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Distribution of benthic microcrustaceans along a water depth gradient in an Austrian Alpine lake – Sedimentary evidence for niche separation

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ABSTRACT

Distribution of benthic microcrustacean (Crustacea: Cladocera) was investigated with paleolimnological approach by using their fossil surface sediment assemblages within a thermally extreme lake in the Niedere Tauern, Austrian Alps. The results from 20 surface sediment samples suggested that the spatial distribution of chydorids is clearly heterogeneous along the water depth gradient (1.8–6.1 m); *Alona quadrangularis* dominated in shallow (warm, minerogenic) habitats, *Chydorus sphaericus*-type succeeded at intermediate depths, and *Alona affinis* dominated in deep (cold, organic) sites. Apparently, these benthic cladocerans exhibit clear habitat and resource segregation. The distributional patterns revealed local community thresholds at approximately 2.5 and 4.5 m water depths and these thresholds were likely to be forced by variances in habitat quality (minerogenic–organic), food resources (periphyton/detritus), thermal properties (warm–cold), and UV-exposure (high–low). The results emphasize the usability of the paleolimnological approach in distributional investigations and its applicability in providing information on species–environmental relationships for environmental change evaluations and paleoecological interpretations.

Introduction

Environmental variation at different geographical scales has a major influence on local species assemblages, as species dispersal abilities, biotic interactions, and adaptation potential to local environmental conditions affect species distributional patterns (Lavergne et al. 2010; White et al. 2010). Environmentally generated heterogeneous species distribution is evident as ecological thresholds, which can be characterized as points at which there is an abrupt change in a property or phenomenon in an ecosystem, e.g. maintenance of particular species (Groffman et al. 2006). In freshwater lakes, which are severely affected by anthropogenic environmental changes, such as climate warming and pollution (Brönmark and Hansson 2002; Heino et al. 2009), the identification and evaluation of such thresholds have become explicitly more important during the period of major anthropogenic environmental perturbations because they can be valuable in global change assessments, environmental quality classifications, and in biodiversity conservation efforts (Catalan et al. 2009).

Paleolimnological approach (Smol 2008) for examining fossil biotic assemblages in lakes' surface sediments provide a cost-efficient and quick way to estimate modern species distribution patterns and diversity of aquatic organisms preserving as fossils. Despite the fact that only a small fraction of aquatic organisms preserve as fossil remains in lake sediments, research on surface sediment assemblages of such organisms has become an important and valid method in contemporary ecological studies (Bjerring et al. 2009; Catalan et al. 2009; Brancelj et al. 2009). In addition to using paleolimnological approach in determining wide geographical distribution patterns (Bjerring et al. 2009; Brancelj et al. 2009; Catalan et al. 2009), it has recently been utilized in identifying patterns at local-scale too, unraveling habitat-specificity of various organisms (Laird et al. 2010; Luoto 2010; Nevalainen 2011). Local species assemblages and site-specific thresholds, however, are not governed solely by local processes, as biogeographical processes have a major contribution (Bilton et al. 2001).

Distributional borders of many organisms, such as mountain lakes located at remote high altitude zones, can be regarded as sensitive indicators of environmental change (Marchetto and Rogora 2004). It is important to evaluate the present species distribution and biodiversity at such sites, because they are likely to respond fast and abruptly to the modern climate warming (Holt and Keitt 2005; Parker et al. 2008). In the current study, with an objective to determine local patterns of Cladocera distribution and to examine local community thresholds within a homogeneous Alpine lake basin, fossil Cladocera from a set of surface sediment samples along a water depth gradient were analyzed. It was hypothesized, based

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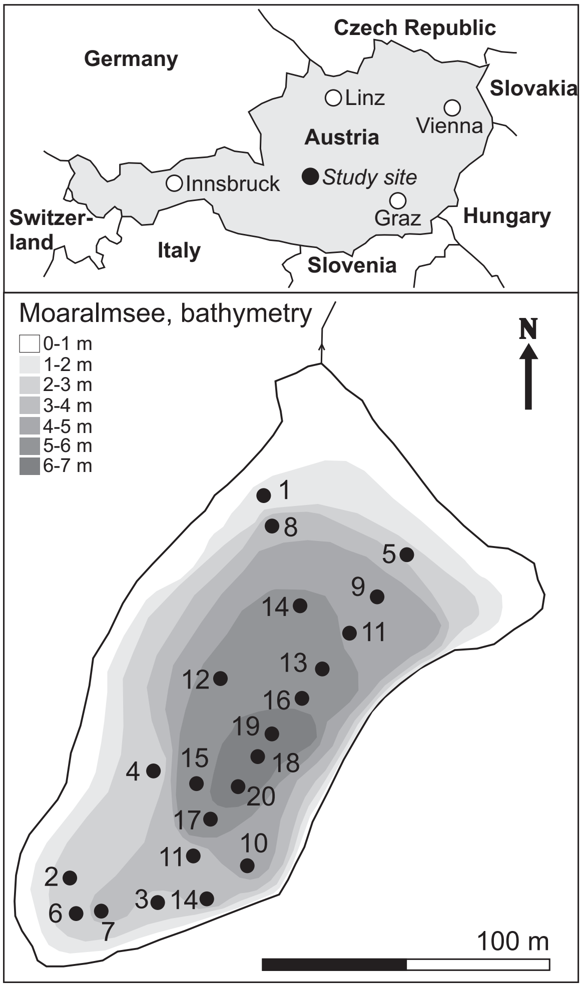

Fig. 1. Location of Lake Moaralmsee in the Niedere Tauern region of the Austrian Alps and distribution of the examined surface sediment samples along the depth gradient within the basin.

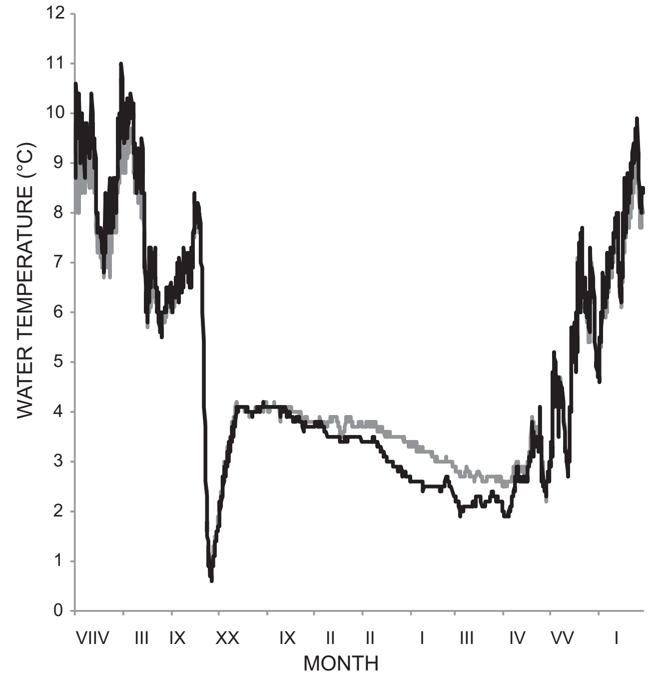

Fig. 2. Annual record (23 July, 2009 to 21 July, 2010) of water temperature at depths of ~1 m (black line) and 3 m (gray line) in Lake Moaralmsee, measured at 4-hour intervals.

on previous results from a limnologically heterogeneous basin (Nevalainen 2011), that no distinct distributional features could be recognized and that no clear site-specific thresholds could be determined due to uniform habitats and environmental extremity (Thompson et al. 2005) in this Alpine lake basin.

Study site

Lake Moaralmsee (47°21.5′N, 13°47.5′E) is located at an altitude of 1825 m a.s.l. in the Niedere Tauern region of the Eastern Alps in Austria (Fig. 1). The lake was chosen for the present study because as a remote high altitude mountain lake it can be regarded to be close to pristine state, although it is most likely affected by long-range atmospheric transport and deposition of pollutants (Marchetto and Rogora 2004), and have homogeneous benthic habitats without any effects of dense aquatic vegetation or river inflows. In addition, the lake is shallow (max. depth 6.1 m, Fig. 1), which reduces thermal stratification of the water column (Fig. 2). Therefore, the effects of water depth and interconnected environmental parameters on benthic fauna can be considered to be maximized in this lake. The lake basin has a maximum length of 232 m, maximum width of 127 m, and maximum depth of 6.1 m (Fig. 1).

Vertical limnological variability within the water column (Table 1), performed using a multiparameter sonde 6600V2 (YSI Inc., Yellow Springs, OH, USA), indicated that Lake Moaralmsee is oligotrophic (average chlorophyll concentration in the water column: 0.27 RFU) and has a pH of ~8 (Table 1). The secchi depth (August 2010) was 6.1 m, down to the deepest location in the lake. The lake can be regarded as an ultra-sensitive high altitude mountain lake because it is unusually cold compared to other lakes at similar altitude; its summer water temperatures are generally 6–7 °C cooler. This fact is caused by its catchment morphology, which causes extensive cold water inflow from snowmelt and groundwater during the summer (Thompson et al. 2005). The annual water temperature measurements (July 2009 to July 2010) from water depths of ~1 and 3 m were measured with 4-hour intervals using 8-bit MINILOG-TR thermistors (Vemco Ltd., Halifax, Nova Scotia, Canada) and the measurements indicated that water temperature hardly exceeds +10 °C even during the summer months (Fig. 2). Although water temperature range during 2009–2010 at depths of ~1 and 3 m in the lake showed no distinct

Table 1
Vertical limnological variation in the water column (0–6 m) of Lake Moaralmsee in July 2010.

Measurement depth	(m)	0	1	2	3	4	5	6
Temperature	(°C)	11.7	11.7	10.0	8.2	7.7	7.2	7.2
Conductivity	(μS cm^{-1})	27	27	28	27	27	27	27
pH	(units)	8.1	8.2	8.4	8.3	8.2	8.0	8.0
Chlorophyll a	(RFU)	0.1	0.2	0.3	0.3	0.3	0.3	0.4
Phycocyanin	(RFU)	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Dissolved oxygen	(mg l^{-1})	11.0	10.9	10.9	11.5	11.4	11.3	11.3
Oxygen saturation	(%)	101.7	100.1	96.9	96.5	95.6	94.2	93.6