REPORTS OF THE FINNISH ENVIRONMENT INSTITUTE 16 | 2013

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This paper is a part of the one-year synthesis study ”Integrated and policy relevant valuation of forest, agro-, peatland and aquatic ecosystem services in Finland” funded by Maj and Tor Nessling Foundation and carried out by the University of Eastern Finland and Pellervo Economic Research PTT together with a large number of voluntary contributing authors from different research institutes, universities and expert organizations, including the Finnish Environment Institute.

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1 Introduction

The history of Finland is related to the past elements of the postglacial nature, being developed since 10 000 years ago, but economically and culturally waters and forests have been of particular importance. However, only lakes are the direct descendants of retiring ice cover, when increasing temperature transformed abiotic ice in the course of millennia back into living elements of nature: lakes and rivers of the inland and the surrounding seas.

The Finns have settled their permanent shelters on the shores of lakes and rivers from the times immemorial (Vilkuna and Mäkinen 1943). In this way they have got an access to the two separate elements of nature: fish from waters and firewood from land, open landscape in the front and protecting forest behind, and drinking water from the lake and hay from lakeshore meadow. Waters have not been a hinder, rather a moving opportunity in summer and during winter as well, easier than hilly and stony terrain. Without lakes and rivers, life would have been many times more difficult – and entirely impossible without water (see Järnefelt 1952, Horppila & Muotka 2011, Figure 1).

The same conclusion can be drawn in regard to the vital role of water ecosystems and their services in our present times. Although the society with its modern man-made systems and infrastructure is fully different, its dependence on water systems has not decreased but become more diversified (Horppila and Muotka 2011). Urban settlements take drinkable water from inland water bodies, agriculture use water for example to irrigation and industry processes water in various ways. Running water operates power installations and water bodies receive and remove waste water. People are boating for fish and pleasure and tourism has transformed all these kind of activities into an industry. All water uses have left their adverse impacts on the aquatic sources, although they are not always easily visible with bare eyes (Horppila and Muotka 2011). In the case of water construction and regulation the impacts are more concrete (Siikamäki 2004). The larger the scale of rivers and lakes are, the more important are their roles and impacts in the society (Tiitiäinen 2010, Simola 2010).

Among the many purposes of the relatively new conceptualization on ecosystem services a fundamental one is to make all the benefits and useful functions of all ecosystems more visible to people and decision makers. This is done to help all people to understand the vital role natural and man-managed ecosystems continues to play in modern societies by providing material goods (fish, wood, crops) and non-material services (climate regulation, flood protection, recreational opportunities) for our well-being. The concept of ecosystem services covers both tangible goods and non-tangible service. In short, ecosystem services are benefits people get from nature, as the concise and popular Millennium Ecosystem Assessment (MA 2005) definition says.

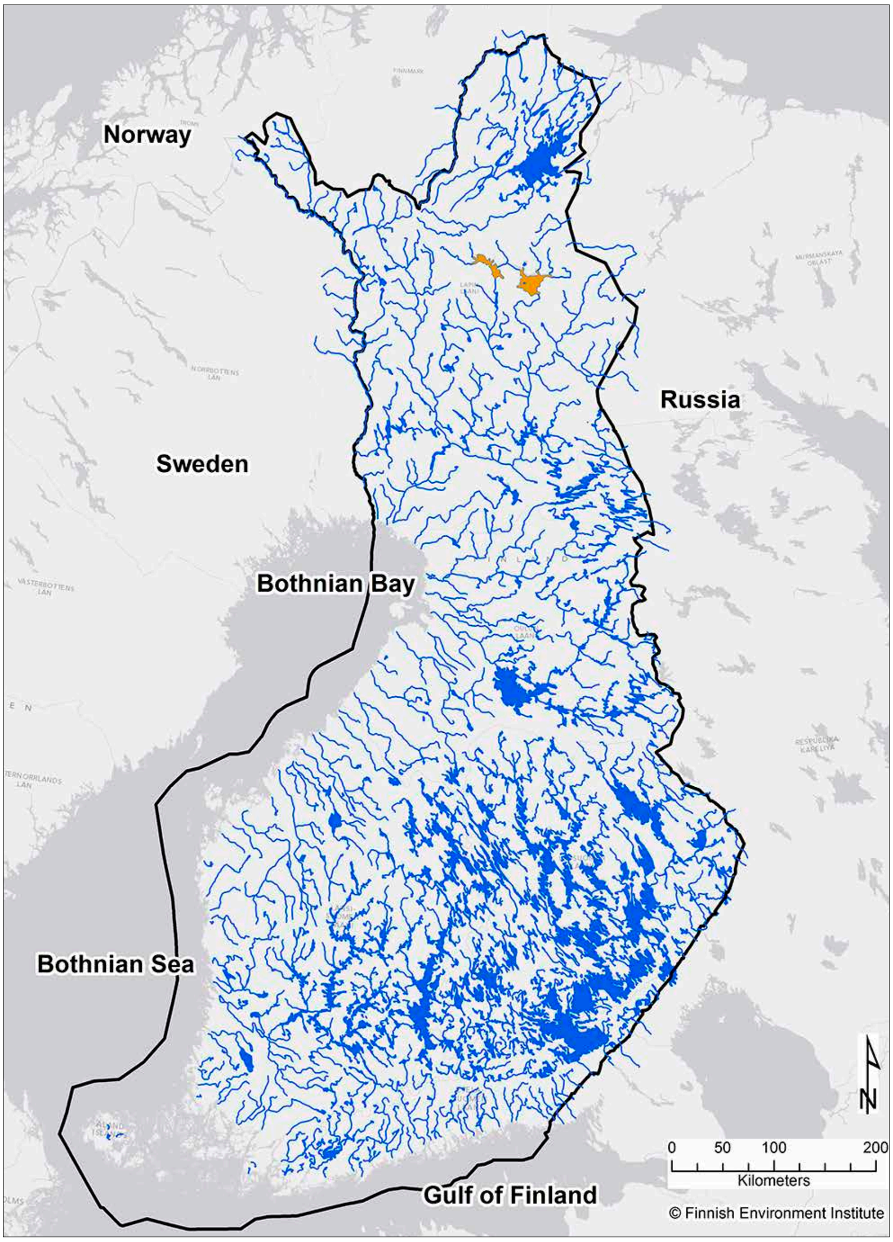

Figure 1. Inland waters of Finland. Two major artificial reservoirs, Porttipahka and Lokka, are marked with orange.

Identification and understanding of the importance of ecosystem services are needed for their full appreciation. Consequently, understanding and appreciation can lead to a better protection and improved management of all ecosystems so that ecosystem services can be utilized and guaranteed sustainably. Ecosystem services also emphasize the necessity of integrating the protection and management of all types of ecosystems in ways that their adverse interactions are minimized and synergic interactions maximized for the benefit for the present and future generations and the entire biosphere.

This is the overall aim of the one-year synthesis study ”Integrated and policy relevant valuation of forest, agro, peatland and aquatic ecosystem services in Finland” funded by Maj and Tor Nessling Foundation and carried out by the University of Eastern Finland and Pellervo Economic Research PTT together with a large number of voluntary contributing authors from different research institutes and universities, among which the collaboration with the Finnish Environment Institute has become very close.

The **general objective** is to produce an up-to-date, integrated and policy relevant synthesis on the ecosystems services of forest, agro-, peatland and aquatic ecosystems in Finland (Figure 2) to serve improved decision making, governance and public communication. The four specific objectives are: Concepts and classifications of ecosystem services (C), Indicators of ecosystem services (I), Valuation of ecosystem services (V) and Policies and decision making (P). Considerations concerning the general conceptual background of the study is found in Saastamoinen et al. (2013).

This report belongs to the sub-study (C) and its purpose is to compile the first systematic suggestions for the classification of the boreal freshwater ecosystem services in Finland. The next chapters feature the overall dynamics of the freshwater ecosystem services in Finland, and more detailed analysis of their present contents and situation.

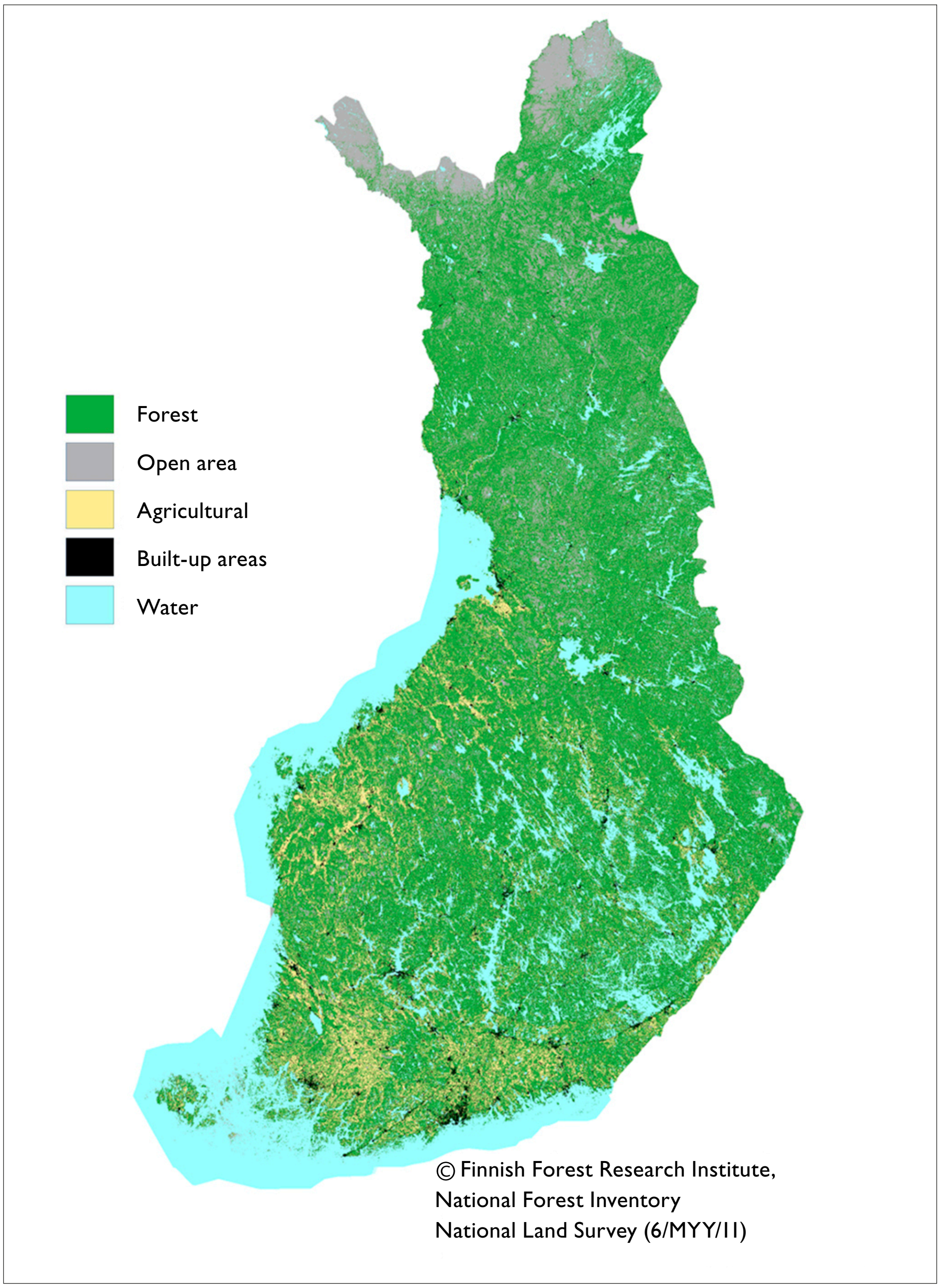

Figure 2. Main land categories and water areas of Finland. Detailed information on water bodies can be found in Figure 1.

We first develop a proposal for the general classification of boreal freshwater ecosystems services in Finland as an application of the (modified) Millenium Ecosystem Assessment (MA 2005) approach. In addition, an experiment is done to apply the more recent and more detailed approach of the Common International Classification of Ecosystem Services (CICES) in the form of its Version 4 / 4.1 (Haines-Young et al. 2012, Haines-Young and Potchin 2012). Some preliminary observations are included concerning the gaps of knowledge for the further assessments of freshwater ecosystem services in Finland.

Figure 3. Many of Finnish freshwaters are surrounded by forests and peatlands resulting to dark water with low visibility.
Photo: Janne Alahuhta

2 Historical evaluation of freshwater ecosystem services

As seen from above, the relative importance of the numerous ways and purposes freshwaters have been used in Finland has been changing during the course of history, but despite that many water benefits -now conceptualised as ecosystem services- have maintained or even increased their vital roles for people, communities, industries and the whole society. Freshwaters, as all ecosystems of the study, are connected and interacting with each other (Figure 2, Figure 3).

Some features of the dynamics of freshwater ecosystem services in the boreal context of Finland are compiled in Table 1 to demonstrate the changes and continuity in the relationships of waters and the society during the past centuries. Services are derived from Millennium Ecosystem Assessment (MA 2005) but some additional – mainly historical- services are also included. Services with italics are those ones originated from MA.

An evaluation of temporal predominance is given to have a rough estimation of the extent each service is considered important at different periods. Three periods given should not be taken literally, but they reflect changes taken place in society. The first period (-1945 in Table 1) from 18th century to Second World War, describe roughly the very long period where shifting and permanent agriculture, tar trade, forest based industrialization and the development of independent nation changed the society and its relationship to the land, forests and waters (for example, Kuisma 1993). The other two periods are considerably shorter. The post-war decades (1945-1980) can be characterized as the period of reconstruction and rapid development of economy, urbanization and effective utilization of natural resources and environment. The most recent three decades (1980-) up to now means the time where environmental deterioration is already widely recognized, goals of sustainable development and the importance of strengthening environmental policies are accepted and, among others, biodiversity has become an important focus of these policies. All these changes in environment, economy, politics and social development, in addition to changes in international environmental and other policies, have in turn been mirrored to the understanding and appreciation of different ecosystem services. It needs to be emphasized that evaluation of temporal changes is service-specific without direct comparability across different services. It also needs to be noted that importance evaluation of ecosystem services in different times is mainly based on the authors' knowledge and judgement and it has not been possible to make any real literature surveys on this topic. The main purpose has been to indicate the existence of dynamic changes in the past, suggesting that the same is probable also in the future.

Table 1. Demonstrative historical evaluation of freshwater ecosystem services in the boreal context of Finland. (-1945: from 18th century to Second World War, the long period where shifting and permanent agriculture, tar trade, forest based industrialization (i.e. log floating) and the development of independent nation changed the society and its relationship to the land, forests and waters (Kuisma 1993), 1945-1980: period of post-war redevelopment, urbanization and utilization of environmental resources, 1980-: heavy aquatic pollution is widely recognized. Evaluation of temporal changes is service-specific without direct comparability across different services. x represents appreciation, X represents high appreciation, and blank box represents no appreciation for a service. Services with italics are those ones originated from Millennium Ecosystem Assessment (MA 2005). Some comments relate to legislation.

	Predominance			
Service	**-1945**	**1945-1980**	**1980-**	**Comments and examples**
Provisioning				
Grazing and fodder	X	X		Subsistence use of water plants as fodder. E.g. muskrat was introduced to Finland in early 1900s and grazing possibilities for muskrat were studied during that period.
Clean water	X	X	X	Storage and retention of water for domestic, industrial and agricultural use.
Food	X	X	x	Production of fish, crayfish and bird game. Use of food resources has changed to a large extent from fishing and subsistence use to aquaculture and market-based use. In addition, some plant parts can be used for eating in case of other food is lacking.
Hydropower	X	X	x	Although hydropower as an abiotic process is not always considered as an ecosystem service in the recent literature -e.g. including still "living" CICES classification-, it has a solid position in the specific water focused ecosystem service surveys (Brauman et al 2007, Ojea et al. 2012). It also illustrates temporal changes in ecosystem service predominance (e.g. Ollila 1998) and the joint production of aquatic and terrestrial ecosystems.
Transportation	X	X	x	Transportation of people and goods has lost some of its importance as roads and trucks provide faster way of transportation. Yet, water transportation made 6% (2008-2010) of total long-distance transport volume of roundwood (Finnish Statistical Yearbook of Forestry 2011). Importance of water courses can be seen in the development and location of settlement.
Biochemical products	x	x	x	Extraction of medicines and other materials from biota. Many plants growing by shoreline and in wetlands have medical benefits, e.g. Garden yellow loosestrife (Lysimachia vulgaris).
Genetic material		x	X	Genes for resistance to plant pathogens, ornamental species etc. Genetic material was not identified until recent decades. Knowledge of decreasing quality and/or quantity of this service due to anthropogenic impacts has emphasized its importance from 80s onwards.
Regulating				
Climate regulation		x	X	Source of and sink for greenhouse gases, influence on local and regional temperature, precipitation and other climatic processes. Aquatic plants can function as sinks (or source) of greenhouse gases. Knowledge of decreasing quality and/or quantity of this service due to anthropogenic impacts has emphasized its importance from 80s onwards.
Hydrological regulation	x	x	x	Groundwater recharge and discharge. In freshwater systems, after melting of snow water levels and discharges are at the highest level in spring. During summer, evaporation is usually larger than precipitation and water levels and discharges drop. At fall rains raise water levels and discharges again. During winter period water levels and discharges decrease to minimum because runoff ceases due to frozen soils and precipitation falls as snow.
Water purification and waste treatment	x	X	X	Retention, recovery and removal of excess nutrients and other pollutants. Includes drinking water purification (surface and ground water), improvement of surface waters from external nutrients derived from agriculture, forestry and industry and freshwater waste treatment. Society waked to water deterioration from municipal wastewater in the middle of 70s and industry also improved its water purification systems during the following decade.
Erosion protection	x	x	x	Retention of soils and sediments. Erosion of soils is typical in regulated water bodies. Channelization of brooks and rivers due to for example drainage causes unnaturally variable fluctuation in discharges thus increasing erosion to an extent. Ponds and small wetlands for example are being used to reduce erosion.
Natural hazards	x	X	X	Flood control and storm protection. Floods -every spring event in Finnish rivers- are regulated through EU Floods Directive and national legislation. Stormwaters create occasional floods in cities. Watersheds were heavily modified and water courses built after World War II to increase the capacity of water bodies for flood control services, however, large hydro-morphological changes were done that decreased naturalness of waters.

Service	Predominance -1945	1945-1980	1980-	Comments and examples
Cultural				
Aesthetic	x	x	x	Finnish cultural landscape is characterised by wetlands and lakes. During agro-society lakes surrounded by fields were typical landscape. Ponds and urban streams have value for mental health in cities (e.g. Lehtoranta et al. 2012, Sarvilinna et al. 2012).
Recreation	x	x	X	Fishing, swimming and boating are most popular free-time activities in Finnish inland waters, summer cottages are often along waters (Sievänen and Neuvonen 2011). 41% of Finns have access to summer cottages on regular bases.
Spiritual and inspirational	x	x	x	Source of inspiration.
Education and research	x	x	X	Opportunities for formal and informal education and training especially in National Parks etc. Number of studies concerning education and research as ecosystem service has increased during past few decades.
Environmental awareness		x	X	Increased awareness of limited natural resources and environmental degradation.
Supporting				
Soil formation	x	x	x	Sediment retention and accumulation of organic matter.
Nutrient cycling	x	x	X	Storage, recycling, processing and acquisition of nutrients. Before WWII recycling of nutrients dominated in water systems and the food production. After the introduction of commercial fertilizers in agriculture, the amount of nutrients in water systems has increased remarkedly causing eutrophication. Now the use of e.g. sediments and water plants has started to interest again since the diminishing amounts of phosphorus to be used as a fertilizer has been talked about.
Habitat	x	x	X	Habitat degradation is decreasing freshwater biodiversity.
Primary production	x	x	X	Bacteria, phytoplankton, diatoms and vascular plants comprise of freshwater primary production. Anthropogenic originated environmental changes affect primary production –often increasing it-, which influences on biodiversity, habitat availability etc.
Photosynthesis	x	x	x	Phytoplankton and vascular plants are primarily responsible for freshwater photosynthesis production.
Water cycling	x	x	X	Humans have made major changes to water cycles through structural changes to rivers, extraction of water from rivers, and, more recently, climate change.

There are many drastic changes in the relative importance of freshwater ecosystems goods and services when comparing the past and present. The role of fish in our diet is one example of those, being also relevant from today's perspective.

During previous centuries, subsistence use related to freshwaters has been very important in Finland. It has been estimated that still during a stone age fish provided 25 % of everyday diet, although it varied a lot between regions and years (Mannermaa 2012). The distribution between freshwaters and seas at that time is not known. Fish and forage resources of inland lakes and rivers formed long an important basis for survival, and settlements were established near waters where it only was possible. Even nowadays boreal freshwaters supply fish, crayfish and bird game, but fish makes roughly only about 1 % of the diet (e.g. Tuomisto et al. 2004). It is considered that it should be much larger to provide a balanced and healthy nutrition.

Otherwise Table 1 is hoped to be largely self-explanatory, in particular for the historical aspects, together with the comments and arguments given within it. To some extent more information about the past is included into the following Chapter 3, which however, primarily characterizes in more detail the contents and present state and importance of the freshwater ecosystem goods and services in Finland.

3 Freshwater ecosystem services based on Millennium Ecosystem Assessment (MA)

Innovation of MA was to bring social sciences more closely together with natural sciences (see Table 1). In addition, biochemical and ecological processes, such as nutrient cycling, were also linked more tightly to ecosystem service sciences. Freshwaters have typically been viewed through natural sciences (e.g. limnology, hydrology and ecology), which emphasize water quality, hydrological flows and habitat quality as potential ecosystem services (Wilson and Carpenter 1999). Clean water supply, transportation via waters and recreation have also been identified as freshwater ecosystem services already decades ago (Postel and Carpenter 1997, Matero and Saastamoinen 1998). MA widely integrated different disciplines, however, cross-scientific approach was adopted among natural sciences in the early 2000s as Water Framework Directive, having a cathment approach, was implemented in Europe (European Communities 2000, Figure 4). Although general guidelines regarding freshwater ecosystem services were identified earlier, contribution of MA was to produce a holistic overall picture of different ecosystem services and document current state and future trends in freshwater system services (Brauman et al. 2007).

3.1 Provisioning services

Several water based benefits, which now are conceptualized as provisioning services related to freshwaters have been more systematically identified from 1970s onwards (Matero and Saastamoinen 1998). As seen earlier, availability of *fish* provided by inland waters have been among the most fundamental ones.

According to Urho and Lehtonen (2008) about 100 fish species (98 teleosteans, one cartilaginous fish and three lampreys) were found to be living in Finnish waters. Altogether 58 fish species can be considered to be native and resident. Annually, it is possible to find 67 bony fishes and two lamprey species in Finnish waters. Urho and Lehtonen (2008) includes a complete checklist of Finnish fish species. The occurrence of species in fresh and Baltic brackish water areas in Finland is also recorded. There are 22 marine fish species, which do not enter freshwaters. More than one third of the species (24) have fresh and brackish water populations and also anadromous ones. The number of native and resident freshwater species is nearly 37, of which 20 are regarded economic species.

The variable conditions (mainly temperature and salinity) have not made it easy for new species to naturalize into Finnish waters. The fish fauna was basically established about 4 000 years ago when the current Baltic Sea era started. Only four species were added to the species list during the last century but two new species were recognised in 2005. In all, 14 new fish species have been imported and introduced into Finnish waters.

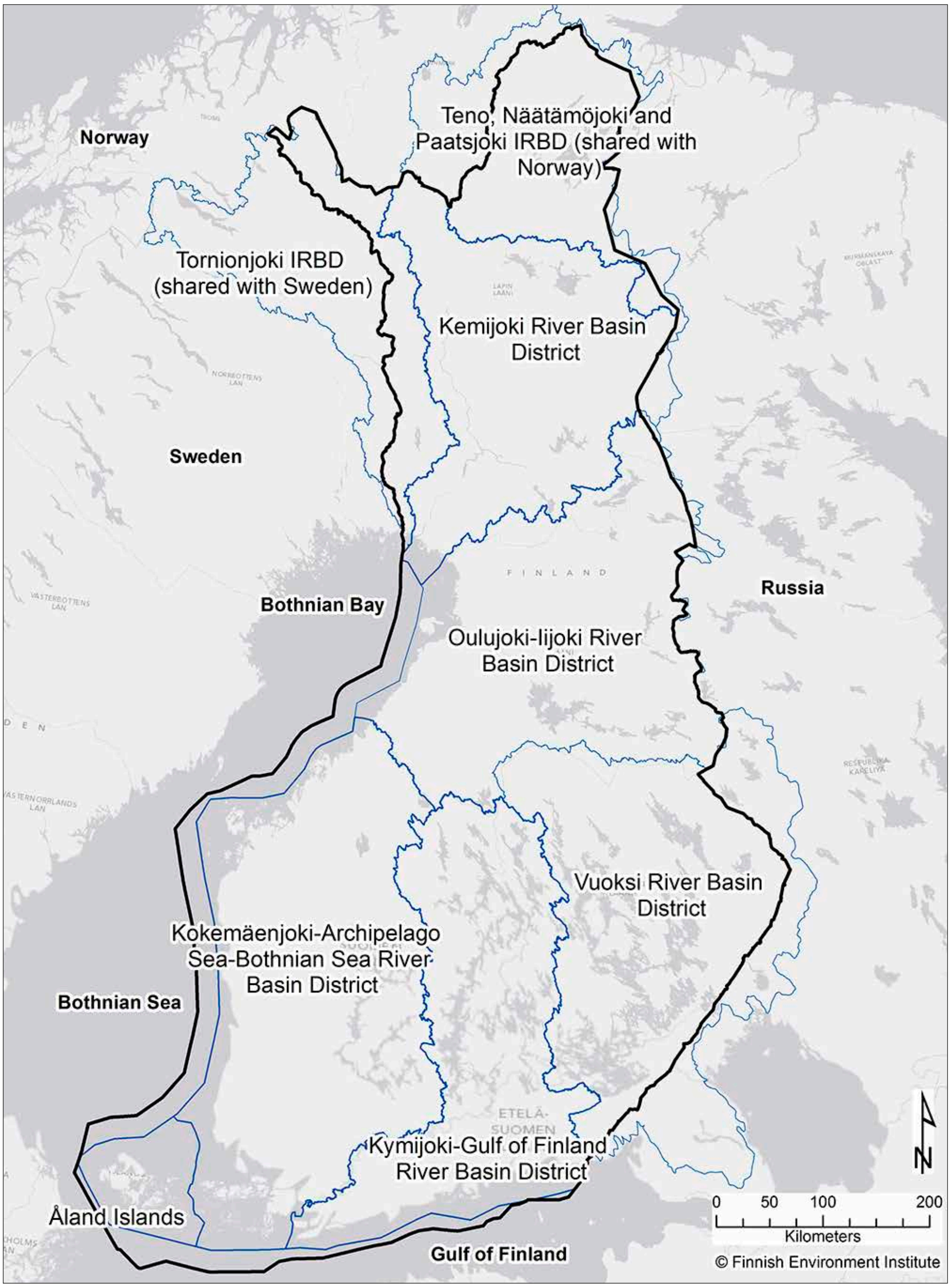

Figure 4. Eight river basin districts in Finland defined under the EU Water Framework Directive (drawn in blue). These districts have been defined on the basis of the natural basins of major rivers. International River Basin Districts (IRBD) are governed together by the neighboring countries. A separate RBD has been defined to cover the autonomous Åland Islands province, where the WFD is being implemented by the provincial government. Finland´s Centres for economic development, transport and environment are responsible for the planning of river basin management in their respective districts, together with local administrative organizations, non-governmental organizations and citizens.

The catch of inland professional fishing in 2010 was about 4.5 million kg. Vendace was the most important species in volume and value. The number of professional fishermen in inlands was only 340, compared to 2 200 professional fishermen in the sea areas, with a total catch of 120 million kg. The majority of eaten fish is farmed, however, whereas professional fishing has petered out in Finland due to high occupational costs and low fish prices. Finns ate 23 million kilograms of domestic fish and 150 000 signal crayfishes in 2010, whereas 533 800 bird game was hunted in 2010 (Finnish Game and Fisheries Research Institute 2011b, 2012a, 2012b).

Clean water for domestic, industrial and agricultural use has also been recognized as a valuable ecosystem service for a long time. Deterioration of freshwater quality awaked authorities to protect inland waters, alarmingly in the 70s latest, which are the most important source of clean water. Clean water can be divided to blue, green, grey and virtual water (Falkermark 2003). Blue water is surface and groundwaters, whereas green water is rain water and soil water. Consumption of blue water has more impact on freshwaters compared to consumption of green water. Grey water is wastewater. Term virtual water is used, when referring to consumed water used in manufacturing products through whole production chain. For example, glass of milk consumes 200 litres of water from growing of grass for cattle to storing of milk carton in stores. Understanding of virtual water consumptions is limited regarding freshwater ecosystem services. In addition, concept of water footprint is to make visible how much people consume of the global water storage (Water Footprint Network 2012). Nowadays, a Finn directly consumes water on average 155 liters daily (Motiva 2012). Daily water consumption on average is divided as following: toilet 26 %, laundry 13 %, kitchen 22 % and hygiene 39 %.

A recognized freshwater ecosystem service related to MA's subject fiber and fuel is *hydropower* production. Dams and artificial lakes, which have great, mostly adverse, ecological consequences, are related to hydropower production and also *flood control*. In addition, waters are regulated for recreational purposes and creating suitable habitats for birds by rising water levels. Historically, lakes and ponds have also been dried or water levels lowered for agriculture. Fish and plants can also be used as *fodder and energy* source. In marginal cases, fish is used as fertilisation in organic farming and in production of biodiesel. Aquatic plants, mostly Common reed *(Phragmites australis)*, have been utilized in construction for a long time.

Biochemical and genetic material as freshwater ecosystem services are rarely mentioned in early ecosystem service studies. Pharmaceutics can possibly be manufactured from aquatic plants. In wider sense, biochemical services can be also seen as producing of essential nutrients and proteins to humans. Fish are source of beneficial protein and fats (Cox and Portocarrero Aya 2011), which are especially important in Finland, where cardiovascular diseases are a national health problem. Fish can also be used in management to mitigate vector-borne diseases by feeding on invertebrates and plants, which spread disease or form living habitat for insects (Holmlund and Hammer 1999). In Finland, encephalitis virus spread by insects has occurred (Brummer-Korvenkanto and Saikku 1975), and changing climate conditions can bring new vector-borne diseases to boreal region. In addition, tuberculosis in fish has been used in medical science to model and study how tuberculosis can be cured in humans. However, biochemicals as freshwater ecosystem services are poorly known (Harrison et al. 2010).

Genetically variable species are more resistant to pathogens and diseases. For example, modern aquaculture is vulnerable to diseases, which can cause vast economical losses and may threaten natural populations. In addition, some aquatic plants have been breed for *ornamental* usage, such as *Calla, Iris, Typha* and *Nymphaea*. Ensuring of genetic diversity of these cultivated and breed species in nature enables their sustainable use for human pleasure and benefit. However, identification of freshwater genetic resources is deficient (Harrison et al. 2010).

3.2
Regulating services

Regulation services introduced by MA have also been widely identified in natural and technical sciences and their benefit for mankind has been recognized earlier. Hydrological flows as regulating service is seen as *retention and discharge of groundwater.* Man-made activities within a catchment affect groundwater, which is important for human consumption and biological processes. *Erosion* is common in rivers, streams and regulated freshwaters, which are used for production of hydropower. Erosion increases sedimentation, thus, interfering natural soil formation. Erosion affects though sedimentation to water bodies by shallowing lakes and rivers, decreasing water visibility, increasing nutrient loading and transporting of toxic chemicals, and reducing living conditions of freshwater species (Figure 5). Erosion can temporarily be increased during heavy rain and floods, which is a typical natural hazard in boreal region. Lakes, rivers and floodplains play an important role in *flood control* as they can store additional water (Baron et al. 2002, Brauman et al. 2007).

Climate regulation is one of the most studied ecosystem service. Inland waters play roles of s*ink and source for carbon*. The total lake sediment C pool in Finland was estimated to be 0.62 Pg, being the third largest after peatlands and soils. An annual sink is in Finnish lakes of 65 Gg C, whereas the total annual CO^2 emission from Finnish lakes was estimated to be 1400 Gg (Rantakari 2010).

Figure 5. One of the tributaries of River Teno situated in Finnish Lapland. It is characterised by low productivity and lack of major human pressures in its catchment. River Teno is most famous for its Atlantic Salmon fishing opportunities. It is a border river between Finland and Norway, where it also runs to the Arctic Sea.
Regulated lakes and reservoirs are also used to control floods in addition to production of hydropower. In Finland there are about 30 artificial lakes the exact number being dependent on definition. Most of them, locating in the coastal region where rivers run to the Gulf of Bothnia are constructed for flood protection while the largest ones constructed for hydropower production are located in Finnish Lapland (Järvenpää et al. 2004).
Photo: Jani Heino

The global climate change affects hydrological flows through temperature and precipitation change. In Finland, temperature and precipitation are predicted to increase 2 - 6 °C and 13 - 26 % by the end of 21st century, respectively (Jylhä et al. 2009). This results in shorter period of snow with smaller cover, postponed freezing of water in autumn, and increased spring and autumn floods (Veijalainen 2012). Intensified run-offs probably have positive effects on hydroelectric power production, but simultaneously they increase erosion, sediment accumulation in waters and nutrient, metal and suspended solids loading from terrestrial land to waters. Exceptional weather conditions, such as storms with heavy rainfalls, will become more frequent, creating pressure for e.g. good stormwater management in cities. Heavy rainfalls also result to short-term discharge peaks to waters and, for example, leaching of metals from acidic sulphate soils to waters can deteriorate water quality and cause severe ecological consequences. On the other hand, drier summers can have negative effects on groundwater recharge and water level in wells impairs drinking water retention. Lower water levels also enhance the expansion of certain competitive plant species on shorelines and thus cause deterioration of biodiversity on banks of water systems (Partanen and Luoto 2006). In addition, growing period becomes longer benefitting some tolerant species, however, native freshwater biodiversity will likely suffer from climate change as boreal species ranges become narrower and southern species invade new habitats in boreal region (Heino et al. 2009, Bellard et al. 2012). Higher temperatures enhance overgrowth of aquatic plants and plankton blooms (Alahuhta et al. 2011, Kosten et al. 2012), resulting in declined property and land values and use of freshwaters for e.g. drinking water, recreation and scenery.

3.3
Cultural services

Cultural services related to freshwaters comprise *spiritual and inspirational values, recreation, aesthetic and educational values.* Recreation has been recognized already in early ecosystem studies (Wilson and Carpenter 1999). Tourism related to trekking, fishing and hunting has high economic value for rural areas. Finland as tourist destination is also valued for its cleanness and naturalness.

The characteristic feature of the Finnish culture, perhaps even unique in its scale, is the large number of *summer cottages*, mostly locating in the very shores of or close to inland waters (Sievänen and Neuvonen 2011). Their total amount is 492 700 (Statistics Finland 2011) and many of them have during the course of time been developed into all-the year round free-time residences. Altogether 41 % of Finns have free-time accommodation regularly to be used. As summer cottages are made occasionally available for relatives and friends, it has been estimated that two thirds of Finns have access to this form of free-time housing, being a basis in particular for many water related activities (Sievänen and Neuvonen 2011).

One of the major recreational activities is fishing. In 2010, there were about 1.7 million recreational fishermen in about one million households in Finland. This large number include all kind of non-professional fishing, meaning that fish caught is not sold but used in the households or sometimes given free to other persons. The border between fishing related to provisional service or regarded as a cultural service is a line drawn into water, open to interpretations. One may add that fishing from natural waters decreases to some extent nutrient storage in the lakes (Silvenius and Grönroos 2004).

The total catch of recreational fishing amounted to 29 million kg, of which over 80 per cent was taken in inland waters, so fresh waters (lakes and rivers) play an important role in fish oriented recreation. Nearly 200 000 fishermen participated in fishing only by rowing or steering boat. The proportion of recreational fishermen was 32 per cent in the whole population, 42 per cent of men and 21 per cent of women engaged in fishing. Fishing was the most, or almost the most, important hobby for nearly 50 000 fishermen and rather important for 200 000 fishermen. For the rest it was a hobby among many others (Finnish Game and Fisheries Institute 2011a).

Good water quality is appreciated in water bodies (Vesterinen et al. 2010, Ravenscroft and Church 2011) so that waters can be used for *swimming, fishing, boating and aesthetic values* (Figure 6). Changes in water quality are also reflected and capitalized in land and property (summer cottage) prices (Artell 2011).

Many national landscapes are related to inland waters in Finland, for which they can be considered cultural heritage beside of inspirational and aesthetic values. Some freshwater species can be valued for their existence, like the endemic and threatened freshwater Ringed seal *(Pusa hispida saimensis)*. Education aspects of freshwaters are addressed by National Parks and other large protected areas, where nature trails and information centres are used to inform the public about nature and natural processes (Harrison et al. 2010). In eight National parks, freshwaters form the basis of the landscape, whereas inland waters are included in most of the National parks. The following freshwater habitats are included in the Natura2000-network: Oligotrophic waters containing very few minerals of sandy plains, Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto-Nanojuncetea, Hard oligo-mesotrophic waters with benthic vegetation of Chara spp., Natural eutrophic lakes with Magnopotamion or Hydrocharition-type vegetation, Natural dystrophic lakes and ponds, Water courses of plain to montane levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation, Fennoscandian natural rivers (Airaksinen and Karttunen 2001). In addition, many eutrophic inland waters have been protected under The Bird Directive. The inspiring values of both lakes and rivers are and have been well captured by numerous Finnish artists in their work.

Figure 6. Urban freshwaters are important for recreation and human welfare, however, these water bodies often suffer from eutrophication and other antropogenic originated deterioration. Lake Tuusulanjärvi is situated in southern Finland and it has been managed for decades with variable success.
Photo: Juha Taskinen

3.4

Supporting services

Soil formation and nutrient cycling are closely linked together (Figure 7). Sediments and organic material are source of nutrients, for which they are important aspect in nutrient cycling. Terrestrial organic matter inputs and coarse woody material are particularly important sources of energy, nutrition and habitat. Freshwater organisms are also adapted to the specific sediment and organic matter conditions of their environment, and do not persist if changes in the type, size, or frequency of sediment inputs occur (Baron et al. 2002). Micro-organisms recycle nutrients from decaying organisms to water and sediments. Phytoplankton and higher aquatic plants take up inorganic nutrients from water and sediment. Anthropogenic nutrient loading from agriculture, sewage, forestry and peat excavation can distort natural nutrient cycling and soil formation (Carpenter et al. 2009, Fitter et al. 2010). In addition, increased decomposition can cause oxygen deficiency as bacteria consume available oxygen from the bottom. Anoxia conditions in bottom can result in releases of nutrients from sediments, enhancing eutrophication (internal nutrient loading). On the other hand, anoxia conditions demobilize toxic heavy metals, e.g. in sediments and acid sulphate soils. Macroinvertebrates and fish, situated in top of trophic level, partly regulate nutrient cycling by consuming phytoplankton and plants (Cox and Portocarrero Aya 2011). Fish can also cause internal nutrient loading, when roaches and other cyprinids blend nutrient-rich sediments.

Habitat availability, primary production and photosynthesis are basic processes sustaining biomass productivity and biodiversity. Habitat availability is related to undis-

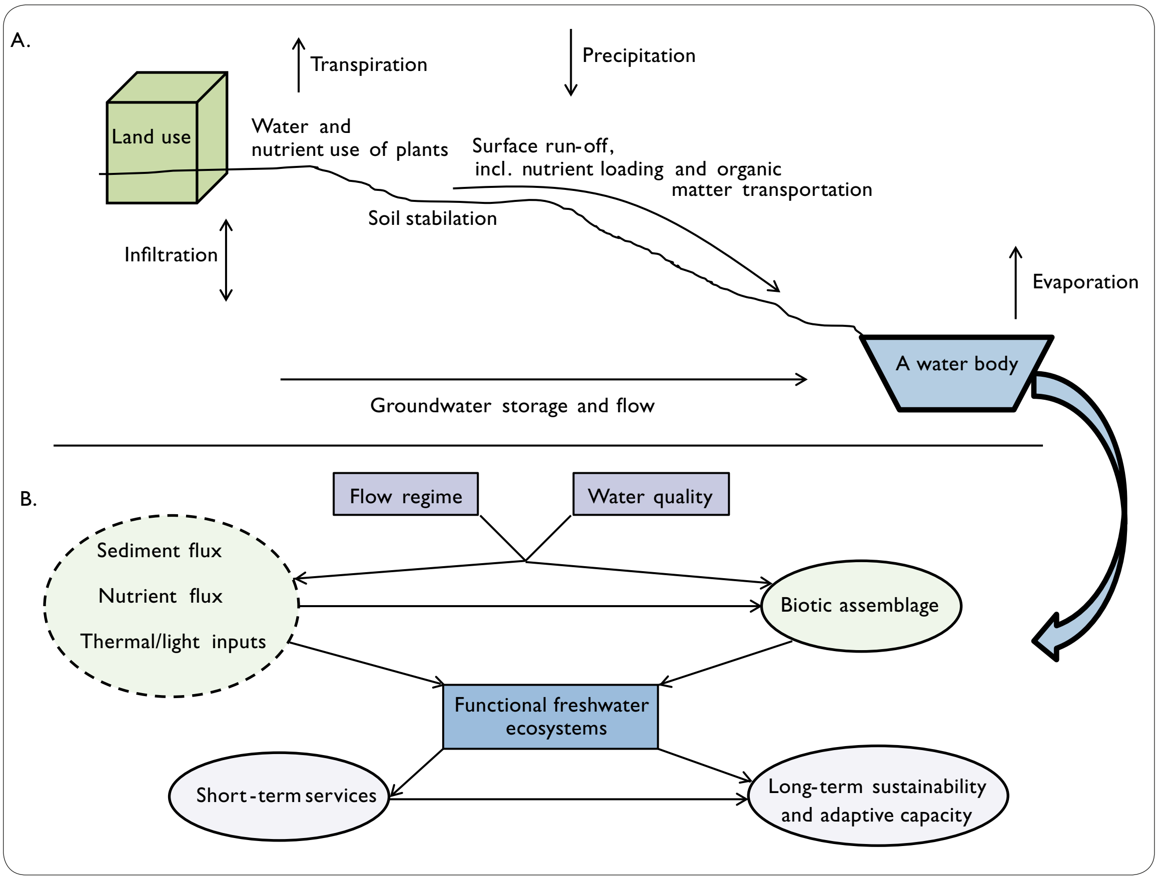

Figure 7. Water cycle-ecosystem interactions at catchment scale (A) and conceptual model of major driving forces that influence freshwater ecosystem (B, Baron et al. 2002).

turbed water bodies, but also local habitats within lake or river. For example, aquatic plants give shelter, breeding area and nutritious for other freshwater organisms, and changes in plant cover, biomass and community composition have wide ecological consequences in freshwater ecosystems. Similarly, changes in primary production, namely phytoplankton, diatom and vascular plants, have direct influence on freshwaters. In addition, primary producers have an essential role in controlling nutrient cycling and food web (down-top) and regulating carbon cycling (Kankaala et al. 2005). Phytoplankton and vascular plants are mainly responsible for photosynthesis in freshwaters.

Diffuse pollution derived from land use has become the main cause of water deterioration in Finland (Table 2). The total pollution caused by human actions currently exceeds the estimated natural leaching for both phosphorus and nitrogen (Finnish Environment Institute 2012). The capacity of natural systems to use nutrients and remove harmful substances can be used in water purification, decomposition, and nutrient cycling. For example, natural wetlands and vegetation in buffer zones adjacent to a water body, along with constructed wetlands, sedimentation ponds, overland-flow fields and filtration of substances to soil, can efficiently improve water quality by removing nutrients from nutrient cycling and hinder sedimentation of inorganic and organic particles (Mattila 2005). In natural and constructed freshwater systems, micro-organisms, invertebrates and vascular plants are responsible for much of the water purification, decomposition and nutrient cycling.

Table 2. Sources of point-source and diffuse water pollution in Finland in 2011 (Finnish Environment Institute 2012). Besides the current levels of diffuse and point-source pollution in Finland the role of historical sediments of pulp and paper industry have been studied to reveal their potential risks to current fish population (Oikari et al. 2010).

Point-source pollution	**Phosphorus (%)**	**Nitrogen (%)**
Pulp and paper industry	3.7	3.5
Other industry	0.6	1.3
Municipalities	4.1	15.3
Fish farming	1.9	0.9
Fur farming	1.1	0.6
Peat excavation and production	0.5	0.7
Point-source pollution total	*11.9*	*22.3*
Diffuse pollution		
Agriculture	68.5	56.8
Scattered settlements	8.8	3.6
Forestry	5.8	4.7
Diffuse pollution total	*83.1*	*65.1*
Deposition	5.0	12.6

Water cycling (hydrological flows) is one of the most studied freshwater ecosystem service (Brauman et al. 2007, Willaard et al. 2012). Hydrological flows regulate quantity and quality of water in water bodies. Other ecosystems within a catchment affect hydrological flows by altering amount and quality of flows. For example, land cover and use within a catchment directly influence on hydrological flows (Carpenter et al. 2011, Barton et al. 2012). Flow characteristics include base flow, annual or frequent floods, rare and extreme flood events, seasonality of flows, flow regime, and annual variability (Baron et al. 2002). These characteristics are related to other introduced regulation services, such as water purification and waste management, erosion control and natural hazard regulation. E.g. low flows can result in decreasing groundwater levels reducing use of groundwater as clean water. Contrary, high hydrological flows can create floods increasing nutrient leaching and stimulate erosion, and fluctuating water levels –typical in regulated water bodies– influence negatively on many biological groups.

4 Suggestion for the classification of sustainable freshwater ecosystem services in Finland

The comprehensive report on ecosystem services provided by MA (2005) has also formed a valuable basis for developing an appropriate classification for freshwater ecosystem services in Finland. Since the publication of MA report, there has been much conceptual analysis and research as well as international debate to further modify and develop MA categories and classification for different purposes. Other classifications and syntheses have been developed for multiple ecosystems, while freshwaters have been covered only superficially in these papers (Fisher et al. 2009; Fitter et al. 2010; Harrison et al. 2010; TEEB 2010; Vihervaara et al. 2010; Maes et al. 2011, 2012; Ratamäki et al. 2011, Primmer et al. 2012). Few specific reviews and overviews on classification of freshwater ecosystem services have been published during recent years (Brauman et al. 2007; Maltby and Ormerod 2011; Barton et al. 2012; Haines-Young and Potschin 2012). The following suggestion is based on the modifications suggested for MA classifications which are seen relevant also for the Finnish conditions (Table 3).

Provisioning services of freshwater ecosystems have been well identified and documented in boreal region. Deficiencies in provisioning service recognition are related to virtual water, ornamental, biochemical and genetic resources. Virtual water consumption should be more profoundly related to clean water supply and retention (Falkermark 2003).

Table 3. Suggestion for sustainable freshwater ecosystem services in boreal region. The mark (!) in the columns means that more research is needed to confirm and understand the meaning of particular service as a freshwater ecosystem service in boreal region. Following MA (2005) supporting services are presented as their own category. However, in Appendix 1 which is based on CICES V4/V4.1 some of the above supporting systems are organized under other, mainly regulating services and supporting services as an independent category has continued to be excluded, although the recent consultation paper (Haines-Young and Potchin 2012) recommend that the issue is looked at again when experimental accounts are available. The CICES V4/V4.1 based version of freshwater ecosystem services (Appendix 1) provides possibilities to proceed into more detailed and systematic description of the services following (still evolving) structures. These two approaches are complementary.

Freshwater ecosystem services			
Provisioning	**Regulating**	**Cultural**	**Supporting**
Food	Macro-climate regulation (!)	Recreation	Nutrient cycling
Clean water (!)	Micro-climate regulation	Aesthetic value (!)	Soil formation (!)
Energy	Air quality regulation	Cultural heritage (!)	Food web dynamics (!)
Transportation	Water flow regulation	Science and education (!)	Habitat (!)
Biochemical resources (!)	Water purification	Inspirational value (!)	Primary production
Ornamental resources (!)	Invasion resistance (!)		Photosynthesis
Construction	Disease regulation (!)		Water cycling (!)
Genetic resources (!)	Seed dispersal and pollination (!)		
	Erosion regulation (!)		
	Natural hazard regulation		

Some aquatic plants have ornamental and construction value, although, importance of these resources has not been considered highly important in Europe (Harrison et al. 2010). Ornamental resources are not fully exploited to their full potential as exotic species dominate in gardening (Lambdon et al. 2008). Increased public awareness about native ornamental plants is needed.

Terrestrial ecosystems dominate when discussing of importance of biochemicals and natural medicine. However, contribution of most European ecosystems to biochemicals and natural medicine is poorly known (Harrison et al. 2010), anticipating that these services can also be derived from rivers and lakes. In addition, our understanding of genetic diversity provided by microbes in sediments is negligible.

Freshwaters can have a valuable role in biological invasion resistance, disease regulation and seed dispersal and pollination. Introduced species create a threat to freshwater biodiversity and climate change can further increase invasion of exotic species (Heino et al. 2009). The impact might stem from predation, competition, and spread of parasites and diseases to which species native to boreal freshwater ecosystems are not adapted (Wrona et al., 2006). Climate and disease regulation are partly intertwined with both having severe ecological and societal consequences, emphasizing importance of further research on these services and their interactions.

Freshwaters regulate micro-climate through temperature and precipitation. Freshwaters –mainly their primary producers- also have potential to contribute to air quality control although terrestrial ecosystem have more significant input for this service. Importance of freshwater plants in relation to dispersal and pollination is generally regarded modest, but this service is poorly known (Harrison et al. 2010). Ecological knowledge of dispersal of different biological groups is not thorough due to their different dispersal characteristics (Cadotte et al. 2011). Concerning water purification, one problem is a scale, because deteriorative substances originate in other ecosystems somewhere within a catchment but negative effects take place in freshwaters (Baron et al. 2002, Rodrigues et al. 2006, Barton et al. 2012). In addition, water purification and waste treatment within a catchment are carried out jointly by terrestrial and aquatic vegetation and soil and aquatic micro-organisms, for which freshwaters should not be treated separately from terrestrial ecosystems. Variation in land ownership between land uses also creates further challenges (fragmented in forestry and centralized in agriculture). Alahuhta et al. (2010) also proposed that land use planning could be integrated more profoundly to freshwater protection through river basin management. Despite overlapping agendas, these planning instruments are operating separately, although, some integration has already been established. For example, buffer zones have been implemented to plans to prevent nutrient and suspended solids transport from peat excavation sites to waters (Alahuhta et al. 2010).

Cultural ecosystem services in general are poorly understood across whole ecosystem service science. Freshwater cultural service categories are recognized, but it is difficult to identify which individual services can be included as freshwater services. Recreation is a well studied cultural service also in Finland, where comprehensive national outdoor recreation studies (Sievänen and Neuvonen 2011) cover extensively also water-based recreation, but other services are less well understood (Harrison et al. 2010). Ecotourism can have high economic and societal value especially in countryside. Cultural heritage should be included more profoundly as a significant cultural service, following the suggestion of recent CICES identification. Freshwaters are a national cultural value in boreal regions as parts of e.g. national parks, where lakes, ponds, rivers and streams are typical feature in landscape. In boreal regions, where freshwaters have much cultural value, multidisciplinary approach in understanding different aspects of freshwater cultural services is especially important. So far cross-scientific aspect has only included social and natural sciences, but history, pedagogy, philosophy and other humanities are required to determine how Finns appreciate cultural values of freshwaters.

Supporting services consist of complex natural phenomena, which often cross-link with other services (Rodrigues et al. 2006, Fitter et al. 2010). For instance, habitat degradation has direct effects on other ecosystem services, which makes this service important for further research. Food web dynamics can be considered valuable inland water service not presented in MA. Many of sediment processes are poorly known especially related to microbial activity and e.g. redox dynamics (Fitter et al. 2010, Harrison et al. 2010). Supporting services are processes, which often create the backbone of freshwater ecosystems. Understanding of these ecosystem processes is of high importance in order to identify and sustain other ecosystem services.

Biodiversity is a key prerequisite for ecosystem services. Biodiversity can be viewed in three different contexts: a) a regulator of ecosystem services, b) a final ecosystem service or c) a good (Mace et al. 2011). In the first case, biodiversity is a factor controlling the ecosystem processes that underpin ecosystem services. When biodiversity is viewed as a final ecosystem service, biological diversity at the level of genes and species contributes directly to some goods and their value. Biodiversity as a good means that natural diversity itself is the object valued by humans. However, definition of biodiversity is not straightforward. It may be that overall biodiversity is not always the important for ecosystem functioning and equilibrium, but also variety or diversity of biodiversity types. Thus, key species and functional groups within ecosystem may have higher importance than overall biodiversity for freshwater resilience and equilibrium (Perrings et al. 2010, Mace et al. 2011). In regard to species diversity, for example the state of fish species in Finland is rather well-known, but its spatial variation within country could be known better. Three fish species are extinct and anthropogenic changes affect fish fauna far more than all natural events. Dredging and damming of rivers have had the most significant impact on our fish stocks, mainly on anadromous species. At least 30 or maybe even as many as 47 salmon stocks have been lost and only six native stocks have survived. Similarly, only nine original sea trout stocks out of 62 rivers running from Finland to the Baltic Sea are viable (Urho and Lehtonen 2008). In 2010, according to the 4th Red list survey in Finland, 12 fish species were classified as threatened, 6 as near threatened and 10 as data deficient. The number of fish species with viable populations was 43 (Rassi et al. 2010).

There are other challenges for freshwater ecosystem services besides of already mentioned. Spatial scale in ecosystem service discipline refers to a situation, where action takes place in one ecosystem and consequences are borne in other ecosystem. Spatial scale also refers to resolution (study unit) and extent (study area). Both of them have major implications of how studied phenomenon needs to be addressed, which explanatory variables are important and what is expected outcome (Rahbek 2005). Freshwater ecosystem service studies have been varied from local to global scales (Naidoo et al. 2008, Willaard et al. 2012), but studies have focused on local or landscape extent and water body resolution in Finland. Catchment resolution and regional (national) extent may offer valuable information on freshwater ecosystems not detectable in other spatial scales (Alahuhta et al. 2011). In addition, regional specificity can be high in inland waters referring to the situation in which results obtained from one region may not be transferrable to another (Alahuhta and Heino 2013). Based on recent review, it is disturbing that there is not a single investigation from Finland concerning spatial co-variation of ecosystem services at national extent (Seppelt et al. 2011, Maes et al. 2011).

Large-scale studies can provide valuable base information on freshwater ecosystem services, but investigations at this scale can rarely address analytically the integration of processes behind interactions between services (Nicholson et al. 2009, Perrings et al. 2010). There is often much information available on ecosystem services separately, like on nutrient cycling, but knowledge on how services interact with each other is inadequate (Bennett et al. 2009, Carpenter et al. 2009). This has important implications for management and policy design, because this implies that we neither know 1) the full capacity of the freshwaters to provide valuable services nor 2) the potential of managing (manipulating) the existing dynamics of ecosystems. In addition, new services can emerge, when polluted ecosystems are restored. For example, restoration of polluted sediments has a significant effect on whole freshwater ecosystem and probably yields improvement in other recognized freshwater services. Furthermore, establishment of national roadmap to restore polluted sediments would generally benefit freshwater ecosystem services (Aimo Oikari, personal communication). Freshwaters are challenging, because interaction between a water body and catchment is unique. Understanding of multiple freshwater ecosystem services and how they co-vary temporally and spatially needs genuinely cross-scientific approach. In addition, climate change, land use and loss of biodiversity have fundamental effects on availability of freshwater ecosystem services. Research on these disciplines is intensively carried out, but knowledge on scenarios and predictions need to be combined to ecosystem service science at different spatial scales (Schröter et al. 2005, Hungate and Hampton 2012).

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Appendix 1.
Draft CICES V4/V4.1.-based classification (Haines-Young et al. 2012, Haines-Young and Potschin 2012) of freshwater ecosystem goods and services in Finland[i]

CICES Section 1 PROVISIONING GOODS AND SERVICES			
Division 11 Nutrition			
Group	**Class**	**Class type**	**Sub-class type (Specification)**
111 Freshwater plants and animals for food	1111 Fish (wild populations)	(Family/Sub-family) 11111 Salmons (2/2)11112 Pikes (1/1) 11113 Cyprinidae (7/19) 11114 Lotidae (1/1) 11115 Percidae (3/3) 11116 Lampreys (1/2) 11117 Anguillidae (1/1)	1a Salmon, b Trout, c Charr, d Vendace, e Whitefish, c Grayling 2a Pike 3a Roach, b Bream, c Other 4a Burbot 5a Perch, b Pike perch 6a River lamprey, b Brook lamb. 7a Eel
	1112 Crayfish	(11121 Crayfish)	1a Danube crayfish, b Signal crayfish
	1113 Aquaculture products	11131 Salmons 11132 Other	1a Salmon, b Trout c Char, d Whitefish2 a Sturgeon, b Pike perch
	1113 Freshwater plant	11131 Fodder	1 a Common Reed
Division 12 Water supply			
121 Water for human consumption	1211 Drinking water	12111 Surface water 12112 Groundwater	1 Purified drinking water 2 Unpurified drinking water
	1212 Domestic water use	12121 Surface water 12122 Groundwater	1 Boiling 2 Hygiene 3 Showering 4 Irrigation 5 Heating 6 Sewage
122 Water for agricultural use	1221 Irrigation water (consumptive)	12211 Surface water 12212 Groundwater	1 Controlled drainage 2 Overflow irrigation 3 Sprinkling irrigation 4 Frost protection irrigation 5 Groundwater irrigation 6 Groundwater dam irrigation
	1222 Water for livestock (consumptive)	12221 Surface water 12222 Groundwater	1 Dairy cows 2 Sucler cows 3 Pigs 4 Poultry 5 Sheep 6 Fur production animals (e.g. Mink and Blue Fox)
123 Water for industrial and energy uses	1231 Industrial water (consumptive)	12311 Surface water 12312 Groundwater	1 Mining industry 2 Textile industry 3 Paper and pulp industry 4 Building industry 5 Food industry 6 Energy industry 7 Metal industry 8 Transportation industry
	1232 Cooling water (non-consumptive)	12311 Surface water 12312 Groundwater	1 Energy industry 2 Metal industry 3 Mining industry

CICES Section 1 PROVISIONING GOODS AND SERVICES			
Division 11 Nutrition			
Group	**Class**	**Class type**	**Sub-class type (Specification)**
Division 13 Materials			
131 Biotic materials	1311 Non-food vegetal fibre	13111 Construction material	1 Common reed
	1312 Non-food animal fibre	13121 Fertilization	1 Fish
	1313 Ornamental resources	13131 Aquatic plants	1 Calla spp. 2 Nymphaea ssp. 3 Iris ssp. 4 Typha spp.
	1314 Genetic resources	13141 Fish genetics 13142 Plant genetics	1 Preservation against pathogens and diseases
	1315 Medicinal and cosmetic resources	13151 Medicinal plants	1 Self-medication 2 Extraction of medical substances 3 Mostly not identified, potential in the future
Division 14 Energy			
141 Biomass based energy	1411 Vegetal based resources	14111 Aquatic plant biomass	1 Reed Canary grass 2 Common reed
	1412 Animal based resources	14121 Gas based energy	1 Non-edible fishes

CICES Section 2 REGULATION AND MAINTENANCE			
Division 21 Regulation of bio-physical environment			
Group	**Class**	**Class type**	**Sub-class type (Specification)**
211 Bio-re-media-tion	2111 Remediation by plants or algae	21111 Sediments 21112 Water	1 Phytoaccumulation 2 Phytodegradation 3 Phytostabilisation 4 Rhizodegradation 5 Rhizofiltration
	2112 Remediation by micro-organism	21121 Sediment 21122 Water	1 Aquatic micro-organisms and inver-tebrates
212 Diluti-on and sequest-ration	2121 Dilution, decomposition, remineralisation and recycling	21211 Domestic waste water treat-ment 21212 Small-scale industrial waste water treatment 21213 Oil spill treatment 21214 Treatment of harmful substan-ces originated from of agriculture, forestry and peat excavation	1 Micro-organisms 2 Invertebrates 3 Aquatic plants
	2122 Filtration	21221 Rural waste waters 21222 Treatment of harmful sub-stances originated from of agricultu-re, forestry and peat excavation	1 Aquatic plants 2 Micro-organisms 3 Invertebrates
	2123 Sequestration and ab-sorption	21231 Capture of atmospheric substances by aquatic plants and algae 21232 Sequestration of nutrients and other harmful substances from water and sediments by aquatic plants, algae and micro-organisms	1 Aquatic plants 2 Micro-organisms 3 Invertebrates
Division 22 Flow regulation			
221 Air flow regulation	2211 Rural microclimate re-gulation	22111 Air flow regulation through different of air pressure compared to terrestrial land	
	2212 Urban microclimate regulation	22121 Air flow regulation through different of air pressure compared to terrestrial land	
222 Water flow regulation	2221 Attenuation of runoff and discharge rates	22211 Lakes and rivers regulate runoff and discharges of lower in the lake chain	1 Attenuation of extreme runoffs 2 Attenuation of point source pollution 3 Attenuation of diffuse pollution
	2222 Water storage for flow regulation	22221 Lakes and ponds acts as wa-ter storages decreasing flows 22222 Regulated water bodies	1 Recreational purposes 2 Drinking water (use or reserve)
223 Mass flow regulation	2231 Erosion protection	22311 Water erosion	1 Erosion on river banks 2 Erosion of regulated water bodies
	2232 Avalanche and gravity flow protection		

CICES Section 2 REGULATION AND MAINTENANCE			
Division 21 Regulation of bio-physical environment			
Group	**Class**	**Class type**	**Sub-class type (Specification)**
Division 23 Regulation of physic-chemical environment			
231 Atmospheric regulation	2311 Global regulation (incl. carbon sequestration)	23111 Use of carbon	1 Aquatic plants 2 Algae 3 Micro-organisms
	2312 Local and regional climate regulation	23121 Balancing extreme climate conditions 23122 Influencing on regional and local precipitation 23123 Reflection of sun radiation from water column 23124 Absorption of heat	
232 Water quality regulation	2321 Water purification and oxygenation	23211 Aquatic plants, algae and micro-organisms purify water by consuming anthropogenic-derived substances 23212 Aquatic plants and micro-organisms (autotrophic bacteria) oxygenize sediments 23213 Aquatic plants transfer pollutants from water to sediments 23214 Demobilization of toxic metals in anoxia conditions by micro-organims.	
233 Pedogenesis and soil quality regulation	2331 Maintenance of soil quality	23311 Water flows affect soil quality and quantity.	
	2332 Maintenance of soil structure	23321 Water maintenances soil structure 23322 Create new soils through sedimentation	1 Agricultural use 2 New habitats
Division 24 Regulation of biotic environment			
231 Lifecycle maintenance and gene pool protection	2411 Pollination	24111 Pollinators of aquatic plants	
	2412 Seed dispersal	24121 Aquatic plant seed dispersal by wind 24122 Aquatic plant seed dispersal by water 24123 Freshwaters provide living habitats for waterfowl, which can disperse seeds (also plants from other ecosystems)	
	2413 Maintaining nursery population	24131 Habitat refuges	1 Oligotrophic water bodies 2 Water bodies for cold-preferring species
242 Pest and disease control (incl. invasive species)	2421 Biological control mechanisms	24211 Fish regulate insects, which can potentially carry diseases 24212 Fish regulate distribution of invasive insects 24213 Freshwaters provide habitats for waterfowl, which regulate e.g. invasive insects	

CICES Section 3 CULTURAL SERVICES			
Division 31 Symbolic			
Group	**Class**	**Class type**	**Sub-class type (Specification)**
311 Aesthetic, Heritage	3111 Landscape character Waters	31111 National 31112 Regional	
	3112 Cultural landscapes		
312 Spiritual	3121 Charismatic or iconic wildlife or habitat	31211 Charismatic animal species 31222 Other animals with symbolic meaning	1 Ringed Seal 2 Swan 3 Pike 4 Salmon
	3122 Sacred places or species	31221 Water related mythology and symbolism	
Division 32 Intellectual and Experiental			
321 Recreational and community activities	3211 Near-area recreation	32111 Fishing 32112 Swimming 32113 Boating 32114 Cross-country skiing 32115 Ice-skating	More detailed categories and areas available (Sievänen et al. 2001; Sievänen and Neuvonen 2011)
	3212 Recreation requiring some travelling but no commercial services,	32121 Fishing (in summer and winter) 32122 Hunting waterfowl 32123 Boating 32124 Swimming 32125 Cross-country skiing 32126 Ice-skating	As above.
	3213 Nature tourism, using paid accommodation and other services, usually longer distance and specific areas	32131 Summer 32132 Winter (snow) tourism 32133 Rural(ity) tourism	As above.
	3214 Summer cottage recreation	32141 Summer time 32141 All-the year round	As above.
	3215 Community activities	32151 Children /youth camps 32152 Other organized	
322 Information and knowledge	3221 Scientific	32211 Research areas 32212 Other experiments	
	3222 Education	32221 Levels of education 32222 Target groups	

[i] The numbering of different levels of classification (e.g. 1 Section, 11 Division, 111 Group, 1111 Class, 11111 Class type is not included inti CICES V4 –which introduced these new "level titles", but are adopted in this "synthesis project" (Saastamoinen et al. 2012). Sub-class type (specification) is neither included in the CICES, although it includes a less systematic last column with a following head note: "Note: this section is not complete and for illustrative purposes only. Key components could change by region or ecosystem. Examples and indicative services, goods (products) and benefits" (Haines-Young et al. 2012).

As explained earlier in the text, supporting services classified in MA (2005) are excluded as a specific independent category (as CICES section). "The supporting services are treated as a part of underlying structures, processes and functions that characterize ecosystems. Since they are only indirectly consumed or used, and may simultaneously facilitate the output of many 'final outputs', it was considered that they were best dealt with in environmental accounts, in other ways" (Haines-Young et al. 2012).

As seen, this arguments from the point of view of environmental accounting. However, at the same time revised CICES Version 4 (V4) adopted new headline "CICES for ecosystem service mapping and assessment" in addition to "CICES for ecosystem counting".

Hydropower was still included in CICES Classification (V3, Haines-Young and Potschin 2011) as a part of Provisioning services among other "Renewable abiotic energy" (Wind, Hydro, Solar, Tidal and Thermal), but is not included in V4/V4.1. The consensus was to "exclude non-ecosystem based natural flows, i.e., renewable abiotic energy sources and abiotic materials" (Haines-Young et al. 2012). From the pragmatic point of view of freshwater ecosystem services of Finland and their joint production and regulation excluding hydropower from other included water services such as "water for agricultural use" and "water for industrial use" may not serve well integrated ecosystem management.

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Abstract

Ecosystem services have become a significant multidisciplinary research agenda in the world. Man-made activities both at global and local scales deteriorate biodiversity and ecosystem functioning, which are essential also to human welfare. Ecosystem services are material and immaterial benefits and services provided by nature. Ecosystem services can be divided to the following main categories: provisioning, regulating, cultural and sustaining services. Different ecosystems provide various services depending also on their geographical location. For example, boreal ecosystems differ ecologically from tropical ones, for which the services they provide also vary. Boreal region is generally known for its high abundance of freshwaters. Quantity of freshwaters is rarely a problem in boreal region, but quality of inland waters is decreased in many places due to anthropogenic pressures.

Freshwaters have received less attention than other ecosystems in ecosystem services research, because direct link between inland waters and terrestrial ecosystems makes evaluation of freshwater ecosystem services challenging. Purpose of this report is to identity and classify freshwater ecosystem services in Finland. The report consists of two parts: 1) historical review of freshwater ecosystem services in Finland, and 2) identification and classification of current ecosystem services in Finnish freshwaters. In historical review, we roughly evaluate how identification and appreciation of freshwater ecosystem services have varied temporally. In the second part, we identify and classify current freshwater ecosystem services in Finland based on two classification criteria, which complement each other. This report is part of project "Integrated and policy relevant valuation of forest, agro, peatland and aquatic ecosystem services in Finland", which is funded by Maj and Tor Nessling Foundation and coordinated by University of Eastern Finland.

Appreciation of freshwater ecosystem services has varied over the decades. In the beginning of 20th century, inland waters were important source of nutriment and way of transportation. Increased pollution of water bodies awaked society to appreciate other services provided by freshwaters in turn of 1970s-80s. Nowadays, freshwaters have a major role among others in flood protection, climate regulation, primary production and recreation. However, identification of many freshwater services is still superficial or deficient. For example, genetic and biochemical resources, control of invasive species and diseases, aesthetic and religious services, and formation of soil and water cycling are generally poorly known in Finland. In addition, large scale studies of freshwater ecosystem services are rarely done in Finland and knowledge on how services interact with each other is inadequate.

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Tiivistelmä	Ekosysteemipalvelut on noussut merkittäväksi tutkimusagendaksi maailmalla, koska ihmisen toiminta heikentää luonnon tilaa ja myös ihmisen hyvinvointi on riippuvainen toimivista ja monimuotoisista ekosysteemeistä. Ekosysteemipalvelut ovat luonnon tarjoamia ja tuottamia ihmiselle välttämättömiä aineellisia ja aineettomia palveluita. Ekosysteemipalvelut voidaan jakaa pääpiirteissään tuotanto-, ylläpito-, sääntely- ja kulttuuripalveluihin. Jokainen ekosysteemi on omanlaisensa, joten myös mahdolliset ekosysteemipalvelut vaihtelevat luonnon eri systeemeissä. Lisäksi luokittelu vaihtelee maantieteellisesti. Boreaalisella alueella palveluiden painotus on erilainen kuin esimerkiksi tropiikissa. Boreaaliset alueet ovat tyypillisesti runsasvetisiä. Veden yleinen saatavuus on harvoin ongelma pohjoisilla alueilla, mutta ihmisen toiminta on huonontanut useiden vesistöjen tilaa heikentäen niiden käyttömahdollisuuksia. Ekosysteemipalvelututkimuksessa vesistöt ovat jääneet osin vähemmälle huomiolle, koska maaekosysteemien suora yhteys vesiin tekee niiden luokittelun ja arvottamisen haastavaksi. Tässä selvityksessä on tarkoitus tunnistaa ja luokitella Suomen sisävesien ekosysteemipalvelut. Selvitys koostuu kahdesta osasta: sisävesien ekosysteemipalveluiden historiallisesta katsauksesta ja nykyisten palveluiden tunnistamisesta ja luokittelusta. Historiallisessa katsauksessa arvioidaan suuntaa-antavasti, miten ekosysteemipalveluiden merkitys on vaihdellut eri aikoina. Toisessa osassa Suomen sisävesien ekosysteemipalvelut tunnistetaan ja luokitellaan perustuen kahteen eri luokittelukriteeristöön (Millennium Ecosystem Assessment ja CICES V4), jotka täydentävät toisiaan. Selvitys on osa Maj and Tor Nesslingin säätiön rahoittamaa hanketta "Metsä-, agro-, suo- ja vesiekosysteemipalvelujen integroiva ja politiikkarelevantti arvottaminen Suomessa", jota koordinoi Itä-Suomen yliopisto. Sisävesien ekosysteemipalveluiden arvostus on muuttunut vuosikymmenten aikana. Viime vuosisadan alussa vesistöt olivat tärkeitä ravinnonlähteitä ja kulku- ja kuljetusreittejä ihmisille. Yhteiskunnan herääminen vesistöjen pilaantumiseen 1970-80-luvuilla nosti voimakkaammin tuotantopalveluiden rinnalle myös ylläpito-, sääntely- ja kulttuuripalvelut. Nykyisin sisävesillä on merkittävä rooli muun muassa tulvasuojelussa, ilmastonmuutoksessa, perustuotannossa ja virkistyskäytössä. Kuitenkin useissa palveluissa tuntemus on edelleen puutteellista sisävesissä. Esimerkiksi geneettiset ja biokemialliset tuotantopalvelut, vieraslajien ja sairauksien hillintää liittyvät sääntelypalvelut, esteettiset ja uskonnolliset kulttuuripalvelut, ja sedimenttien muodostumiseen ja vedenkiertoon liittyvät ylläpitopalvelut tunnetaan huonosti Suomen sisävesissä. Lisäksi Suomessa on tehty vähän laajan mittakaavan tutkimuksia sisävesien ekosysteemipalveluista ja ymmärrys ekosysteemipalveluiden välisistä prosesseista vaatii lisätutkimusta.	
Asiasanat	Ekosysteemipalvelut, ekosysteemipalveluiden luokittelu, sisävedet, Suomi	
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Sammandrag	Ekosystemtjänster har blivit en betydande forskningsagenda ute i världen eftersom mänskliga aktiviteter försämrar tillståndet i naturen och eftersom också människans välmående är beroende av fungerande och mångsidiga ekosystem. Ekosystemtjänsterna består av materiella och immateriella tjänster som naturen producerar och erbjuder och som är nödvändiga för människan. De kan i huvuddrag indelas i produktions-, underhålls-, reglerings- och kulturtjänster. Varje ekosystem har sina särdrag, och därför varierar de eventuella ekosystemtjänsterna också i naturens olika system. Dessutom varierar klassificeringen geografiskt. I det boreala området har tjänsterna en annan betoning än exempelvis i tropikerna. De boreala områdena är vanligen vattenrika. Den allmänna tillgången på vatten är sällan ett problem i de nordliga områdena, men den mänskliga verksamheten har försämrat tillståndet i många vatten och begränsat deras användning. I forskningen kring ekosystemtjänster har vattnen fått mindre uppmärksamhet eftersom landekosystemens direkta förbindelse med dem gör det svårt att klassificera och värdera dem. I den här utredningen är syftet att identifiera och klassificera ekosystemtjänsterna i insjöarna i Finland. Utredningen består av två delar: en historisk översikt över insjöarnas ekosystemtjänster och en identifikation och klassificering av de nuvarande tjänsterna. I den historiska översikten ger vi en riktgivande bedömning av hur ekosystemtjänsternas betydelse har växlat under olika tider. I den andra delen identifierar och klassificerar vi de finländska insjöarnas ekosystemtjänster utifrån två olika kriteriesystem för klassificering (Millennium Ecosystem Assessment och CICES V4), som kompletterar varandra. Utredningen ingår i projektet "Metsä-, agro-, suo- ja vesiekosysteemipalvelujen integroiva ja politiikkarelevantti arvottaminen Suomessa" (Integrerande och politikrelevant värdering av skogs-, agro-, myr- och vattenekosystem i Finland), som finansieras av Maj och Tor Nesslings stiftelse och koordineras av Östra Finlands universitet. Värdesättningen av insjöarnas ekosystemtjänster har förändrats under årtiondenas gång. I början av förra seklet var vattnen viktiga näringskällor och far- och transportleder för människorna. När samhället blev uppmärksamt på nedsmutsningen av vattnen på 1970- och 80-talen fick underhålls-, reglerings- och kulturtjänsterna också en större betydelse vid sidan av produktionstjänsterna. Idag har insjöarna en viktig roll bland annat i skyddet mot översvämningar, i klimatförändringen, i primärproduktionen och i rekreationen. Trots det är kännedomen om insjöarnas roll bristfällig i många tjänster. De genetiska och biokemiska produktionstjänsterna, regleringstjänsterna i samband med kontrollen av främmande arter och sjukdomar, de estetiska och religiösa kulturtjänsterna samt underhållstjänsterna i samband med sedimentbildning och vattencirkulation är dåligt kända i de finländska insjöarna. Dessutom har det gjorts rätt få undersökningar i större skala om insjöarnas ekosystemtjänster i Finland, och förståelsen av de processer som verkar mellan ekosystemtjänsterna kräver vidare forskning.	
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