outside the cages at the beginning and the end of the experiment. The sampled fishes (20 ind. per sampling day) were replaced with an equal number of individuals. Due to the lack of *C. pidschian*, the fish density in the first cage declined after the 12th day, as no fish were added into the cage after the sampling.

Differences in whitefish food between experiment days were tested by Kruskal-Wallis test or Mann-Whitney U-test. Statistical differences in prey densities during the experimental period were tested by one-way ANOVA.

4 RESULTS AND DISCUSSION

4.1 Abiotic factors

4.1.1 Freezing effect

When several types of shore habitat were studied in Lake Pyhäjärvi (I), it was observed that the sandy bottom froze most easily. The bottom of the stony and marshy shores did not freeze in winter. Bottom freezing is a typical phenomenon in regulated lakes, and it depends on the amplitude and period of draw-down in winter (Hellsten et al. 1989). From autumn till spring the MZ biomass decreased by over 70 % in the frozen sandy area of Lake Pyhäjärvi, while it remained about the same in the unfrozen area during the same period. The MZ mortality measured in winter samples supported this observation. The MZ mortality in the sandy bottom was over fourfold higher compared with the frozen soft bottom or unfrozen marshy area. Freezing also seemed to decrease strongly the species richness. The decreased biomass of MZ in the regulated frozen shore seemed to be compensated by the high biomass below the regulated zone.

Although bottom freezing seemed to be sporadic in Lake Pyhäjärvi, it may be detrimental for MZ in winter on the strongly regulated shores, which are eroded and become minerogenic, or even on the shores of natural lakes dominated by sandy bottoms.

The oligochaetes was the dominant group on both the frozen and unfrozen shores. It seemed that all groups suffered and no single species benefited from bottom freezing.

4.1.2 Water quality and habitat impact

4.1.2.1 Effects on macrozoobenthos diversity

The species richness of the littoral macrozoobenthos (MZ) or only chironomids increased as the sampled area increased in the eight data sets collected from the littoral zone of several lakes, but the increase in the number of taxa seemed to be more even when the explanatory factor was the number of individuals or the biomass (II). However, the sample representativeness (Baltanas 1992) or the calculating method used (Karakassis 1995) may cause a great error. The results on the whole MZ and the chironomids alone were parallel. An autocorrelation is possible here, because there might be a relationship between the increases in the individual numbers (or biomass) of the whole MZ and the chironomids. Total phosphorus and water colour and spatial scale of sampling did not seem to explain the variation in species richness.

A clear relationship was found between the species richness and the biomass of the benthic community in this study. On the basis of his marine benthic studies Rex (1981) also has pointed out the same. The results here together with the results of study III raise the question: Does a disturbance have a direct effect on the three important components of a community (abundance, biomass and species richness). Because in this study nearly all the lakes were oligotrophic, and the number of study lakes was also small, more studies are necessary to secure the representativeness of the materials.

4.1.2.2 Effects on macrozoobenthos biomass

Traditionally the max. occurrence of macrozoobenthos (MZ) in lakes has been observed in the littoral (Rasmussen 1988). Any clear reason for the maximum occurrence of the MZ in different depth zones of the littoral in different lakes has not been presented (Särkkä 1983).

Water level fluctuation is an important factor in the littoral (III). Its effects on the littoral MZ can be seen in the regression model by an equation

$$\log \text{MZ biomass mg ODW m}^{-2} = 4.25 - 1.33 \log \text{BI} \text{ , where}$$

$$\text{BI} = \frac{\text{water level fluctuation in the previous year (m)}}{\text{Secchi disk value in the same open water season (m)}} \times 100$$

This model was based on data largely derived from samples taken in autumn and in the sheltered bays of oligotrophic lakes. Therefore, many uncertain factors may still affect the results. Seasonality may cause variation in the total biomass of MZ, though the variation in the size distribution (biomass spectra) of littoral MZ communities is observed to be relatively constant (e.g. Rodriguez & Magnan 1993).

One of the complex factors is water transparency, which includes e.g. the effects of colour, turbidity and the shading of phytoplankton. Rasmussen and Kalff (1987) came to an almost similar conclusion and showed that the quantity of phytoplankton, the chlorophyll content, the total phosphorus content of the water, Secchi disk transparency, and the morphometry of the lake have close relationships with the MZ biomass in the sublittoral and the profundal areas (Rasmussen & Kalff 1987, Rasmussen 1988). In the littoral studies, a definite conclusion was not reached. Rasmussen (1988) tried to find relationships between the total biomass of zoobenthos among the richest vegetation of the littoral area and several environmental factors. His results indicated that the chlorophyll content of the water, the exposure and the slope are important factors for the littoral MZ, but he did not study the effects of water level fluctuation. His results also indicate the importance of water transparency for the littoral MZ, supporting the results in the present study (III). Also Rodriguez and Magnan (1993) pointed out the need for a more comprehensive MZ study. Based on the results from three Laurentian Shield lakes in Canada they argue that the taxon-based and size-based (biomass spectra) approaches can emphasize strikingly different aspects of community structure. No theory exists for predicting the response of zoobenhic biomass spectra to environmental change (Rodriguez & Magnan 1993).

Other factors clearly affecting the littoral MZ seem to be the water content of the sediment (Sed) and exposure (Exp, measured as the degree of the angle opening towards the offshore) (IV). In Lake Inari the relationship between the macrozoobenthos biomass (MZB) and these factors could be represented by a regression model

$$\log \text{MZB mg WW m}^{-2} = \frac{358.23 - 0.24\ \text{Exp (degree)} + 0.65\ \text{Sed (\%)}}{100}$$

This means that the MZ biomass was greater in sheltered areas with soft bottoms than on more open and minerogenic shores. Soft and organic bottoms generally contain more water than solid minerogenic bottoms. Therefore they were observed to be favourable for vegetation and many bottom animals (Brinkhurst 1974). Vegetation has also a notable effect on the habitat structure, whenever it is present. The higher vegetation shelters the shore from the waves, and the nutrient-rich sediment can thus stay in the habitat better than without vegetation. In general aquatic vegetation is sparse in Lake Inari, but the quantity of sheltered areas is quite big. It is caused by the large number of islands (over 3000).

4.2 Fish predation

Predation has two distinct roles. First, it reduces the individual numbers of macrozoobenthos (MZ). The predation effects are not usually permanent, but the decreasing effect on the abundance is restored the next year (Thorp 1986). Second, size-selective predation affects the community structure and is especially obvious when a new species is brought into the system or changes occur in the population of keystone species (Mittelbach et al. 1995). It can actually cause a great change at the primary production level (e.g. Power 1990). The long-term effects of predation on the prey and the communities in aquatic ecosystems are not well known, and the results of the predation studies have often been contradictory (Thorp 1986, Walls et al. 1990).

The results did not support the postulated effects of the predator roles (V). Fish predation was not found to influence the number of the benthos or zooplankton during the short experiment. However, the two fish forms studied had diet shifts during the 29-day experiment. Both fish species seemed to eat more selectively at the beginning of the experiment. The timing of the shifts seemed to have no clear relationship with the decrease of the prey density. The sparsely-rakered benthos-feeding *Coregonus pidschian* ate many large individuals of the MZ at the beginning of the experiment, but switched to zooplankton prey when the density of chironomids decreased in the MZ. The chironomids could be the key prey group, whose lowered density forced the fish to change its prey type and feeding habitat. The densely-rakered plankton-feeding whitefish used mainly one prey species (*Bosmina longispina* Leydig) at the beginning of the experiment, but when it had decimated the largest individuals of this prey species, it moved to the bottom and started to feed on benthic cladocera and MZ. A similar change in the diet of this plankton feeder and a decrease in the size of *Bosmina longispina* during the open water season could be seen in the samples taken from all parts of Lake Vuokalanjärvi in that year (Miinalainen, unpubl.). The results of the littoral fish studies in Canada (Pierce et al. 1994) support the conclusion of the importance of chironomids for fishes. Total fish biomass in ten southern Quebec lakes correlated positively with the biomass of chironomids, but there was no significant correlation between the total fish biomass and the total invertebrate biomass or prey variables. Also Leppä et al. (1995) observed in Lake Pohjalampi that the intensive fishing concentrating on many dominant fish species in the lake caused a 2-5 fold increase in the number of chironomids during two study years.

Although the size-selective predation against zooplankton has already been known (see Walls et al. 1990), the heterogeneity of the littoral areas and the complex interactions between species makes the description of the process uncertain (Schriver et al. 1995).

Top-down control on the prey or even on the whole ecosystem does not appear immediately, and it can take many years due to the complexity of the system (Gulati et al. 1990, DeMelo et al. 1992, Ramcharan et al. 1995).

The field-experiment-method used here is probably better than a descriptive study or a laboratory experiment. However, the difficulty of assaying a sufficient number of replicates is general problem in field experiments as it was in this case. More replicate-experiments should be performed out or more study cages should be built. One alternative for the greater amount of work could be a comparison of the field experiment results with the descriptive field material collected from the whole lake area and the monitoring data.

5 CONCLUSIONS

1. Due to water level regulation, bottom freezing affects the abundance, biomass and diversity of macrozoobenthos. Due to the narrow freezing zone and the differences in the sensitivity of various bottom types to freezing, in normal years the effects of freezing are less pronounced in the clear-water and slightly regulated lakes than might be assumed from the results of Grimås (1961) on strongly regulated lakes. The harm may, however, be marked in eutrophic and polyhumic lakes, which have a shallow lighted littoral zone.

2. A close relationship was observed between the MZ biomass and diversity in the lake littoral, conforming the findings of Rex (1981) in marine environment. A slight variation in the characteristics of the habitat type and a variation in water quality did not seem to affect the species richness of MZ. The disturbance factors affecting the biomass and abundance of littoral MZ are probably among the factors influencing the diversity, but their role is not clear.

3. Water quality and the general characteristics of a lake were not observed to affect the biomass of littoral MZ, as Rasmussen (1988) in Canada found earlier. Among the factors affecting the structure of shore habitat, exposition and water level fluctuation were the most important ones affecting the MZ biomass. Waves and the slope of the littoral area affect the bottom quality and thus also MZ. Vegetation in the open water season has an effect on the staying of the nutrient rich sediment in the littoral and also indirectly on MZ, although a clear evidence was not found in this study. The importance for MZ of the water content and organic matter in the sediment is probably very marked.

4. The impact of fish predation on the littoral macrozoobenthos is probably quite complex, because the results of earlier studies have been contradictory. An experimental study, such as the present one, illustrates on a small scale what may happen in the whole lake, but two or more scales should be studied in order to understand the whole picture. The total abundance of the offered prey for fishes does not seem to be the best basis for studying

the fish-prey-interaction. Instead, the abundance or size changes of the key prey species seem to be better ones.

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YHTEENVETO

Järven ranta-alueen pohjaeläimistön biomassaan ja monimuotoisuuteen vaikuttavien ympäristömuuttujien erittely

Tässä väitöskirjatyössä pyrittiin erittelemään niitä ympäristömuuttujia, jotka vaikuttavat järven ranta-alueen pohjaeläimistön biomassaan ja monimuotoisuuteen. Työ perustui yhteensä 13 järven tutkimustuloksiin. Pääosa tutkimusjärvistä oli karuja ja kirkasvetisiä järviä, joka vaikuttaa osaltaan tulosten sovellettavuuteen. Ranta-alueen pohjaeläimistöä käsittävät tutkimukset ovat verrattain paljon työtä vaativia, ja käytettävien tutkimusmenetelmien puutteellisuudet vaikeuttavat tulosten tulkintaa.

Tutkimuksessa tarkasteltiin järven ranta-aluetta muovaavien abioottisten (aallokko, pohjan jäätyminen, pohjarinteen kaltevuus, pohjan laatu, veden laatutekijöistä erityisesti veden väriä (näkösyvyys), sähkönjohtavuutta ja happamuutta (pH), järven rehevyystasoa, vedenkorkeuden muutoksia) ja bioottisten tekijöiden (kalapredaatio) sekä ihmisen vaikutusta (vedenkorkeuden säännöstely) litoraalin pohjaeläimistöön.

Tutkimusten tarkastelutavat olivat toisistaan poikkeavat, joka johtui tarkasteltavien muuttujien luonteesta. Ranta-alueen pohjan jäätymisen vaikutusta pohjaeläimistöön tarkasteltiin O.l. Pyhäjärvellä perinteisellä kuvailevalla menetelmällä. Pohjan jäätymisen todettiin pienentävän pohjaeläimistön yksilömäärää ja kokonaisbiomassaa ja vähentävän pohjaeläimistön monimuotoisuutta. Vaikka pohjaeläinbiomassa väheni jäätymishäiriön vuoksi yli 70% talven aikana, näytti pohjaeläimistö kompensoituvan syvemmällä litoraalissa. Pohjan laatu vaikutti jäätymisestä johtuvaan pohjaeläinten kuolevuuteen siten, että orgaanista ainesta enemmän sisältävillä pohjilla kuolevuuden havaittiin olevan yli neljä kertaa vähäisempää kuin hiekkaisilla pohjilla.

Ranta-alueen pohjaeläinyhteisön monimuotoisuutta tarkasteltiin korrelaatio- ja regressioanalyysin avulla. Pohjaeläinyhteisön monimuotoisuuden mittaamiseen liittyy monia menetelmällisiä ongelmia. Pohjaeläinyhteisön lajiluku kasvoi tarkasteltavan alueen koon, alueen yksilötiheyden ja biomassan noustessa. Sen sijaan veden väri ja järven rehevyys eivät selittäneet pohjaeläinyhteisön monimuotoisuuden vaihtelua.

Järven rannan eri vyöhykkeiden pohjaeläinbiomassan ja ranta-alueen eri ympäristötekijöiden keskinäistä suhdetta tarkasteltiin useilta järviltä kerätyllä aineistolla korrelaatio- ja regressioanalyysin avulla ja pyrittiin mallintamaan askeltavan regressioanalyysin avulla. Järven yleiset piirteet ja veden laatu eivät selittäneet ranta-alueen pohjaeläinbiomassan suuruutta. Sen sijaan vedenkorkeuden vaihteluiden aiheuttama häiriö yhdessä veden kirkkauden (näkösyvyys) kanssa näyttivät vaikuttavan keskeisesti ranta-alueen pohjaeläinbiomassan tasoon. Tulos tulkittiin siten, että mitä suurempi osa kesällä olevasta valaistusta pohjasta talvella joutuu olemaan kuivilla, sitä huonommaksi tilanne muodostuu. Veden kirkkaus vaikuttaa ratkaisevasti siihen, miten herkkä ranta-alue on veden korkeuden vaihteluille. Järven sisäisistä tekijöistä rannan avoimuus ja pohjasedimentin vesipitoisuus selittivät parhaiten ranta-alueen pohjaeläinbiomassan suuruuden vaihtelua.

Kalapredaation (pohja- ja vaellussiika) vaikutusta tarkasteltiin Vuokalanjärvellä yksinkertaisen koejärjestelyn avulla. Kalat sijoitettiin kahteen häkkiin ja niiden annettiin vapaasti syödä häkissä olevaa ravintoa 29 päivää kestävän kokeen ajan. Kalapredaation vaikutusta pohjaeläinmäärään ei ollut havaittavissa kokeen aikana. Kummallakin siikalajilla havaittiin selvä muutos ravintokoostumuksessa. Ravintomuutokseen johtavaksi syyksi esitettiin avainsaalislajin määrän tai sen suurten yksilöiden väheneminen.

Tässä työssä saatuja tuloksia voidaan käyttää mm. kehitettäessä malleja kalojen pohjaeläinravintovarojen arviointia varten ja säännöstelyn kalataloudellisten vaikutusten kuvaamiseksi. Tulosten avulla voidaan vähentää mallien epävarmuustekijöitä.

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