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PhD Thesis

Paleoecological investigation of high mountain lakes in the Southern Carpathians

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INTRODUCTION

High mountain lakes have great potential in limnology and paleoecology. In the last few decades, lacustrine sediments of the remote lakes have been studied in details concerning the climate changes. The lacustrine sediments are especially appropriate for high resolution, multi-proxy studies, including abiotic and biotic proxies. These are special archives of the past climate fluctuations. However, the research of these lakes is far behind of lowland water bodies (rivers, lakes, esp. of recreational lakes, reservoirs and baths).

AIMS

The main aims of this study are:

a, to explore the diatom and cladoceran assemblages of high mountain lakes in the Southern Carpathians

b, to identify the main environmental factors for the distribution pattern of diatom and cladoceran assemblages

c, to compare the biota of three different mountain regions of South Carpathians, looking for similarities and dissimilarities

d, to build a training set for diatoms and cladocerans in the Southern Carpathians region for quantitative paleocological reconstructions in the future

MATERIALS AND METHODS

Sampling procedure:

The field work was completed from 2011 till 2014, in four sampling campaigns: 22-25th August 2011, 7-23rd August 2012, 13-25th July 2013, and 15-17th July 2014 respectively. Sediment samples were taken from the deepest points of the lakes, while water samples from the water column. The lakes are accessible only by foot, meaning ca. ten hours climbing a day; including a 600-1200 meter level difference. Equipment was required for sampling, like boat, drill, weights, their transport to the sampling places caused difficulties.

Research area:

Altogether 80 samples (40 sediment and 40 water samples) were collected successfully from high mountain lakes in three mountain regions of the Southern Carpathians between 2011 and 2014. Twenty-five lakes were sampled in the Retezat Mountains, nine in the Parang Mountains and six in the Fagaras Mountains, respectively. This means that 25% of the lakes of Retezat, 29% of the lakes of Parang, and 20% of the lakes of Fagaras were sampled in the frame of the present research, but the bad accessibility of the lakes have not allowed to visit more water bodies.

Sampling methods:

Physical and chemical properties of lake water were measured during the field work (water depth, local factors, coastal vegetation, and coverage). The top 2 cm of the uppermost sediment layer was sampled by belly boat and gravity corer at the deepest point of each lake, than later 1 cm^3 amount

of the sediment samples examined for the following chemical parameters: loss of ignition (LOI), SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, BaO, MnO_2, SrO, TiO_2.

The conductivity, temperature and pH of the water were measured on-site by portable water quality meter (WQC-24), at one meter depth below surface (if the lake was deep enough). Lake water samples were collected in plastic bottles for further laboratory analyzes and the following chemical parameters were measured: Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}, NH_4^+ CO_3^{2-}, HCO_3^- , Ca^{2+}, Mg^{2+}, Na^+, K^+.

The water depth (considered one of the main local variables) was estimated for several points of the lake from a bellyboat with a portable depth echosounder. For the characterization of lake banks three types (rock, grass, dwarf pine) were distinguished as local factors. The area of the 40 lakes was estimated with Google Earth and Shapes (http://www.earthpoint.us/Shapes.aspx) programs, while the altitude was measured with GPS.

For the siliceous algae analyses, samples were prepared by standard digestion procedure with 30% hydrogen peroxide. From each sample at least 400 valves were counted by means of light and scanning electron microscope.

For cladoceran analysis 2 cm^3 sediment samples were used. After the potassium hydroxide treatment the remains were dyed with safranine mixture for better visibility at microscope. At least 300 individuals were counted in each sample.

For the statistical analysis the R programming language, a free software environment was used. Principal component analysis (PCA) and

redundancy analysis (RDA) were also performed. Hellinger transformed abundances of taxa and scales transformed environmental variables data were included in the PCA and RDA models.

THESES

1. Abiotic and biotic characters of the studied 40 lakes have been given on the basis in this work. Till now the knowledge about the three mountains' lakes (Retezat, Pareng, Fagaras) was restricted, so my results contribute significantly to the assessments of Southern Carpathians mountain lakes and theirs communities. A database was built for the quantitative reconstruction of this region.
2. The results of the abiotic variables, the local parameters and the chemical parameters of the water did not show a clear distinction between the three mountains, in contrast with the chemical parameters of sediment, which indicate significant differences.
3. The type of the catchment area and the pH best explain the variance in the diatom assemblages that are quite different and characteristic to the three mountain regions. However, the strength of the explanatory factors is significantly less for cladocerans that do not reveal any distinguished pattern regarding the three mountain regions. The differences between lake's cladoceran assemblages are presumably due to the grazing pollution.
4. More than 300 diatom taxa were distinguished in the 40 lakes, most of them are rare, hardly identifiable, and their taxonomic status requires further revision. Algological data for the three mountains are sparse. As of the cladocerans, although the remains of only nine species were

detected in the samples, my results significantly expand the knowledge for the region. The presented data will contribute significantly to the exploration of the flora and the fauna of the Southern Carpathians.

5. *Diadesmis fukushimae*, a rare oligotraphentic diatom, was found in three of the studied lakes. Its occurrence in the Parâng and Retezat Mountains (Lake Rosiile, Negru and Peleaga) is the second European record of the species. Investigation by scanning electron microscopy showed that this species should be transferred to the recently established genus *Humidophila*. A new combination is proposed and published as *Humidophila fukushimae* (Lange-Bertalot, M. Werum et Broszinski) Buczkó and Kövér comb. nov.
6. As a main result of the present study the validity of the Fretwell-Oksanen model was tested and proved. Oksanen emphasized that the model is valid only in vertebrates, but we have expanded it to the lacustrine ecosystem of the Southern Carpathians lakes.

PRACTICAL APPLICABILITY OF THE RESULTS

The here presented water and sediment chemistry data constitute the basis for the assessment of the studied lakes in the present, and they are appropriate in the future too for monitoring changes.

Another important approach for reliable reconstruction of changes in trophy of the lakes could be to extend the survey for phosphorus (TP) measurement. An appropriate database (training set) for epilimnetic total-phosphorus-based trophic assessment is required. The present study showed that the biodiversity of the Southern Carpathian Mountains lakes is poorly known.

According to the general recommendation for building a reliable calibration database, at least 40 lakes must be involved in the analysis. The most efforts were paid for visiting and sampling the 40 lakes in this research. The limited number of high mountain lakes is a strong constraint of increasing the sample size in the Southern Carpathians. A possible way of increasing the sample size for lake level reconstructions could be the use of "in-lake transects". The in-lake-training set study samples are collected not only at the deepest point of the lake, but along transects of the lake bed, in line with water depth. In this way we can gain for more information for the water level reconstruction, which usually is one of the main aims of the paleoecological research.

Another possible direction toward the better understanding of the paleolimnology in high mountain lakes is the so-called “top-bottom” study. This method is widely used for comparing the pre-industrial and recent status of lakes.

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