Euro-limpacs

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PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	X
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Preface

During meetings of the WP8 task 3 team an overview of current and future causes of ecosystem degradations was generated. For each degradation type, various specific restoration measures are applied to restore the ecosystem to a less degraded stage. A Europe-wide survey was carried out to give an overview of restoration projects in Europe (deliverable 33). As the number of causes of ecosystem degradation and the number of types of restoration measures are very large, the WP8 task 3 team identified a set of key degradation types and restoration measures in European freshwater ecosystems.

This report (deliverable 73) summarizes information on these key degradation types and associated restoration measures in European freshwater ecosystems. The various sections are each authored by a number of Euro-limpacs participants and deal with a specific freshwater ecosystem type. These sections contain abstracts and outlines which are planned to be worked out into journal papers to be submitted to the Journal of Applied Ecology before the end of 2005. The editors of this journal have accepted a proposal for a special feature with the following title: “Restoration of biodiversity and ecosystem functioning in European freshwater ecosystems: An evaluation of successes and failures in the light of climate change”.

Jos T.A. Verhoeven
Merel B. Soons
The WP8 task 3 team

RESTORATION OF BIODIVERSITY AND ECOSYSTEM FUNCTIONING IN EUROPEAN FRESHWATER ECOSYSTEMS:

AN EVALUATION OF SUCCESSES AND FAILURES IN THE LIGHT OF CLIMATE CHANGE

Introduction

On the brink of implementation of European policies (EU Water Framework Directive) in the restoration of freshwater ecosystems, it is time for a European-wide evaluation of restoration measures applied to the conservation of freshwater ecosystems. We have identified key threats to the conservation of freshwater ecosystems (lakes, streams, rivers and freshwater wetlands) in Europe. For these threats, we will generate an overview of the successes and failures of restoration measures that have been applied. For this purpose we bring together European specialists in freshwater ecosystem ecology from within and without WP8 task 3 (see below) of the EU 6th Framework RTD programme 'Euro-limpacs'.

To disseminate the results of our findings, we aim to publish a set of nine short and concise overview papers in a scientific journal. We propose to edit a special feature in the *Journal of Applied Ecology* to present the overviews, preceded by a brief introduction and followed by a synthesis paper. Guest editors of the special feature will be Jos T.A. Verhoeven and Merel B. Soons, Utrecht University, who are the lead participants of WP8 task 3. The title will be 'Restoration of biodiversity and ecosystem functioning in European freshwater ecosystems: An evaluation of successes and failures in the light of climate change'.

Key degradation types and restoration measures

The overview papers will cover the following key topics, based on the most common combinations of ecosystem types and stress types in Europe:

1. Restoration of eutrophicated Northern European lakes: External loading reduction and internal measures

Martin Søndergaard and Erik Jeppesen (NERI, Silkeborg, Denmark), Eddy Lammens and Rob Portielje (RIZA, The Netherlands), Ilkka Sammalkorpi and Antton Keto (Finish Environment Institute, Finland), Lars-Anders Hansson (Lund University, Lund, Sweden), Anders Hobæk (NIVA, Norway)*

Abstract

Eutrophication is a serious problem for many European lakes and many types of restoration projects have been carried out for the past 20-30 years in order to improve lake water quality. In the coming years lake restoration may be an important measure in order to achieve a good ecological state as required by the Water Framework Directive.

In densely populated areas nutrient loading reductions have been applied widely by improved waste water treatment or diversion of sewage from cities. Internal measures have included several biological techniques, but particularly removal of zooplankti- and benthivorous fish species such as roach (*Rutilus rutilus*, L) and bream (*Abramis brama*, L) has been widely used in order to improve the potential top-down control of phytoplankton by improved zooplankton grazing. Physical and chemical measures such as sediment dredging, hypolimnetic aeration and alum treatment have also been conducted in several lakes in most North European countries.

The effect of the different restorations differs considerably. Generally it appears that the rate of success increases as the external loading on nutrients is reduced and with the intensity of the restoration intervention. In biomanipulation projects there is a risk that the lakes will return to turbid water conditions if not a sufficient number of fish are being removed. A large pool of mobile phosphorus in sediment also seems to increase the risk that a lake will return to turbid conditions due to a high internal loading of phosphorus.

Long term stability issues of the restorations carried out are generally not well described. Often only the first few years after the restoration can be documented by data. Some case stories however indicate that restoration of lakes in some cases should be seen as a management tool which needs to be conducted regularly in order to maintain a satisfactory water quality. The degree to which a restoration has long term and permanent effects depends on whether it is possible to establish mechanisms which stabilize the clear water state. In shallow lakes, a high coverage of submerged macrophytes is a prerequisite for such a development.

Expected changes in the future climate leading to higher precipitation and warmer lake water might counteract the improvements normally achieved by restoration of lakes. Higher precipitation will increase the external nutrient loading and higher temperature might improve conditions for zooplanktivorous fish species such as carp, which will diminish the possibility to have a top-down control of phytoplankton. Climate changes therefore might require a larger and more comprehensive restoration effort in the future.

Synthesis and applications: Lake restoration has been used widely in Northern Europe to improve lake water quality, but the success rate differs depending on external nutrient loading and intensity of the conducted restoration. Long term effects are not well described, but in some case lake restoration should be regarded as a tool which needs to be conducted several times or even regularly in order to maintain satisfactory lake water quality.

Outline

Introduction

Methods

Results:
- An overview of the different restoration methods used in lakes in Northern Europe.
- An overview of how frequently they have been used.
- Description on how successful the restorations have been (success defined as a chlorophyll a decrease by > 50% or a Secchi disk depth improvement of more than 50%).
- Description of the longevity of the restorations. Were multiple restoration measures needed to create long-lasting effects?
- Description of failures. Defined as a chlorophyll a reduction of < 10% and a Secchi disk improvement of <10%.
- Presentation of case studies. One from each country/restoration method.

Discussion should include sections on:
- Are there regional differences in the restoration of lakes and if, then why ?
- How successful is the restoration of lakes? Are the lakes being recovered to nearly pristine conditions or are minor or less improvements also considered as satisfactory?
- Can lakes be restored by a single intervention or should restoration be regarded more as management tool, which under some circumstances need to be conducted several times or even with regular intervals to maintain a satisfactory lake water quality? Does the answer to this question depend on factors such as the loading history of the lake?
- Do short term and long term effects of the restorations differ?
- When restorations were failures what were then the reasons and what could be done to avoid failures in the future? Can more general rules be advised apart from known advises on maximum nutrient loading or does each lake has its "own life" which makes it difficult to make more general rules?
- How important is the internal loading of phosphorus originating from the sediment for a successful restoration and can a successful restoration depend on the ability to shift the lake to have a higher nutrient retention capacity of the sediment. Can improved retention of nitrogen and phosphorus be made permanent?
- Discussion of the role of nitrogen for establishing clear water conditions and high coverage of submerged macrophytes in shallow lakes.
- Discussion on lake restoration in relation to the Water Framework Directive.
- Discussion in relation to climate changes. Would climate changes affect the way restoration projects should be carried out in the future?

2. Will climate changes affect future liming strategies?

Frode Kroglund (NIVA, Grimsatad, Norway), Richard Wright (NIVA, Oslo, Norway), Atle Hindar and Øyvind Kaste (NIVA, Grimsatad, Norway)*

Abstract

It is commonly acknowledged that anthropogenic acidification has affected Atlantic salmon (*Salmo salar*) populations on both sides of the Atlantic Ocean (NOU, 1999). While acidification implies a pH reduction, water quality (WQ) deterioration and toxicity is in Norway mainly related to the concurrent increase of cationic (inorganic or labile) forms of aluminium (Al), more than to the increase in H^+ activity. While the H^+ activity at a pH >5.4 has no observable effect on smolt quality and post-smolt performance, similar pH values are associated with population extinction and major fish kills in water containing elevated concentrations of Al (LEIVESTAD and MUNIZ 1976; Farmer, Saunders et al. 1989; Hesthagen 1989; Lacroix 1989; Hesthagen and Hansen 1991; Fivelstad, Olsen et al. 2004). A WQ-limit for Norwegian clear water rivers must as such be linked to Al, while pH-based WQ-limits appear to be satisfactory for organic rich rivers in Canada. Due to the extreme sensitivity of Atlantic salmon, Al concentrations around the detection limit can still be the cause for population declines, while population extinction occurs first at higher Al concentrations. Due to the link between Al and ANC. ANC has proven to be a more robust predictor of WQ than Al (Kroglund, et al. 2002).

Aluminium exercises its toxicity by being accumulated onto the gill surface, affecting gill form and function. This accumulation initiates a series of physiological responses where high concentrations result in mortality due to respiratory and osmoregulatory failure. Concentrations that are sub-lethal in freshwater can still exercise population effects by reducing seawater tolerance, thereby affecting the marine survival of post-smolt (Kroglund and Finstad, 2003). A low pH will aggravate the effects of Al, but increased concentrations of e.g. calcium (Ca), ionic strength and the presence of various organic and inorganic ligands will act to reduce toxicity (see reviews in (Rosseland, Staurnes et al. 1994; Gensemer and Playle 1999).

River WQ is currently recovering from prior acidification in Norway, where many water bodies have turned from being chronically acid to becoming more episodically acid (SFT 2002). While annual average ANC and pH is increasing, the concentration Al is decreasing. Although WQ has improved considerably, it is still not satisfactory for Atlantic salmon (*Salmo salar* L.) due to the episodes. The ecological effect of an episode depends on episode intensity, duration and timing. While an episode during spring can have detrimental effects to smolt quality, a similar episode during summer and fall can have no observable effect due to life history stage variation in sensitivity (Rosseland et al, 1994). Present models predict WQ recovery to take decades. In the meantime (Wright and Cosby, 2003), to increase the biological recovery rate, satisfactory WQ is presently restored in a number of rivers supporting salmon by liming. The operational liming target is defined according to pH, where the rationale behind this is the relationship between pH and the rates at which Al is transformed from toxic to non-toxic forms (Teien et al, 2005). Any change to the physico-chemical properties of water affecting WQ can/should affect current liming strategies.

Climate changes can offset recovery through several independent pathways. Climate changes can e.g. affect weathering rates, mobilization of Al, cycling of organic matter and nitrogen, pH and the concurrent concentration of Al. Furthermore, if climate becomes “wetter and wilder”, sea salt episodes can affect the salmon populations by creating episodes having high toxicity (Hindar et al 2004). Any of these changes can influence WQ, where the biological effects of these changes are uncertain. We have evaluated current acidification trends and possible climate effects for three acidified rivers in Norway. All rivers are limed, and are at present under varying levels of recovery. WQ-data is available prior to liming, from limed sites and from sites upstream the liming activity. The climate effects will be evaluated with respect to the WQ requirement of Atlantic salmon, and how climate changes can affect current liming strategies.

Outline

Introduction

Atlantic salmon is a sensitive species, with a well defined water quality requirement with respect to acidifcation.

- Atlantic salmon is sensitive to acidified water
- The smolt stage (a preadaptation to seawater migration) is extremely sensitive
- Even hours in moderately acidic (pH <6.0; >5 ug labile Al) during the final smoltification stage is sufficiant to disrupt seawater tolerance.

Water quality has in numerous rivers within Norway been toxic to salmon. Water quality has been restored in many of these rivers by addition of lime. This has led to improved salmon catches in all treated rivers, raising salmon catches to levels exceeding 40 tons annually.

Water quality is currently improving, although it still is unsatisfactory for smoltification.

Climate changes can offset recovery through several pathways. This can affect future liming strategies, where the mitigation actions are to be kept at an ecological and economically sound level.

Model rivers: River Bjerkreim and Tovdal

MAGIC simulation of expected water quality recovery, and effects relating to climate effects will be performed.

Warmer climate:

- effects on aluminum mobilization
- base cation generation.
- mineralization of organic matter
-

Wetter climate:

- effects on base cation depletion
- transport of organic matter
- organic matter – Al interactions

Wilder climate:

- effects due to enhanced sea salt deposition

Acidification will go from being chronic to becoming more episodic. Episodes are more difficult to detect and act against than a to mitigate water quality during semi-stable condition. This will in turn influence the need for a satisfactory monitoring program and methods to detect changes in water quality. Focus must be placed on how to predict and handle episodes, and how climate can affect timing, duration and intensity.

Various episodes have different chemical properties, thus toxicity. How will climate influence the relationship between pH and the labile forms of aluminum?

The results will be discussed in light of the current understanding of climate effects on water quality, and how these changes can act on Atlantic salmon as a target organism. Focus will be placed on how these changes in water quality can influence current liming practices.

3. Diatom evidence for the recovery of UK lakes from acidification

Rick Battarbee, Don Monteith, Gavin Simpson and Annette Kreiser (Environmental Change Research Centre, University College London, UK)*

Abstract

Surface water acidification became a prominent environmental issue in Europe and North America in the 1980s following observations of declining fish populations in rivers and lakes in Scandinavia and Canada. It was claimed that long-range transported air pollutants, principally sulphur, were to blame. Despite the detailed examination of alternative hypotheses primarily related to the role of land-use change and natural acidification processes, the evidence overwhelmingly supported the sulphur deposition hypothesis. The key processes can be simulated by the MAGIC model and palaeolimnological studies provided the key space and time evidence needed to support the hypothesis.

Following international agreements on S and N abatement sponsored by the UNECE and the newer demands of the EU Water Framework Directive (WFD), current research focuses on the effectiveness of remediation strategies. In the context of the WFD targets have been set for sites to achieve “good ecological status” by 2015 and in the UNECE member states must make progress to achieve emission reductions associated with minimising critical load exceedance by 2010.

Assessing the response of lakes to remediation requires an analysis of the long term chemical and biological data-sets that are being generated by national and international monitoring programmes. Ideally, as long-term data-sets are insufficiently long to cover the period prior to acidification, this analysis needs to be combined with palaeolimnological data in order to identify conditions prior to acidification and help in the setting of targets for restoration.

To date there have been several reviews of the chemical response to the reduction in acid emissions and deposition and a few, more geographically limited, reviews of biological response, but none that combine palaeolimnological and contemporary data. In this paper we present diatom data from sediment cores, sediment traps and from sampling of live epilithon to define biological (diatom) goals for the restoration of UK lakes and assess the extent to which diatom floras in UK lakes are beginning to respond to improved water quality.

Outline

Introduction

Sites

- We will use data from over 100 sites across the UK for which we have sediment records to set up the typology and 11 lake sites from the UK Acid Waters Monitoring Network to assess the extent of recovery

Methods

- The paper uses existing chemical, biological and palaeolimnological data generated by various past research projects and by the UK AWMN. The data are analysed using standard multi-variate techniques

Results

Reference status

- Establishing a typology for acid lakes within the UK using physico-chemical criteria from a 100 plus lake dataset
- Establishing a typology for acid lakes using biological criteria from a 100+ lake data-set
- Comparing physico-chemical and biological classifications (to generate an ecologically relevant physico-chemical typology)

Current status and evidence of recovery for AWMN lake sites
- Corrie nan Arr
- Lochnagar
- Loch Chon
- Loch Tinker
- Round Loch of Glenhead
- Loch Grannoch
- Scoat Tarn
- Burnmoor Tarn
- Llyn Llagi
- Llyn cwm Mynach
- Blue Lough

Discussion

- Typologies
- Diatoms as indicators of whole lake ecology
- Reference conditions
- Recovery signal and factors confounding recovery
- Evidence for climate influence
- Climate change in future and Eurolimpacs hypotheses

Conclusions
Acknowledgements

References

4. Re-meandering of lowland streams in North-western Europe

Nikolai Friberg, Annette Baatrup-Pedersen and Morten Lauge Pedersen (NERI, Silkeborg, Denmark), Piet Verdonshot and Rebi Nijboer (Alterra, The Netherlands), Leonard Sandin (SLU, Sweden)*

Abstract

The natural physical characteristics and the biota of streams and riparian areas in Northwestern Europe have been strongly altered and in many cases lost due to human manipulation and impact on the landscape. The primary reason for the deterioration of streams and riparian areas has been the change in land use from forested land to intensively cultivated land. Cultivation of farmland has resulted in extensive straightening and culverting of streams and drainage of riparian wetlands in lowland areas. The physical impacts of straightening and channelization are in many streams perpetuated by maintenance of streams and banks with the removal of all higher vegetation and regular dredging of the stream channel. One way of counteracting decades of stream degradation in lowland areas is active remeandering of stream channels. Several remeandering projects have been carried out during the last two decades and this paper presents an overview of these projects in relation to their objectives, scale, actual restoration measure, monitoring programme and the effects on the physical environment and the biota. Common for the majority of projects carried out until now is that they often have unclear objectives, are spatially limited, focus on few organism groups, mainly macroinvertebrates, and have a limited spatio- temporal monitoring programme. This makes it presently very difficult to evaluate the ecological effects of the projects conducted, as well as it limits the possibility of elucidating general patterns that could optimise restoration strategies in the future. None of the projects carried out have considered the effects of global change on the restoration success in the future. Important findings and shortcomings of projects conducted until know is illustrated through a series of case studies. They show that streams recover rapidly after establishing the new meandering channel, which is in accordance with the general perception that stream ecosystems are highly resilient. A key feature of restoration of lowland streams is that flooding of riparian areas will become more frequent if natural processes are allowed to rule. In a climate change scenario predicting higher precipitation and hence runoff, re-meandering projects would be in direct conflict with an anthropogenic use of riparian areas for farming and housing. In addition, recolonisation could be limited in the future for certain organisms, e.g. some insect species as an increase in temperature are likely to decrease the size of adults and hence their dispersal abilities between catchments.

Outline

Introduction
- Stream restoration project in general – global perspective, all stream types
- Recovery chain – degradation and subsequent rehabilitation to a new or the original condition
- Restoration in a WFD context – can reference conditions be restored? and reference conditions as restoration targets in a changing global environment
- Specific short introduction to lowland streams
- Geographical scope of the paper (North-western Europe) and rationale for this (e.g. lowland areas are among the most heavily modified)
- Aims:
- to review existing restoration projects in lowland streams within the geographical unit focussing on objectives, scale, biological elements and naturalness of the restoration measures
- to present and discuss advantages and disadvantages of a number of selected case studies
- to elucidate general patterns in recovery of the macroinvertebrate/(macrophytes) community along a spatio-temporal gradient which could be used in global change context

Existing restoration projects

- Overview of re-meandering projects carried out and put in a comprehensive table. Emphasis will be on:
  - Motivation – why was it carried out? For aesthetic reasons, landscape improvement, single species conservation, general conservation, improving biodiversity?
  - Restoration target – was there a predefined target i.e. that the restored stream should achieve the same ecological quality as undisturbed, reference streams within the same area (stream type)? Or was the target that it should improve compared to a unrestored reach(es)?
  - Scale – from single reaches being re-meandered to entire stream valley restorations
  - Measure – from static bend channels to truly dynamic systems which are subject to natural processes
  - Organisms – which groups were targeted – macroinvertebrates, fish, macrophytes, riparian vegetation? Or other end-points as e.g. house prices in the surrounding area
  - Evaluation – how was the monitoring programme designed (if any!). Temporal-spatial scale of the sampling effort etc.
  - Results – what was achieved? Was the restoration physically stable (or did all coarse substrates get covered by fines)? Was there an increase in species diversity, endangered species etc.

Case studies

- This part will comprise of at least 2-3 case studies and actual data (maybe modified) will be shown. One obvious case will be the River Gelså in Denmark, maybe the River Cole in the UK and a case from The Netherlands or Sweden.
- Advantages and disadvantages of the cases shown should be outlined – so all cases presented should not necessarily be success histories. These should cover several biological elements/organism groups and at least one should include valley restoration i.e. riparian vegetation.
- Also at least one should have time-series of data collection (Gelså has this) to open the discussion on re-colonisation/recovery abilities of various species and organism groups.

Effects of restoration projects

- This part will be re-analysing existing data to address the following questions:

- Recovery time using data from several projects to elucidate the effects of 1) scale, 2) restoration measure and 3) organism group
- Effects of climate on recovery of the biota (diversity, composition and functional diversity) after a restoration. Restoration and space for time within North-western Europe gradient (too narrow?) – using data on at least macroinvertebrates from Netherlands, UK, Germany, Denmark and hopefully Sweden.

Discussion

- What are the pros and cons of the restoration projects carried out until now – on the negative side we know that:

- Most projects have not been conducted with a clear environment objective and their success or failure have not been clearly evaluated partly for this reason
- The majority of existing projects are very spatially limited – a single reach in a disturbed system is being restored ignoring other pressures or upstream degradation. In relation to the number of lowland streams that are physically modified today only a insignificant part have been restored
- The majority of projects carried out are heavily engineered with riprap structures that fix meander bends and deepened channels to prevent flooding and erosion of surrounding areas

- Most projects only survey macroinvertebrate communities
- None of projects carried out have considered how changes in temperature and especially runoff will affect restoration measures

- From the case studies and the novel analysis it should be discussed how the different organism groups respond in relation to their re-colonisation strategies/life strategies (r vs. k strategy) and what effects can be predicted within a climate change scenario.

- Discussion on how quality of lowland streams can be improved (to e.g. meet the demands of the WFD) taking the cost of active restoration into account – today the price is between 50,000 to 130,000 euros per km. This could be done by using macrophytes as ecological engineers, reducing agricultural use of riparian zones, etc. As climate change is likely to increase precipitation and hence runoff, many riparian areas and stream valleys are at risk of flooding and this risk will increase if streams are being restored to a more natural state. Therefore, to allow restoration in lowland stream systems, human activity should be limited in their surroundings. Also important is the value of setting biologically relevant and organism- specific restoration targets if the ecological quality of lowland streams is to be improved in the near future, e.g. prior to 2016 when the majority of all streams should have good ecological quality in accordance with the EU WFD.

5. Success and failure of stream restoration projects in which large wood has been used

Jochem Kail, Marc Gerhard and Daniel Hering (University of Duisburg-Essen, Essen, Germany), Susanne Muhar (BOKU, Vienna, Austria), Arturo Elosegi (University of the Basque Country, Spain)*

Abstract

Wood is increasingly used in Central European restoration projects to improve the hydromorphological status of streams and rivers. A mail survey was carried out to summarize the experiences that have been gained so far to provide information for the design of future projects. The survey revealed the following aspects:

First, wood has been used successfully in many restoration projects, mainly to increase structural complexity by initiating natural channel dynamics with fixed wood structures. Failure rate of the wood structures is low (8%), and preliminary monitoring results indicate that the hydromorphological status improved rapidly in most projects. From an ecological point of view, there is potential for improvement in regard to the amount of wood and the size and type of wood structures. The amount of wood placed in the streams (median volume 27.9 m^3 ha^{-1}) is low compared to the amount in some of the most natural streams in Central Europe (41.4 m^3 ha^{-1}) and in other temperate forested ecoregions comparable to those investigated (126 m^3 ha^{-1}). The size and the potential effect of some wood structures on stream hydraulics and morphology is low and can be increased without interfering with local restrictions. Furthermore, in most of the cases, complex natural shaped wood structures could have been used instead of bare cylindrical logs to benefit from positive side effects.

Second, in some projects, large natural shaped wood structures without additional anchoring were used. Because the data on the restoration projects investigated indicate that costs can be markedly reduced and positive side effects are to be expected, it is highly recommended to use such soft engineering methods in future projects whenever possible.

Third, the effect of wood structures on stream morphology is strongly dependent on the natural setting, problems occurring during the implementation of the projects are generally site specific, and therefore, schematic project designs are not applicable to most specific restoration sites.

Fourth, the potential effects of wood placement must be evaluated within a watershed and reach-scale context. Otherwise, the wood placement can have adverse effects on stream morphology and biota.

Fifth, there is a lack of knowledge on the use of wood in stream restoration, an urgent need to improve the monitoring programs of future restoration projects and a strong need to communicate the monitoring results.

Outline

- Nature and extent of measures
- Costs of stream restoration with wood
- Monitoring effort and results
- Assessment of projects by project managers

Discussion

- Objectives and general project design
- Nature and extent of wood measures
- Monitoring

6. Recovery of stream ecosystems after reduction in eutrophication and organic pollution

Nikolai Friberg, Annette Baatrup-Pedersen and Jens Skriver (NERI, Silkeborg, Denmark), Leonard Sandin (SLU, Sweden), Iwan Jones and Amalie Deflandre (CEH, UK), Andrea Buffagni (IRSA, Italy)*

Abstract

Organic pollution and eutrophication have impacted streams and their riparian areas throughout the world. This has changed the ecology of stream ecosystems substantially and species have been lost at local and regional scales. The strong dependency of many stream organisms on high oxygen levels has been the main reason for the marked change in stream ecosystems when polluted with easily degradable organic matter. Microbial processes are depleting oxygen as organic matter decomposes. Many streams are naturally nutrient limited and an increased loading with nutrients from point and diffuse pollution sources has promoted primary production beyond natural levels. Eutrophication has resulted in changes in structural as well as and functional properties of the stream ecosystem. This also applies to riparian areas, which have been actively fertilised when used for agricultural purposes or when flooded by nutrient- enriched stream water. Both organic pollution and excessive loading with nutrients are still very common pressures on stream ecosystems globally. However, in several areas in Europe and the US organic pollution or eutrophication, or both, have been reduced as a result of rehabilitation measures. This has had substantially societal costs and to continue and expand these investments it is very important to be able to detect environmental changes (improvements). The present paper reviews the changes that organic pollution and eutrophication inflicts on stream ecosystems including riparian areas. This includes both direct and indirect effects on the biological structure on the relevant biological components i.e. algae and macrophytes (primary producers), macroinvertebrates and fish. Effects on the riparian zone will focus on plant communities. Through a series of existing case studies and novel analysis of monitoring data we address how stream ecosystems recover after a reduction in organic pollution and/or eutrophication. The effects of both organic pollution and eutrophication are highly dependent on climate and so are the recovery processes. By comparing recovery of stream ecosystems across a latitudinal gradient we can predict temporal effects of climate change on a local scale.

Outline

Introduction
- History and extent of organic pollution and eutrophication
- Very generalised summary of effects on stream ecosystems including riparian areas
- Summary of history, efforts and investments in sewage plants and reductions of agricultural - productions in sensitive areas
- Brief presentation of expected recovery processes in relation to the reduced pollution/loading in relation to stream type and region
- Aim:
    - to review the direct and indirect effects of organic pollution and eutrophication on relevant organism groups;
    - to elucidate general recovery patterns from existing case studies and novel analysis of monitoring data;
    - to relate recovery with climate by comparing recovery processes along a latitudinal gradient.

Impacts of organic pollution and eutrophication on stream ecosystems

- This will be review on the effects of organic pollution on mainly macroinvertebrates in streams as other organism groups are very little investigated – throughout the paper focus will only be on macroinvertebrates.
- Direct effects of eutrophication on benthic algae (phytoplankton will be covered in the lake paper and is only important in large rivers anyway) and macrophytes will be presented as well as indirect effects on macroinvertebrates and fish. Direct effects of eutrophication on riparian plant communities will also be presented.
- A conceptual figure on the main ecological changes after impacting stream ecosystems with organic pollution and nutrients will summarise the review, which will be short as the main focus is recovery.

Recovery of stream ecosystems
- Presentation of case studies which include different organism groups and spatial scales.
- One case will be the substantial reduction of organic pollution in Danish streams measured as BOD and the subsequent recovery of macroinvertebrate communities where sensitive species both are increasing in abundance and recolonising new streams, both within and among catchments. This will include already published regional data from the County of Fyn as well as national data analysed specifically for this purpose and paper. It will include direct links i.e. streams in which both BOD and macroinvertebrates (approx. 100) have been monitored as well as indirect links i.e. the general decrease in BOD concentration in DK streams compared with the dispersal and recovery of sensitive species in large number of streams (approx. 1000).
- One case should focus on recovery of in-stream primary producers and another on riparian plant communities.
- One case should deal with indirect recovery effects on macroinvertebrates and/or fish preferably including something about food webs

Climate and recovery
- In this section existing studies along latitudinal gradient will be compared to elucidate general patterns such as recovery time. If time permits it would be interesting to analyse data from several countries together in one new analysis.

Discussion
- The discussion will depend much on what recovery studies we will be able to find
- Which organism groups are good indicators of recovery.
- It should address how dispersal abilities affect recovery, how indirect effects, and hence recovery, is likely to change with climate, if eutrophication is likely to increase as an environmental problem with climate change.
- Organic pollution and eutrophication compared with other stressors on stream ecosystems and how they interact i.e. a how degraded physical environment are likely to increase the effects of organic pollution etc.

7. Restoration of wetlands through rewetting and land use change

J.T.A. Verhoeven (Utrecht University, Utrecht, The Netherlands), B. Clément (University of Rennes, Rennes, France), M. Blackwell (Royal Holloway Institute for Environmental Research, London, UK)*

Abstract

Riparian zones along streams, river floodplains and lake littoral zones have lost much of their original area in Europe because of habitat destruction associated with agriculture, urbanization and water management. The remaining wetlands of these types are often degraded in terms of species diversity, extent, and natural functioning. Losses of biodiversity and ecosystem services such as flood detention, water quality enhancement and food chain support have occurred in these remaining wetlands in the last 50 years as a result of progressive river and stream regulation, ever more intense agricultural use and fertilization.

Restoration of river floodplain habitat has become a major activity along regulated rivers in western and central Europe. In particular in the Rhine river basin, new ideas on floodplain restoration have been put forward and many projects have been carried out or planned. Most of these projects remain within the reduced floodplain area confined by dikes and artificial levees. The emphasis in these restoration projects is twofold (1) to restore the biodiversity characteristic for floodplains, including oxbows and other floodplain pools, side channels and erosion/sedimentation habitats; (2) to create more water storage capacity in order to strengthen the floodwater detention function of the floodplains.

Riparian zones along streams have been shown to mitigate nitrate pollution in agricultural catchments. Restoration of these buffer zones has been proposed in several European countries. In some regions, experiments with restored buffer zones have been carried out. Information on the efficacy of these restored wetlands is still limited. Experience outside Europe has indicated that buffer zones must be present along the major part of the stream in order to be effective for water quality enhancement.

Water quality problems in shallow lakes have spurred research of the role of submerged as well as littoral vegetation in the nutrient cycling of the lake ecosystem. Water level manipulation and turbidity have resulted in the deterioration of lake littoral zones. Studies have shown that a wide littoral zone enhances the water quality of the lake because of nutrient retention in the vegetation and sediment of these zones. Major restoration projects are underway in the littoral zones of several countries in West and central Europe.

Outline

Introduction

Status of riparian zones, river floodplains and lakeshore wetlands in Europe
- loss of area
- loss of functionality: river floodplains
- loss of functionality: riparian zones bordering streams
- loss of functionality: littoral zones of lakes
- loss of biodiversity: particularly threatened habitat types, communities and species

Restoration of river floodplains
- Floodplain restoration along the river Rhine: opportunities and limitations along a highly regulated and navigated river
- Floodplain restoration along medium-sized rivers
- Rehabilitation of polluted floodplains

Restoration of riparian zones

- Slope wetlands
- Riparian zones along streams and ditches

Restoration of littoral zones of lakes

- Littoral zones as part of biomanipulation projects
- Littoral zone restoration for biodiversity enhancement

Discussion: restoration targets, reference conditions and evaluation of successes and failures.

8. Reconnection of isolated wetlands by surface water flows and by dispersal of biota

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Abstract

During the past centuries large areas of wetland have been drained, mainly for conversion into agricultural land. This has resulted in a loss of total wetland area and increased distances between remaining wetland patches. Also, surface water flows that fed into wetlands and connected wetlands to each other and to their natural surroundings have been cut off, displaced or regulated, thereby increasing loss and (hydrological) isolation of wetlands further. As wetlands are among the world's most threatened ecosystem types, their restoration is receiving much attention in ecological research. This, however, concerns mainly the restoration of their abiotic conditions. To achieve full restoration of wetland ecosystems it is important to also restore the connectivity of wetlands in the landscape. We give an overview of restoration measures aimed at restoring the connectivity of wetlands in North-western Europe, the success (or failure) of these measures, and an estimate of how future climate change may interact with the success (or failure) of these measures.

Plans for restoration of wetland connectivity exist mainly on paper. The EU has the Natura 2000 network and national nature conservation plans in EU countries often also include some form of nature connectivity. In reality, such plans are often carried out at a slow pace. When wetland restoration projects are carried out, connectivity is taken into account in only relatively few cases. The distances between wetlands are often still very large and wetlands often remain very small and hydrologically isolated.

When it comes to connectivity, there a re roughly two categories of wetlands: 1. wetlands that are naturally connected to similar wetlands through surface water flows (mainly wetlands in river systems, e.g. floodplains, marshes and fens along rivers, riparian forests), and 2. wetlands that are not naturally connected to similar wetlands through surface water flows (e.g., springs, stream heads, bogs, moorland pools, ponds).

Wetlands that are naturally connected to similar wetlands through surface water flows are most affected by loss of connectivity. When the surface water flows that connect them cease or are decreased, the species composition in such wetlands changes due to dehydration and/or disrupted regional species dynamics. Efforts aimed to restore dehydration in many cases involve inlet of surface water from the nearest available source, which may be a different water type than the original connecting surface water flow. Efforts aimed at restoring connectivity to restore regional species dynamics often do not take into account the distances that species are able to cover during their dispersal. Some species disperse over relatively short distances only. Other species are completely dependent on surface water flows. Overview of dispersal distances versus success of wetland restoration. For these systems, however, climate change may aid the restoration of connectivity when increased frequency of occurrence of extreme weather events increases the frequency of flooding and of storms.

Wetlands that are not naturally connected to similar wetlands through surface water flows have also become more isolated, but for these systems the effects of fragmentation may not be as large as for wetlands that are naturally connected to similar wetlands through surface water flows. For example, the high beta-diversity of pond systems is partly due to the isolated position of ponds in the landscape. However, with large-scale landscape alterations occurring, the species compositions in even these systems may become adversely affected by isolation. Some of these systems are dependent on specific water sources, and are very vulnerable to inlet of surface water from the nearest available source, which may be a different water type than the original water source. Reconnection is therefore also of importance in these wetland types, but has received little attention so far.

Outline

Introduction: description of problem of disconnection
- overview of disconnections that have occurred in wetlands
-- causes
-- degree of disconnection (different for two wetland types)
-- effects (biological isolation, dehydration, changed hydrodynamics, changes water quality)

Overview of measures for re-connecting (national within EU countries, EU as a whole)
- which measures are taken to re-connect wetlands?
- problem: these measures are mostly on paper (aims to create corridors and 'ecological networks'), and if they are carried out, their results are often also on paper (an 'ecological network' then exists, but success of 're-connection' for dispersal of biota is often not known)
- re-introductions are a subject of debate

Results of re-connections (2 mini-reviews):
To what extent are re-connection aims and measures successful?
- wetlands not naturally connected by surface water flows (ponds, bogs, stream heads); in these systems, dispersal of biota between patches is limited also under natural conditions
- wetlands naturally connected by surface water flows (periodically flooded systems, fens); in these systems dispersal of biota has often become very limited and should be restored to previous, more natural, connectivity levels
- problems when connections are restored, but by using water from a different source (effects on water quality, consequences of that)
- case studies as examples (if possible)
- problem: how to define 'success' or 'failure'

Discussion & conclusions for wetland water quality (and possible wetland physics and biochemistry)
Discussion & conclusions for biota (local and regional species compositions and dynamics)

9. Long-term change of arctic lake ecosystems: reference condition, degradation under toxic impacts and revitalization

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Abstract

In the Arctic ecoregion anthropogenic changes of water ecosystems have their peculiarity caused by their high vulnerability to anthropogenic stress. Based on retrospective analysis of Arctic lake ecosystem modification under toxic and nutrient impact, 3 phases of its quality condition were selected: benchmark, trends of degradation and revitalization after the decrease of toxic pollution. In this work attention was focused at changes of basic parameters of water chemistry and phyto – zooplankton, benthos and fish communities. Under the influence of lake contamination by heavy metals and nutrients, which started in the thirties of the last century and achieved their maximum in the eighties, the typical arctic ecosystem was transformed. In the degradation phase there was a decrease in number of species typical for the Palearctic and in biodiversity of biocenoses. Number and biomass of eurybiontic species has risen due to absence of competitive links with typical northern species in toxic conditions and afflux of nutrients. In formed plankton biocenoses small forms of organisms (r-strategists) were predominant. They provide faster biomass cycling in the ecosystem. In benthos biocenoses predominant development had midges (Chironomidae family) which were more steady to heavy metal water pollution. In conditions of toxic pollution decreasing, which goes on during the last ten years, there is a recolonization of lake by arctic habitants, which is proved by change of dominant complexes, rise of biodiversity index of plankton boicenoses and rise of individual mass of organisms. Benthos biocenoses are more inert to revitalization. Accumulated nutrients in the ecosystem are effectively utilized by higher parts of the trophic structure, providing their higher biomass. In accordance with Odum’s ecosystem succession theory, we can conclude, that through critical phase ecosystem has transformed to more stable condition with new parameters. That is why achievement of reference condition of arctic ecosystems after anthropogenic press will be rather long and, possibly, not feasible. Proceeding from the certain regularities of arctic ecosystem modification, we can estimate that with possible climate giving in arctic regions, ecosystem will transform in direction of more significant domination of eurybiontic species in the biocenoses structure, which will get advantages in development comparably to typical Palearctic inhabitants. That is why with warming climate the recovery of water arctic ecosystems is impossible.

* Names not mentioned in any final order. More authors may be included.