Fresh water

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Norway has a rich and varied natural history associated with rivers and lakes. This chapter describes the environmental conditions and the most important impact factors for Red Listed species in fresh water in Norway. Fresh water is here defined as streams, rivers, ponds, lakes and systems of these, and it covers both the open water bodies themselves and their beds.

Around 5 % (17 000 km^2) of the area of Norway can be characterised as fresh water. Aquatic systems in Norway are characterised by many small lakes (some 870 800 lakes are less than 0.01 km^2 in area; cf. the Norwegian Mapping Authority) and rapidly flowing rivers. Only 2163 lakes have an area of more than 1 km^2, but these have a total surface area of 10 200 km^2, corresponding to 60 % of the area of lakes in Norway. In most lakes, the retention time of the water is short (i.e. the water is rapidly exchanged), but it is longer in some deep lakes. The four deepest lakes in Europe are in Norway. They are all deeper than 400 m, and the deepest part is below sea level. More than 250 000 km of river courses have a discharge in excess of 1 m^3/s. Most rivers are small, with a drainage basin of less than 10 km^2 and a length of a few kilometres. Only 14 rivers are more than 200 km long. The distance from the mountaintops to the fjords is particularly short in western Norway and along the coast of northern Norway. Practically all the large rivers have their source in the mountains, and Norwegian rivers are therefore mainly characterised by waterfalls and rapids with few or no gently flowing stretches, the main exception being the Glomma in south-eastern Norway.

A number of factors help to change freshwater systems in Norway, including physical disturbances (infrastructure, generation of hydroelectricity, flood-control embankments and filling-in), pollution (eutrophication, acidification and contaminants), introduction and spreading of alien species, and changes in climate. About 1/3 of the lake area in Norway, just less than 6000 km^2, is affected by hydroelectricity development. Some 1000 km^2 have been inundated, and 15 of the 20 highest waterfalls in Norway have been

Most rivers in Norway are comparatively small and typically have many waterfalls and rapids. The distance from the mountaintops to the fjords is especially short in western Norway and along the coast of northern Norway. Photo: John Atle Kålås.

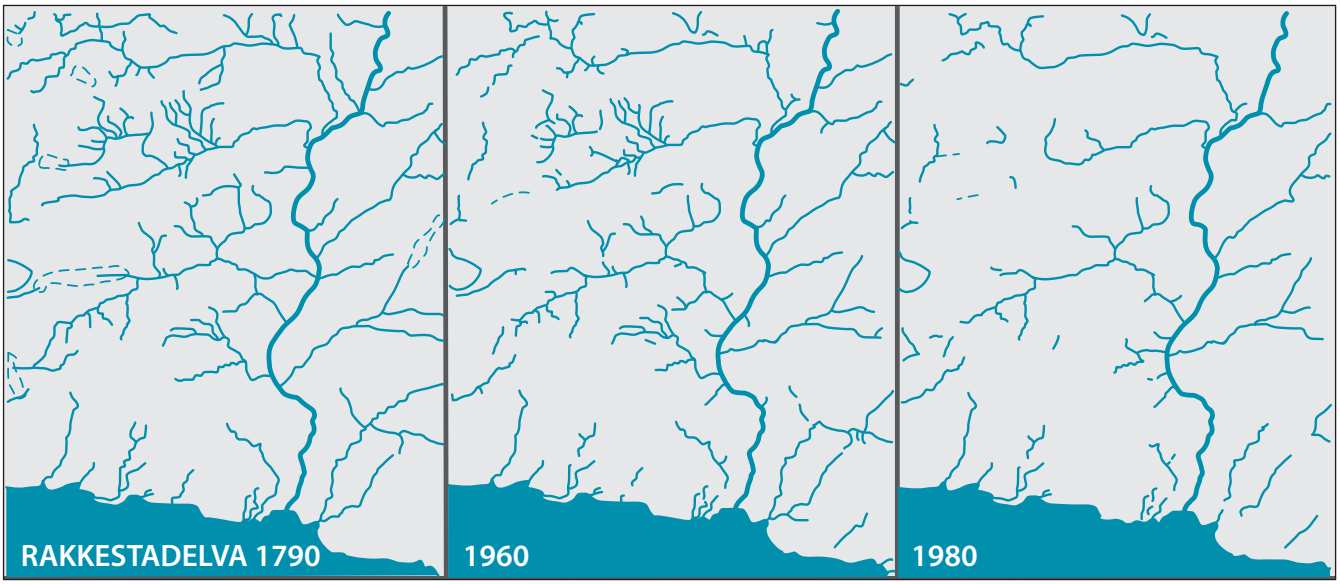

Figure 1. If we study old maps like these, which show the catchment of "Rakkestadelva" in Østfold, we will see that many former watercourses no longer exist. Wetlands have been ditched and reclaimed, and streams culverted. Small streams are now rare habitats in the lowlands of south-eastern Norway. In the county of Østfold alone, more than 1500 kilometres of streams and ditches have been blocked since 1960. Ditching of wet and marshy land began in the early 1800s, but it was not before the advent of mechanical excavators around 1930 that this work got underway in earnest. Blocking of streams and ditches increased significantly after government grants were introduced in 1959. Source and illustration: Norwegian Institute for Forestry and Landscape and the County Governor of Østfold.

harnessed. In addition, numerous stretches of river have had flood-prevention embankments built on them or been regulated to generate electricity, obtain drinking water and water for irrigation purposes, float timber, and so on.

Disturbances in the form of road building, drainage and filling-in are a particular threat to smaller water bodies (ponds and streams) and have led to the loss of many such water bodies, or they have become more isolated (Figure 1). The tolerance limits for acidification of fresh water are exceeded for at least 10 % of the land area in Norway, reduced from 30 % in the 1980s[1, 2]. Areas in southernmost and western Norway are particularly affected by acidification. Pollution in the form of influx of nutrients (eutrophication) to fresh water is primarily a problem in built-up areas and lowland districts with intensive farming. The largest single source of excessive eutrophication is farming, whereas nutrient influx from industry and the general public has been significantly reduced in recent years[3]. Lake sediments in large parts of southern Norway are contaminated by lead, mercury and cadmium, mainly derived from long-transported airborne pollution. The quantities are now declining and, apart from mercury, there is little risk that current levels are hazardous to plants and animals. Mercury has shown little change since 1995 and can also accumulate in the food chains to give high concentrations in freshwater fish, for example. Moreover, too little is known about the quantities and biological effects of new kinds of pollutants like brominated flame retardants.

Fresh water and biological diversity

Fresh water in Norway is categorised in slightly different ways depending on the objective of the categorisation. In work relating to the EU Water Framework Directive, fresh water is divided into types based on size (area and depth) and geological (alkalinity and humus), climatic and biogeographical factors[4]. The basis for the typology is the water body. In work performed by the Directorate for Nature Management to survey biodiversity in fresh water in Norway, a division is used which is more based on visual factors (physical conditions and geological processes) at the landscape level[5] and geological conditions at the water body level[5, 6].

"Habitat types in Norway" (NiN) categorises habitats in five main levels. All these levels may be crucial for the presence of Red Listed species, but the occurrence of a species is often directly tied to properties in the microhabitat (substrate). NiN gives a more

detailed classification and description of freshwater habitats[7].

Information on all known animal species which have their main occurrence in fresh water in Norway has been compiled[8]. They amount to 2800 species, the most species-rich groups being chironomids (505 species), rotifers (288 species) and beetles (274 species). Forty-three reproducing species of freshwater fish are known in Norway, 32 of which occur naturally. In addition, two species, the European eel (*Anguilla anguilla*) (CR) and the flounder (*Platichthys flesus*), spend just part of their life in fresh water. All the six species of amphibians in Norway are attached to fresh water. Fresh water is an important feeding and/or reproducing medium for about 80 species of birds (32 % of the species breeding in mainland Norway) and six species of mammals (7 % of those recorded in Norway).

There is no correspondingly complete overview of freshwater plants and their distribution in Norway. Phytoplankton (microscopic algae drifting or suspended in open water) are the most species-rich group (at least 1050 species). There is a vast array of small, benthic algae (at least 900 species) in running water. This group is poorly investigated in still water. A total of 20 stoneworts and 97 aquatic vascular plants have been recorded in fresh water, and there are also many species which live in the transition between water and land. Bryophytes are poorly investigated, but some 30-40 species are thought to have fresh water as their most important habitat. Thus, all told we know of some 5000 species of animals and plants which mainly live in fresh water in Norway.

Whorled water-milfoil (*Myriophyllum verticillatum*) is known in the lowlands of south-eastern Norway and a few isolated occurrences in the counties of Rogaland and Finnmark. It is vulnerable to dredging, dumping and filling-in in the shore zone, and also to damming, regulation of water levels, filling-in of ponds, blocking of streams and reclamation of wetlands. The 2010 Norwegian Red List for Species allocated whorled water-milfoil to the near threatened (NT) category. Photo: www.biopix.dk./J.C. Schou.

Important environmental factors

The diversity of species in fresh water is influenced by both abiotic and biotic factors, and the interaction

The smooth newt (*Triturus vulgaris*) was assessed as near threatened (NT) on The 2010 Norwegian Red List for Species. Impact factors which were cited were the filling-in and draining of ponds where it breeds, pollution and release of fish. Photo: www.biopix.dk/Niels Sloth.

between these. Important fundamental environmental factors are the current conditions, the grain size of the substrate and the quality of the water, including its content of humic substances and nutrients, and its pH and content of lime and other ions. In addition, there is significant variation as a consequence of the regional temperature gradient. Biotic factors include every possible interaction between species (negative and positive), like competition for sites to live and for food, and that some species eat others (predation).

The lime (calcium) content is regarded as one of the most important abiotic factors in fresh water. Natural differences in the calcium content cause marked differences in the diversity and composition of the species. The diversity of freshwater organisms in general displays a positive relationship with the lime content even though the most lime-rich lakes (the calcareous lakes) may have a low diversity of aquatic plants. As calcareous water bodies generally occur in parts of the country where human impact is greatest, many lime-demanding species are Red Listed.

For many species, it is important to have good access to food, and the diversity of plants and animals is often somewhat higher in naturally nutrient-rich (eutrophic) water bodies than more nutrient-poor (oligotrophic) ones. Fresh water in the mountains has a particularly low diversity of species because of the short growing season and the consequent limited production. There is also a distinct east-west gradient, with the highest diversity of species in the south-eastern part of Norway and the lowest in western Norway. For many species, this is explained by the climatic conditions and geographical variations in the habitat diversity. For instance, most rivers in south-eastern Norway are warmer and have higher calcium and nutrient contents than those in western Norway. The steep slopes in western Norway also mean that the substrate in rivers and streams is more unstable, especially where substantial flooding occasionally occurs. Many plants and animals have problems establishing populations under such conditions. However, the diversity of freshwater organisms in Norway is also determined by immigration after the last Ice Age. The most important immigration route was from the east, and many species of plants and animals are lacking in western Norway even though suitable water bodies are present. These species have still not reached there because their dispersal is hindered by mountains and waterfalls.

Vascular plant vegetation is first and foremost found on soft bottoms (bottoms dominated by fine gravel, sand, silt or clay). There are few or no vascular plants on hard bottoms consisting of bedrock, boulders,

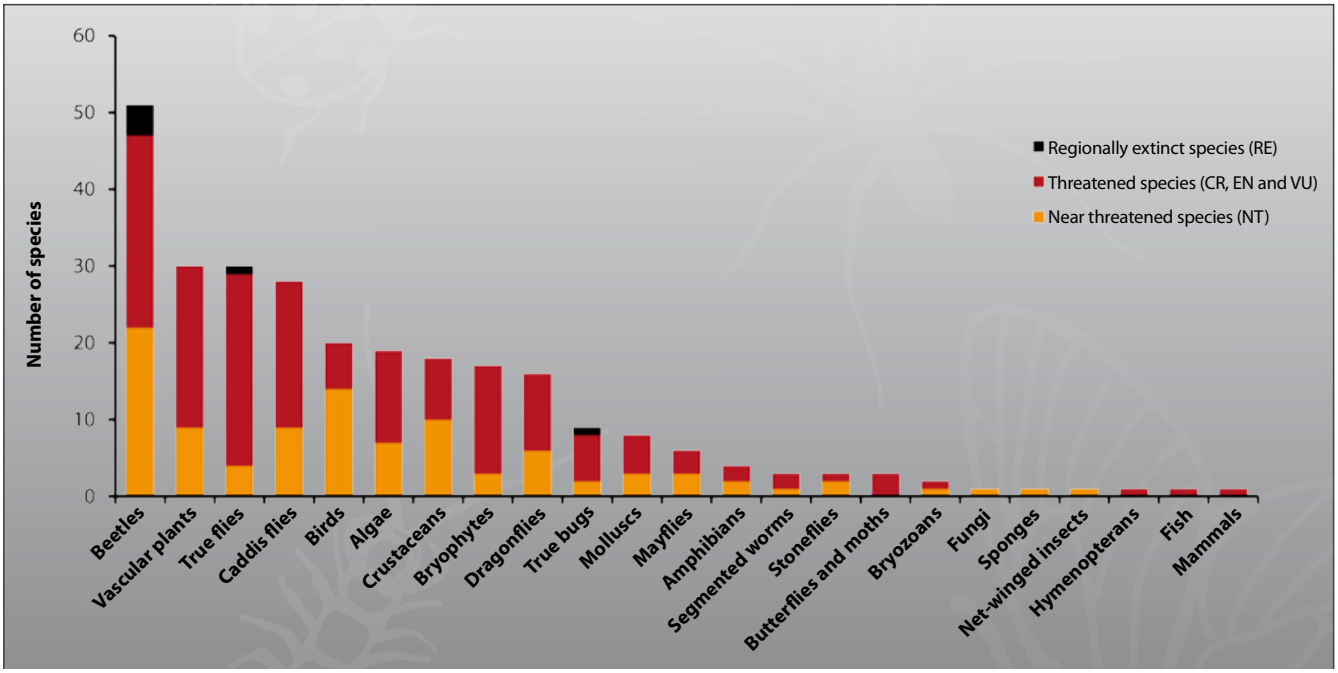

Figure 2. The numbers of regionally extinct (RE), threatened (CR, EN and VU) and near threatened (NT) freshwater species in various groups of species (273 species in all). Regionally extinct species (RE) are those which are assumed to have died out in Norway since 1800. Threatened species include the Red List categories critically endangered (CR), endangered (EN) and vulnerable (VU).

Stabilisation of river beds and other disturbances cause marked changes in habitats and plant and animal communities. On the Gudbrandsdalslågen at Ringebu, south-eastern Norway. Photo: Børre K. Dervo.

rocks and stones, but benthic communities dominated by bryophytes, green algae and animals grow on these elements in the substrate. The vegetation also provides valuable microhabitats for many animals and other plants (encrusters). With the exception of planktonic algae and rotifers, the open water contains few species compared with the bottom in fresh water. There are many differences in the fauna and flora of rivers and lakes, but gently flowing rivers may contain many species that are normally found in lakes. Likewise, zones where waves break on exposed lake shores may have species which normally occur in flowing water.

Organisms strongly influence one another, but detailed knowledge about such interactions, both within and between species, is often limited. The quantity of fish and the composition of the fish community have a great deal to say for the diversity of zooplankton and other invertebrates like molluscs, crustaceans and insects. Moderate grazing by fish may promote a greater diversity of zooplankton and other small invertebrates because the competitive or prey-predator relationship between the species changes[9]. Intensive grazing, however, may lead to some species disappearing, or their occurrence being held very low. Large, easily visible invertebrates and species which are poor swimmers are particularly prone to fish predation. A reduction in such larger invertebrates may also negatively affect aquatic birds since they form an important food item for such species in the breeding season[9]. A study of ponds in the agricultural landscape has also shown that the number of individuals and the diversity of species among invertebrates and amphibians were drastically reduced in the presence of fish[10]. Corresponding situations can be found between zooplankton and other grazing invertebrates on the one hand and phytoplankton and aquatic plants on the other. The best-known relationship is that between phytoplankton and zooplankton, which may mutually influence one another and lead to changes in the species composition and density[11].

On the whole, little is known about the specific environmental demands of many freshwater species in Norway. Decline and loss of species often occurs even though we are unable to determine the reasons.

Impact factors and Red List species

About 7 % (267 species) of the threatened and near threatened species have a significant proportion (> 20

Farm ponds and other water bodies in the agricultural landscape contain a distinctive flora and fauna, which often includes many Red Listed species. Such water bodies are threatened by both physical disturbance and pollution. From Vivelstad, Lier, south-eastern Norway. Photo: Børre K. Dervo.

The number of localities containing the freshwater pearl mussel (*Margaritifera margaritifera*) have dropped by more than 30 % since 1900. The species is assessed as vulnerable (VU) on The 2010 Red List and is one of 55 Norwegian species on the Global Red List. The freshwater pearl mussel is vulnerable to a number of impacts like pollution and changes in land use. Photo: Heidi Sørensen.

%) of their population in fresh water (Figure 2), and the largest groups are found among beetles, vascular plants, true flies, caddis flies and birds. All of 17 of the 20 species (85 %) of freshwater algae (stoneworts) are Red Listed. A large proportion of the amphibians (67 %) and dragonflies (37 %) are also on the Red List. The Red Listing of algae has been limited to macro algae (algae that are visible to the naked eye), 19 being threatened and near threatened, but planktonic algae have not been assessed. The two groups of animals with most species in fresh water, rotifers and chironomids (a group of true flies), have not been assessed either, because our knowledge of their distribution and habitat demands is too poor.

The most important impacts affecting Red Listed species in fresh water are dealt with below.

Land-use changes

Changes in land use in the catchment area or the habitats of the species are considered to be a threat to 174 species (64 % of the threatened and near threatened species) in fresh water. These range over most groups of plants and animals. Physical disturbances to habitats are the most important threat. These include filling-in of ponds and blocking of streams, watercourse regulation (water level fluctuations, altered currents, drying out and mud sedimentation), dredging, dumping and filling-in in the shore zone, and canalising. Species which inhabit the zone between water and land (riverbanks and shores) are regarded as being especially vulnerable to such disturbances.

The cultivated landscape used to be a heterogenic landscape with a mosaic character. Its ponds are valuable habitats for birds, amphibians and a number of invertebrates like water beetles, water bugs and dragonflies. Rationalisation in farming over nearly a century has brought the demand for larger, continuous fields, which have resulted in small lakes and ponds disappearing and streams being culverted. An investigation of ponds in farmland, carried out at the end of the 1980s, showed that about 1/3 of the ponds in Romerike (a district in south-eastern Norway) had been destroyed during the previous 10 years[10]. Likewise, 1/3 of the ponds investigated in the nearby county of Østfold were in danger of being destroyed[12]. In Østfold alone, 80 % of the ponds and other similar water bodies depicted on maps from 1790 had disappeared between 1950 and 1990. Moreover, since 1960, more than 1500 km of streams and ditches have been blocked in Østfold's agricultural landscape[13]. See also Figure 1.

Specialised species whose occurrence is limited to such habitats are particularly negatively affected by these changes in the agricultural landscape (see also Figure 1). These may be lime-demanding species, species that only occur in water bodies lacking fish, or species which prefer special habitats, like those which are adapted to living in ponds which periodically dry up. Fish will have problems surviving in ponds which become dry in some summers or completely freeze in winter. This may favour newts and several species of beetles and dragon-

flies, which would otherwise have been eaten by the fish.

The decline in the number of farm ponds is continuing in some areas, albeit not at the same rate as in the last 50 years[14]. In several places, for instance in the counties of Hedmark and Oppland, efforts have begun to restore former ponds and construct new ones in the hope of improving the situation for species that depend upon such habitats.

A pristine flood plain contains a mosaic of various habitats in different phases of succession and linked to specific landforms. This mosaic includes ox-bow lakes, meanders and braided river courses. Bars are found alongside riverbanks, and courses that have a steeper gradient may form alluvial fans. Floods lead to more or less regular disturbances which may obstruct the establishment of perennial vegetation. Supplies of new sediment to the flood plains play an important role in these systems because new microhabitats are formed. Flood protection measures along the larger rivers, however, lead to the flood plain habitats becoming more homogeneous, small water bodies dry out and the diversity of freshwater species declines[15, 16]. The Red Listed species, whorled water-milfoil (*Myriophyllum verticillatum*), which is otherwise only found in just a few localities in Norway, is common on the flood plain along the Gudbrandsdalslågen river, but only in meanders and small lakes with direct or regular contact with the river. Any measures to prevent flooding in these areas will have a negative effect on the occurrence of this species[17].

The European eel used to be found in most lowland rivers and streams. Its population has, however, declined by some 50-70 % over the last 10-15 years, and the eel is now assessed as endangered throughout its range[17, 18]. It is probably the combined effect of various pressures, both in the sea and in fresh water, that have produced the severe decline in the density of eels in Norwegian rivers and streams. The factors thought to be having a negative effect on the eel population include various physical disturbances on small, coastal watercourses, like the blocking of streams, which are hindering the eels on their immigration.

Pollution

Pollution is reported to be the second most important impact factor affecting threatened and near threatened species in fresh water (110 species, ca. 40 %). Long-transported pollution in the form of sulphur and nitrogen has led to acidification of large tracts of southern Norway. The scale of the contamination has declined in recent years, but even with the full effect of international agreements on reduced emissions, the tolerance limits for acidification will be exceeded for 7 % of the land area of Norway after 2010, too. Acidification has led to the loss of 9600 fish stocks in lakes and damaged a further 5400[19]. Even though there are signs of improvement[20], it will take a long time or require massive measures before a general positive trend in the fish stocks can be expected. Snails[21] and other lime-demanding creatures are especially sensitive to acidification because their calcium metabolism is disturbed. Populations of snails[22] and amphibians[23] have been lost in large parts of southernmost Norway. It is

Box 1. Glacial relicts

Freshwater species which came to Norway at the end of the Ice Age, some 10 000-11 000 years ago, are generally called glacial relicts. They include several crustaceans, such as *Limnocalanus macrurus* and *Mysis relicta*, and a fish, fourhorn sculpin (*Myxocephalus quadricornis*) (DD). Their dispersal has largely taken place westwards via a series of cool, ice-marginal lakes (lakes which were dammed up by the ice) from areas east of the Ural Mountains via the Baltic Sea. In Norway, these species now live in areas that were below sea level when Scandinavia was undergoing deglaciation. They are adapted to a cool climate, and often occur in deep lakes where they live in the cool layer of water.

The fourhorn sculpin (*Myoxocephalus quadricornis*) (DD) is a glacial relict that is on the Red List. In Norway, it is only found in two lakes in south-eastern Norway and its distribution in Norway was not documented before 1978. Photo: Arild Hagen.

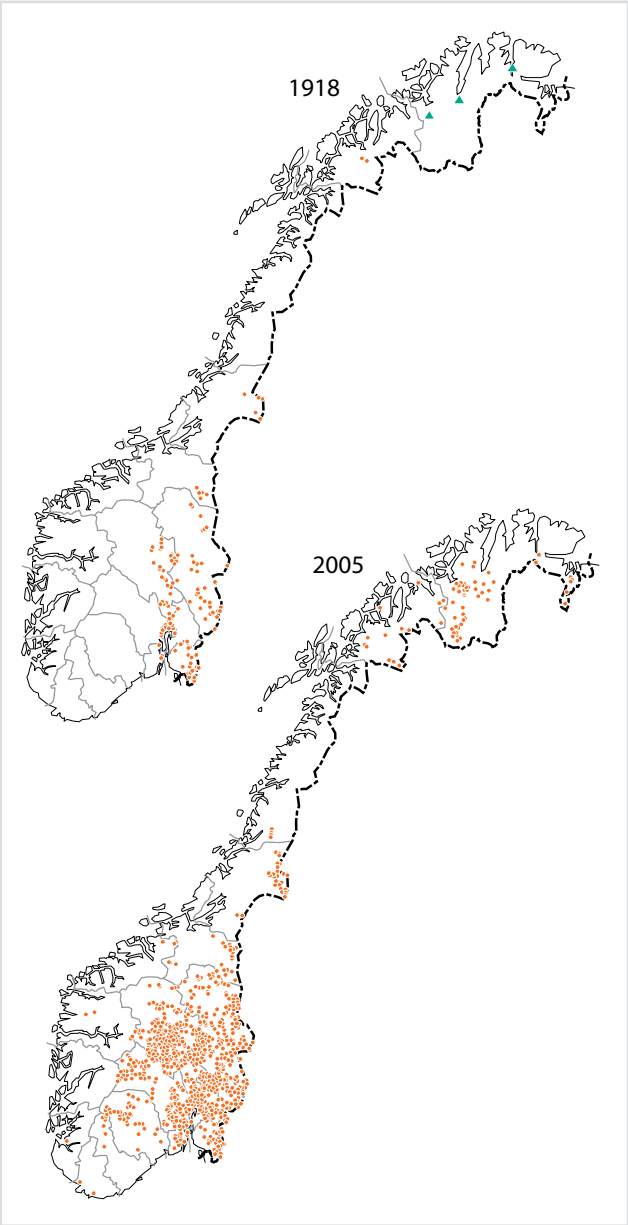

Figure 3. The distribution of the common minnow (*Phoxinus phoxinus*) in Norway in 1918 and 2005. Green triangles indicate incomplete information on its occurrence in 1918. Its natural range is rivers in the lowlands of south-eastern Norway and a few localities in the counties of Nord-Trøndelag, Troms and Finnmark. The present distribution is a result of its dispersal with the help of people, because it is widely used as bait. Such deliberate and accidental dispersal may have major ecological consequences for the indigenous fauna, especially fish populations. Source: Norwegian Institute for Nature Research.

also estimated that 94 % of the 47 known populations of the freshwater pearl mussel (*Margaritifera margaritifera*) in the counties of Aust- and Vest-Agder died out during the most intensive period of acidification[24]. More than 50 % of the species in some groups of aquatic plants formerly present in the most contaminated rivers in southern Norway have succumbed[25]. On most rivers, there are, however, still some less acidified stretches where sensitive species can survive. Little is known regarding how long these will require to re-establish populations in areas that were seriously acidified.

Liming of lakes and rivers can reduce the negative effects of acidification. Even though most species are favoured by a somewhat higher content of carbonate in the water, there are species which react negatively to liming. Many dragonflies, for example, are common in naturally acid tarns and bog pools, and some Red Listed species are exclusively found in rivers and lakes that have little lime. Liming of such localities is therefore regarded as a threat factor for such species.

Overfertilisation (eutrophication) is still a significant threat to the biological diversity in fresh water. Moderate eutrophication may increase the diversity at first, especially if the water body was originally very poor in nutrients. Many species, however, react negatively to increasing inputs of phosphorus and nitrogen, which often lead to excessive vegetation choking water bodies, sedimentation, oxygen depletion and poor light conditions. This applies to many of the Red Listed stoneworts (the *Chara* genus), for example. These mainly occur in extremely calcareous lakes, and it has been shown that these species entirely or partly die out when the light conditions worsen due to eutrophication[26, 27]. *Dytiscus latissimus* is an aquatic beetle found in moderately nutrient-rich lakes or lakes with well-developed aquatic vegetation, and it has declined greatly or become extinct in large parts of Europe due to deteriorating water quality. The continuing healthy state of this species in Norway may indicate that the quality and state of the water is good. This species was placed on List II of the Bern Convention and was also protected in Norway in 2001.

Despite a great reduction in the discharges and emissions of many pollutants in recent years, they are still an environmental problem. This applies, for example, to organic toxic compounds which can be enriched in the food chain. It is primarily species that are high in the food chain, like fish and birds, which seem to be threatened by such pollutants[28]. Organic toxic compounds are believed to have a negative impact on three Red Listed species in fresh water. That so few species are regarded as being threatened by organic

toxic compounds may be explained by the poor state of knowledge on their effects on most freshwater species. Species that occur exclusively in flowing water, and have a limited distribution, may be threatened by rotenone treatment; an example of this is the crawling water beetle, *Brychius elevatus* (NT).

Climate change

With the present state of knowledge, it is difficult to assess the effects changes in climate can be expected to have on the risk of species becoming extinct. The 2010 Red List reports no freshwater species which react negatively to climate change. Nevertheless, a milder climate may be critical in the long run for species in the mountains and the Arctic. One example is the fairy shrimp, *Tanymastix stagnalis* (CR), which, in Norway, is confined to a few localities in the Trollheimen mountains[29, 30]. Among fish, the Arctic lamprey (*Lethenteron camtschaticum*) (DD), is believed to be vulnerable to climate change. It has so far only been recorded in the River Pasvik in eastern Finnmark.

Species which live in cold water in deep lakes may also be negatively affected by a rise in the water temperature. This applies to several glacial relicts (see Box 1) like the copepod, *Limnocalanus macrurus* (NT), which has only been recorded in a few large lakes in south-eastern Norway.

Utilisation and alien species

Other impacts are thought to have little significance for the freshwater species on the Red List. Utilisation (fishing and hunting) poses a threat to less than 1 % of the species (e.g. European otter, *Lutra lutra* (VU)), and alien species are also reported to be a threat to only 1 % of the threatened and near threatened species (e.g. amphibians). Unknown impacts are reported to be a threat to 6 % of the species.

Indigenous species of fish have been extensively released and spread in Norway. This concerns, in particular, the brown trout (*Salmo trutta*), but also the common minnow (*Phoxinus phoxinus*), which originally had a more limited distribution[31] (Figure 3). Alien species of fish have also been relatively extensively spread in this country[32]. Such releases are regarded as a threat to indigenous species and stocks of fish, and may have negative consequences for invertebrates which are vulnerable to fish predation. The release of fish in lakes that lack fish may also have negative impacts on birds which are dependent upon comparatively large invertebrates as food in the breeding season[10].

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