MEETING of COST 869

Mitigation options for nutrient reduction in surface water and groundwaters

Working Group 2

17–19 September 2008

Location: Hellenic Centre for Marine Research (HCMR), Mavro Lithari, 19013, Athens-Anavyssos, Greece

Topic of the meeting:

N/P limitation and interactions between N and P in surface water

Local organizers

Nikos Skoulikidis and Dora Kouvarda

Co- organizers

Petri Ekholm, Ken Irvine & Wim Chardon

Proceedings edited by Wim Chardon

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12:00 – 12:30	The role of N as a limit to primary production in European waters – perspectives from the European Nitrogen Assessment *Penny Johnes, UK*
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09:00 – 12:30	Excursion to the archaeological site of Cape Sounion (see http://en.wikipedia.org/wiki/Cape_Sounion)
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ABSTRACTS OF ORAL

PRESENTATIONS

A short introduction to COST 869, WG2 and factsheets, and topics for this workshop

Wim Chardon, ALTERRA, Wageningen UR, Wageningen, The Netherlands.
wim.chardon@wur.nl

COST 869 (European **CO**operation in the field of **S**cientific and **T**echnical Research) will focus on the steps that need to be taken within the EU Water Framework Directive in order to effectively reduce the nutrient losses from point and diffuse sources to surface waters and groundwater. The Action will be undertaken in the context of balancing measures to reduce phosphorus (P) losses with those necessary to reduce other nutrient losses such as nitrogen (N). Such measures are often conflictory, and need to be considered as part of an integrated program of measures.

The outcomes of the discussions within the COST Action will be reported to the new board of the WFD dealing with the interaction between agriculture and water quality.

In August 2008 the following 28 countries participated in the Action: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and United Kingdom. More information about the Action can be found on the website of the Action: www.COST869.alterra.nl.

Within COST 869, four working groups (WG) are active. Their goals are, respectively, to:

WG1: develop methodologies to localize critical source areas and transport routes in catchments,
WG2: study the influence of nutrients on ecological processes in surface waters,
WG3: evaluate different types of mitigation options, create factsheets about options,
WG4: evaluate projects in example areas.

During this workshop of WG2, the following questions can be discussed:

- a too high N or P concentration deteriorates overall water quality, where do we find N or P limitation?
- a too low N/P ratio in surface water stimulates growth of toxic blue-green algae,
  * should the N/P ratio be based on total N and P, or on e.g. nitrate and ortho-P?
  * do we find seasonal patterns in the N/P ratio; if so, can this be explained?
  * does the N/P ratio tend to change over a longer period?
  * will an increase of water temperature increase the risk of blue-green algae blooms?
- removing nitrate by denitrification reduces the N/P ratio, and may cause mobilization of P. Should we take care with this kind of remediation of N?
- which other interactions of N and P in surface water do we know of?

Testing the applicability of the Redfield ratios across taxa and water bodies

Kenneth Irvine, Jennifer Brady, Valerie McCarthy and Louise Donohue
School of Natural Sciences, Trinity College, University of Dublin, Ireland.

Redfield et al (1963) proposed that healthy marine phytoplankton contain a molecular C:N:P ratio of 106:16: 1. Departure from this ratio implies nutrient deficiency, and not only sub-optimal growth for phytoplankton, but also sub-standard food resources for primary consumers of the phytoplankton. A number of studies (Morris and Lewis, 1988; Hecky et al. 1993) have tested the applicability of the Redfield ratio for freshwater phytoplankton, suggesting that seston ratios can be indicative of the relative importance of N and P limitation. Nutrient ratios in the bodies of both pelagic herbivores and benthic invertebrates may also help explain community structure and, through retention of limiting nutrients, provide a feedback to phytoplankton dynamics (Sterner and Hessen, 1994; Walve and Larsson 1999; Elser et al., 2000; McCarthy et al., 2007). We report here on preliminary analysis of a large dataset, from both published and unpublished work, to a) test if C:N:P ratios within taxa across a range of habitats and trophic positions are consistent with stoichiometric theory; b) evaluate if there are some general relationships between compliance or departure from the Redfield ratio across taxa; and c) to discuss the implications of this work for assessing or predicting the relevant limitation of N and P in surface waters.

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The role of N as a limit to primary production in European waters – perspectives from the European Nitrogen Assessment

Penny Johnes
Director Aquatic Environments Research Centre, University of Reading, UK

Under the ESF funded Nitrogen in Europe programme (www.nine-esf.org) the European Nitrogen Assessment is being undertaken, with one focus being to document the extent of our knowledge of nitrogen turnover processes and their effects in European freshwater aquatic ecosystems (wetlands, standing and running waters, the hyporheic zone and groundwaters). The key processes and controls of nitrogen turnover in freshwaters are being discussed to understand the observed trends and the impacts of these processes on the ecological status and societal value of European freshwaters. As part of this assessment the relative role of N versus P as limits to primary production have been assessed.

In this presentation the data being reviewed under the ENA for European Freshwaters will be presented, and contrasts between the role of different chemical forms and physical stores of N and P fractions in limiting the production of different structural elements of European freshwaters will be assessed. The need for an holistic approach to assessment of the role of nutrients and other factors as limits to productivity and controls on ecosystem structure and function in freshwater ecosystems will be highlighted.

Variations and spurious correlations related to DIN, DIP, TN, TN, DIN/DIP and TN/TP in lakes, rivers and marine systems

Maria Khalili
Department of Aquatic Sciences and Assessment Box 7050, 750 07 Uppsala

Inherent variations and uncertainties in empirical data from aquatic systems ultimately constrain approaches to predictions and possibilities to identify critical thresholds and points of no return. This presentation addresses coefficients of variations (CV) in lakes, rivers and marine systems for total phosphorus (TP), total nitrogen (TN), dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), DIN/DIP-ratios and TN/TP-ratios. Key questions are: How do the CV-values vary among lakes, rivers and marine systems? Are there patterns in the CVs related to the trophic conditions? Are there seasonal patterns in the CVs? Which Redfield ratio should be used; DIN/DIP or TN/TP?

I will show results that show that DIN varies most of the studied nutrients and it is the variability in DIN that governs the high uncertainty in the DIN/DIP-ratio (CV = 0.8 to 1.4). The maximum variation for DIN is found in Skagerack and the minimum in lakes. The CVs for the TN/TP-ratio are significantly lower (0.4 to 0.5). The CVs for DIN and TN seems to increase steadily from the Bothnian Bay, the Bothnian Sea, the Baltic Proper to the Skagerack. There is also a pattern of lower variabilities in oligotrophic lakes for DIN/DIP compared to TN/TP. Results from an experiment to illustrate spurious correlations (using randomly generated data) is also shown, which clearly suggests that for low-productive systems, one can find almost any ratio of DIN/DIP or TN/TP. This implies that one must be very cautious in interpretations of what DIN/DIP or TN/TP actually represent in low-productive systems.

key words: coastal systems, lakes, rivers; coefficients of variation, phosphorus, nitrogen, DIN, DIP; Redfield ratio; sampling

Nutrient limitations in French coastal and lake ecosystems: variability, assessment, emerging issues related to bio-availability of particulate P

Jean-Marcel Dorioz (1) and Chantal Gascuel-Odoux (2)

(1) INRA, UMR CARRTEL, Hydrobiologie lacustre, F-74200 Thonon les Bains
(2) INRA, Agrocampus-Ouest, UMR1069, Sol Agro et hydroSystem, F-35000 Rennes.

Since P limitation of lakes primary production has been fully demonstrated (after the limiting nutrient controversy during the mid 1970 s), the control of lake eutrophication has been based on controlling P concentration to decrease algal biomass, mainly thanks to reducing the external P inputs. This strategy has led to some significant improvement associated with sharp reductions in point sources discharges (large deep alpine lakes). However, in some case diffuse sources and internal P loads (released from lake bottom sediments) slow down and delay rehabilitation or seem to be able to stabilize the lake trophic state. Biological processes and feedback process or N/P interactions, are also involved in this stabilization.

P status is also an important parameter for phytoplankton growth in transitional waters such as estuaries and some coastal waters, and should be included in management programs designed to control coastal eutrophication (Carpenter, 2008). But the studies dealing with nutrient limitations in estuaries, costal waters of the Atlantic Ocean or in oligotrophic parts of the Mediterranean sea, has evidenced either a P or an N deficiency (see, Labry et al, 2002). Modelization of phytoplankton and algal growth in coastal waters and estuaries allows to investigate the seasonal and spatial variability of the nutrient limiting factor. Models (Perrot el al, 2007) indicate NO_3 as the key controlling factor of the “green tides” (overgrowth of marine macrophytes which ruin some parts of the Atlantic cost and for which the level of concern of local people is very high). These findings have been used to established sharp standards and targets for $N\text{-}NO_3$ levels in rivers and to reinforce N management on watersheds.

Once point sources of nutrients have been sufficiently reduced, diffuse sources become the main phosphorus provider for aquatic ecosystems. Most of the total-P is transferred as particulate-P from terrestrial sources. The N/P ratio of the inputs changes (Lancelot et al 2007) and new issues related to particulate-P emerge: assessment of both the long-term and short term impacts of particulate-P inputs become an important management concern. Management strategies need especially extensive understanding of spatial and temporal variability of properties of particulate-P (bioavailability, sorption balance….). Since the properties of particulate-P are affected by changes in the distribution of the constituents to which P compounds are incorporated or attached (Poulenard et al 2008), we would like to proposed a conceptual model to try to establish the links between some bio and physical behaviour of particulate-P and the origins of associated sediments (the P carrier phase) within watersheds, during various hydrological events .

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The impact of N/P ratio shifts on phytoplankton structure and biomass in two Greek gulfs influenced by anthropogenic activities

Kalliopi Pagou - Greece

Abstract to be received

Sediment mineralization processes and N *vs.* P limitation in the Baltic Sea

Jouni Lehtoranta, Petri Ekholm*, Heikki Pitkänen
Finnish Environment Institute, *petri.ekholm@environment.fi

Primary production is dominantly P limited in the Bothnian Bay whereas in the Bothnian Sea the spring bloom is P and summer production N limited. In the open Gulf of Finland and the main basin of the Baltic, production tends to be N limited. We propose that this pattern is linked to shifts in sediment microbial mineralization pathway. On the basis of indirect evidence (in lack of direct measurements), we conclude that the bottom sediments of the non-stratified and oligotrophic northernmost (the Bothnian Bay), and the poorly stratified and mesotrophic next northern (the Bothnian Sea), sub basins of the Baltic have tolerated the external nutrient load rather well, as they are still in a state in which Fe reduction and coupled cycling of Fe and P prevail in the surface sediments. Since Fe-reducing bacteria are unable to reduce Fe(III) oxides completely, part of the Fe-bound P may be permanently buried in the sediments. The good ability of the sediment to retain P results in low concentrations of P in water, a state that in turn promotes P limitation of primary production.

In contrast, the sediments of the nutrient-loaded and stratified sub-basins, the Gulf of Finland (the most eutrophied sub basin) and the Baltic Proper, appeared to have reached a state in which SO_4 reduction is the dominant mineralisation pathway. Sulphate reduction followed by sulphide formation leads to efficient reduction of Fe(III) oxides. Subsequently, Fe-bound P dissolves into the pore water and is transported to the overlying water, whereas Fe is buried as sulphides (uncoupled Fe and P cycling). The capacity of sediments to retain P is limited; high amounts of bioavailable P exist in the water column, primary production tends to be N limited and extensive blue-green algal blooms are common. We maintain that the decisive factors controlling the above regional distribution of Fe and SO_4 reduction are the flux of labile organic matter to the sediments and the variation in hydrodynamics. Sulphate reduction will be triggered when the flux of organic matter reaches a critical threshold value, resulting in anoxia at the sediment–water interface, followed by the collapse of benthic fauna and inhibition of Fe re-oxidation. The only way to drive the sediments back into an Fe-reduced state is to strongly reduce bioavailable N and P loading to the Baltic Sea, and thus the flux of labile organic matter to the sediments. Even so, recovery may also necessitate favorable hydrodynamic conditions.

Seasonal and long-term trends in phytoplankton as a function of P and N loads in shallow Lake Balaton.

Vera Istvánovics[1] and István Sisák[2]

1 – Water Resources Management Team of the Hungarian Academy of Sciences, Budapest, Hungary
2 – Pannon University, Dept. of Crop Production and Soil Sciences, Keszthely, Hungary

Rapid eutrophication of large (600 km^2), shallow (3.2 m) Lake Balaton has been reversed by a set of large-scale management measures (sewage diversion, P removal from sewage, pre-reservoir construction on the largest tributary, the Zala River; etc.) taken during the late 1980ies. Further load reduction resulted from the collapse of agriculture after 1989 and from lasting droughts (e.g. 2000-2004). The trajectory of eutrophication and recovery has been tightly followed in Basin 1 of Lake Balaton (38 km^2). The Zala River (catchment area 2500 km^2) carries about 30% of the total nutrient loads of the whole lake to this basin.

We present seasonal and long-term changes in the biomass and composition of phytoplankton (weekly to biweekly data) as a function of external nutrient loads (daily data) in Basin 1. Where adequate, we consider both the results of experimental work concerning in-lake N and P cycling and high frequency field data of phytoplankton and relevant physical conditions. Our conclusions that may apply to other shallow, temperate lakes are as follows:

1. P, N and light limitation of algal growth shows dynamic, unpredictable variability. In contrast to this, limitation of the maximum biomass (carrying capacity) is more predictable. In spring, N or P limitation prevails depending on the external N and P loads. In summer, the carrying capacity is P determined.
2. Internal loads of both P and N are key components in satisfying algal nutrient demand during summer.
3. Yearly mean biomass of phytoplankton decreased by a factor of about 3 in the post-management period. Duration of the high-biomass summer period also decreased significantly. Nevertheless, the share of N_2-fixating cyanobacteria did not change much (up to 90-95% in the summer and 30-40% on a yearly basis). This may be due to the molar ratios of external NO_3-N to PO_4-P well below the Redfield ratio during summer (5 and 1 before and after inundation of a reed-dominated anaerobic wetland area at the mouth of the Zala River, respectively).
4. Although low N:P loading ratios are thought to provide competitive advantage to cyanobacteria as also observed in Lake Balaton, the relationship is not as straightforward as it may seem. Thus, N_2-fixation is rarely a major source of N for cyanobacteria in Basin 1 since fixation has high energy demand and ammonium uptake affinity of the dominant cyanobacteria exceeds that of other phytoplankters. High temperature, low light availability and pulsed nutrient supply also select for N_2-fixing cyanobacteria. These selective forces prevail during the summer while the need for atmospheric N is restricted to the periods of exceptionally high growth.

Influence of catchment characteristics and lake factors on P and N in Finnish Lakes

Kirsikka Niemi
Finnish Environment Institute, University of Helsinki, Finland

Between a lake and its catchment there is a strong interaction. Despite of that, it is not possible to create one reliable model between them. Different kinds of lakes react on different ways to nutrient load. In this research lakes were grouped in different lake types based on Finnish national lake typology. In different lake types the intensity of effect between the controlling factors and nutrients of the lakes differ.

Table 1 Finnish lake typology (SA=Surface Area, D=Depth)

Abbreviation	**Name**	**Characteristics***
LNh	Large, non-humic lakes	SA > 4,000 Ha, color < 30
Lh	Large, humic lakes	SA > 4,000 Ha, color > 30-90
Nh	Medium and small, non-humic lakes	SA: 50 - 4,000 Ha, color < 30
Mh	Medium, humic deep lakes	SA: 500 - 4,000 Ha, color: 30–90, D > 3 m
Smh	Small, humic, deep lakes	SA: 50 - 500 Ha, color: 30–90, D > 3 m
Hh	Deep, highly humic lakes	Color > 90, D > 3 m
SNh	Shallow, non-humic lakes	Color < 30, D < 3
Sh	Shallow, humic lakes	Color: 30-90, D < 3 m
SHh	Shallow, highly humic lakes	Color > 90, D < 3 m
NrCr	Nutrient-rich and chalky-rich lakes	
Nr	Nutrient-rich lakes	
Sd	Lakes where is short detention time	Detention time < 10 days

The growth of agricultural land area in the catchment increases the total phosphorus and the total nitrogen concentrations in all types of lakes. Part of the agricultural land and total phosphorus correlated very strongly in large non-humic lakes. Suchlike correlation was with total nitrogen in large and medium humic lakes.

Defining the degree of change is important to eliminate the effects of other factors and to review the effect of the influential factor on the variable alone. For example on the flat there is more agriculture area than on land of variable topography, but there the mean depths of lakes are lower too. When we want to know how the agriculture land influences total phosphorus concentration in lakes we have to eliminate the effect of mean depth. When the part of the agriculture land in the catchment increases 10 % the effect on the nutrients of the lake is the strongest in lakes where is short detention time. There the total phosphorus concentration increases 30 µg/l and the total nitrogen concentration increases 350 µg/l. One meter increase of mean depth in lakes influences strongest in nutrient-rich lakes where the total phosphorus and the total nitrogen concentrations decrease 20 µg/l and 150 µg/l respectively. Reviewing the relationship between those nutrients 10 % growth of agricultural land influences strongest in large non-humic lakes where N/P-value decreases 700 units. The chance in mean depth influences the N/P-value much less thought the correlation between them was quite good in most of the lake types.

The methods developed in this research can be used for analysing the trends in different types of lakes. Results can also be utilised concretely in implementation of Water Framework Directive (WFD).

Processes determining limitation in aquatic systems

Roos Loeb and Piet Verdonschot
Alterra, Wageningen UR, Wageningen, the Netherlands. roos.loeb@wur.nl

Nutrient limitation is an old but still not solved theme dealt with in various ways, from correlative field surveys and field experiments to bio-assays and the determination of internal nutrient concentrations. Not only P and N limitation, but also limitation by C and Si has been shown. Understanding nutrient limitation of a specific water body is interesting, but it is even more challenging to understand and be able to predict the type of nutrient limitation from landscape processes.

In over 100 articles dealing with nutrient limitation in aquatic systems that we studied, P limitation was the most common type. The general view on nutrient limitation is, however, strongly influenced by the results of the analyses of large datasets in which other nutrient limitation types than P limitation tend to be overlooked. Nutrient limitation of a group or species is determined by their relative nutrient demand, the available nutrient sources and the -relative- nutrient availability.

A well known example of the importance of nutrient demand is the high Si demand of diatoms, which can cause Si limitation and a shift to dominance of other algae. Less known, however, is that the relative nutrient demand of macrophytes differs significantly from that of algae, known as the Redfield ratio. Relative to phosphorus, nitrogen concentrations in macrophytes are about twice as high as in algae. Combined with the relatively higher availability of phosphorus for macrophytes, because of uptake by the root system, nitrogen limitation will occur much more often for macrophytes than for algae.

The type of nutrient limitation for algae is determined by several landscape processes. Processes in calcareous soils cause a lower availability of P and thus enhance P limitation. However, soils containing apatite may increase the availability of P and enhance N limitation. Hydrological processes also affect the type of limitation. Groundwater discharge may lower the redox potential and thereby increase the P availability. Lake stratification can cause silicium to remain in the hypolimnion and hence cause Si limitation. Atmospheric processes, like N deposition, may cause a switch of N-limited to P-limited conditions. Algae in oligotrophic waters may be limited by N in the absence of N-deposition. Of course, water quality and primary production itself also influence the type of limitation: the surface water by the supply of nutrients and, for instance, sulphate, whereas a high primary production may lead to depletion of CO_2 (and to a lesser extent of N), causing C limitation.

In conclusion, limitation is the result of a complex balance between landscape processes steering the supply and availability of substances and biological processes in the water body itself.

Factsheets of mitigation options – Introduction to database

Wim Chardon and Oscar Schoumans
Alterra, Wageningen UR, Wageningen, The Netherlands. wim.chardon@wur.nl

A main activity of WG3 is to develop a database with factsheets about mitigation options. This will be an important tool to share knowledge among participants in the Action. Each factsheet will contain the following information about the option:

- Description, incl. if effect is aimed at nitrogen (N) or phosphorus (P)
- Rationale, mechanism of action
- Relevance, applicability & potential for targeting
- Effectiveness, including uncertainty
- Time frame
- Environmental side-effects / pollution swapping
- Administrative handling, control
- Costs
- References

At present (September 2008) a total of 70+ factsheets have been written in draft and are in the process of reviewing. They are available via the website of the Action: www.COST869.alterra.nl under “List of options and factsheets”.

The factsheets are categorized in 10 groups, of which 2 are related to measures in surface water or to ecological processes in water:
(8) Measures in surface water
(9) Options for abating consequences of eutrophication in surface water

During the presentation more information will be given about the measures mentioned under these categories, and participants are asked if they know of experience with these measures, either with positive or negative results.

Also, we will discuss if more measures in surface water are possible.

Trends in N/P ratios and limitations in Dutch surface waters

Jeroen de Klein - NL

Abstract to be received

Occurrence of cyanobacteria in Czech dimictic reservoirs with different N/P ratio in water

Josef Hejzlar - *Biology Centre AS CR, Institute of Hydrobiology, Na Sadkach 7, 370 05 Ceske Budejovice, Czech Republic, e-mail hejzlar@hbu.cas.cz*

The contribution will present results of long-term monitoring studies of phytoplankton and water chemistry in three reservoirs used for drinking water supply that represent different levels of agricultural and municipal pollution in their catchments and hence show large differences in the N/P ratio in water. Phosphorus was the limiting nutrient for phytoplankton in all these reservoirs during the summer period. A summary of water quality conditions in these reservoirs is in Tab. 1.

Table 1 Main characteristics and nutrient concentrations during July-September period of the year in the reservoirs of Svihov, Rimov, and Lipno (N_{min} = sum of nitrate, nitrite, and ammonia N; P_{min} = dissolved reactive P)

Reservoir	Svihov	Rimov	Lipno
Period of study	1992-1997	1984-2004	1994-2005
Surface area, km^2	10	2	45
Mean / maximum depth, m	16 / 50	16 / 42	6 / 20
Mean water retention time, yr	1.0	0.2	0.9
Farmland area in catchment, %	63	45	3
N_{total}, mg/l	10	2.5	1
P_{total}, µg/l	12	20	30
N_{total}/P_{total}, mol/mol	>1000	300	100
N_{min}/P_{min}, mol/mol	>2500	>1000	>100

In Lipno Reservoir, where the N/P ratios were lowest and nitrate concentration decreased during summer months commonly below 0.1 mg/l, cyanobacteria (*Woronichinia naegeliana*, *Anabaena crassa*) dominated the summer phytoplankton community regularly in all years of the studied period. In the reservoirs of Svihov and Rimov with higher N/P ratios due to higher N inputs from the agricultural use of catchment the dominance of different cyanobacteria species (*Aphanizomenon* sp., *Microcystis aeruginosa*, *W. naegeliana*) alternated in different years with the dominance of other phytoplankton groups like diatoms and green algae. A correlation analysis between phytoplankton species and chemical and climatic conditions indicated that cyanobacteria dominance occurred mainly in climatologically warm years. In conclusion, the study indicated that the ecological conditions that support the dominance of cyanobacteria in these reservoirs are complex and that low N/P ratios might be one (but not only) of the controlling factors.

Nutrient ratios in surface freshwaters of the Balkans and possible controlling factors

Nikos Skoulikidis
Institute of Inland Waters, Hellenic Centre for Marine Research, 46.7km Athens – Sounio Av, 19013, Anavissos, Greece. nskoul@ath.hcmr.gr

Sixteen large Balkan rivers that contribute 83% to the total Balkan river outflows in the Mediterranean, 29 small/medium Greek rivers, 37 reference streams and 19 major Greek lakes were examined for their nutrient levels and ratios. In the vast majority of the rivers, nutrient ratios indicate P-limited photosynthesis. In large rivers, N/P ratios range between 7 for the Axios/Vardar, a heavily polluted river with industrial P inputs, and 409 for Krathis, a nearly ´pristine´ river in N. Peloponnese (average: 90.6, median: 37.8, StDev: 120%).

Balkan rivers drain three zones with distinct climatic, geological and hydrochemical features. Zone 1, located in the NE Balkans, displays silicate geology. Zone 3, that extends along the western Balkans, presents carbonate geology, while zone 2, placed in-between, exhibits a mixed geology. In large Balkan rivers, average N/P ratios increase from zone 1 towards zone 3 together with the portion of carbonate rocks in the respective basins. The same result is valid for small/medium Greek rivers, where N/P ratios are positively correlated with the percentage of carbonate rocks in their basins. Finally, in the majority of reference sites photosynthesis is also P-limited, while N/P ratios also increase from zone 1 to 3.

Focusing on individual rivers, a downstream N/P ratio increase is apparent in the Acheloos R. (W. Greece). In the Evrotas R. (S. Peloponnese), only 7 of 36 sites that generally lie on clean tributaries of mostly silicate basins reveal N-limited photosynthesis. In the Krathis R., a downstream increase of dissolved N together with a decrease of N bound on river sediments is attributed to leaching and/or mineralization processes. The opposite is apparent for P, due to its retention in river sediments. These mechanisms may control photosynthesis which is by far P-limited.

In the Greek lakes, according to data of the Ministry of Agricultural Development and Food, photosynthesis is governed by N, which generally presents lower levels than in the rivers. In fact, in nine out of sixteen lakes, photosynthesis is N-limited, as a result of relatively low DIN concentrations. This result needs to be validated with newer data from individual lake studies.

N and P pollution inputs, geological background and biogeochemical processes acting in the water column and sediments may control nutrient ratios and photosynthesis in surface freshwaters of the Balkans.

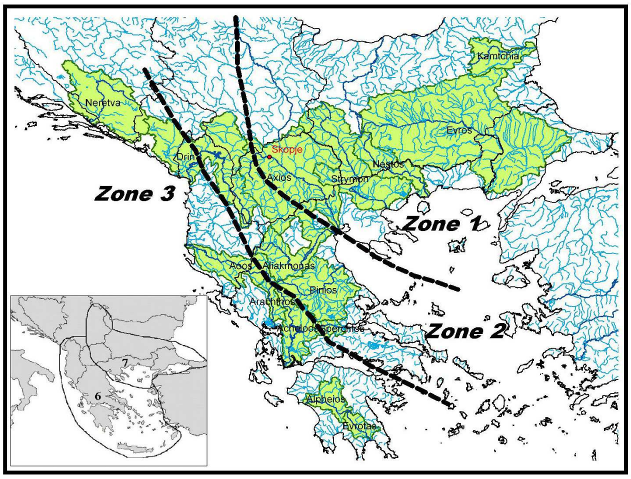

Fig. 1. Large Balkan rivers and river zones

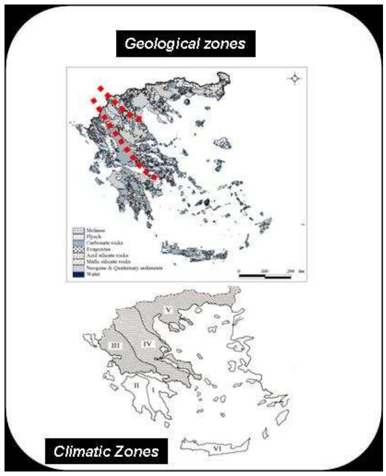

Fig. 2. Geological – climatic zones

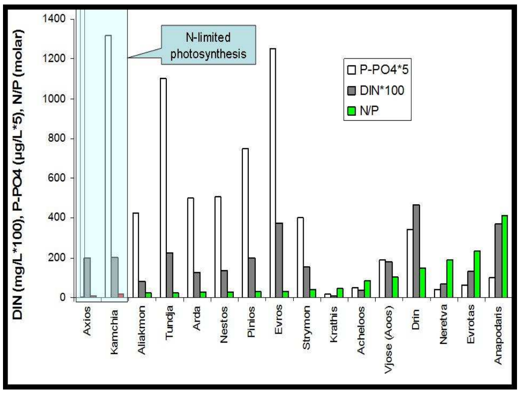

Fig. 3. Nutrient levels and ratios in Balkan rivers

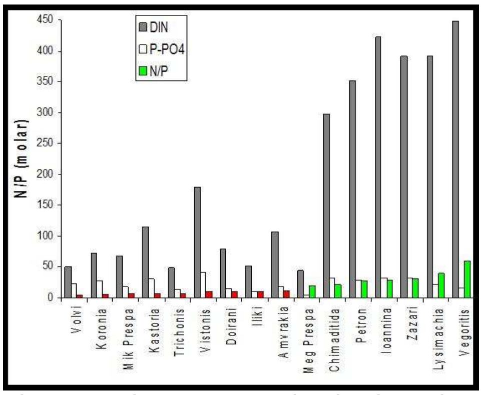

Fig. 4. Nutrient levels and ratios in major Greek lakes

Effect of changing hydrology on nutrient availability and primary production in riverine landscapes

Thomas Hein, Stefan Preiner, Iris Baart, Elisabeth Bondar-Kunze, Manuel Felkl, Claudia Leichtfried, Matthias Mair, Gabriele Weigelhofer & Nina Welti
Wasserkluster Lunz GmbH, Inter Univ. Center for Water Research, 3293 Lunz am See, Austria, email: thomas.hein@boku.ac.at
Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Applied Life Sciences, Max Emanuel-Straße 17, 1180 Vienna, Austria.

The biogeochemical dynamics in lotic ecosystems are mainly controlled by geomorphology and the hydrological regime at the landscape level. The morphological complexity of river corridors creates multiple pathways of surface and subsurface hydrologic exchange processes. Ecosystem functions related to nutrient transformation and water borne productivity are influenced by these exchange processes, especially in subsystems of higher hydrologic retention. In developed areas, these structures function not only in terms of water retention and sediment regulation, but they are also effective buffers of nutrient inputs. In large rivers, floodplains and riverine wetlands can be the primary regulation sites for nutrient dynamics.

Main focus of this work was to describe the relevance of hydrological connectivity to nutrient levels and aquatic primary production patterns in floodplains of the River Danube in Austria. To calculate potential primary production and compare different situations, a dynamic biomass model was developed. We analysed basic information on habitat structure, surface and groundwater dynamics, and estimates of light availability statistically and combined them with biomass measurements of phytoplankton and macrophytes.

The experience of river management, including rehabilitation, so far point to the importance of a more integrated approach including key ecosystem processes. Generally, river restoration and rehabilitation schemes need to integrate an evaluation of biogeochemical processes to obtain a better understanding of future reactions of the whole ecosystem.

Spatial and temporal variations in TP-phytoplankton relation in German rivers and its consequences for the implementation of the WFD

Gregor Ollesch[1], Ute Mischke[2], Ralph Meissner[1]

[1] Helmholtz Centre for Environmental Research – UFZ. gregor.ollesch@ufz.de
[2] Leibniz-Institute for Freshwater ecology and Inland Fisheries

The implementation of the European Water Framework Directive (WFD) requires an evaluation of watercourses which also includes a recording of phytoplankton characteristics. The phytoplankton growth is controlled by the nutrient status of the water bodies and abiotic factors like water retention time or shadow effects. Thus, an evaluation has to consider the specific conditions of each type of water body. However, in Germany more than 20 major types of watercourses exist due to climate and landscape differentiation.

Chlorophyll$_a$ (chl$_a$) and total phosphorus (TP) concentration are key parameters to estimate the (auto-) trophic status of water bodies. The relationship of these two key parameters is positively correlated also in rivers, if environmental conditions are comparable to lake systems. However, in almost all small creeks and rivers the physical conditions limit algal growth, so the empirically observed chl$_a$/TP ratio is lower and varies considerably. Therefore phytoplankton assessment is restricted to few German river types, which exhibit an increasing trend of phytoplankton biomass with increasing nutrients and which are plankton-rich (>20µg/l chl$_a$ in seasonal mean). Subtypes are established to take differences in phytoplankton response into account. For example, the average biomass production differs strongly in large streams in south-western Germany from those in the eastern part, independently if they are dominated by gravel (type 10) or sand (type 20). More relevant for phytoplankton growth is the fact that these regions differ very much in mean precipitation. So, an area specific discharge of 10 l s^{-1} km^2 was identified as a threshold value, which explains the lower chl$_a$ production in the streams like Rhine and Danube by dilution effects in comparison to Elbe or Odra. Based on this river type-specific trophic status system, a procedure was developed to assess the ecological status based on biomass and indicator taxa of phytoplankton (Mischke & Behrendt 2007). The software “PhytoFluss” with user interface was developed for environmental authorities to apply this procedure in practice.

ABSTRACTS OF

POSTER PAPERS

Estimating critical phosphorus and nitrogen loading for good water quality in Finnish lakes with the model tool LLR

Anita Pätynen
Finnish Environment Institute, University of Jyväskylä, Finland. Anita.Patynen@ymparisto.fi

”Water quality models for WFD implementation in estimating target nutrient loads and lake monitoring (LakeState)” is a two year (2006-2008) project of the Finnish Environment Institute. One outcome of the project is the model tool LLR (Lake Load Response) that can be used when planning actions to achieve good water quality in lakes. For good water quality, the parameters here are total phosphorus, total nitrogen and chlorophyll a concentrations, and phytoplankton biomass. The aim has been to create an effective but easy-to-use tool that will soon be accessible through the Internet. LLR has already had some users within Finland's environmental administration and the feedback has been positive, so clearly there is a need for this kind of tool.

The basis of LLR is the LakeState (LS) model, that consists of three component models. One is Chapra’s model for retention of total phosphorus and nitrogen, with which it is possible to estimate the in-lake nutrient concentrations as a function of incoming loading and water flow. The model uses observations from the study lake for results, and Bayesian statistics with the Marcov chain Monte Carlo (MCMC) simulation method is used to get more reliable estimates.

The second model is the hierarchical, linear regression model for chlorophyll a. With this the concentration of chlorophyll a can be estimated from measured or estimated in-lake nutrient concentrations. The model is calibrated with observations from 2000 Finnish lakes, and Bayesian statistics and MCMC are also used in the estimation. Being hierarchical, the model uses information both from the study lake and from lakes of the same type when making estimations. Observations from the lake are weighted more but if the data are sparse, observations from similar lakes are also used. All Finnish lakes are divided into 13 different types according to some features like depth and the amount of humic substances in the water, and it is presumed that lakes within the same type are more similar.

The third model is a logistic regression model for phytoplankton biomass. This uses measured or estimated in-lake nutrient concentrations to estimate the probability with which the phytoplankton biomass will exceed the limit for good water quality. The model is calibrated with observations from 1200 Finnish and Norwegian lakes.

LLR is made to ease the use of the LS model. It works best for lakes with quite simple basin shapes and without internally nutrient loading. As input data the user gives the depth, volume and type of the lake, which for most Finnish lakes can be found from the LLR database by giving the name of the lake. For estimating how changes in loading influence the in-lake nutrient concentrations, prior observations about loading, concentrations and water outflow, averaged for the lake’s retention time, are needed. The biggest problems in the use often arise from inadequate loading data. For estimating changes in chlorophyll a concentration and phytoplankton biomass, the data needed come from the LLR database, if the study lake was found there when giving the basic lake information. If not, the user gives all chlorophyll a, total phosphorus and total nitrogen concentrations observed in the lake in July and August in different years.

After all the data has been brought in, LLR gives graphs and tables that show the present loading – water quality relations, and by how much the loading must be reduced to achieve good water quality with 50 % probability. The percentage can be raised, but this makes the limits for loading stricter and often harder to achieve. As lake management usually must balance between costs and effectiveness, LLR can be very helpful in realistic management planning by showing different possibilities.

Climatic, hydrological and hydrochemical effects on benthos of the stream Graisupis, Lithuania

Kazimieras Gaigalis, Antanas Sigitas Šileika, Kęstutis Arbačiauskas, Aušra Šmitienė

Water Manage. Inst. of LUA, Lithuania

Benthos parameters, climatic factors, stream water discharge, and nitrogen and phosphorus concentrations in water of the stream Graisupis have been analysed. It was determined that the ecological status of the monitoring stream became worse according to the benthos parameters during the studied period. The number of taxa sensitive to pollution (stoneflies, mayflies and caddisflies), the mean Chandler biotic index and benthos biomass decreased. This happened under the conditions of increased weather temperature, reduced rainfall and stream water discharge, increased phosphorus concentration, reduced nitrogen concentration and reduced N/P ratio. The analysis has shown that the deterioration of the stream Graisupis ecological status was determined by the reduction of rainfall during summer time, which caused longer periods of stagnant stream water or small water discharge, and deteriorated oxygen conditions due to organic matter destruction in the stagnant water. Deterioration of the conditions could be indirectly indicated also by the reduced N/P ratio. The investigation has shown that climatic factors and possible global environmental change have to be considered when agricultural pollution impact on monitored stream ecological status is to be evaluated.

Nutrient inputs to the Serpentine Lakes Complex

Deborrah Ballantine

NIWA - National Institute for Water and Atmospheric Research, Gate 10 Silverdale Road, Hillcrest, Hamilton, dballantine@slingshot.co.nz

The Rotopiko Lakes are a complex of three small peat lakes located 20 km south-east of Hamilton in the Waikato region. The lakes were identified as a priority site for management to protect the regionally rare submerged plant communities that they contain. One of the key threats to these submerged plant communities was the continued input of nutrients from the adjoining agricultural land. Water quality measurements indicated that the Rotopiko Lakes, particularly Rotopiko North were stressed due to excess nutrient loadings. Even though the lakes were surrounded by a vegetated marginal strip, a number of small drains conveyed agricultural run-off directly to the lakes, and interception and treatment of the drain inflows was seen as a priority management action to avoid the loss of the unique submerged plant activities. The Rotopiko Lakes nutrient problem is a working example of a “research by management” opportunity in nutrient mitigation for the protection of freshwater carried out by Aquatic Pollution in NIWA.

N/P ratio in selected Polish rivers

Leszek Hejduk
Warsaw University of Life Sciences, Dept. of Water Engineering, Warsaw, Poland;
leszek_hejduk@sggw.pl

The area of Poland is located in the continental division of 3 seas: Baltic Sea (99,7%), Black Sea (0,2%) and North Sea (0,1%). The two main river basins, Vistula and Odra, cover 88% of the Polish territory. The mean outflow from Vistula river is 1054 m^3/s and from Odra river 535 m^3/s. Based on statistical data, the loads of various forms of nitrogen and phosphorus for three gauging point at Vistula and Odra river as well as from area of Poland are presented.

Based on the statistic data, the N/P ratio has been calculated for period of 16 years. The average N/P ratio is 15,4 when the total N and total P is used for calculation, and 6,8 for nitrates and orthophosphates. During the considered period, an increase of the ratio can be observed. The yearly load of nitrogen put into the Baltic Sea from the territory of Poland shows a stabilization during the past 4-5 years. The yearly load of phosphorus put into Baltic Sea from the territory of Poland decreased from 1998 to 2003, and shows a slight stabilization since 2003. Along the Odra river, the total nitrogen load increased about 7 times from Chałupki (Poland Czech Republic border) to Krajnik (gauge at the mouth of the river). The average N/P ratio decreases along the river. The load of the total nitrogen increased along the Vistula river and at the mouth, similarly like in Odra river. However the loads are 2 times higher. The average N/P ratio decreases along the river.

LIST OF DELEGATES

Country	Delegate	Email address
Austria	Thomas HEIN	thomas.hein@boku.ac.at
Belgium	Georges HOFMAN	georges.hofman@ugent.be
Czech Rep.	Josef HEJZLAR	hejzlar@hbu.cas.cz
Finland	Petri EKHOLM	petri.ekholm@ymparisto.fi
Finland	Kirsikka NIEMI	Kirsikka.Niemi@ymparisto.fi
Finland	Anita PÄTYNEN	Anita.Patynen@ymparisto.fi
France	Jean Marcel DORIOZ	dorioz@thonon.inra.fr
France	Chantal GASCUEL	chantal.gascuel@rennes.inra.fr
Germany	Ralph MEIßNER	ralph.meissner@ufz.de
Germany	Gregor OLLESCH	gregor.ollesch@ufz.de
Greece	Nicolaos SKOULIKIDIS	nskoul@ath.hcmr.gr
Greece	Konstantinos GRITZALIS	kgritz@ath.hcmr.gr
Greece	Sofia LASCHOU	sofial@ath.hcmr.gr
Greece	Aleka PAVLIDOU	aleka@ncmr.gr
Greece	Kalliopi PAGOU	popi@ath.hcmr.gr
Greece	Prof. SCOULOS	??
Greece	Prof. DASENAKIS	edasenak@chem.uoa.gr
Greece	Ioannis Karaouzas	??
Greece	Theodora Kouvarda	??
Hungary	Istvan SISAK	talajtan@georgikon.hu
Hungary	Vera ISTVÁNOVICS	istvera@goliat.eik.bme.hu
Ireland	Ken IRVINE	kirvine@tcd.ie
Israel	Iggy LITAOR	litaori@telhai.ac.il
Israel	Moshe SHENKER	Shenker@agri.huji.ac.il
Lithuania	Antanas Sigitas SILEIKA	sigitas@water.omnitel.net
Lithuania	Kazimieras GAIGALIS	syzak@kaunas.init.lt
Netherlands	Wim CHARDON	wim.chardon@wur.nl
Netherlands	Jeroen de KLEIN	Jeroen.deKlein@wur.nl
Netherlands	Roos LOEB	roos.loeb@wur.nl
New Zealand	Deborah BALLANTINE	d.ballantine@niwa.co.nz
Norway	Åge MOLVÆRSMYR	Aage.Molversmyr@iris.no
Poland	Leszek HEJDUK	Leszek_hejduk@sggw.pl
Romania	Daniela DANA	danadaney@yahoo.com
Romania	Romulus MOCANU	mocanu@administrativ.ucv.ro
Romania	Grigore ADRIANA	g.adriana_elena@yahoo.com
Romania	Anghelescu LETITIA	letitia_elena@yahoo.com
Slovakia	Jaroslav ANTAL	Jaroslav.Antal@uniag.sk
Sweden	Barbro ULEN	Barbro.Ulen@mv.slu.se
Sweden	Maria KHALILI	Maria.Khalili@ma.slu.se
Sweden	Kurt PETTERSSON	kurt.pettersson@ebc.uu.se
Switzerland	Emmanuel FROSSARD	emmanuel.frossard@ipw.agrl.ethz.ch
UK	Penny JOHNES	p.j.johnes@reading.ac.uk