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The zoobenthic community of shallow salt pans in Austria – preliminary results on phenology and the impact of salinity on benthic invertebrates

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Abstract

A three-year project on the benthic community of salt pans (shallow saline lakes) in the Seewinkel area of Eastern Austria has been carried out since 1996. Most of the salt pans investigated are very shallow (mean depth mostly < 0.5 m), highly alkaline and inorganically turbid. Salinity ranged from 1.6 to 4.5 g l^{-1} in 1996 and 1997, but reached its highest values (> 50 g l^{-1}) during the dry summer of 1998. A comparison of the benthic community in 20 salt pans at two sampling dates in 1997 revealed a negative relationship between salinity and species richness of Oligochaeta and benthic Crustacea. However, the decline of diversity was observed at salinity values much lower that those reported in the literature for most benthic invertebrates. It is thus doubtful whether or not salinity has in fact directly affected the benthic community in the salt pans of Seewinkel. Rather, it is suggested that biotic interactions controlled by changes in the hydrochemical situation are responsible for the reduction in diversity of the benthic community. Actual experiments or more detailed data on changes over a full gradient of salinity will be necessary to attribute changes in the species composition of benthic invertebrates to any environmental impact with certainty. The phenology of benthic invertebrates in Unterstinker, a sub- to hyposaline (0.5–20 g l^{-1}) salt pan studied in greater detail, was distinctly influenced by the development of submerged macrophytes. Abundances of chironomids and crustaceans, the two dominant major benthic groups, were high only in June and July, when Charophyceae had stabilized the lake bottom and prevented further erosion of fine sediments. Substrate characteristics and the abundance of macrophytes appeared to determine the seasonal development of the benthic community as long as the ion concentration remains low (< 3 g l^{-1}).

Introduction

The so-called Seewinkel in Eastern Austria has been of scientific interest for several decades. It is the best known of numerous salt pans (shallow saline lakes) which provide a unique habitat in Europe for many rare plants and animals (e.g. Wendelberger, 1959; Hustedt, 1959; Hödl & Eder, 1996; Zulka & Milaszowski, 1998). As one of the most important wetlands in Central Europe, the Seewinkel and parts of the Neusiedler See were declared a national park by the Austrian government in spring 1994.

Limnological research has a long tradition in Seewinkel. However, most studies concentrated on zooplankton (Stundl, 1949; Löffler, 1957, 1959; Newrkla, 1974; Metz & Forró, 1989, 1991; Schall, 1990). Our knowledge of the benthic community of algae and invertebrates, especially quantitative data concerning phenology, is sparse. Only faunistic data on 'Entomostraca' collected by Löffler (1959) provide some information about the benthic community of different salt pans.

Since 1996, a three-year study of the benthic community of the Seewinkel has been carried out. The project concentrates on three aspects: faunistics, temporal and spatial distribution within and between different salt lakes and the role of benthic invertebrates as food of aquatic birds. This paper presents first results on phenology and the impact of salinity on species composition.

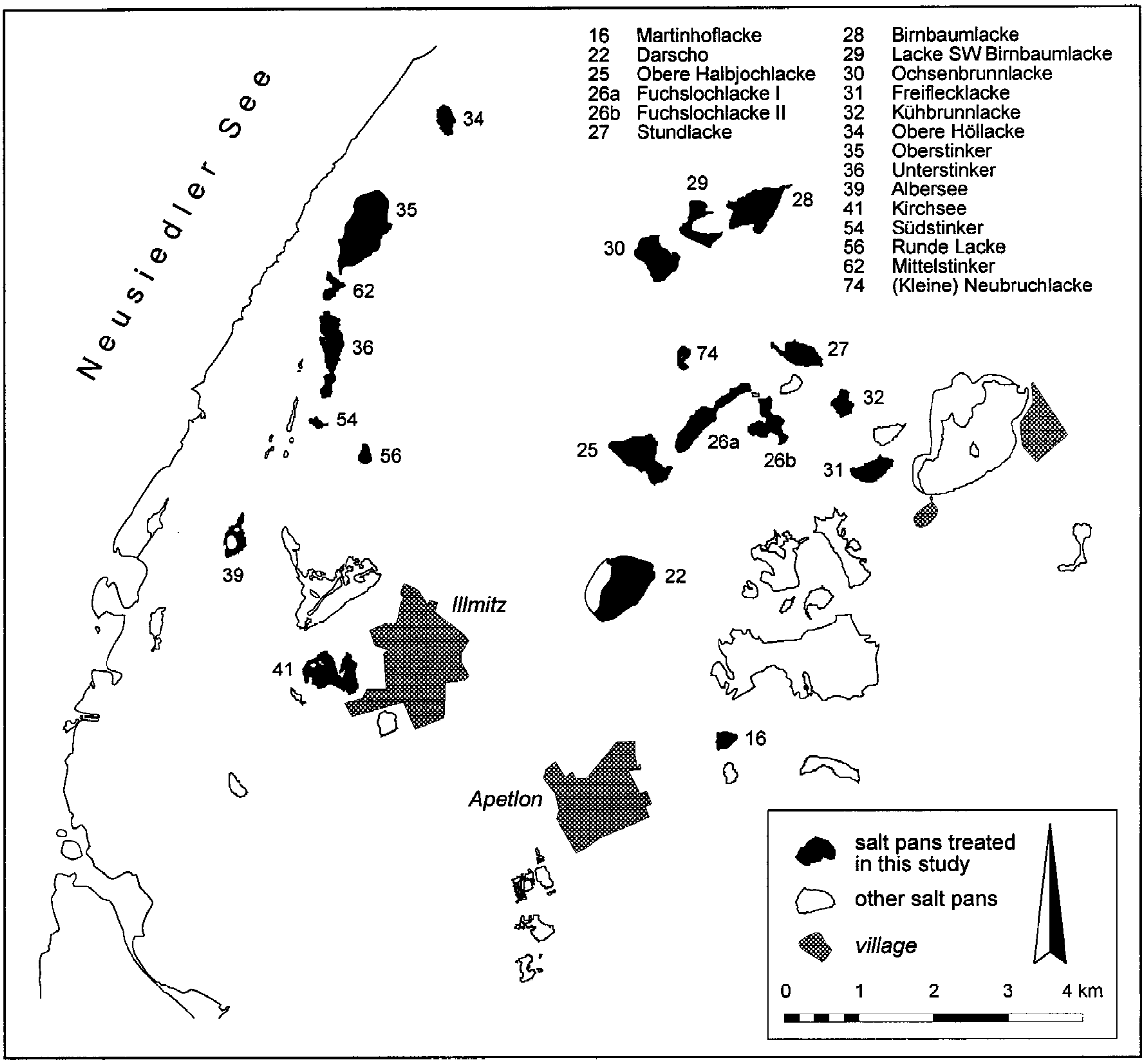

Figure 1. Map of Seewinkel with the salt pans studied.

Description of sites studied

The Seewinkel (47° 82′ N, 16° 77′ E, alt. 115 m) is situated east of Neusiedler See on the border between Austria and Hungary (Figure 1). There used to be at least 139 salt pans of different size and characteristics. Today, due to artificial drainage of the basin and a drop in groundwater level, only 36 salt lakes covering a total area of 7.55 km^2 remain. Among these 36 lakes, 20 have been chosen for this study, three of them (Unterstinker, Albersee, Fuchslochlacke) for detailed quantitative sampling. Only in Unterstinker has the phenology been investigated in detail.

Most salt pans of the study area originated from ice-lenses that were formed during the last glacial period (Riedl, 1965). Some pans in the western part of Seewinkel have probably been isolated from Neusiedler See (Löffler, 1965). Due to the lack of substantial surface in- or out-flows the hydrology of the salt lakes depends on the interplay of precitipation (mean precipitation in eastern Seewinkel 1980–1990: 570 mm a^{-1}) and evaporation. The influence of groundwater on the water regime in the salt lakes strongly varies between different years and is only partly understood. Some lakes are connected to the groundwater throughout the year, others are influenced

Table 1. Sampling schedule from 1996 and 1997. Ust . . . Unterstinker, Alb . . . Albersee, Fuchs . . . Fuchslochlacke, Q . . . 17 further salt pans (see Figure 1). Quantitative samples were taken from Ust, Alb and Fuchs. The remaining salt pans were sampled only qualitatively. The figures in the columns indicate the number of sampling stations. 1 sample in each salt pan was taken for hydrochemical analyses

1996	Ust	Alb	Fuchs	1997	Ust	Alb	Fuchs	Q
03.04.96	1			28.01.97	1			
16.04.96	1			08.04.97	1			
08.–09.05.96	6	4	5	22.04.97	6			
23.05.96	1			12.–15.05.97	1	4	6	1–2
13.06.96	1			27.05.97	1			
26.06.96	1			11.06.97	1			
09.07.96	1			25.06.97	1			
23.07.96	1			15.07.97	1			
06.–07.08.96	6	4	6	29.07.97	6			
20.08.96	1			19.–21.08.97	1	4	6	1–2
04.09.96	1			03.09.97	1			
18.09.96	1			16.09.97	1			
03.10.96	1			08.10.97	1			
24.10.96	1			28.10.97	1			
26.11.96	1			18.11.97	1			

only at high water levels, when groundwater can flow into the salt pan from the shoreline margins (Krachler, 1992; Steiner, 1994).

The salt pans can be roughly classified into two types: ‘black water’ and ‘white water’ lakes. Owing to a high amount of humic substances, black water lakes have a reddish-brown colour. White water lakes are typically grey, which is due to heavy wind action eroding fine sediment from the lake bottom. Most salt pans are very shallow (< 50 cm) and some of them dry up nearly every year. The dominant salt in the waters of Seewinkel is Na_2CO_3. NaCl and Na_2SO_4 play a minor role. The salt enrichment, originating during the Riss/Würm iceage, came from influence of mineralized groundwater in arid climatic conditions (Riedl, 1965).

Materials and methods

The project started in April 1996 and will continue until spring 1999. This paper presents data from 1996 and 1997. In these two years Unterstinker was sampled on 15 dates each year. Albersee and Fuchslochlacke were sampled in spring and summer in both years and 17 further lakes were sampled only twice a year in 1997. A sampling schedule is given in Table 1.

Only a part of the results from the zoobenthos samplings and some figures from chemical analyses are considered in this paper. Techniques and procedures of the chemical analyses are described in Donabaum et al. (1999). Salinity was calculated as the sum of the eight major anions and cations (Wetzel, 1983). In some cases salinity was derived from the following linear regression between conductivity and salinity:

$$\begin{aligned} S &= 7.2042 \text{ x } 10^{-4} + 0.5647\,\mathrm{K}_{25} \\ N = 82,\ r^2 &= 0.77,\ \mathrm{RMS} = 0.1690,\ p < 0.0001 \\ &\mathrm{S} \ldots \text{ salinity } [\mathrm{g\ l}^{-1}] \\ &K_{25} \ldots \text{ conductivity } [\mu\mathrm{S\ cm}^{-1}] \\ &\text{standardized to a temperature of } 25\ {}^{\circ}\mathrm{C} \end{aligned} \tag{1}$$

Quantitative samples of macrozoobenthos were taken using a Gilson-Corer (diameter 6 cm, area 28 cm^2), the uppermost 8 cm were analyzed. The number of replicate samples was 4 – 5 in Albersee and Fuchslochlacke and 6 in Unterstinker. Qualitative samples from the center of the lakes were taken with a hand net (mesh size 100 μm). The net was grazed over the sediment surface along a stretch of several meters and was regularly dipped into the sediment to a penetration depth of about 3–5 cm. The total area sampled with this procedure was approximately 0.25 m^2. All samples were preserved in 5% formaldehyde, sieved in the lab through a 100 μm mesh and subdivided into two classes (0–1 mm and $>$ 1 mm). The finer fraction of some large samples was subdivided into 4 – 16 subsamples.

For comparison of different lakes within our study area, the number and the relative proportion of species found in the qualitative samples were considered. No statistical tests were made to evaluate the comparability of the qualitative samples. However, much attention was directed to grazing the hand sweep over areas of comparable size and to maintaining the penetration depth.

For analysis of phenology, mean abundance was calculated after log transformation of the data. 95% confidence limits are given. Annual mean abundances in Unterstinker were calculated as the arithmetic mean of abundances on individual sampling dates.

Four groups of benthic invertebrates are highlighted in this paper: Oligochaeta, Cladocera, Copepoda and Chironomidae. The attribution of copepods to either plankton or benthos was not always clear, as in many species the preference for a certain habitat changes in the course of development. In the case

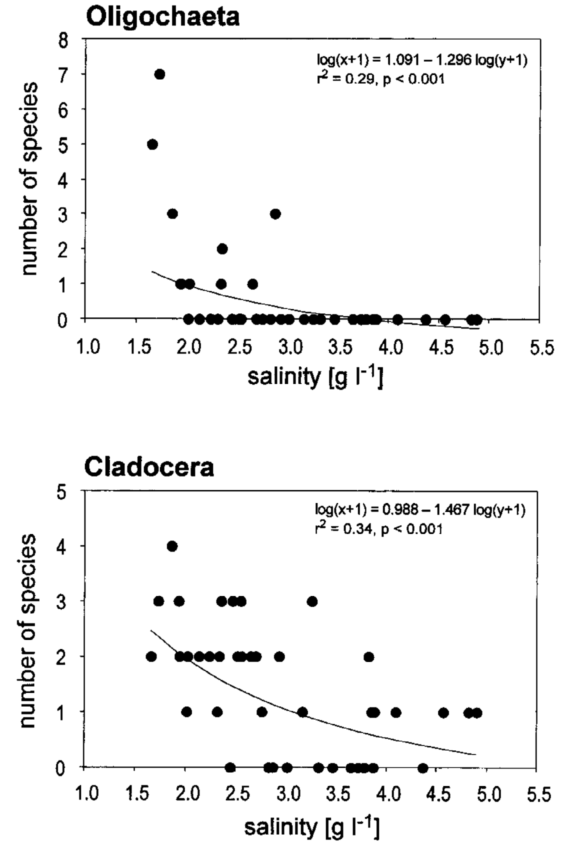

Figure 2. Relation between salinity and number of species of Oligochaeta and benthic Cladocera, based on qualitative samples of 20 salt pans of Seewinkel in May and August 1997.

of shallow lakes with a depth of a few centimeters to decimeters the distinction is even more difficult. For the sake of clarity in this paper all cyclopoid species are included in the analyses. Calanoids (*Diaptomus* spp. and *Arctodiaptomus* spp.) are not considered, harpacticoids have not been found at all.

Results

Impact of salinity on the benthic community

The first two years of the study were characterized by heavy rainfalls in spring and a high groundwater level. Because of the hydrological conditions, salinities in all salt pans remained comparatively low. The highest salinity was measured in a small bay of the Runde Lacke (7.9 g l^{-1}, K_{25} = 10 210 μS cm^{-1}). Most figures, however, were between 1.6 and 4.5 g l^{-1} (K_{25} = 1500–5500 μS cm^{-1}). Recent measurements during August 1998 revealed much higher conductivities, with a maximum of more than 70 000 μS cm^{-1} in the Ochsenbrunnlacke, which correspond to a salinity of over 50 g l^{-1}. According to Hammer (1986) the salt pans of Seewinkel can be classified as sub- to hyposaline (0.5–20 g l^{-1}) in rainy years, but mesosaline (20–50 g l^{-1}) in warm summers just before drying up.

Although the range of ion concentrations of the salt pans was rather narrow during 1996 and 1997, the benthic community showed a significant dependence on the hydrochemical environment. Figure 2 gives the relation between salinity and species number of Oligochaeta and benthic Cladocera in 20 different salt pans at two dates. Oligochaeta were present only in salt pans with a salinity of less than 3 g l^{-1}. The highest number of oligochaete taxa could be found in the Stundlacke at 1.7 g l^{-1}. Benthic cladocerans, on the other hand, occurred in all salt pans studied. However, in waters with higher salt concentrations no more than one species could be found at a time; in most cases these were *Oxyurella tenuicaudis* (Sars) or *Chydorus sphaericus* (Müller). A clear relation between species composition and salinity was found also for copepods (Figure 3). At lower salt concentrations (up to 3 g l^{-1}, subsaline conditions) the copepod community was dominated by five taxa: *Eucyclops* spp., *Cyclops* sp., *Mesocyclops leuckarti* (Claus), *Megacyclops gigas* (Claus) and *Megacyclops viridis* (Jurine). With higher salinities *M. viridis* turned out to be the dominant copepod species in most salt lakes. Its proportion among the cyclopoids exceeded 100% in some waters. Table 2 gives a list of oligochaete, cladoceran and copepod species together with the maximum salinity and conductivity at which they were found.

Phenology

Phenology of benthic invertebrates was studied in detail in Unterstinker, a soda pan (dominated by Na_2CO_3) in the western part of Seewinkel. For chemical characteristics see Table 3. The seasonal changes of turbidity (total dissolved solids) are shown in Figure 4a. In both years, high turbidity in spring accounted for the grey appearance of the lake water. In late April macrophytes (*Chara canescens* Desvaux & Loiseleur in Loiseleur-Deslongchamps and *Potamogeton pectinatus* Linnaeus) began to develop, which by June had covered nearly all of the lake bottom. As a result, wind and wave action could not erode the lake bottom anymore and turbidity sharply declined and remained low until the end of July. After more than two months of clear water *Chara canescens* started to degrade and

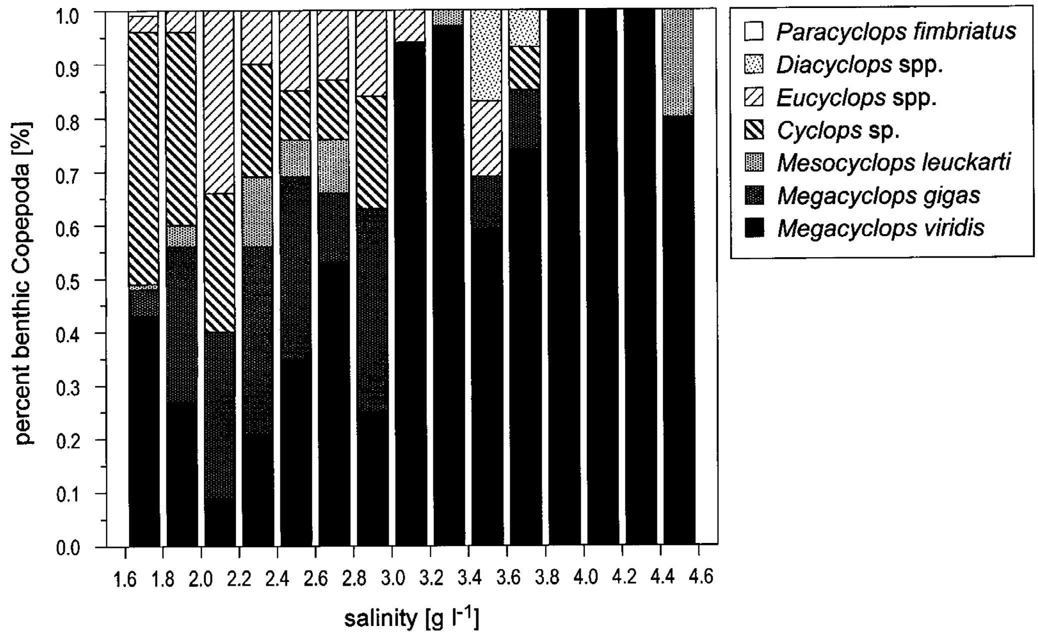

Figure 3. Relative proportion of cyclopoid species in 20 salt pans of Seewinkel. Each vertical bar corresponds to the mean species composition of cyclopoids within a class of salinity (width: 0.5 g l^{-1}). The relative proportion of *Megacyclops viridis* is distinctly enhanced towards hyposaline conditions.

the sediment was eroded again. Turbidity rose to 50–150 mg l^{-1} until the end of the year. Higher figures of turbidity occurred after heavy storms (e.g. in April or November 1997). (On 28th January 1997, sampling under ice revealed that all macrophytes had been degraded and only their rhizomes had remained in the sediment.)

Total abundance of benthic invertebrates of Unterstinker varied between 589 ind. m^{-2} and 119 484 ind. m^{-2}. Mean abundance was 23 594 ind. m^{-2} in 1996 and 3698 ind. m^{-2} in 1997, respectively. Cladocera, Ostracoda and Chironomidae were the most abundant and among the macrozoobenthic invertebrates (excluding nematodes and small crustaceans) the last group was by far the dominant one (Table 4).

In spite of marked differences in abundance between the two years, the seasonal development of benthic invertebrates was similar. After low abundances in late winter and spring, densities (number m^{-2}) rose to a maximum in June and July, followed by a sharp decrease in the second half of July. Abundances during the rest of the year remained comparatively low. The seasonal development in 1996 of chironomids and *Oxyurella tenuicaudis*, the cladoceran species most abundant in Unterstinker, is given in Figures 4b,c. Other crustacean species (*Megacyclops viridis*, *Macrothrix rosea* (Jurine)) showed a phenology similar to *O. tenuicaudis*.

Discussion

Salinity has been noted as a key factor for invertebrates of saline lakes by many authors (e.g. Remane & Schlieper, 1971). Several studies have revealed a clear negative relationship between salt concentration and species diversity (Hammer, 1986; Tudorancea et al., 1989; Metz & Forró, 1989; Hammer et al., 1990; Timms, 1993) or benthic biomass (Timms, 1983; Hammer, 1986). However, it is not only the maximum values, but strong short-term changes of salt concentration or temperature, that may affect freshwater organisms (Hammer, 1986; Frey, 1993). This is especially true in shallow waters, which are often affected by drastic changes of water level and may totally dry up during summer (Garcia & Niell, 1993; Comín et al., 1993).

Extreme environmental conditions and a high dynamic of salinity are characteristic features of most salt pans in Seewinkel. Several waters dry up every year, which leads to high salinities immediately before completely drying up. Jungwirth (1973) found a maximum alkalinity of 390 meq l^{-1} in the Birnbaumlacke

Table 2. Species list of Oligochaeta and (mero)benthic Crustacea from twenty salt pans in Seewinkel. The number of salt pans (N), the maximum conductivity K_{25} and the maximum salinity S at which the species have been found in our study area is given

	N	K_{25} [μS cm^{-1}]	S [g l^{-1}]
OLIGOCHAETA			
Tubificidae			
Limnodrilus hoffmeisteri Claparede	3	2660	2.4
Limnodrilus sp.	1	2300	2.9
Potamothrix hammoniensis (Michaelsen)	2	2110	1.9
Potamothrix sp.	1	2160	1.7
Tubifex tubifex (Muller)	2	2300	2.9
Tubificidae gen. sp.	2	2660	2.4
Naididae			
Chaetogaster diaphanus (Gruithuisen)	1	2100	1.7
Chaetogaster diastrophus (Gruithuisen)	1	2530	1.9
Nais communis Piguet	2	2100	1.9
Nais elinguis Muller	1	2110	1.7
Nais pardalis Piguet	1	2160	1.9
Nais simplex Piguet	1	2150	1.7
Nais variabilis Piguet	4	2850	2.6
Pristinella bilobata (Bretscher)	2	2110	1.9
Enchytraeidae			
Enchytraeidae gen. sp.	2	2300	2.9
CRUSTACEA			
CLADOCERA			
Iliocryptidae			
Iliocryptus sordidus (Lieven)	2	2160	1.9
Macrothricidae			
Macrothrix hirsuticornis Norman & Brady	3	2890	1.9
Macrothrix rosea (Jurine)	6	4550	3.8
Chydoridae			
Alona affinis (Leydig)	1	2550	
Alona rectangula Sars	6	3640	3.3
Chydorus sphaericus (Müller)	13	4510	3.9
Oxyurella tenuicaudis (Sars)	16	5440	4.9
COPEPODA			
Cyclopoida			
Copepodites III–V	13	5360	3.8
Megacyclops viridis (Jurine)	20	10210	7.9
Megacyclops gigas (Claus)	13	4690	3.9
Megacyclops sp.	11	3850	3.8
Mesocyclops leuckarti (Claus)	9	10210	7.9
Cyclops sp.	17	10210	7.9
Eucyclops serrulatus (Fischer)	14	4410	3.0
Eucyclops speratus (Lilljeborg)	1	2440	2.4
Eucyclops macrurus (Sars)	7	3660	2.9
Diacyclops bisetosus Rehberg	1	2270	2.5
Diacyclops bicuspidatus (Claus)	1	3030	2.9
Diacyclops sp.	3	3850	3.8
Paracyclops fimbriatus (Fischer)	1	2110	1.7
ISOPODA			
Asellus aquaticus Linnaeus	1	2110	1.7

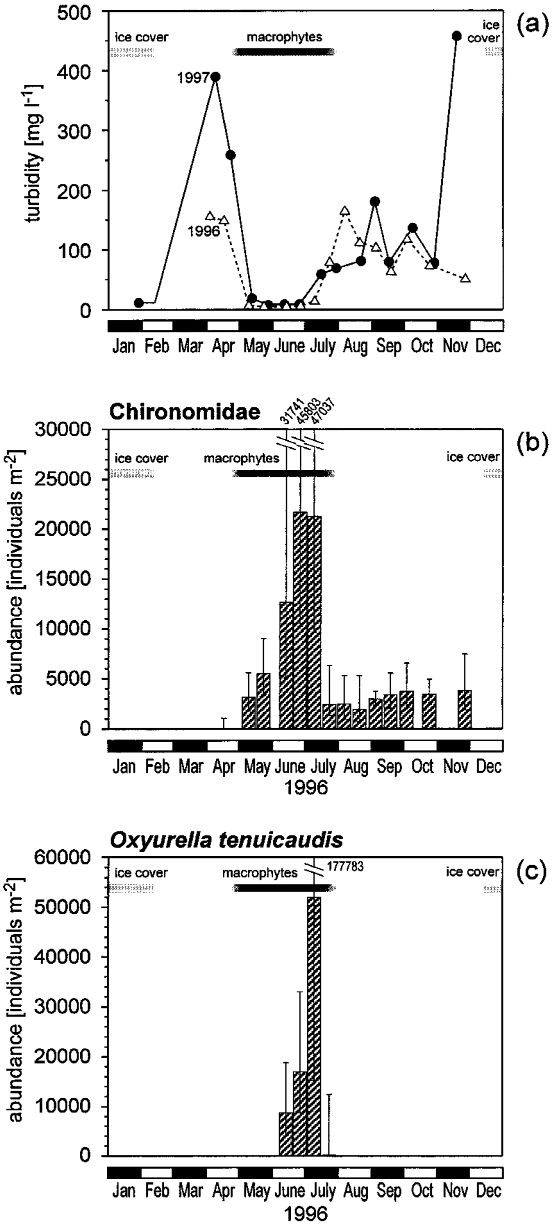

Figure 4. Seasonal variation of turbidity (a) and phenology of chironomids (b) and the cladoceran *Oxyurella tenuicaudis* (c) in Untersinker. Abundances are given as geometric means ± C.L. The other (mero)benthic crustaceans, which were abundant in Untersinker (*Megacyclops viridis, Macrothrix rosea*) showed a very similar seasonal pattern.

(Figure 1, Nr 28) before the lake dried up. In Albersee, a small salt pan in the western part of Seewinkel (Figure 1, Nr 39), Schall (1990) found conductivities of up to 46 000 μS cm^{-1} at the end of July a few days before the pan dried up.

Under such environmental conditions a specialized fauna has established in the salt pans. Several invertebrates in Seewinkel can be considered tolerant of salinity, e.g. the rotifers *Brachionus plicatilis* Muller and *Hexarthra fennica* (Levander) (Zoufal et al., 1989) or the calanoid *Arctodiaptomus spinosus* (Daday), a typical inhabitant of soda lakes (Löffler, 1959). During the first two years of this study, salinities of the salt pans remained rather low and were clearly below the levels given as upper tolerance limit in the literature: *Oxyurella tenuicaudis* is known from waters with a salinity of 6 g l^{-1} (Hammer, 1986). *Alona rectangula* tolerates at least 12.6 g l^{-1} (Löffler, 1961), *Chydorus sphaericus* at least 59 g l^{-1} (Hammer, 1986). Alonso (1990) found *Macrothrix hirsuticornis* in Spanish lakes at salinities of up to 45 g l^{-1}, *Diacyclops bicuspidatus* at 10 g l^{-1} and *D. bisetosus* at 25 g l^{-1}. Among the oligochaete species from Seewinkel, *Potamothrix hammoniensis* (Michaelsen) tolerates 7 g l^{-1} Cl^- (Moroz, 1977 cit. in Verdonschot et al., 1982), *Tubifex tubifex* (Muller) has been reported from waters with a salinity of up to 10 mg l^{-1} (Brinkhurst & Gelder, 1991), and *Nais elinguis* Muller occurs even at 19.5 g l^{-1} Cl^- (Verdonschot et al., 1982) or at a salinity of 28 g l^{-1} (Hammer, 1986).

Considering these high tolerance limits, the question arises whether or not the observed decline of species richness with increasing salinity from 1.6 to 4.5 g l^{-1} is a consequence of the physiological constraints the organisms have to undergo. In fact, a closer look at literature data on the relationship between salinity and diversity reveals that there are only few cases in which a decline of species richness can be attributed to increasing salinity with certainty. Many authors suggest that other factors are responsible for changes in community structure at enhanced salt concentrations. Green (1993) found a marked reduction in rotifer species richness at a very low level of salinity (K_{25} = 1–3000 μS cm^{-1}) and assumed biotic interactions such as predation or competition as one reason. Melack (1988) suggested effects of salinity on key elements which in turn affect other biota in cascade fashion. Wurtsbaugh & Berry (1990) pointed in the same direction. Herbst (1988) assumed a limitation of population density of the dipteran *Ephydra hians* Say by biotic factors at the lower end of the salinity spectrum (20–30 g l^{-1}) and by physiological constraints at the upper end (80–90 g l^{-1}). Williams et al. (1990) and Williams (1993) summarized these indications and stressed the importance of scale when effects of increasing salinity are interpreted.

The results of this study on the benthic community of the Seewinkel salt pans, though preliminary, also indicate only indirect effects of the salt concentration. Species that dominate at higher salinities (*Megacyclops viridis*, *Chydorus sphaericus*, *Oxyurella tenuicaudis*) may simply be euryecious species or ubiquists (cf. Löffler, 1959). However, the evidence from the field data presented in this paper is not not very strong. More detailed data on changes over a full gradient of salinity and especially actual experiments, should clarify the relationship between salinity and diversity.

Besides, it is not only the absolute concentration of ions in the water, but also their composition that may affect community structure. Different impacts of the major anions are well known (Löffler, 1959; Tudorancea et al., 1989; Santamaría et al., 1992). According to Hammer (1986), fish tolerate chloride waters better than sulfate waters and sulfate waters better than bicarbonate waters. Similar effects may be true for invertebrates. In the salt pans of Seewinkel, which are dominated by Na_2CO_3, benthic community structure may thus be affected by increased alkalinity even at the lower end of the salinity spectrum.

Salinity aside, substrate, macrophyte standing crop and turbidity also play an important role for determining community structure of benthic invertebrates in Seewinkel (Löffler, 1957). This might be especially true in salt pans that remain moderately saline throughout the year. In Unterstinker salinity did not exceed 3.7 g l^{-1} in 1996 and 1997. The most striking change in physical and chemical characteristics was the rapid development of the macrophytes *Potamogeton pectinatus* and *Chara canescens*. In late April, the latter species formed a dense carpet upon the sediment and prevented further erosion of fine sediments by wind and waves. Subsequently, the water colour turned from grey – as a result of inorganic turbidity – to reddish-brown, which stems from humic substances dissolved in the water. A stabilizing effect of macrophytes has been reported by several authors (e.g. Evans & Stewart, 1977; Mason, 1977; Jónasson & Lindegaard, 1979). A reduction of inorganic turbidity as a consequence of macrophyte growth has been found in Lake Tåkern (Hargeby et al., 1998). In Neusiedler See, areas with extensive macrophyte growth are characterized by lower inorganic turbidity than the open water zone (Schiemer, 1979; Wolfram, 1996).

The phenology of the benthic invertebrates of Unterstinker indicates a marked influence of the physical (and chemical) properties of the sediment on the bot-

Table 3. Chemical characteristics of Unterstinker in 1996 and 1997

		1996				1997			
		N	mean	min	max	N	mean	min	max
pH	[-log H$^+$]	15	9.3	8.9	9.7	15	9.1	8.2	9.7
conductivity	[μS cm^{-1}]	15	2423	1580	3280	15	2670	1154	3680
salinity	[g l^{-1}]	15	2.2	1.1	2.8	12	2.6	1.9	3.7
salinity	[meq l^{-1}]	15	57	34	68	12	65	48	92
P_{tot}-P	[μg l^{-1}]	15	76	24	139	15	137	37	703
$PO_4{}^{3-}$-P	[μg l^{-1}]	15	4	2	8	15	4	1	11
SiO_2-Si	[μg l^{-1}]	15	2845	306	5736	15	2618	151	10477
N_{tot}-N	[mg l^{-1}]	15	1.63	0.94	2.17	15	2.62	1.35	4.17
$SO_4{}^{2-}$-S	[mg l^{-1}]	15	81	61	111	14	71	40	99
Cl^-	[mg l^{-1}]	15	127	82	183	14	132	58	203
Ca^{2+}	[mg l^{-1}]	15	14	6	43	15	15	0	55
Mg^{2+}	[mg l^{-1}]	15	62	43	78	15	85	73	105
Na^+	[mg l^{-1}]	15	503	307	726	13	569	363	858
K^+	[mg l^{-1}]	15	15	10	22	13	16	11	22
alkalinity	[mval l^{-1}]	15	19.19	5.15	30.19	15	26.73	18.82	37.79
water hardness	[mval l^{-1}]	15	5.79	3.87	6.89	15	7.71	6.42	10.90
dry weight	[mg l^{-1}]	15	73.97	4.79	165.30	15	123.02	7.60	457.10
ash free dry weight	[mg l^{-1}]	15	51.55	0.73	128.20	15	99.66	4.40	391.60
Chl-*a*	[μg l^{-1}]	15	6.8	1.0	15.2	15	12.6	0.4	41.0

tom fauna. In spring, abundances of chironomids and crustaceans started to grow and reached a maximum during the 'clear water phase' in summer, but rapidly decreased in number in late summer and autumn after the '*Chara* carpet' had broken down. A stable sediment and macrophytes as structural elements are key factors in determining benthic abundance and biomass (e.g. Beattie, 1982; Swanson & Hammer, 1983; Winnell & Jude, 1984). It can thus be assumed that in Unterstinker the presence of *Chara canescens* and consequently the stabilization of the sediment, are substantial requirements for high abundances of benthic organisms.

Table 4. Abundances of major groups of benthic invertebrates in Unterstinker during 1996 and 1997. Mean . . . arithmetic mean of 15 dates, min . . . lowest abundance (arithmetic mean), max . . . highest abundance (arithmetic mean). The macrozoobenthos as defined in this paper excludes Nematoda and Crustacea. Sampling dates are given in Table 1

	Mean	Min	Max	Mean	Min	Max
		1996			1997	
Nematoda	1918	177	9196	230	236	2063
Oligochaeta	8	118	118	0	0	0
Hydracarina	8	118	118	2	59	59
Cladocera	9046	472	82937	88	236	1474
Copepoda	916	59	5954	216	236	1474
Ostracoda	3218	236	13204	244	236	2122
Odonata	169	59	531	22	59	295
Trichoptera	51	59	177	18	59	118
Coleoptera	20	59	59	4	59	59
Heteroptera	157	59	354	53	59	589
Chironomidae	7093	354	26703	2374	531	16741
Other Diptera	990	59	3419	448	59	3124
Total zoobenthos	23594	589	119484	3698	1945	21987
Total macrozoobenthos	8496	236	30652	2920	766	17035

Conclusion

The preliminary results of this study suggest two main impacts on the benthic invertebrates of Seewinkel: 1. Salinity can be used as differential variable when interpreting differences between the benthic communities of the various salt pans of Seewinkel. However, it is not clear so far whether salinity has a direct influence on benthic organisms, exerting physiological constraints, or merely induces changes of biotic interactions that affect community structure. 2. Substrate characteristics and the abundance of macrophytes seem to determine the seasonal development of benthic invertebrates in sub- to hyposaline salt pans, in which inorganic turbidity and salt concentrations remain low during summer. However, there are several aspects of the distribution of zoobenthic organisms in the waters of Seewinkel which are still waiting for an explanation. Analyses of benthic groups other than oligochaetes and crustaceans on species level, as well as the results of samplings in 1998 may shed some light on these questions.

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