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MANAGEMENT OF AQUATIC BIODIVERSITY AND ECOLOGICAL STATUS IN TRANSBOUNDARY SURFACE WATERS ALONG THE GREEN BELT OF FENNOSCANDIA

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The Green Belt of Fennoscandia offers an interesting area for environmental research and monitoring activities. The aquatic ecosystems of the western edge of boreal coniferous zone enable assessment of the pristine characteristics of various water ecosystems and the relationship of catchment areas to lotic and lentic ecosystems. The differences of land use in catchment areas also make it possible to assess the human impacts on water ecosystems and to distinguish between natural and anthropogenic changes. The importance of the Green Belt of Fennoscandia increases with global climate change. Assessment of ecological changes in water bodies, conservation of aquatic biodiversity, mitigation of harmful ecological and socio-economical impacts and adaptation to transient conditions requires long-term transnational co-operation on water ecosystems and their catchments along the Green Belt of Fennoscandia.

K e y w o r d s : Aquatic biodiversity, sustainable use of natural resources, ecological status, ecological monitoring.

Х. Луотонен, Т. Хокканен, С. Хельстен, П. Лильяниеми, Т. Кольстрем, Н. Филатов. УПРАВЛЕНИЕ БИОРАЗНООБРАЗИЕМ ВОДНЫХ ЭКОСИСТЕМ И ЭКОЛОГИЧЕСКОЕ СОСТОЯНИЕ ТРАНСГРАНИЧНЫХ ВОДОЕМОВ ЗЕЛЕНОГО ПОЯСА ФЕННОСКАНДИИ

Территория ЗПФ чрезвычайно интересна с точки зрения экологических исследований и мониторинга. Водные экосистемы на западной границе бореальной зоны позволяют выявить естественные характеристики различных водных экосистем и связь водосборных территорий с проточными и застойными экосистемами. Различия в землепользовании на территориях водосборов позволяют также оценить воздействие человека на водные экосистемы и отличить естественные изменения от антропогенных. Роль ЗПФ растет в связи глобальным изменением климата. Оценка изменений в экологии водоемов, сохранение водного

биоразнообразия, снижение негативных экологических и социально-экономических последствий и адаптация к меняющимся условиям требуют долгосрочного межнационального сотрудничества по водным экосистемами и водосборам ЗПФ.

Ключевые слова: биоразнообразие водных экосистем, устойчивое использование природных ресурсов, экологическое состояние, экологический мониторинг.

INTRODUCTION

The conservation of biological diversity and need to develop balanced combination between economic development and nature conservation is one of the most important issues in global environmental policy.

Aquatic biodiversity has been in underestimated position in European nature protection field. This is clearly seen in the second assessment of Europe's environment (anonymous 1998), where freshwater biodiversity was not dealt with because e.g. data are scarce and relate mostly to water quality or fisheries.

However, aquatic biodiversity, water ecosystems, habitats and typical species assemblages in different kinds of water ecosystems have an increasing role in this discussion. Implementation of the European Water Policy Directive [2000] has focused on the ecological status of surface waters and has also emphasized the wider view concerning activities in river basins (land use, use of natural resources) and their responses in water ecosystems. Assessment and monitoring of the ecological status is carried out based on the variety of biological groups: fish, macroinvertebrates, phytoplankton and macrophytes. Also the Habitat Directive [1992] requires monitoring of the ecological status of aquatic habitats. All these activities are also increasing our knowledge of aquatic biodiversity.

Anthropogenic impacts have changed the ecological status of water environments and aquatic biodiversity in extensive areas, especially on the Finnish side of the Green Belt of Fennoscandia. Intensive forestry (clear-cuttings, thinnings, drainage, scarification and fertilization), agriculture, modification of river channels, development of hydro-power, reservoirs and regulation of water levels have impacted the hydrology, water quality and habitat characteristics of water bodies.

The global climate change has created a new challenge for co-operation at the Green Belt of Fennoscandia. The aquatic ecosystems and freshwater biodiversity are highly vulnerable to the impacts of global climate change [Heino et al., 2009]. The increasing impacts of climate change also require more intensive research and monitoring activities to clarify the changes in water ecosystems. The most important effects caused by changing climate in water ecosystems include the increasing water temperature, changes in precipitation and runoff [EEA Reports, 2007, 2008]. The Green Belt of Fennoscandia is situated at the border between East and West, North and South, and it can also be a corridor for invasive aquatic species [Panov et al., 2009]. It is also a border area where there have been applied different kinds of land use management strategies. Watercourses are connected via channels and large waterways to the Caspian Sea, which is a significant source of endemic invasive alien species already observed in Finnish water bodies.

Waters from the Green Belt of Fennoscandia flow via northern rivers to the Arctic Ocean, some rivers discharge also into the White and Baltic Seas. Most rivers in the middle of the Green Belt of Fennoscandia flow into the Gulf of Bothnia.

Many valuable surface water bodies and their catchments are located in the Green Belt of Fennoscandia. Lake Inarinjärvi, Lake Pyhäjärvi and Lake Saimaa are included in UN/ECE program «Monitoring and assessment of transboundary and international lakes» [Pietiläinen, Heinonen, 2002]. Lake Pyhäjärvi is also a part of Natura 2000 network of European Union [Luotonen et al., 2002]. Lake Ladoga, as a part of the Vuoksi River Basin, is one of the topic areas on the Russian side. River Paatsjoki, River Oulankajoki, River Koitajoki, River Jänisjoki, River Kiteenjoki and River Tohmajoki are examples of different kinds of transboundary river ecosystems. Many nature protection areas (especially on the Russian side of the border) include plenty of different surface water body types.

AQUATIC BIODIVERSITY IN THE GREEN BELT OF FENNOSCANDIA

The Green Belt of Fennoscandia covers the western edge of the northern coniferous zone. The longitudinal dimension of the Green Belt from the Arctic Ocean to the Baltic Sea includes a variety of water body types: lakes, ponds, rivers, brooks,

springs, all having valuable species and aquatic and semi-aquatic habitats. Also the riparian zones of water bodies and the ecotones often including valuable wetlands between terrestrial and aquatic ecosystems are important.

In the northernmost part of the Green Belt of Fennoscandia a narrow strip is situated in the arctic zone, but the area mainly belongs to the boreal zone. Based on the natural and geological characteristics, two main types of catchment areas can be distinguished: catchment areas dominated by peatlands with typical humus-rich waters and the other major type consisting of moorlands and sandy esker areas dominated by oligotrophic clear water lakes and rivers.

The influence of both continental and marine climate is seen in the area. E.g., aquatic macrophyte flora of large clear water lakes of Finland consists of both subatlantic species like *Littorella uniflora* and eastern species like *Myriophyllum sibiricum*. Additionally, there is a very clear downward latitudinal trend in species richness of aquatic macrophytes over Scandinavian region [Heino &Toivonen, 2008].

The aquatic biodiversity of the Green Belt of Fennoscandia consists of different surface water types with a great variety of habitats. Coastal brackish water areas, headwater streams, humic, clearwater and calcareous lakes and ponds, and springs are some examples of the diversity of aquatic ecosystems.

The rich species diversity in the area includes also several threatened or endangered species, some of them living only in this area. Some species exist only in very small isolated habitats, whereas the life cycles of other species involve also extensive living area including several different habitats, e.g. the migrant salmonid fishes which spawn and live their first years in rivers and then descend to sea to grow and, after some years, returning back to home river to spawn. Examples of valuable and typical species for the Green Belt of Fennoscandia include salmonid fish species (salmon, trout, grayling and whitefish), and especially threatened species, e.g. endemic freshwater trout *Salmo salar* m. sebago and arctic char *Salvelinus alpinus* in Lake Saimaa and the whitefish *Coregonus pallasi* in the lower course of the River Koitajoki. In some large lakes there are also relict fishes, e.g. fourhorned sculpin *Myoxocephalus quadricornis*.

Aquatic invertebrates include species which live their whole life or only part of their life cycle in aquatic habitats. The invertebrate fauna is still poorly known, but biological monitoring of water bodies has increased the knowledge of invertebrate species and their distribution in the area. A well-known example of threatened macroinvertebrate species in the area is the freshwater pearl mussel *Margaritifera margaritifera*.

Vascular plants and aquatic and semi-aquatic mosses reflect the diversity of water bodies, varying from threatened isoetid assemblages (*Isoetes lacustris, Lobelia dortmanna*) typical of oligotrophic clear-water sandy-bottom lakes to nymphaeids such as *Nuphar lutea, which dominate in* humic dark water bodies.

Especially springs and their seepage surfaces harbour valuable vascular and bryophyte species, existing only at these small, restricted and isolated habitats.

Among mammals, a number seal species or subspecies live in the area, especially the highly endangered Saimaa ringed seal (*Pusa hispida saimensis*). The European mink (*Mustela lutreola*), which became extinct from Finland in the 1900s, still lives on the Russian side of the Green Belt of Fennoscandia.

The bird fauna is also rich: waterfowl, arctic birds, waders and e.g. the rare Red-throated Diver (*Gavia stellata*), which prefers uninhabited nature areas.

A good summary of aquatic species in Karelia and Russian border area is given in the publication «Biotic Diversity of Karelia» [Gromtsev et al., 2003]. No such recap for the border area has yet been made for the Finnish side.

EXAMPLES OF ON-GOING AND COMPLETED PROJECTS

The Green Belt of Fennoscandia offers an interesting bicentric target area for environmental research and monitoring activities: human impacts are mainly focused on the Finnish side of the border area, while the Russian side still has wide areas in pristine or near pristine state. This gives possibilities to research both human impacts and natural reference condition in same types of water ecosystems and in some cases in same catchment or sub-catchment areas.

Some areas near the border, in the Green belt of Fennoscandia, have been included in several national and international research and monitoring programmes. However, these activities in general have been focused on restricted areas or in many cases on single surface water bodies. Development work for research and monitoring focused on extensive geographical areas, regarding also the Green Belt area, has been made in Russia [Litvinenko, Filatov, 2006, Lozovik et al., 2006, Filatov et al., 2007, Menshutkin et al., 2008] and in Finland [Vuori et al., 2008].

In the last decades also transboundary co-operation has developed. Until now the co-operation

in the Green Belt of Fennoscandia has been active and successful. Several research and development projects have been carried out, especially during the past two decades. Target areas and aims of the projects have been diverse. The co-operation has focused mainly on some hot spot areas: the northern border area (Russia, Norway and Finland) between River Paatsjoki, Oulanka-Paanajärvi area with pristine east-flowing rivers and Kuhmo region with common nature protection areas, and south-eastern border area on the Vuoksi River basin, especially Lake Ladoga. Some examples of the co-operation are described in detail below:

- River Paatsjoki: Development and implementation of an environmental monitoring and assessment system in the joint Finnish, Norwegian and Russian border area (Interreg IIIA Kolarctic). Along with the monitoring development, assessment of acid fall-out and its impacts on water bodies was carried out [Stebel et al., 2007]. Additional examples of evaluation of the water level regulation effects on downstream of the transboundary River Paatsjoki are shown by Hellsten et al. (2002).
- Lake Inarinjärvi, a large regulated boreal lake, and headwaters of the River Paatsjoki have been the target area for several projects which aimed to clarify and mitigate the impacts of water level regulation [Hellsten et al., 2002].
- Oulanka – Paanajärvi valley contains an area with remarkable nature conservation values. The area includes Oulanka National park and Paanajärvi area (National Park). Several research projects have been focused on the aquatic environment [Viramo, 1996; Kuusela, Koutaniemi, 2003]. In addition to the valuable Lake Paanajärvi, pristine east-flowing rivers have been targets of research.
- In Kuhmo region, environmental research of aquatic ecosystems has been focused e.g. on the water bodies in nature protection areas and to clarify the impacts of Kostomuksha mining industry wastewaters. The ecotoxic impacts of the wastewaters (e.g. heavy metals) on fish fauna have been studied by Tkatcheva [Tkatcheva et al., 2002; Tkatcheva, 2007].
- Lake Tuulijärvi area: Ecology and reference conditions of lotic and lentic water bodies and their relationship to characteristics of the catchment areas were studied in Interreg III Karelia project «The pristine border areas supporting research and legislation». One part of the research was focused on the water bodies (e.g.lake littoral), land use and vegetation of catchments. The aim of the research was to classify the ecological characteristics of small humic lakes using littoral macroinvertebrates and macrophytes. The pristine assemblages of both were compared with impacted water bodies of the same type on the Finnish side.
- River Koitajoki: Habitat characteristics and macroinvertebrate assemblages in boreal forest head streams and their relation to silvicultural activities in the catchment were studied by Liljaniemi et al. (2002). Also heavy metals in aquatic mosses were studied in both impacted and pristine tributaries of the River Koitajoki [Vuori et al., 2003].
- Lake Tolvajärvi area: The macroinvertebrate and aquatic bryophyte assemblages and the ecological condition of pristine or near pristine lotic water bodies were studied and compared with macroinvertebrate assemblages of impacted lotic water bodies on the Finnish side [Vuori et al., 1999].
- Lake Karelian Pyhäjärvi: Assessment of the ecological state of an oligotrophic transboundary Lake Karelian Pyhäjärvi was based on phytoplankton, macrophytes, macroinvertebrates (profundal and littoral) and fishes. Also, land use in the catchment area and the nutrient level history (based on profundal sediment diatoms) were studied [e. g. Luotonen et al., 2002; Ryabinkin et al., 2008].
- Lake Ladoga: Several research and monitoring development projects were carried out in the 1990s and early 2000s [e. g. Simola et al., 1996; Simola et al., 1997; Peltonen et al., 2000; Simola et al., 2003; Luotonen et al., 2003; anon. 2004; Filatov et al., 2006].

THE NEEDS AND CHALLENGES OF GREEN BELT FUTURE CO-OPERATION IN MANAGEMENT OF AQUATIC BIODIVERSITY AND ECOLOGICAL STATUS OF SURFACE WATERS

Experiences of the Green Belt of Fennoscandia co-operation show that the border area is important for environmental research and long term monitoring, and especially for multidisciplinary research and development activities. Historical differences in land use management give also good possibilities for future activities. Current situation with global environmental problems and change promote possibilities and needs to produce information on the impacts of global changes on ecosystems of the transboundary region. Moreover, more research, monitoring and development of co-operation are needed to cover the demand for information. The ecological and socio-economic problems are quite similar along the Green Belt

of Fennoscandia zone despite ecological or ecoregional differences. Some issues where the strengthening of co-operation is necessary:

ENVIRONMENTAL RESEARCH

- **Research of characteristics of aquatic ecosystems and habitats (including riparian zones and ecotone areas).** Although water bodies have been important in human activities, their ecological features are insufficiently known. In the Green Belt of Fennoscandia, there still exist pristine or nearly pristine catchment areas for studying the ecological status of water bodies with diverse land- and hydro-morphological forms. Species diversity is poorly known and more taxonomic work with e. g. the ecoregion approach is needed to assess the assemblages in different water bodies.
- **Long term monitoring for assessing among-year variation** in aquatic assemblages (e. g. phytoplankton, macroinvertebrates, fishes) is needed. Variation of hydro-morphological and climatic features among years has increased in last decades. To assess changes in aquatic ecosystems long-term monitoring data are needed from water bodies which are pristine or modified by human impacts.
- **Research of anthropogenic impacts on water ecosystems.** A wide variety of natural resources, such as extensive forests and minerals are found in the Green Belt of Fennoscandia. Exploitation of these resources influences aquatic ecosystems. More research on the responses of aquatic ecosystems, assemblages and species in catchments to land use and use of natural resources is needed. Also, assessing the ecological status of surface water using the catchment approach is absolutely needed.
- **Research into the environmental factors enabling the spread of invasive alien species.** Extensive inland waterways of Russia are major pathways for invasive alien species into the Finnish lake district. Active control measures and monitoring activities are needed to prevent harmful effects of these introductions.

ECOLOGICAL MONITORING

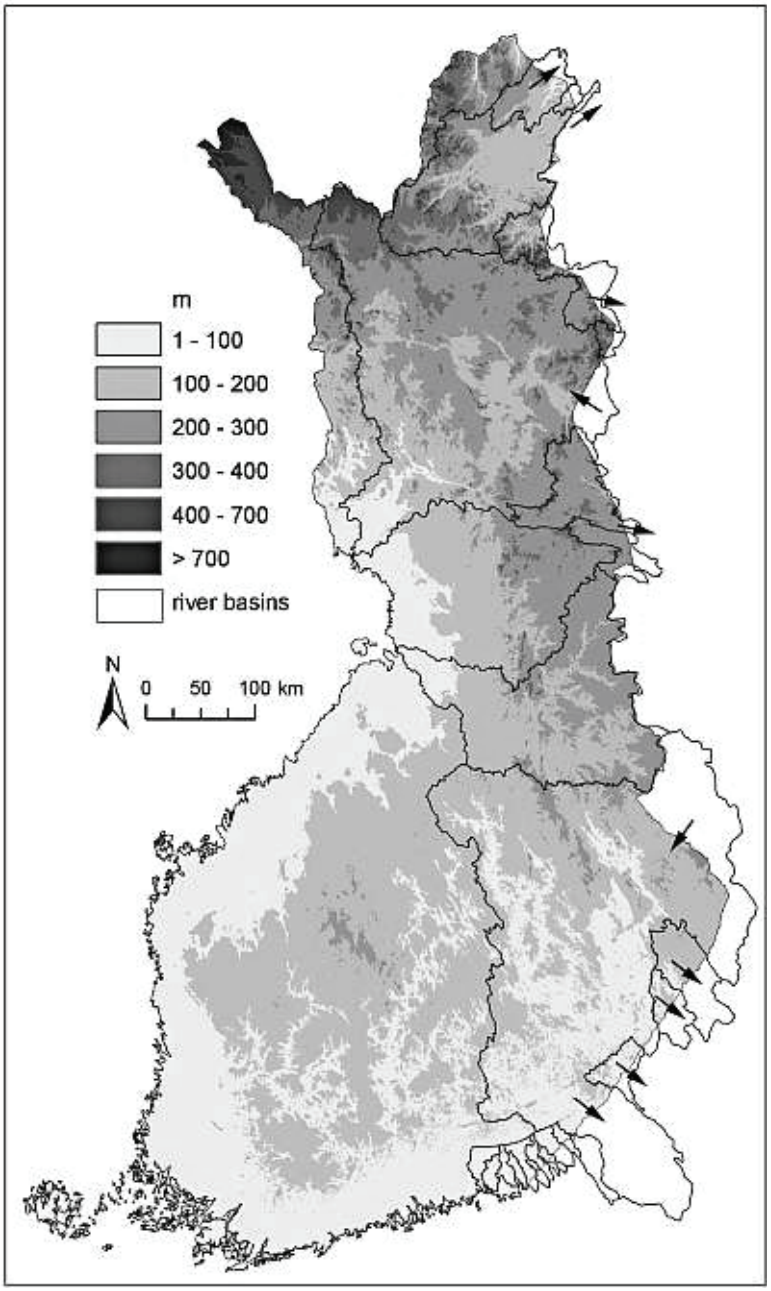
- **Development of common monitoring strategy and programme** for transboundary river basins. The Green Belt of Fennoscandia covers over 1000 km of border area South to North. The common monitoring strategy and programme enables e.g. assessment of the impacts of global climate change on aquatic ecosystems. This type of activities is important from the whole boreal zone point of view, and the chain of research stations along the border (Mekrijärvi, Kuhmo, Oulanka, Värriö, all on Finnish side of the border but in tight co-operation with the Russian party) gives good grounds for the studies.
- **Assessing the ecological status of transboundary surface water** using common assessment metrics. Assessment of the ecological status of aquatic ecosystems is one of the key issues in EU water policy. Its implementation requires harmonization of monitoring methods and handling of monitoring data.
- **Long term monitoring programme focused on the changes inflicted by global climate change and common plan for mitigation of the impacts of global climate change.**
- **Monitoring of invasive alien species and their impacts on water ecosystems.** Invasive alien species are one of the threats to aquatic ecosystems. Increased transport has widened the possibilities for spreading of many exotic species to areas where they normally do not live. Global climate change can also change the ecological conditions, so that alien species have better possibilities for spreading.

Nature conservation

- **Inventory of valuable aquatic ecosystems.** The present nature conservation network includes also aquatic ecosystems, especially in PAs on the Russian side. It is important to inventory the values of aquatic biodiversity to maintain and promote the aquatic conservation network. The catchment or sub-catchment approach is especially needed.
- **Common aquatic nature conservation strategy and conservation plan.** For conservation of aquatic habitats and species a common conservation strategy and plan are needed. Tools for conservation are e. g. establishment of new protected areas and especially development of best practices in the use of natural resources.
- **Creating the programme of measures and restoration activities needed for impacted water bodies.** Especially on the Finnish side of the Green Belt of Fennoscandia, intensive forestry has changed the aquatic ecosystems and their catchment areas. Restoration activities for habitats and especially their catchments are needed.

Natural resources

- **Development of the strategy and programme for sustainable use of natural resources** in transboundary catchment areas.



Map of transboundary catchment areas and the most intensive co-operation areas

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