Implementing the European Water Framework Directive at local to regional level
Case Study Northern Baltic Sea River Basin District, Sweden

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Abstract

In 2000, the European Union introduced the Water Framework Directive (WFD) with the goal to achieve good water status by 2015 in surface water, groundwater, estuaries and adjacent coastal waters, managed according to the natural boundaries of river basins. In many member states, the implementation of the WFD has led to relatively large changes in water resources management at the local level, because of a primary WFD focus on larger river basins. The overall aim of this thesis is to find out how the implementation of the WFD has affected local to regional level water management. A related investigation question is if, and how, programmes of measures that are set up as part of the WFD process can be tailored to efficiently address multiple water quality problems, such as nutrient loading and eutrophication of inland water bodies and coastal waters. More specifically, the considered study area is the Northern Baltic Sea River Basin District (NBS-RBD) in Sweden, in which nutrient loadings are relatively high and problems of eutrophication are severe. Interviews were made with individuals from the NBS-RBD, having direct involvement in water planning and land use planning at the municipal level. Interviews were also made with representatives for superior levels and associations. The degree of eutrophication and phosphorous load contributions to inland and coastal waters from 27 different catchments of the NBS-RBD were spatially analyzed.

Results show that, despite divergent views regarding the priority of water issues in physical planning among the local-level planners, they had all participated in successful inter-municipal projects. Such collaborations could help increase the understanding and acceptance of WFD-related goals and costs, as well as facilitate conflict solving. Physical planners have generally been reluctant to accept the new environmental quality standards, in part because they lack precise definitions, but also because they could challenge the tradition of weighing various objectives against each other. Furthermore, in NBS-RBD, catchments with the highest phosphorous load per arable area only overlap marginally with catchments that contain the highest degree of eutrophicated water bodies. The high-eutrophication group of catchments can hence not be expected to recover more than other catchments if a remediation strategy that primarily targets agricultural areas of high impact is followed. Such a strategy can be efficient for decreasing total nutrient load contributions, provided that it can be accepted that some catchments will remain more eutrophicated than others due to human activities. Results also show that a preferential mitigation of the Baltic Sea eutrophication is most likely to come at a cost of a higher degree of eutrophication in the inland catchments. To fulfill the goal of achieving good status in all inland waters within the EU, as well as in the Baltic Sea, emissions from inland sources must therefore be drastically reduced, which may be impossible to achieve in a foreseeable future. More generally, the results imply that high WFD targets and reduction demands may give rise to conflicts on the local scale. Local environmental planners have an important role to play to solve or mitigate effects of scale related mismatches.
List of papers

The licentiate thesis consists of a comprehensive summary and two papers:

I.


II.

Andersson, I., Jarsjö, J., Petersson, M. Saving the Baltic Sea, the inland waters of its drainage basin, or both? Case study Northern Baltic Sea River Basin District, Sweden. (Manuscript in preparation for journal submission)

I performed the interviews, made all the recalculations and other interpretations of the data and authored the main part of both manuscripts

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1. Introduction

Achieving a sustainable use of water has today become a global challenge on a par with climate change. Water management failures are often well-known, like the Aral Sea depletion (Levintanus, 1992), the arsenic contamination of drinking water in Bangladesh (Smith et al., 2000) or, in a European context, the eutrophication of the Baltic Sea (Aarnio et al. and references therein, 2007). Sustainability, ecosystem services, and a holistic and integrated approach are all concepts that recently have been connected to water management. Within the European Union, the search for a new water management approach more integrated with environmental policy started in 1995 (Kaika and Page, 2003). At that time there were a number of water policies within the EU, such as the Drinking Water Directive and the Urban Waste Water Directive; however, these policies lacked a holistic approach (Hedin et al., 2007). This ambition in water policy was seen as a response to the continued growth of urban areas, the introduction of a private sector to water resource management, and an increasing concern for the environment (Kaika, 2003). After a long political process including consultation and conciliation processes, the European Union decided on the Water Framework Directive (WFD) in the year 2000 (Kaika and Page, 2003). The overall aim of the WFD is to achieve good water status\(^1\) by 2015 in surface water, groundwater, estuaries and adjacent coastal waters using both qualitative and quantitative aspects of water use (Griffith, 2002; Gipperth and Elmgren, 2005). The directive is a combination of regulating emissions and producing common environmental goals and quality standards. The actual state of the environment and not the economical or technical possibility of the performer decides what legislation the member states have to impose (Entson and Gipperth, 2010). In a six year water management cycle, common target-oriented environmental goals and science-based quality standards are formulated, and a program of measures and management plans that regulate emissions are developed (Howarth, 2009; Entson and Gipperth, 2010; European Parliament and the Council of the European Union, 2000).

The process was, according to Kaika and Page (2003), affected by lobbying, especially from the environmental groups, resulting in a “greening” of the directive. The WFD has been described by

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\(^1\) For water bodies designated as heavily modified the goal became “non-deterioration”
Moss (2008) as “potentially ground-breaking legislation”, by Howarth (2009) that it “…adopts an innovative, holistic and target-oriented approach”, by Hering et al. (2010) as “changing management objectives to ensure ecosystem integrity”, and by Fairley et al. (2002) “to provide a more holistic and integrated approach to water management and conservation”. Although the directive is characterized by ecological understanding, this has been partly ignored by governments when implementing the directive according to Moss (2008). At the same time the aim with the directive to achieve close to “undisturbed” or natural conditions may be difficult to fulfill, including the definition of a natural state, but also the possibilities and even the desirability of natural conditions (Bishop et al., 2009). The aspiration to have natural as a goal for water management may even jeopardize the implementation of the directive when goals tend to become over-ambitious and impossible to fulfill within a given timetable.

The foundation of the WFD, influenced by the ecosystem perspective, is that water should be managed according to natural boundaries of river basins2 putting the question of scales and levels for water resource management in focus (Lundqvist, 2004; Moss, 2004; Nilsson 2006; Hedin et al., 2007; Hedelin and Lindh, 2008; Hammer et al., 2011). In many member states, implementation of the WFD has led to relatively large changes in water resources management at the local level. This is because primary river basins commonly contain several local land use planning units, which after implementation of the WFD, have not retained their main responsibility for local water issues. The attempt to obtain a perfect spatial fit for water management may create problems, especially with other policy sectors that are structured along political and administrative boundaries. The problem of eutrophication of rivers, lakes, coastal areas and seas was a driver for new water legislation and eutrophication has now become an obstacle for fulfilling the aim of good water status by 2015. Emissions from inland sources must be considerably reduced to achieve real improvements in all waters including the Baltic Sea.

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2 According to the WFD a river basin is defined as “The area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta.” River Basin Districts in Sweden contains several river basins that are referred to as catchments in this summary. The dominant catchment within the NBS-RBD, Norrström, including Lake Mälaren, also contains several sub-catchments, which are also referred to as catchments in this summary.
Within the Baltic Sea Drainage Basin the riparian EU countries, together with Russia, act within the Helsinki Commission (HELCOM) that aims to protect the marine environment of the Baltic Sea Area. If the WFD goals could be fully achieved, the requirements for good ecological status of the Baltic Sea would, in principle, also be met. The aim of this thesis is to find out how the implementation has affected water management on different scales (local to regional) in the Northern Baltic Sea (NBS) River Basin District (RBD) in Sweden.

2. Theoretical framework

2.1 The Water Framework Directive and the concept of sustainability

The foundation of the WFD is that water should be managed according to the natural boundaries of river basins. All of this reflects an ecosystem approach (Convention on Biological Diversity, 1995) connected to the concept of sustainability. Sustainability can be interpreted in at least two ways; the first ecological interpretation sees sustainability as a basis for biodiversity conservation while the other one has socio-economic sustainability of human well being at its center. The WFD can be said to represent both these interpretations. One example of the first, more ecological based interpretation of sustainability is that high ecological status is defined as a water body with no or minimal human impact, in the directive called “undisturbed conditions”, while good status is defined as a situation only slightly deviating from the high status condition (European Parliament and the Council of the European Union, 2000). On the other hand, the aim of the directive is to secure the supply of sufficient, good water to the people within the European Union, reflecting the second, more socio-economic interpretation of sustainability within the directive. This ambiguity is described by Kaika and Page (2003) in the terms of conservation versus sustainability and can be seen as a result of the long political process that preceded the directive.

2.2 WFD and spatial fit

The concept of sustainable development including the two interdependent perspectives; ecosystem and socio-economic system, raises the question of spatial fit (Ostrom, 1990; Ostrom et al., 1994; Young, 2002; Folke et al., 2007). One aspiration within the WFD was to achieve spatial fit between the ecological (river basin) system and the socio-economic (the water management administration) system. This spatial fit presupposes that all water management actually is being
taken care off at this specific level. In fact, operative water issues, such as fresh water supply and wastewater treatment, as well as local water planning are often handled at the municipal level. This implies that the effort to solve problems of spatial fit also creates new problems at the vertical scale (Moss, 2004). A complication is also that river basin districts consist of several river basins, with varying size, population and impact on the environment. In the Swedish NBS-RBD, the largest river basin in size (22,000 km²) and population (about one million) can be compared to the smallest one (226 km²) with about 3000 inhabitants. At the same time several rather big coastal areas in between catchments within the district are not considered as river basins, since they do not have well-defined surface run-off.

A prerequisite for a sustainable development is the integration between water use management and systems as floodplain management, agricultural drainage and spatial planning. The necessary integration between water management and other systems is taking place at the horizontal scale. The most important integration at this level is probably that between land use planning and water management. If water management after WFD implementation takes place at the river basin level while physical planning is still in the hands of the municipality, this may cause a disintegrative process between land use and water management. Another complication is that land use planning is primarily focused on urban areas, while water management includes areas with forestry and agriculture as well (Hedin et al., 2007).

The implementation of the WFD has resulted in some countries having a regional organization; like Sweden, Norway, Germany, Estonia and Finland, while the main actor is at the national level in Denmark, Latvia, Lithuania and Poland (Hedin et al., 2007). The situation in Sweden (fig.1) shows that the vertical collaboration between local, regional and the new supra-regional level is now more intense, but WFD implementation at the supra-regional level might give rise to conflicts, since the local level is still partially responsible for water planning.

2.3 The WFD and eutrophication

Eutrophication can be defined as an increase in the rate of supply of organic matter to an ecosystem most commonly caused by nutrient enrichment, thereby focusing on the process itself instead of causes or consequences (Nixon, 1995). The links between nutrients and aquatic productivity has been known since the early 1900s even if most of the research has been done during the last forty years. Eutrophication in freshwaters has earlier been described as a logical
consequence of the natural aging because lakes become less deep and more biologically productive over geological time. Studies show that this succession from nutrient-poor to nutrient-rich is not a necessary evolution in lakes unaffected by human activity, even though such lakes nowadays are extremely rare (Smith et al., 2006). This early recognition of eutrophication was limited to freshwaters and the scientific awareness about a similar threat towards marine ecosystems did not emerge until the 1950s. It was in 1990 that eutrophication was seen as a major problem exemplified by the eutrophication in the Baltic Sea and in the coastal zones of the North Sea, the Adriatic and the Mediterranean (Nixon, 1995). The main consequences of eutrophication in lakes and rivers is an increased growth of macrophytes, thereby threatening the function of the ecosystem (Mainstone and Parr, 2002, Hilton et al, 2006), while in the oceans, cyanobacterial blooms and the formation of dead zones at the ocean bed are the most severe effects (Stal et al., 2003; Diaz and Rosenberg, 2008) (fig. 2).
There has been a general consensus that phosphorus (P) is the limiting factor in lakes and watercourses whilst nitrogen (N) is an important limiting factor in coastal waters and oceans (Granéli et al., 1990; Pitkänen and Tamminen, 1995; Swedish Environmental Protection Agency, 2007 a, b; Tamminen and Andersen, 2007; Conley et al., 2009). The high targets of improving the eutrophication situation in both freshwater and the oceans, increases the importance of correct basic data as a basis for decision-making. If, for example, measures are concentrated on removal of P from lakes and rivers, the problem of eutrophication is only exported downstream to N limited coastal areas (Conley, 2000). To report the nutrient loads in Sweden for both WFD-related and HELCOM-related purposes the HBV/NP-model are used. This model simulates residence, transformation and transports of nutrients and calculates the retention of both P and N calibrated against observed time series of river discharge and riverine nutrient concentrations. Retention can be defined as the net effect of various processes, such as biological uptake (assimilation), or the removal of nutrients from the water phase, such as sedimentation or denitrification, and may occur in streams, lakes and groundwater. This process is dependent on the residence time, where a longer time increases the amount of nutrients that can be removed from the water phase (Andersson et al., 2005). In the HBV/NP-model, the retention of P is calculated for both particulate and soluble reactive P (Andersson et al., 2005), and in the PLC5-reporting of the Swedish P load to the Baltic Sea (further explained), the P retention in lakes and water courses was found to be between 0 and 99% with some exceptions where lakes had a net supply of P (Brandt et al, 2008). Retention of P is a process that delays the downstream transport of nutrients for a shorter or longer time, and P stored by sedimentation may later be released (Hoffmann et al., 2009). The process of P retention is complicated, e.g. varying water flow and watercourse depth influence the retention while the slow leaching of P to the subsurface water systems makes predictions more difficult (Olli et al., 2008 ; Darracq et al., 2008 ). An increased knowledge of how this process works may improve the methods for decreasing the eutrophication problem (fig. 2).

Within the EU the political ambitions to take actions against the eutrophication problem are manifested through the WFD for inland and coastal waters, and through the EU Marine Strategy Framework Directive for the oceans (European Parliament and the Council of the European Union, 2008). The WFD goal of achieving high or at least good ecological status implies a situation with undisturbed conditions or a situation only slightly deviating from this. Concerning
the eutrophication situation the EU states that “nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality element” (European Parliament and the Council of the European Union, 2000), which implies that all water bodies within the European Union must be considered as protected areas. The Marine Directive is in practice and working in the Baltic Sea drainage basin through the HELCOM initiative Baltic Sea Action Plan (BSAP) adopted in 2007. It has the goal of achieving a good ecological status for the Baltic Sea until 2021 by reducing excessive inputs of nutrients (Backer et al., 2010). Inland pollution sources are a main cause for the eutrophication of the Baltic Sea, mainly emanating from agriculture and municipality waste water treatment plants (Andersen and Laamananen, 2009).

## 3. Objectives

The overall aim of this thesis is to find out how the implementation has affected (or will affect) local to regional level water management. The local level can be interpreted as the municipal level, from an administrative viewpoint, while the River Basin District Authority (RBDA) is the regional (or supra-regional) level. From an ecosystem perspective catchments can be considered as local or regional depending on the actual size of the area. The rather high target attached to the WFD, especially the goal of “undisturbed” conditions, may give rise to conflicts when WFD-
related demands must be realized on a more local scale. The focus here will be (I) how to make water management work at the local scale after the implementation and (II) possibilities to identify inland areas of high impact that contributes considerably to eutrophication problems seen in both inland and coastal waters. The study area of the thesis is the Northern Baltic Sea River Basin District in Sweden.

3.1 Water management at the local scale
Since WFD can be regarded as an answer to the demands and needs for water management influenced by an ecosystem perspective, water cannot be regarded as an individual phenomenon but as an integrated part of a system where land use especially plays an essential role. In many countries land use and water use has been managed at the local (municipal) scale facilitating the integration between these two policy sectors often under the umbrella of spatial planning. In Paper I, the situation in Sweden, where the local level is traditionally stronger than the regional level, is investigated (Böhme, 2002). The aim was to determine how the implementation of the WFD has influenced local-level water management, including the interpretation of new environmental quality standards. This study included interviews with individuals directly involved in water management and land use planning at the municipal level in one catchment of the NBS-RBD in Sweden, as well as representatives from superior levels and associations.

3.2 Eutrophication and regional management
In Sweden, the over-ambitious goals of the WFD, to a large extent, concerns the problem of eutrophication. In the study area, NBS-RBD the authority has estimated that 80% of the costs during the first management cycle 2009-2015 will be designated to measures concerning eutrophication (Northern Baltic Sea River Basin District Authority, 2009a). The eutrophication of the Baltic Sea is mainly due to nutrient pollution from inland sources and will therefore benefit from measures taken to fulfill the WFD-targets. The aim in Paper II was to find out if, and to what extent, one can identify “high-impact” areas that have, or causes, multiple problems, which then potentially can be addressed in a relatively efficient way by tailoring region-specific remediation measures. As case study, we analyze spatially the degree of eutrophication, and phosphorous load contributions to inland and coastal waters from 27 different catchments of the NBS-RBD in Sweden.
4. Study area

4.1 Baltic Sea and its Drainage Basin

The Baltic Sea is one of the largest brackish water areas in the world, situated in northern Europe; it covers 377,000 km² with a fourfold larger drainage area and a population of about 85 million. The countries within the drainage basin are all members of the EU except for Belarus, Russia and Ukraine (fig. 3a). The sea is divided into several sub-regions separated by sills and is almost entirely closed. These circumstances together with human activities, such as agriculture make the sea sensitive to eutrophication. The sub-basins have varying physico-chemical and biological characteristics, which affect their response to human induced pressures. The salinity of greatest impact on the biota varies from about 20-25 in the southwest, to 6-8 in the Baltic proper, down to about 1 in the most eastern and northern part of the sea. The gradient from sea water to lake water conditions effect the sensitivity to N and P. The limited exchange with the outside sea causes a long residence time for the water and implies that nutrients stay for a long time in the sea. The vertical stratification of water masses due to differences in salinity causes oxygen depletion and hypoxia increases the release of P from sediment to the overlaying water (Andersen and Laamanen, 2009). Since the 1800s, the Baltic Sea has changed from an oligotrophic clear-water sea into a eutrophic marine environment (HELCOM, 2007). The problem of eutrophication is today the most serious threat to the Baltic Sea ecosystem. The sources for nutrients in the areas are mainly agriculture activity for N and municipality waste water treatment plants for P. The nutrient loads reach the Baltic Sea mainly via rivers within the basin or via direct waterborne discharge (75% for N and 95% for P). Riverine nutrient load consists to a large degree of diffuse load mainly coming from agriculture, 60% for N and 50% for P (Andersen and Laamananen, 2009). Sweden, with its long coastline to the Baltic Sea, belongs almost totally to the Baltic Sea Drainage Basin. The majority of Sweden belongs to the circumpolar boreal region and areas with agricultural land decrease to the north. Ten percent of the Swedish area is covered with freshwater as a result of geological phenomena like faults, rifts and irregularities in the till layer, resulting in numerous small lakes (Jonasson, 1996).
4.2 Northern Baltic Sea River Basin District, Sweden

Sweden was divided into five river basin districts when the WFD was implemented (fig. 3a). The NBS-RBD is the smallest district in Sweden covering about 44,000 km² including estuaries and adjacent coastal waters (fig. 3b). The water in the district discharges into the Baltic proper, the part of the Baltic Sea that has the lowest ecological status mainly due to eutrophication (Andersen et al., 2010). The NBS-RBD has the largest population of the Swedish district with nearly 3 million people, and the largest expected population increase in Sweden resulting in urban pressure affecting land use and water resources. The district is dominated by Lake Mälaren with its dominating discharge to Stockholm, the lake being the water supplier for (today) 2 million people. The lake must be protected as a water supply for the growing population and is at threat from pollution connected to flooding, and from the middle of the 21st century, possible salt water intrusion from the Baltic Sea due to sea level rising caused by global warming (Stensen et al., 2010). The majority of the district is situated below the highest marine coastline and is dominated by areas with till soils and areas with clay and fine-grain soils mixed with till soils (Lundqvist, 1994; Persson, 1994). The land use in the river basin district is mainly forest (61%) and arable land (22%). The total load of P from anthropogenic sources has been estimated to be 390 tons annually whereof 210 tons reach the Baltic Sea (Northern Baltic Sea River Basin District Authority, 2009b). The diffuse nutrient supply through groundwater and surface water transport from agricultural land dominates, together with emissions from waste water treatment plants, domestic waste water in rural areas, and storm-water. Changes in land use may improve the eutrophication situation if agriculture activity decreases, but at the same time the population growth increases nutrient loads from other sources.

4.2.1 Oxunda catchment

The catchment Oxunda (270 km²) is situated in the eastern part of the RBD where it enters the Lake Mälaren at the border between the urban suburbs of Stockholm in the southern part, and more rural areas of forest and agriculture in the northern part (Northern Baltic Sea River Basin District Authority, 2008) (fig. 3b). The five municipalities covering the river basin have been working with water cooperation since 1999 in accordance with the WFD principles of the natural boundaries of river basins. The goal of the cooperation is to promote biological diversity and retain or improve the value of the environmental and cultural characteristics in the catchment.
Projects such as cleaning and detaining storm water, recreating the meandering of water courses and decreasing algal blooms in the lakes are some examples of ongoing processes conducted by the cooperation (Oxunda Water Cooperation, 2009). NBS-RBD including Oxunda catchment is today in a transition phase due to urbanization and population growth, while at the same time the status for surface water must improve dramatically, especially concerning the eutrophication problem to reach the WFD goal in due time.

5. Methods

5.1 Qualitative methods in Paper I
The objective in paper I was to find out how the implementation of the WFD had affected the water management at the local (municipal) level. Qualitative interviews with persons directly
involved in water management in municipalities were performed. In Sweden, the municipal level by tradition is very strong, manifested by the municipal monopoly for physical planning including both land use and water use. The persons interviewed were divided into two groups, where the first group represented the persons heading the physical planning (senior physical planners) based on the Planning and Building Act with several interests to take into account, including the exploitation of resources. The second group comprised persons responsible for environmental planning (environmental planners) based on the Environmental Act (including the WFD) representing the more environmental conservation interest. By interviewing them, we expected to find out whether the implementation of the WFD had influenced water management at the local level, and maybe even threatened the municipality monopoly on planning. The questions posed mainly concerned current cooperation on the horizontal scale (between different sectors at the local level), as well as cooperation on the vertical scale (between sectors connected to water management at different levels). If the interpreted answers showed that the necessary cooperation on both scales worked or not worked the conclusion would be either to find out how the implementation could increase cooperation or, if it did work, find out how to maintain it.

Oxunda catchment was selected because its well-functioning inter-municipal water cooperation was already working in accordance with the WFD principle, with water management according to natural boundaries (Northern Baltic Sea River Basin District Authority, 2008). We therefore expected our interviewees to be well-informed, thereby allowing more in depth discussions of questions brought up by implementation of the WFD. If we consider the WFD implementation as a process of learning (Bishop et al., 2009) the chosen catchment can be used to “study what may be” ( Schofield, 1990). This gives an opportunity to analyze how the situation may develop in other areas in the future, from a local level perspective limited by the fact that additional problem dimensions that may occur in larger inland water systems that are shared among several EU member states, cannot be evaluated from the present material. The possibilities of generalizing the result may be with countries or regions with similar organization when it comes to differences between administrative units for spatial planning and the boundaries of the river basin districts, but also with countries sharing the same regional organization with respect to the WFD (Hedin et al. 2007).
5.2 Qualitative and quantitative methods in Paper II

The objective in Paper II was to find out if, and to what extent, one can identify “high-impact” areas that have, or cause, multiple eutrophication problems, which can then potentially be addressed in a relatively efficient way by tailoring region-specific remediation measures. The quantifications and analyses here are mainly based on data from the Pollution Load Compilation 5 (PLC5) reporting to HELCOM (Brandt et al., 2008) including anthropogenic P load contributions from different sources within NBS-RBD to catchment outlets and the Baltic Sea, together with land use and eutrophication of water bodies within these (Northern Baltic Sea River Basin District Authority, 2008; Water Information System Sweden, 2009). Data produced for the RBDA were also analyzed, including WFD-related P-reduction demands from the Program of Measures set up by the Water District Board of NBS-RBD.

The PLC5 data on P-loads in catchments are based on spatially aggregated information from monitoring and modeled data on diffuse and point source emissions, and pollutant transport models, divided into a natural and an anthropogenic part. The anthropogenic part of the P-load consists of main point sources, such as waste water treatment plants; industries; septic tanks in rural areas; forest clear cuts; storm water drainage; and the part of the load from arable land that can be derived from agricultural practices (Brandt et al., 2008). In the PLC5 quantifications, the HBV-NP model, described by Andersson et al. (2005) is used to calculate the net load of nutrients where the retention is taken into consideration.

Data from the PLC5 reporting on the (net) contribution of each catchment to the Baltic Sea is combined with data on the loads to Lake Mälaren reported in the Program of Measures of the NBS-RBDA, both emanating from the same observational and HBV-NP modeling material, however, the NBS-RBDA reports do not explicitly state the relative contribution of different sources. Since the various source contributions to the Baltic Sea are available from PLC5, the relative contribution for each basin of its different sources to the Baltic Sea was estimated. These

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3 27 catchments are included in the study, 11 of them within the large Norrström River basin. (fig. 3b). Data is not presented for some coastal discharge areas lacking well-defined surface run-off, and islands of the Stockholm archipelago.
relative contributions were then multiplied with the reported loads to the basin outlets thereby obtaining the un-reported contributions of the various sources to Lake Mälaren. This is consistent with the assumption that the P-retention in Lake Mälaren is the same regardless of its original source (appendix Paper II).

The required P (and N) reduction demands (in tons per year) that each catchment has to meet in order to reach the WFD goal of good status are not legally binding, and regard the mass flows of P at the basin outlets, which in the case of the considered catchments are located either at Lake Mälaren or the Baltic Sea. The basin specific demands were basically related to the measured or modeled P concentrations in the furthest downstream water body of the catchment, taken as representative for the whole catchment; the larger the deviation of this P concentration from a likewise estimated natural, or undisturbed concentration, the higher the reduction demand. These currently suggested P-reduction demands and the principles of their determination, will be subject to refinement, and may also be modified or changed (Northern Baltic Sea River Basin District Authority, 2009b). Scenario analysis was therefore applied to investigate to what extent the use of alternative principles can modify the current suggestion of how reduction demands should be distributed among catchments, assessing also the robustness of the related identification high priority areas for remediation measures.

Three scenarios A-C was set up, representing different conceivable environmental parameters that remediation programmes may target, such as phosphorous loads to different water systems, and the degree of eutrophication. For each of the three scenario parameters, ranks were estimated for the top 10 of the 27 considered catchments, assigning higher ranks for higher values of the environmental parameter. It was specifically hypothesized that catchments of high-impact character existed within NBS-RBD which would then be the case (i.e., the hypothesis would be supported) if one (or a group of) catchments would receive high ranks with respect to many, or all, of the considered environmental variables. The rankings from the three scenarios were compared to actual reduction demands given in the Program of Measures within the NBS-RBD. The objective of the WFD is to have close to undisturbed conditions, as referred to earlier, and since agriculture is the main source for the anthropogenic P load in the district, the best way to reach this would be to concentrate on areas having the highest amount of anthropogenic P in relation to their surface area. Having an agricultural activity that is more “polluting” would then
lead to higher reduction demands. The first two scenarios were based on this principle: the actual load to the catchment outlet either in Lake Mälaren (Norrström), or in the Baltic Sea (coastal discharge) (A) and the actual load to the Baltic Sea (B); while the third scenario was based on the part of water courses and lakes within every catchment being eutrophicated (C) (table 1).

6. Summary of results

6.1 Paper I

The results from the interviews with the senior physical planners and environmental planners at the municipal level within the Oxunda catchment indicated that WFD implementation had not yet led to any appreciable change in water management practices, but that resources at the County Board had improved, which was not perceived to be the case at the municipal level. The interviewees at the municipal level believed that the WFD objectives and implementation methods were indistinct, especially regarding what kind of cooperation the RBDA wanted to promote. They were also unclear on how to interpret environmental quality standards and other WFD related legislation, and were unsure on how binding the directive was going to be and they expressed a need for guidance in these matters as well as financial support. The representative at the regional level (County Board) agreed on that: “We do not know what legal status those environmental quality standards are going to get relative to other standards in the Environmental Act. We are examining this now and there is not much to lean upon. All municipalities wonder what is going to happen, the county governor wonders, everyone wonders.”

The differences between the two groups concerned mainly expectations on the WFD for “what might be” where the environmental planners had expected the WFD to be tougher and the strength of the directive was perceived to be low. One of the environmental planners interviewed expressed it like this: “Bad waste water treatment systems are still approved by the municipality. We should say no to that. The WFD is not supporting us in this issue”. The senior physical planners expected that the monopoly on municipal planning would remain after implementation of the WFD but feared that the WFD would add constraints to the planning process. The environmental planners wanted to increase the weighting and consideration of water issues in the planning process while the senior physical planners expressed fear that implementation of the
WFD may offset the balance between water issues and other issues too far toward water issues, the latter exemplified by this interview quotation: “Societal planning is coordination of different interests and therefore also a very complex matter where these interests have to be weighed against each other. The WFD is one of many factors to consider. However, additional restrictions or decisions that are proposed need prior discussion and/or description of how to apply them in the planning process and how to weigh them against other interests.

Nevertheless, interviewees at the municipal level had experienced an increased focus on water issues and extended cooperation between land use planners and water planners during the last few years, and the intra-municipal collaboration between water issues and physical planning was perceived to be well-functioning. The results of the current interviews also showed that despite their differing perspectives on water issues, both environmental planners and physical planners viewed the target formulation and achievements of the inter-municipal Oxunda Water Cooperation as highly successful. The environmental planners have an important role to play in the cooperation, both on horizontal and vertical scale. Even if they are formally guided by the Environmental Act (including the WFD), they expressed an understanding for different needs in the municipal planning process, and they could therefore bridge the gap between the different perspectives and mitigate possible conflicts.

6.2 Paper II
The reduction required from the NBS-RBDA (in the Program of Measures) varies considerably between 0 and 40% in 22 of the here considered 27 catchments of the NBS-RBD, while five have reduction demands between 45 and 85% \(^4\). These high reduction demand areas have a considerable part of their anthropogenic P load coming from agriculture, which is also the case for several of the catchments having rather low reduction demands. The catchment area in the high reduction demand areas constitutes more than 20% arable land. Two of these also have a relatively high anthropogenic P load, while several catchments have similar area averaged anthropogenic P loads as the three other high reduction demand areas. Regardless of the reduction demand, catchments that have a relatively high percentage of arable land also have relatively high P loads of anthropogenic origin. Even so, the scatter is considerable. The reason for this may be areas dominated with clay soils that easily leak phosphorus, catchments with few

\(^4\) As part of the total anthropogenic P load to the basin outlet
lakes making the retention smaller (Brandt et al. 2008), or areas with large waste water treatment
plants. The two areas having the highest reduction demand also have a high degree of arable land,
high anthropogenic P loads to their outlets and also have high percentages (>70%) of
eutrophicated water bodies in their basins. Several other catchments have the same high degree of
eutrophication, while the three other high reduction demand areas have less than, or much less
than, 70% of their water bodies eutrophicated. There is a considerable scatter in the expected
positive relation between the percentage of arable land and the percentage of eutrophicated water
bodies within the basin, in part due to anthropogenic nutrient loads from sources other than
agriculture.

Two out of the five high reduction demand areas have their outlet to Lake Mälaren while the
other three discharge direct to the Baltic Sea. The considerable (modeled) retention caused by
Lake Mälaren reduces the P load to between 26 and 72% from the outlet in Lake Mälaren, to the
outlet in the Baltic Sea. This implies that the contribution to the Baltic Sea from each of the
catchments with an outlet to Lake Mälaren is less than the contribution from two of the other
high reduction demand areas.

Table 1 shows the 10 catchments with the highest reduction demands in NBS-RBD, together with
the alternative top 10 rankings of the catchments in the district, according to values of the
environmental parameters considered in Scenarios A to C. Relatively different sets of basins hold
the Rank 1 to 10 positions in the different cases. For instance, only 5 out of 10 of the catchments
on the reduction demand top 10 list are found on the Scenario A top 10 list, which is only slightly
higher than the re-appearance of 37% of the catchments that could be expected, on average, if 10
basins were randomly selected for a top 10 list, out of the 27 considered basins. All of the top 10
basins of scenario B discharge directly into the Baltic Sea, since the anthropogenic P load
contributions to the Baltic Sea from the basins discharging into Lake Mälaren are relatively
small, due to the modeled retention of Lake Mälaren. Scenario C, referred to as the most WFD
influenced, contains seven from the top 10 list and thereby represents the highest similarity with
the top 10 list of high reduction demand areas.

Taken together, the results indicate that there are basins that have similarly high, or higher,
anthropogenic P load to the basin outlet, degree of eutrophication, and P load contribution to the
Baltic Sea, as the high reduction demand areas identified in the Program of Measures for NBS-
RBD. The different results for different strategies triggers a discussion concerning what principles should govern the efforts to solve the eutrophication problems, both in inland, coastal and marine areas.

7. Discussion

The overall aim of the thesis was to find out how the implementation has affected (or will affect) local to regional level water management. An assumption was that the rather high targets attached to the WFD, especially the goal of “undisturbed” conditions may give rise to conflicts when WFD related demands must be realized on a more local scale. This is most likely in regions where both agriculture and urban development causes eutrophication and other pollution problems in inland waters, as in the considered study area. The focus of Paper I was how to make water management work at the local scale after the implementation of the WFD, considering the (I) disintegrative process when parts of the water planning are moved from the municipal level to the supra-regional level and (II) conflicts between the supra-regional and municipal levels when it comes to coordinating land use planning and water planning. The result from paper I indicated that the environmental planners considered the case study of Oxunda had an important role to play to maintain the Swedish tradition of weighing various good objectives against each other. The role for the environmental planners to act as integrating factors, both on horizontal and vertical scales, implies that they can contribute to environmental problem solving (Young, 2002) and mitigate the effects of scale related mismatches (Moss, 2004). The results also support the reasoning of Carter (2007), who stated that effective collaboration between authorities and municipalities may prevent severe system malfunction. While Hedelin (2005) stated that such collaboration could potentially mitigate the effects of anticipated problems regarding low accountability and the legitimacy of WFD regulations implemented in Sweden, caused by unclear formal relationships between the supra-regional and municipal levels.

The theoretical framework of this thesis puts the concept of sustainability within water management in focus. In Paper I the effort to have a perfect spatial fit between ecosystems and socio-economic systems, after the WFD implementation, is discussed, together with the new mismatch problems that this has created. Water management according to natural boundaries
must, however, be seen as a “good” thing when trying to achieve the sustainable management of water, and as shown in Paper I, the new problems of mismatch can be solved by good cooperation, where environmental planners at the local level may have a key role.

In Paper II the focus was to find out possibilities to identify inland areas of high impact that contributes considerably to eutrophication problems seen in both inland and coastal waters. There are basins with similarly high, or higher anthropogenic P loads to the basin outlet, degree of eutrophication, and P load contribution to the Baltic Sea, as the high reduction demand areas identified in the NBS-RBD. The scenarios set up here differ concerning which catchments to be considered the most eutrophicated or “eutrophicating” ones. Even if the considerable scatter in the expected positive relation between the percentage of arable land and the percentage of eutrophicated water bodies within the basin in part is due to anthropogenic nutrient loads from other sources than agriculture, it may also indicate that high P loads not always cause a high degree of eutrophicated water bodies.

However, to fulfill the goal of achieving good status in all inland waters within the EU, as well as good status in the Baltic Sea, emissions from inland sources must be drastically reduced. Eutrophication is a well investigated field, especially when it comes to physical and biological processes and mitigation methods. Mitigation methods discussed are often the creation or maintaining of wetlands intercepting smaller or greater parts of the Baltic Sea Drainage Basin (Jansson et al. 1998; Söderqvist, 2002; Trepel and Palmeri, 2002). More general nutrient management policy studies are rarer but have been discussed by, e.g. Turner et al. (1999), who claimed that most countries (in the Baltic Region) probably would gain net economic benefits from a simulated 50% N and P reduction policy. Carstensen et al. (2006) presented a study where an active management strategy could document significant decreases in nutrient concentrations on a large regional scale. Wulff et al. (2007) stated that drastic land use changes are required to improve the eutrophication situation in the Baltic Sea. Within the coming decade, as required by the WFD and the BSAP, the required drastic measures are not possible to fulfill from a socio-economic perspective (Volk et al., 2009). The enormous reduction demand put on the river basin considered here, NBS-RBD implies that a huge part, in some catchments up to greater than 80%, of the nutrient load emanating from anthropogenic sources will have to be reduced. Retention processes can also delay targeted effects of mitigation measures considerably (Darracq et al.,
2008) and ecosystems need to react to measures taken, which may considerably prolong the time it takes to reach WFD targets (Hering et al., 2010). A limited awareness of WFD targets at the municipal level, as shown in Paper I, may also indicate that it may take time to address them in an effective way. Given these circumstances the best result on a short time-scale could be achieved by starting with catchments having the largest impact on the Baltic Sea, and leave eutrophicated water bodies with high retention to the sea untreated. The WFD target of a good ecological status close to undisturbed, or pristine, conditions raises the question, is it a reasonable goal to attain in areas where people are living? Since the actual classification in the district under consideration showed that only about 25% of the water bodies were rated as having good status it seems difficult to achieve the target by 2021\(^5\). A question to be put is whether unrealistic timetables are favorable for achieving desired results or not. However, the timetable is a sign of political will and not a calculated year based on measures to be implemented. The WFD is, however, legally binding which is not the case for the BSAP, even if the BSAP might be prestigious for the Swedish Government. This voluntary nature (and thereby lack of sanction mechanism) of the HELCOM (BSAP) hampers the implementation of measures (Österblom et al., 2010). Even if it is the RBDAs mission to fulfill the WFD demands rather than the BSAP, the two agendas need to be synchronized, which is also emphasized by the Swedish Government (2010)\(^6\). According to a report made on behalf of the Swedish government by the RBDA in the NBS the location of measures for improving the situation in the Baltic Sea and in the inland waters of NBS-RBD differs due to the high retention in Lake Mälaren and Lake Hjälmaren. From a coastal and marine perspective, areas with high estimated load contributions to the Baltic Sea should be prioritized, at least in the short run (Larsson and Pettersson, 2009).

Scientific based legislation can be seen as an interface between science and the socio-economic system. To decide upon such legislation is often complicated as in the WFD case, where the decision was preceded by a long and complicated political process. The implementation of such legislation is a political process as well and if the legislation is perceived to be too rigid, the stakeholders may tend to ignore it, especially if sanctions seem unclear and if the scientific basis

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\(^5\) Sweden has promised to achieve good status for all waters classified as eutrophicated within the WFD system by 2021 and not by 2027 which might have been a possibility.

\(^6\) 1 July 2011 a new authority was founded in Sweden (Swedish Authority for Sea and Water) taking over the responsibility for questions targeting the Marine Directive, the WFD and the BSAP which may facilitate these efforts.
is not reliable. In Sweden, the environmental legislation is today stricter than when the Environmental Act was introduced in 1987, making the weighing between different interests at the municipal level more difficult. According to the WFD (and other environmental legislation) this weighing is not “allowed”\(^7\), but the municipality praxis based on the planning monopoly still supports this pragmatic way of decision making. In Sweden, the concept of ecological status has become an environmental quality standard in accordance with the Swedish Environmental Act, thereby making the concept legally binding, and in this matter implemented the directive more robustly than other EU countries may have done.

The effort to achieve the good status in all waters within a very short timetable can be interpreted as sustainability with a focus on the ecosystem, thereby leaving out the “human” system, since the ambition here is to have close to undisturbed conditions. Opinion varies whether “good status” is too ambitious, or maybe not ambitious enough to e.g. maintain aquatic biodiversity. To define the “natural state” raises some questions, e.g., how can we be sure how the situation would have been if all human disturbances had not been there and how do we know what the natural state will be taking the effects of climate change into account. However, there is a need for guidance regarding the interpretation of the environmental quality standards, especially the concept of ecological status. The possibility for individual countries to interpret this concept in different ways can become problematic. If some countries overestimate problems and consider large numbers of water bodies as below “good”, “unnecessary” improvements by 2015 may be undertaken and already insufficient resources will be used inefficiently. A prerequisite for sustainable water management is a well functioning cooperation at the horizontal as well as at the vertical scale. The national level must provide guidance and support using unequivocal legislation. The consequences of eutrophication are severe, including the fact that large fractions of the limited resource phosphorus is now lying at the bottom of the oceans. At the same time, the demands must be reasonable and achievable with today’s technology or else it should be admitted that today’s goals are over-ambitious.

To have natural conditions as a reference value for the status classification of water bodies can be compared with the objectives related to climate change, where a pre-industrial carbon dioxide concentration is not on the agenda, since there is a consensus that this is unachievable. If this

\(^7\) There are possibilities to get a time delay for reaching the good status due to technical or economical reasons until 2027.
huge demand for reduction will be fulfilled especially in the rural areas with agriculture, is it possible for people to still live and work here when all areas shall be considered as protected areas with or without minimal human impact?

7.1 Conclusions

The aim of the thesis was to find out how the implementation has affected (or will affect) local to regional level water management. The hypothesis was that the high targets attached to the WFD, may give raise to conflicts when demands must be realized on the more local scale. Paper I showed that WFD may cause a disintegrative process and increase the risk that conflicts will arise between the supra-regional and municipal levels, and even give rise to a dual system of water management threatening the municipal monopoly on physical planning. The result indicated that the environmental planners in the considered case study, Oxunda, have an important role to play to solve or mitigate effects of scale related mismatches, horizontal as well as vertical. They could therefore bridge the gap between the different perspectives (as shown above) and thereby mitigate possible conflicts. The Swedish tradition of weighing various good objectives against each other could then be maintained. However, in the considered RBD with eutrophication as the dominating problem, the weighing between different interests to a large extent will take place outside the municipality domain since agriculture and forestry are not normally a target for land use planning. Local farmers, land-owners and stakeholder organizations, like angler associations, together with the RBDA, the county board and intra-municipal cooperation and Water Councils will be the main stakeholders here.

The results in Paper II indicated that there are basins that have similarly high, or higher, anthropogenic P load to the basin outlet, degree of eutrophication, and P load contribution to the Baltic Sea, as the high reduction demand areas. The group of catchments with the highest P-load contributions per arable area did not coincide with the group of catchments that have the highest degree of eutrophicated water bodies and none of the catchments with the highest load contribution per arable area to the Baltic Sea were located in the Lake Mälaren Basin. Using a strategy for remediation measures that primarily targets agricultural areas of high impact cannot be expected to also target catchments within the high eutrophication group. This does not imply that it is less effective in terms of decreasing the total number of eutrophicated water bodies in
Table 1. Ranking of priority basins according to current reduction demands, and values of the environmental parameters considered in alternative scenarios A to C (absolute values shown within brackets). Blue colored cells contain basins with direct Baltic Sea discharge, and uncolored cells contain basins with discharge to Lake Mälaren. Basin names written in bold characters show basins having the top 10 highest reductions in the current Program of Measures (column 2). Basins marked with * lack well-defined surface run-off.

<table>
<thead>
<tr>
<th>Rank</th>
<th>High reduction demand areas</th>
<th>Scenario A</th>
<th>Scenario B</th>
<th>Scenario C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduction demand in the Program of Measures for NBS-RBD</td>
<td>Anthropogenic P-load from agriculture per arable area: Contribution to basin outlet</td>
<td>Anthropogenic P-load from agriculture per arable area: Contribution to the Baltic Sea</td>
<td>Part of water bodies being eutrophicated within the basin</td>
</tr>
<tr>
<td></td>
<td>% of anthropogenic P load</td>
<td>kg km$^{-2}$ year$^{-1}$</td>
<td>kg km$^{-2}$ year$^{-1}$</td>
<td>% of water bodies</td>
</tr>
<tr>
<td>1</td>
<td>Örsundaån (85)</td>
<td>Sagån (48)</td>
<td>Svärtaån (45)</td>
<td>Svartån (94)</td>
</tr>
<tr>
<td>2</td>
<td>Sagån (80)</td>
<td>Hedströmmen (46)</td>
<td>Olandsån/Skeboån*(32)</td>
<td>Tyresån/Trosaån*(88)</td>
</tr>
<tr>
<td>3</td>
<td>Olandsån (77)</td>
<td>Svärtaån (45)</td>
<td>Kilaån(28)</td>
<td>Örsundaån (86)</td>
</tr>
<tr>
<td>4</td>
<td>Tämnarån (69)</td>
<td>Örsundaån (44)</td>
<td>Tyresån/Trosaån*(27)</td>
<td>Tyresån (83)</td>
</tr>
<tr>
<td>5</td>
<td>Svärtaån (51)</td>
<td>Fyrisån (40)</td>
<td>Olandsån (26)</td>
<td>Oxundaån (78)</td>
</tr>
<tr>
<td>6</td>
<td>Köpingsån (39)</td>
<td>Arbogaån (36)</td>
<td>Tämnarån (26)</td>
<td>Trosaån (77)</td>
</tr>
<tr>
<td>7</td>
<td>Mälarens Närområden* (37)</td>
<td>Olandsån/Skeboån*(32)</td>
<td>Skeboån (24)</td>
<td>Köpingsån (75)</td>
</tr>
<tr>
<td>8</td>
<td>Kolbäcksån (36)</td>
<td>Kolbäcksån (29)</td>
<td>Tyresån (20)</td>
<td>Sagån (73)</td>
</tr>
<tr>
<td>9</td>
<td>Oxundaån (36)</td>
<td>Kilaån (28)</td>
<td>Norrtäljeån/Åkerströmmen*(19)</td>
<td>Svärtaån (63)</td>
</tr>
<tr>
<td>10</td>
<td>Tyresån/Trosaån (32)</td>
<td>Tyresån/Trosaån*(27)</td>
<td>Åkerströmmen (18)</td>
<td>Eskilstunaån; Mälarens närområden* (62)</td>
</tr>
</tbody>
</table>
NBS-RBD, however, one must accept that some catchments will remain more eutrophicated than others due to human activities. In contrast to the WFD, the BSAP brings priority to catchments with high load contributions to the Baltic Sea. It is therefore plausible that a prioritizing from a Baltic Sea and BSAP perspective must come at a cost of accepting higher P-load contributions from catchments of Lake Mälaren than from catchments with direct discharge to the Baltic Sea, which may also imply accepting a higher degree of eutrophication in the Lake Mälaren and its catchments.

However, to fulfill the goal of achieving good status in all inland waters within the EU, as well as good status in the Baltic Sea, emissions from inland sources must be drastically reduced, which is not possible to fulfill:

- From a socio-economic perspective
- Due to retention processes and delays caused by ecosystem factors
- Due to a limited awareness of WFD-targets at the municipal level

Given these circumstances, an achievable result on a short time-scale could be to start with catchments having the largest impact on the Baltic Sea, and leave eutrophicated water bodies with high retention untreated. However, if the EU countries do not fulfill their obligations, sanctions (currently unclear as to what these may comprise) will be put on the individual countries. What possible sanctions that can be put on individual municipalities from the RBDA are even more unclear, and there is a risk of “municipality” ignorance towards decisions coming from regional, supra-regional or national levels, especially if the local environmental sector is weak. Who is going to prioritize issues when increased pressure for nutrient load reductions will be put at the local level? The most probable scenario for where reductions are going to be made is “where it goes, because people are willing to do so”.

### 7.2 Future work

Possible future work could continue in four different directions. The first would be to examine, on a national level, the possibilities for environmental planners to work as integrating actors trying to bridge the gap caused by the new water organization. This could also be an opportunity on the European level in countries with similar organizations as Sweden. The second direction could be to study the future work performed by the Water Authorities to reach the goal with good
status, especially, how to decide upon the necessary priorities and to find out what pressure the EU will put on Sweden and what pressure Swedish Authorities will put on municipalities not achieving the required status. The third direction would be to examine the possibilities of a more integrated approach for inland waters, coastal waters and the sea when the new Swedish Authority for Sea and Water will begin its work. The last direction could be to examine the priorities and efforts to be made in the entire Baltic Sea Drainage Basin to fulfill the aim with the WFD as well as the BSAP.

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Paper I
Impact of the European Water Framework Directive on local-level water management: Case study Oxunda Catchment, Sweden

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A B S T R A C T

The Water Framework Directive (WFD) of the European Union provides a common framework for water policy that focuses on holistic and integrated water management in river basins. In many member states, implementation of the WFD has shifted the main responsibility for local water issues from the municipal level to the regional or supra-regional levels. In this study, we investigated how the implementation of the WFD has influenced local-level water management including the interpretation of the new environmental quality standards. Specifically, we considered Sweden, which has traditionally had relatively strong governance at the municipal level. Because a sufficient amount of time has now passed for evaluation of WFD-related effects on operational water handling, we interviewed individuals directly involved in water planning and land use planning at the municipal level in one sub-catchment in the Northern Baltic Sea River Basin District of Sweden, as well as representatives for superior levels and associations. Despite divergent views regarding the priority of water issues in physical planning among the local-level planners interviewed, they all participated in successful inter-municipal pre-WFD collaboration projects. Although such collaborations could help increase the understanding and acceptance of WFD-related goals and costs, as well as facilitate conflict solving, as shown in the Oxunda Catchment, they have not gained much attention in the WFD implementation process. Additionally, physical planners have generally been reluctant to accept new environmental quality standards resulting from WFD implementation, in part because they lack precise definitions, but also because they could challenge the municipal routine of weighing various objectives against each other. Furthermore, despite WFD-related increases in ambition levels, lack of resource improvements at the municipal level were identified as potential problems by local environmental planners.

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Introduction

In 2000, the European Union introduced the Water Framework Directive (WFD) with the goal of protecting its water resources and thereby securing its fresh water supply. Prior to adoption of the WFD there were a number of water policies in the EU, including the Drinking Water Directive and the Urban Waste Water Directive; however, these policies lacked a holistic approach. Conversely, the WFD covers all water resources in the European Union, including surface water and groundwater, freshwater and estuaries and adjacent coastal water. Furthermore, the WFD regulates both qualitative and quantitative aspects of water use (Griffith, 2002; Gipperth and Elmgren, 2005). Water management according to the WFD includes characterization, setting of environmental quality standards, monitoring and development of programs of measures and management plans (European Parliament and the Council of the European Union, 2000).

The goal of the WFD is to achieve good water status by 2015. At a minimum, the water status of surface water, groundwater, estuaries and adjacent coastal waters should not deteriorate. The foundation of the directive is that water should be managed according to the natural boundaries of river basins, which reflects an ecosystem approach (Convention on Biological Diversity, 1995) that is related to the concept of sustainability. However, according to Hedelin and Lindh (2008), the WFD has aspects of conservationism since it defines good water status as a state in which deviation from the pristine conditions of an aquatic system is small. Prior to implementation of the directive, the only countries to organize their water management according to natural river basins were France, England and Wales (Hedin et al., 2007).

Kaika (2003) describes European Water Policy as occurring in three waves. The first wave started in 1975 and focused on drinking water quality, while the second wave began in 1991 and was geared toward control of emission levels. The WFD, which

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represents the third wave, provides a more holistic water management approach for river basins and stipulates that water quality, emission control and groundwater protection must be seen in one context. This change in water policy can also be seen as a response to the continued growth of urban areas, the introduction of a private sector to water resource management, and increasing concern for the environment (Kaika, 2003).

The European Communities states that “water resources must be planned and managed in an integrated and holistic way” (European Communities, 2003). Integrated management can have several definitions. One such definition focuses primarily on different water systems and water properties (e.g. surface water, groundwater, water quantity, water quality) and their interaction. A second broader definition considers water as one system that interacts with other systems, incorporating the concepts of land and environment, e.g. floodplain management, agricultural drainage and spatial planning. A third definition, puts in economical and social aspects and the connection between economy and environment (Mitchell, 1990; Jepson, 2001). While the WFD may reflect all of these dimensions, this study will focus on the second definition, especially the integration between land use planning and water planning.

In many member states, implementation of the WFD has led to relatively large changes in water resources management at the local level. This is because primary river basins commonly contain several local land use planning units, which, after implementation of the WFD, have not retained their main responsibility for local water issues. This has led to a shift in governance from the local or municipal level to the regional or supra-regional level. If monitoring data interpretations reveal that environmental targets are not met, the next step in WFD-related water management is to identify and implement appropriate adaptation measures. Key measures include treatment of highly contaminated source zones in urban or industrial areas (Göbel et al., 2007; Jarjsjö et al., 2005), and decreased nutrient loading from rural areas via change of land-use (Darraçq et al., 2008), which emphasizes the importance of physical planning in reaching WFD related targets.

In Guidance Document No. 11, which concerns implementation of the WFD, the European Commission states that river basin planning must be coordinated with other relevant planning processes. Specifically, they state that implementation must ensure that the body responsible for land use planning takes the objectives it creates into account. They go on to suggest that the land use and water planning processes support each other to the greatest extent possible (European Communities, 2003). A crucial issue will be how the WFD will affect the local level still responsible for land use planning, and at least partly, still responsible for water planning.

The study was conducted to determine how the implementation of the WFD has influenced local-level water management including the interpretation of new environmental quality standards. We specifically investigated the situation in Sweden, which by tradition has relatively strong governance at the municipal level. More generally, as reflected by the fact that independent local authorities are recognized as the main principle of democracy in many European countries, we expect that experiences from local level water management in Sweden can bring up issues of relevance to implementation of the WFD in many other EU member states.

The WFD-related changes in institutional structure and responsibilities started in 2004; therefore, a sufficient amount of time has passed to evaluate the effects of the plan on operational water handling. This study included interviews with individuals directly involved in water management and land use planning at the municipal level in one sub catchment of the Northern Baltic Sea River Basin District in Sweden, as well as representatives for superior levels and associations.

Spatial fit and institutional interplay

Problems associated with the concept of spatial fit are familiar to scientists attempting to determine optimal units of governance for policy fields (Ostrom, 1990; Ostrom et al., 1994; Folke et al., 1998, 2007; Young, 2002). The possibility for environmental regimes to solve environmental problems is closely connected to the problem of fit. According to Young this possibility is “determined in considerable measure by the degree to which they are compatible with the biogeophysical systems with which they interact” (Young, 2002, p. 55).

Organization of water management around river basins is a method of attempting to obtain a perfect spatial fit. However, this method often creates new boundary problems and mismatches on the vertical scale (Moss, 2004). When the WFD was introduced the European Communities (2003) anticipated that spatial conflicts with other policy sectors, structured along administrative and political boundaries but with a significant impact on water, would occur.

The relationships between water management institutions and other institutions refer to problems of a different type. The boundaries identified here are not related to physical territories but rather to political responsibilities and social spheres of influence and are the most common source for conflict between formal institutions (Mitchell, 1990). The close connection between land and water likely makes land use planning the most important sector interconnected with water management and water planning. The relationships between these sectors can be referred to as institutional interplay (Moss, 2004). In the present study, the concept of institutional interplay or horizontal integration refers primarily to the interplay between water planning and land use planning. This interplay is affected by implementation of the WFD, because it targets river basins that are much more extensive than municipalities spatially. On the one hand, this necessitates decisions on water issues at higher levels; however, many decisions regarding land use planning are made at the local level and must be coordinated with water planning. As part of this study, we investigated the extent to which local water planners and land use planners experience such overarching, WFD-related conflicts impact operational water handling.

The WFD

The structure of the WFD

European directives normally leave the details to the member states during their process of transposition into national legislation. For example, the method by which different states organize their water administration when implementing the WFD is a national decision as long as they adhere to the leading principle of management according to natural boundaries for river basins. Nonetheless, the WFD has copious annexes to the main text containing more details than is usual for European directives (Moss, 2008).

Annex no. 5 is explicit with respect to how classification and typologies should be designed. For surface water the status classification consists of a combination of ecological and chemical statuses, where ecological status is classified to be; high, good, moderate, poor or bad based on biological, physical–chemical and hydro-morphological qualitative factors (Water Information System Sweden, 2009). Based on this classification the condition for high ecological status is defined as being a pristine condition with no or minimal human impact. According to Moss (2008), good ecological status is defined as being slightly poorer than high status, while the meaning of moderate, poor or bad status lacks useable guidelines. The WFD stating that good ecological status should be
achieved by 2015 makes the boundary between good and moderate status crucial. This lack of a precise definition may undermine the effectiveness of the WFD (Moss, 2008).

In the main body of the WFD, the concept “of an environmental objective” is used to describe the overall purpose of WFD-related programs of measures. With respect to surface waters this objective is designed to prevent further deterioration of the water status in all water bodies or, if necessary, to take measures to restore good water status by 2015. If there are special circumstances concerning technical, economic or natural conditions, a delay in achieving good status until 2027 is permitted (European Parliament and the Council of the European Union, 2000). Two different means of control are used to achieve the environmental objective, emission limit values and standards for the desirable environmental quality for a specific water body (Emmelin and Lerman, 2004). The directive uses the term environmental quality standard exclusively to describe concentrations of pollutants that should not be exceeded (European Parliament and the Council of the European Union, 2000).

**WFD in Sweden**

Upon implementation of the WFD, Sweden was divided into five river basin districts (RBDs), each of which comprises several river basins. In Europe, this type of regional organization has also been implemented in Norway, Germany, Estonia and Finland while the main actor is at the national level in Denmark, Latvia, Lithuania and Poland (Hedin et al., 2007). In Sweden, each district has a River Basin District Authority (RBDA) governed by a Water District Board that is appointed by the Swedish government. In practice one County Board within the RBD becomes the district authority.

The RBDAs in Sweden presented WFD-related standards and plans in March 2009 and the Water District Board accepted revised versions in December 2009. The RBDA is responsible for the entire process of standards and plans concerning the district, but can delegate preparation of proposals for the standards and plans and the task of accomplishing the management plan to each county board. However, all county boards must cooperate with the RBDA and be a link between the authority and the municipal level. In practice the county boards have kept most of their old responsibility for water management (Swedish Environmental Protection Agency, 2005).

The WFD states that cooperation and coordination should take place at all levels and that information, participation and consultation should become a part of water management (European Parliament and the Council of the European Union, 2000). The municipal level is the traditional level in Sweden for public participation. For instance, a certain level of advertisement and consultation with the public is compulsory when municipal master plans and detail plans are handled. The Swedish method of fulfilling the demands in the WFD for cooperation and participation is to encourage the establishment of Water Councils with the goal of creating a more pro-active and cooperative body consisting of stakeholders related to one or several specific river basins. The initiatives for establishing Water Councils can originate from municipalities or water associations (Southern Baltic Sea River Basin District Authority, 2009).

As stated earlier, the concept of environmental quality standards in the WFD is used exclusively for measurable concentrations of pollutants in water bodies. Nevertheless, in Sweden, it was decided to allow the concept of ecological status to become an environmental quality standard in accordance with the Swedish Environmental Act. This makes the environmental quality standards legally binding (Northern Baltic Sea River Basin District Authority, 2008). One reason for this decision was to achieve some kind of uniformity in the environmental legislation to make the environmental quality standard a unifying concept (Emmelin and Lerman, 2004).

However, several members of the Swedish parliament from different political groups including the Federation of Swedish Farmers, the Swedish Association of Local Authorities and Regions and the Municipality of Stockholm questioned this decision. They argued that Sweden was the only member of the European Union making this decision and that the WFD definition of good status is too imprecise for such legislation to be effective (Swedish Parliament, 2009). Lerman (2009) stressed the importance of the divide between the impact of violations against environment quality standards, which may threaten the environment and health, and the more general objectives of maintaining a good environment. All such good objectives in a society should receive attention and be weighed toward each other in a political process.

**The Swedish municipalities and the WFD**

The Swedish municipalities are responsible for supervising local activities that may affect the environment and health such as domestic wastewater treatment and well drilling. They are also responsible for operative water issues, such as fresh water supply and wastewater treatment as well as for local water planning issues. In the Swedish administration, the local level is traditionally stronger than the regional level (Böhmé, 2002). The municipality holds a monopoly on making land and water use plans, based on the Planning and Building Act (Swedish Code of Statutes, 1987). Therefore the municipal level is important to the integrated land use planning and water use planning that is promoted through the WFD (Fig. 1).

However, implementation of the WFD in Sweden has resulted in part of the water planning moving from the municipal level to the new RBDA with the goal of attaining a better spatial fit between administrative and natural boundaries for river basins (Fig. 1). The vertical collaboration between the local, regional and the new supra-regional level is more intense, but WFD implementation at the supra-regional level might give rise to conflicts since the local level is still partially responsible for water planning. This may cause a disintegrative process between land use planning and water planning, demonstrating the importance of co-operation between municipalities and RBDAs (Hedelin, 2005; Carter, 2007). Therefore, the municipal plan monopoly is challenged through the WFD in Sweden and possible tension is built into the system between the municipal level and the new supra-regional level for the RBDA (Lundqvist, 2004). The Water District Boards are appointed by the central government and do not reflect the results of local elections. Accordingly, the Swedish commission of inquiry that was revising the Environmental Act when the WFD was going to be implemented stated: “When conflicts arise because large-scale municipal planning contributes to unachievable environmental objectives for water, the water planning – which comprises the ecological status in a whole water area – must be superior to the municipal planning” (Ministry of the Environment, 2002, p. 87, translated). Accordingly, the WFD is sometimes described as a new phenomenon in Swedish management. “The extremely top down, command-and-control EU WFD perspective runs counter to much of what has historically characterized Swedish political and administrative culture” (Lundqvist, 2004, p. 422). Lerman (2009) describes this in a similar way, “The state has decided when the municipalities are not allowed to overthrow the interest of the state. But if you study the environmental quality standards for water, then the basis is scientific, without political considerations. Why is good ecological status in a certain water body going to overthrow the plan monopoly?” (Lerman, 2009).

**Study area**

The Northern Baltic Sea RBD is the smallest of the five Swedish districts by area covering approximately 44 000 km², including
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Fig. 1. (a) Organization of water management in Sweden before implementation of the WFD. Horizontal integration: Institutional interplay between land use planning and water planning. Some vertical collaboration exists, the national and regional level is responsible for coordinating, advising and supervising water planning. Mismatches between political boundaries for water planning and natural boundaries for river basins. (b) Organization of water management in Sweden according to the WFD. Disintegrative process between land use planning and water planning due to implementation of the WFD at the supra-regional level. Spatial fit at the supra-regional level between administrative and natural boundaries. Vertical collaboration is more intense, but WFD implementation at the supra-regional level might give rise to conflicts since the local level is still responsible for water planning at the local level.

Fig. 2. (a) The five river basin districts of Sweden: 1. Bothnian Bay, 2. Bothnian Sea, 3. Northern Baltic Sea, 4. Southern Baltic Sea, 5. Skagerrak and Kattegat. (b) The Northern Baltic Sea River Basin District, with the largest catchment in the district marked, Norrström including the Lake Mälaren, where the Oxunda sub-catchment is situated. (c) The Oxunda River Basin including the studied municipalities. The river mouth situated in the northwestern part at the municipality border of Sigtuna and Upplands-Väsby. ©Lantmäteriet Gävle 2010. Permission I 2010/1625.
estuaries and adjacent coastal waters. However, it has the largest population, 2.9 million. Of these people, 2.6 million are in urban areas, and it is expected that the population will grow between 20 and 35% from 2005 to 2050 (Office of Regional Planning, Stockholm County Council, 2010). The studied sub catchment is situated in the eastern part of the RBDA where it enters Lake Mälaren, which is located in the largest catchment within the district (Norrström; Fig. 2). Lake Mälaren is used as a fresh water reservoir, and discharges into the Baltic Sea via Stockholm and Södertälje. The Oxunda Catchment covers 270 km² and is situated at the border between the urban suburbs of Stockholm in the southern part, and more rural areas of forest and agriculture in the northern part (Northern Baltic Sea River Basin District Authority, 2008). The water quality issues in the area are related to the land use, and eutrophication and environmental pollutants via storm water runoff from urban areas is currently the main focus (Northern Baltic Sea River Basin District Authority, 2008). Water quality has been studied in the River Oxunda by the county administrative board since the 1960s, and there has been a particular focus on the high nutrient load of nitrogen and phosphorus. The primary problems associated with a high nutrient load within the sub catchment are eutrophication of water bodies within the catchment. Lake Mälaren is also a partly eutrophicated fresh water reservoir, and the Baltic Sea is known to be subject to eutrophication (Darraq et al., 2008; HELCOM, 2009). Larsson et al. (1985) found that the inputs of nutrients into the Baltic Sea have increased eight times for phosphorus and four times for nitrogen since the nineteenth century. To a large extent, this is a result of historic land use changes within the Baltic Sea Drainage Basin during the last two centuries, where draining of wetlands and lakes, increased agricultural fertilization, upstream dam building projects, increased industrial activities as well as a population increase have contributed to the change.

Five municipalities, Sigtuna, Sollentuna, Täby, Vallentuna and Upplands-Väsby, are responsible for the local land use planning and water planning in the Oxunda Catchment, and these cities started the Oxunda Water Cooperation in 1999. Each of these municipalities takes their drinking water from Lake Mälaren. The goal of the cooperation is to promote biological diversity and retain or improve the value of the environmental and cultural characteristics in the sub catchment (Oxunda Water Cooperation, 2009). The Oxunda Water Cooperation is not an official water council and participation is limited to the municipal representatives. According to one of the coordinators, the project is composed of a mutual agreement among the five municipalities, instructions for the project, means of control and objective instruments together with a political group and a group with officials. One of the municipalities administers the project, and is therefore responsible for working out local programs of measures, contacts with relevant authorities and implementation of the measures. Projects such as cleaning and detaining storm water, recreating the meandering of water courses and decreasing algal blooms in the lakes are some examples of ongoing processes conducted by the cooperation (Oxunda Water Cooperation, 2009).

Methods

The study is based on qualitative interviews of employees that handle issues concerning physical planning including land use planning and water planning at the municipal level. One representative each from the County Board in Stockholm, the Northern Baltic Sea RBDA in Västerås and the Swedish Association of Local Authorities and Regions was also interviewed and official documents from governments and stakeholder organizations were evaluated. Individual interviews were conducted with two persons in each of the five municipalities. Since the WFD-related legislation at the local level may influence the municipal plan monopoly we interviewed the employees heading the planning department as well as the employees responsible for water issues in the planning process. Specifically, the physical planning interviewees (hereafter referred to as senior physical planners) were responsible for the planning process in the municipality, including the municipal master plans and detail plans. The environmental planning interviewees (hereafter referred to as environmental planners) had titles such as environmental coordinator, planning ecologist and environmental planner. Specifically, the environmental planners handled local-level WFD implementation (storm) water issues in the planning process, and inter-municipal cooperation, including interaction with the Oxunda Water Cooperation. Fresh water supply, wastewater treatment, and associated planning were handled at other departments in all five municipalities. In four of the five considered municipalities, the interviewed environmental planner was located at a department with physical planning functions, headed by the interviewed senior physical planner. This organization was recently introduced in several of the municipalities. The fifth municipality had the environmental planner placed at the department for Environment and Health. In all cases, interactions between environmental planners and senior physical planners were primarily to discuss storm water planning in development projects. The list of the interviewees is attached in appendix A. Both physical and environmental planners collaborated with the County Board on water issues, the environmental planners mainly with the department that works together with the RBDA and the senior physical planners mainly with the planning department concerning groundwater and storm water questions.

A letter of introduction was sent to each of the respondents in advance with an explanation of the project and an overview of the questions that were going to be discussed. The questions targeted the following main issues:

(i) Current intra-municipal cooperation on water issues and other aspects of physical planning (only municipal level)
(ii) Current cooperation on water issues between (a) different municipalities, and (b) concerned parties at different administrative levels (all levels)
(iii) To what extent the WFD and the new RBDA had influenced the municipal handling of water issues, if any (only municipal level)
(iv) Possible future decrease in municipal influence over land use and water use due to the WFD, especially in the light of the new environmental quality standards (all levels)

The interviews were recorded, edited, and translated into English. Since the purpose of the interviews was to give a general impression of the interviewee's opinion, some statements were worded, giving them a character of written language. The interviews were also concentrated in those parts lacking valuable information according to the methodology described by Kvale (1997). The interviewees were later given an opportunity to comment on their statements and our interpretations.

Based on the interview responses to the above main issues, we expect that we can interpret how the WFD implementation influences operational water handling at the local level (i.e. targeting the main aim of this study), and identify possible problems. For example, if the responses to (i) and (ii) showed that current municipal cooperations on water issues are perceived to be non-functioning, main issues in WFD-implementation may include (depending on the responses to (iii) and (iv)) organizing of efficient local level management and possibly increasing the awareness and acceptance of WFD-related goals. Alternatively, if the responses to (i) and (ii) showed that current cooperations are perceived to be well developed and functioning, main issues in WFD-implementation may include how to maintain local-level involvement, and/or how to shift priorities toward the new environmental quality standards.
The sub catchment of this study, the Oxunda Catchment within the Northern Baltic Sea RBD, was selected because of its well-functioning inter-municipal water cooperation according to the RBDA (Northern Baltic Sea River Basin District Authority, 2008). As pointed out by Bishop et al. (2009) the implementation of the directive constitutes a process of learning. Since the inter-municipal water cooperation was already established before the decisions regarding the WFD were made and was influenced by the discussions within the European Union concerning management according to natural boundaries, it is expected that the interviewees are well-informed. Hence, the interviews allowed more in-depth discussions of questions brought up by implementation of the WFD and the associated new way of organizing water management. The approach used in the present study is consistent with the concept of “studying what may be” (Schofield, 1990), especially with regard to the chosen study area (Oxunda Catchment), where the situation (in this case with respect to the principles of the WFD) is more developed than in other catchments. This gives an opportunity to analyze how the situation may develop in other areas in the future from a local level perspective. The fact that the interviews targeted many employees at the local level can enable a relatively detailed evaluation of (different) views. However, the chosen local to regional focus and the targeted, relatively small, river basin also implies that (additional) problem dimensions that may occur in larger inland water systems, shared among several EU member states, cannot be evaluated from the present material. Furthermore, the vicinity of the study area (with historical and ongoing agriculture) to the expanding city of Stockholm also means that issues related to land use change are important on the interviewee agendas, which is much less of an issue in areas that are not subject to pressures from an increasing population. The current investigation is therefore more relevant for conditions prevailing in many parts of southern Sweden, where agriculture is relatively important, but regional centres (e.g. surrounding the three major cities in Sweden) are expanding, than for conditions in many parts of northern Sweden, which are forest-dominated and sparsely populated, with decreasing populations.

More generally, the combination of interviewee positions and study region characteristics considered here imply that water-related challenges and problems may be shared, at least, with:

(I) Countries or regions in which there is a mismatch between the administrative units for spatial planning and the boundaries of the river basin districts, which for instance is common in the northern region of Europe (Hedin et al., 2007).

(II) Countries in which the regional organization with respect to the WFD is similar to the organization in Sweden, e.g. Norway, Germany, Estonia and Finland.

(III) Expansive regions in which interests and pollution impacts of both urban populations and rural populations need to be considered.

Results

Issue (i), current municipal water handling

The environmental planners expressed satisfaction with the interplay between water issues and planning issues. Those who were situated at a planning department emphasized the advantage of being situated there. “It is a real good position to be situated at the Planning Department. We have money, which is not the case at the Department for Environment and Health. The municipal ecologists placed there have difficulties achieving things, while I can join the development projects and insist on getting compensation in favor of the environment” (Interview 7). Furthermore, the senior physical planners expressed their appreciation over the fact that the environmental planners were placed at the Planning Department. A common opinion was that water issues today were so important that they may be viewed as a prerequisite for a good planning. “We see it as an advantage having environmental staff in the Planning Department since environmental questions are becoming more and more important with increasing demands on making Environmental Impact Assessments” (Interview 12). “Today water issues have become more important and moved over to the Planning Department, as a result of an increased level of ambition not only for water issues, but for all environmental issues. This is only the beginning” (Interview 10). The head of the Planning Department in the only municipality in which the environmental planner was placed at another department (Environment and Health), was satisfied with the cooperation between the two departments; but admitted that there could be problems with resources: “The Department for Technical Measures and the Department for Environment and Health is located outside our organization and we have no influence on their budgets. The municipalities often say that we have to plan harder and they engage people at the Planning Department while sometimes forgetting that the whole chain has to work” (Interview 6).

Issue (ii), current collaborations

All environmental planners viewed the Oxunda Water Cooperation as the most important collaboration project with respect to water issues. Specifically, they saw it as a model for other possible cooperation projects. The project success was explained by the size of the catchment and a political will that made quick decisions possible. “What we are doing has an enormous impact; it is easy to get public support. We are in a more operational phase and now, after ten years, we can see a trend and the environmental situation in waters is improving” (Interview 3). One of the environmental planners played a key role in the beginning of the project, but the interviewed participants considered the cooperation so well established that they did not think that current progress could be linked to achievements of a single person. “We are all real enthusiasts now, we are doing well and we are good partners. I really think this kind of cooperation should be recommended; it is highly successful” (Interview 5). Even before implementation of the WFD, participants in the Oxunda Water Cooperation attempted to harmonize their work with the intention of the WFD, working with water management according to the natural boundaries of the river basins. “In that manner we became somewhat of a model for the River Basin District Authorities” (Interview 3). Perceived shortcomings of the project included unclear financing and the cooperation being limited to the municipalities. Environmental planners had different views regarding the value of using the opportunity given by the WFD to establish an official Water Council. Some feared that this could generate bureaucracy and lead to fewer measures being taken, while others acknowledged that this could widen the circle of participants and increase the power of the project. Some municipalities of the Oxunda Water Cooperation were planning new cooperation projects in other river basins with other municipalities, in some cases including a broader range of participants. However, there was apprehension concerning this: “There is a risk when many persons are involved that one cannot speak one’s mind. Maybe it is better to occasionally involve a reference group” (Interview 9).

The senior physical planners considered the Oxunda Water Cooperation to be an important association even if they were not personally involved: “The Oxunda Water Cooperation is highly valuable and something that the municipality is proud of” (Interview 4). According to the County Board in Stockholm there are collaboration projects similar to the Oxunda Water Cooperation in several sub-basins of the region, although there are no official Water Councils within the county of Stockholm. Based on their view, the
existing water cooperation is very useful since it is organized according to river basin boundaries. The cooperation also initiated remediation measures and discussions on their possible results. However, one perceived weakness was the lack of a broader stakeholder involvement, which may result in local opinions being missed. The possibility of involving more stakeholders is sometimes problematic. “Involving the public force you need to pull yourself together, you become an authority, questions are asked and maybe one cannot speak one’s mind” (Interview 1).

Issue (iii), influence of the WFD and the new RBDA

The general opinion of the environmental planners was that water management practices had not changed appreciately at the municipal level due to implementation of the WFD. Comments made included: “Bad waste water treatment systems are still approved by the municipality. We should say no to that. The WFD is not supporting us in this issue” (Interview 7). Despite such concerns, the majority of the environmental planners believed that the WFD may provide some support for improved handling of water issues, although concrete examples are lacking due to the directive’s novelty. “The difference today is that there are persons at the County Board working full time with RBDA issues. There is an ongoing systematic work and an increase in ambition level” (Interview 11). The representative from the County Board in Stockholm also viewed the resource reinforcement as substantial and thought that water management was now better organized.

Furthermore, the senior physical planners expressed that they had experienced increased focus on water issues after the implementation of the WFD, even though they were not directly involved in WFD-related work. However, water is one of many factors that have to be taken into consideration within the planning process: “Societal planning is coordination of different interests and therefore also a very complex matter where these interests have to be weighed against each other. The WFD is one of many factors to consider. However, additional restrictions or decisions that are proposed need prior discussion and/or description of how to apply them in the planning process and how to weight them against other interests. Weighing interests and finding means of compensation must always be possible. Planning is coordination.” (Interview 6). “I cannot say that I have noticed an impact of the WFD. There is, however, a great focus on storm water issues. The last two years they have almost dominated the planning process” (Interview 8).

Both the coordinator for the WFD at the County Board and the director for the RBDA emphasized the importance of the new coordination at the river basin level and coordination between counties. “We did not call it water management before the WFD” (Interview 1). “Before the introduction of the WFD water management in Sweden did not exist, at least not in the way we define it now, and in principle there were no existing objectives for water management or at least there are new types of objectives now, questions of ecological and chemical status” (Interview 2).

Issue (iv), possible decrease in municipal influence due to the WFD

Environmental planners had generally high expectations of the WFD as a powerful instrument for environmental improvements, and felt that these had not yet been fulfilled. The directive has also been perceived as too generally formulated, and the legal status of the environmental quality standards was perceived to be unclear. “The legally binding environmental quality standards make the municipal politicians ask; what possible sanctions are there? The answer is that after we have reported to the EU there might be fines for Sweden. The local politicians then feel detached from such higher-level implications and well…” (Interview 5). “The main problem that I can foresee is that these WFD issues will be ignored since the directive is not so legally binding” (Interview 9). One divergent comment was: “These [the environmental quality standards] will be a strong juridical instrument. We are already working in the right direction; the difference is that, when working with the detailed plans, the demands on formally showing how to fulfill these standards have increased” (Interview 3).

Some senior physical planners thought that the impact of the WFD was modest, whereas others thought that the WFD implied severe limitations for the municipality, even threatening the municipal plan monopoly stated in the Planning and Building Act. “Traditionally the municipalities in Sweden have had a large responsibility when compared to many other countries in Europe. The situation in Europe is different and this is now probably influencing us giving a more top-down-perspective” (Interview 10). Another senior physical planner toned down the issue: “These quality standards are a foreign body in the Swedish tradition, where we always worked by weighing things against each other. We’ll see what is going to happen in the long run. In the beginning it is always a fuss but then in practice it will show up that our old tradition to weigh different interests against each other will remain in the long run. We will make compromises if we think one solution is better even if this means that the environmental quality standards are not fulfilled” (Interview 4). The Oxunda Water Cooperation stated in their comments on the draft river basin management plan that the legal status of the environmental quality standards appeared to be vague. The municipalities were given a long list of measures to implement but no concrete financial support. They also expressed a need for guidelines and support for emission abatement of long-term contamination by wastewater, storm water and point sources. Further, they emphasized the importance of cooperation on the local scale, as well as the concern about a lack of these issues in the document (Northern Baltic Sea River Basin District Authority, 2009).

The coordinator for the WFD at the County Board in Stockholm stated: “We do not know what legal status those environmental quality standards are going to get relative to other standards in the Environmental Act. We are examining this now and there is not much to lean upon. All municipalities wonder what is going to happen, the county governor wonders, everyone wonders” (Interview 1). The director for the Northern Baltic Sea RBDA did not perceive the WFD to be more top-down than any other legislation in Sweden, regardless of whether the legislation is based on decisions in the European Union or in the Swedish Parliament. “The reaction is more because the municipalities are used to plan their land and water use themselves and within their own boundaries, now they are forced to go outside these boundaries and find ways to cooperate” (Interview 2). The representative of the Swedish Association of Local Authorities and Regions depicted two possible scenarios at the municipal level as consequences of the WFD, either the environmental quality standards are going to be weakened like the standards for air have almost been, or, if the standards will be literally put into practice they will be immensely governing. In that case, the monopoly on making plans may be weakened; however, it is difficult to know to what extent, “The RBDA cannot answer… sometimes they do not even know what an environmental quality standard is” (Interview 13).

Synthesis of results

At the municipal level, the main views on the current state of WFD implementation were:

- WFD implementation has not resulted in any appreciable change in water management practices.
- It is still not clear how binding the directive, especially the environmental quality standards are going to be (this opinion was shared by regional level interviewees).
It is still not clear what kind of cooperation the RBDA wants to promote.

Resources at the County Board level have been greatly improved, but there has been no improvement at the municipal level.

These views reflect the belief by the senior physical planners and environmental planners that the WFD objectives and implementation methods are indistinct. Consequently, both the interviews and the local written response to the draft river basin management plan expressed the need for guidance on how to interpret environmental quality standards and WFD-related legislation, as well as for how WFD-related cooperation should be implemented. Nevertheless, interviewees at the municipal level also reported that they had experienced an increased focus on water issues and extended cooperation between land use planners and water planners during the last few years.

Senior physical planners and environmental planners shared the following main views regarding current pre-WFD management practices:

• The Oxunda Water Cooperation is a well functioning inter-municipal collaboration project.
• The value of using the opportunity given by the WFD to establish an official Water Council is questionable.
• Intra-municipal collaboration between water issues and physical planning issues is well functioning and highly valued.

However, senior physical planners emphasized that water is one of many factors involved in the planning process, and stressed the importance of weighing different interests against each other to obtain the best outcome for the entire municipality.

The expectations regarding the directive were more evident among environmental planners than senior physical planners, probably due to the better knowledge of the directive in the first group. The main expectations regarding the WFD were:

• The environmental planners expected that the WFD would bring more focus to water issues and support tougher environmental measures than has been seen to date. They were disappointed with the strength of the directive, which was perceived to be low.
• The senior physical planners expected that the monopoly on municipal planning would remain after implementation of the WFD, but feared that the WFD would add constraints to the planning process.

At the municipal level, we found that senior physical planners were conservative in the sense that they consider pre-WFD weighting of land-use and water use issues to be well balanced. Further, senior physical planners expressed fear that implementation of the WFD may offset this balance too far toward water issues. Conversely, municipal environmental/water planners want to increase the weighting and consideration of water issues in the planning process, and fear that the WFD may be too weak to support such a shift.

Discussion and conclusions

Implementation of the WFD may cause a disintegrative process by moving parts of the water planning from the municipal level to the supra-regional level, which implies that compromises can be solved to a lesser extent at the municipal level. Accordingly, when the WFD is fully implemented, there is a risk that conflicts will arise between the supra-regional and municipal levels when it comes to coordinating land use planning and water planning. Carter (2007) indicated that the integrated environmental management that includes both water planning and land use planning and is conducted at the municipal level in Sweden with the support of the municipal monopoly is threatened by the WFD and that this might give rise to a dual system of water management. The results of our interviews indicated that there is such a risk, since the view of the WFD of senior physical planners and environmental planners differed, with the former thinking that the WFD could bring too much focus to water issues, and the latter thinking that WFD could be too weak. The different views represented by the two groups reflect the conflict between the scientific and the socio-economical perspective, between legislation based on the Environmental Act and the Planning and Building Act and between environmental conservation and exploitation. Emmelin and Lerman (2006) used the concepts “environment” paradigm and “planning” paradigm to describe this.

However, the results of the current interview also showed that despite their differing perspectives on water issues, both environmental planners and physical planners viewed the goal formulation and achievements of the inter-municipal Oxunda Water Cooperation as highly successful. This view is also shared by the RBDA, which has officially stated that the water cooperation between the five municipalities belonging to the Oxunda Catchment is well functioning (Northern Baltic Sea River Basin District Authority, 2008). These results generally imply that the environmental planners in the Oxunda Catchment function as integrating actors both on horizontal and vertical scales, which means that they can contribute to environmental problem solving (Young, 2002) and mitigate effects of scale-related mismatches (Moss, 2004). For example, even if the environmental planners are formally guided by the Environmental Act (including the WFD), they expressed an understanding for different needs in the municipal planning process during the interviews. In this light, the primary explanation for the success of the Oxunda Water Cooperation must be that there are well functioning goal and resource compromises between physical planning and environmental planning units. Accordingly, the results of the present study support the reasoning of Carter (2007) who stated that effective collaboration between authorities and municipalities may prevent severe system malfunction such as dual systems of water management. Such effective collaboration could also potentially mitigate the effects of problems anticipated by Hedelin (2005), regarding low accountability and the legitimacy of WFD-regulations implemented in Sweden, caused by unclear formal relationships between the supra-regional and municipal levels.

The results of the present study also showed that municipal-level employees expressed concerns regarding the lack of financial support. Considering the relatively ambitious goals of the WFD, it is likely that many measures to improve water quality would need to be taken at the local level, at least in regions where both agricultural and urban development causes eutrophication and other pollution problems in inland waters, as in the considered study area. The financial concerns of the municipal-level employees are shared by Hammer et al. (2011), who pointed out that many costly measures, such as wetland creation for decreasing nutrient loads to recipients must be taken at the local level. Moreover, the continued and possibly extended need for local level water quality monitoring indicates that the lack of financial support from the national level to the municipal level is problematic.

It is obvious that necessary evaluations of the effectiveness of WFD-related remediation measures will require detailed understanding of past fluctuations in environmental variables (Hannerez et al., 2005). It is of particular interest to maintain monitoring that has been on-going for periods of time (e.g. decades as in the case of the Oxunda Water Cooperation) to prevent scientifically useful data series from being discontinued or terminated as a result of changes in the institutional environment. These findings supports the general opinion of the interviewees that resource improvements from
the county board level to the municipal level are required to maintain existing long-term monitoring and manage new WFD-related work with targets, action plans, new action plan-related monitoring, remediation measures, and results communication.

Both senior physical planners and environmental planners pointed out that the WFD-related environmental quality standards lack a precise definition, and expressed the need for guidance regarding their interpretation. This highlights the more general problem that individual EU countries can choose to interpret these standards in different, including potentially problematic, ways. For example, a certain interpretation may imply that a relatively large fraction of water bodies are classified as having an ecological status below “good”, which then would necessitate that they be improved by 2015 according to the WFD. The standards can then provide a basis for unrealistic goal formulations, without necessarily providing aid in prioritizing remediation measures. In such cases, there is a risk that available (finite) resources for remediation will be used inefficiently. As indicated earlier, in Sweden, the suggested legally binding environmental quality standards challenge the municipal routine of weighing various good objectives against each other (Lerman, 2009), as well as the portion of the Swedish Environmental Act that states that benefits of measures must be proportional to their costs.

Several actors in Sweden, including the Municipality of Stockholm, the federations of Swedish Farmers and the Swedish Association of Local Authorities and Regions, are raising opinions regarding legally binding environmental quality standards for various reasons. For example, the Swedish farmers may not want to have further restrictions concerning the use of fertilizers. As shown by the interview responses of this study, the senior physical planners, who are supported by the municipal plan monopoly and have many different interests to take into consideration, consider neglecting some violations of the environmental quality standards and associated decisions by the RBDA, even if the standards will be legally binding. This is particularly likely if sanctions seem unclear. However, the extent of such neglect must depend on the strength of sanctions from the RBDA against municipalities that fail to meet their requirements. In turn, this is likely to be related to the strength of sanctions imposed by the European Union on the Swedish government if Sweden fails to achieve the objective of good water status. The current case of Sweden’s failure to comply with the EU’s air quality standards can be taken as a sign of how far the European Union is prepared to go to impose the environmental objectives. Currently, the European Commission has given Sweden two warnings for not fulfilling the objectives and since the Swedish Government has not taken necessary measures prescribed by the European Commission (2010) the case has been taken to the European Court of Justice. Given that the EU will treat WFD-related standards in a similar way as the air quality standards, this example shows that the municipalities must follow WFD-related standards more closely during their planning process than some of the interviewed physical planners anticipated. However, a recently proposed change in the Swedish Environmental Act confines the stricter requirements for the environmental quality standards to those quality standards containing limit values (Swedish Government, 2010). Regardless of how the legislation will be formulated, the results of the interviews show that necessary municipal involvement in WFD-related measures for improving water quality will be difficult to achieve without associated guidance and financial support from the superior levels to the municipal level. The complexity concerning cooperation between different levels and between different institutions must be taken into account by the European Union when supra-national directives are imposed. Different outcomes of ongoing and future implementations at the national level must be seen in the context of how the individual member countries are organized.

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Appendix A. Interviews

1. Coordinator for WFD, Preparatory Secretariat, County Board of Stockholm, 07.04.2009
2. Director of Northern Baltic Sea River Basin District Authority, 16.04.2009
3. Municipal Ecologist, Sollentuna Municipality, 06.03.2009
4. Head of Planning Department, Sollentuna Municipality, 06.03.2009
6. Head of Planning Department, Upplands-Väsby Municipality, 08.04.2009
8. Head of Planning Department, Sigtuna Municipality, 07.04.2009
9. Environmental Planner, Vallentuna Municipality, 04.05.2009
10. Head of Planning Department, Vallentuna Municipality, 08.04.2009
11. Environmental Planner, Täby Municipality, 06.04.2009
12. Head of Planning Department, Täby Municipality, 06.04.2009
13. Representative of Swedish Association of Local Authorities and Regions, 02.06.2009

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Lerman, Peggy, juridical advisor on environmental matters, Lagtollen AB, personal communication 01.06.2009.


Paper II
Saving the Baltic Sea, the inland waters of its drainage basin, or both? Case study Northern Baltic Sea River Basin District, Sweden

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Abstract

The Baltic Sea and the inland waters of its drainage basin suffer from high nutrient loadings and severe eutrophication. This study investigated whether one can identify inland areas of high impact that makes considerable contributions to problems observed in both inland and coastal waters. In this case study we spatially analyzed the degree of eutrophication and phosphorous load contributions to inland and coastal waters from 27 different catchments of the Northern Baltic Sea River Basin District in Sweden, which covers an area of 44,000 km² and includes the city of Stockholm. The results showed that the group of catchments with the highest phosphorous load contributions to their outlets per arable area only overlaps marginally with the group of catchments that contains the highest degree of eutrophicated water bodies. Hence, the high-eutrophication group of catchments cannot be expected to recover more than other catchments if a remediation strategy that primarily targets agricultural areas of high impact is implemented. Although not fully compatible with the intention of the European Water Framework Directive, such a strategy can be efficient for decreasing the total nutrient load contributions, provided that it can be accepted that some catchments will remain more eutrophicated than others due to human activities. The findings presented herein also show that a preferential mitigation of Baltic Sea eutrophication following the Baltic Sea Action Plan is most likely to come at a cost of a higher degree of eutrophication in the inland catchments that discharge into the principal Lake Mälaren.
1. Introduction

The Baltic Sea, which is one of the largest brackish seas on earth, has an area of approximately 377,000 km$^2$ and a fourfold larger drainage basin populated by 85 million people. The Baltic Sea is subject to severe eutrophication, which causes cyanobacterial blooms and the formation of dead zones in the oceans (Stal et al., 2003; Diaz and Rosenberg, 2008). Indeed, this is one of the most severe environmental problems in the EU (Aarnio et al. and references therein, 2007). The riparian EU countries together with Russia act within the Helsinki Commission (HELCOM), which is the governing body of the Helsinki Convention from 1974 that aims at protecting the marine environment of the Baltic Sea Area. In 2007 HELCOM, now also including the European Commission, adopted the Baltic Sea Action Plan (BSAP) with the goal of achieving good ecological status in the Baltic Sea by 2021. The BSAP specifically considers eutrophication, hazardous substances, biodiversity and good environmental performance of shipping. The new EU Marine Strategy from 2008 and BSAP are complementary and compatible with each other (Backer et al., 2010).

The inland water quality of the Baltic Sea Drainage Basin is primarily regulated by the EU Water Framework Directive (WFD), which was introduced in 2000 with the goal of achieving good status of surface water, groundwater, estuaries and adjacent coastal waters by 2015. A long political process that was also influenced by environmental groups preceded the decision. This process included negotiation and conciliation processes between the European parliament, the European Commission and the member states (Kaika and Page, 2003). The directive requires that inland waters be monitored and characterized. In a six year water management cycle, common target-oriented environmental goals and science-based quality standards were formulated, and a program of measures and management plans that regulate emissions were developed (Howarth 2009; Entson and Gipperth 2010; European Parliament and the Council of the European Union, 2000). The first stage in the water management cycle imposed by the WFD is to characterize all water bodies through a status classification, in which a combination of ecological and chemical statuses are used for surface waters. Unless the conditions are at least classified as good, remediation measures must be taken during
subsequent stages in the WFD management cycle. A good ecological status can only be reached in water bodies that only deviate slightly from a pristine state with no or minimal human impact, in the directive called “undisturbed conditions” (European Parliament and the Council of the European Union, 2000). Reducing the effects of eutrophication of inland waters, estuaries and coastal waters is therefore of great importance to achieve good ecological status according to the WFD (Hilton et.al, 2006; Cherry et. al, 2008). Increased growth of macrophytes is the primary effect of the eutrophication process in lakes and rivers, thereby threatening the function of the ecosystem (Mainstone and Parr, 2002; Hilton et.al, 2006).

Inland pollution sources are a primary cause of eutrophication of the Baltic Sea. In the drainage basin, the loads to surface waters predominantly emanates from diffuse sources (mainly agriculture) of nitrogen (N) and from point sources (primarily municipality waste water treatment plants) of phosphorus (P). The nutrients reach the Baltic Sea primarily via rivers within the basin and direct discharge from e.g. wastewater treatment plants (75% for N and 95% for P). Riverine nutrient loads consist to large degree of diffuse loads, primarily from agriculture, 60% for N and 50% for P (Andersen and Laamananen, 2009). This study focused on loadings from P, which is the main limiting factor of growth in lakes and watercourses, while both N and P are important for coastal waters, estuaries and for the Baltic Sea (Swedish EPA, 2007 b, c, Granéli et al., 1990; Pitkänen and Tamminen, 1995; Tamminen and Andersen, 2007, Conley et al., 2009). In the latter waters, the relative importance of N and P varies between basins and seasons.

The WFD-goal of achieving good ecological status of all inland water bodies within the EU implies that emissions from inland sources must be considerably reduced. Accordingly, drastic land use changes are needed, which are also needed to achieve real improvements of the eutrophication situation in the Baltic Sea (Wulff et al., 2007). If the WFD goals could be fully achieved, the conditions for fulfilling the requirements of the BSAP / Marine Directive for the ecological status of the Baltic Sea would also be met. However, it is clear that the goals cannot be fulfilled, at least not within the coming decade, as required by the WFD and the BSAP. The failure to meet these goals will occur for three main reasons. (I) The relatively radical measures needed are not feasible from a
socio-economic perspective (Volk et al., 2009). For example, in the most populated river basin district (RBD) of Sweden, the Northern Baltic Sea (NBS) RBD, the reduction demand of P from the RBD authority (RBDA) of 100 tons per year is larger than the estimated anthropogenic load contribution from agriculture within the RBD to the Baltic Sea (Larsson and Pettersson, 2009). The Swedish Environmental Protection Agency foresees that the target reduction in P discharged to the Baltic Proper will not be met (Swedish EPA, 2009), costs may be high, and it is not clear what measures can be taken to address these issues (Swedish Government, 2010). (II) Retention processes and ecosystem response times can delay targeted effects of mitigation measures considerably. Indeed, P loading to the surface and coastal waters may continue to increase, even if the nutrient source inputs are stabilized at present levels owing to slow transport through the subsurface water systems and even subsequent release (Darracq et al., 2008). Furthermore, ecosystems need to answer to measures taken, which may considerably prolong the time it takes to reach WFD targets (Hering et al., 2010). (III) WFD-implementation requires involvement at many administrative levels. Not least at the local (municipal), awareness of WFD-targets is still relatively limited (Andersson et al., 2011), which indicates that it may take time to address them in an effective way.

Since WFD and BSAP goals cannot be fully met in the near future, it is clear that there is a need to prioritize certain (sub) goals, regions, and/ or water systems. A key question asked herein is if, and to which extent, one can identify “high-impact” areas that have or cause multiple problems, that can then potentially be addressed in a relatively efficient way by tailoring region-specific remediation measures. As a case study, we spatially analyze the degree of eutrophication, and phosphorous load contributions to inland and coastal waters from 27 different catchments 1 of the NBS-RBD, which covers

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1 According to the European Water Framework Directive, a river basin is defined as, “The area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta.” River Basin Districts in Sweden contain several river basins that are referred to as catchments in this study. The dominant catchment within the NBS-RBD, Norrström, including Lake Mälaren, also contains several sub-catchments, which are also referred to as catchments in this study.
an area of 44,000 km$^2$ and includes the city of Stockholm. For example, it is conceivable that the same key areas in mixed rural-urban regions such as the NBS-RBD could be shown to have high anthropogenic load contributions to inland water systems, high anthropogenic load contributions to coastal areas and the sea, and a high degree of inland water eutrophication. Then, (various) problems related to WFD-regulated inland loads, BSAP-regulated loads to the coast, and eutrophication problems regulated by both WFD and BSAP can potentially be decreased simultaneously by taking measures to decrease anthropogenic nutrient loads within the (spatially limited) high-impact areas. Conversely, if these high-impact areas cannot be identified, it implies that available resources must be partitioned among different goals. A primary challenge would then be to decide on how to compromise within and between goals regulated by the WFD and BSAP, such as whether or not equal priority should be given to inland waters and Baltic Sea waters, and to what extent high anthropogenic loads should be targeted when inland eutrophication problems are particularly severe.

2. Study Area: Northern Baltic Sea River Basin District

The study area consisted of the NBS-RBD (Sweden), which covers 44,000 km$^2$ and is one of five WFD-related RBDs in Sweden. Of these five RBDs four completely drain into the Baltic Sea (fig. 1a) and its sequence of sub-basins and sills. Under normal conditions there is a net outflow from the Baltic Sea through the Danish Straits (fig. 1a). Relatively rare net inflow events involving deeper waters are governed by atmospheric conditions. Additionally, sub-basin responses to human induced pressures are influenced by their varying physicochemical and biological characteristics. The problem of marine eutrophication is known since the 1960s and is today the most serious threat to the Baltic Sea ecosystem (Arnio et al., 2007). The latest report from HELCOM (2010) showed that the total input of P had been reduced by 45% but that N had only been reduced by 30% between 1990 and 2006. Despite the achieved reductions, almost all basins and coastal waters have been affected by eutrophication, except for the Bothnian Bay and northeastern parts of the Kattegat. This situation has been further complicated by leaking sediments having retained nutrients in the past. Diffuse waterborne sources are
responsible for about one half of the total P inputs to the Baltic Sea, and approximately 80% of these originate from the agriculture sector (Andersen et al., 2010).

In addition to land areas, the NBS-RBD is composed of lakes (including lake Mälaren, which has a surface area of 1,100 km²), estuaries, adjacent coastal waters of the Baltic Sea, and islands (including the Stockholm Archipelago) (fig.1b). From a hydrological viewpoint, the NBS-RBD is dominated by the drainage basin of Lake Mälaren, which is also known as the Norrström drainage basin. Lake Mälaren covers a land area of 22,000 km² and discharges to the Baltic Sea through the towns of Stockholm (98% of the discharge) and Södertälje. Lake Mälaren, which is the third largest lake in Sweden, supplies water to about two million people, and consists of several different basins between which the exchange is small. The NBS-RBD has the largest population of the five Swedish RBDs. Specifically, the NBS-RBD has 2.9 million residents, 2.6 million of whom live in urban areas. The population of the region is also expected to grow by 20 – 35% from 2005 to 2050 (Office of Regional Planning, Stockholm County Council, 2010). The land use in the river basin district is mainly forest (61%) and arable land (22%). Till soils dominate the forest area, while clay and fine-grain soils dominate the agricultural area (Northern Baltic Sea River Basin District Authority, 2009a).

The total load of phosphorus from anthropogenic sources in the NBS-RBD has been estimated at 390 tons annually, of which 210 tons are estimated to reach the Baltic Sea (Northern Baltic Sea River Basin District Authority, 2009a). The diffuse nutrient supply through groundwater and transport of surface water from agricultural land dominates, together with emissions from waste water treatment plants, domestic waste water in rural areas and storm-water. In addition to respective mass loading, the relative impact of different sources depends on how their P-fractions impact eutrophication, and the relations between their peak loads and seasonal variations in biological activities (Jarvie et al., 2005). However, taken together, these four main sources account for 97% of the total anthropogenic P load in the district (Northern Baltic Sea River Basin District Authority, 2009a). Phosphorous has been monitored in Lake Mälaren since the 1960s, and the monitoring shows that the introduction of chemical precipitation to the sewage water treatment process led to large improvements in the 1960s and 1970s, reducing the P input to the lake by 60% (Wallin, 2000). Sewage water from the western suburbs of
Stockholm was also diverted from Lake Mälaren to the Baltic, thereby improving the status of regions of the lake close to the city (Willén, 2001). However, nutrient loading of coastal waters from inland sources has lead to poor water quality status and high nutrient levels in the Baltic Sea immediately outside the Stockholm outlet of the Norrström Drainage Basin (Water Information System Sweden, 2009a). The majority of the water bodies within the NBS-RBD are eutrophicated. Indeed, only one out of 963 lakes and water courses were classified as having high ecological status, while 27% were recognized as having good ecological status. Lake Mälaren has been classified as having moderate ecological status in the western part and good ecological status in the eastern part, including the outflow to the Baltic Sea (Northern Baltic Sea River Basin District Authority, 2008).

3. Methods and Scenario description

3.1 Methods
The quantifications and analyses conducted in this study are primarily based on data (2006) from the Pollution Load Compilation 5(PLC5)-reporting to HELCOM (Brandt et al., 2008). These data include anthropogenic P load contributions from different sources within the NBS-RBD to 27 catchment outlets and the Baltic Sea, as well as land use and eutrophication of water bodies within these catchments (Water Information System Sweden, 2009a, Northern Baltic Sea River Basin District Authority, 2008).

Data produced for the RBDA are also analyzed herein, including WFD-related P-reduction demands from a Program of Measures set up by the Water District Board of NBS-RBD. The currently suggested P-reduction demands in the different catchments and the principles of their determination (further explained below) from the Program of Measures will be subject to refinement, and may also be modified or changed (Northern Baltic Sea River Basin District Authority, 2009b). Here, we apply scenario analyses (section 3.2) to investigate the extent to which the use of alternative principles (explained in 3.2) can modify the current suggestion of how reduction demands should be distributed
among catchments, assessing also the robustness of the identified high-priority areas for remediation measures.

The 27 catchments considered here comprise all catchments of the NBS-RBD for which PLC5 data are reported, including those located in the Norrström Drainage basin (grey-lined catchments in fig. 1b) and all adjacent catchments that drain directly into the Baltic Sea (black-lined catchments in fig. 1b)².

The PLC5 data used for determination of P-loads in the catchments³ are based on spatially aggregated information from monitored as well as modeled data of diffuse and point source emissions, and pollutant transport models. More specifically, both the gross loads (emitted at the source location) and the net loads (i.e., load contributions to recipients, which account for retention due to biogeochemical processes along the transport pathways) are divided into a natural and an anthropogenic part. The anthropogenic part of the P-load consists of primary point sources such as waste water treatment plants, industries, septic tanks in rural areas, forest clear cuts, storm water drainage, and the part of the load from arable land that can be derived from agricultural practices (Brandt et al., 2008). In the PLC5 quantifications, the HBV-NP model, described by Andersson et al. (2005) is used to calculate the net load of nutrients. Direct monitoring data describing (net) loads at basin outlets are available for approximately 40% of the Swedish PLC5-basins (from 470 monitoring stations). The data were used to calibrate the HBV-NP model, adjusting retention parameters for groundwater, lakes, and rivers so that the observed net loads at the outlets were consistent with estimated gross loads for the sources (see Andersson et al., 2005, for details). In the present study, we combined data from the PLC5-reporting on the (net) contribution of each PLC5-basin to the Baltic Sea with data describing the loads to Lake Mälaren reported in the Program of Measures of the NBS-RBDA (appendix). The reporting from HELCOM-PLC5 and NBS-RBDA are based on the same observational and HBV-NP modeling material; however, the NBS-RBDA reports do not explicitly state the relative contribution of different

² Data are not presented for some coastal discharge areas lacking well-defined surface run-off, or for islands of the Stockholm archipelago.

³ The PLC5 calculations were made at the small sub-basin scale (so called PLC5-ID) and then subsequently summarized to PLC5-basins and main river basins.
sources (agriculture, waste water, etc) to the PLC5-basin outlets. As a result, the various source contributions to Lake Mälaren are not given. However, the various source contributions to the Baltic Sea are available from HELCOM-PLC5. For each basin, we then estimated the relative contribution of its different sources to the Baltic Sea. Next, these relative contributions were multiplied by the reported loads to the basin outlets located in Lake Mälaren (fig. 1b), to obtain the contributions of the various sources to Lake Mälaren that were not reported. This is consistent with the assumption that the P-retention in Lake Mälaren is the same regardless of its original source.

The percentage of eutrophicated water bodies within a catchment is estimated from biological and physicochemical factors of the water bodies. The content of P is used when making the classification and reference values are set up for nutrients where good status represents at least double the reference value. If the lake or water course is considered to be naturally eutrophicated, specific reference values for the object are used. Monitoring data are often insufficient, in which case either an assessment based on similar objects or an expert assessment is used. (Swedish EPA, 2007a).

A Program of Measure has been set by the Water District Boards in each Swedish district with the goal of achieving good status by 2015; however, this has been prolonged to 2021 for all aquatic systems with eutrophication problems. In the Program of Measures taken by the Water District Boards in December 2009 the measures are addressed to authorities and municipalities. These measures contain the same 37 or 38 measures that have to be implemented to fulfill the standards that have been set for all five Swedish RBDs (Entson and Gipperth, 2010). The Program of Measures for the NBS-RBD also contains estimated basin-specific P-loads (consistent with the above described PLC5 P-load estimations), and the required P (and nitrogen) reduction demands (e.g., in tons per year) that each catchment has to meet to reach the WFD-goal of good status. The required reductions are not legally binding and regard the mass flows of P at the basin outlets, which in the case of the considered catchments are located at either Lake Mälaren or the Baltic Sea. The basin-specific demands were related to the measured or modeled P concentrations in the furthest downstream water body of the catchment, and were taken to

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4 Some smaller areas within Norrström are summarized and presented together as “Mälarens närområden”.

be representative of the entire basins\(^5\) (Martin Larsson, personal communication). The larger the deviation of this P concentration from a likewise estimated natural or undisturbed concentration, the higher the reduction demand. In total, the reduction demands for the NBS-RBD correspond to about 25% of the anthropogenic P load of 390 tons in the RBD. These findings imply that the measures have to be comprehensive and are probably rather costly. The Water District Board of the NBS-RBD has estimated that 80% of the costs during the first management cycle (2009-2015) will be assigned to measures concerning eutrophication (Northern Baltic Sea River Basin District Authority, 2009b).

3.2 Scenarios
We develop three scenarios that represent different conceivable environmental parameters that remediation programmes may target, such as phosphorous loads to different water systems, and the degree of eutrophication. For each of the three scenario-parameters, we estimated the ranks for the top 10 of the 27 considered catchments, giving higher ranks for environmental parameters with higher values. In the subsequent evaluation of the catchment-specific ranking, we specifically hypothesized that catchments of a high-impact character exist within the NBS-RBD. This hypothesis would be supported if one (or a group of) catchments would receive high ranks with respect to many, or all, of the considered environmental parameters. The rankings from the three scenarios are also compared to actual reduction demands given in the Program of Measures within the NBS-RBD.

The ambition with the WFD is to have nearly undisturbed conditions as referred to earlier and agriculture is the main source of the anthropogenic phosphorus load in the district; therefore, a good option may be to focus on the agricultural areas that contribute the highest loads of anthropogenic phosphorus with respect to their surface area. Having an agricultural activity that is more “polluting” would then lead to higher reduction demands. Two scenarios are formulated based on this principle. The first scenario (Scenario A) considers the actual load contribution to the catchment outlet, located either

\(^5\) Of the 27 catchment investigated in the study 15 reduction demands are based on measurements, two on modeled results and ten on estimations based on e.g. the part of the water bodies that are eutrophicated.
at Lake Mälaren (Norrström) or to the Baltic Sea (coastal discharge). The second scenario (Scenario B) considers the actual load to the Baltic Sea. In addition, Scenario C considers the percentage of water courses and lakes within each catchment being eutrophicated. Scenario C represents the most local perspective and possibly also the most WFD impregnated perspective.

4. Results

The reduction demand from the Program of Measures, set up by the Water District Board of the NBS-RBD, varies considerably between the 27 considered catchments of the NBS-RBD (fig. 2; y-axis). Most of the basin-specific demands vary between 0% (no demand) and 40% of the net anthropogenic P load. Five of the 27 catchments have high reduction demands between 45% and 85% of the net anthropogenic P load, which implies that drastic measures would be needed to meet the demands. These areas are referred to as high reduction demand areas in the remainder of the paper. As shown in fig. 2, a considerable part of their anthropogenic P load of these high reduction demand areas (more than 70%) comes from the agricultural sector. However, fig. 2 also shows that some basins in the NBS-RBD in which agriculture is the dominating source of anthropogenic P have low reduction demands. This may be due to lower-than-average overall anthropogenic pressure in the basin.

All of the high-reduction demand areas (red symbols), which have high P-load fractions of agricultural origin, are located in catchments in which the arable land constitutes 20% or more of the total catchment area (fig. 3a). Fig. 3a also shows that the total P-load of anthropogenic origin per catchment area (fig. 3a; y-axis) is relatively high in the two catchments that had the highest reduction demand (Sagån, Örsundaån), which both have their outlets in Lake Mälaren (fig 3a; red triangles). However, the figure also illustrates that there are several catchments in the NBS-RBD (fig. 3a; blue symbols) that have similar area-averaged anthropogenic P-loads to the three other high-reduction demand areas, which have their outlets in the Baltic Sea (fig 3a; red diamonds). There are also many catchments that have similar percentages of arable land as the “red-diamond” catchments. Regardless of the reduction demands, fig 3a shows more generally that catchments that have a relatively high percentage of arable land tend to have relatively
high P-loads of anthropogenic origin. Nevertheless, the scatter is considerable.
Specifically, for any given percentage of arable land (fig. 3a; x-axis), the anthropogenic P-load from agriculture can differ considerably (fig. 3a; y-axis). There might be different reasons for this large variation between areas. For example, areas may be dominated with clay soils that easily leaks P and catchment while containing few lakes, which would make the retention smaller (Brandt et al., 2008). The outlier catchment Tyresån/Trosaån shown in fig.3a, which has a very high P-load of 28 kg year\(^{-1}\) km\(^{-2}\), contains a waste water treatment plant that cleans water for about 300,000 individuals, the majority of these lives outside of the catchment area.

As shown in fig. 3b Sagån and Örsundaån (red triangles), which are located in basins with high degree of arable land (fig 3b; x-axis), have high anthropogenic phosphorous loads to their outlets (fig. 3a) As a result, these basins have high reduction demands (fig. 2), as well as high percentages (>70%) of eutrophicated water bodies in their basins (fig 3b; y-axis). However, fig. 3b also shows that there are a relatively high number of basins that have such a high degree of eutrophication. Notably, the three other high reduction demand areas (fig 3b; red diamonds) are located in basins in which less than, or much less than, 70% of the water bodies are eutrophicated. Fig. 3b also indicates that there is considerable scatter in the expected positive relationship between the percentage of arable land and the percentage of eutrophicated water bodies within the basin, in part due to anthropogenic nutrient loads from sources other than agriculture, such as loads from storm water and private waste water solutions as well as municipal waste water in the relatively densely populated basins of Tyresån and Tyresån/Trosaån.

While figs 2 and 3 show the anthropogenic P-loads to the basin outlets, fig. 4 shows the estimated anthropogenic load contributions to the Baltic Sea. The direct influence on the P-loading of the Baltic Sea from the coastal basins is illustrated by the 1:1 Baltic Sea P-load – basin outlet P-load relationship shown in fig 4 (circles and diamonds). The modeled additional P-retention for the Norrström basins that discharge into Lake Mälaren is shown by their considerably reduced Baltic Sea loadings (squares and triangles). According to this HBV-NP modeling (described in the methods section), the resulting P-loading to the Baltic Sea is between 26 and 72% of the loading to the outlets at lake Mälaren (fig.4). As a result, the two Norrström basins (fig 4; red triangles) that had the
highest P-loads to their outlets of the high reduction demand areas, as well as the highest reduction demands of all basins in NBS-RBD, is estimated to contribute less to the P-loading of the Baltic Sea than two of the other high reduction demand areas, which discharge directly into the Baltic Sea (fig 4; red diamonds).

Taken together, the results shown in figures 3 and 4 hence indicate that there are basins that have similarly high, or higher, anthropogenic P-loads to the basin outlet, degree of eutrophication, and P-load contribution to the Baltic Sea, as the high reduction demand areas identified in the Program of Measures for the NBS-RBD. Table 1 shows more details regarding the 10 basins (shown in bold characters) that have the highest reduction demands in NBS-RBD, from the Örsundaån basin that has the highest reduction demand (i.e., Rank 1 of column 1), corresponding to 85% of its anthropogenic P-load at the basin outlet, to Tyresån/Trosaån, which has the tenth highest reduction demand (Rank 10), corresponding to 32% of its anthropogenic P-load at the basin outlet. Table 1 also shows alternative top-10 rankings of the basins in the NBS-RBD, according to values of the environmental parameters considered in Scenarios A, B and C. Specifically, the top contributions to the basin outlet of the anthropogenic P-load from agriculture per arable area (Table 1; Scenario A) vary between 48 kg·km$^{-2}$·year$^{-1}$ in the Sagån basin (Rank 1) and 27 kg·km$^{-2}$·year$^{-1}$ in the Tyresån/Trosaån basin (Rank 10). The top contributions to the Baltic Sea of the anthropogenic P-load from agriculture per arable area (Table 1; Scenario B) vary between 45 kg·km$^{-2}$·year$^{-1}$ in the Svärtaån basin (Rank 1) and 18 kg·km$^{-2}$·year$^{-1}$ in the Åkerströmmen basin (Rank 10). Finally, the part of water bodies being eutrophicated within highly ranked basins varies between 94% in the Svartån basin (Rank 1) and 62% in the basins of Eskilstunaån and Mälarens Närområden (both share Rank 10). Therefore, these result show that the four Rank 1 positions in Table 1 (representing the highest current reduction demand and the highest parameter values in scenarios A to C) are held by four different basins. More generally, relatively different sets of basins hold the Rank 1 to 10 positions for the different cases. For example, only 5 out of 10 of the catchments on the reduction demand top-10 list also appear on the Scenario A top-10 list (shown in bold characters). This re-appearance of 50% of the basins is only slightly higher than the reappearance of 37% of the basins that would be expected on average, if 10 basins were randomly selected for a top-10 list, out of the 27 considered basins. All of
the top-10 basins of scenario B discharge directly into the Baltic Sea (as indicated by the corresponding blue colored row in Table 1). Therefore, the anthropogenic P-load contributions to the Baltic Sea from the basins discharging into Lake Mälaren are relatively small, owing to the estimated retention of Lake Mälaren. Scenario C, referred to as the most WFD impregnated, contains seven catchments from the top-ten list; accordingly, this scenario has the highest similarity with the top-ten list of high reduction demand areas.

Fig. 5a shows the spatial distribution of the 10 basins that have the highest reduction demands in NBS-RBD (corresponding to the Rank 1 to 10 catchments in Table 1; using the same color coding as in column 1 of Table 1). A comparison with fig. 1 shows that these basins are located both in areas dominated by agriculture and forest. For comparison, fig. 5b shows the location of the top 1 to 5 ranked catchments in scenarios A to C, where the letter of the two-character acronyms refers to the scenario and the following number refers to the basin’s rank in the considered scenario (following also the “Rank” color coding of column 1, Table 1). The different results for different strategies summarized in fig. 5b indicates the need for a discussion concerning what principles should govern efforts to solve the eutrophication problems both in inland, coastal and marine areas.

5. Discussion and Conclusions

According to the WFD, all inland water bodies of the NBS-RBD should achieve at least good status by 2021, and eutrophication is not allowed. These ambitious goals do not aid in the necessary prioritizing between areas. Therefore, we conclude that, for the NBS-RBD, the group of catchments with the highest P-load contributions per arable area (i.e., the Scenario A group) does not coincide with the group of catchments that have the highest degree of eutrophicated water bodies (i.e., the Scenario C group). Accordingly, the high-eutrophication group of catchments cannot be expected to recover more than other catchments if a remediation strategy that primarily targets agricultural areas of high impact is followed. This does not imply that the strategy is less effective in terms of decreasing the total number of eutrophicated water bodies in the NBS-RBD; however, one must then accept that some catchments will remain more eutrophicated than others
due to human activities. For instance, it is possible that this strategy can effectively decrease the total number of eutrophicated water bodies if costs for (remediation) measures are relatively low when P-load contributions per arable area are high. Accordingly, this result raises the question of how reasonable it is to achieve the WFD goal of good ecological status, which specifically means conditions that are nearly undisturbed or pristine, in densely populated areas. The difficulties involved in the definition and ambition of undisturbed conditions are further discussed by Moss (2008) and Bishop et al. (2009). Conversely, even if good status is achieved in all waters, it may not be sufficient to maintain aquatic biodiversity (Hering et al., 2010).

In contrast to the WFD, the BSAP brings priority to catchments with high load contributions to the Baltic Sea. Here, we show that none of the catchments with the highest load contribution per arable area to the Baltic Sea (i.e., the Scenario B group) are located in the Lake Mälaren Basin. In contrast, of the group of catchments with the highest P-load contributions per arable area to the catchment outlet (i.e., the Scenario A group), 60% are located in the Lake Mälaren Basin. Therefore, it is plausible that prioritizing from a Baltic Sea and BSAP perspective must come at a cost of accepting higher P-load contributions from catchments of Lake Mälaren than from catchments that discharge directly to the Baltic Sea. This may also imply accepting a higher degree of eutrophication in Lake Mälaren and its catchments. This result is consistent with the finding in a study conducted on behalf of the Swedish government by the RBDA in the NBS in which the location of measures for improving the situation in the Baltic Sea and in the inland waters of the NBS-RBD differs owing to the high retention in Lake Mälaren and Lake Hjälmaren. From a coastal and marine perspective, areas with high estimated load contributions to the Baltic Sea should be prioritized, at least in the short run (Larsson and Pettersson, 2009). According to the present results for the NBS-RBD, such areas only overlap to a small extent with areas that should be prioritized from the inland water perspective of the WFD.

A fact that can affect prioritization is that the WFD is legally binding in Sweden whereas the BSAP is not, even if the BSAP might be better for the Swedish Government. Furthermore, the overall goal of the RBDs is to fulfill the WFD demands rather than the BSAP. The time limitation is emphasized through the previously mentioned promise
from the Swedish Government to achieve good status for all waters classified as eutrophicated within the WFD system by 2021, and not by 2027 which might have been possible. Measures under consideration include already used ones such as creation of artificial wetlands, protection zones and altered methods for spreading manure. To meet the goals of WFD and BSAP within a reasonable period of time, animal farms may also need to be moved; however, this may be difficult from a political perspective. Furthermore, in 2010, the Swedish Environmental Protection Agency proposed a system with fees for N and P that was initially limited to some point sources but will eventually include other sources such as agriculture (Swedish EPA, 2010). However, such a system may be difficult to introduce for both political and more formal reasons, since a WFD-system with compulsory environmental quality objectives may not be compatible with a system based on fees. For example, the suggested fee system considers relatively large areas, and does not take into account each water body covered by the WFD agenda.

The differences in estimated P-load contributions from different areas to the main recipients exemplified here emphasize the fact that effective remediation measures need to be underpinned by a relatively detailed understanding of nutrient transport processes, and not simply the least retention processes. For example, a possible continued slow leaching of phosphorus through the subsurface water systems may complicate the predictions for the phosphorus load to the surface and coastal waters (Darracq et al., 2008). The results from the Swedish Environmental Protection Agency, which is responsible for the PLC5-reporting show deviations between measured and simulated loads in the river mouths, implying that the P-modeling can be further refined (Brandt et al., 2008). However, the retention processes of phosphorus are complicated. For instance, the retention decreases with increasing water flow and watercourse depth (e.g., Olli et al., 2008). Accordingly, development of additional (site-specific) models will be dependent on relatively detailed monitoring data. The current problem of available monitoring data being insufficient has been discussed by e.g. Hannerz and Destouni, (2006), Bishop (2008) and Hering et al. (2010). Although the WFD has increased the amount of monitoring data, these data are not yet centrally stored and therefore not easily accessible for research and model development purposes (Hering et al., 2010).
Acknowledgements

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Figures and Table

Fig. 1 A. The Baltic Sea drainage area (yellow) and surrounding countries (EU countries typed in blue, country code ISO 3166-1). The five river basin districts of Sweden (green) whereof no 3 and 4 constitute the Baltic Proper: 1. Bothnian Bay, 2. Bothnian Sea, 3. Northern Baltic Sea, 4. Southern Baltic Sea, 5. Skagerrak and Kattegat. Baltic Sea ArcView GIS data from Baltic Drainage Basin Project (BDBP) (UNEP/GRID-Arendal, 2001). B. The Northern Baltic Sea River Basin District with the dominating drainage basin into Lake Mälaren (Norrström) is divided into (sub) catchments and the catchments with direct outflow to the Baltic Sea. Parts of the catchments dominated by forest are green. Data from Swedish water archive. SVAR (SMHI 2010) ©SMHI 2010 ©Lantmäteriet Gävle2010. Permission I 2010/0056).
Fig. 2 The reduction demand in NBS-RBD as part of anthropogenic P load calculated on basis of the annual decrease in P-load decided by the NBS-RBDA 2009 ((y-axis). P load from agriculture are divided into a natural and an anthropogenic part. The x-axis shows the anthropogenic part as part of the total anthropogenic P load. The five catchments with the highest reduction demand in letters.
Fig. 3. A. P load for catchments within the NBS-RBD. Anthropogenic P load per area. Values at the catchment outlet. B. Eutrophicated water bodies in percentage for each catchment.
Fig. 4. The direct influence on the P-loading of the Baltic Sea from the coastal basins is illustrated by the 1:1 Baltic Sea P-load – basin outlet P-load relationship (circles and diamonds). The modeled additional P-retention for the Norström basins that discharge into Lake Mälaren is shown by their considerably reduced Baltic Sea loadings (squares and triangles).
Fig. 5. Ranking of priority catchments within the Northern Baltic Sea River Basin District corresponding to table 1. A) Top ten high reduction demand areas in the Program of Measures for NBS-RBD. B) Top five high rank catchments in the three scenarios where letters refer to scenario and number refer to ranking; Scenario A - Anthropogenic P-load from agriculture per arable area contribution to catchment outlet (Lake Mälaren or the Baltic Sea), Scenario B - Anthropogenic P-load from agriculture per arable area contribution to the Baltic Sea, Scenario C – Level of eutrophication within catchment. Catchment borders from Swedish water archive. SVAR (SMHI 2010) ©SMHI 2010 ©Lantmäteriet Gävle 2010. Permission I 2010/0056.)
Table 1. Ranking of priority basins according to current reduction demands, and values of the environmental parameters considered in alternative scenarios A to C (absolute values shown within brackets). Blue colored cells contain basins with direct Baltic Sea discharge, and uncolored cells contain basins with discharge to Lake Mälaren. Basin names written in bold characters show basins with the top 10 highest reductions in the current Program of Measures (column 2). Basins marked with * lack well-defined surface run-off.

<table>
<thead>
<tr>
<th>Rank</th>
<th>High reduction demand areas</th>
<th>Scenario A</th>
<th>Scenario B</th>
<th>Scenario C</th>
</tr>
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<tr>
<td></td>
<td>Reduction demand in the Program of Measures for NBS-RBD</td>
<td>Anthropogenic P-load from agriculture per arable area: Contribution to basin outlet</td>
<td>Anthropogenic P-load from agriculture per arable area: Contribution to the Baltic Sea</td>
<td>Part of water bodies being eutrophicated within the basin</td>
</tr>
<tr>
<td>1</td>
<td>% of anthropogenic P load</td>
<td>kg km⁻² year⁻¹</td>
<td>kg km⁻² year⁻¹</td>
<td>% of water bodies</td>
</tr>
<tr>
<td>1</td>
<td>Örsundaån (85)</td>
<td>Sagån (48)</td>
<td>Svärtaån (45)</td>
<td>Svartån (94)</td>
</tr>
<tr>
<td>2</td>
<td>Sagån (80)</td>
<td>Hedströmmen (46)</td>
<td>Olandsån/Skeboån* (32)</td>
<td>Tyresån/Trosaån* (88)</td>
</tr>
<tr>
<td>3</td>
<td>Olandsån (77)</td>
<td>Svärtaån (45)</td>
<td>Kilaån (28)</td>
<td>Örsundaån (86)</td>
</tr>
<tr>
<td>4</td>
<td>Tämnarån (69)</td>
<td>Örsundaån (44)</td>
<td>Tyresån/Trosaån* (27)</td>
<td>Tyresån (83)</td>
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<td>Svärtaån (51)</td>
<td>Fyrisån (40)</td>
<td>Olandsån (26)</td>
<td>Oxundaån (78)</td>
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<td>6</td>
<td>Köpingsån (39)</td>
<td>Arbogaån (36)</td>
<td>Tämnarån (26)</td>
<td>Trosaån (77)</td>
</tr>
<tr>
<td>7</td>
<td>Mälarens Närområden* (37)</td>
<td>Olandsån/Skeboån* (32)</td>
<td>Skeboån (24)</td>
<td>Köpingsån (75)</td>
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<tr>
<td>8</td>
<td>Kolböcksån (36)</td>
<td>Kolböcksån (29)</td>
<td>Tyresån (20)</td>
<td>Sugån (73)</td>
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<tr>
<td>9</td>
<td>Oxundaån (36)</td>
<td>Kilaån (28)</td>
<td>Norräljeån/Åkerströmmen* (19)</td>
<td>Svärtaån (63)</td>
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<tr>
<td>10</td>
<td>Tyresån/Trosaån* (32)</td>
<td>Tyresån/Trosaån* (27)</td>
<td>Åkerströmmen (18)</td>
<td>Eskilstunaån; Mälarens närområden* (62)</td>
</tr>
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</table>
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Appendix

Phosphorus load to the Baltic Sea and Lake Mälaren. The anthropogenic (A) part and the part with agriculture anthropogenic (A) origin

### Catchments with outlet to the Baltic Sea

<table>
<thead>
<tr>
<th>Geographical data</th>
<th>P load to outlet in the Baltic Sea</th>
<th>Data from Programmes of Measures</th>
<th>Eutrophication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>Arable land</td>
<td>Population</td>
<td>P load (A) to outlet in Baltic Sea</td>
</tr>
<tr>
<td>km²</td>
<td>%</td>
<td>number</td>
<td>kg year⁻¹</td>
</tr>
<tr>
<td>54 Tammisaari</td>
<td>1258.0</td>
<td>19.9</td>
<td>15157</td>
</tr>
<tr>
<td>55 Forssmark</td>
<td>375.4</td>
<td>6.6</td>
<td>840</td>
</tr>
<tr>
<td>56 Olanders</td>
<td>880.6</td>
<td>26.5</td>
<td>12773</td>
</tr>
<tr>
<td>56/57 Olanders/Skeboan</td>
<td>334.0</td>
<td>14.3</td>
<td>8105</td>
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<tr>
<td>57 Skeboan</td>
<td>482.8</td>
<td>8.6</td>
<td>6390</td>
</tr>
<tr>
<td>57/58 Skeboan/Broström</td>
<td>4733.4</td>
<td>15.7</td>
<td>6601</td>
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<tr>
<td>58 Broström</td>
<td>226.6</td>
<td>22.3</td>
<td>2964</td>
</tr>
<tr>
<td>59 Norsjön</td>
<td>351.8</td>
<td>28.3</td>
<td>17920</td>
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<tr>
<td>59/60 Norrtäljeån/Akenström</td>
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<tr>
<td>60 Akenström</td>
<td>395.9</td>
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<td>61/62 Tyresån/Trosaån</td>
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<td>63 Trosaån</td>
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<tr>
<td>66 Kilaån</td>
<td>432.0</td>
<td>18.3</td>
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</table>

### Catchments with outlet to Lake Mälaren (Närområden)

<table>
<thead>
<tr>
<th>Geographical data</th>
<th>P load to outlet in Lake Mälaren</th>
<th>Data from Programmes of Measures</th>
<th>Eutrophication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>Arable land</td>
<td>Population</td>
<td>P load (A) to outlet in Lake Mälaren</td>
</tr>
<tr>
<td>km²</td>
<td>%</td>
<td>number</td>
<td>kg year⁻¹</td>
</tr>
<tr>
<td>61 Eskilstunaån</td>
<td>4182.5</td>
<td>24.7</td>
<td>256336</td>
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<td>62 Arbogaån</td>
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<td>63 Hedemoraån</td>
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<td>64 Köpingsån</td>
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<td>17330</td>
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<td>65 Krottelån</td>
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<td>66 Nyköpingån</td>
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<td>68 Sävaån</td>
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<td>66/67 Örsundaån</td>
<td>372.0</td>
<td>24.5</td>
<td>15977</td>
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<tr>
<td>68/69 Oxundaån</td>
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<td>37.4</td>
<td>15977</td>
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<td>61/62 Mälaren närområde</td>
<td>5558.4</td>
<td>26.6</td>
<td>1002632</td>
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* The following small sub catchments are summarized together with the dominating one; "Mälarenens närområden".
Enköpingån, Ekån,Fiskévs kanal, Sävaå, Hågåån, Kivåtsån, Råckåsån
The reduction demand for Mälarenens närområden has been used for all resulting in very small differences compared to if the individual numbers had been used.

** Red estimations
Green: measurements
Yellow: modeling