International Workshop

Water level fluctuations in lacustrine systems - ecological impacts and prospects of future climate change

University of Konstanz, December 11-13, 2005

SFB 454
Bodenseelitoral

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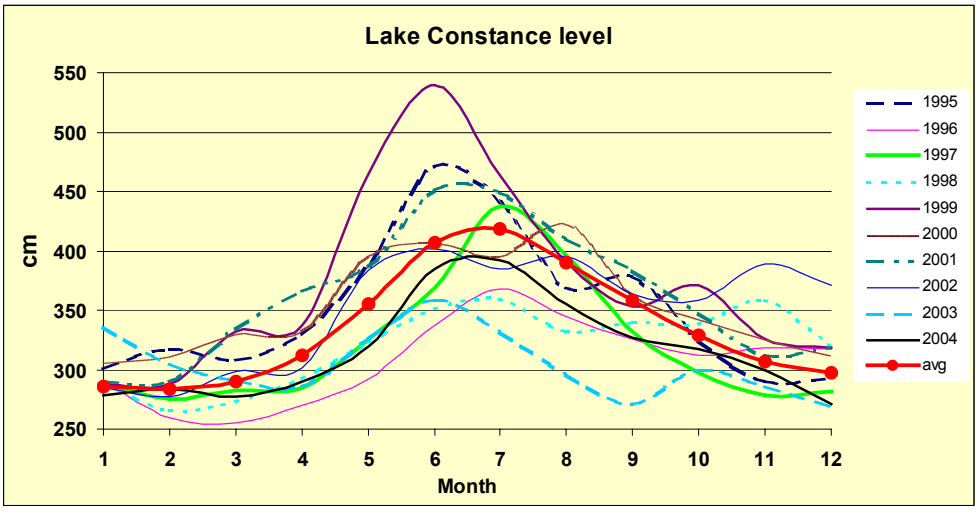

Rationale and scope of the workshop

Many lacustrine systems are undergoing more or less regular water level fluctuations (WLF) at various temporal patterns (short-term, annual, long-term). Structure and function of the littoral zone, an important buffer zone in the land-water interface, are especially affected by WLF. This concerns abiotic (e.g., hydrodynamics, erosion, resuspension and particle settlement, nutrient input by groundwater seepage) as well as biotic processes and components (e.g., microbial communities, invertebrates, fish, reed belts). Life cycles of organisms often include littoral and pelagic stages. WLF, affecting littoral stages, may thus also interact with the pelagial. Some species have evolved life cycle strategies that are adapted to or even depend on WLF. The impact of WLF may be of particular significance if key species of the littoral community are affected. The temporal patterns as well as the magnitudes of WLF are predicted to alter with future climate change. Concomitant ecological consequences are to be expected. Last but not least, assessment practices and water management policies have to pay attention to WLF in pertinent water bodies (lakes, ponds, reservoirs).

Typical topics and questions to be answered in the workgroups

- How do we define WLF?
- What are the typical temporal patterns?
- At which spatial scales are WLF effective?
- Impact of WLF on physical processes.
- Impact of WLF on biogeochemical processes
- Impact of WLF on biotic processes.
- How is future climate change going to affect the patterns of WLF?
- Can we predict how altered patterns of WLF will affect the ecology of littoral zones and of lacustrine systems in general?
- Are WLF adequately considered in applied issues (assessment and management)?

Publication of the results

One output of the workshop should be a special issue of an international journal (e.g., Hydrobiologia). Participants who want to contribute should indicate this during the workshop to the organizing committee and confirm this by sending a preliminary abstract (approx. 300 words) to the matthias.wantzen@uni-konstanz.de until the end of the year 2005. We have a tentative deadline for manuscripts in April 2006 so that the full peer-reviewing process could be finished by the end of 2006.

Organizing committee

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Important information

- The Workshop is at Waldhaus Jakob, Eichhornstr. 84, D-78464 Konstanz, and not at the University!
- We would like to install all **Power Point Presentations** beforehand to avoid loss of time during the workshop. Please send your file to silvia.berger@uni-konstanz.de latest on **6th December 2005**. Be assured that your files will not be distributed, and all copies will be deleted after the workshop.
- For late submission of **Power Point Presentations you** should contact Philipp Fischer during the workshop.
- Bus connections in Konstanz are available on http://sw.konstanz.de/verkehr/omnibus/linienplan.htm
- Train connections from Zurich to Konstanz are available on http://fahrplan.sbb.ch/bin/query.exe/dn?seqnr=1&ident=cj.023891.1133361007&OK#focus

PROGRAMME

Saturday, 10 December 2005

Hour	Session title	Author/Presenter	Title/Notes
19:00	Get together	all	

Posters

(Poster session will be on Monday afternoon, however posters should be exhibited throughout the workshop)

Number	Author	Title/Notes
P 1	White, M.S. et al.	Characterizing natural water fluctuations in small lakes within the Laurentian Great Lakes region and its effects on water quality and aquatic communities.
P 2	Kroth, P.	Role of diatoms in biofilms
P 3	Terasmaa, J. et al.	Human-impact on the lake sediment structure and composition: the results of the repeated studies of Lake Martiska sediments in 1986 and 2003
P 4	Wantzen, K.M. et al.	*Floodpulse advantage* for benthic invertebrates?
P 5	Solimini, A. G. et al.	Climate change effects on water level variation and the response of benthic invertebrates in a Mediterranean lake (Lake Bracciano, Central Italy)
P 6	Abrahams, C.	Applying Grime´s CSR theory to shoreline habitat management
P 7	Miksa, S. & Heege, T.	Monitoring of water constituents in Lake Constance during the flooding event of August 2005 using MERIS satellite data
P 8	Jöhnk, K.	Analysis of 190 years of daily records of lake levels at Lake Constance
P 9	Brauns, M., Garcia, X.F. & Pusch, M.	Environmental factors and eulittoral macroinvertebrate community structure of lowland lakes

Sunday, 11 December 2005

Hour	Number	Session Title	Author/Presenter	Title/Notes
10:00		Introduction	Rothhaupt, K.O.	Opening address
10:20	Keynote 1	Introduction	Wantzen, K.M.	Floodpulses and water level fluctuations: comparing lakes and rivers
11:00	T 1	Session I: Physics & Biogeochemistry	Skoulikidis, N. & Zacharias, I.	Heavy metal distribution in Vegoritis Lake sediments and possible origin from geogenic and anthropogenic sources
11:20	T 2	Session I: Physics & Biogeochemistry	Nöges, T. & Nöges, P.	Lake Võrtsjärv - a large shallow ecosystem driven by water level changes
11:40	T 3	Session I: Physics & Biogeochemistry	Gerhardt, S. et al.	Water level fluctuations and the chemistry of iron and sulfur
12:00	T 4	Session I: Physics & Biogeochemistry	Bussmann, I. et al.	Influence of water level fluctuations on methane emission from the littoral zone
12:20	T 5	Session I: Physics & Biogeochemistry	Hofmann, H. et al.	Temporal and spatial scales of water level fluctuations
12:30		Lunch		
14:00	T 6	Session II: Effects on animals	Aroviita, J. & Hämäläinen, H.	The impact of water level regulation on composition and diversity of littoral macroinvertebrate assemblages in boreal lakes
14:20	T 7	Session II: Effects on animals	Rothhaupt, K.O. & Baumgärtner, D.	Vertical and seasonal distribution patterns of benthic macroinvertebrates in the littoral zone of Lake Constance, a lake with seasonal water level fluctuations
14:40	T 8	Session II: Effects on animals	Sutela, T. & Vehanen, T.	Effects of water level fluctuation on the nearshore fish community
15:00	T 9	Session II: Effects on animals	Wacker, N. & Fischer, P.	Effects of shelter availability in the littoral zone on the ontogenetic habitat shift in juvenile burbot (*Lota lota*)
15:20	T 10	Session II: Effects on animals	Probst, W.N. et al.	Is bream spawning mediated by water level fluctuations? - Evidence for adverse effects of epilithic growth on egg attachment for bream *Abramis brama*
15:40	T 11	Session II: Effects on animals	Fischer, P. et al.	Effects of water level fluctuations on the littoral benthic fish community in a large lake
16:00		Coffee-break		
16:30	WG I	Work group introduction, splitting up into groups	Fischer, P.	WG 1: Causes of WLF WG 2: Effects of WLF and adaptations WG 3: Management
16:50	WG	WGs 1- 3		Parallel sessions in separate rooms
19:00		Dinner		
20:10	WG	Report of WG 1		
20:20		Report of WG 2		
20:30		Report of WG 3		

Monday, 12 December 2005

Hour	Number	Session Title	Author/Presenter	Title
09:00	Keynote 2	Session III: Management	Gasith, A.	Water level fluctuation in a lake ecosystem: ecological effects and management related issues
09:40	T 12	Session III: Management	Zohary, T.	Extreme water level draw-down of Lake Kinneret corresponds with indication of ecosystem destabilization plankton
10:00	T 13	Session III: Management	Tarvainen, A. et al.	Use of water level fluctuation analysis tool (REGCEL) in development of Finnish lake regulations
10:20	T 14	Session III: Management	Zacharias, I. et al.	Impacts from climate change and agricultural practices on a lake's water level and the associated interactions with priority wetland habitat
10:40		Coffee-break		
11:00	T 15	Session IV: Plants	Okruszko, T. et al.	Flooding of riparian wetlands - interaction between water level fluctuations and vegetation zones. Biebrza wetland case study
11:20	T 16	Session IV: Plants	Nechwatal, J. et al.	Flooding events and rising water temperatures increase the significance of the reed pathogen *Pythium phragmitis* in Lake Constance, Germany
11:40	T 17	Session IV: Plants	Peintinger, M. et al.	Water level fluctuations and dynamics of amphibious plants at Lake Constance : long-term study and simulation
12:00	T 18	Session IV: Plants	Schmieder, K. et al.	Effects of hydrologic variations on the dynamics of shore vegetation of Lake Constance, Germany
12:20		Fast Lunch		
13:00		Walk to the boat		
13:30		Excursion (until 16:30)	Werner, S.	The Wollmatinger Ried: a lacustrine floodplain wetland
16:30		Walk back to Waldhaus Jakob		
17:00	POSTERs	Coffee-break		
18:30	WG	Work groups		WG 1: Causes of WLF WG 2: Effects of WLF and adaptations WG 3: Management
20:00		Dinner		

Tuesday, 13 December 2005

Hour	Number	Session Title	Author/Presenter	Title
09:00	Keynote 3	Session V: Shallow lakes	Tóth, L.	Effects of the water level fluctuation on the littoral habitats of Lake Balaton, the largest shallow lake in Central Europe
09:40	T 19	Session V: Shallow lakes	Kagalou, I. et al.	Water level fluctuation: impacts on shallow mediterranean lakes (Lake Psamvotis, Greece)
10:00	T 20	Session V: Shallow lakes	Muskó, I.B. et al.	Reaction of macroinvertebrates upon the water level fluctuation in the littoral zone of Lake Balaton
10:20	T 21	Session V: Shallow lakes	Balogh, C. et al.	Effect of water level fluctuation on zebra mussels in Lake Balaton (Hungary) in the aperiod of 2000-2004
10:40	T 22	Session V: Shallow lakes	Brauns, M. et al.	Potential changes in eulittoal invertebrate composition following water level fluctuations in North-German lowland lakes
11:00		Coffee-break		
11:20	T 23	Session VI: Case studies	Ostendorp, W.	Lake level fluctuations: a systematic view of causes and consequences for littoral ecosystems
11:40	T 24	Session VI: Case studies	Cantonati, M. et al.	Neo- and paleolimnology of a carbonate mountain lake characterized by marked water level fluctuations
12:00	T 25	Session VI: Case studies	Kahl U. et al.	The impact of water level fluctuations on the year class strength of roach: implications for fish stock management
12:20		Lunch		
13:30	WG	Work groups		Preparation of final statements
15:00	WG	Statement of WG 1		
15:10	WG	Statement of WG 2		
15:20	WG	Statement of WG 3		
15:30		Coffee-break		
16:00	End	Press conference		
20:00		Dinner		
20:30	Dinner talk		Dollase, D.	7 th framework program: perspectives

Abstracts

Poster

P 1

Characterizing natural water fluctuations in small lakes within the Laurentian Great Lakes region and its effects on water quality and aquatic communities

Michael S. White, M. A. Xenopoulos, K. Hogsden, R. A. Metcalfe, P. J. Dillon

Trent University, Peterborough, Ontario, Canada

We compiled long-term (~20 year) data sets on water level, water quality and aquatic biota from four remote research areas in the Laurentian Great lakes region to elucidate patterns of natural lake level fluctuation and its associated effects on water quality and aquatic communities. Of the sixteen natural lakes yearly amplitude did not exceed 1.27m (m=0.26, sd=0.15) and water levels did not deviate greater than 0.75m (m=0.10, sd=0.11) from the long term mean. Correlation analysis revealed significant correlations with water quality parameters (DOC, Ca^{2+}, Conductivity, pH, SO^{4+}) however, correlations were area specific with no pattern consistent across all research areas. PCA analyses demonstrated a clear separation between boreal shield lakes and those of glacial till origin. Of the long-term biotic information available (periphyton, macrophytes, macroinvertebrates and fish) only macroinvertebrates demonstrated a significant relationship with natural water level fluctuations. Species richness followed a unimodal response (P=0.002, r^2=0.66) with richness decreasing in years where water level was either higher or lower than the long term mean. Correspondingly, NMS ordination proved that community structure was similar in years close to the mean water level and increasingly dissimilar in years where water levels differed from the long-term mean.

P 2

Role of diatoms in biofilms

Peter Kroth

University of Konstanz, Germany

Diatoms are unicellular algae that are found either in the pelagial zone as phytoplankton or in benthic areas on the surface of various substrates. Together with cyanobacteria and heterotrophic bacteria diatoms can form biofilms which are mainly consisting of carbohydrates. Not much is known yet how these organisms react on fluctuating water levels with its possible effects of dessication and high light exposure.

P 3

Human-impact on the lake sediment structure and composition: the results of the repeated studies of Lake Martiska sediments in 1986 and 2003

J.-M. Punning, J. Boyle, Jaanus Terasmaa, A. Mikomägi, T. Vaasma

Tallinn University, Estonia

Lake Maritska, located in the Kurtna Kame Field of NE Estonia, has been subjected to well-documented anthropogenic environmental change since the 1950s, providing a valuable opportunity to study the impact of human activity on lake biogeochemical properties. Oil shale mining and processing nearby emitted substantial amounts of alkaline fly ash, characterised by a high concentration of several heavy metals and harmful organic compounds, into the atmosphere in 1960-1990 leaving a sharp reference level in the sediment. Groundwater abstraction from the late 1950s caused the water level in L. Martiska to fall abruptly, reaching a minimum of ca. - 3 m in 1992. Since then reduced abstraction has resulted in recovery, the water level currently standing at ca. -0.5 m.

The aim of the work was to compare the rich historical material about the drastic changes in the human impact with the sediment record to identify the factors dominantly affecting the sediment lithological composition and accumulation of heavy metals and other microelements into the sediments. To this end, comprehensive lithological-geochemical studies of the upper sediment in L. Martiska were undertaken in 1986 and repeated in 2003.

The water level fluctuations are clearly reflected in the lithological composition and grain-size variations of the studied sediment cores. During the regression and transgression phases, displacement of the erosion-transport-accumulation limits caused redistribution of previously accumulated sediments and their return into the biogeochemical matter cycling in the lake. Thus sediments in 2003 core originate in principal from two different sources: in-lake concurrently supplied sediments (mainly atmospheric input, influx from the catchment, autochthonous organic matter) and reworked marginal sediment comprising fine sands and silts.

The ^{210}Pb chronology of the sediment record is in contradiction with the historical records of lake level fluctuations, suggesting that changes in ^{210}Pb flux and focusing caused by lake level change have invalidated the dating models.

P 4

Floodpulse advantage for benthic invertebrates in lakes?

Karl M. Wantzen, Johannes Pucher, Jens Bierfeld & Michael Korn

University of Konstanz, Germany

The term "floodpulse advantage" was coined by Junk et al and Bailey et al. to delineate the advantages for fish species which can use ressources deriving from the inundation of floodplains, e.g. fruit-feeding fish which can swim into flooded Amazonian forests. In the updated floodpulse concept, a general validity of the ecological advantages of flood-adapted species in predictable pulsing has been hypothesized. Here, we show that in floodpulsing lakes like Lake Constance, several benthic invertebrate species are specialized in using the dry-fallen sediments for oviposition and resting stages of eggs during winter, and their larvae develop in the moist crevices and puddles which develop in spring. These habitats are warmer than the lake water, they have sufficient food (FPOM) and are inaccessible for fish predators. Several species such as *Ecdyonurus dispar* (Ephemeroptera)

were found almost exclusively in this upper zone, therefore they may be dependent on this special habitat. We conclude from our findings that the predictable water level fluctuations have a positive effect on biodiversity by providing a special habitat for highly specialized species. On the other hand, a short-termed floodpulse during summer did not reveal increased densities of benthic macroinvertebrates of the recently-flooded zones, indicating that the invertebrate fauna of Lake Constance is not adapted to unpredictable floodpulses.

P 5

Climate change effects on water level variation and the response of benthic invertebrates in a Mediterranean lake (Lake Bracciano, Central Italy)

Angelo G. Solimini, L. Mastrantuono, P. Nöges and M. Bazzanti

European Commission Joint Research Centre, Ispra, Italy

Progressive increase of temperature and lower rainfall are some of the main climatic changes occurring in the Mediterranean areas. Consequently, lakes of these regions experience an altered hydrologic balance with large water level reductions and/or fluctuations within and between years. Knowledge on the effects of these water level changes on flora and fauna and the development of useful biological indicators are required to assess current condition and forecast future trends. Here, we present the case of a volcanic lake (Bracciano, Central Italy), one of the largest and deepest Italian lakes. The average air temperature in the Bracciano basin increased by 1.5 degrees over the last 30 years while rainfall showed a decreasing trend. Large fluctuations of the water level with annual means differing by more than 1 m occurred in the last 6 years. To infer the possible response of benthic invertebrates to those changes, we sampled the littoral zone in 2 different periods characterised by 'normal' (1998-1999) and 'reduced' (2003-2004) water level. Samples were collected every 2 months using a standard technique at several sites along the lake shore. Secchi transparency, TP and macrophyte abundance were also directly measured or obtained from competent authorities. Results show a reduction of aquatic vegetation coverage mainly at low depth ranges in years of reduced water level. Benthic invertebrates showed a decrease of taxonomic richness and numerical relative abundances, especially because of the marked reduction of all invertebrates strongly associated with macrophytes (mainly chironomids, oligochaetes, nematodes, water mites and gastropods). On the other hand there was an increase of microcrustaceans (cladocerans and copepods) which constituted at some sites as much as 90% of the total assemblage. The implications of those findings for the development of an indicator based on benthic invertebrates and possible effect of water fluctuations on the sublittoral and profundal fauna are also discussed.

P 6

Applying Grime´s CSR theory to shoreline habitat management

Carlos Abrahams

Baker Shepherd Gillespie, Bakewell, United Kingdom

The frequency and magnitude of water level fluctuations in lakes and reservoirs are likely to increase with climate change. Subsequent impacts on shoreline communities will occur, but appropriate management could mitigate these and allow adaptation. Grime´s CSR theory can be used as a simple model to aid shoreline management. Its application indicates that disturbance from hydrologic fluctuations and stress from wave action will need to be managed to prevent the loss of littoral vegetation and maintain nature conservation interest under the pressure of climate change impacts.

P 7

Monitoring of water constituents in Lake Constance during the flooding event of August 2005 using MERIS satellite data

Sabine Miksa, Thomas Heege

DLR Remote Sensing Technology Institute, Wessling, Germany

Flooding events cause radical changes in the concentration and composition of water constituents in Lakes. Exceeding spatial gradients of suspended matter should appear due to the non-uniform inflows and the hydrodynamic caused transport paths. Additional nutrient loadings of the incoming water masses can increase the production rates of phytoplankton, while increased suspended matter decreases the light availability and reduces the production. Spatial resolved information are necessary to investigate such effects, but difficult to determine by traditional in situ measurements.

Therefore, we analyzed satellite date to study the impact of the flooding event from August 2005 in Lake Constance. MERIS full-resolution satellite data were acquired at 6 cloud free days in July, August and September 2005 encompassing the flooding event in late August. The analysis was made by the software MIP which was developed at DLR for processing multispectral and hyperspectral images from surface waters.

P 8

Environmental factors and eulittoral macroinvertebrate community structure of lowland lakes

Mario Brauns, Xavier-François Garcia and Martin Pusch

Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany

The eulittoral zone of many lakes in Central Europe is subjected to various human impairments e.g. lakeshore modification or water level fluctuations. To assess the impacts of these alterations it is necessary to know, which environmental factors determine the macroinvertebrate community and how these environmental factors are modified by human impairments. In contrast, little is known about the environmental factors that structure the macroinvertebrate community in the eulittoral zone of lowland lakes. Thus, we related catchment land use (7 categories), habitat type (9 categories), water chemistry (5 variables) and water residence time to the eulittoral macroinvertebrate composition of 36 North-German lowland lakes using non-metric multidimensional scaling (MDS). The MDS analysis revealed that the macroinvertebrate community was significantly correlated to total phosphorous concentration, lake water conductivity, the percentage of forest in the catchment, and to percentage of coarse woody debris (CWD) and root habitats. Our analysis demonstrated that the macroinvertebrate community of the studied lakes is among other factors strongly dependent on the presence of complex habitat types as CWD and roots. Consequently, an alteration or loss of these important habitat types through human impairments may have severe impacts on the eulittoral macroinvertebrate community.

Talks

Keynote 1

Floodpulses and water level fluctuations: comparing lakes and rivers

Karl M. Wantzen and Karl-Otto Rothhaupt

University of Konstanz, Germany

In river studies, the floodpulse concept has become an overarching theme to explain patterns of biodiversity, biogeochemistry, and biomass turnover. Attempts to consider water level fluctuations (WLF) as ecological drivers in lakes have been made only recently, however large similarities occur between both types of pulsing ecosystems. Floodpulses shape the physical and chemical setting of the habitat, and they intensify aquatic-terrestrial linkages and organic matter dynamics. Due to the variability of the environmental factors during the flood cycle, floodpulses act as "landscape filters" which select for adapted biota, but the sequential use of littoral habitats also fosters biodiversity. The reuse of organic matter and nutrients of aquatic and terrestrial origin during the phase changes improves the productivity of floodplains. Merging results from current research at a large prealpine lake (Lake Constance) and neotropical river-floodplain-systems (Paraguay River, Pantanal), we will compare and analogize flood effect patterns in lakes and rivers and reveal the benign effects of flooding for landscape management.

T 1

Heavy metal distribution in Vegoritis Lake sediments and possible origin from geogenic and anthropogenic sources

Nikolaos Skoulikidis and Ierotheos Zacharias

Hellenic Centre for Marine Research, Institute of Inland Waters, Anavissos Attikis, Greece

Vegoritis is a large, deep, mesotrophic, typical karstic Lake in NW Greece, located in Ptolemais basin, which comprises a Late Pleistocene-Quaternary neotectonic depression. As a result of human pressures during the last six tee years, the level of the Lake underwent dramatic fluctuations. In addition, the Ptolemais Basin and the Lake itself is subjected to the effluents of lignite mines, electric power generating plants, agricultural manufacturing units, partly treated urban wastewaters, landfills and agrochemicals from an extensively cultivated area. Pollutants are carried into the lake through both, the atmosphere and surface runoff. In order to identify the levels, and assess the origin of heavy metals in surface lake sediments, 26 samples were collected in September 2001using a grab sampler. Samples were analyzed for their grain size, as well as for their mineral, organic matter, major element, heavy metal, pesticide and PCB´s content and the origin of heavy metals has been attributed to geogenic and anthropogenic sources. Despite the anthropogenic disturbance, the levels of micropollutants were low possibly due to the low retention time of Lake water. Even Cu, Pb and Zn, which are mainly derived from human activities, exhibit lower levels than in nearly pristine lakes. Only Ba, Cr, Ni and As are present in relatively high values. Ba is derived from the erosion of acid silicate rocks, Cr primarily from serpentinites and secondarily from pollution, whereas for Ni the opposite is true, while As is primarily attributed to fly ash deposition.

T 2

Lake Võrtsjärv - a large and shallow ecosystem driven by water level changes

Tiina Nöges and Peeter Nöges

European Commission Joint Research Centre, Ispra, Italy

The unique hydrological properties of the unregulated shallow L. Võrtsjärv (270 km^2, mean depth 2.8 m) in Estonia, amplify the effect of the North Atlantic Oscillation to its water level. The large amplitude of the water level, which exceeds the mean depth of the lake, is the main driving force of the ecosystem. Control of phytoplankton growth is mediated through snow and ice conditions in winter, which determine light penetration, and through water level in summer. In years of high water level accompanied by increased DOC influx from the catchment, the illumination at the lake bottom and in the whole water column is diminished. Nutrient levels and the N/P ratio are controlled by the water budget as well as by the sedimentation/resuspension balance both of which are the functions of the affluence. Lasting low-water periods in L. Võrtsjärv bring about a number of adverse biological phenomena expressed in destabilizing of the ecosystem. An increase in phytoplankton and bacterioplankton biomass deteriorates the transparency and gas regime of the lake. Low water level in cold winters (low winter NAO conditions) strongly increases the fish-kill risk. Low-level periods accelerate the overgrowing of shallow areas with macrophytes and deteriorates the spawning conditions for pike due to its restriction from spawning places and for pike-perch, because the spawn can be buried under sediments.

T 3

Water level fluctuations and the chemistry of iron and sulfur

Simone Gerhardt, Claudia Wilderer and Bernhard Schink

University of Konstanz, Germany

Due to the low solubility and slow diffusivity of oxygen in water, oxygen supply is about 1.000 times faster in aerated environments than in water-saturated ones. Water level fluctuations therefore cause dramatic changes in oxygen supply for microbes inhabiting littoral sediments, and influence directly also the redox state of iron, sulfur, and manganese compounds. Microbial redox activities compete with chemical redox reactions in the transformation of these compounds, and microbes also add to these redox processes by oxidation and reduction of carbon and nitrogen compounds. Thus, water level fluctuations change the entire spectrum of redox chemistry in a littoral sediment, with dramatic consequences for the microbial community. The redox state of iron also affects the release of phosphate from the sediment and, with this, influences primary productivity.

Microbial activities in sediments can adapt quickly (within minutes) and reversibly to changes in oxygen supply at the scale of millimeters, as experiments with day/night cycles of oxygen distribution have shown. The sulfur system reacts considerably slower, and this is even more so for the iron system which reacts to changes within a time frame of several hours to half days. How the respective microbial communities can adapt to changing conditions is not clear. Rapid changes in the redox environment will cause severe problems for individual cells, especially if they are strictly linked to specific substrate supply patterns within gradient distributions of substrates and reaction products. Inappropriate life conditions (lack of electron donors or electron acceptors, exposure to toxic oxidants or reductants) impair the energy supply of living cells severely, and only in few instances such stress situations have been studied at the physiological level. To escape such unpleasant situations, some specialized microbes may be able to cope with water level changes by flotation devices. Others can migrate within their habitat by active movement, but only over short distances, up to few centimeters

per day. Thus, it depends strongly on the rate at which water levels change whether microbes can cope with the respective changes by locomotion. Finally, numerous microbes can survive inappropriate life situations as resting stages (spores, cysts, akinetes), and wait for better times to come.

T 4

Influence of water level fluctuations on methane emission from the littoral zone

Ingeborg Bussmann, Monali Rahalkar and Bernhard Schink

University of Konstanz, Germany

Methane is an important greenhouse gas, and its concentration in the atmosphere is increasing at a rate of 5 ppb per year. Methane emission from lakes is controlled by complex interactions of microbially mediated processes (production and consumption) as well as by physical processes (sediment resuspension, temperature, wind, and water currents). Especially the resuspension of sediment is an important source of methane release. WLF will influence the methane cycle at different levels: Changing water levels will dramatically alter the environment of the methane-oxidizing bacteria. Decreasing water levels will expose the methane oxidizing bacteria (MOB) to drying and to excess amounts of toxic oxygen, and insufficient supply with their key substrate methane. Increasing water levels will either expose the MOB to frequent disturbance of their environment (sediment resuspension) or to oxygen limitation. The physiological capabilities of MOB to adapt to the different scenarios will be discussed. Changing water levels will lead to changes in methane emission. Increasing water levels will lead to flooding of so far aerated sediment layers which are poor in methane. Their exposure to waves will not lead to significant methane emissions. The former surf zone will be "moved" to deeper waters and thus methane emissions from these areas will be reduced. Decreasing water levels will expose soft sediments rich in methane to the surf zone and to frequent sediment resuspension. This will lead to increased methane emission. With data on methane distribution in the water column and sediment of the "Litoralgarten" we discuss the above hypotheses.

T 5

Temporal and spatial scales of water level fluctuations

Hilmar Hofmann, Andreas Lorke and Frank Peeters

University of Konstanz, Germany

Water level fluctuations (WLF) of surface water bodies generated by internal and external physical processes, such as long-term precipitation, high discharge events, basin-scale oscillations, or short-term surface waves, affect especially the littoral zone. These processes occur at various temporal and spatial scales, which can be divided into a macro scale and a micro scale. The macro scale describes well known long-term temporal (days to years) and wide-ranged spatial (meters to kilometres) scales. The micro scale, on the other hand, is characterized by short-term temporal (seconds to hours) and locally limited (centimetres to meters) spatial scales. The impacts of micro scale WLF on habitat and organisms are often underestimated due to a lack of appropriate measurements. Although the forcing at both scales is different and hence interactions between them are limited, their superposition has major consequences for the interface between the aquatic and the terrestrial ecosystems. The understanding and consideration of WLF at a wide range of temporal and spatial scales allows to understand changes of abiotic and biotic processes, e.g. resuspension, sediment transport, migration of fishes, phytoplankton growth and abrasion or coverage of biofilms in the shallow littoral zone.

T 6

The impact of water level regulation on composition and diversity of littoral macroinvertebrate assemblages in boreal lakes

Jukka Aroviita and H. Hämäläinen

University of Jyväskylä, Finland

Regulation of lake water level for power production and flood control is among the major anthropogenic disturbances in boreal aquatic ecosystems. In Finland, over 300 lakes, representing one third of the total inland water area of the country, are artificially regulated.

To study the effects of regulation on lake littoral macroinvertebrate communities, samples were taken from upper stony littoral and from lower soft bottom littoral habitats of 11 lakes of varying regulation amplitude (wintertime fall in water level 1.19-6.75 metres). Twelve unregulated (wintertime fall in water level 0.11-0.55 m) lakes with otherwise similar characteristics were used as a reference.

Nonmetric Multidimensional Scaling ordinations showed that the composition of macroinvertebrate assemblages was strongly associated with the amplitude of water level regulation. Species diversity (richness and Shannon index) also decreased with increasing intensity of regulation. In particular, many species of Ephemeroptera (eg. *Ephemera vulgata, Centroptilum luteolum, Caenis horaria, Leptophlebia* spp.), Trichoptera (eg. *Cyrnus trimaculatus, C. flavidus, Polycentropus flavomaculatus*) and Coleoptera (*Oulimnius tuberculatus*), that were typical of reference lakes, were missing or occurred only in low numbers in regulated lakes.

Freezing and flushing of sediments in late winter are probably the most important factors leading to the impoverished littoral macroinvertebrate fauna in regulated boreal lakes. Our results show that water level regulation has a major impact on functionally significant lake littoral macroinvertebrates, and we suggest their use in assessing the ecological status of lakes according to Water Framework Directive.

T 7

Vertical and seasonal distribution patterns of benthic macro-invertebrates in the littoral zone of Lake Constance, a lake with seasonal water level fluctuations

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In Lake Constance, the annual amplitude of natural water level variations is about 2 m, with low water in January/February and high water in July. We assessed abundance and biomass of benthic invertebrates and their seasonal dynamics along a depth gradient in the littoral zone (seven sampling depths from the surf line down to 7 m below the average annual low water level, LWL). The community compositions in the different depth zones differed significantly. Diversity and species richness were highest at the LWL and lowest at the surf line. Community patterns in the dynamically flooded eulittoral zone were influenced by the previous development of the water level. Generally, this shallow zone was an important habitat for pioneer species.

T 8

Effects of water level fluctuation on the nearshore fish community

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Fish community in the littoral area of eight regulated lakes (winter drawdown 1.54-6.75 m) and five reference lakes was sampled with electrofishing in August 2003-2005. Area of the lakes studied ranged between 12 and 887 km^2, and mean depth between 4.2 and 9.7 m. Mean depth in the electrofished areas was 30 cm, and the bottom was in most cases stony. Each electrofished area covered 100 m^2 and the number of these areas averaged 20 per lake. No evident response of the water level fluctuation on species richness was recorded. Total fish density based on a single electrofishing run per area in stony bottoms of regulated and reference lakes averaged 19.3 and 32.7 fish per 100 m^2, respectively. Combined proportion of littoral fish species including minnow (*Phoxinus phoxinus*), bullhead (*Cottus gobio*), alpine bullhead (*Cottus poecilopus*), nine-spined stickleback (*Pungitius pungitius*) and stone loach (*Barbatula barbatula*), supplemented with zoobenthos feeders ruffe (*Gymnocephalus cernuus*) and young burbot (*Lota lota*) in the fish community of stony shores responded negatively to the water level fluctuation. Besides water level fluctuation, also trophic level and bottom quality affected the fish community.

T 9

Effects of shelter availability in the littoral zone on the ontogenetic habitat shift in juvenile burbot (*Lota lota*)

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Most lake populations of burbot inhabit three distinct habitats during their ontogenesis: the pelagial zone during their larval phase, the littoral zone as juveniles and the profundal zone afterwards. Juvenile burbot aggregate in shoreline areas that have a high percentage cover of stones which provide interstitial shelter. The lake level of Lake Constance fluctuates annually by about 1.5 m, reflecting the discharge of the alpine Rhine River. This strongly affects the availability of the substratum and therefore the suitability of the habitat for juvenile burbot.

In mesocosm experiments the importance of interstice shelter availability, interstice size and light intensity as environmental factors for habitat selection in small (age class 0) and large (> age class 1) burbot was examined. Four stone sizes (pebbles, gravel, cobbles and stone) providing ascending sizes of interstice shelter were offered to both age classes in a shallow area (17 cm water depth) and a deep area (85 cm water depth). For juvenile burbot, the availability of interstice substratum shelter seems to be an overall important factor for habitat selection explaining their distinct preferences of shallow littoral habitats with stone coverage. In contrast, for adult burbot increasing water depth, independent of the absolute light intensity and shelter availability seem to be the proximate factor leading these age classes to greater water depth at some time during their ontogenetic development.

T 10

Is bream spawning mediated by water level fluctuations? - Evidence for adverse effects of epiltihic growth on egg attachment of bream *Abramis brama*

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The influence of epilithic colonization on the egg attachment of bream (Abramis brama) was assessed in a lake experiment with artificial substrate. Eggs adhered better to clean control surfaces than to surfaces colonized by chironomids, algae and bacterial biofilm. Within a natural bream spawning habitat, eggs were distributed in the most shallow water accessible to spawning females, coinciding with lowest values for chlorophyll a and ash free dry mass along a depth gradient. No eggs were found below a depth of 40 cm. We assume that shore spawning fish such as bream actively search shallow water habitats with clean spawning substrate to enhance egg attachment and subsequent survival. The success of this spawning strategy in temperate lakes may be impaired by water level management and climate change, resulting in lower water level fluctuations during spring.

T 11

Effects of water level fluctuations on the littoral benthic fish community in a large lake

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A significant disagreement between the expected (modelled) and the observed average cohort lengths of littoral dwelling juvenile burbot (*Lota lota* L.) was observed in Lake Constance, Germany. Temporarily coupled with the onset of the autumnal water level decrease in September, particularly the largest members of the age-0 cohort started to migrate towards the profundal zone. This indicates a complex size-selective inter-habitat migration, with autumnal lake level draw-down as the major proximate factor. By using an individual based modelling approach (IBM), the effects of short and long term water level fluctuations were calculated. The results showed that water level fluctuations may provoke either an increase or decrease in average population growth in littoral dwelling burbot, depending on the amplitude and timing of the water fluctuation regime. The study shows that water level fluctuations affect not only the behaviour and distribution of individual fish within the littoral itself but can also control the temporal and spatial distribution patterns of a particular fish species in an entire lake ecosystem.

Keynote 2

Water level fluctuation in a lake ecosystem - ecological effects and management related issues

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The fluctuation in water level of aquatic systems is a natural phenomenon reflecting seasonal changes in water budget (losses and gains). Man-made regulation of water inflow or outflow may accentuate or diminish water level fluctuations. Such fluctuations are an important source of ecological variance. Rise and fall of water level may influence the biota either directly (e.g., scouring and desiccation effects) or indirectly by modifying interactions via effects on ecosystem structure (size, depth, complexity). This in turn influences the services provided by the ecosystem, including availability of water for human use and recreation, as well as the threats associated with it, mostly flooding or desiccation. Correspondingly, human interaction with pulsating systems aimed at maximizing a certain service (e.g., diversion of water for irrigation) or minimizing a major threat, often results in compromising the ecology of the ecosystem. The latter is particularly pronounced in regions with distinct wet and dry periods (e.g., Mediterranean), where water is available seasonally, and competition for freshwater by the various sectors is severe. I will present the case of Lake Kinneret (170 km^2), one of the central reservoirs of freshwater in Israel, where the natural water level fluctuation has been almost tripled by human action. I will illustrate the effects of this hydrological change on ecosystem structure (littoral zone complexity) and its cascading influences on biotic structure and interactions. I will discuss related managerial aspects that are usually provoked after consecutive drought years (a natural phenomenon in Mediterranean-type climates), which force the Water Commissioner to take decisions on how to divide the risk ensuing from water drawdown among the major reservoirs. Hydrologists usually recommend taking most of the share from the lake, highlighting the handicap that ecologists face in convincing the authorities of the ecological risks. This disadvantage derives from the inherent difficulty of relating causes and effects in complex systems, mainly large ones that can not be experimentally manipulated. However, the fact that ecological effects of water level fluctuation can not be simply demonstrated on an ecosystem level does not mean they do not exist and may one day prove highly detrimental. Global warming and its impact on distribution of precipitation worldwide is expected to bring the issue of water level fluctuation and its consequences to the attention of the public and decision makers also in regions currently unaffected by this phenomenon. This calls for concerted efforts by ecologists, hydrologists and managers to develop a comprehensive understanding of the impacts of water level fluctuation and suggest ways to minimize its adverse effects.

T 12

Extreme Water level draw-down of Lake Kinneret corresponds with indications of ecosystem destabilization

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Lake Kinneret is Israel's only natural freshwater lake, supplying about half of the country's drinking water. Water shortage has led to extreme water level draw-down and fluctuations, culminating in the lowest ever water level in 2002, 5 m below the full supply level. Until the mid 1990s the phytoplankton of Lake Kinneret demonstrated distinct year-to-year stability expressed in a typical winter-spring bloom of the dinoflagellate *Peridinium gatunense*, followed by predictable seasonal succession. However, *Peridinium* did not bloom in 5 of the 10 years since 1996. At least 5 alien species invaded the lake, of those 3 formed massive blooms. Those new blooms were of the N_2-fixing cyanobacteria

Aphanizomenon ovalisporum and *Cylindrospermopsis cuspis* in summer-fall, and of the filamentous chlorophyte *Debarya* sp. that bloomed in spring 2005. Winter *Aulacoseira* blooms, which occurred in the past, have intensified. Fungal epidemics of *Peridinium*, never reported in the past, became a recurring event. These changes are interpreted as indicators of declining in ecosystem stability, and are likely a result of man-induced changes including the water level draw-down.

T 13

Use of water level fluctuation analysis tool (REGCEL) in development of Finnish lake regulations

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Alteration in water level fluctuation is the most important hydromorphological pressure in Finnish lakes. There are more than 300 regulated lakes in Finland. In most cases the purpose for the water course regulation is either hydropower generation or flood prevention or both. During the last decades there has been large public pressure to modernize old regulation policies. Extensive research projects have been carried out in order to find out the effects of regulation and means to mitigate its negative impacts. Water level fluctuation analysis tool (REGCEL) was developed in Finnish Environment Institute (SYKE) between the years 1999-2000. REGCEL is a calculation sheet which gives an overall picture of the impacts of the regulation in northern climate. The model is based on the known or estimated relationships between water level fluctuation and factors related to environmental, social and financial impacts. The REGCEL model have been applied to several purposes.

Model has been applied in 12 lake regulation development project in Finland. In lake regulation development projects REGCEL-tool has been used to evaluate current status of lake and to compare different regulation practices. Also new regulation practice alternatives can be estimated and compared by this analysis tool. Finally altered regulation practice has been followed with annual REGCEL-analysis producing several water level indicators. Results from REGCEL-analysis have been also applied in initial designation of heavily modified lakes according to EU water framework directive. REGCEL-applications covers also some Scandinavian and Scottish regulated lakes. REGCEL-analysis tool can be also used to estimate the effects of changed water level fluctuation caused by climate change. REGCEL model has also been basis of the impact assessment part of a value-tree based model REGAIM, which includes value tree model, hydrological model and impact assessment model. REGAIM-model has been used to create target regulations in personal face to face computer aided decision analysis.

T 14

Impacts from climate change and agricultural practices on a lake´s water level and the associated interactions with a priority wetland habitat

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Climate change and human activities influence significantly the hydrologic regime of freshwater bodies and therefore constitute crucial factors for riparian and aquatic habitats. Particularly, the seasonal and interannual water level fluctuations in a large lake are very important hydrologic features that relate to

specific environmental impacts and natural disasters, such as wetlands loss and flooding events. This study attempted to analyze the past climatic and water management alterations in Trichonis Lake as well as the land use changes to quantify the impacts on the surrounding priority wetlands (NATURA 2000 network). Regression analysis and Cumulative Sum method have been applied in rainfall and water level time series to identify relevant past trends while remote sensing and GIS techniques have been used to map and illustrate the changes in the land use and morphology of the wetland area. The local water management scheme for the study period has been analyzed and taken into account, focusing on the alterations in irrigation demands which is the most important water use factor in the area. Thus, a comparative assessment occurred between the estimated alterations in rainfall and anthropogenic water abstractions to identify the contribution of each one of these factors on the measured water level fluctuations in the lake and the associated wetlands extent changes during the study period. The above approach indicated that the expansion of cropland in the study area, the enlargement of irrigation infrastructure and the lack of an integrated water management plan are mainly the responsible factors for the measured decrease in the wetland habitat extent while climatic parameters and trends have had a relatively low influence at the particular area. Moreover, apart from direct wetland loss there is also indirect pressure in the habitat due to the introduction of adverse hydrologic conditions such as high annual water level fluctuations and fast monthly hydrologic transitions. Consequently, an integrated environmental management strategy has to be developed to attempt eliminating the impacts originating from unsustainable water management and land use practices.

T 15

Flooding of the riparian wetlands - interaction between water level flutuations and vegetation zones. Biebrza wetlands case study

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The Biebrza Wetlands lie in Northeast of Poland in an ice-marginal valley, some 195 000 hectares in area. It forms one of the last extensive, fairly undisturbed river-marginal peatland in Europe, containing endangered plant and animal species in a large variety of fully developed ecosystems.

The most characteristic feature of the Biebrza River is flooding, which appears there almost every year. Water which inflows into Biebrza valley, is accumulated here due to the small longitudinal slopes of the basins as well as due to the fact that valley is closed downstream by the moraine formation. The Biebrza valley plays the role of a large reservoir for surface water and shallow groundwater which is blocked by the river flood.

In period 1999-2005, extensive investigation of the flooding phenomena was carried out in order to capture the main processes involved in the inundation of the river valley, to measure the main characteristics of particular floods and to combine them with characteristic patterns of wetland ecosystems. Investigation included RS using Landsat images, hydraulic modeling using UNET HEC-RES package, chemical analysis of flooding water and mapping of wetland ecosystems.

The stratigrafic soil-profile data showed the way the valley was inundated and colonised by wetland plant communities. The surface soil cover describes the current status of soil-water conditions, showing by slight mursh layer decrease of water saturation of the soil profile.

Analysis of hydrological data for the closest gauge station in Burzyn allowed for comparison of plant communities zone location with flood extension. Contrary to general expectation flood magnitude, frequency and duration have not proofed that there is a decrease in flood magnitude. As a result, each zone of the plant community is characterized by the inundation frequency and average flood duration. It was also proofed that river water is responsible for inundation of part valley only. The other part of it is inundated by the groundwater seepage or snow-melt in situ, what agrees with earlier, qualitative description of water sources for the particular plant communities.

Results of this study confirmed that fully developed wetland ecosystems are formed by the different type of water, even if the habitats are located in the same river valley. This conclusions as well as lesson learned from the monitoring and modelling of flooding phenomena in natural river valleys give major guidelines in protection and restoration of riparian wetlands.

T 16

Flooding events and rising water temperatures increase the significance of the reed pathogen *Pythium phragmitis* in Lake Constance, Germany

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Pythium species are economically significant soilborne pathogens with worldwide distribution, causing seedling damping-off or root rot of numerous different host plants. Grasses and cereals are among the major hosts of this genus. Being oomycetes, these organisms are dependent on the presence of water for zoospore release and dispersal. *Pythium phragmitis* is a newly described pathogen of common reed (*Phragmites australis*), widespread in the reed-belt of Lake Constance, Germany. It is highly aggressive towards reed leaves and seedlings, while it does not affect roots. In the context of 'reed decline' phenomena, *P. phragmitis* infection of reeds inundated during flooding events may be of particular significance. We could show that flooding itself is not necessarily detrimental for reed plants, while in the presence of the pathogen, most submerged leaves were killed within several days. Significant losses in assimilating leaf area could thus be the result of *Pythium* infection rather than of flooding alone. As a consequence of rising mean temperatures on a global scale, flooding events in Lake Constance will occur earlier in the growing period, and *Pythium* infection coincide with smaller plants in spring. In parallel, an increase in average water temperature has been found for Lake Constance. Considering the fact that *P. phragmitis* has a rather high optimum growth temperature, pathogenicity and spread of this species may be considerably favoured by milder winters and higher mean water temperatures. We propose that *P. phragmitis* could be a contributing factor in the dieback of reed stands likely to be promoted by predicted climate change phenomena.

T 17

Water level fluctuations and dynamics of amphibious plants at Lake Constance: long-term study and simulation

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Natural lakeshores are habitats often characterized by highly variable environmental conditions. Only few studies, however, examine the dynamics of lakeshore plants. In our study we investigate the long-term dynamics of amphibious plants at Lake Constance - a pre-Alpine lake with unregulated water level regime. Consequently, the amphibious plants were yearly flooded for several weeks in summer. We address two questions. (1) Is there a relationship between water level fluctuations and dynamics of the amphibious plants? (2) Is there any evidence for biotic interaction among species?

Small amphibious plants cover the nutrient-poor gravel shores at Lake Constance and *Littorella uniflora*, *Ranunculus reptans*, and *Agrostis stolonifera* belongs to the dominating species. However,

also tall plants as the sedge *Carex acuta* and the grass *Phalaris arundinacea* are co-dominant. We established two permanent transect with the size of 1 x 8 and 1 x 10 m, respectively, at the lakeshore in the nature reserve “Halbinsel Mettnau” near Radolfzell. Between 1988 and 2004 we estimated abundance of the plants using a grid frame (cell size: 10 x 10 cm). Thus, we obtained 1800 presence-absence data per year and species. We used standard linear regression and a Markov models to examine the effect of flood duration and interactions among species. The parameters of the Markov models were determined by non-linear regression using a Gauss-Newton algorithm. We show that the abundance of *A. stolonifera* and *P. arundinacea* decreased and that of *R. reptans* increased after long flooding durations. *L. uniflora* showed no effects. *A. stolonifera* and especially *C. acuta* are strong competitors replacing the characteristic species under moderate conditions. Therefore, to some extent the co-existence of the amphibious species was maintained because *A. stolonifera* decrease dramatically after extreme floods. However, the continuous increase of the competitive sedge *C. acuta* is an example of an invasion by an indigenous species since this species did not occur before the 1980th years.

T 18

Effects of hydrologic variations on the dynamics of shore vegetation of Lake Constance, Germany

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Water level fluctuations play a major role in the dynamics of shore vegetation of Lake Constance. This is due to Lake Constance is the only great lake in the northern alpine forelands which exhibits an essentially natural water level regime with mean yearly fluctuations of about 2 m between low water in January/February and high water in June/July. While these average water level fluctuations can be regarded as internalised by the ecological system, even indispensable for the existence of the endemic plant community of the “Strandrasen”, extreme floods and low water periods represent disturbance events causing spatial and species dynamics in the shore vegetations communities. Extreme floods in the last 50 years occurred in 1965, 1987, and 1999, extended low water periods in summer accumulated in the last fifteen years (1989, 1992, 1996, 1998 and 2003). In particular, the extreme floods in 1965 and 1999 led to a loss of more than 30 hectares of aquatic reed belt in Lake Constance. Low water levels lead to the lake ward extension of reed belts as well as other plant communities. In particular, low water periods following extreme floods increase diversity in species composition and spatial extent of shore plant communities, as the low water year 2003 shows. Thus, hydrological disturbance events cannot only be regarded from their damage potential but also from their potential creating new habitats, essential for the maintenance of a diverse shore vegetation. Hence, Lake Constance may serve as a model to investigate the disturbance ecology of shore plant communities, their limits of flooding tolerance, and their strategies of rehabilitation and space re-occupation in dependence of time and water level fluctuations.

Excursion

The Wollmatinger Ried: a lacustrine floodplain wetland

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The excursion by boat leads us along the adjacent shallow water zone of nature reserve “Wollmatinger Ried”, a protection area of international significance. The annual water level fluctuation

of Lake Constance (yearly amplitude of some 2 m) here has strong impact on the littoral zone, reminding the tides of the wadden sea. However, with only one yearly tide: a flood during summer and a low tide during winter.

During the winter the appearing huge mudflats are of international importance as migration stopovers and wintering area for waterbirds in impressive numbers. The protected area provides shelter for up to 60.000 waterbirds concentrating within an area of about 2,5 km². Among them are 20.000 Pochards (*Aythya ferina*), 20.000 Tufted ducks (*A. fuligula*) and Coots (*Fulica atra*). In addition to these species, the area also is of international interest to Red Crested Pochard (*Netta rufina*) and dabbling ducks like Gadwall (*Anas strepera*), Shoveler (*A. clypeata*), Pintail (*A. acuta*) and Teal (*A. crecca*). Moreover, the site represents one of the few inland overwintering sites for Whooper Swan *Cygnus cygnus* (up to 200 ind.), foraging on tubers of the submerged macrophytes like Pondweed.

This comparatively small area with its impressive waterfowl densities demonstrates the potential of naturally occurring water level fluctuations in shallow water zones. However, mainly due to human disturbances the waterbirds still have to concentrate within a few square kilometres of protected littoral zones at Lake Constance.

Keynote 3

Effects of the water level fluctuation on the littoral habitats of Lake Balaton, the largest shallow lake in Central Europe

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Historical extreme decreases of the water level of Lake Balaton (area: 596 km^2, mean depth: 3.2 m; Hungary) were previously recorded in the late summers of 1938 and 1949. However, the most dramatic decrease (0.9 m) of the water level occurred in 2000 - 2004 as a result of chronic drought and increased summer evaporation. Almost all rocky and reed-colonized underwater littoral surfaces became dry by the summer of 2003. Changes in the littoral morphology and the degree of the shrinking of the littoral surfaces were studied during the drought period based on 40 x 40 solution orthographic aerial and on-the-spot digital photographs using image analysis, and then modeled. According to the estimations, underwater surface area of the rocky littoral ranges between 97 and 231 m^2 10^{-1} m and that of the artificial concrete littoral between 30 and 35 m^2 10^{-1} m at the upper regulation level of the lake (+110 cm). A decreasing rate of 14 to 18 % of the underwater surface area for each 10 cm reduction in the water level was estimated. The original 1.8% cover of the reed belts of the total lake area decreased to 0.07% with the withdrawing water line and the underwater surface of the reed belts decreased from the total 15.8 km^2 to 5.7 km^2. The fluctuating water level and the changes of the shoreline morphology is modeled and displayed on GPS-compatible Standard Cartographic Projection System. Strong links between the seasonal variation in water level, the surface of the underwater littoral and the density of veliger larvae of sessile *Dreissena polymorpha*, is found in Lake Balaton. OTKA Found (No. 049365) and BALOKO Project (3B/022/2004) supported this study.

T 19

Water level fluctuation: impacts on a shallow Mediterranean lake (Lake Pamvotis, Greece)

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Water level fluctuations are regarded to be an important factor for a lake ecosystem function affecting also its conservation value.

Lake Pamvotis is a shallow Mediterranean lake (mean depth of 4.3 m and maximum depth of 7.5m) and occupies an area of 22.8 km^2. The basin has no naturally occurring surface outflows and is recharged by karstic springs. In terms of biodiversity, Lake Pamvotis is of global significance. Under the European Community Council Directive on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive, 92/43/EC) lake Pamvotis is included to the Natura Special Conservation areas as "natural eutrophic lake with *Magnopotamion* or *Hydrocharition* type vegetation. Aquatic macrophyte communities can be influenced by changes in nutrient levels and physical conditions. Another factor that can mediate the coverage and structure of macrophyte communities is water level alteration resulting from anthropogenic modulation of hydrology.

Strong effects of mainly anthropogenic changes in the fluctuation of water -level are shown for this area using a GIS system for depicting the land uses/cover changes. Indeed, a set of aerial imagery acquired in 1945 through 1966 was used to monitor and assess the spatial and temporal changes in land cover/use focused mainly on the lake's surface area and its surrounding ecosystem. The significance of the changes in land cover/use distribution within Pamvotis wetland is further discussed depicting the role of the anthropogenic influence on the fragile ecosystem that resulted in the shrinkage of lake's extent.

The purpose of this analysis was to examine changes in macrophyte community composition, species occurrence and area covered with water quality and water level changes over the past century, using historical data, aerial photos and GIS techniques.

Moreover, a set of annual measurements of lake's depth and water chemistry during the high and low water level period are also presented. It seems that water budget data as well as the response of the key eutrophication parameters are affected from the hydrological alterations. Although the area is among the most humid in all over Greece, Mediterranean climate also results in changes in hydrological regime. According last climatologically data effects of climate change are anticipated that might affect the functioning and the structure of this shallow ecosystem.

T 20

Reaction of macroinvertebrates upon the water level fluctuation in the littoral zone of Lake Balaton

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The water level of Lake Balaton gradually decreased from 2000, was extremely low in 2003 and a regeneration period started due to intensive precipitation in 2004. Water level fluctuations of a shallow lake mostly influence the littoral zone and the invertebrates living in the encrustation of different substrata.

We studied the qualitative and quantitative relationships of the invertebrates living on submerged macrophytes in 2000, 2001 and 2002 as well as on stones in the extremely dry 2003 and the subsequent regeneration period (2004) at different sampling stations of littoral zone in Lake Balaton, four times a year. Submerged macrophytes were sampled with a bag-shaped sampling device makes possible to sample quantitatively the submerged macrophytes and the animals (larger than 300 µm) encrusting macrophytes. In the stony littoral zone we sampled near the water surface and from the bottom. The encrustation of the stones was brushed and sieved (mesh size: 300 µm).

Nearly 100 animal taxa were identified; Ponto-Caspian invasive Amphipoda (*Chelicorophium curvispinum* and *Dikerogammarau*s species) and zebra mussels (*Dreissena polymorpha)* dominated in spatially and seasonally different degrees. The density of invertebrates (ind m^{-2}) on submerged macrophytes gradually decreased from 2000 by 2002. Much more invertebrates on the stones occurred at the bottom than near the water surface if the water was enough deep. *Dikerogammarus* species and zebra mussels were forced back and *C. curvispinum* came to the front on the stones in the regeneration period as compared to the droughty 2003 year. The density of invertebrates (ind m^{-2} stone surface) slightly increased in 2004 as compared to that in 2003.

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T 21

Effect of water level fluctuation on zebra mussels in Lake Balaton (Hungary) in the period of 2000-2004

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The water level of Lake Balaton extremely decreased (93 cm) by 2003 due to considerable evaporation, as the consequence of radical climate change from 2000. A regeneration period started thereafter with intensive precipitation. The most visible changing was observed in the littoral zone, where large number of benthic animals live together with the Ponto-Caspian invasive exotic species, the zebra mussel (*Dreissena polymorpha)*. They are dominant on different substrata and exert serious ecological impacts on invaded part of the lake.

The aim of this study was to follow the population dynamics and quantitative relationships of zebra mussels on submerged macrophytes and on the stones from the stony littoral zone of Lake Balaton in the period of 2000-2004. We collected animals settled on submerged macrophytes (2000-2002) and on stones from two depths (2003-2004) at four sampling stations of different trophic area of the lake (Keszthely, Szigliget, Tihany, Balatonalmádi), four times from May till October. We determined the density, measured the length, calculated the relative abundance and the biomass of zebra mussels and compared the data with the abundance of planktonic larvae.

Our results show that the density and the relative abundance of zebra mussels on submerged macrophytes decrease parallel with water level decline in contrast with the maximal lengths of the mussels which increased by 2002. Vertical stratification of zebra mussel density and length could not evolve on the stones during the droughty period in the shallow stations (Keszthely, Szigliget, Balatonalmádi) as compared to Tihany, where the lake is deep enough for stratification. In the recoveration period (2004), at increasing water level, stratification occurred everywhere, and the density of the mussels increased. Zebra mussel larvae considerably reduced by 2004.

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T 22

Potential changes in eulittoral invertebrate composition following water level fluctuations in North-German lowland lakes

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Lakes in North-East Germany are highly sensitive to climatic changes, as precipitation is low and higher temperatures in the future are forecasted. Especially the many lakes fed by groundwater will suffer a substantial lowering of their water level. This will probably be accompanied by a change of the riparian vegetation from trees to reed, which is able to follow the receding shoreline more quickly. As tree roots constitute the most important habitat for eulittoral macroinvertebrates in North-German lowland lakes, severe effects can be expected. Hence, we examined if that loss in the eulittoral zone can be compensated by the availability of the major infralittoral habitat types. For that purpose, we examined differences in the faunal characteristics between the habitat-specific communities in terms of species richness, species composition, densities of major groups, and functional feeding groups. We collected 43 macroinvertebrate samples from the five major habitat types sand, stones, reed, CWD, and roots in seven North-German lowland lakes. Species richness did not significantly differ between the five habitats, while species composition on roots significantly differed from those of sand and stones. The densities of Odonata and Coleoptera, as well as the density of predators, were significantly lower on sand than in roots. The macroinvertebrate community in reed, stone and CWD habitats did not show pronounced differences to the community of root habitats. We conclude that the loss of root habitats in the eulittoral zone can be substituted in the infralittoral zone provided that reed, stone and CWD habitats are present there.

T 23

Lake level fluctuations: a systematic view of causes and consequences for littoral ecosystems

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This contribution tries to define `fluctuations´ and `trends´ of different hydrological key varaibles (e.g. mean water level, range, extremes, seasonality, return period) along different time scales. The relevance of these time scales, ranging from a few seconds to several millenia, corresponds with the life span of organisms affected. Direct methods (e.g. hydrograph) and proxy methods (e.g. sedimentological records) can be used to identify fluctuations and trends. They should be accompanied by appropriate statistical tools (e.g. time series and extreme value analysis).

Possible causes and background scenarios comprise (i) climate fluctuations and change (i.e. acceleration of the hydrological cycle), (ii) landscape and groundwater water balance (i.e. agriculture, ground sealing, water diversion), (iii) slow geologic processes (tectonic and isostatic earth crust movements), (iv) fast geologic processes (modification of outflow characteristics by landslides, erosion or sedimentation), (v) biogenic processes (e.g. lake marl formation, peat growth) and (vi) anthropogenic impacts and management for different purposes. Finally, (vii) the lake type (following Hutchinson's typology) is one of the most important factors.

Lake level fluctuations and trends may affect many aspects of littoral ecology like wave action and longshore currents, solid matter budget of coastal cells, transparency of the water column, ground

water level in the landward part, redox potential, nutrient availability and toxine formation in sediments and waterlogged soils, diaspore transportation, and competitive relations between species.

Littoral biocenoses are among the most affected ecosystems if water level changes occur in appropriate time scales. This can be well demonstrated using the riparian vegetation as an example. Many wetland plants exhibit a `flooding tolerance syndrome´ to cope with a sudden but temporal increase in water level. The flooding tolerance comprises a set of anatomical, morphological, physiological and reproductional traits. However, `draught tolerance characteristics´ as an adaptive reaction to drawdowns of water level, are not very abundant in wetland plants. One remarkable feature is the plasticity of life history traits (e.g. the clonal growth) by means of which wetland plants can stand their ground when the water level gets higher. A successional change would then occur at a low rate. Contrary, lake level drawdowns may set on very quick changes and a very marked succession.

When we consider practical problems like ecological quality assessment of standing water bodies (as required by the European Water Framework Directive), water management plans and species and habitat protection plans (as required by the European Wild Habitats Directive) we should look at littoral ecosystems as very dynamic ecosystems, in which hydrological and morphological changes are the dominant driving forces.

T 24

Neo- and paleolimnology of a carbonate mountain lake characterized by marked water level fluctuations

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Lake Tovel is an oligotrophic, meromictic mountain lake (1178 m a.s.l., max. depth = 39 m) of the Dolomites (Adamello-Brenta Natural Park), which used to be well-known because of impressive red summer dinoflagellate blooms. These disappeared in 1964 and represent a phenomenon of scientific and socioeconomic relevance which made Lake Tovel a classical research site for Italian limnology and motivated the Autonomous Province of Trento to fund a multidisciplinary Project (SALTO/BEST) specifically devoted to the problem. The Trento Science Museum (MTSN) participated in this Project and has been conducting investigations on the lake since the beginning of the last century. This long-term research activity is bound to continue also because, thanks to a Life Project (TOVEL), the Museum now owns a Limnological Station on the shores of the lake. This is run by the MTSN Limnology and Phycology Section which has phytobenthos and paleolimnology among its main research topics. One of the most peculiar aspects of Lake Tovel are water-level fluctuations. By means of neo- and paleolimnological data collected since 1999 this contribution will focus on the spatial and temporal extent of WLFs, aiming at showing their relevant influence on long-term development of the lake and their effects on the littoral zone and especially on the depth-distribution of microphytobenthos and of chironomids. The microphytobenthos was characterized considering a variety of parameters including taxa composition, diatom biovolume, concentrations of characteristic pigments of the two dominating groups (fucoxanthin as a marker pigment for diatoms and scytonemin a photoprotective pigment exclusive of cyanobacteria), organic matter, chlorophyll, pheophytin and photosynthetic efficiency. The chironomid taxa along the depth-transect were all typical of the littoral zone of an oligotrophic lake. The low number of head capsules usually found and their absence below 12 meters is associated to the low oxygen content of the monimolimnion.

T 25

The impact of water level fluctuations on the year class strength of roach: implications for fish stock management

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Water levels in reservoirs usually fluctuate seasonally over a wider range than it is true for most natural lakes because they depend not only on the hydrology of the catchment area, but also on the amount of withdrawal of water by subsequent users and the inflow from other reservoirs within a system of interconnected reservoirs. The impact of these water level fluctuations on the littoral biocoenosis is thus particularly strong, which is one reason for the often poorly developed macrophyte cover. Many fish species such as roach heavily depend on the shallow water region as spawning habitat as well as a refuge to prevent predation. Therefore, water level fluctuations (and their timing) may decide about recruitment success of roach and the availabilty of refuges for juvenile roach.

To investigate these relationships we studied water level fluctuations in a drinking water reservoir and length frequency data of roach over a period of seven succeeding years. The results indicate a strong impact of water levels on the year class strength of roach. Constantly high water levels with large areas of flooded plants led to a very strong roach year class while decreasing water levels shortly after the spawning period were found to results in a total cancellation of the new roach year class. Consequently, water quantity management in reservoirs can be used as a biomanipulation tool to reduce the planktivorous fish stock and to improve water quality which should be an interesting option especially in drinking water reservoirs.