MEETING of COST 869

Mitigation options for nutrient reduction in surface water and groundwaters

Working Group 2

6–8 May 2009

Location: West Transdanubian Water Authority
Department Kis-Balaton, H-8360 Keszthely, Hungary

Topic of the meeting:

Ecological response to system manipulation

Local organizer

Vera Istvánovics

Co-organizers

Petri Ekholm, Ken Irvine, Penny Johnes & Wim Chardon

Proceedings edited by
W.J. Chardon & V. Istvánovics

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	Conference dinner

Friday 8 May

08:00 – 13:00	Excursion to the lake Kis-Balaton (pickup at the hotels). We will visit the area of the Kis-Balaton wetland on the Zala River. This has been reconstructed for eutrophication management of Lake Balaton. Now it belongs to the Balaton Highlands Nature Protection Park. It is beautiful with very diverse birds.
13:00	End of the meeting - Lunch - Transport to airport

Abstracts of oral presentations - Presenting author, title page

Abstracts of oral presentations - Presenting author, title page

Thursday

Abstracts of poster presentations - First author, title page

ABSTRACTS OF ORAL PRESENTATIONS

Ecological response of 80 lake restorations in Denmark

Martin Søndergaard, Lone Liboriussen and Erik Jeppesen
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During the past 20 years about 80 Danish lakes have been restored by various measures to combat eutrophication. Restoration methods include sediment dredging (1 large lake and many small), aluminium treatment (6 lakes), hypolimnetic oxygenation (6 lakes), pike (*Esox lucius*) stocking (50 lakes) and removal of plankti- and benthivorous fish (mainly roach, *Rutilus rutilus*, and bream, *Abramis brama*) (36 lakes).

The results obtained have been very diverse depending on the method used, the restoration intensity and pre-conditions of the lake (external nutrient loading, etc.). The best results were obtained by aluminium treatment and fish removal, whereas the other methods showed less clear effects. Aluminium addition had very marked and immediate effects on lake water quality, but long term effects (> 5 years) are still not well described. In lakes where less than 200 kg fish ha^{-1} were removed within a 3-year period only minor effects were observed, but at higher removal rates both chemical and biological variables were markedly affected. Here the concentrations of chlorophyll, total phosphorus, total nitrogen and suspended solids decreased to 50-70% of the level prior to removal.

The most significant and long-lasting effects were found for suspended solids and Secchi depth, while the most modest effects were seen for chlorophyll *a*. This probably reflects an efficient and persistent reduction of the bream stock which reduced resuspension and suspended solids, while the biomass of roach quickly returned to former levels, decreasing the zooplankton grazing with less control on chlorophyll *a*. Total algal biomass also declined after fish removal, particularly that of cyanobacteria, whereas the biomass of cryptophytes increased, indicating enhanced grazing pressure by zooplankton. The abundance and species number of submerged macrophytes increased in the majority of the lakes. For most variables the effects of the fish removal were significant for 6-10 years, after which many lakes tended to return to pre-restoration conditions, probably mainly because of consistently high external and internal phosphorus loading. This indicates that although fish removal is an efficient tool to create clear water with cascading effects on most trophic levels, repeated fish removal is presumably required to obtain long-term effects in the most nutrient rich lakes.

Catchment nutrient sources and impacts in an Irish mesotrophic lake

Chris Barry & Bob Foy
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Lough Melvin is a polymictic, humic and alkaline lake in north-west Ireland which, by virtue of its low nutrient status, is an increasingly rare example of a lake with a natural post-glacial flora and salmonid community. However since monitoring began in 1990, phosphorus (P) in the lake has risen 50% from 19 to 28 μg P L^{-1}. Three annual programmes of lake and inflow nutrient monitoring have shown increases in P export intensity from diffuse sources across the catchment but the spatial pattern of this increase has not been uniform. CORINE land cover P export coefficients gave catchment and sub-catchment P exports within 10% of those estimated from monitoring in all but one area, where a large increase in P loss over time indicates catchment specific impacts on P losses compared to those predicted from changing land use. In 2001, lake P was higher than predicted from inflow concentrations, which was attributed to a pulse of P associated with clear-felling of coniferous forestry in the catchment but this source of P declined from 2000 to 2007. Post 2012, conifers planted in the 1970s and 1980s will reach harvestable size and predictions of P loads from planned clearfelling suggest a potential increase of lake P concentration to 34 μg P L^{-1} by 2015. There is evidence that the impact of increasing P is being modified by other limnological factors as, despite considerable P enrichment, phytoplankton abundance has remained indicative of oligo-mesotrophic status, apparently being capped by the combination of the deep mixing depth and a humic matter restricted photic zone. With respect to the latter the lake is becoming browner reflecting higher inputs of dissolved organic carbon. A more subtle and less studied littoral response by filamentous benthic algae may be a more likely impact of P-induced degradation in Lough Melvin.

Does agri-environmental erosion control abate coastal eutrophication?

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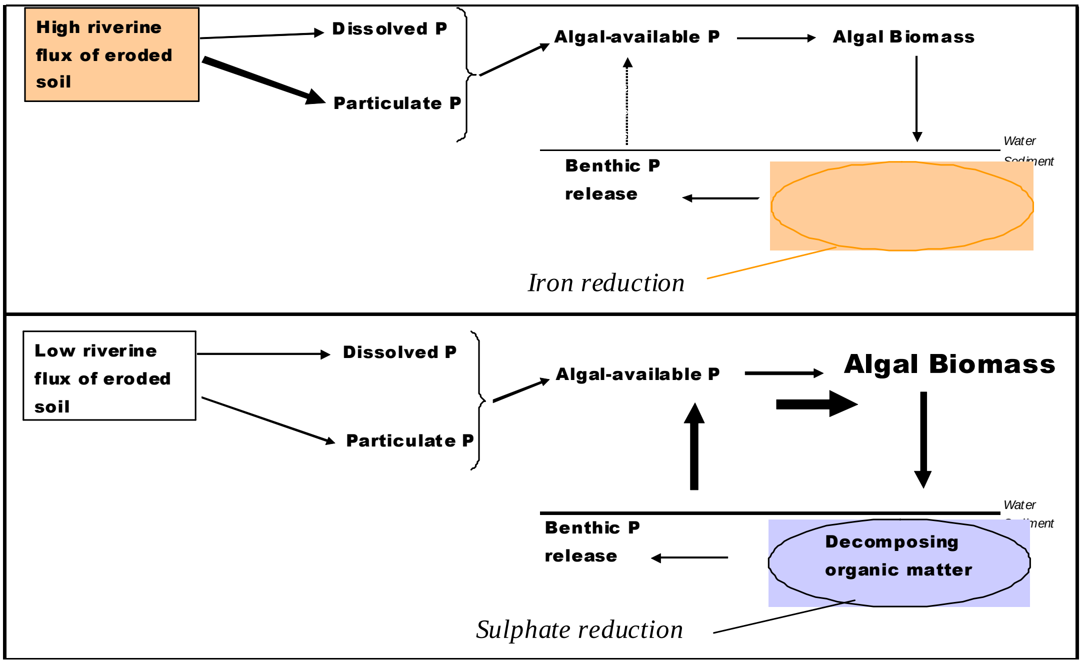
Phosphorus (P) losses from cultivated areas contribute to eutrophication of coastal waters. Especially in regions having a fine soil texture, P is transported from fields to receiving waters largely in association with eroded soil particles. Erosion control has thus been considered a seminal agri-environmental measure to cut down P fluxes and eutrophication. Apart from P, eroded soil also carry iron oxides and clay, which both may counteract the eutrophying effect of P. Comprehensive analysis of the effect of soil erosion, and its control, on aquatic systems appears to be lacking. Here, we discuss the mechanisms by which eroded soil might reduce primary production in coastal waters. We focus on the microbial and chemical cycling of carbon, iron and sulphur in coastal sediments, which have a strong impact on the benthic release of P. If valid, our hypothesis might challenge some of the current agri-environmental measures aimed at abating eutrophication.



Case studies of lake restoration in NE Germany

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In past and recent years quite different attempts were made to restore various highly eutrophied lakes in NE Germany. Preferentially, in-lake measures were conducted aiming at the lowering of the concentration of phosphorus (P) in the lakes. In Lake Jabel ($V = 12.9 \times 10^6$ m^3, $A = 2.44$ km^2, z_{max} 23 m, $z_{mean} = 5.3$ m) the Al application in 1975 and the hypolimnetic withdrawal in 1989 failed. The diversion of the major tributary, delivering 80% of the external P and 94% of nitrate loading, as intended in 1996, was given up because of far-reaching ecological consequences. The second Al application in 2005 could lower the P concentration, however, because of a still high external P loading only short-term improvements are to presume. In Lake Arendsee ($V = 147 \times 10^6$ m^3, $A = 5.13$ km^2, z_{max} 49 m, $z_{mean} = 29$ m) the hypolimnetic withdrawal in 1978 was inefficient since not enough P could be eliminated. Also the mechanical resuspension of autochthonous calcite for sediment capping in 1995 failed to control internal P loading. More effective and more costly restoration measures such as an Al application are currently considered. However, because of open issues pertaining sources and dues of external P loading and the huge water volume to treat by Al application, this measure is still under examination. The aim of my contribution is to present the basic principle of the respective restoration technique, the reasons for their failure, and to discuss the perspectives for both lakes.

Guidelines for restoration of floodplain lakes along large lowland rivers

Gerben van Geest
Deltares; The Netherlands

Along unregulated rivers, there is a strong lateral gradient in connectivity between the river and floodplains. Nowadays however, most temperate rivers are heavily regulated and characterized by embankments and modified hydroperiods. Consequently, the connectivity gradient has been strongly reduced, and has severely affected biodiversity patterns and ecological functioning of floodplains.

Along large rivers in Europe and North America, various floodplain restoration or rehabilitation projects have been realized in recent years. In these projects, much attention has been paid to the restoration of habitats that are highly connected to the river, such as secondary channels. However, less attention has been paid to the restoration potential of lakes that are characterized by low connectivity. In this presentation, data will be presented on ecological functioning of 70 floodplain lakes along the Lower Rhine of The Netherlands during 1999 – 2008. Based on this information, guidelines will be given for the conservation and development of ‘low connectivity’ lakes.

Restoration projects and biomanipulation (BM) practice in Estonia

Ain Järvalt[1], Lea Tuvikene[1], Tiia Pedusaar[2], Ilkka Sammalkorpi[3], Arto Hautala[4]

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The first lake in Estonia where rearrangement of fishery took place was shallow (mean depth 2.8 m) and eutrophic lake Võrtsjärv (270 km^2). In the 1950s and 1960s L. Võrtsjärv was regarded as a ruffe lake because the bulk of the fish caught these consisted of small bream, ruffe, young perch and roach. Attempts to reduce the abundance of these undesirable fishes by intensive trawling were unsuccessful. Fine-meshed trawl damaged the stocks of valuable fish (first of all, pikeperch) and therefore their numbers become scanty (except for bream). At the end of the 1960s trawling was stopped, elvers were regularly introduced into the lake and the protection of commercial fishes was improved. As a result of these measures, the total each of fish decreased in the 1970s, but the stocks and catches of commercial fishes (above all those of pikeperch and eel) began to grow rapidly. The increasing pressure of predatory fishes (mainly pikeperch and pike) led to a sudden fall in the abundance of less valuable small fish. Annual by catch of non-valuable fish (60-70% small bream) is 150-200 tons.

In the beginning of 1990s real BM as a restoration method, was first used in Lake Harku, situated in Tallinn, and having significant recreational value. Unfortunately the amount of removed fish was insufficient and due to lack of funding the sediment removal was not performed.

Recent experience of BM in Estonia is from the fourth largest lake in Estonia shallow (975 ha, mean depth 3.4 m, max 5.5 m) and eutrophic (TP 30-60 mg/m^3) natural hardwater lake Lake Ülemiste. Improving the water quality of Lake Ülemiste, the raw water source of the City of Tallinn by biomanipulation has been considered as a management alternative by AS TallinnaVesi since 2001. Lake Ülemiste was biomanipulated after reduction of external loading and the shifts in water quality were studied during the active-phase of the measure. The main aim of this project was to reduce the chemical and energy costs of treatment caused by high phytoplankton biomass. Cyprinid´s stock was reduced from 200-250 kg ha^{-1} to about 70 kg ha^{-1} in the period of 2004-2008. Conduction of pre- and during manipulation comparison revealed that phosphorus availability in the lake decreased, achieving the target level (<50µgl^{-1}) on the last intervention year. Predomination of filamentous cyanobacteria were replaced by co-domination of picocyanobacteria in summer months and more diverse vernal phytoplankton composition in the lake. Zooplankton grazing was not likely involved in the water quality improvement. Until now only some preliminary results are available.

Stream restoration in the Netherlands – two examples differing in scale

Roos Loeb, Karin Didderen, Piet Verdonschot
Alterra, Centre for Ecosystem Studies, Team Freshwater ecology, Wageningen, The Netherlands

Lowland streams in the Netherlands have been severely altered in hydromorfology, hydrology and nutrient loads. Over the last decade national and international policies, such as the Water Framework Directive, have stimulated local water boards to start stream restoration programmes, aiming to improve ecological quality.

In conservation management and restoration of fresh water ecosystems, the importance of knowledge of ecosystem functioning is increasingly emphasised. Nevertheless most restoration programmes are currently performed with little or no scientific involvement. Furthermore, monitoring programmes sufficient to evaluate the effects of restoration measures are hardly ever incorporated in the restoration programme.

In order to improve the understanding of the processes and factors that lead to successful stream restoration, the effects of stream restoration measures were studied.

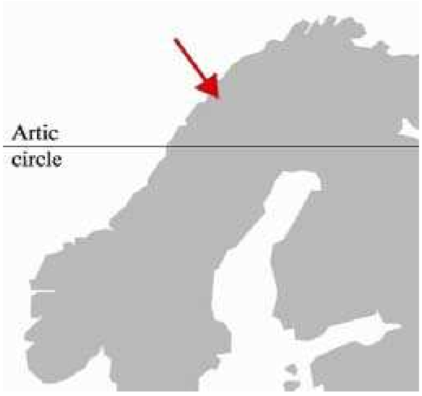
We will present the results of a national survey on stream restoration projects among water board employees in the Netherlands.

The restoration projects differ highly in scale. Although restoration on a catchment scale is seen as the most effective for ecological restoration, most stream restoration projects only address a small part of the stream. We will present the short-term results of different scale stream restoration projects: a small-scale project involving the introduction of woody debris and a large-scale project where a complete new meandering upper course was constructed.

Rehabilitation of an euthrophicated and regulated river.

Karl Jan Aanes, *Research Manager, NIVA, Norway*

Introduction.



Along with the regulation of Lake Børsvann in1914 the water flow have been heavily reduced in the river Børselva. The water was taken to a power plant outside the catchment area. During the years and along with the increased farming activity the river has developed into a eutrophic river overgrown with water plants.
The paper presented will give information about the project, ideas behind it and how we were able to succeed with rehabilitation of the river system to achieve environmentally sound watercourse maintenance trough various types of restoration measures combined with a new flow regime and a reduced nutrient input.

The problems raised and connected to Børselva are of general interest for the future handling of regulated rivers and at the same time be able to take care of the natural values of the river and its neighborhood. The project has received funding from: The national Research Board, Norwegian Water Resources and Energy Administration, Local Authorities and Electricity Board and Research grants from NIVA.

Problems

Three main reasons were seen as the background for the problems in Børselva:

- Erosion in a tributary created siltation problems and sediment was trapped in the river.
- The high input of nutrients and organic material created eutrophication problems.
- The reduction of water flow.

Siltation

The input of silt was ended when rehabilitation was carried through in a tributary.

Eutrophication

The main reason for the eutrophic situation is the high input of nutrients over a long period from the agricultural activity along the river. The whole river was drastically changed and nearly 70% of the river bed was covered with water plants. This is supported by the input of fine sediments and reduced water fluctuations/floods connected to the regulation.

Water quality

Results from a physico-chemical monitoring program described the water quality in the river as bad or very bad according to our national standards. The picture given was supported by results from biological studies (stream vegetation and benthic fauna). To attack the different sources of pollution an intense monitoring program was set up to describe all the sources along the river (22 stations). Results indicated that 80 % of the nutrients and organic material was connected to the farming activity and the system is heavily overloaded with nutrients and organic matter.
In 1986, the owner had to develop a flow regime for the river to ensure satisfactory quality in the watercourse. Together with the flow limitations given by the national authority there was an instruction to conduct a clearing of the watercourse and to reduce the nutrient load, to restore the free passage and to improve the watercourse's self-purification properties. A project running for 5 + 5 years was started late in 1997/98 to fulfill these limitations set by the government.

Water quality changes of the Romanian rivers in Transilvania after 1990 with special emphasis on the effects of agriculture

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Surface waters are represented mainly by rivers in the Transylvanian part of Romania. The most important running waters are the Someş, Barcău, Crişul Repede, Crişul Negru, Crişul Alb, Mureş and the Olt. Water quality of these rivers generally improved after the 1990's as many large industrial facilities were shut down after the political changes. We investigated the changes in water quality and in the composition of aquatic communities during the last two decades in the frames of several research projects. Agriculture in general used far smaller amounts of fertilizers after 1990 as the large state-run kolkhozes were also dismantled. These kolkhozes used large quantities of artificial fertilizers and pesticides. While the quality of surface waters improved after 1990, the role of decline in industrial versus large-scale agricultural activities cannot be quantified anymore. However, misuse of agricultural chemicals is still wide-spread today as a bequest of agricultural practices in the kolkhozes, where extensive use of these chemicals was facilitated by state subventions. An example of such misuse was observed on the Crişul Alb in 1997: almost the entire mussel population was wiped out when a container used for pesticide storage was cleaned in the river. Due to the usage of fertilizers all investigated Transylvanian rivers presented increased levels of nitrogen, phosphorus and potassium. This caused an increase in the numbers of organisms forming the phytoplankton and biotekton. However, the role of communal wastewater in the eutrophication should also be emphasized beside the agriculture despite recent upgrades of many waste-water treatment facilities. Mussels immediately repopulated the lower reaches of the Mureş river after the closing of the agrochemical factory in Arad in 1992. Land improvement activities were an important component of pre-1990 agricultural practices. These mainly affected wetlands along the rivers. Drainage of these areas destroyed many representative wetland ecosystems while the areas gained were often still not suitable for agriculture. As the central government strongly facilitated the increase of agricultural lands, the fields were extended toward the riverbanks. Riverside bushes, small forests and dead river branches were destroyed in the process. This trend is still wide-spread today as rivers and their floodplains are treated separately by the authorities despite the provisions of the Water Framework Directive. As subsistence farmers working on small strips of lands are not competitive in the EU, they increasingly abandon their fields. These become occupied by aggressively spreading invasive plant species which replace native communities.

Demands for gravel for constructions strongly have increased in the past decades. This gravel was mainly extracted from riverbeds sometimes down to the slate layer (e.g. in the case of the Mureş). As a result, groundwater is freely flowing into the rivers during dry periods, resulting in strong desiccation of agricultural fields. Determining the present-day anthropogenic impact on Transylvanian rivers would be the most important step in the near future.

Nutrient emissions in the Zala River Basin (Hungary)

Adrienne Clement[1] and István Sisák[2]
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[2] University of Pannonia, Georgikon Faculty of Agriculture, Hungary, Keszthely

River Zala is located in the western part of Hungary, it belongs to the watershed of Lake Balaton. River Zala is conducting water into the smallest, western bay with 5 % of the total lake volume from almost half of the watershed (2622 sqkm). Water quality began to deteriorate in the late 1960`s in the western bay, and eutrophication spread out to the whole lake in the later decades with its worst period in the late 1980` s and early 1990`s. Significant improvement has been achieved since then, due to the reduced nutrient load but the water is still eutrophic to hypertrophic in the most sensitive tourist season especially at the lakeshore.

Total P load from the Zala river basin changed dramatically in the past 30 years. There was a sharp increase between the 1960`s and 1980`s both from diffuse and point sources. In 1985, the Upper Kis-Balaton reservoir was inundated in order to protect Lake Balaton against high nutrient loads carried by the river Zala. Total P retention in the reservoir is 20-50% (depending on the inflow P concentration). In 1992, phosphorus precipitation was introduced at the largest wastewater treatment plant (Zalaegerszeg) of the Zala catchment. Now all of the collected wastewaters are treated biologically and chemically (additional P removal). Economic changes in 1989/90 resulted in a significant drop in fertilizer use. The previous P surplus of approximately 26 kg/ha/yr in the 1980`s has been replaced by mining of soil P reserves within a few years and only slight improvement has been achieved for the last few years. The nutrient deficit limits the agricultural production to-date thus increase of the fertilizer use is expected in the near future.

Even though load reduction resulted in considerable improvement in water quality of Lake Balaton (particularly in the western bay), the current P load is about two times higher than the desirable value. Due to the control of point sources, the major portion of P emissions is now associated with diffuse sources. Therefore future water quality management of the lake must reduce the non-point pollution.

Catchment models were applied in order to estimate nutrient emissions from different sources and economic sectors in the Zala catchment. Results indicated that agricultural activity has significant impact on the total P budget of the catchment. The area is sensitive to soil erosion by water and the majority of the watershed is agricultural area, in particular arable land which is 54 % of the catchment. The late 1980`s and early 2000`s have been compared regarding the P loads and their sources. Since the main P sources are related to erosion, BMP must focus on erosion protection.

Long-term relationship between soil surplus nutrient content and river water quality in Zala River catchment (Hungary)

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The Hungarian Zala River is one of the most frequently monitored streams throughout the world. Water quality parameters are measured every day at Zalaapáti station, just upstream of the Kis-Balaton Reservoir. Since the measuring program started in the 1980-ies, more than 20 years long, daily time series are available, which are highly feasible to calculate accurately the yearly nutrient loads and examine their trends. Intensive agricultural cultivation with high amount of applied mineral and organic fertilizers before 1990 led to an increased phosphorus (P) content of topsoil and nitrogen (N) concentration of groundwater in the Zala River catchment. To determine the agricultural nutrient surplus, statistical data at county level were collected and yearly soil nutrient balances (inputs and losses) were calculated. Diffuse emissions and the transport processes present linkages between soil nutrient surplus and river loads. Soil erosion and sediment transport carry significant amounts of adsorbed P into receiving water bodies, while leaching and groundwater flow convey remarkable N fluxes towards surface waters. Comparing water quality and soil surplus trends, in case of P water quality responses follow quite rapidly the changes of soil P content because surface emissions quickly appear in the recipient. In contrast, due to the slow movement of subsurface water, changes of river nitrogen concentrations respond delayed on the variations of nitrogen surplus. The time delay depends on the average residence time of the groundwater.

Long-term experience of eutrophication management in large and shallow Lake Balaton, Hungary

Vera Istvánovics[1], András Specziár[2], László G.-Tóth[2], Judit Padisák[3], Adrienne Clement[1] and László Somlyódy[1],

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2 – Balaton Limnological Research Institute of the Hungarian Academy of Sciences

3 – Department of Limnology, University of Veszprém

Nutrient loads of Lake Balaton have been reduced by about 50% during the past 20 years from high levels (1.46 mg TP m^{-2} d^{-1} and 14.6 mg TN m^{-2} d^{-1}) that prevailed in the early 1980ies. Although this moderate reduction was not expected to significantly improve the trophic status of this large (600 km^2), shallow (3.2 m) lake, clear signs of recovery have been observed after a delay of roughly 10 years. This was attributed to the quick decrease in internal P load due to the faster than expected immobilization of mobile P in the sediments that contain about 50% high magnesian calcite. Mean annual biomass of phytoplankton decreased substantially because summer blooms of N_2-fixing cyanobacteria became much shorter and smaller. In the same time, cyanobacteria are still dominate in most summers in the south-western areas where nutrient loads are the highest. Crustacean zooplankton have not shown a pronounced response to diminishing primary productivity probably due to the strong constraints set by the specific geological and morphological features of the lake (high turbidity due to both strong wind action and intense carbonate precipitation). In contrast, strong dependency and threshold behaviour of zoobenthos have been demonstrated as a function of algal biomass and productivity. Below the threshold algal biomass, *Tanypus* and *Procladius* species dominate, biomass and energy transfer efficiency of zoobenthos to higher trophic levels (fish) are low. Above the threshold*, Chironomus balatonicus* gains dominance; both the biomass and transfer efficiency increase significantly.

Long-term experiences from the restoration of large and shallow Pyhäjärvi (SW Finland)

Anne-Mari Ventelä, *Pyhäjärvi Institute, 27500 Kauttua, Finland*

Pyhäjärvi, located in the centre of an intensive agricultural area in southwest Finland, is an example of a large and shallow lake suffering from eutrophication. During the last 20 years the quality and general usability of water in Pyhäjärvi has varied: studies and frequent monitoring data show that it first deteriorated due to increased algal blooms, then showed some slight but evident signs of recovery in 2003-2007 and is now deteriorating again. These changes have been driven by both a variety of human activities and climate related factors such as exceptionally dry or wet periods.

Pyhäjärvi has been the target of an intensive restoration programme since 1995 when the Pyhäjärvi Protection Fund (PPF) was created by local municipalities, private industries and local associations to act in collaboration with regional environmental and agricultural authorities. Since 1995, all farmers in the catchment have committed to the European Union's (EU) agri-environmental programme to implement basic water protection measures. In addition, more intensive catchment management practices such as buffer zones, sedimentation ponds, and wetlands have been introduced. New innovative treatment methods such as filtering ditches and sand-filters were also constructed and tested for their ability to remove P from runoff waters. PPF also has been active in promoting waste water treatment in the rural catchment. However, all external load reduction measures in the catchment have been seriously challenged by the recent warm and wet winters with high external load.

Also, Pyhäjärvi has been the object of intensive biomanipulation for decades. It has been done by commercial fishermen, whose annual harvest rate approaches the total production of vendace (Coregonus albula), which is the main planktivore in Pyhäjärvi. The restoration project has also subsidized the harvest of commercially unwanted fish since 1995. In 2002-2006, the EU provided funds for this fishing, which was especially intensive in 2002-2004 and apparently resulted in water quality improvement. Lately, weak ice cover in exceptionally warm winters 2007 and 2008 prevented practically all seine fishing and left planktivorous fish stocks unusually strong in Pyhäjärvi, triggering new deterioration of water quality. Under the warming climate scenarios, there is an urgent need for the commercial fishermen to find new efficient fishing methods in order to be able to maintain food web structure favourable for water quality.

Contrasted responses of three deep eutrophicated peri-alpine lakes to reduction of external phosphorus loading: some ecological processes and social perceptions

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The studied lakes (Lake Annecy, Lake Bourget and Lake Léman shared with Switzerland) are peri-alpine lakes located within the same eco-region; they are subjected to the same kind of socio-economic development and history. The eutrophication of these lakes began in the 60's and control policies were implemented in the 80's. Based on the established role of phosphorus (P) in causing eutrophication of lakes (Vollenweider, 1968; Carpenter, 2008), the objective of managers was to reduce the external P loads. The implemented measures aimed at decreasing/controlling point sources of pollution (first, sewage facilities and treatments, then implementation of tertiary sewage treatments and finally TPP ban or reduction).

Despite the similarity in the characteristics of these French lakes, the policies implemented at the watershed scale to control point sources have been more or less drastic according to local situations. Progress in controlling point pollution has been consequently more or less slow (but always costly). Sharp and early reductions in point source discharges resulted in a return to an oligotrophic state in Lake Annecy. In the two other Lakes in contrast, less drastic measures and slower implementation of the latter, have globally led to significant but limited and delayed improvements.

The monitoring of these lakes since the 60's or the 80's has provided the opportunity to examine the processes and interactions determining these global ecological responses to P reduction (ORE Lacs, 2006). We will present data from Lake Bourget and Lake Léman which exhibit contrasting ecological responses, in terms of magnitude, phytoplankton composition and water quality. These differential responses seemed to be due to residual P from diffuse sources (CIPEL, 1988) and internal P loads, known to slow down and delay rehabilitation or to stabilize the lake trophic status. Biological and feedback processes or N/P interactions as well as climate warming (Anneville et al, 2005; Tadonléké et al. submitted) seemed also to be involved in the maintenance of relatively high trophic status or in the delay of water quality improvement in these lakes, even though both have experienced considerable reduction in in-lake P.

Because of the relative improvement of water quality observed since 2000 in these lakes, the services expected from them in the next future is greater: increase of water supply for cities (Lake Léman will supply water for 1 million persons), biodiversity (WFD, Natura 2000..), recreation, sport fishing and fisheries. Moreover, restored lakes are indicators of the regional quality of life and environment (Unesco project for Annecy) and as such are magnets for another step of development characterized by urban sprawl and the occurrence of a set of new pressures exerted on the sensitive lake ecosystems. This shows that a lake, its watershed and the people living within, constitute a functional unit that should be managed as a whole system (a "biosocial system"), at both long-term and short term scales.

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Nutrient management for ecological benefit at Barton Broad and Bosherston Lily Pools, UK – achievements, costs and long term sustainability issues.

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Over the past 20 years considerable effort and finance has been expended in pursuit of ecological restoration in two shallow UK lakes: Barton Broad, part of the Norfolk Broads National Park in Eastern England, and Bosherston Lily Pools, part of the Pembrokeshire Coast National Park in South West Wales. Both are shallow (mean depth ~ 1 m), hypertrophic marl lakes with the capacity to support nationally rare Charophyte communities. Both are popular tourist destinations, forming an important feature supporting the local economy. Bosherston Lily Pools is part of the Pembrokeshire Marine Special Area for Conservation, the Stackpole Estate National Nature Reserve, and was designated a Site of Special Scientific Interest for its Charophyte population.
In both cases point source discharges from Sewage Treatment Works in the catchment have been targeted for management, and in neither case have adequate controls been implemented on nutrient delivery from agricultural sources. In both cases, sedimentary P pools have been physically extracted from the lakes using suction dredging in an attempt to increase water depth and decrease internal loading of P from the lake sediment pool.

In both cases some form of biomanipulation has been implemented. In the case of Bosherston Lily Pools, this has occurred as a side effect of other management practices, including manipulation of water levels in the three arms of the lake, leading to hydrologically isolated systems with no hydrochemical connectivity during summer low flows, and regular 'weed' harvesting. In Barton Broad there has been a deliberate attempt to manipulate ecosystem structure in order to suppress algal production, including the installation of a fish curtain to exclude planktivorous fish including roach, and the installation of exclosures to stimulate plant recolonisation of the lake.

The total sums invested in mitigation of nutrient losses to these waters are estimated at €7 million for Barton Broad, and €2 million for Bosherston Lily Pools. Restoration attempts have been partially successful, in terms of halting further damage to ecosystem structure and the nationally rare Charophyte populations (Bosherston Lily Pools) and supporting recolonisation by a range of aquatic macrophyte species, including Charophytes in protected, biomanipulated areas of Barton Broad. However, these attempts have failed to address continuing nutrient losses from agricultural sources in each catchment, estimated as 90% of the total P loading delivered to Barton Broad, and 99% of the total N load an 85% of the total P load delivered to Bosherston Lily Pools from their respective catchments. This loading compromises restoration efforts, and raises questions about (a) the long term sustainability of these ecosystems and (b) whether we can afford to support such long term restoration measures, given that there are over 55,000 water bodies of more that 1 ha in area in England and Wales alone.

Restoration of Zdworskie Lake (Poland) – restoration works and their results

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Within the presentation restoration work conducted in Zdworskie lake and its basin after ecological disaster and their effects on lake status are shown.

The aim of reparation work was to restore water supply and to improve water quality. Increasing of water supply was achieved by constructing broad-crested weir in the outflow, bentonite structure for filling the riverbed of the main inflow and artificial alimentation by connecting Dobrzykowski channel with the lake. Improvement of the lake water quality should be achieved by biomass removal, placing bales of barley straw around watering-places, constructing floating containers with macrophytes, phosphorus inactivation using iron chloride, partial dredging, biomanipulation using the Zebra Mussel *Dreissena polymorpha.*

The effects of the restoration work were maintenance of the normal water level, improvement of phosphorus fixation conditions in the sediments and general improvement of water quality in the lake. However, at the moment it is impossible to state, which work brought about the improvement of water quality to the greatest extent.

Effect of eutrophication on the functioning of reed (*Phragmites australis*) dominated vegetation

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Stands of the common reeed (*Phragmites australis*) are among the most common emergent vegetation of both riverine and lacustrine wetland habitats in Europe. The most valuable and largest areas are protected as Ramsar localities. *Phragmites* is also the most common plant species used in constructed wetlands for wastewater treatment in Europe. Reed dominated vegetation is exposed to a variety of environmental factors as well as to various types of human impact. Eutrophication, understood as elevated nutrient (especially N and P), affects the reed vegetation both directly, i.e. by promoting the plant growth, and indirectly, i.e. by promoting accumulation of organic matter at the bottom and its subsequent anaerobic decomposition. Young plant parts (root tips, rhizome buds) are most susceptible to injury caused by both oxygen defficiency and toxicity of anaerobic products of microbial metabolism. The anoxic stress and toxicity of anaerobic metabolites act as predisposing factors that weaken the plants ability to withstand catastrohic events such as massive mechanical damage or high water levels. The dynamics of the reed stands is then the net outcome of the processes of dieback and regeneration.

Water management practices in the Water management practices in the drainage basin of Lake Kinneret, Israel

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Lake Kinneret (LK), Israel is a relatively large (~165 km^2, ~4.2 x 109 m^3)) and deep (24m average) monomictic lake fed mainly by the Jordan River and several smaller streams (500 - 600 x106 m3 year-1). The lake and its drainage basin are regularly monitored since 1968. The data base collected and additional observations in the lake bed sediments are used to evaluate the consequences of water management practices in the drainage basin on biogeochemical parameters and fluxes in the lake.

Poor management of water resources in the drainage basin during the 1970's have led to intensive degradation through enhanced oxidation of organic matter (peat) in the Hula Valley. This in turn resulted in enhanced erosion of the local soils, both by water and Aeolian. The consequences were increasing loads of organic particles in the river Jordan that crosses through this valley as well as in streams that are located out of the valley. In retrospect this shows that not only water erosion occurred but also that dust formed in this valley spread over all of the drainage basin, including LK itself. The effects of a decade of increased loads of allochthanous organic matter were to decrease DO and pH levels of LK surface water, through shifting the balance between photosynthesis and respiration, in favor of the later. Only during the early 1980's, due to improved irrigation practices in the Hula Valley, this trend was reversed and in LK indicated by a rise in DO and pH. However we do not identify an improvement in the status of LK ecosystem that may be associated with these prominent changes.

Influence of mining safekeeping activities on hydrological situation and aquatic biocoenosis in a small catchment

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Technical intervention has degraded water bodies and modified hydrological processes. This paper describes the modification of the regional water balance and runoff generation processes by mining activities in the Eastern Harz Mountains, Germany. The pristine condition before 1973 is characterised by a well balanced water flow with soil moisture increase and storage filling in winter and high discharge situations during spring. Base flow contribution guaranteed a minimum of water flow during summer time. The opening of a mine led to a decrease of the regional groundwater level. The related hydrological situation with long dry periods and episodic flash floods had significant negative effect on the chemical and biological water quality. In the course of the safekeeping at the end of the mining activity in 1989 the groundwater level rose again since 1993 and has reached a new stable situation in 1999. The annual runoff volume is now about 50 % of the runoff volume that was recorded at the end of the sixties. Although the physical and chemical parameters indicate a good water quality, the concentrations and loads of sediment and nutrients may reach critical levels during spring snowmelt floods. Due to a reduced base flow dry situations occur in summer and fall which narrows the biological water quality. The safekeeping process that has started already in 1991 and was accompanied by other measures like fish passes did not carry the region to the former conditions so far. Today it is unclear if the safekeeping process will further improve the hydrological situation and thus open the opportunity for a natural ecological status of the regional surface water bodies.

The redevelopment and restoration programme for the Lakes of Mecklenburg – Western Pomerania (Germany)

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The important role of the waters in the natural landscape and the increasing significance that the lakes in particular have an essential economic value in Mecklenburg-Western Pomerania (e.g. for the tourist industry) needs approaches to protect these valuables.

An inventory of the water quality showed that the trophical situation is often not sufficient. Based on these results the conclusion was drawn to reduce the nutrient input from point and diffuse sources into the lakes. Moreover, there is a need to improve the trophical situation in some lakes by active restoration measures.

Due to the determined differences of lake water quality in Mecklenburg-Western Pomerania a redevelopment and restoration programme has been developed. Because of the high costs and the continuity of the projects it was necessary to make a decision regarding the ranking of lakes for restoration. To support the ranking decision a chart system was used which not only consider the classification of the trophic status but also several selection criteria such as lake morphometry, standard of the redevelopment, quality of the data sets available for the respective lake, territorial importance of the lake, activity of the stakeholders and financial aspects.

To ensure a sustained success of restoration, lake internal measures are only carried out when the catchment area has been redeveloped or a success regarding the reduction of nutrient inputs into the lake is visible. At the present time more than 20 restoration projects have been successfully realized and further projects are in the planning process. The available experiences and results show that in particular several precipitation techniques with aluminium are successful, sustainable and reasonable.

Lake Malmsjön restoration -dosing aluminium addition based on mobile sediment phosphorus content

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Dimictic Lake Malmsjön (0.9 km^2, mean depth 3.5m, water renewal time 1 yr) south of Stockholm experienced poor sewage treatment until 1974. Eutrophication recovery was slow due to excess phosphorus (P) stored in the sediment, and the lake acted as a source of P. An aluminum (Al) chloride solution was injected into the sediment in autumn 2006, and the amount of Al added was calculated based on the stock of sediment P that was considered to be potentially mobile. This P, 8.2 g P/m^2, was found to be mostly organically bound and aluminum corresponding 11 times this amount (90 g Al/m^2) was suggested as an amount sufficient to inactivate P mobilized from this degradable organic P pool in the future. Lake trophic status is now expected to be controlled by the external loading.

AQUATOX- Ecological Risk Assessment Model
Case study: Nutrient study at Lake Pyhäjärvi

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AQUATOX (developed by the US EPA) is an ecosystem simulation model which predicts the fate of various pollutants, nutrient, organic loadings, toxic chemicals and temperature, and their effects on the ecosystem including macrophytes, phytoplankton, invertebrates and fish. AQUATOX covers various aquatic ecosystems, such vertically stratified lakes, reservoirs, ponds, rivers and estuaries.

Simulations can be run with the constant run feature which requires very little input data. When more data is available, dynamic time series can be used as an input data. The water column can be divided and scenarios modelled separately for the epilimnion and hypolimnion. In this study we tested the functionality of the model in a boreal environment. Our test case Lake Pyhäjärvi in Finland; a shallow, mesotrophic and agriculturally loaded and recreationally high-value lake. We focussed primarily on total phosphorus and nitrogen balance simulations. For the epilimnion the model underestimated values when compared to actual observed concentrations. Further we noticed a time lag for seasonal changes. Temporal synchrony with real data for simulated total nitrogen values was comparatively better and within the range of observed values. For the hypolimnion the model performed better for both nutrients. Simulated peaks and the magnitude of concentrations fitted well with the observed. In all simulations we used constant input data.

We conclude that AQUATOX may be a useful tool to simulate the impact of scenarios with decreasing nutrient loads from the catchment areas however the biological aspects of the model remain yet untested. Future research should include water bodies of varying sizes and typology and assess the capability of AQUATOX to encompass biological changes as well.

Long term effects of aeration and biomanipulation on internal loading and cyanobacteria in Lake Tuusulanjarvi under a high external phosphorus load

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Lake Tuusulanjärvi (592 ha, mean depth 3.2 m, retention time 250 d), was heavily eutrophicated by municipal sewage loading since the 1960´s. Sewage diversion decreased the external P load from 1.6 to 0.8 g P m^{-2} a^{-1} in 1979. Due to the still high external load and an even higher internal loading the lake remained hypertrophic, with e.g. summer TP > 100 µg L^{-1}. After severe blooms of N-fixing cyanobacteria in 1997 measures to reduce both external and internal loading had to be taken.

1. A large scale construction of wetlands to reduce the external loading from agriculture,
2. Deliberate regulation of summer stratification to prevent oxygen depletion and internal loading in deep areas (> 6 m; 20 % of lake area), and
3. Mass removal of cyprinids to reduce their impact on the water quality in the shallower areas (< 6 m, 80 % of lake area).

The biomass removed in 1997-2007 was 543 tonnes / 914 kg ha^{-1}. The results were:

1. Epilimnetic TP, biomass of cyanobacteria and Chl/Tp ratio decreased after years of intensive fish removal in the 2000´s,
2. The internal P load to hypolimnion decreased clearly in 1998-2008, and
3. The effect of improved transparency after fish removal was amplified by dry summers resulting into nuisance level colonization of *Myriophyllum* in the shallow areas.

Results of 12 monitoring years suggested that inter annual changes in water quality were less related to hypolimnetic oxygen concentration or changes in external phosphorus loading (0.4-1.2 g P m^{-2} a^{-1} in 1998-2008) than to the intensity of fish removal.

Blooms of cyanobacteria could be reduced by fish removal and controlled destratification even at excessive external loading, but the effort had to be intensive and continuous, unlike in Finnish lakes with lower external phosphorus loading. The municipalities paid c. 300 000 € a^{-1} for a better ecological state earlier than would have been possible without the in-lake measures. The external P-load will be reduced by the wetlands in the 2010´s. The impact of extreme conditions predicted in climate change scenarios also affected the need and outcome of restoration measures.

Successful restoration of the shallow urban lake Alte Donau in Vienna: A case study based on bistable theory

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Floodplain and ox-bow lakes form excellent examples of alternative stable states. Clear water, macrophyte dominated stages can alternate with turbid conditions characterised by high algal concentrations. Stable states can switch from one to the other domination through alterations of natural factors such as changes in water level, reduction in through-flow etc. Forward switches are often associated with anthropogenic pressure. In such cases, restoration to the original, macrophyte dominated stage is difficult and needs careful planning to establish sustainability. A case study from a shallow, urban, seepage lake, the 'Alte Donau' within the city property of Vienna is presented. Results on switches between stable states, causes, consequences and successful restoration measures will be detailed.

ABSTRACTS OF

POSTER PAPERS

Effect of enhanced water exchange on phosphorus dynamics and biological activity in an urban backwater system in Vienna (Austria)

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Due to human impacts, floodplains in urban regions are often simultaneously affected by eutrophication, loss of hydrological dynamics and even land use change. In order to mitigate some of these effects in a degraded floodplain within the city limits of Vienna, the “Dotation Lobau” water enhancement scheme, was initiated in 2001.

Our study indicates that this management approach positively affected the urban backwater system, the Obere Lobau. The significance of the effects, however, depends on the historical and current trophic situation of the respective water bodies. A backwater system with eutrophic conditions can shift, after the enhancement of surface water connectivity with lower phosphorus concentrations, to a backwater with stable mesotrophic characteristics. The surface water connectivity introduced particulate phosphorus export up to 30 % increase over the influent loading and dissolved phosphorus up to 14 % increase over the influent loading. However in sections with submersed macrophyte development, which provide enhanced filtering capacities for particulate matter, sediment and phosphorus accumulation is raised. At the same time, water transparency increased resulting in a positive feedback for further macrophyte development. This study highlights that the evaluation of restoration measures should include the dynamics of potential growth limiting factors and ecosystem processes such as gross primary production and community respiration to understand the trophic development of an urban floodplain area, subjected to restoration measures.

Changes of the phytoplankton assemblage and related characteristics in the Srebarna Lake (Northeastern Bulgaria) after restoration activities

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The Srebarna Lake is located on the right-hand bank of the Danube River in Northeastern Bulgaria. It is a Protected Site from 1942 and after that a Nature Reserve (since 1948), Ramsar Site (1975), UNESCO Biosphere Reserve (1977) and from 1983 it is included in the List of the World Heritage Sites under the UNESCO Convention. Several stages in the development of Srebarna Lake depending on the man-induced changes can be marked off (Michev at al., 1998) but the main restoration activity starts in 1994 when the hydraulic system “the Danube – connecting canal – Srebarna Lake” was put into operation. After the reconnection of the lake with the Danube River the water level of the lake significantly increased. It follows only the large magnitude changes in the water level of the Danube River, while the lower variations did not influence lake level. This leads to decrease of the plankton primary production (which still remains within the borders of hypertrophy) and of the total phytoplankton numbers and biomass. The water level and nitrogen concentration were the main factors controlling the year-to-year fluctuations of the primary production and phytoplankton quantity. The total phytoplankton biomass shows a positive correlation with nitrates. With the water level raising, the share of Cyanophyta from the total biomass becomes smaller while that of Cryptophyta increased. The composition and dominant structure of phytoplankton remained relatively stable and predictable. Unpublished data about fishes and birds shows that the results from the restoration activities are far remote from the other countries with well managed wetlands. These results clearly show the need of additional restoration measures.

Macrophytic vegetation in the littoral of Lipno reservoir (Czech Republic)

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Aquatic macrophytes are an essential component of littoral communities in lakes and their reasonable development positively affects biodiversity and stability of the aquatic ecosystem and water quality. The aim of this study was to characterise development of littoral macrophytes in Lipno Reservoir, an artificial lake with seasonal water level fluctuation, and highlight controlling factors for the macrophyte occurrence. The development of macrophytes was examined at 114 segments of shoreline 50 m long situated along the whole reservoir perimeter in regular 1-km distances. The segments were surveyed for phytocenology, morphology, pedological characteristics of substrate, and anthropogenic impacts. The survey identified 53 macrophyte species (25 hydrophilic terrestrial, 19 emergent, 2 floating-leaves, 2 free-floating, 5 submersed, and 2 amphibious). The vegetation cover of the examined segments was 14% on average with approximately one third of the segments without any macrophytes and another third with the vegetation cover less than 10%. Macrophytes occurred in the uppermost eulittoral zone only, up to the level of 90% probability of water surface fluctuation. A correlation analysis indicated the major factors for macrophyte occurrence in the littoral zone as morphology, light conditions in water, and erosion effect of waves that together with water level fluctuation contributed to the loss of fine particles from the substrate in the littoral zone.

Erosion as a source of sediment pollution

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Eroded soil particles can become pollutants in water resources, either alone or with adsorbed chemical substances on their surface. Not all eroded soil particles become sediment in surface water sources. One way to calculate the amount of sediment is to use so-called the delivery ration DR.

For our analysis we used the Williams equation in the form:

$DR = 1{,}366.\ 10^{-11}.\ A^{-0{,}0998}.\ I^{0{,}3629}.\ CN^{5{,}444}$

where:
DR – (=SY/SL) – delivery ratio
SY – sediment yield in tons per hectare per year[t/ha/year]
SL – soil loss in tons per hectare per year[t/ha/year]
A – area of basin in km^2
I – average basin slope in ‰
CN – representative value of run-off curve number for observed basin

We exploit the fact that we know the quantity of sediment in the water reservoir after its 15 years operation because sediment was removed from this reservoir.

The soil loss (SL) was calculated by using the USLE. Using the value of DR the theoretical quantity of sediment in the water reservoir (SY_t) was calculated. We compared this value with the amount of dredging sediment from the water reservoir – SY_r , and we came out that :

$SY_r/SY_t = 1{,}05$

This means that using the equation for calculating the DR can be used with a relatively good result to calculate the sediment yield in our agricultural basin.

The Coherens 3d hydrodynamic model – a possible tool for the planning of lake management actions

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Coherens is a 3D hydrodynamic and water quality model for ecosystem modelling. It consists of a physical model, a biological model, a sediment model and modules for the spreading of harmful substances. The loading of nutrients from the catchment to the lake can be read to the model as dynamic boundary conditions, or constant loading values can be changed by the user for different test runs.

The Coherens-model has been set up for Lake Pyhäjärvi within the CatchLake2 project. Lake Pyhäjärvi has an area of 154 square kilometers, an average depth of 5.4 meters and it is located in south-western Finland. Two major rivers discharge into the lake and one river runs out. Simulations were first performed for a short event in 6.-9.5.2006, characterized by large spatial difference in the lake water quality. The suspended matter results were qualitatively compared to spatial variability of turbidity obtained from MERIS satellite images. The results thus far are promising but more validation of the transport model is still required.

The next step will be to make simulations using different sources of boundary conditions (flow rate and concentrations of suspended matter and nutrients) at the river mouths. Also an ecological sub-model, which has been incorporated in the model for eutrophication calculations, needs to be validated. After that the Coherens-model could be used for the planning of lake management actions.

Biomanipulation and water quality changes of Lake Ülemiste (Tallinn, Estonia)

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Lake Ülemiste (975 ha) is a shallow (mean depth 3,4 m) eutrophic lake, which has been the main reservoir of drinking water for Tallinn since the 14th century. The water level is controlled by a Water Treatment Plant. The catchment area of the lake has been enlarged from 70 km² to 1865 km² and it extracts water from three river systems by a complex interlinkage of reservoirs and canals. The lake water is turbid, with its phytoplankton assemblage containing mainly cyanobacteria. The main problem is high phytoplankton biomass, which increases the cost of water treatment. The main aim of a biomanipulation (BM) project was to reduce the chemical and energy costs of treatment caused by high phytoplankton biomass in the water.

Before biomanipulation, in vegetation periods of 2000-2003, the content of total phosphorus (TP) exceeded 60 µg/l, Secchi depth stayed below 90 cm and average phytoplankton biomass was 16 mg/l. The estimated fish biomass exceeded 250 kg/ha.

In 2004-2008 as much as 187 kg/ha of fish was removed. After the fish removal, TP decreased more than 30%, phytoplankton biomass decreased from 16 to 7 mg/l and Chl-a from 32 to 22 µg/l. The average Secchi depth during the vegetation period dipped as much as 20 cm. Clearwater period in spring elongated for 3 to 4 weeks compared with that before BM. The share of filamentous forms in the composition of cyanobacteria has decreased, instead of them more colonial forms of pikoplankton have appeared. BM did not affect remarkably neither the abundance nor biomass of zooplankton. Unfortunately, the main aim of the BM project is not yet achieved as the cost of purification has not fallen notably.

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