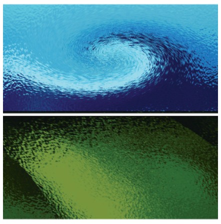
Transitional Waters Bulletin
TWB, Transit. Waters Bull. 5 (2011), n. 2, 75-84
ISSN 1825-229X, DOI 10.1285/i1825229Xv5n2p75
http://siba-ese.unisalento.it



RESEARCH ARTICLE

Ecosystem services assessment of the Nemunas River delta

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Abstract

1 - The concept of ecosystem services recognizes the services, and benefits, provided to people by ecosystems.

2 - The Nemunas River Delta, in Lithuania, provides many ecosystem services to the people of the area, including food, fuel, transportation, climate regulation, water purification, natural hazards regulation, fishing, and recreation (including birdwatching and cultural benefits).

3 - We conducted a meta-analysis of existing studies done on the region to create a conceptual model for the services, using the DPSIR framework (Drivers→Pressures→State →Impact →Response). This approach allowed us to identify trade-offs between services, and synergies, where services respond similarly to pressures.

4 - This work contributes to the understanding of services in transitional waters, where few studies have been conducted, and provides a framework for future decisions and modeling efforts.

Keywords: Ecosystem Services; Fishing; Deltas; Wetlands; Birding; Recreation.

Introduction

Transitional waters are typically diverse, highly productive, ecologically important systems, and are valued for the services they provide to human societies (Elliot *et al.*, 2007). Ecosystem services are the benefits that people obtain from ecosystems (Carpenter *et al.*, 2009). Examples include the provision of fisheries, climate regulation, and recreation. The concept of ecosystem goods and services is of value to managers and policy makers as it allows the linkages between human and ecological systems to be understood by non-scientists, stakeholders, and other interested parties. Daily *et al.* (2009) demonstrated that quantifying ecosystem services, and changes in services under different scenarios, can support environmental decision-making.

Transitional waters such as river deltas or estuaries are under constant pressure including habitat loss and pollution from their surrounding catchments (Nobre, 2009; Zaldivar *et al.*, 2008). The increasing demand for their resources by changing land use, over application of fertilizers and pesticides in watersheds and unsustainable forms of fishery and tourism is leading to their degradation. These pressures have a profound impact on human wellbeing since the goods and services provided by these particular ecosystems are affected as well. Yet, increasing use of their resources by all sectors of society and the improper management by conflicting stakeholder interests are both responsible for the degradation of these ecosystems. This impairment reduces ecosystem services; the benefits for society and economy decrease accordingly.

Despite these threats, few studies have tried to determine how important transitional waters are to human welfare. For the sustainable management of environmental resources, identifying and quantifying ecosystem goods and services are increasingly required (Troy and Wilson, 2006). An understanding of production functions and ecosystem valuation is crucial for decision making. Here we focus on the Nemunas delta, in the Baltic region. We consider the services provided by the delta and relate these to drivers and pressures, as well as the human responses. This approach allowed us to identify important tradeoffs, which may occur among services (e.g., Swallow *et al.*, 2009), and an understanding of these can better outline effects of decisions for single services. We also highlight where services respond similarly to pressures (and may be bundled, or considered together). This work contributes to the understanding of ecosystem services in transitional waters, where few studies have been conducted.

Methods

Description of Nemunas catchment

The Nemunas River, the 14th largest river in Europe, drains an area of 98,000 km² (Fig. 1). The river rises in Belarus and flows for a length of 937 km through Lithuania. The Nemunas River is used for a variety of purposes along its course. The Belarusian section of the catchment supports industrial activities including metal processing and chemical industries. The city of Kaunas, in Lithuania, with a population of 400,000, is the country's principal user of the river, for industry and hydropower generation. The lower Nemunas River is used for water transport, and there have been proposals to deepen its watercourse below Kaunas to make it more consistently usable. The lower reaches of the river form the border between Lithuania and Kaliningrad (Lithuanian Water Partnership, 2002). In Kaliningrad, industrial centers near the river have large pulp and paper production facilities. The Nemunas River drains into the Curonian Lagoon and then into the Baltic Sea. The lagoon is an important resource, and the Curonian Spit – the long, thin, curved sand-dune spit that separates the Curonian Lagoon from the Baltic Sea – is on UNESCO's World Heritage List.

At its delta where the river meets the

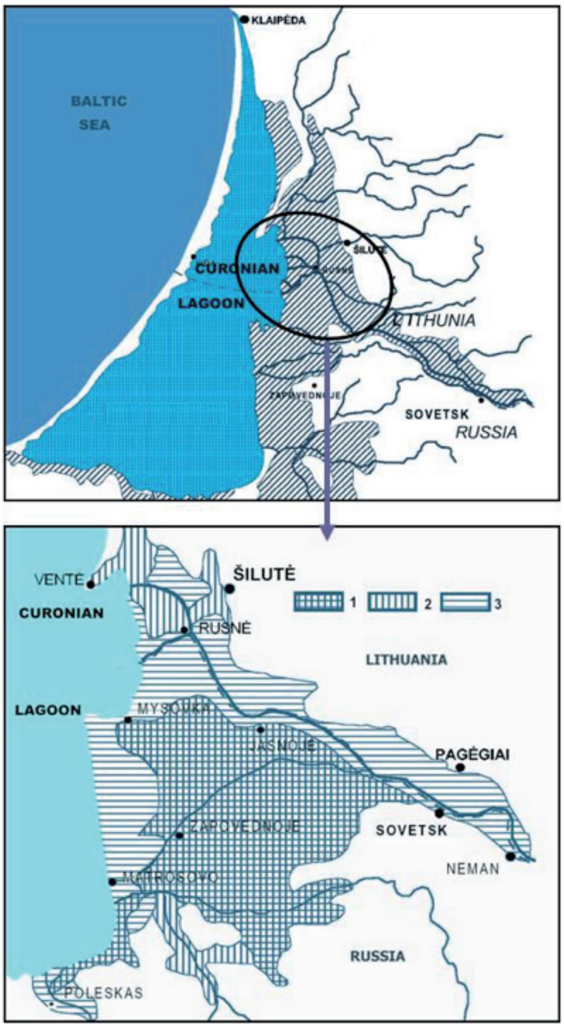

Figure 1. Location of the Nemunas delta (top), and map of delta region (bottom), with flood risk areas indicated: (1) areas protected from 1% probability floods, (2) areas protected from common (10% probability) floods, and (3) unprotected areas.

lagoon, the Nemunas River splits into four main river branches and canals mixing with polders and wetlands (Fig. 1). Dikes have been built in the area from 1840, for flood control, and polders were constructed in the 1900s (Nemunas Euroregion Marijampolė Bureau, 2006). After the Second World War, the Nemunas floodplain land was nationalized, with agriculture based on collective farming, and by the late 1990s, the delta was characterized by a highly developed agriculture, intensive peat mining, and vast fishery ponds (Latsanovsky and Vyčius, 2004). The Nemunas Delta Regional Park, created in 1992, provides protection for resources within the Nemunas delta (Gasiunaite *et al.*, 2008); the wetlands are considered globally significant and are protected under the Ramsar Convention.

Research approach

We have analyzed the ecosystem services of the delta region using the DPSIR framework: Drivers→Pressures→State→Impact →Response. The Drivers, or Driving Forces, are human influences and activities, as well as the natural conditions, affecting ecosystems. For this study, drivers were taken from the United Nations International Standard Industrial Classification of All Economic Activities (http://unstats.un.org/unsd/cr/registry/), and would be applicable to other transitional waters and associated landscapes across the European Union. The Pressures are the direct stresses affecting ecosystem function and condition, i.e., pollutant release. The State reflects the current environmental (physical, chemical, and biological) conditions of natural systems. The Impact is the measure of the effects due to changes in the state of the environmental system; here we equate these to ecosystem services (Atkins *et al.*, 2011; Rounsevell *et al.*, 2010). The Response is the societal response to solve environmental problems in terms of management strategies. More description of this framework can be found in Smeets and Weterings (1999), Pirrone *et al.* (2005) and Maxim *et al.* (2009).

We have used the DPSIR framework to create a conceptual model for the delta system. Conceptual models can demonstrate the linkages among management actions, environmental stressors, and ecological and societal effects, and provide the basis for developing and testing hypotheses to explain current conditions (Gentile *et al.*, 2001). We built the conceptual model using the IHMC CmapTools software (Cañas *et al.*, 2004). Literature review was used to develop the different steps of the DPSIR, although there are few studies available characterizing the state of the delta system itself; most studies have focused on the chemistry and ecology of the lagoon system. Once our model was developed, we considered trade-offs and synergies among services, through further review of the literature.

Results and Discussion

Conceptual DPSIR model

The overall conceptual DPSIR model for the Nemunas delta is presented in Fig. 2. These drivers create pressures that interact with one another and affect the state of the system. Nearly all of these drivers alter land, which can alter flow and result in pollution. For example, agriculture leads to excess nutrient loading to the system (Sileika *et al.*, 2006). Pollution can result from recreational use (Russell, 2007) and mining uses (Martuzevicius and Kliucininkas). Shipping transportation is supported by dredging, which alters the physical habitat in the river channel (Dailidienė and Davulienė, 2008). Transportation, as well as manufacturing, construction, and public works leads to release of greenhouse gases, related to climate change (Carpenter *et al.*, 2009). Climate change will alter future Nemunas river flows, although there is much uncertainty associated with these predictions

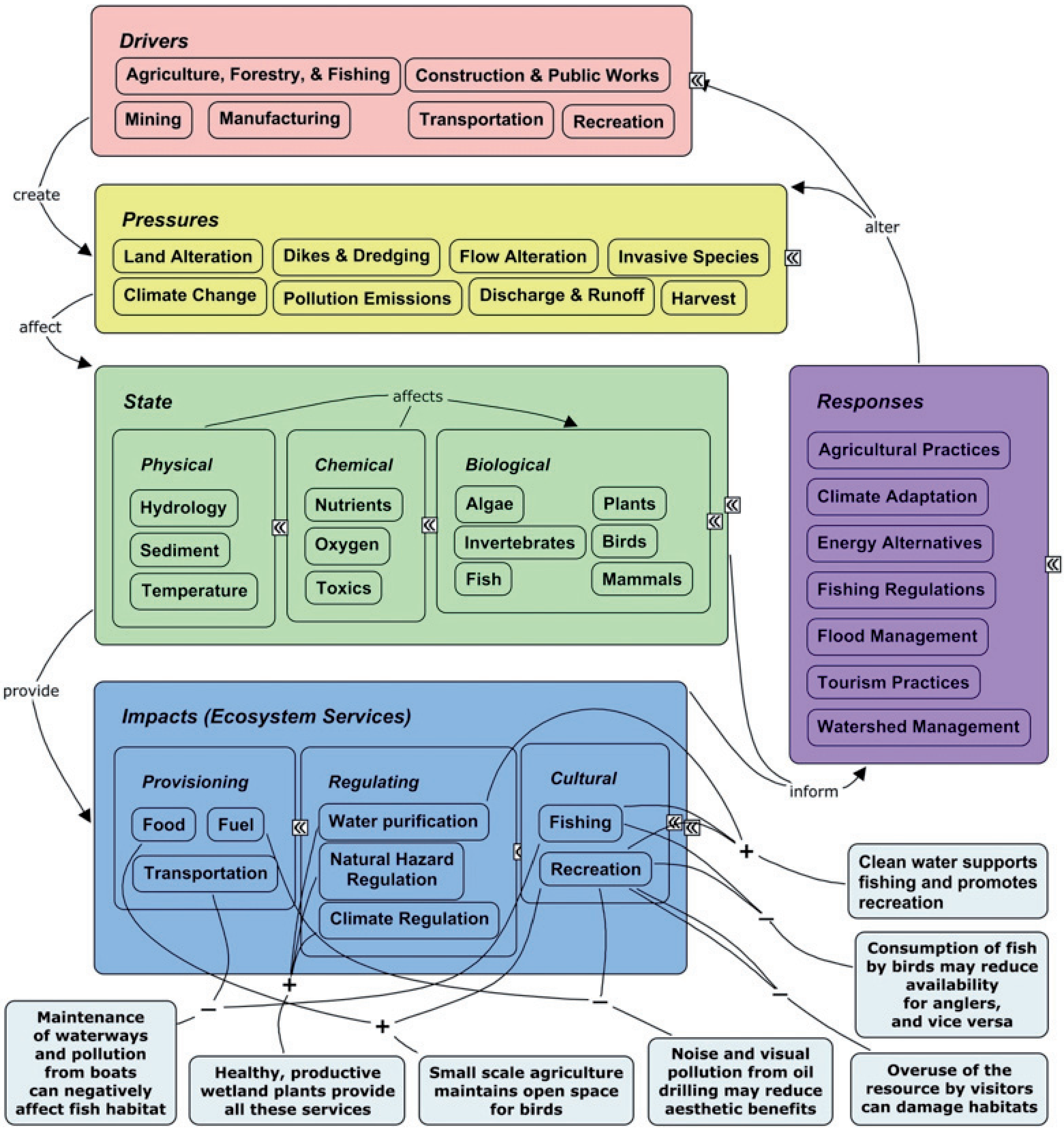

Figure 2. Conceptual model for the Nemunas Delta region, representing Drivers, Pressures, State, Impact (Ecosystem Services), and Response. Synergies (indicated with +) and trade-offs (indicated with –) among ecosystem services in the Nemunas River delta.

(Graham, 2004; Kriaučiūnienė *et al.*, 2008). Dumbrauskas and Punya (2003) have noted that flooding has lessened after the 1960s, and is shifting in time, possibly due to global warming.

Pressures affect the state of the delta system. There is a history in the basin of nutrient impacts on the delta and lagoon. Sileika *et al.* (2006) demonstrated an upward trend in nitrate from 1997-2002, due to increased agricultural activity and fertilization, along with declines in ammonia and phosphate, due in part to a reduction of point sources. Nutrient levels in the Curonian lagoon have not decreased, and during summers there are still intensive phytoplankton blooms (Pilkaitytė and Razinkovas, 2006). The blooms are formed by possible toxic cyanobacteria *Aphanizomenon flos-aquae*, *Microcystis* spp., *Anabaena* spp., *Planktothrix agardhii* (Paldavičienė *et al.*, 2009), which usually are washed ashore and decay, making the shore unattractive to visitors due to smell and view. The toxins are also found in the mussels and fishes feeding on phytoplankton (Paldavičienė *et al.*, 2009). The physical, chemical and biological state of the delta and the Curonian lagoon are strongly influenced by the alteration of freshwater inputs from the Nemunas River, which provides 96% of the freshwater inflow to the system (Gasiūnaitė and Razinkovas, 2004). Invertebrates and fish in the system are significantly influenced by invasive species (Olenin *et al.*, 2007).

Fig. 2 lists the provisioning and regulating services provided by the Nemunas delta. Provisioning services include small-scale agricultural food production, as well as oil drilling, which occurs in the area but is not permitted in the Nemunas Delta Park. The lower Nemunas river is an important system for commercial waterway shipping, although engineering is necessary to maintain these channels (Dumbrauskas and Punya, 2003). Wetlands of the delta provide the regulating service of water purification, the benefit of which is accrued to the downstream lagoon. Vaikasas and Rimkus (2003) estimated that 35% of the inflow of suspended sediments was deposited in the delta, along with associated nutrients, organic matter, and heavy metals. The delta system provides flood protection for nearby communities by temporarily storing flood waters (Dumbrauskas and Punya, 2003). Wetland plants and soils also sequester carbon, providing regulation for the global climate (Jenkins *et al.*, 2010).

The delta also provides cultural ecosystem services (Fig. 2). It is a popular destination for eco-tourism and recreation; the Nemunas Delta Regional Park was created in 1992 to support these activities. Although the tourism industry is in its infancy in this region, there is potential for this to increase (IMEW, 2004). The IMEW (2004) reported that fishing is the dominant form of tourism in the delta (70%). We represent this as the service of fishing, including ice fishing, and do not distinguish between locals and visitors. The provisioning of this service depends on healthy populations of catchable-sized fish (Boyd and Banzhaf, 2007). The remaining tourism is mostly nature viewing, boating and water activities, and cultural heritage (IMEW, 2004), which we grouped as recreation. The natural and cultural character of the delta provides spiritual, religious, educational, and aesthetic value to visitors and tourists (Carpenter *et al.*, 2009). An important part of the nature viewing is birding; the Nemunas River Delta is considered the most important bird area in Lithuania. It is a key stop-over site for many migratory waterbirds and hosts many rare varieties of birds during the spring breeding season (the total reported number of species is about 200, of which about 40 species are listed in the IUCN Red Book of Endangered Species) (Birdlife International, 2009). The support of bird populations is also a benefit for biodiversity and conservation (Turner *et al.*, 2007), which are valued for spiritual and existence benefits (Boyd and Banzhaf, 2007).

The responses in the conceptual model indicate that there is much for humans to control in this delta system (Fig. 2). Fisheries regulation, including catch limits, could serve the region; more than 100 small private fishing enterprises are licensed to fish, so the proper control of landed catches becomes difficult, resulting in a substantial uncontrolled landing of fish, up to 60% of the yield (Breber *et al.*, 2008). Foster and Sileika (1996) have advocated for sustainable agricultural practices in the delta region, including setting standards for animal density limits, manure storage and handling technologies, and water regimes for pastures and meadows.

Breber *et al.* (2008) note that a pilot program encouraging farmers to cut reeds along the lagoon fringes, to sell as thatching material, also improves fish habitat and migration. Lukianas *et al.* (2006) provide several recommendations for management of flooding through both engineering – the rearrangement of the system of dikes, and regulation of water and sediment with pumping stations – and with enhancement of the natural environment. Also, responsible tourism practices could support the sustainability of the region (Russell, 2007).

In the watershed, water quality may be controlled through economic instruments such as taxes on natural resources, charges on the discharge of water pollutants, municipal charges for drinking water, sewage treatment, and fines for exceeding established discharge limits (Lithuanian Water Partnership, 2002). Razinkovas *et al.* (2008) showed that nutrient reduction in the watershed will decrease algae in the lagoon system, although this influence may be small. Also, water quality controls could shift N:P ratio even more towards the nitrogen limitation, favoring nitrogen-fixing cyanobacteria and prolonged algal blooms, further degrading water quality in the Curonian lagoon (Razinkovas *et al.*, 2008). Zylicz (2003) noted that marketable permits would be useful instruments to manage water quality in this region. The EU Water Framework Directive (EC, 2000) requires that the Nemunas is assigned to an international River Basin District, with appropriate coordination of water resources management with Poland, Byelorussia and the Kaliningrad region of Russia (Lithuanian Water Partnership, 2002). Katinas *et al.* (2008) have noted that promotion of renewable energy sources, particularly wind energy and biomass power plants, could reduce the energy sector's impact on the environment in Lithuania.

Trade-offs and synergies

We have focused on four tradeoffs among services for the Nemunas Delta region (Fig. 2). First, the fishery service may form a tradeoff between anglers and birds, because both consume fish. Žydelis and Kontautas (2008) found that in a 2001-2002 study in the Curonian Lagoon, birds consumed 2/3 of the amount landed by commercial anglers, but there is a size selectivity that reduced competition between the two. A second tradeoff is between oil drilling and recreation/aesthetic benefits. Oil drilling provides an economic benefit, but also creates noise and visual problems. A major oil drilling site is located just north of the delta, and previous conflict has been experienced, resulting in compensation of local residents by the oil company. Third, the rubbish and noise associated with current and future recreational use may be an issue (IMEW, 2004; Russell, 2007); this is essentially a feedback of a driver that is also a service. Fourth, maintenance of waterways for boat traffic can negatively affect fish habitat (Carss *et al.*, 2009). Additionally, trade-offs may occur between flood protection and agriculture (Lukianas *et al.*, 2006), where flooding can damage crops, however, flooding deposits nutrients that support long-term agricultural productivity (Vaikasas and Rimkus, 2003).

Three synergies among services have also been identified for the delta region (Fig. 2). First, healthy, productive wetlands provide several services, including clean water, flood control, and climate regulation through carbon sequestration (e.g., Jenkins *et al.*, 2010). Dadaser-Celik *et al.* (2009) demonstrated that the marginal benefit of water quality treatment by wetlands can be significant. Second, there is a positive interaction between agricultural production and use of the resource by birds in this region. In an effort to improve habitat for vulnerable bird species, the Institute of Ecology of Vilnius University, through support of the Wings Over Wetlands Project (2010), spearheaded the re-introduction of traditional sustainable farming, as well as restoration of open meadow floodplain habitats through clearing of shrubs and restoration of open meadow vegetation managed by grazing, across the Nemunas River Delta. The restored habitat now supports several globally threatened bird species, including Great Snipe (Gallinago media), Aquatic Warbler (Acrocephalus paludicola), and Corncrake (Crex crex). A newly established bird observatory is being used as a base for scientific research. Third, water purification reduces pollution, which supports fishing and promotes recreation (Repečka, 2003; Söderqvist and Hasselström 2008; Paldavičienė *et al.*, 2009).

Applications and Future Directions

The conceptual model developed here can be used to support future work. Because the delivery of services is spatially explicit (Boyd and Banzhaf, 2007), a first step would be to create a map, or atlas of the services provided by the delta. A next step will be to identify the types of mathematical models and decision tools needed to represent the steps of the conceptual model (Rekolainen *et al.*, 2003). Gentile *et al.* (2001) have noted that for the Everglades and South Florida systems in the USA, their conceptual model supports the development of performance criteria for system recovery for stressors that are determined to be most important in shaping the landscape, and guides the use of numerical models for developing quantitative performance criteria in the scenario analysis. Future work would include linking to studies on valuation on services. Söderqvist and Hasselström (2008) report on an assessment for the Nemunas delta using contingent valuation to estimate a total consumer surplus for the delta of 277 kEUR. The scale of the study is an issue for consideration. Here, we focused on the delta, but a broader spatial view would consider the upland watershed, and the downstream lagoon. For example, salinity in the delta depends on the freshwater input, which in turn depends on water uses within the catchment (Dailidienė and Davulienė, 2008), so catchment management is a consideration for the delta services. The delta is generally less desirable than the Curonian lagoon for recreation because it is less frequented by visitors, and without recreational amenities (Söderqvist and Hasselström, 2008), but the delta supports ecosystem services in the lagoon. Decisions should also consider time scale, and recognize that the system is being managed under conditions that are changing. For example, Pustelnikovas (2008) has hypothesized that based on patterns of uplift and sedimentation under future climate and land use, the Nemunas river bed and delta will shift south–westwards, and the lagoon will turn into a bog in the next thousand years. In addition to environmental changes, there are also changes occurring in the social and policy context in which environmental decisions are made (Rinkevièius, 2006).

A strength of our conceptual model is that it provides a framework for considering the complex relationships that occur in environmental systems. A conceptual model supports management decisions, which must include ecological, social, political, and economic considerations (Reiter *et al.*, 2009). Daily *et al.* (2009) note that in order to bring about a change in environmental decision making, it is important to embed the values of natural capital in institutions, so that ecosystem services values can be incorporated into policy and financial incentives for management. A services perspective for the Nemunas delta region can serve as the basis for integrated, holistic management of the Nemunas Delta, where unintended consequences of management decisions can be considered. As ecosystem services science develops, additional studies can support more comprehensive analysis and decision support tools for the region.

Acknowledgements

We are grateful for the support of the Erasmus Mundus MSc in Biodiversity and Conservation within EU Erasmus Mundus Visiting Scientist Program. We thank John Johnston and an anonymous reviewer for helpful comments on the manuscript. This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for publication.

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