DISSERTATIONES GEOGRAPHICAE UNIVERSITATIS TARTUENSIS

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Ecosystem services of Estonian wetlands

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ABSTRACT

The identification and assessment of ecosystem services is increasingly seen as important to the making of informed decisions regarding the use and management of wetlands and their benefit to society. In Estonia, as in other countries, the area of wetlands has diminished remarkably due to different utilization for economic needs. Comparatively large areas of natural wetlands have, however, been preserved and contribute significantly to environmental and biological diversity. Based on the analysis of the relevant information sources and literature, a first attempt has been made to describe the diversity and challenges for the use of Estonian wetlands in the perspective of the ecosystem services approach. The definition of wetlands in the Ramsar Convention and the ecosystem services categorization of the Millennium Ecosystem Assessment are followed. The Driving Forces-Pressures-State-Impact-Responses (DPSIR) framework is utilized to comprehensively analyze the complex issue of wetland use.

The analysis shows that Estonia has achieved good results in the integration of wise use of wetlands into the legal framework and development strategies. Substantial progress has been achieved in the area of wetland conservation, and a significant proportion of valuable wetlands (a total of 33 wetland habitat types covering more than 300,000 ha) are legally protected. Several wetland types, particularly mires (especially ombrotrophic bogs) and semi-natural wetlands (coastal and floodplain meadows) have been preserved in Estonia in considerably large numbers and total area, providing habitats for a number of species threatened globally or on a European scale.

Estonian wetlands provide the array of provisioning, regulating, cultural and supporting ecosystem services. The most important of these are biodiversity support, the sequestering and releasing of carbon, pollution retention and cultural services. In order to ensure more balanced decision-making, it is important that the full value of ecosystem services provided by wetlands be recognized. The existing expertise and large amount of information on biodiversity components and the functioning of wetland ecosystems is an excellent basis for further research and for integrating ecosystem services within the practice of wetland use and valuation. The most crucial challenges are: 1. management of drained wetland areas that have become sources of greenhouse gases; 2. achievement of the sustainable use of peat resources and ensuring of the restoration of cut-away peatlands; 3. maintenance of the traditional management of valuable semi-natural wetlands.

1. INTRODUCTION

Wetlands globally cover an area estimated to range from 5.3 to 12.8 million km^2. In recent decades wetlands have received intense scientific and political attention. The values of wetlands and the role wetland ecosystems play in maintaining biodiversity and environmental quality are widely accepted (Masing et al., 1990; Costanza et al., 1997; Joosten and Clarke, 2002; Verhoeven et al., 2006). The need for the conservation of wetlands is increasingly coupled with the recognition that wetlands provide services and goods that are important welfare constituents. A key finding of the Millennium Ecosystem Assessment carried out between 2001 and 2005 under the auspices of the United Nations has been that wetlands and the ecosystem services they provide are hugely valuable to people worldwide (Millennium Ecosystem Assessment, 2005).

The degradation and loss of wetlands was identified within the Millennium Ecosystem Assessment process as being more rapid than that of other ecosystems. The underlying cause of the decline of ecosystems in terms of the species that live in them and the services that they provide for humans is the fact that humans give a relatively low value to ecosystems compared to the value given to activities that potentially degrade them (Daily, 1997). Biodiversity support, water quality improvement, flood abatement and carbon sequestration are key functions that are impaired when wetlands are lost or degraded (Zedler and Kercher, 2005). Additional efforts are needed to stop the alarming degradation of these diverse ecosystems. The very critical situation of Europe's wetlands and the very urgent need for action was recognized by the Commission Communication to the Council and the European Parliament (COM, 1995) on the Wise Use and Conservation of Wetlands.

The Baltic Sea catchment area is the region that has the most remaining and most varied types of wetland in Europe (WWF, 2008). The Baltic Sea is considered to be one of the most threatened marine ecosystems, as it is affected by industrial, agricultural and municipal pollution, transport, and also the continued clearing of forests and the deterioration of wetlands in the catchment area (Jannson et al., 1998). The maintenance, sustainable management and restoration of wetlands is recognized to be of great importance at catchment level (Paludan et al., 2000; Blackwell et al., 2002) in order to decrease the nutrient load and the danger of eutrophication in the Baltic Sea.

Wetland ecosystems

Wetland is a generic term covering a large number of habitat types that occupy the transitional zone between deepwater aquatic and well-drained terrestrial environments (Mitsch and Gosselink, 2000) and which do not fit neatly into aquatic/terrestrial classification systems (Shine and de Klemm, 1999). There is a wide range of definitions and interpretations of the term wetland. These definitions tend to reflect different national traditions as well as differences in the characteristics of the environment worldwide. Mitsch and Gosselink (2000) have thoroughly considered the conceptual content of the term and found that no absolute answer to "What is a wetland?" should be expected, as wetlands have a considerable range of hydrologic conditions, they are found along a gradient at the margins of well-defined uplands and deepwater systems, and there is a great variation in their size and location and the human influence on them. Despite differences in definition, all wetlands share some common hydrological, soil, and vegetative characteristics. Their most notable distinguishing features are the presence of standing water, unique wetland soils, and vegetation adapted to or tolerant of saturated soils (Mitsch and Gosselink, 2000).

Formal definitions serving as a basis for the classification and comprehensive inventory of wetlands developed in Canada and in the United States differ from one another. According to the definition of wetlands adopted by wetland scientists in the U.S. Fish and Wildlife Service (Cowardin et al., 1979), wetlands are lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. In Canada, where there are vast areas of inland peatlands, wetland is defined as land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity that are adopted to a wet environment (Warner and Rubec, 1997). Wetlands are subdivided into two broad categories: organic wetlands (more simply referred to as peatlands) and mineral wetlands.

A widely used and internationally accepted definition is that found in the Ramsar Convention (Ramsar Convention Secretariat, 2006): wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt including areas of marine water, the depth of which at low tide does not exceed 6 meters. An additional and frequently used term is "peatland", which for the purpose of the Ramsar Convention is defined as "an area of landscape with a naturally accumulated peat layer on its surface". An "active peatland" or "mire" is a peatland where "peat is currently forming and accumulating".

Wetlands have been classified in a variety of ways to meet different objectives (Mitsch and Gosselink, 2000). As wetlands are characterised by complexity, dynamic character and the difficulty in precisely defining their often fluctuating boundaries, different scales and classification units are applied. In order to improve understanding, international classification systems have been advocated (Finlayson and van der Valk, 1995; Scott and Jones, 1995). The only global classification system of the Ramsar Convention lists a total of 35 broad wetland types, and is sufficiently flexible that it could be used to classify European wetlands at the national scale (Hughes, 1995).

The concept of ecosystem services

Increasing attention is being devoted to the value of ecosystems in providing ecosystem services. Ecosystem services, the benefits that people obtain from ecosystems, have been seen as a powerful tool to understand human relationships with the environment and to design environmental policy (Brauman et al., 2007). The Millennium Ecosystem Assessment (2005) gave a great impulse to the concept and the further development of the ecosystem services framework (Turner and Daily, 2008), and encouraged scientific studies in the area of ecosystem services (Carpenter et al., 2009).

The development of the concept of ecosystem services is described in several publications (e.g. Mooney and Ehrlich, 1997; Millennium Ecosystem Assessment, 2003). Two widely influential works were published in 1997 by Daily (1997) and Costanza et al. (1997). Within the last decade, research on ecosystem services and promotion of the concept has increased markedly (e.g. De Groot et al., 2002; Kremen and Ostfeld, 2005; Cowling et al., 2008; Daily and Matson, 2008). The concept has been applied as a basic approach in policy documents and strategic programmes, e.g. the Worldwide Millennium Ecosystem Assessment (2005). One of the overall objectives of the EU Sustainable Development Strategy (Council of the European Union, 2006) is to improve management and avoid overexploitation of natural resources, recognizing the value of ecosystem services. The global review of the economics of ecosystems and biodiversity (TEEB) initiated in 2008 (European Communities, 2008; Jones-Walters and Mulder, 2009) puts a strong focus on ecosystem services, since this approach is believed to be particularly fruitful for an economic assessment of the consequences of biodiversity loss.

Ecosystem services have been defined by Daily (1997) as the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. According to Costanza et al. (1997), ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions. The Millennium Ecosystem Assessment defines ecosystem services as “the benefits that people obtain from ecosystems”. This definition is derived from commonly referenced and representative definitions by Daily (1997) and Costanza et al. (1997), and includes both natural and human-modified ecosystems as sources of ecosystem services, using the term “services” to encompass both the tangible and the intangible benefits humans obtain from ecosystems, which are sometimes separated into “goods” and “services” respectively (Millennium Ecosystem Assessment, 2003).

Ecosystem processes and functions contribute to the provision of ecosystem services, but are not synonymous with ecosystem services. The comprehensive assessment of ecosystem services involves the translation of ecological complexity (ecosystem structures and processes) into a more limited number of ecosystem functions that, in turn, provide the goods and services that are valued by humans (De Groot et al., 2002). Ecosystem processes and functions describe biophysical relationships that exist whether or not humans benefit from them. These relationships generate ecosystem services only if they contribute to human well-being, defined broadly to include both physical well-being and psychological gratification. Thus ecosystem services cannot be defined independently of human values (EPA-SAB, 2009).

Ecosystem services have been categorized in a number of different ways. De Groot et al. (2002) distinguished functional groupings, such as regulation, carrier, habitat, production, and information services. The Millennium Ecosystem Assessment (2003) categorizes ecosystem services into four broad areas: provisioning, regulating and cultural services that directly affect people, and supporting services that are needed to maintain the other services. Each service possesses sub-categories.

Provisioning services are the products obtained from ecosystems; regulating services are the benefits obtained from the regulation of ecosystem processes; cultural services are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences; supporting services are services that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating and cultural services in that their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people.

The importance or "value" of ecosystems is viewed and expressed differently by different disciplines and schools (see De Groot et al., 2006). The Millennium Ecosystem Assessment (2003) defines "value" as "the contribution of an action or object to user-specified goals, objectives, or conditions" and "valuation" as "the process of expressing a value for a particular good or service in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology and so on)". The economic valuation of ecosystems is a rapidly developing discipline (e.g. Farber et al., 2006; Hein et al., 2006; Farley, 2008; Maler et al., 2009). Many different methods are available for the performance of monetary valuation (see De Groot et al., 2006). Whether or not the values of ecosystem services are monetized, the ecosystem services framework provides a way to assess trade-offs among alternative scenarios of resource use and landscape change (Brauman et al., 2007). It has, however, been emphasized (Daily and Matson, 2008) that a lack of scientific understanding of the factors influencing the provision of ecosystem services and of their economic benefits limits their incorporation into land-use planning and decision-making.

Wetland ecosystem services and their valuation

The valuation of ecosystem services is increasingly seen as important in making more informed decisions regarding the use and management of wetlands and their benefit to society (Barbier et al., 1997; Emerton and Bos, 2004; De Groot et al., 2006). The overview of peer-reviewed science magazines from Elsevier B.V publications (Science Direct, ISI Web of Science) shows that during the period 1997–2009, about 120 articles were published in magazines on wetland ecosystem services. The largest number of papers is produced by scientists of the USA and China, and Europe (particularly Sweden) has also made fundamental contributions. There is also a substantial literature on wetland valuation, including several meta-analyses that examine subsets of the available wetland valuation literature (Woodward and Wui, 2001; Brander et al., 2006). In Estonia the first studies on the economic value of ecosystems have been carried out on seminatural communities (incl. wetland habitats) (Gren et al., 1996; Ehrlich and Habicht, 2001), and an attempt has also been made to evaluate the conservation of the internationally important wetland of Nigula as an investment (Merivee, 2006).

In order to ensure more balanced decision-making (i.e. that multiple uses and values be considered), it is crucial that the full importance (value) of wetlands be recognized (De Groot et al., 2006). State and local entities responsible for the management of wetlands are challenged with how to evaluate ecosystem services provided by wetlands in order to make informed land-use decisions. The challenge is to integrate ecosystem services and environmental management .

The Ramsar Convention

The Convention on Wetlands of International Importance (the Ramsar Convention) established in 1971 is the only global agreement dedicated to a specific type of ecosystem. At the centre of the Ramsar philosophy is the concept of "wise use". The Convention promotes the wise use of wetlands as a means of maintaining their "ecological character" – the ecosystem components and processes that comprise the wetland and underpin the delivery of ecosystem services (Finlayson et al., 2005). As of 2009 there are 159 contracting parties. Estonia joined the convention in 1993. The purpose of this thesis is to highlight the status of Estonian wetlands and services provided by them in the context of the Ramsar philosophy and to assess the challenges to their wise use. To this day wetlands have often been treated from different viewpoints depending on the interests of different disciplines or sectors. With the thesis, an attempt is made to introduce Estonian wetlands in a wider perspective, following the broad wetland definition of the Ramsar Convention (covering both natural and man-made wetlands) and the ecosystem services approach of the Millennium Ecosystem Assessment as basic concepts.

Objectives

The objectives of the thesis are the following:

(1) to review the current knowledge on wetlands in Estonia;
(2) to analyze the diversity of Estonian wetlands and the main ecosystem services provided by them;
(3) to analyze the threats and main challenges to wise use of wetlands in Estonia;
(4) to assess the current practice of integrating ecosystem services into wetland restoration.

2. MATERIAL AND METHODS

Study area

The target for the study is Estonia. The whole territory of Estonia (45,227 km^2) falls within the Baltic Sea catchment area (as defined by the Helsinki Convention), corresponding to 2.6% of this. The development of the landscape, which is characterized by uplands and lowlands, has been strongly influenced by the activity of glaciers and melting waters, as well as subsequent postglacial transgressions and regressions of the Baltic Sea. The process of land elevation, which is still causing land to rise from the sea at a rate of up to 3 mm per year, is characteristic of the coastal zone. The flat topography, the wide variety of glacial formations and the humid climate supports considerable water resources and wetland ecosystems, particularly mires, which are heterogeneously distributed throughout the landscape. Various coastal wetlands are connected with the long and diverse shoreline.

Material and methods

Analysis of data and materials on Estonian wetlands

The relevant literature and reports were reviewed to analyze the diversity and status of wetlands. Habitat types of the EU Habitat Directive compared with the units of the classification of the Ramsar Convention were used. Data were obtained from the Estonian Information Centre's EELIS system and the Ministry of Environment's Natura 2000 database.

For presentation of ecosystem services of wetlands the scheme developed by the Millennium Ecosystem Assessment (2005) was followed.

The Driving Forces – Pressures – State – Impact – Responses (DPSIR) analysis

The Driving Forces – Pressures – State – Impact – Responses (DPSIR) framework, which is considered to be a useful tool for clarifying and logically ordering the main processes and problems in environmental planning (European Environment Agency, 1998), was utilized to comprehensively analyze the complex issues of wetland use.

The DPSIR approach treats the environmental management process as a feedback loop controlling a cycle consisting of five stages (Figure 1). Drivers are the underlying causes, which lead to environmental pressures; e.g. human demands for peat resource. These driving forces lead to pressures on the environment, e.g. extraction of peat, alteration of hydrology of the surroundings. The pressures in turn affect the state of environment. This refers to the quality of the various environmental media (air, soil, water, groundwater, landscape) and their ability to support the demands placed on them (e.g., supporting human and non-human life, supplying resources, etc.). Changes in the state may have an impact on human health, ecosystems, biodiversity, etc. Impact may be expressed in terms of the level of environmental harm. The task of decision-makers is to assess the driving forces, pressures, state and their ultimate impact. From the impact, they must determine appropriate responses, in order to direct the final impact in the desired direction (a reduction in environmental harm). These responses will influence the drivers, pressures and states, thus completing a feedback loop.

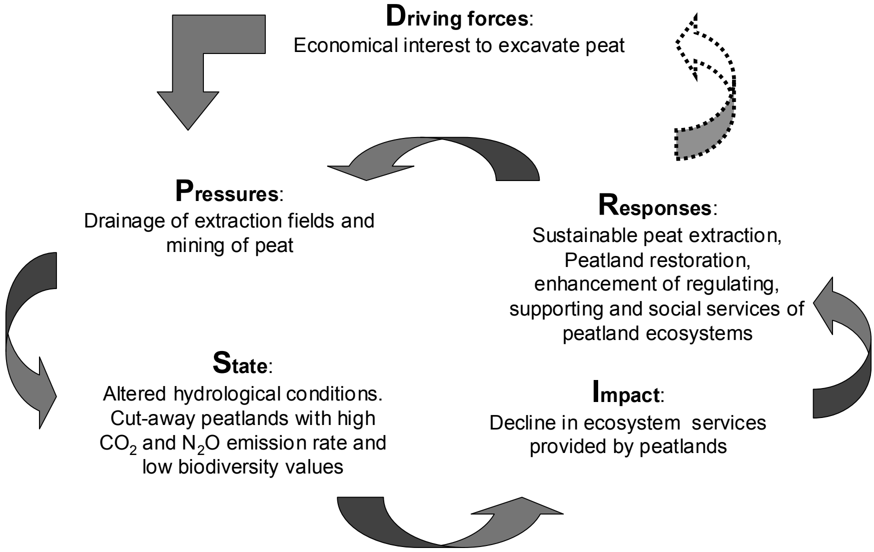

Figure 1. The Driving Forces – Pressures – State – Impact – Responses (DPSIR) framework for reporting on environmental issues as a basis for wetland use assessment. Economical interest to use peat resources is used as an example.

Using DPSIR framework is considered to be well justified as it directs attention to policy-relevant issues and helps to discover where the most serious deficiences in knowledge lie (Auvinen et al., 2007).

Evaluation of fluxes of greenhouse gases

To illustrate the critical influence of human interaction on wetland ecosystem services, the evaluation of fluxes of greenhouse gases (carbon dioxide – CO_2, methane – CH_4 and nitrous oxide – N_2O) from Estonian transitional minerotrophic fens and ombrotrophic bogs is used. Emissions estimates are based on a cartographical analysis and published data from boreal regions, with emphasis given to differences between drained and undisturbed areas (Salm, 2007). Available sources indexed by the ISI Web of Science, Scopus and Biosis were taken into account. The following maps were used: a digital database of the land cover of Estonia (1:100,000) by the CORINE Land Cover project; landscape site type maps (1:100,000) of the Institute of Ecology and Earth Sciences of the University of Tartu; the map layer compiled on the basis of the data of the Agricultural Registers and Information Board and the Estonian Environment Information Centre reflecting areas of active drainage (1:10,000).

Analysis of linkages between ecosystem services and peatland restoration

Peatland restoration is a challenge for Estonia. With the aim to examine the current practice of integrating ecosystem services into peatland restoration publications indexed by the ISI Web of Science were analyzed. Word combinations relevant to peatland ecosystem services (Table 1) in title, keywords and abstract were used. The ecosystem services were classified according to the scheme developed by the Millennium Ecosystem Assessment (2005).

Table 1. Peatland ecosystem services and relevant beneficial functions adapted from Millennium Ecosystem Assessment (2005) and Joosten and Clarke (2002).

Ecosystem services of inland wetlands (Millennium Ecosystem Assessment, 2005)	Beneficial functions of peatlands (Joosten and Clarke, 2002)
Provisioning services	**Production functions**
Fiber and fuel	Peat extracted and used / wild plants (incl. forests and energy biomass)
Food	Wild plants/wild animals
Fresh water	Water
	Peat substrate
	Carrier functions (space and substrate used)
Regulating services	**Regulation functions**
Climate regulation	Regulation of global climate/ of regional and local climates
Water regulation	Regulation of catchment hydrology
Water purification and waste treatment	Regulation of catchment hydrochemistry
Erosion protection	Regulation of soil conditions
Cultural services	**Informational functions**
Recreational and aesthetic	Recreation and aesthetic functions
Spiritual and inspirational	Spirituality and existence functions
Educational	Signalisation and cognition functions
Supporting services	
Biodiversity	
Soil formation	
Nutrient cycling	

The phrases used in combination with "peatland restoration" were "gas regulation", "methane", "nitrous oxide", "carbon dioxide", "carbon sequestration", "climate regulation", "water regulation", "water quality", "water purification", "nutrient cycling", "peat accumulation", "biodiversity", "habitat", "peat prodution", "peat extraction", "wild berries", "biomass", "energy crop", "wood production", "amenity", "recreation", "tourism"and "cultural heritage".

3. RESULTS AND DISCUSSION

3.1. Estonian wetlands

3.1.1. Wetland concept and present state of knowledge

Wetland research has long traditions in Estonia, and the content of the term wetland was known long before the appearance of the term itself. Although a great deal of research has been performed on different types and aspects of wetland ecosystems, the research object has often not been defined as a wetland. Terms used are "mire", "peatland", "wet grassland", etc. Wetland science or wetland ecology as a unique multidiscipline encompassing many fields and including ecology, chemistry, hydrology and engineering (Mitch and Gosselink, 2000), has not been widely practiced in Estonia.

The term wetland was introduced at the beginning of the 1970s through the participation of Estonian scientists in the IUCN International Biological Programme. In 1974, the contributions to the programme "Estonian Wetlands and their Life" (Kumari, 1974) were published. As a result of the activities of Erik Kumari, the Matsalu wetland complex was already included on the list of internationally important wetland sites in 1975. The value of peatlands was highlighted and promoted by Viktor Masing, and mainly due to his efforts, 30 mire protection areas were established in 1981. In 1978 the project "Anthropogenic influences on the ecosystem state and natural resources of lakes, bogs, rivers, deltas, estuaries and coastal zones" was launched, with two subprojects: the anthropogenic eutrophication of fresh-water water bodies, and anthropogenic influence on wetland ecosystems. The project "Freshwater wetlands of international and republic-level importance in the Estonian SSR and their biotechnic resources" (Zobel, 1988) resulted in the compilation of a list of mires that required protection. From 1981–1984 Estonian scientists participated in the international project "Ecosystem Dynamics in Freshwater Wetlands and Shallow Water Bodies (Masing et al., 1990). During recent decades, several international meetings on wetlands (e.g. Järvet and Lode, 2003; Mander et al., 2008; Mander and Mitsch, 2009) have been organised in Estonia. Estonian scientists have joined the network of the Society of Wetland Scientists.

Various wetland habitats have been the subject of scientific research since the period when national science began to develop in the 19th century. For example, Matsalu Bay as one of the most important coastal wetlands and bird habitats in the entire Baltic area, has been continuously investigated since 1870 (Lotman, 1998). Studies into mire ecosystems were initiated in 1910, when the first complex investigations were carried out in the Männikjärve Bog of the Endla mire system, followed by multidisciplinary ecological investigations performed in the 1950s (Kimmel, 1998).

Mires have been the subject of the most intense and diversified research (for example, Masing, 1982, 1984; Ilomets, 1984; Aaviksoo, 1993; Loopmann, 1996; Karofeld, 1998, 2004; Kasemetsa, 1998; Aaviksoo et al., 2000; Frenzel and

Karofeld, 2000; Ingerpuu et al., 2001; Aber et al., 2002; Paal, 2005). Knowledge also exists on bodies of fresh water (e.g. Ott and Kõiv; 1999; Nõges et al., 2001, Kangur et al., 2001), the coastal waters of the Baltic Sea (Piirsoo et al., 2001) and coastal landscapes (Ratas et al., 2003; Rannap et al., 2007). Wetland bird communities and the importance of wetlands for rare and vulnerable bird species (Kuresoo, 1990; Leivits, 1990; Pehlak et al., 2006) have been investigated.

Since the 1990s, the hydrological and ecological functions of wetlands in the landscape have been studied, in particular purification efficiency and nutrient assimilation in plants in riparian buffer zone wetlands (Kuusemets et al., 2001; Mander et al., 2005; Kull et al., 2008). The environmental and technological aspects of constructed wetlands for wastewater purification have been intensively investigated in recent decade (Mander and Mauring, 1997; Lesta et al., 2006; Noorvee et al., 2007; Öövel et al., 2007; Vohla et al., 2007).

3.1.2. Wetland types and coverage

Classification

Wetlands have been treated differently by different authors, depending on the approach and the purpose of the inventory or the research project. Therefore different definitions and classifications have been used. For the most comprehensive wetland inventory (Paal et al., 1998), the second phase of which will be completed by 2010, the classification system extracted from the detailed hierarchical classification system of Estonian vegetation types (Paal, 1997), which extends to the level of plant communities, has been used. Based on this classification, Estonian wetlands constitute 17 site type groups, 30 site types and at least 112 community types (Masing et al. 2000).

In Europe, habitat data are often systematized and presented according to the Nomenclature of Annex I of the EU Habitat Directive. This has also recently become the practice in Estonia. The habitat directive is the central piece of nature conservation on the EU level, and this is how habitats are described in Natura 2000 site databases and practical LIFE-nature management projects. The units of the national classification system have been linked to those of the Habitats Directive (Paal, 2007).

The categories listed in the Ramsar Classification System for Wetland Type (Ramsar Convention Secretariat, 2006) are intended to provide a very broad framework to aid rapid identification of the main wetland habitats represented at each site. Table 2 (see also **II**) presents the wetland types in Estonia by the habitat types of the EU Habitat Directive, compared with the units of the classification of the Ramsar Convention, as global classifications systems have been advocated for better international understanding (Finlayson and van der Valk 1995; Scott and Jones 1995). As the Ramsar classification is specifically based on the wetland landscape, whereas the wetland habitats listed in the Habitats Directive are largely identified by their plant composition and in some cases by a range of ecological characteristics, the match of units is approximate.

Table 2. The diversity of natural wetland types in Estonia based on the habitat types of the EU Habitat Directive, approximately compared with the units of the global classification of the Ramsar Convention

Wetland type (Ramsar classification system)	**Habitat type (EU Habitat Directive, Annex I)**	**Area estimation in Natura 2000 database (ha)**
Marine/Coastal Wetlands	**Coastal and halophytic habitats**	
Permanent shallow marine waters	Large shallow inlets and bays	100,000
Marine subtidal aquatic beds	Sandbanks partly exposed at low tide	50,000
Rocky marine shores	Reefs	20,000
Sand, shingle or pebble shores	Annual vegetation of drift lines	
	Perennial vegetation of stony banks	
	Humid dune slacks	
Estuarine waters	Estuaries	51,800
Intertidal mud, sand or salt flats	Mudflats and sand flats	40,000
Intertidal marshes	*Salicornia* and other annuals on mud and sand	
	Boreal islets and small islands	5300
	Boreal Baltic coastal meadows	18,000
	Boreal sandy beaches with perennial vegetation	1200
Coastal lagoons	Coastal lagoons	5850
Inland Wetlands	**Freshwater habitats**	
	Standing and running water	
Permanent rivers/streams	Watercourses in lowlands	6500 km
Permanent freshwater lakes	Mineral-poor oligotrophic lakes	1542
	Oligotrophic to mesotrophic standing waters	54,762
	Hard oligotrophic-mesotrophic waters with *Chara*	7057
	Natural eutrophic lakes	31,082
	Natural dystrophic lakes and ponds	1368
Seasonal freshwater lakes	Karst lakes	
	Meadows	
Seasonally flooded meadows, Sedge marshes	Hydrophilous tall-herb fringe communities of plains	4000
	Northern boreal alluvial meadows	20,000
	Mires	
Non-forested peatlands; includes shrub or open bogs, swamps, fens	Active raised bogs	280,000
	Degraded raised bogs still capable of regeneration	56,500
	Transition mires and quaking bogs	28,000
	Mineral-rich springs and spring fens	500
	Calcareous fens	1100
	Alkaline fens	22,000
Shrub-dominated wetlands	Can be found in various habitat types	
	Wet forests	
Freshwater, tree-dominated wetlands	Fennoscandian deciduous swamp woods	49,000
	Alluvial forests	1100
Forested peatlands;	Bog woodland	50,000
Freshwater springs	Fennoscandian mineral-rich springs and spring fens	400
Total		*900,160*

According to the comparison made, Estonia has a total of 33 wetland habitat types that represent the five main types of natural wetland forms described in general terms by the Ramsar classification: marine (coastal wetlands), estuarine (deltas), lacustrine (wetlands associated with lakes), riverine (wetlands along rivers and streams), and palustrine (marshes, swamp forests, mires). There are also numerous anthropogenic wetlands, including constructed wetlands (sewage treatment plants) and reservoirs.

Of marine and coastal wetlands, the most characteristic are shallow bays, lagoons with shallow stagnant brackish water and coastal meadows located as narrow belts along the shoreline. Also, reedbeds are widespread along the coast. Mires, wetland forests, inland water bodies and floodplains form a pattern of typical inland wetlands. The typological variation of mires that are still widely distributed is relatively large (Masing, 1982, Masing et al., 2000, Paal, 2005). Several wetland forest types (mesotrophic and oligotrophic bog forests) are among the most common in Estonia, while at the same time floodplain forests have survived only very fragmentarily (Paal, 1998). Wet floodplain grasslands covering extensive areas along the lower courses of rivers are mostly of anthropogenic origin. Of about 1200 bodies of fresh water, many are shallow, and several transitions between aquatic and wetland communities can be observed.

Wetland coverage

Wetlands of the region developed during the post-glacial period. Being very dynamic ecosystems, they are in permanent natural development. Nevertheless, most of the changes in wetland distribution and quality are caused by direct or indirect human impact. Since the 1950s, several surveys on different wetland types have been performed in Estonia, but as the whole range of wetlands or the entire territory of the country has not been covered, there is no comprehensive estimate of the current wetland area. Likewise, it is difficult to evaluate the original extent of wetlands. In the most recent and comprehensive overview of wetlands (Paal et al.,1998), several wetland types were excluded, and protected wetlands were also not assessed. The CORINE Biotopes project completed in the Baltic States in 1997–1998 provided a valuable database on natural areas, but wetland coverage is under-estimated due to the classification system used.

The estimate of wetland coverage of 1,452,500 ha in Estonia by Stevenson and Frazier (1999) is quite rough. The estimations systematized in the framework of Natura 2000 (Table 2 in **II**) make it possible to assess that the area of preserved valuable wetlands is over 900,000 ha. It must be taken into account that the area estimates for several habitats are still very preliminary, because detailed mappings of some wetland areas have not been conducted. In addition, this database does not include all wetland types, and there are also differences in how some habitats have been interpreted. Consequently, the actual area of preserved wetlands in Estonia is most likely more than a million hectares.

Wetland loss

When large areas of wetland are drained, the ecosystem services these wetlands performed are lost (Zedler and Kercher, 2005). Ilomets and Kallas (1995), Leibak and Lutsar (1996), Paal et al. (1998) and Paal (2005) have shown that in Estonia vast areas of wetlands have been damaged and degraded, mainly due to agricultural and forestry drainage. Mires, especially several minerotrophic mire types, as well as floodplain grasslands, have suffered most (Table 3). Estimations of lost and of preserved pristine mire area differ depending on what degree of drainage is accepted (**III**). According to Ilomets and Kallas (1995), about 70% of peatlands have been drained or affected by drainage to the extent that peat accumulation processes are ceasing, and only the mineralization of accumulated organic matter is proceeding. The majority of preserved mires are ombrotrophic bogs. The cessation of traditional land use (grazing, mowing) has caused a decrease in the distribution of coastal and floodplain meadows and some minerotrophic fen types.

Table 3. Loss of particular wetland types after Ilomets and Kallas (1995); Leibak and Lutsar (1996); Paal et al. (1998) and Paal (2005).

Wetland type	Area in 1950s (ha)	Area in 1990s (ha)	Main reason for decline
Spring fens	1500	400	Drainage of surrounding area
Species-rich fens	74,900	7000	Mostly drainage for agriculture
Poor fens	152,300	30,000	Drainage for agriculture and forestry
Transitional bogs	76,200	10,000	Drainage for agriculture
Wooded transitional bogs	151,800	ca 8000	Mostly drainage for forestry
Bogs and bog forests	380,000	250,000	Drainage for forestry and industry
Coastal grasslands	28,750	18,000	Overgrowing due to cessation of traditional use
Floodplain grasslands	83,000	20,000	Drainage, overgrowing due to cessation of traditional use

Although the loss of certain wetland types as minerotrophic fens has been dramatic (90%), the situation in Estonia concerning the total area of wetlands is not as critical as in many other countries in Europe (see Stevenson and Frazier, 1999; Brinson and Malvarez, 2002; Moore, 2002). Overall losses exceeding 50% of original wetland area have been reported for the Netherlands, Germany, Spain, Greece, Italy, France and parts of Portugal and Belgium.

3.2. Wetland ecosystem services

The identification and valuation of ecosystem services is a new and developing approach. Wetlands are characterized by functional and ecological complexity, which makes it difficult to recognize and assess the full range of their ecosystem services. Several studies have been initiated, but only in very recent years, e.g. in 2007 U.S. Environmental Protection Agency launched a special program with the aim of identifying, characterizing and assessing wetland services that contribute to human well-being and produce the information and methods needed to shape policy and management actions that conserve and enhance the benefits of wetland services (EPA-SAB, 2009). Case studies to examine ecosystem services of certain wetlands have been initiated in Great Britain (McInnes et al., 2008). There are several examples of the assessment of ecosystem services at a catchment or regional geographical scale (Gleason et al., 2008; Murray et al., 2009). In Estonia, few studies have yet been carried out on the valuation of ecosystem services (Gren et al., 1996; Ehrlich and Habicht, 2001; Merivee, 2006).

Ecosystem services can be classified in different ways. The categories of services are overlapping (Millennium Ecosystem Assessment, 2003), and the classifications often reflect the individuality of their authors (Ehrenfeld, 2000). The ecosystem functions and services used by Costanza et al. (1997) and the classification of ecosystem functions, goods and services by De Groot et al. (2002) are quite similar to the system of landscape functions devised by Bastian and Schreiber (1994) (**I**) and the beneficial functions of peatlands by Joosten and Clarke (2002) (**IV**). Here an attempt has been made (Table 4) to identify the main ecosystem services delivered by Estonian wetlands according to the categorization of the Millennium Ecosystem Assessment approach (Millennium Ecosystem Assessment, 2005). Examples are given only for some sub-services that have been a target of study.

Table 4. Main ecosystem services provided by Estonian wetlands

Services	Explanation (sub-services)	Most relevant
Provisioning		
Fuel	Peat (heat and electricity production); fuel wood	Peatlands, constructed energy wetlands
Fiber (materials)	Gardening peat, reed and cattail (construction), wood, hay	Peatlands, reedbeds, floodplain and coastal meadows
Food	Fish (coastal and inland lake fisheries), berries	Low sea, lakes, rivers, peatlands, wet forests
Biochemical products	Peat in chemical industry; curative mud; herbs as natural medicines	Peatlands
Land	For grazing	Coastal meadows
Fresh water	Drinking water	Some rivers

Services	Explanation (sub-services)	Most relevant
Regulating		
Climate regulation	Regulation of greenhouse gases (source and sink)	Peatlands
Hydrological regimes	Groundwater recharge and discharge; storage of water	Rivers, lakes, peatlands
Pollution control	Retention, recovery and removal of excess nutrients and pollutants	Rivers, constructed wetlands
Natural hazards	Flood control, storm protection	Floodplains, coastal wetlands
Cultural		
Spiritual and inspirational	Personal feelings and well-being ("home landscape", island of silence)	All, in particular bogs, coastal meadows
Recreational	Opportunities for tourism and recreational activities; bird watching	All, in paricular peatlands, coastal and floodplain meadows
Aesthetic	Appreciation of natural features	All wetlands
Educational	Opportunities for formal and informal education and training	All wetlands
Research	Sediments as an archive for study, survey field	Peatlands, lakes
Supporting		
Biodiversity	Habitats for species	All wetlands
Soil formation	Sediment retention and accumulation of organic matter (peat accumulation)	All wetlands
Nutrient cycling	Storage, recycling, processing and acquisition of nutrients	All wetlands

Provisioning services

Peat for energy production and horticultural use

Peat is the second most important strategic energy source in Estonia after oil shale, and it has so far been treated as a renewable natural resource. Geological peat resources in Estonia amount to 2.37 billion tons (Orru et al., 1992; Orru and Orru, 2008). Economically exploitable reserves of peat are estimated at 1520 million tons. The first written records of the use of peat as a fuel in Estonia date back to 1861 (Valk, 1988). Highly decomposed peat has been used for heating and electricity production. Estonia holds 3rd to 4th place in the world in the export of horticultural peat. It has been assumed that this increasing trend is likely to continue, as high quality horticultural *Sphagnum* peat resources are very limited in Europe (Paal et al., 1998). According to Statistics Estonia (Figure 2), in the last decade 0.34–1.27 million tons of peat has been excavated annually. In 1999–2002 the extraction of low-decomposed peat that is used in horticulture was dominant. Since 2003 the extraction of fuel peat is increasing due to the rising use of peat in peat-and-wood-based combi-power plants.

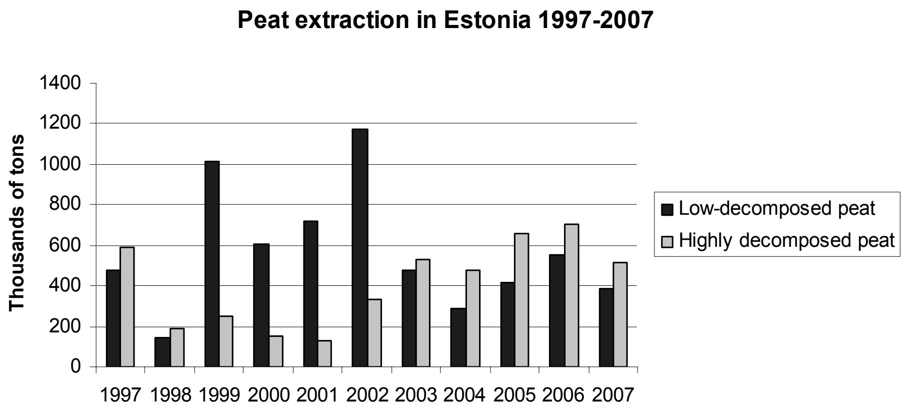

Figure 2. Peat extraction in Estonia in 1997–2007.

Peat, and also curative mud, is used in balneology and balneotheraphy. The amount of peat suitable for balneological purposes in Estonia is estimated at 1 million tons (Orru and Orru, 2008).

Biomass for energy production and construction

Emergent macrophytes of natural and constructed wetlands are highly productive. Reed (*Phragmites*) is a well-known and valuable building material, especially for roofs. Likewise, clay-sand plaster with phytomass of cattail (*Typha*) is a highly valued building material for environmentally-friendly construction (Madisson et al., 2009).

Wetland-based energy production is considered to be a promising source for small-scale heating plants (Mander et al., 2001). Based on the average biomass production of reed (*Phragmites*) and cattail (*Typha*) of 1.5 kg m^{-2} yr^{-1}, the estimated energy value of one hectare of an energy reed-bed is approximately 200 GJ. A significant amount of oil shale, the main Estonian national fossil energy source, but also some of the imported fuel and gas, can be replaced by energy production from wetlands. A large proportion of drained agricultural areas are not of interest for further agricultural use, and can be used for wastewater treatment and as energy wetlands. About 30% of Estonia's annual heat consumption and 20% of electrical energy production could be covered (Mander et al., 2001).

Food

The main wetland food resources are fish and wild berries. Low coastal waters and inland lakes (particularly Lake Peipsi and Lake Võrtsjärv), as well as some smaller lakes and rivers, are important for local small-scale fisheries. According to data from Statistics Estonia, the total catch of coastal fisheries in 2008 was 12.643 tons. Vetemaa et al. (2006) found that rapid changes in political and economical developments have caused over-fishing of some of the most important coastal fishery resources. This has caused the loss of the importance of the coastal fishery during recent years, and as there are few alternative employment possibilities in many coastal areas, increasing social problems have hit households that depend on fishing.

Peatlands and wet forests are valuable sources of wild berries. Berry picking is increasingly popular, and for some residents of the countryside forms an important source of living. The potential annual yield of cranberry (*Oxycoccus palustris*) could be 5 tons, and bilberry (*Vaccinium myrtillus*) and cowberry (*Vaccinium vitis-idea*) are also of great potential (Paal et al., 1998).

Regulating services

Climate regulation

Peatlands cover over 4 million km2 worldwide (3% of the world's land area), and contain 30% of all global soil carbon (Parish et al., 2008). Peatlands influence climate on a global scale, sequestering CO_2 and emitting CH_4 and a small amount of N_2O into the atmosphere (Minkkinen et al., 2002).

The alteration of peatlands due to human activities or climate change may lead to a changing role (source versus sink) of peatlands with respect to greenhouse gas emissions and their influence on the greenhouse effect. Most relevant are changes in land use (e.g. drainage) that directly affect C sequestration and the emission of greenhouse gases (Mosier et al., 1991). Alongside Sweden, Finland and Russia, Estonia has one of the largest areas and proportions of peatlands of all European countries. 22.5 % of the country (1,010,000 ha) is covered by peat. The majority of peatlands in Estonia have, however, been degraded. The estimation (**III**) confirmed that one of the main ecosystem services of peatlands, the accumulation of carbon and the binding of CO_2, has fallen in quantity in Estonia. The annual loss of C from peatlands is estimated to be 38 to 86 tons C x 10^3 year $^{-1}$.

Water regulation

Wetlands exert a strong influence on the hydrological cycle (Bullock and Acreman, 2003) but this is site-specific. Wetlands, and in particular riparian wetlands, represent an interface between the catchment area and the aquatic environment. They control the exchange of water and related chemical fluxes from the upper catchment area to surface waters like streams and lakes. Hattermann et al. (2006) showed that despite the relatively high uncertainty of eco-hydrological models, simulation results indicate that although wetlands represent a relatively small part of the total catchment area, they may have a significant impact on the catchment's overall water and nutrient balances.

Pollution control

Water quality improvement and the control of pollutant transport are the most important regulatory functions of wetlands (Mitsch and Gosselink, 2000, 2007; Blackwell et al., 2002; Zedler and Kercher, 2005; Verhoeven et al., 2006).

Wetlands are very efficient in removing pollutants from inflowing water (**I**). One of the means for using wetland ecosystem services is in wastewater treatment (Mander and Mauring, 1997; Öövel et al., 2007). There are about 100 wetlands in Estonia that are spontaneously used as primary or secondary treatment systems. About 40 of these are constructed wetlands (CW) with more or less controlled fluxes (10 hybrid CWs consisting of vertical subsurface flow (VSSF) and horizontal subsurface flow (HSSF) filters, and in some cases also of free water surface wetlands (FWSW); 14 HSSFs and about 16 FWSWs). About 10 systems are covered by the monitoring of purification efficiency. Free water surface wetlands have structural and functional attributes that can even enhance the quality of the landscape and provide a high biodiversity (Hansson et al., 2005). Restored and enhanced wetlands can provide compensation for the loss of wetland functions and services caused by human development activities. In Estonia, for instance, prime candidates for restoration include 100,000 ha of wetlands that were degraded through artificial drainage and intensive farming (Lesta et al., 2006).

Cultural services

Very few information on cultural services which provide humans with re-creational, spiritual and aesthetic values can be found in academic literature. However, the significance of these non-material life support functions and services is indicated by the large amounts of money that are spent in such areas as recreation, arts, religion, species conservation, and pure science (Joosten and Clarke, 2002).

Estonia's ancient mires and particularly bogs are described by Masing (1997) as nature monuments and the obvious analogy with cultural monuments is found. Both are unique, outstanding or significant objects, from which one can get valuable information about life and environment of the past, also there is a beauty in both of them. The study on cultural and historical values in landscape planning and local people perceptions (Alumäe et al., 2003) with focus on rural landscapes demonstrated that lakes belong to the list of outstanding natural objects which are regarded by people as most essential valuable features forming valuable landscape. A peculiar kind of archaeological find are the sacrificial sites discovered in wetlands (Jaanits, 1988). Some of these were used for at least a thousand years. The oldest objects so far found on sacrificial sites may date from the beginning of our era and the most recent from the Middle Age.

Wetlands are an important resource for scientific research, including the study of past environments and climate change. There is extensive literature on the development of the environment and landscape in Estonia based on analyses of sediment sequences of mires and lakes (e.g. Veski, 1998; Kimmel et al., 1999; Poska et al., 2004; Punning et al., 2005; Veski et al., 2005), and palaeo-climatic reconstructions (Charman et al., 2004; Sillasoo et al., 2007) have also been carried out.

Supporting services

Biodiversity

The Millennium Ecosystem Assessment recognises that biodiversity forms the foundation of the vast array of ecosystem services that critically contribute to human well-being. Still the role of biodiversity in providing these services is purely quantified and ecologists are called to measure and analyze ecosystem services to develop a better understanding of their underlying ecology (Kremen and Ostfeld, 2005).

Estonian vital wetland ecosystems greatly contribute to biological diversity (Masing et al., 2000; Kuus and Kalamees, 2003; Paal, 2005; Ministry of Environment, 2008) and species at risk. Estonia has a total 33 wetland habitat types (Table 2 in **II**), of which six types are priority habitats for the EU. These are boreal Baltic coastal meadows, karst lakes, active raised bogs, calcareous fens, alluvial forests and bog woodlands. At least 117 of the 166 species of European Union importance listed in the Annexes of the EC Habitat Directive that have been recorded in Estonia are fully or partially dependent on wetland habitats (Table 3 in **II**). All six globally threatened bird species present in Estonia – *Gallinago media*, *Crex crex*, *Aquila clanga*, *Haliaeetus albicilla*, *Polysticta stelleri* and *Anser erythroporus* – depend on wetlands. Of these, *Gallinago media* and *Crex crex* directly depend on the active management of floodplain meadows.

3.3. Wetland use and management

Because of the many services and multiple values of wetlands, many different stakeholders are involved in wetland use, which can lead to conflicting interests and the over-exploitation of some services at the expense of others. Additional activities needed for integrated assessment of the role of wetland ecosystems in development planning include analysis of pressures, trade-offs, and management implications (De Groot et al., 2006).

3.3.1. DPSIR analysis

Table 5 presents the results of Driving forces – Pressures – State – Impact – Responses analysis used in order to briefly present the wide spectrum of activities, pressures and impacts related to the use of wetlands in Estonia (**II**). It is difficult to assess all of the various aspects of wetland values against human economic interests and factors influencing wetlands. Direct and indirect drivers and also the continuing impact of ancient activities affecting current wetland quality must be taken into account. For example, the modification and direct damage of wetlands by drainage for agriculture, which used to be the main driving force for wetland loss in Estonia (most intensively in the period 1950–1980), has now practically ceased, but the impact of earlier activities causes the continuing alteration and degradation of valuable habitats and a decline in ecosystem services.

Table 5. The most essential aspects related to the sustainable use of Estonian wetlands according to the DPSIR model. Abbreviations: IPPC – Integrated Pollution Prevention and Control; EIA – Environmental Impact Assessment; ICZM – Integrated Coastal Zone Management

Drivers	**Pressures**	**State**	**Impact**	**Responses**
Intensive agriculture and land reclamation and forest drainage in the period 1950–1980 and continuing influence thereof	– Conversion into farmland – Drainage of wet forests, fens and floodplains – Dredging of rivers and streams – Lowering of the water table of lakes – Intensive use of mineral fertilizers	– Lost or dramatically changed wetland habitats – Large proportion of drained wetland areas characterized by peat degradation and mineralization causing emission of greenhouse gases – Water pollution: high concentration of N in rivers and groundwater – Accelerated eutrophication and overgrowing of water bodies	– Loss of biodiversity: loss of habitats and decline in numbers of several endangered species – Emission of greenhouse gases causing climate change – Eutrophication of water bodies	– Legislation and strategies promoting conservation – Management activities (buffer zones etc.) – Creation and restoration of wetlands – Decreasing nutrient loading by restoring wetlands in the catchment area – Support of traditional land use
Peat industry	– Peat extraction – Drainage of extraction fields and surrounding areas	– Overexploitation of resources – Destroyed mires – Drained surrounding areas of excavation fields – Cut-away fields as a source of greenhouse gases	– Loss of biotopes – Emission of greenhouse gases causing climate change	– Legislation and strategies – Regulation of use of peat resources – Restoration of excavation fields – Protection
Changes in agricultural land use A Abandonment B Intensification	– Ending of traditional land use – Land abandonment – Overgrowth of open habitats – Increasing use of fertilisers	– Overgrowth of wet meadows by bushes and reeds – Loss of open wetland habitats and landscape – Pollution of watercourses	– Loss of biotope and landscape diversity – Decrease in numbers of several species/ habitat loss and degradation – Eutrophication	– Management: reversing the succession of wetlands by reed and bush cutting, mowing and grazing – Supporting traditional extensive agricultural practices under agri-environmental schemes etc. – Implementation of IPPC – Following ‘Good Agricultural Practices’

Drivers	Pressures	State	Impact	Responses
Forestry	– Reconstruction of forest drainage systems	– Drained wetland forest habitats – Bogs affected by drainage of edges	– Loss of habitats – Decrease in numbers of several species	– Strategies looking for compromise between forestry and conservation interests
Development projects	– Construction (harbours, roads, bridges, reservoirs, dams, windmill parks etc)	– Damaged or influenced wetland habitats	– Loss of biotopes	– Controlled planning and implementation of EIA – Development of ICZM – Public control (NGOs)
Industry	– Extraction of mineral resources (oil shale, limestone) – Pollution	– Destroyed mire habitats – Degraded mire habitats – dropped ground water level	– Loss of habitats – Loss of mire species (Sphagnum) and changed plant composition – Degradation of habitats (fens)	– Controlled planning and implementation of EIA – Public control (NGOs)
Energy production	– Peat cutting – Damming of rivers for local power stations – Creation of energy-wetlands	– Destroyed habitats – Disturbed fish resources	– Loss of habitats – Harmed species – Support to sustainable use	– Legislation and strategies
Tourism and recreation	– Visitor pressure	– Growing interest	– Possible negative impact (depends on carrying capacity)	– Visitor management – Development of ICZM
Natural succession		– Overgrowing and filling in of shallow water bodies	– Habitat change – Changed living conditions of species	– Technical measures
Climate change	– Increase in temperature – Change in seasonal precipitation pattern	– Trend towards milder winters – Lowering groundwater level	– Habitat change – Changed living conditions of species – Increased mineralization	– International legislation and strategies

Despite conservation successes, Estonia's natural wetlands and their ecosystem services are continuously threatened by the growing influence of urban development, agriculture, forestry and mining. Therefore the integration of wetland management into environmental planning is an important issue. In general, the DPSIR framework is a useful tool to clarify and logically order the complex series of processes and environmental problems connected with the sustainable use of wetlands. However, in the case of such a complex issue as wetlands, it is not easy to present all aspects of the pressures (which can have a positive or negative impact) and the degree of intensity of the impact, and the details of efforts to respond to them. Accordingly, only the most crucial challenges will be discussed herein.

Greenhouse gas emissions from peatlands due to the effect of drainage

The estimation of the global warming potential of Estonian peatlands (transitional fens and ombrotrophic bogs) based on greenhouse gases (GHG) CO_2, CH_4 and N_2O and carbon C accrual in biomass, and the effects of drainage on these processes (**III**) illustrates the effect of drainage as a driver of wetland degradation and environmental damage. For this study, data were derived from a review of the literature on boreal peatlands. Areal estimates of peatland types were multiplied with the values of the interquartile range of literature-derived GHG fluxes. The effect of drainage and the radiative forcing of Estonian peatlands were also evaluated. Drained peatlands are a large net source of C. Collectively, undrained and drained peatlands emit 38 to 86 tons C x 103 $year^{-1}$, and for Estonian peatlands, more C is released into the atmosphere than is sequestered. Thus due to drainage, Estonia's transitional fens and ombrotrophic bogs have gone from sinks to sources of C.

Cut-away peatland areas, which are estimated to cover approximately 10,000 ha, provide an additional source of greenhouse gases. Against this background, the need to restore degraded peatlands to natural ecosystems is evident. After restoration, cut-away peatlands may return to a functional state that is close to that of pristine mires and restore a net carbon sink function (Vasander et al., 2003). Approaches and techniques valid for restoration procedures (Lode, 1999) suitable for Estonian peatlands must be elaborated. For this, much research is needed, and only long-term monitoring of the current restoration projects will confirm whether it is possible to restore the ecological functions of the cutover peatland to return it to a peat-accumulating ecosystem (Rochefort and Lode, 2006).

Impact of peat extraction

In 2005 the State Audit Office audited the national government's activities in planning the use of peat resources and managing their extraction, and found that the use of peat reserves had not been organized in a sustainable manner (State Audit Office, 2005). Additional pressure on mires comes from oil shale mining and processing (Karofeld and Ilomets, 2008). In order to find a compromise between the interests of peat extraction and conservation, the drafting of the concept of the conservation and sustainable use of Estonian peatlands has recently been initiated, with the aim of preparing a strategy and relevant action plan by the end of 2010. There is an opportunity and challenge in this process to implement a framework for the integrated assessment and valuation of wetland services (De Groot et al., 2006) including monetary valuation. Improvement of peat production and combustion methods can be applied to decrease to some extent the greenhouse effect of peat energy (Kirkinen et al., 2007; Waddington et al., 2009).

Maintenance of semi-natural wetland habitats

The maintenance of semi-natural wetland types such as coastal and floodplain meadows and paludified meadows, which is of first-level priority from the point of view of biodiversity (Ministry of Environment, 2008), has become seriously threatened as such traditional grasslands have been set aside from agricultural use for economic reasons (Leibak and Lutsar, 1996; Masing et al., 2000). Burnside et al. (2007) found that grazing abandonment reduced the extent of coastal wetland grasslands of particular conservation value. For further preservation, it is of essential importance that financial means necessary for the continuing of management measures be sought. EU agri-environmental schemes are one tool supporting the management of these important habitats (Young et al. 2004). The promotion of traditional practices is an important aspect of the management of protected sites.

Development pressure

There is growing development pressure (housing, golf courses, etc.) on virgin coastal areas, despite legal restrictions. There are also several project ideas that may have a great influence on wetlands. For example, there is a discussion of two alternatives for the creation of a road link between the island of Saaremaa and the mainland, either by building a bridge, which would seriously impact the areas of low coastal waters, or by digging a tunnel, which would probably be more expensive, but less environmentally damaging. The Eesti Energia corporation and several other companies have reserved huge areas of the coastal sea for the investigation of possibilities for the establishment of off-shore wind farms in addition to the wind farms that have already been established on coastal meadows (Kull and Laas, 2003). Applying an Integrated Coastal Zone Management (ICZM) approach to promote sustainable planning and resolve conflicts will be a challenge.

Tourism and recreation

In recent years, the development of infrastructure as the precondition for the functioning of wetlands as tourist and educational sites has been rapid. There are at least 16 centers that mainly introduce different wetland types and provide information, guided nature tours and educational packages. There are over 50 boardwalks and about 30 observation towers that facilitate wetland visits and appreciation, and these have become increasingly popular. Wetlands have not, however, been studied from the point of view of carrying capacity and disturbance sensitivity. According to Paal (2005), mire tourism is still in a rather embryonic stage, considering its perspectives and the vast mire areas, and there has not yet been any significant negative impact on the local wildlife due to tourism. However, the study of the influence of disturbance on the distribution pattern and number of bog bird fauna based on the example of *Pluvialis apricaria* in Nigula Bog (Konnov, 2003) showed that the boardwalks in wetlands affect the distribution pattern and population of birds. It is evident that there should be a common strategy for the whole of Estonia for the development of tourism facilities in wetlands.

Impact of climate change

Climate warming due to enhanced greenhouse effect is expected to have a significant impact on the natural environment at high latitudes. Changes in the region's climate will ultimately lead to changes in the productivity of marine and coastal ecosystems (Kont et al., 2008), and its impact on inland wetlands and their biodiversity has not been sufficiently investigated or generalized (Ilomets, 1996; Kont et al., 2007). The main projected impacts on inland wetlands and their biodiversity are associated with changing hydrological conditions due to increases of temperature and changes in seasonal precipitation patterns that lead to shorter periods with snow cover, higher evapotranspiration and reduced groundwater recharge. Lowering the groundwater level is expected to increase mineralization rates, which in turn could increase the availability of nutrients and result in eutrophication; this would affect wetlands species composition (Kull et al., 2008; Smith et al., 2008).

3.3.2. Policy framework and management of wetlands

Policy framework

There is no specific act or other legal document dedicated exclusively to wetlands in Estonia, and there is also no special wetland policy or strategy. However, the whole legal framework generally supports the protection and sustainable use of wetlands (**II**). The Estonian Environmental Strategy, the national strategy "Sustainable Estonia 21", sectoral strategies and action plans, EU legislation and international conventions are the documents which provide objectives for improving or maintaining the country's environmental status. As wetlands are a common feature in the Estonian landscape, all legislation related to planning, environmental assessment, water management and biodiversity protection also concern the wise use and preservation of wetlands.

Policy goals, targets and measures related to wetlands are included in the National Environmental Strategy and relevant Action Plans, despite the fact that the term "wetland" is not applied. The "green network" promotes nature protection outside the protected territories by establishing an inter-linking and buffering territorial structure for valuable conservation areas.

Cross-sectoral and ecosystem-based approaches to wetland management - such as river (or lake) basin-scale management, and integrated coastal zone management – that consider the trade-offs between different wetland ecosystem services – are more likely to ensure sustainable development than sectoral approaches. Integrated river basin management is a useful tool that offers new possibilities for the integration of prudent wetland use and conservation into environmental management and planning. There are challenges to better implement ecotechnological measures and wetland use in watershed management planning and practice in Estonia (Kimmel et al., 2005).

3.3.3. Wetland conservation

There are calls to include the ecosystem services approach in conservation planning (Chan et al., 2006; Egoh et al., 2007) as this can broaden and deepen support for biodiversity protection and attract additional funding (Goldman et al., 2008). In Estonia classical nature conservation is approached as the establishment of a protected area network rather than the conservation of the entire natural environment. A significant proportion of preserved valuable wetlands are legally protected and have been included in the system of protected areas (Figure 3). An overview of this is given in **II**.

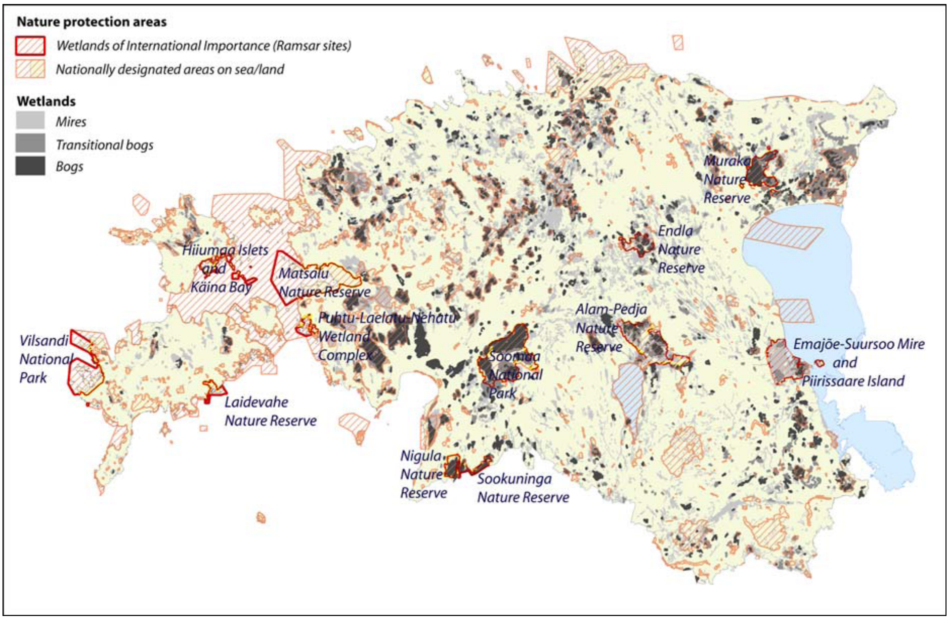

Figure 3. Distribution of wetlands, nationally designated areas and Wetlands of International Importance (Ramsar sites).

A fundamental landmark concerning wetland protection was the establishment of twenty-eight mire reserves in 1981, saving more than 120,000 hectares of mires from melioration, after the decade-long discussion about peatland values initiated and lead by Viktor Masing. The implementation of the Natura 2000 network has significantly increased the proportion of protected wetlands. A total of 66 Special Protection Areas established to fulfill the requirements of the Birds Directive and 509 Special Conservation Areas established pursuant to the requirements of the Habitat Directive belong to the Natura 2000 network in Estonia. As these areas either partially or fully overlap, there are a total of 490 Natura 2000 sites with a total area of 1.4 million hectares (16% of Estonia's territory). 51% of this is located in the sea (predominantly shallow seawater areas), and the total area of mainland Natura 2000 sites is 691,800 ha. Wetland habitats make up a prominent part of this. All Special Protection Areas and 80% of the Special Conservation Areas include a greater or lesser amount of wetland habitats. In total, 33 wetland habitat types covering more than 300,000 ha (Table 6) are protected. 175,000 ha of mires (approx. 45%–60% depending on estimates of total preserved area), 80,000 ha of wet forests, 13,700 ha of flood-plain meadows (nearly 70%) and 11,200 ha of coastal meadows (approx. 50%) are under protection.

Table 6. The area of the main wetland types protected in the framework of Natura 2000, according to the database compiled by the Ministry of the Environment of Estonia.

Wetland type	**Estimated total area (ha)**	**Protected area (ha)**
Marine/Coastal Wetlands	292,150	44,290
shallow marine waters	267,650	33,000
marshes/coastal meadows	24,500	11,200
Inland Wetlands	608,410	270,400
seasonally flooded meadows	20,000	13,700
non-forested peatlands	388,100	175,000
wet forests	100,100–161,100	80,000
Total wetland area reflected in Natura 2000 database	900,160	314,690

Twelve sites with a total surface area of 224,213 hectares have been designated as Wetlands of International Importance. According to the recent assessment by WWF (2008) as to what extent the existing network of Ramsar sites meets the objective of the representation of the diversity of wetlands in the Baltic Sea catchment area, the representation of wetland types is generally acceptable in Estonia, with some reservations for freshwater lakes, calcareous/alkaline fens and bog woodlands.

3.3.4. Implications for restoration

Wetland loss and degradation have substantial and lasting effects, most notably the loss of ecosystem services. Services could be restored through careful planning and restoration (Zedler and Kercher, 2005). In restoration planning, the main limiting factor can be shortcomings in the science and practice of ecological restoration. It is important to understand why and when restoration efforts fall short of recovering the full suite of ecosystem services (Palmer and Filoso, 2009).

In Estonia, the main priority must be the restoration of drained peatlands, due to their contribution of emissions of greenhouse gases (Kimmel et al, 2008; **III**). The analysis of the publications indexed by the Institute of Science Information (ISI) Web of Science from 1980 to 2009 (**IV**) indicated that the concept of ecosystem services is not referred to explicitly in studies on peatland restoration. The interpretation of the content of studies that were identified using search phrases related to various beneficial functions of peatlands showed that the publications on peatland restoration mainly include information on regulating and supporting ecosystem services that are critical to sustaining vital ecosystem functions delivering benefits to people. The key issue concerning the effect of peatland restoration on the provisioning of ecosystem services is the balance of greenhouse gases and their role in global climate regulation.

Several studies report the enhancement of ecosystem functions (which can be translated into the provision of ecosystem services) compared to degraded peatlands, but that the values remain lower than those of the intact ecosystems. Peatland restoration enhances CO_2 sequestration, although restoration (at least in the short time) does not restore the net carbon sink function to that in natural bogs (Waddington and Price, 2000). However, although restoring hydrology similar to natural sites may re-establish CH_4 dynamics, there is geographic or site-specific variability in the ability to restore peat decomposition dynamics (Basiliko et al., 2007). A detailed understanding of hydrological, hydrochemical and ecological process-interactions will be fundamental in adequately restoring degraded peatlands and understanding the impacts of such management actions at the catchment scale (Holden et al., 2004, Ramchunder et al., 2009).

The key issue concerning the effect of peatland restoration on the provisioning of ecosystem services is the balance of greenhouse gases and their role in global climate regulation. Drainage, harvesting and restoration change the ability of the peat profile to produce and emit CO_2 and CH_4. In establishing restoration goals on degraded peatlands, it is important to consider the effect of restoration activities on various components of the ecosystem and the time scales. The restoration of wetlands should be carefully designed to curtail the emission of methane while sequestering soil carbon as the balance of methane emission and carbon sequestration of wetland ecosystems is complicated (Whiting and Chanton, 2001). In the short term, wetlands enhance global warming, whereas in the long-term perspective all wetlands become compensators of the greenhouse effect. Rewetting of drained peatlands is an effective means of reducing emissions of CO_2 and N_2O, but revives CH_4 emissions. In the mid- and long-term, however, the rewetting of peatlands always leads to a substantial net reduction of climate relevant emissions from the peat body compared with the drained baseline (Joosten, 2009).

One of the long-term strategic objectives of the nature conservation in Estonia (Estonian Ministry of the Environment, 2008) is to ensure the preservation of mires of high conservation value and the restoration of spoiled peatlands by protecting and improving the naturalness of their ecological functions and promoting the sustainable use of natural resources associated with peatlands. The challenge is to integrate the ecosystem services framework providing possibilities to assess trade-offs among alternative scenarios of resource use, landscape management and restoration priorities into peatland restoration planning. The valuation process involving stake-holders and monetary valuation could help raise awareness and encourage cross-sectoral co-operation.

4. CONCLUSIONS

1. Based on the analysis presented above, we can conclude that Estonia has achieved good results in wetland protection and the integration of the wise use of wetlands into the legal framework and development strategies. Although a large proportion of wetlands have been converted to agricultural land and drained for forestry, and are continuously destroyed for peat and oil shale mining, Estonia is still rich in wetlands, both in terms of their total area (over 1 million ha) and the great variety of habitats (a total of 33 habitat types). The array of provisioning, regulating, cultural and supporting services are provided by wetlands. Important among these are biodiversity support, the sequestering and releasing of carbon, pollution retention and cultural services.

2. Several wetland types whose preservation is considered to be of priority responsibility in the Baltic Sea catchment area, particularly mires (especially ombrotrophic bogs) and semi-natural wetlands – coastal and floodplain meadows – have been preserved in Estonia in considerably numbers and total area, providing habitats for a number of species that are threatened on a global or European scale.

3. There is a legislative framework in place that supports the sustainable use and conservation of wetlands. The main threats affecting wetlands are addressed in several strategies. The compensation network where legally protected areas are supplemented by areas included in the green network ensures the maintenance of the provision of the main wetland ecosystem services.

4. There are still crucial challenges: first, the addressing of drained wetland areas that have become sources of greenhouse gases; second, attaining sustainable use of peat resources and ensuring the restoration of cut-away peatland areas; third, the maintenance of the traditional management of valuable semi-natural wetlands.

5. The main priority must be the restoration of drained peatlands due to their role in sequestering and releasing greenhouse gases (CO_2, CH_4 and N_2O) i.e. the global climate regulation ecosystem service. Approaches and techniques valid for restoration procedures suitable for Estonian peatlands must be elaborated. Further research is needed to enhance scientific understanding of the factors influencing the provision of ecosystem services and the effects of restoration activities on them.

6. There has been few effort in applying ecosystem services concept and framework in environmental management and conservation planning in Estonia. In order to ensure more balanced decision-making it should be followed that all ecosystem services of given wetland or wetlands generally are taken into account. The valuation process involving stake-holders and monetary valuation could help raise awareness and encourage cross-sectoral co-operation. The existing expertise and large amount of information on biodiversity components and the functioning of wetland ecosystems is an excellent basis for further research and the implementation of the ecosystem services approach.

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SUMMARY IN ESTONIAN

Eesti märgalade ökosüsteemi teenused

Üks aastatel 2001–2005 ÜRO egiidi all läbi viidud globaalse kokkuvõtte Ökosüsteemide Hinnang Millenniumi Vahetusel (Millennium Ecosystem Assessment) põhijäreldusi oli, et hoolimata sellest, et märgalad on inimkonnale erakordselt kasulikud, degradeeruvad ja hävivad nad kiiremini kui teised ökosüsteemid. Koos sellega degradeeruvad või kaovad ka nende ökosüsteemi teenused. Hiljuti esilekerkinud ja kiiresti areneva ökosüsteemi teenuste kontseptsiooni (Costanza et al., 1997; Daily, 1997; Daily et al., 1999; De Groot et al., 2002; Kremen, Ostfeld, 2005; Millennium Ecosystem Assessment, 2005; Farber et al., 2006; Cowling et al., 2008) põhirõhk on ökosüsteemi teenuste hindamisel ja väärtustamisel lähtudes inimeste heaolust. Selle lähenemise on oma dokumentidesse lülitanud ka rahvusvaheline märgalade ehk Ramsari konventsioon. 1971. aastal loodud, ainukese ühele kindlale ökosüsteemile pühendatud leppega, on tänaseks ühinenud 156 riiki. Käesolevas töös analüüsitakse lähtudes Ramsari konventsiooni märgala-käsitlusest ja ökosüsteemi teenuste kontseptsioonist Eesti märgalade mitmekesisust ja olukorda ning nende poolt osutatavaid ökosüsteemi teenuseid, märgalasid mõjutavaid tegureid ja nende mõistliku kasutamisega ning taastamisega seotud probleeme. Analüüsi aluseks olid olemasolevad kirjandusallikad, aruanded ja muu materjal ning Keskkonnaministeeriumi Natura 2000 andmebaasis sisalduvad andmed. Märgalade kasutamisega seotud protsesside ja probleemide loogiliseks järjestamiseks kasutati Põhjused-Tegurid-Seisund-Mõju-Vastused (DPSIR) analüüsi. Ökosüsteemi teenuseid vaadeldi liigestuse kohaselt, mida kasutab globaalne kokkuvõte Ökosüsteemide Hinnang Millenniumi Vahetusel.

Märgala on üldtermin, millega iseloomustatakse elupaiku, mis asuvad sügavaveeliste vee-elupaikade ning kuivade maismaa-elupaikade üleminekualal. Absoluutset vastust küsimusele „Mis on märgala?" ei ole (Mitsch, Gosselink, 2000), sest varieeruvus nende hüdroloogilistes tingimustes, suuruses ja paiknemises sügavaveelise/kuiva gradiendil on väga suur. Siiski iseloomustab kõiki märgalasid 1) maapinnalähedane või madal seisev vesi; 2) unikaalsed märgalamullad, 3) taimkate, mis on kohanenud või talub veega küllastunud muldi. Ramsari konventsiooni rakendusliku määratluse kohaselt on märgalad „sood ja looduslikud ning inimtekkelised, seisu- ja vooluveelised, alalised ja ajutised, mageda-, riim- ja soolaseveelised veealad, sealhulgas merealad, mille sügavus ei ületa kuut meetrit".

Keskkonnaministeeriumi Natura 2000 andmebaasi analüüs ja kõrvutamine Ramsari konventsiooni paindliku klassifikatsiooniga, mis võimaldab märgalade kiiret hindamist ning rahvusvahelist võrdlemist, näitas, et Eestis esineb 33 märgala elupaigatüüpi, mille kogupindala on ligikaudu 900,000 ha. Arvestades, et andmebaasis sisalduvad pindalad põhinevad valdavalt eksperthinnangutel, mitte kaardistamise tulemustel, erinevusi klassifikatsiooniühikutes ning nende interpreteerimises, samuti seda, et andmebaas ei kajasta kõiki märgalasid, võib

Eestis hinnanguliselt olla umbes miljon hektarit säilinud märgalasid. Merelistest märgaladest on kõige iseloomlikumad madalad lahed, laguunid, rannaniidud ja roostikud, sisemaistest märgaladest sood, soometsad, veekogud ja luhad. Lisaks on Eestis arvukalt Ramsari klassifikatsiooni arvatud inimtekkelisi märgalasid (s.h. heitveepuhastus-märgalad).

Ökosüsteemide Hinnang Millenniumi Vahetusel määratleb ökosüsteemi teenuseid kui kasu, mida inimesed saavad ökosüsteemidest ning jagab teenused nelja suurde gruppi: utilitaarsed; regulatiivsed; kultuurilised ja toetavad. Ökosüsteemi teenused põhinevad ökosüsteemide protsessidel ja funktsioonidel, mis eksisteerivad ökosüsteemis hoolimata inimese võimalikust kasust. Teenustest räägitakse seotuna inimeste väärtushinnangutega ja heaoluga (nii füüsilise kui vaimsega). Maailmas areneb kiiresti ökosüsteemi teenuste majanduslik hindamine (Farber et al., 2006; Farley, 2008; Maler et al., 2009), Eestis on vastavaid uuringuid seni tehtud veel vähe (Ehrlich, Habicht, 2001; Merivee, 2006).

Eesti märgalade utilitaarsetest (varustavatest) teenustest (mida inimene vahetult kasutab) on olulise tähtsusega ressursiks turvas, mille tööstuslik varu Eestis on 1,520 miljonit tonni, ning mida kaevandatakse soojuse ja energia tootmiseks ning kasutamiseks kasvusubstraadina. Lisaks on energia tootmiseks ning ehitusmaterjalidena kasutatavad suure produktiivsusega märgalataimed, eelkõige pilliroog ja hundinui. Neid liike ja ka muud märgalade biomassi on perspektiivne kasutada energiatootmiseks väike-katlamajades. Hinnanguliselt (Mander et al., 2001) võiks umbes 30% Eesti küttevajadusest ja 20% elektrienergiatoodangust katta märgalapõhiselt. Otseselt toiduks kasutatavast märgalaressursist on olulisemad kala ja marjad. Rannakalanduse kogupüük 2008. aastal oli 12,643 tonni. Rannakalapüügi osatähtsuse vähenemine mõjutab otseselt rannaelanike elujärge (Vetemaa et al., 2006). Marjade korjamine (jõhvika potentsiaalne kogusaak aastas ulatub 5 tonnini) on teatud osale elanikkonnast otsene elatusallikas.

Regulatiivsetest teenustest (kasu, mida inimesed saavad (enamasti kaudselt) ökosüsteemi reguleerivatest protsessidest) on väga oluline märgalade roll kliima reguleerijana. Sood mõjutavad globaalset kliimat, sidudes CO_2 ning emiteerides CH_4 ja vähesel määral N_2O. Eesti on Euroopas Soome, Rootsi ja Venemaa kõrval üks sooderikkamaid maid (turbaalad katavad 1,010,000 ha ehk 22.5%). Eksperthinnangute kohaselt on 70% sellest alast aga kuivendatud või kuivendusest tugevalt mõjutatud. Kuivendatud ja kuivendamata siirdesoode ja rabade kasvuhoonegaaside voogude analüüs kinnitas, et tingituna ulatusliku kuivenduse mõjust on Eesti soode ökosüsteemi teenus süsiniku sidujana vähenenud. Sood tervikuna on muutunud süsiniku emiteerijaks.

Märgalade üheks oluliseks regulatiivseks ökosüsteemi teenuseks on ka reovete puhastamine. Lisaks on vabaveelistel puhastus-märgaladel funktsionaalseid ja struktuurilisi omadusi, mis võivad maastiku kvaliteeti suurendada ning toetada bioloogilist mitmekesisust. Lesta et al. (2006) analüüsi kohaselt on Eestis umbes 100,000 ha kuivendusest ja intensiivsest põllumajandusest rikutud maad, mida oleks võimalik märgalana taastada.

Märgalade kultuurilised ökosüsteemi teenused on seotud inimeste hingeliste ja esteetiliste väärtustega ning teadus-haridus ja rekreatsioonivaldkonnaga. Maailma märgalade ökosüsteemi teenuste väärtuste kokkuvõtliku hinnangu kohaselt (De Groot et al., 2006) on puhkevõimaluste ja esteetilise informatsiooniga seotud ökosüsteemi teenuste rahaline väärtus kõige suurem. Eesti looduslikuna säilinud märgalade potentsiaal selles osas on väga suur.

Toetavate ökosüsteemi teenuste (mis on vajalikud selleks, et toota ja toetada ülejäänud teenuseid, nt. mullateke, toitaineringe) hulgas on keskne koht bioloogilisel mitmekesisusel. Looduslike märgalade ökosüsteemidel on väga suur osa Eesti looduse elurikkuses. Eestis esinevast 33 märgala-elupaigatüübist 6 elupaigatüüpi (rannaniidud, karstijärved, rabad, lubjarikkad madalsood, lammimetsad ja rabametsad) on Euroopas esmatähtsad elupaigad. Loodus- ja Linnudirektiivi lisades loetletud 166-st Eestis esinevast liigist sõltuvad vähemalt 117 liiki tervikuna või osaliselt märgaladest. Kõik 6 Eestis esinevat globaalselt ohustatud linnuliiki on samuti märgaladega seotud.

Märgalade kaitse korraldamine Eestis on olnud edukas. Märgalad (üle 300,000 ha) moodustavad olulise osa kaitsealade võrgustikust. Kõik Natura 2000 võrgustiku linnualad ja 80% loodusaladest sisaldavad märgala-elupaiku. Eesti on nimetanud 12 esinduslikku ala rahvusvaheliselt tähtsate märgalade nimestikku. Siiski tuleb rohkem tähelepanu pöörata Ramsari konventsiooni filosoofia kesksele põhimõttele – riigi kõigi märgalade mõistlikule kasutamisele. Sellele aitaks kaasa ökoloogilise lähenemise printsiibi laialdasem rakendamine ning märgalade lülitamine integreeritud rannikukavadesse ja valgalapõhistesse veemajanduskavadesse. Eesti märgalade mõistliku kasutamise peamised väljakutsed on: 1) kuivendatud ja kuivendusest mõjutatud turbaaladelt lähtuva kasvuhoonegaaside emissiooni ohjamine; 2) turba kaevandamise korraldamine säästval moel; 3) märgalade väärtuslike pärandkoosluste (luha- ja rannaniitude ning märgade niitude) säilitamine; 4) märgalade ökosüsteemi teenuste igakülgne (kaasaarvatud rahaline) hindamine ning nende väärtuste arvestamine otsuste tegemisel märgalasid ohustava arendustegevuse korral; 5) märgalade ja nende ökosüsteemi teenuste taastamine.

Märgalade, sealhulgas ka soode taastamine on maailmas uus ja laienev maakasutuspraktika. Taastatud soo võib hakata uuesti süsnikku siduma ning on oluline haruldastele ja ohustatud liikidele. Arvutuste kohaselt oleks Eesti kuivendatud rabade ja siirdesoode hüdroloogilise taastamise korral nende kasvuhoonegaaside emissioon 2.3 kuni 2.7 korda madalam kui praegu. Siiski on rikutud sooalade taastamisel väga oluline detailselt mõista hüdroloogilisi, hüdrokeemilisi ja ökoloogilisi protsesse ja nende protsesside vastasmõju, et hinnata õigesti taastamise mõju kogu valgalale. Samuti tuleb arvestada, et süsiniku sidumise protsess soodes on tihedalt seotud metaani emissiooniga. Kuivendatud soode veetaseme taastamine on efektiivne vahend CO_2 and N_2O emissiooni vähendamiseks, kuid virgutab CH_4 emisiooni. Tervikuna ning vaadeldes keskmisel ja pikal ajaskaalal toob veetaseme taastamine rikutud soodes siiski kaasa olulise kliimat mõjutavate emissioonide vähenemise võrreldes kuivendatud aladega.

Käesolevas töös läbi viidud esmane analüüs kinnitab Eesti märgalade ja nende ökosüsteemi teenuste mitmekesisust ja olulisust. Ökosüsteemi teenuste kontseptsiooni rakendamine oleks üheks võimaluseks korraldada paremini loodusressursside kasutamise, looduskaitse ja ökoloogilise taastamise planeerimist. Märgalade ökosüsteemi teenuste täpsemaks määratlemiseks, kirjeldamiseks ja hindamiseks on vajalikud edaspidiseid uuringud ja erinevate teadusvaldkondade ning huvirühmade koostöö.

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PUBLICATIONS

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1981–1992	Institute of Geology, Estonian Academy of Sciences, researcher
1992–2005	Endla Nature Reserve Administration, scientific director, since 2000 monitoring and science specialist
2006	State Nature Protection Centre, Jõgeva-Tartu region, monitoring and science specialist
2006–2007	Environmental Department of Jõgeva County, specialist (project manager)
2008–	Environmental Board, Jõgeva-Tartu region, conservation management specialist

Other activities

Estonian Ramsar Commission, secretary

Rewards

Order of White Star of the Republic of Estonia, V class

Publications

Kimmel, K., Kull, A., Salm, J.-O., Mander, Ü. 2009. The status, conservation and sustainable use of Estonian wetlands. Wetlands Ecology and Management, doi 10.1007/s11273-008-9129-z (in press).

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Conference thesis

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Popular science publications

Ilomets, M. Kimmel, K., Stén, C.-G., Korhonen, R. 2007. Mires in Estonia and Southern Finland. NGO GeoGuide Baltoscandia, Tallinn, 32 pp.

Leito, T., Kimmel, K., Ader, A. 2008. Estonian Conservation Areas. Eesti Loodusfoto Ltd. 296 pp.

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Teenistuskäik

1981–1992	TA Geoloogia Instituut, teadur
1992–2005	Endla looduskaitseala administratsioon, direktori asetäitja teadusalal, alates 2000 seire- ja teadustöö spetsialist
2006	Riiklik Looduskaitsekeskus, Jõgeva-Tartu regioon, seire ja teadustöö spetsialist
2006–2007	Keskkonnaministeerium, Jõgevamaa keskkonnateenistus, koosseisuväline spetsialist (projektijuht)
2008–	Keskkonnaamet, Jõgeva-Tartu regioon, looduskasutuse spetsialist

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Autasud

Valgetähe V klassi teenetemärk

Publikatsioonid

Teaduspublikatsioonid

Kimmel, K., Kull, A., Salm, J.-O., Mander, Ü. 2009. The status, conservation and sustainable use of Estonian wetlands. Wetlands Ecology and Management, doi 10.1007/s11273-008-9129-z (in press).

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Konverentside teesid

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DISSERTATIONES GEOGRAPHICAE UNIVERSITATIS TARTUENSIS

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