Coalition Clean Baltic
FOR PROTECTION OF THE BALTIC SEA ENVIRONMENT

Hydropower Hotspots in the Baltic Sea Catchment Area

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Björn Möllersten

Contributions to country studies and hotspots:

Belarus: Nina Polutskaya
Estonia: Taavi Nuum
Latvia: Ojars Balcers and Elita Kalnina
Poland: Piotr Gruszka and Agnieszka Fabis

Coalition Clean Baltic, CCB
Östra Ågatan 53, SE- 753 22 Uppsala, Sweden
Tel: +46 18 71 11 55/+46 18 71 11 70
fax: +46 18 71 11 75
E-mail: secretariat@ccb.se
gunnar.noren@ccb.se
Org. number: 802015-1281, www.ccb.se

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Preface

The Coalition Clean Baltic working group on Small Scale Hydropower in the Baltic Sea Area has initiated this study. The amount of information presented varies a lot in between the countries, as it is based on information that has been available to the CCB-organisations involved. The result is more an example of available information than a full report of hydropower hotspots, which was the intention. The report might serve as a base for reflections upon possible future actions to be taken.

Photos No 1, 2 and 3 Björn Möllersten, No 4 Hans Isgren.

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Summary

Very few free-flowing large rivers (with a mean annual discharge of at least 350 m^3/s) remain on the European continent. The ones that exist are in northwestern Russia (three rivers) and in the northernmost Sweden and Finland (one river system).

Large areas lack important habitats such as waterfalls, rapids and floodplain wetlands. This has had a negative impact on many species of fauna and flora. Dams constructed on the rivers dry out riverbeds below the dams, impeding dispersal of organisms. As a consequence, many species have become threatened or even locally extinct. Numerous genetically unique populations of salmon (*Salmo salar*) and brown trout (*Salmo trutta*) have been lost forever.

In Sweden, level or flow control for hydroelectric power affects by far more red-listed species of fresh waters than any other factor (177 species). The second most important factor is eutrophication (107 species), followed by acidification (80 species).

To mitigate negative effects of installation of hydropower plants, it is important that the courts or other authorities prescribe a minimum release of water to be led past the power station and allowed to flow in the natural river channel. To be meaningful from an ecological point of view, the minimum release should correspond to 10–30 per cent of the mean annual discharge of the river. If there are salmonids in the waterway, the minimum release should be at least 30 per cent of the mean annual discharge. This has been shown by research in North American waters.

All hydroelectric plants – old as well as new ones – should be complemented with fishways. During the past ten years, there has been a trend towards creating nature-like fishways, which can be used not only by fish but also by many different aquatic organisms, migrating up or down the river.

Very important to bear in mind, however, is that environmental considerations, such as construction of fishways and water release in natural river channels, can only to a minor extent compensate for damage caused by hydroelectric power plants. It is therefore extremely important to preserve running waters in their natural state.

There is a widespread conception that renewable energy is by definition environmentally sustainable. This is a misunderstanding, as the concept of sustainability includes preservation of biodiversity. Because regulation of rivers for hydropower purposes is one of the main threats to red-listed freshwater species in the Baltic Sea catchment area, hydropower – when developed in the way that has been the case in Sweden and Finland at least – cannot be considered environmentally sustainable. Furthermore, as biodiversity (according to Convention on Biological Diversity) comprises diversity *within* species, *between* species and of *ecosystems*, a fair number of running waters have to be maintained as intact natural ecosystems, regardless of how many species are threatened by hydropower exploitation.

Overview

Very few free-lowing large rivers remain on the European continent. One has to go to the far north to find large rivers that are unaffected along the whole river stretch by human interference. Four such rivers exist, of which three are located in north-western Russia and one in northern Sweden and Finland (Dynesius & Nilsson 1994). The Russian rivers have their outflow into the Arctic Ocean and the White Sea and the Swedish/Finnish river into the northern part of the Gulf of Bothnia.

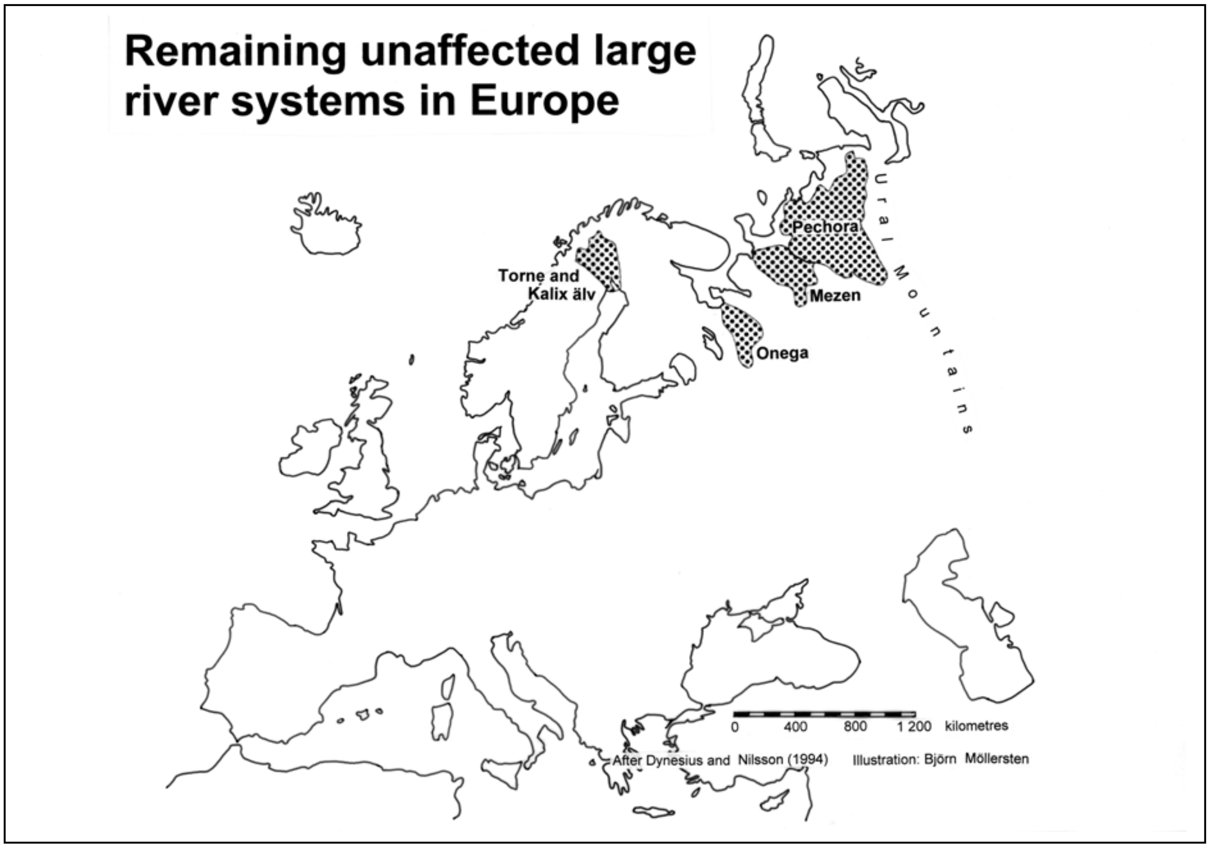

Figure 1. Remaining unaffected large river systems in Europe.

Torneälven/Tornionjoki and Kalixälven is the only large free-flowing river system that has its outflow into the Baltic Sea. The rivers together form one river system, as they are connected by the bifurcation Tärendöälven, which leads about 50 per cent of the water of Torneälven/Tornionjoki to Kalixälven.

Photo 1. Rapids in Pirttimysätno, the name of the upper reaches of Vittangiälven, a tributary to Torneälven/Tornionjoki. Although relatively water-rich, Pirttimysätno is very little known. It flows through alpine and sub-alpine zone.

Three large moderately affected rivers flows to the Baltic Sea, namely the Estonian river Narva/Narova, which flows close to the Russian border, and the better known Oder/Odra and Wisła. All other large rivers in the Baltic catchment area are strongly affected because of fragmentation by dams and flow regulation. These rivers are Dalälven, Indalsälven, Ångermanälven, Umeälven, Luleälven, Kemijoki, Neva, Daugava/Dvina and Nemunas/Neman.

Classification of rivers

A river with a mean annual discharge in the most water-rich section (in humid climates normally close to the mouth) of 350 m^3/s or more is regarded as a large river. This refers to the conditions before any significant human manipulation. The rivers have been classified with regard to fragmentation and flow regulation. The degree of fragmentation is determined by the longest main-channel segment without dams, compared to the whole main channel. As for tributaries, fragmentation is determined by the existence or not of dams in the largest tributary. The degree of flow regulation is determined by reservoir live storage, reservoir gross storage capacity, interbasin diversion and irrigation consumption. Reserve live storage is the water volume that can be used for regulation of water flow, i.e. the water volume that is above the lowest threshold in the outlet. Gross storage capacity is the total water volume that can be held by a dam, including water below the lowest threshold.

A study similar to the one conducted by Dynesius and Nilsson (1994) on large rivers was made for medium-sized rivers (mean annual discharge more than 40 m^3/s but less than 350 m^3/s) in Finland, Norway and Sweden (Dynesius & Nilsson 1994). Out of 59 medium-sized rivers in Finland, Norway and Sweden, 17 are within the Baltic Sea catchment area. Four of these are unaffected, three are moderately affected, and nine are strongly affected. All of the unaffected or moderately affected medium-sized rivers of Finland, Norway and Sweden within the Baltic Sea catchment area have their outflow in the Gulf of Bothnia.

Among the fragmented and regulated river systems of Finland, Norway and Sweden, there are only two rivers that have unaffected tributaries with a mean annual discharge larger than 100 m^3/s. Vindelälven (200 m^3/s) flows in northern Sweden, and Ounasjoki (140 m^3/s) in northernmost Finland.

The fragmentation and regulation of rivers have had many negative impacts. Large areas lack important habitats such as waterfalls, rapids and floodplain wetlands (Dynesius & Nilsson 1994). This has had a negative impact on many species of fauna and flora. The regulation has created unnatural water-level fluctuations, to which species are not adapted. Dams constructed on the rivers dry out riverbeds below the dams, impeding dispersal of organisms. As a consequence, many species have become threatened or even locally extinct. Numerous genetically unique populations of salmon (*Salmo salar*) and brown trout (*Salmo trutta*) have been lost forever (Bernes 1994).

An example from Sweden illustrates this. Level or flow control for hydroelectric power affects by far more red-listed species of fresh waters than any other factor (Table 1). The second most important factor is eutrophication, followed by acidification.

Table 1. Factors affecting red-listed species in Swedish fresh waters.
Every individual species can be influenced by several factors.

Factors	**Number of species**
Acidification	80
Eutrophication	107
Hunting, fishing, plant collecting	24
Introduction of species	23
Lake lowering	35
Level or flow control for hydroelectric projects	177
Persistent pollutants	33
Random or unknown factors	72
Recreation (disturbance, vegetation damage)	19

Source: Bernes 1994.

A well-known species in the Baltic Sea that has been severely affected by the regulation of rivers for hydroelectric purposes is the salmon. The Baltic salmon belongs to the same species as the Atlantic salmon, but is genetically separate as it exclusively spawns in rivers flowing into the Baltic Sea.

The salmon's life-cycle

Adult salmon spawn in the autumn. After hatching in spring, the young fish (called parr) spends 1–4 years close to the site where it was born and defends a territory. When the salmon has reached the silvery smolt stage (length 10–20 cm), it migrates in the spring from the river to the sea. 1–4 years are spent at sea, before the salmon returns to the river where it was born to spawn. At this time the salmon normally has a length of 50–110 cm and a weight of 2–20 kg. Most salmons die after spawning, but some survive and return to the sea and may even spawn a second time.

Salmon needs rivers with clear and rapidly flowing water and bottoms with gravel where the spawn can be buried and washed with oxygen-rich water. When dams began to be built in the 1940s for production of hydroelectricity, a sharp decline in the population of Baltic salmon started. Before that decline, according to estimates, 8–10 million smolt were produced every year (Baltic Salmon Rivers 1999). Regulation and fragmentation of rivers, together with pollution and overfishing, has lead to a reduction of annual natural smolt production to about two million. Today, there are 37 rivers in the Baltic catchment area with wild smolt production, compared with 80–120 before the human disturbances began.

Belarus

Natural gas, predominantly imported from Russia, is very important to Belarussian electricity production. In 2002, about 94 per cent of the generation of electricity in the country took place in natural-gas fired combined power and heating plants and in natural-gas fired electricity plants. 25 TWh electricity had its origin in such plants. To a minor extent, oil was used for electricity production as well.

Hydroelectric power is insignificant to Belarus. 28 GWh were generated by hydropower plants in 2002, which is about 0.1 per cent of the total electricity production.

There are about 20 mini hydropower stations in the Belarussian part of the Baltic catchment area. Half of them are in rivers of Neman/Nemunas basin, and the others in Dvina/Daugava basin. These power stations were built in 1951–60, and their average capacity amounts to 100–150 kW (Polutskaya 2005). The Belarussian Ministry of Energy has adopted an extensive programme for building of new hydropower stations and rebuilding of old ones.

Hotspot: Grodno

Situation: 8 km north of Grodno, westernmost Belarus (see Appendix 1)
River: Neman
Capacity: 17 MW
Start of operation: Construction has not yet started

Grodno hydropower plant, which is part of the Belarussian hydropower programme, was approved by the State Environment Expertise in 2004. The construction of the power station will involve a ten metres high dam, which will hold a 50 kilometres long reservoir. It would add less than six per cent of the total power generation capacity of the county of Grodno (Polutskaya 2005).

According to independent experts, the reservoir could cause problems with siltation, deterioration of river water quality, degradation of fisheries and aquatic biodiversity, and erosion of riverbanks. Fine sand and other sediments, that is naturally transported in the water and along the riverbed, will to a certain extent be trapped by the dam. This may dramatically change the river hydrology (Polutskaya 2005). These effects are likely to be more pronounced in Lithuania, where the river widens and slows down, after passing through the Grodno heights.

Estonia

Most of Estonia's electricity is obtained from the northeastern corner of the country, where two huge power plants are fired with locally mined oil shale.

The differences in altitude are very small in the Estonian landscape, leading to a very limited potential for hydroelectric power. In 2002, only 6 GWh electricity was generated by hydroelectric power plants. This corresponds to 0.07 per cent of the total electricity production in Estonia. River Narva/Narova, which follows the border with Russia, represents about half of Estonia's potential hydroelectric power. All of the exploited hydroelectric power of Narva/Narova is used by Russia. Apart from Narva/Narova, at least half of the economically feasible hydroelectric resources in Estonia have been developed (Nuum 2005).

Electricity suppliers are obliged to pay more than market price for electricity from renewable sources, until the renewable electricity corresponds to two per cent of the total supply of the company. At present, the total price is 81 cents per kilowatt-hour.

In Estonia, there are 112 rivers and creeks or sections of rivers and creeks that are protected as "salmonid rivers" against hydropower development. The prohibition applies both to new power stations and to reconstruction of older ones, in such a way that the water level is raised or the water regime is changed. Out of these 112 streams, 28 are protected in their entirety. Seven out of the 28 streams that are protected from source to mouth can be regarded as "large" (not very small). These are: Kaberla oja, Kolga jõgi, Kunda jõgi, Loobu jõgi, Podisoo jõgi, Selja jõgi and Valgejõgi.

Hotspot: Kotka

<u>Situation</u>: 58 km east of Tallinn (see Appendix 1)
<u>River</u>: Valgejõgi
<u>Mean annual discharge</u>: 3.4 m^3/s
<u>Height of fall</u>: 2 m
<u>Capacity</u>: 200 kW
<u>Start of operation</u>: Not yet started

At Kotka, seven kilometres from the mouth of Valgejõgi, a water mill and a dam were built 150 years ago. After the Second World War, Kotka hydropower station was raised. It was rebuilt in 1996. Two years earlier, permission to reconstruct the power plant was given by the environmental authorities, provided that a fish ladder would be built. However, there is still no fish ladder at Kotka, and therefore the power station has not been put into operation.

Valgejõgi has the best water quality among Estonian salmon rivers, and falls into the Gulf of Finland. River lamprey (*Lampetra fluviatilis*) spawns in the river, and there are populations of brown trout and grayling (*Thymallus thymallus*). The last time salmon parr were found was in 1976 (Baltic Salmon Rivers 1999). There are potentially valuable reproduction areas for migratory fish in Valgejõgi upstream of Kotka dam, but these are inaccessible because of the dam (Nuum 2005). About 11 kilometres from the estuary are the Nõmmeveski rapids, 1.2 kilometres long and with a gradient of 14 metres. The lower third of Valgejõgi is within the borders of Lahemaa National Park.

Latvia

In 2002, 2,5 TWh hydroelectric power was produced in Latvia, corresponding to 62 per cent of the country's electricity generation. Most of the remaining electricity generation takes place in natural-gas fired combined heating and power plants. In order to favour renewable energy and at the same time further employment in the countryside, a system of double tariffs on electricity from small-scale hydropower stations has been introduced.

According to Latvian legislation, operators of hydroelectric power stations have to leave the gates open from four weeks before summer solstice to four weeks after, when required in order to reduce damage to pastures from raised water levels. When fish are spawning, every hydropower station is obliged to leave the gates open. Fish ladders are compulsory as well. This act was passed by the Latvian republic before the Soviet invasion in June 1940. Today, however, the act is not implemented. Furthermore, hydropower pressure groups are lobbying against it (Balcers & Kalnina 2005).

On Latvian rivers, there are more than 150 hydropower stations with a capacity below two megawatts each. Most of the power stations are on salmonid rivers. In the whole of Latvia, there are only two functioning fishways (Balcers & Kalnina 2005).

In January 2002, the Latvian government passed a regulation that concerns 211 rivers and river sections. According to the regulation no permission can be given to construction of hydropower plants on these rivers and river sections.

One of the protected rivers is Salaca, situated in the northernmost part of the country and flowing into the Gulf of Riga. Salaca is the most important wild salmon river in Latvia (Baltic Salmon Rivers 1999). About 40 kilometres from the river mouth, the river channel is partially blocked by a dam of an old paper mill, which was closed in the 1980s. During low water, the dam may be impossible to pass for ascending salmon. There are both salmon and sea trout in Salaca. The entire catchment area of the river is within North Vidzeme Biosphere Reserve.

Hotspot 1: Galgauskas

Situation: 14 km west of Gulbene, county of Gulbene, eastern Latvia (see Appendix 1)
River: Tirza
Capacity: 520 kW
Start of operation: 2000

Tirza is a tributary to the medium-sized river Gauja, and the confluence between the two rivers is close to the headwaters of Gauja. Galgauskas mini power station is situated 15 kilometres upstream of the place where Tirza falls into Gauja. The river is affected by rapid water-level fluctuations all the way down to the confluence.

Hotspot 2: Āžu

Situation: 31 km west of Gulbene, county of Gulbene, eastern Latvia (see Appendix 1)
River: Tirza
Capacity: 235 kW
Start of operation: 2001

Tirza is a tributary to the medium-sized river Gauja, and the confluence between the two rivers is close to the headwaters of Gauja. Āžu mini power station is situated 30 kilometres upstream of the place where Tirza falls into Gauja. The river is affected by rapid water-level fluctuations almost all the way down to the confluence.

Hotspot 3: Ogre

Situation: 34 km east of central Riga, county of Ogre (see Appendix 1)
River: Ogre
Capacity: 630 kW
Start of operation: 2002

The tributary Ogre falls into the large river Daugava only 42 kilometres from Daugava's estuary in the Gulf of Riga. Ogre mini power station is situated three kilometres upstream of the confluence of the rivers. The power plant has lead to changes in water level of up to 40 centimetres. Ogre power plant is situated within a Natura 2000 area.

Poland

Polish electricity production is heavily dependent on coal (hard coal and lignite), which is burnt in combined heating and power plants. No coal-fired electricity plants exist. In 2002, the electricity production from coal-fired plants amounted to 135 TWh, which means that Poland got 93.5 percent of its electricity from such plants. The hydroelectric power production was 3.9 TWh in 2002, corresponding to 2.7 per cent of the country's electricity generation.

The highest energy potential is in the Wisła river basin, representing 68 per cent of the country's hydropower resources. Other energy-rich rivers are Dunjec, San, Bug, Odra, Bobr and Warta. The highest concentration of existing medium-sized and large hydropower stations is in the mountainous areas along the southern and southwestern border. In central Poland, hydropower plants are few, and in the eastern part of the country almost absent.

The southern parts of Poland are the most suitable for construction of small hydropower stations in terms of water resources (Gruszka & Fabis 2005). Taking into account existing hydropower-related infrastructure, the western and northern parts of the country are also considered very attractive.

There are more than 700 hydropower plants in Poland. Those with a capacity exceeding 0.5 MW have a combined capacity larger than 2,222 MW. In 2002, there were about 580 small hydropower stations, with a capacity less than 5 MW and a total capacity of 185 MW. 73 of the small hydropower stations that operated in 2002 had a capacity between 0.5 and 5.0 MW, and a total capacity of 136 MW. Thus, there are more than 500 small hydropower stations with a capacity below 0.5 MW and a combined capacity of only 49 MW. Despite their large number, they account for only two per cent of the total capacity of Polish hydroelectric power plants.

Many Polish hydropower stations are devoid of fish ladders, and those ladders that do exist do not function properly. Consequently, most rivers are inaccessible for migratory fish species, and as a result many populations have suffered heavy losses or even gone extinct (Gruszka & Fabis 2005). Programmes aimed at making rivers accessible for migratory fish are being elaborated on the county level. The programmes are supposed to include construction of modern fish ladders as well as demolition of dams that are not used for energy purposes. In some coastal counties, modern fish-ladders are already being constructed.

Support for construction of mini hydropower stations in Poland can be obtained from a large number of institutions, both national and international. Agreements on bilateral cooperation with Western European countries, including Denmark, Germany, Sweden and the UK, provide opportunities for financial support to small-scale hydropower development (Gruszka & Fabis 2005).

According to the "Strategy of Renewable Power Industry Development", elaborated by the Ministry of Environment in 2000, the share of renewable energy is to increase to 7.5 per cent in 2010 and 14 per cent in 2020. The authorities characterize hydropower as sustainable, renewable and "green" energy. Regulation of rivers and creation of reservoirs, measures that from an ecological point of view are disastrous, are put forward as advantageous for the environment.

Hotspot: Włocławek

Situation: Near the town of Włocławek, central Poland (see Appendix 1)
River: Wisła
Mean annual discharge: 1,030 m^3/s
Height of fall: 8,8 m
Capacity: 160 MW
Annual electricity production: 739 GWh
Start of operation: 1970

This hydropower station, the largest of Poland, constitutes a key obstacle for fish migration to the Wisła basin above the dam. There is a fish ladder, but only very few fish manage to pass it. This has contributed to the disappearance of migratory fish species, including sturgeon (*Acipenser sturio*), salmon and sea trout, in the middle and upper parts of the river basin (Gruszka & Fabis 2005). There is work going on making Wisła accessible for migratory fish, but it is still in its initial phase.

The construction of the dam has completely changed the character of the river in the area. There are 3.5 metres of erosion downstream of the dam. In addition, untreated waste, including waste from heavily polluted industrial areas, has settled in the reservoir, rendering the sediment highly toxic.

Sweden

Sweden is a country rich in hydroelectric power. On average, the hydroelectric power plants annually generate 65 TWh electricity, which corresponds to about 45 per cent of the country's electricity generation. Another 45 per cent is generated by nuclear power plants. Most of the remaining 10 per cent is produced by industrial backpressure, and in a number of combined power and heating plants.

In terms of developed hydroelectric power resources per capita, Sweden is among the world's top five countries. Sweden is surpassed only by Norway, Iceland, Canada and Paraguay.

About 70 per cent of the economically feasible hydropower resources have been exploited, which has led to very severe damage, especially in the mountains in northwestern Sweden. Large-scale hydropower exploitation in northern Sweden began in the early 1900s.

In 1910, the construction started of the large power station Porjus, 90 kilometres downstream of Stora Sjöfallet National Park. Nine years later, the Swedish Parliament decided to approve the damming of the rich lake system in the very heart of the Stora Sjöfallet National Park. The lake system and the Great Waterfall (Stora Sjöfallet) at the eastern end of the lake chain were the main reasons for the creation of the national park, which happened in 1909. The regulation was carried out because it was considered necessary for the operation of the Porjus power plant and the other power plants that later would be built downstream on river Lule älv. After the original construction, the dam (called Suorva dam) was heightened three times, the last time 1966–72. Simultaneously, in the late 1960s, the Great Waterfall was obliterated, as the water was lead past it to a new power station.

Photo 2. Suorva dam in Stora Sjöfallet National Park.

Photo 3. Dry riverbed of Vietasätno in Stora Sjöfallet National Park. The river disappeared when it was forced into a tunnel after construction of Vietas hydropower station in the late 1960s.

The mean annual electricity generation of river Lule älv today is almost 14 TWh, in Sweden paralleled only by river Ångermanälven. In the course of the twentieth century, most of the Swedish rivers became harnessed for hydroelectric purposes. The most intense development took place during the period from 1950 to 1980.

One characteristic of the Swedish climate is that the precipitation is stored in the winter as snow. This is especially pronounced in the central and northern part of the country. The water level in the rivers is lowest at the time of the year when demand for electricity reaches its peak. Conversely, during high water in the summer, the need for electricity is low. As most of the energy-rich rivers are in Central and Northern Sweden, the water must be stored from summer to winter. Very severe damage has been caused to numerous large lakes used as reservoirs in the mountains in the northwest. The difference between high and low water in the reservoirs can be as much as 35 metres. On the eroded shores between high- and low-water marks almost nothing can live. The negative impact is made even worse by the fact that species are adapted to the natural pattern of low water in winter and high water in summer. Many species cannot cope with the reversed high- and low-water pattern.

Apart from the large reservoirs in the upper reaches of the rivers, the differences between high- and low water is leveled out in a regulated river. But in the small reservoirs immediately above the power stations, large fluctuations can arise during the course of a day and a night, or even from one hour to next. More water is led through the turbines at daytime, when demand for electricity is high. Severe erosion is a common consequence.

According to the Environment Act, the Swedish large and medium-sized rivers that are still free flowing are protected against hydropower development. The four largest – Torne älv, Kalix älv, Piteälven and Vindelälven – have been appointed “National Rivers”. The protection includes the entire catchment area of the rivers. In fact, Piteälven is not 100 per cent free flowing, as there is one dam in the lower reaches of the river. The same applies to Vindelälven, which is a tributary to the heavily regulated river Umeälven. Immediately below the point of confluence, a hydropower station was brought into operation in 1958.

Apart from the four National Rivers, there are 12 smaller rivers that are protected according to the Environment Act, their entire catchment areas included. Some of those, especially in southern Sweden, have a limited number of power stations. In addition, there are 24 smaller tributaries (with catchment areas) of regulated rivers, and ten free-flowing sections of otherwise exploited rivers, where construction of hydropower plants is not permitted.

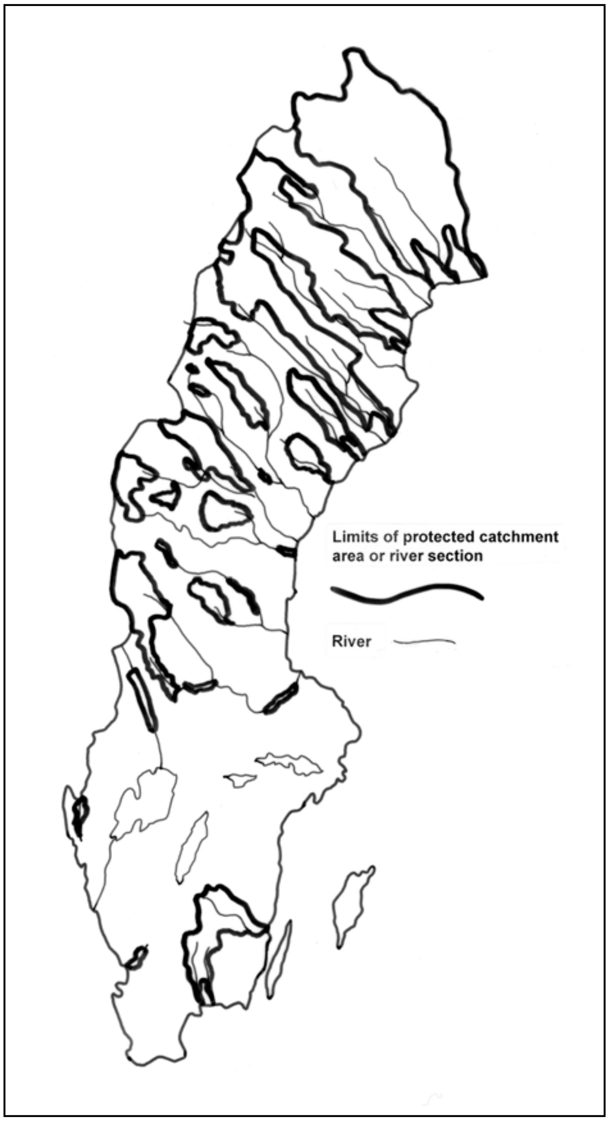

Figure 2. Swedish river catchment areas and river sections protected against hydropower development according to the Environment Act. Map after Nilsson & Tobiæson (1996).

The Swedish electricity certificate scheme, introduced in 2003, is intended to further renewable electricity. Hydroelectric power is included in the scheme, which implies that the scheme poses a threat to rivers and streams. From the beginning, only electricity from small-scale power plants was classified as renewable, but in 2006 the Government will put forward a bill proposing that large-scale hydropower will qualify as well. Old plans to develop hydropower, including on the protected river Sävarån, are being referred to once again.

The electricity certificate scheme

As from May 2003, there is a scheme being run in Sweden to promote use of renewable energy sources for electricity generation. Electricity producers using sun, wind, water and biofuels get one so-called electricity certificate from the state for each megawatt hour they generate. The certificates are to be sold to electricity suppliers, who are obliged to include a certain share of renewable electricity in their energy mix. This share will increase gradually from one year to next. In 2003, the compulsory share of renewable electricity was 7.4 per cent, and in 2010 the share will be 16.0 per cent.

During the last three decades, subsidies have periodically been given to small-scale hydropower, as hydropower is renewable and because electricity from mini power stations by many people is regarded as environmentally friendly. For two periods, direct subsidies were given to construction of new power plants or to restoration of old ones. However, many of the "restorations" were in fact constructions of new plants, often associated with intensified regulation of water flow. The first period of direct subsidies lasted from 1978 to 1987, the second one from 1997 to 2002.

The state has also guaranteed a least-price of small-scale hydropower (as well as of wind power). The electricity suppliers have been obliged to buy all electricity that was produced in hydroelectric mini power stations, and to pay a settled price above the market level. The least-price system was in November 2000 replaced by a price support amounting to SEK 0.09 per kilowatt-hour. Now the electricity certificate scheme has replaced the price support.

There are about 1,550 hydroelectric power plants in Sweden, of which around 1,200 are defined as mini power stations (power plants with a capacity of 100–1,500 kW). Despite the large number of mini power stations, almost all hydroelectric power (97.5 per cent) is generated by the approximately 350 large-scale hydropower plants (Möllersten 2002a). The mini power stations are of minimal significance in terms of power generation, but the collected damage caused by these plants is very large.

There are more than 5,290 dams in Swedish rivers and streams (Svenskt dammregister 1995). As a consequence, a great majority of Swedish rivers, regardless of size, are affected by damming for hydropower or other purposes.

Hotspot: Ljungå

Situation: 45 km east of Bräcke, county of Jämtland, central Sweden (see Appendix 1)
River: Ljungån
Mean annual discharge: 6.7 m^3/s
Height of fall: 15 m
Capacity: 1,2 MW
Annual electricity production: 4,800 MWh
Start of operation: Not yet started

Photo 4. Ljungå mini power station under construction. March 2002.

Ljungån is part of the catchment area of the medium-sized, heavily regulated river Ljungan. In the lowest reaches of Ljungån there is a 500 metres stretch of rapids. Previously, here were two dams and a very small power station, but both the power plant and the dams are since long demolished. During the last 30 years, the water system of Ljungån, apart from one regulated source-lake, has been unaffected by regulation for hydroelectric purposes. Ljungån has its outflow in lake Holmsjön.

Sampling in 1997 and 1998 has shown that Ljungån has extremely high biodiversity in the bottom-living fauna (Lingdell & Engblom 1997). The results of the samplings, when compared with 9,520 standardized samplings from sites all over Sweden, showed that only two samples had a greater biodiversity than the Ljungån samples. Among the dominating species and genera, there were those sensitive to pollution and those sensitive to acidification, indicating that Ljungån is neither affected by pollution nor by acidification.

Bottom-living fauna

Animals living in and on the riverbed make up the bottom-living fauna. Animal groups typical of bottom-living fauna are snails, mussels, leeches, worms, crustaceans and insects. Among insects, the larvae stage of groups such as stoneflies, mayflies and caddis flies belong to the bottom-living fauna. Several beetles are part of the bottom-living fauna both as larvae and as fully developed individuals. Bottom-living fauna is usually divided into five so-called functional groups, reflecting how they get their food. *Shredders* (common among stoneflies) mostly feed on leaves that have fallen into the water. *Scrapers* (for example many mayflies and snails) eat microscopic growth on stones and vegetation. *Filterers* (blackfly larvae and many mussels and caddis flies) filter free-floating bacteria and fine organic material from the water. *Detritus eaters* (for example midge larvae and many earth worms) feed on dead organic material. *Predators* are common among beetles, dragonflies and leeches. Bottom-living fauna is important as food for many organisms, including salmonids.

Most small animals living in water are sensitive to environmental changes, which makes them ideal as environmental indicators. Even short periods of for example low oxygen levels or low pH values influence the composition of bottom-fauna. When periodic chemical samples are taken, such brief changes are easily missed.

Brown trout and grayling migrate from lake Holmsjön to Ljungån to spawn, but migration related to foraging and wintering also occurs. A great part of the Ljungån populations of brown trout and grayling probably winters in lake Holmsjön.

The power station, which has been granted investment support, will result in the rapids lying dry most of the year. The uppermost part of the rapids will be dammed instead. The water judgment requires a minimum release of 0.5 m^3/s through a constructed fish ladder from April to October. During high water May–June, there will arise a water surplus, which is released in the natural river channel.

Permit to construction of the mini power station was given by the Water Rights High Court in 1994. However, this case has been extremely protracted, as the developer has not complied with the conditions established by the Water Rights High Court, regarding the design and exact position of the concrete dam. In addition, the developer went bankrupt, and the project was taken over by an official receiver. The project has been taken to court once again (Isgren 2005).

Conclusions on Hotspot

The exceptionally rich bottom-fauna where the mini power station is being built will be wiped out (Möllersten 2005b). A fair minimum release in the natural channel all the year round would have saved at least part of the high biodiversity. The minimum release that is prescribed in the fish ladder during summer half term will favour only the fish fauna.

The dam will impede fish migration, which only partly can be compensated by the fish ladder (Möllersten 2005b). Not only fish that migrate to spawn will be hampered, but also fish migration due to foraging and wintering. Fish moving downstream run the risk of being cut into pieces when they pass the turbines.

The National Board of Fishery estimates that 5,000 m^2 of riverbed where salmonids spawn and grow up will be laid dry or be dammed (Möllersten 2005b).

Discussion and Conclusions

Regulation for hydropower purposes is the largest threat against red-listed species of lakes and watercourses in Sweden. The same applies with a high degree of probability to the other sparsely populated Baltic Sea states within boreal and semiboreal zones – Finland and Estonia. In Latvia, Lithuania, Belarus, Poland and Germany, where the share of agricultural land as well as the population density is larger, other factors, especially eutrophication, may be of greater relative significance. Still, however, hydropower development is probably one of the main threats against freshwater biodiversity in those countries as well.

Most countries in the Baltic catchment area have introduced legislation or plans to protect rivers against hydropower exploitation. In Sweden, 50 river catchment areas or sections of rivers enjoy protection. In Estonia and Latvia, there are 112 and 211 protected rivers or river sections, respectively. More than 100 Lithuanian rivers and streams are protected against further hydropower development. In Finland, 55 lakes, rivers and other watercourses are totally or partly protected.

However, this protection is by no means one hundred per cent reliable. A freely flowing river or stream is always potentially threatened – as long as it has not been exploited and in this way destroyed. In Sweden, for example, at least one river that is protected by the Environment Act is mentioned as suitable to develop for hydroelectric power. The only things that are able to stop companies and policy makers that want to "develop" rivers are a conscious public opinion, a strong environmental movement, and resistance from local people directly affected by exploitation plans.

To mitigate negative effects of installation of hydropower plants, it is important that the courts or other authorities' decisions prescribe a minimum release of water allowed to flow in the natural river channel. To be meaningful from an ecological point of view, the minimum release should correspond to 10–30 per cent of the mean annual discharge of the river. If there are salmonids in the waterway, the minimum release should be at least 30 per cent of the mean annual discharge. This has been shown by research in North American waters (Degerman 1998).

All hydroelectric plants – old as well as new ones – should be complemented with fishways. During the past ten years, there has been a trend towards creating nature-like fishways, instead of the traditional types made of concrete or a combination of concrete and other materials. The bottom of nature-like fishways is covered with gravel, stones and boulders, which protects the fishways against erosion and provides fish with places where they can stay (Sandell et al 1994). Nature-like fishways can be used not only by fish but also by many different aquatic organisms, migrating up or down the river.

According to Hebrand (2006), there are a number of conditions that have to be fulfilled when constructing well-functioning nature-like fishways: there has to be sufficient water-flow in the fishway; inlet and outlet must be able to accommodate to fluctuating water levels; the shape of the fishway has to be correct; the fishway has to be stable; and the water flow must be controllable.

It is also important to monitor the function of the fishway. Installing equipment recording all fish passing op or down the fishway may be the best option. However, there is no equipment that is wholly reliable. For example, various objects can be mistaken for fish. Even more important, fish that are deterred from passing the fishway are not recorded (Hebrand 2006).

Very important to bear in mind, however, is that environmental considerations, such as construction of fishways and water release in natural river channels, can only to a minor extent compensate for damage caused by hydroelectric power plants. It is therefore extremely important to preserve running waters in their natural state.

There is a widespread conception that renewable energy is by definition environmentally sustainable. This is a misunderstanding, as the concept of sustainability includes preservation of biodiversity.

Because regulation of rivers for hydropower purposes is one of the main threats to red-listed freshwater species in the Baltic catchment area, hydropower – when developed in the way that has been the case in Sweden and Finland at least – cannot be considered environmentally sustainable. Furthermore, as biodiversity (according to Convention on Biological Diversity) comprises diversity *within* species, *between* species and of *ecosystems*, a fair number of running waters have to be maintained as intact natural ecosystems, regardless of how many species are threatened by hydropower exploitation.

According to the EU Habitat Directive, EU member countries are obliged to select areas for nature protection containing habitats listed in Annex I of the Directive or species listed in its Annex II. This can be used as a tool in work aiming at protecting rivers and streams against exploitation for hydroelectric purposes. Annex II comprises about 700 species. Out of 101 Habitat Directive species occurring in Sweden, at least eleven are negatively affected by hydropower development. In Appendix 2 of this report, there is an account of Swedish species of the Habitat Directive negatively affected by harnessing of hydroelectric power.

Every kilowatt-hour, regardless of how it has been generated, has some kind of negative environmental impact. The only kilowatt-hour that causes no damage to the environment is the one that is not used. Improving energy efficiency is one of the most urgent environmental measures. According to the OECD Environmental Performance Reviews (2004), promotion of energy conservation should be prioritised over subsidisation of even the most environmentally friendly types of energy supply.

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Appendix 2: Land use and population density in Baltic catchment area countries

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Appendix 3: Swedish species of the EU Habitat Directive negatively affected by hydropower development

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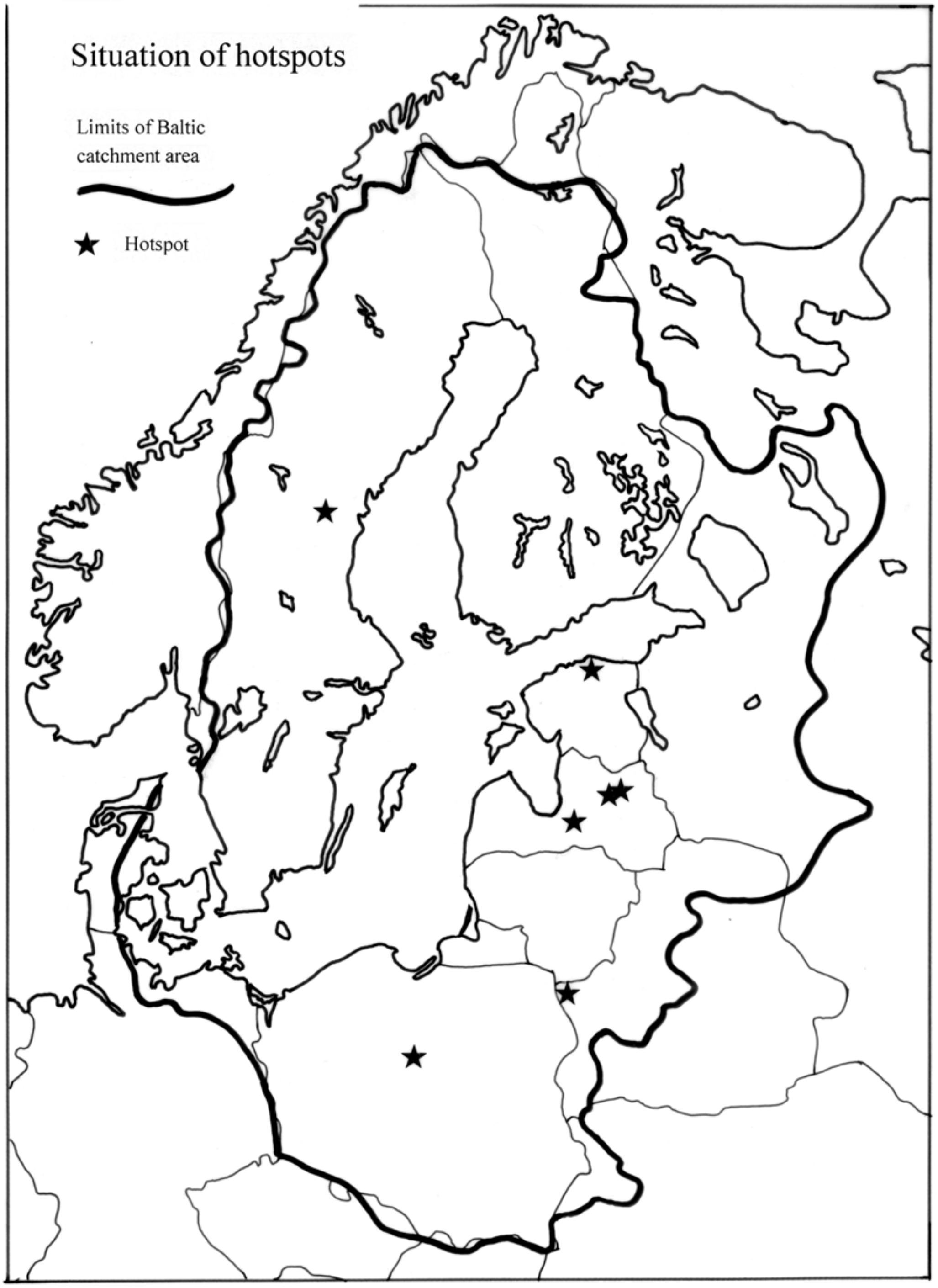
Appendix 1


Situation of hotspots
Limits of Baltic catchment area
Hotspot

Appendix 2

Land use and population density in Baltic Sea catchment area countries

Country	**Forest land 2000 (percentage of total country area)**
Belarus	45
Estonia	46
Finland	65
Germany	30
Latvia	45
Lithuania	31
Poland	28
Sweden	60

Country	**Arable land, permanent crops and garden 2002 (percentage of total country area)**
Belarus	28
Estonia	14
Finland	7
Germany	34
Latvia	29
Lithuania	46
Poland	44
Sweden	6

Country	**Population density 2002 (inhabitants per square kilometer)**
Belarus	49
Estonia	30
Finland	15
Germany	230
Latvia	37
Lithuania	56
Poland	119
Sweden	20

Note: Statistics on Russia are not included in Appendix 2, as the general statistics apply to the whole of Russia, whereas only a very small share of the country is within the Baltic Sea catchment area.

Appendix 3

Swedish species of the EU Habitat Directive negatively affected by hydropower development

Species	**Habitat**	**Threats**
Mosses		
Scientific name *Dichelyma capillaceum* Swedish name Hårklomossa	Rocks, lower parts of tree trunks and bushes along shores of lakes and slowly flowing watercourses, where water level fluctuates in a natural way. The species is confined to the zone that is flooded every year, and grows only where the difference between high- and low-water levels is fairly large.	The main threats are changes of water level regime and of water quality. The species disappears if the lake or watercourse is regulated, so that the water level is more constant or fluctuates frequently.
Scientific name *Hygrohypnum montanum* English name Montane hygrohypnum moss Swedish name Späd bäckmossa	Boulders of silicate rock permanently or periodically soaked by water from watercourses, especially in or close to forest brooks.	Changes of water quality and hydrology of the watercourses where the species grows.
Vascular plants		
Scientific name *Trisetum subalpestre* Swedish name Venhavre	The species occurs exclusively in connection with free-flowing watercourses, mainly on erosion shores along rapids.	All kind of influence on the water regime can jeopardize the specie's continued existence.
Scientific name Persicaria foliosa Swedish name Ävjepilört	Shallow, clayey shores along rivers, streams and lakes. By the Bothnian Bay the species also occurs in brackish water. The species is a very weak competitor, and on some sites it is dependent on grazing.	Regulation of watercourses is the greatest threat. Decreasing grazing intensity is a serious threat to the specie's survival in some sites.
Dragonflies		
Scientific name *Ophiogomphus cecilia* Swedish name Grön flodtrollslända	The larvae live in running waters such as rivers and streams. They are found on gravel and stone beds at various depths. Watercourses with clear water flowing through forest are preferred.	The most important threat is regulation of rivers for hydropower development. Changes of water quality may be detrimental to the species.

Table continued on next page

Species	**Habitat**	**Threats**
Butterflies		
Scientific name *Euphydryas aurinia* English name Marsh fritillary Swedish name Ärenprisnätfjäril	Open damp land where Devil's-bit Scabious (*Succisa pratensis*), the host plant of the species' larvae, is abundant. Examples of biotopes are edge zones around open forest fens, grazed damp meadows, cobblestone shores, power line strips, and clear-fellings.	Ceasing cultivation of grazed meadows has so far been the main threat. Another threat is draining of wetlands. Sites by regulated watercourses are often affected by the reversed water regime, with absent spring flood and high water in summer. Many sites by regulated rivers have been destroyed due to unnaturally high water in summer.
Mussels		
Scientific name *Margaritifera margaritifera* English name Freshwater pearl mussel Swedish name Flodpärlmussla	The species is dependent on running water with sand, stone or gravel beds, where the current speed is sufficiently high to prevent clogging of riverbeds. The mussel larvae live as parasites on gills of salmon or brown trout for up to ten months. The dispersal, especially upstream, happens with the help of young trouts.	Absence of reproduction is the main threat. A population of the species can survive for many years without reproduction, as one individual mussel normally becomes 90 years old (maximum life length up to 250 years). Sites of the species are destroyed for example at road construction and driving with heavy machinery in watercourses. Hydropower development normally leads to a strong deterioration of mussel biotopes, as it creates an unnatural water regime and as trout populations are damaged and prevented from migrating. Acidification is another threat; directly as it makes uptake of calcium more difficult for the mussels; indirectly as it damages trout populations. Clogging of riverbeds due to logging, soil scarification, and ditching is a serious threat. Freshwater pearl mussel is also sensitive to eutrophication.
Scientific name *Unio crassus* Swedish name Tjockskalig målarmussla	Mainly running water, principally on sand and gravel beds. The ecological requirements of the species are on the whole in accordance with those of the Freshwater pearl mussel. It is unclear what fish species are hosts for the mussel larvae; there are a number of potential species. The dispersal, especially upstream, happens with the help of the host fish.	The species is considerably more threatened than the Freshwater pearl mussel. The threats are deterioration of water quality (acidification, eutrophication, pollution), destruction of sand and gravel beds, and decline of host fish species.

Table continued on next page

Species	**Habitat**	**Threats**
Fish		
Scientific name *Aspius aspius* English name Asp Swedish name Asp	Oligotrophic and mesotrophic lakes. The species spawns in running water over gravel and stone beds but also over areas rich in vegetation and with clean water with a high content of oxygen. Some populations spawn in shallow areas in lakes.	Migration obstacles in the form of dams or incorrectly placed road culverts. Other threats are pollution and various kinds of physical disturbances of the habitat.
Scientific name *Salmo salar* English name Atlantic salmon Swedish name Lax	Atlantic salmon is dependent on free-flowing rivers where migration is not impeded. Furthermore, in these rivers there has to be suitable spawning and growth areas. After 1–4 years the young salmon migrates into the sea, where it spends 1–4 years. When the salmon is mature to spawn, it returns to the river where it was born. The spawning takes place in rapidly flowing water on gravel beds, where the female buries her fertilized spawn.	Hydropower development and other activities that involve damming of rivers pose serious threats, as they hamper salmon's migration. Acidification, persistent chemicals and eutrophication threaten salmon, as do diseases, especially M74 syndrome and the parasite *Gyrodactylis salaris*. Releases of reared salmon, to compensate for losses due to hydroelectric development or fishery, can alter genetically unique salmon populations. Over fishing, in salmon rivers and on the sea, is a serious threat. Cage farming in coastal waters involves a risk of diseases being transmitted to wild salmon.
Mammals		
Scientific name *Lutra lutra* English name Eurasian otter Swedish name Utter	A vigorous population of otter requires large areas with more or less continuous water systems. Ideal environments for otter include waters offering abundant and accessible feed throughout the year. If the lakes are covered with ice in winter, the otter needs running water where it finds opportunities to feed.	High concentrations of PCB have previously caused a drastic decline in otter population in Sweden. The pesticide situation has improved, however, and since the early 1990s the otter population has increased. Regulation of watercourses, and harnessing of waterfalls and rapids pose a threat. Road traffic kills a fairly large number of otters every year. Otters are also accidentally trapped and drowned in stationary fishing gear.

Appendix 4

Energy and capacity units, examples of energy use, and conversion of energy units

Energy units

kWh	kilowatt hour (one thousand watt hours)
MWh	megawatt hour (one million watt hours)
GWh	gigawatt hour (one billion watt hours)
TWh	terawatt hour (one thousand billion watt hours)

Capacity units

kW	kilowatt (one thousand watt)
MW	megawatt (one million watt)

Energy use

1 kWh is the amount of energy developed by a 70-watt bulb shining for 14.3 hours or by an electric hotplate during one hour.

1 MWh is the amount of energy used by a modern refrigerator and freezer unit during one year.

1 GWh is the amount of energy used by 1,000 modern refrigerator and freezer units during one year.

1 TWh is the amount of energy used during twenty-four hours in Denmark.

Conversion of energy units

In international energy statistics, energy is often expressed as ton of oil equivalent (toe) or thousand ton of oil equivalent (ktoe).

1 toe is equal to 11.63 MWh.

1 MWh is equal to 0.086 toe.