

Conservation of Nordic Nature in a Changing Climate



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Nordic Council of Ministers



National Environmental Research Institute
Danish Ministry of the Environment

Conservation of Nordic Nature in a Changing Climate





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Nordic Environmental Co-operation

The Nordic Environmental Action Plan 2005-2008 forms the framework for the Nordic countries' environmental co-operation both within the Nordic region and in relation to the adjacent areas, the Arctic, the EU and other international forums. The programme aims for results that will consolidate the position of the Nordic region as the leader in the environmental field. One of the overall goals is to create a healthier living environment for the Nordic people.

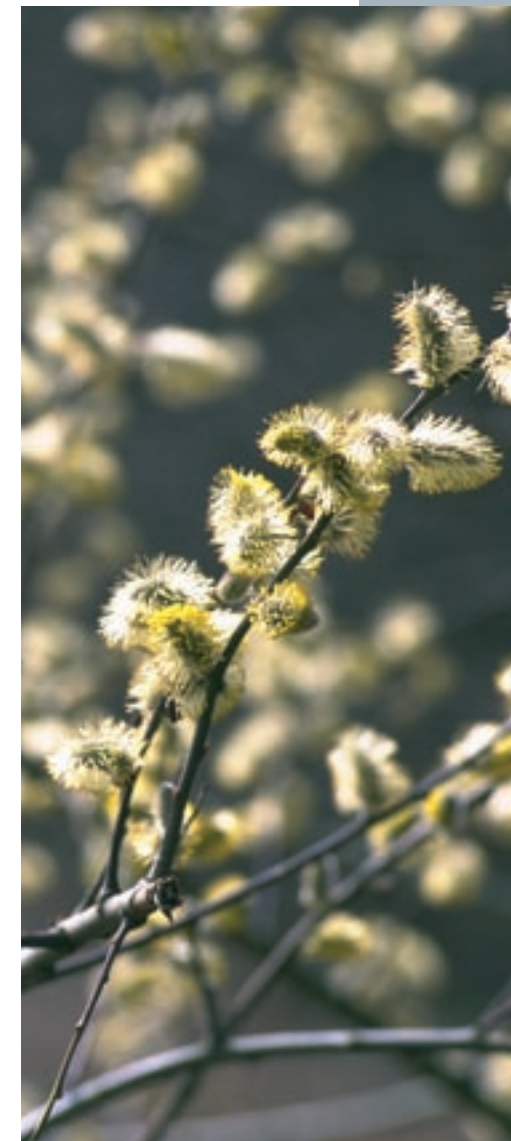
Nordic co-operation

Nordic co-operation, one of the oldest and most wide-ranging regional partnerships in the world, involves Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland and Åland. Co-operation reinforces the sense of Nordic community while respecting national differences and similarities, makes it possible to uphold Nordic interests in the world at large and promotes positive relations between neighbouring peoples.

Co-operation was formalised in 1952 when *the Nordic Council* was set up as a forum for parliamentarians and governments. The Helsinki Treaty of 1962 has formed the framework for Nordic partnership ever since. The *Nordic Council of Ministers* was set up in 1971 as the formal forum for co-operation between the governments of the Nordic countries and the political leadership of the autonomous areas, i.e. the Faroe Islands, Greenland and Åland.

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Introduction

In the Nordic Council of Ministers' Environmental Action Plan 2001-2004, the need for an evaluation of the effects of the expected climate change on the Nordic nature is emphasised. Through my work at the Ministry of Environment I recognised and supported this need. Therefore, I initiated an idea to a project that should look at the possible climate effects on the Nordic nature including a nature management view on this problem. On this basis, the Working Group for Nature, Recreation, and Cultural Environment (NFK) and the Working Committee (AU) initiated this project in January 2004. A project group was established with seven representatives of environmental agencies and directorates in Finland, Norway, Sweden, and Denmark:

- Heikki Toivonen, Finnish Environment Institute (SYKE), Finland
- Else Løbersli, Directorate for Nature Management, Norway
- Ulf Grandin, Swedish University of Agricultural Sciences, Sweden
- Ola Inghe, Swedish Environmental Protection Agency, Sweden
- Hans Erik Svart, Danish Forest and Nature Agency, Denmark
- Jes Fenger, National Environmental Research Institute (NERI) Denmark
- Maria Mikkelsen, NERI, Denmark, Project Manager

The main theme of the project is climate effects on the Scandinavian and Finnish na-

ture south of the polar circle, but also examples outside this area are used when relevant. In this report, the area of Scandinavia and Finland south of the polar circle is referred to as "the Nordic countries", "the Nordic region" and "the North".

The project group's work is based on existing knowledge, including the IPCC's climate predictions, papers in international journals and national environmental management reports.

This project report shortly summarises the changes in climate and nature over the past two million years. Examples of possible climate effects are then presented, before we look at how the climate and nature might change over the next 100 years. Finally, we present an initial recommendation on how the expected climate effects could be integrated in the management of nature and natural resources.

The primary target groups are public servants, politicians and managers, including farmers, foresters and others working with the management and administration of nature and natural resources.

During the period February 2004 – October 2005 the group has held four project group meetings, one review meeting, and a final workshop.

The project group wishes to thank the Danish Environmental Institute, Department of Atmospheric Environment, Roskilde, for housing and administering the project.

We also wish to thank Erik Framstad,

NINA, Norway; Johan Sonesson Skogforsk, and Urban Emanuelsson, the Swedish Biodiversity Centre, Sweden; and Michael Stoltze, the Danish Society for Nature Conservation, Denmark; for valuable comments on, and discussions of, the report. In addition, many thanks to Maria Pedersen for helping to organise the meetings, to Niels Henrik Bastholm for helping with the translation of the report, and to Britta Munter and Helle Thomsen for their help with the graphics and layout of the report, and the project's web-site (<http://nonaklim.dmu.dk>).

Maria Mikkelsen, 18 September 2005

The NoNaKlim project group.
Standing from left:
Heikki Toivonen,
Jes Fenger,
Hans Erik Svart,
Ola Inghe,
Ulf Grandin.
Sitting from left:
Maria Mikkelsen and
Else Løbersli.



Resumé

Så længe Jorden har eksisteret har klimaet varieret af naturlige årsager. Siden midten af det 19. århundrede er klimaet blevet gradvist varmere, og de fleste eksperter er nu enige om, at denne klimaforandring delvis er betinget af det antropogene bidrag til drivhuseffekten.

Den stadigt stigende drivhuseffekt, og de deraf følgende globale klimaændringer står højt på listen over tidens miljøproblemer. En af hovedårsagerne til drivhuseffekten er udslip af kuldioxid, CO₂ fra afbrænding af fossile brændstoffer, men også metan, CH₄ og lattergas, N₂O fra landbrugsproduktionen bidrager.

Der gøres internationale anstrengelser for at begrænse udslippet af drivhusgasser, men alle beregninger viser imidlertid, at selv med de mest optimistiske begrænsninger vil klimaændringerne ikke helt kunne undgås. Derfor er det vigtigt, at man udover at søge at begrænse udslippet af drivhusgasser, også udarbejder og integrerer klimatilpasningsstrategier i samfundet, heriblandt på naturområdet. Det foreslås derfor i denne rapport, at natur- og ressourcforvaltningerne inddrager klimaændringens nuværende og mulige kommende effekter på naturen i sit arbejde. Fremfor en reaktiv ad hoc planlægning anbefales det, at der anvendes en proaktiv tilpasning (planned adaptation), som tager højde for hele spektret af udviklingsmuligheder i klimaet og de mulige effekter af dette på naturen.

På natur- og ressourcforvaltningsområdet indebærer en proaktiv tilpasningsstrategi bl.a. en prioritering af områderne:

- Videnoparbejdning og udvikling
- Handlinger
- Lovgrundlag og støtteordninger
- Regionalt samarbejde.

Indenfor området videnoparbejdning og udvikling er der en række områder, som bør belyses yderligere, herunder viden om klimaændringens samspil med øvrige stressfaktorer på naturen, og naturens feedback-mekanismer på klimaet, samt kendskab til spredningsbiologi som en nødvendig forudsætning for sikring af dyr og planters tilpasningsmuligheder gennem migration.

Den indsamlede viden vil være et værktøj til gennemførelse af konkrete handlinger, som kan styrke naturens robusthed, elasticitet og tilpasningsevne til et klima i ændring. Dette vil finde anvendelse indenfor administrationspraksis, konkret naturforvaltning og naturpleje, samt indenfor natur- og ressourceudnyttelse i de primære erhverv.

Ved desuden at inddrage mulige klimaeffekter når lovgrundlag og støtteordninger skal opdateres og revideres, sikres en lovgivning, som indeholder relevante krav og rammer for at sikre målopfyldelse af den givne lovs intention i et ændret klima.

Dertil kommer, at flere af de ovenstående proaktive tilpasningstiltag optimeres ved at blive løst i et regionalt samarbejde. Problemstillingen er grænseoverskridende og landene har også indenfor klimaeffektområdet forskellige styrker og svagheder. Dette indebærer muligheden for et fælles løft, ressourcebesparelse og effektivitet.

Udfordringen for de nationale natur- og ressourcforvaltninger er at lovgive, planlægge og administrere med en usikker fremtid for natur og klima for øje. Men med de anbefalede tilpasningstiltag *in mente* i de nationale forvaltninger og relevante fora er der god mulighed for at begrænse de negative effekter af klimaforandringen for naturen ved at handle i god tid.

Beregning af de økonomiske konsekvenser ved valget af en reaktiv henholdsvis proaktiv tilpasningsstrategi i natur- og ressourcforvaltningerne, ligger udenfor rammerne af dette projekt. Det skal dog nævnes, at det er en nødvendig forudsætning for en prioritering af de økonomiske ressourcer. I rapporten behandles ej heller spørgsmålet om tilpasning kontra årsagsbehandling, idet dette arbejde foregår i mange andre fora, f.eks. Kyoto-protokollen.

Summary

For as long as the earth has existed, the climate has changed due to natural causes. Since the middle of the 19th century, the climate has gradually become warmer. Now most experts agree however that this warming is not only due to natural causes. The anthropogenic contribution to the greenhouse gasses in the atmosphere plays a role in this warming.

The continuously increasing greenhouse effect, and the resulting global climate changes, is high on the list of today's environmental problems. One of the main causes of the greenhouse effect is the emission of carbon dioxide, CO₂ from the burning of fossil fuels, but methane, CH₄, and laughing gas, N₂O, from agricultural production also contribute.

Because of this connection between emissions and climate change, great international efforts are being made to reduce the emissions of greenhouse gasses. However, all the calculations show that even with the most optimistic reductions in emissions, further climate changes cannot be avoided. It is therefore important apart from reducing the emissions of greenhouse gasses to create and integrate climate adaptation strategies in all relevant areas, including the area of nature management. This report recommends that institutions managing nature and natural resources incorporate both effects that are already known and possible future effects of climate change in their work. Instead of reactive *ad hoc* planning, we recommend a pro-

active strategy – planned adaptation – taking into account the entire spectrum of possible future climate changes, and the effects they might have on nature.

For the management of nature and natural resources, planned adaptation implies integrating and prioritising the following areas:

- The upgrading of research and knowledge.
- Tangible actions.
- Legislation, regulation and subsidies.
- Regional cooperation

As far as the upgrading of research and knowledge is concerned, two main areas should be emphasised. The relations between climate changes and other stress factors on nature – and the natural feedback mechanisms, and knowledge about migration biology and functionality as an important condition for goal-oriented nature management that secures options for plants' and animals' adaptation through migration.

This upgrading of research and knowledge will make it possible to propose tangible actions to strengthen nature's resistance, resilience and adaptability within all areas of administration, nature management, and production based on natural resources.

Climate changes should also be taken into consideration in all relevant legislation and regulation in the future, in order to en-

sure that the overall objective of the individual laws and regulations, including subsidies, is met.

Finally, most of the above mentioned pro-active strategies are best carried out in regional cooperation. The climate change is a global problem, and the effects on nature and natural resources cross national borders, and cannot be handled efficiently by individual countries. Regional cooperation will strengthen joint operations, save resources, and increase effectiveness.

The challenge facing the national managements of nature and natural resources is that of good, effective planning, administration and legislation against an unknown and uncertain future for both climate and nature. We hope that, with the recommended planned adaptation strategy in mind, the national managements of different sorts and politicians will act in time to minimise the negative effects of the current and future climate change.

The economic consequences of choosing a reactive or a planned adaptation strategy for the management of nature and natural resources lie outside the scope of this project. However, calculating the economic consequences of a specific strategy is a necessity in the prioritising of resources. Moreover, the question of adaptation versus a reduction of the causes of the problem is not dealt with in this report, since this is dealt with by several other organisations and committees, such as the Kyoto protocol.

1 The climate and nature to date

From the beginning to the end of the last ice age

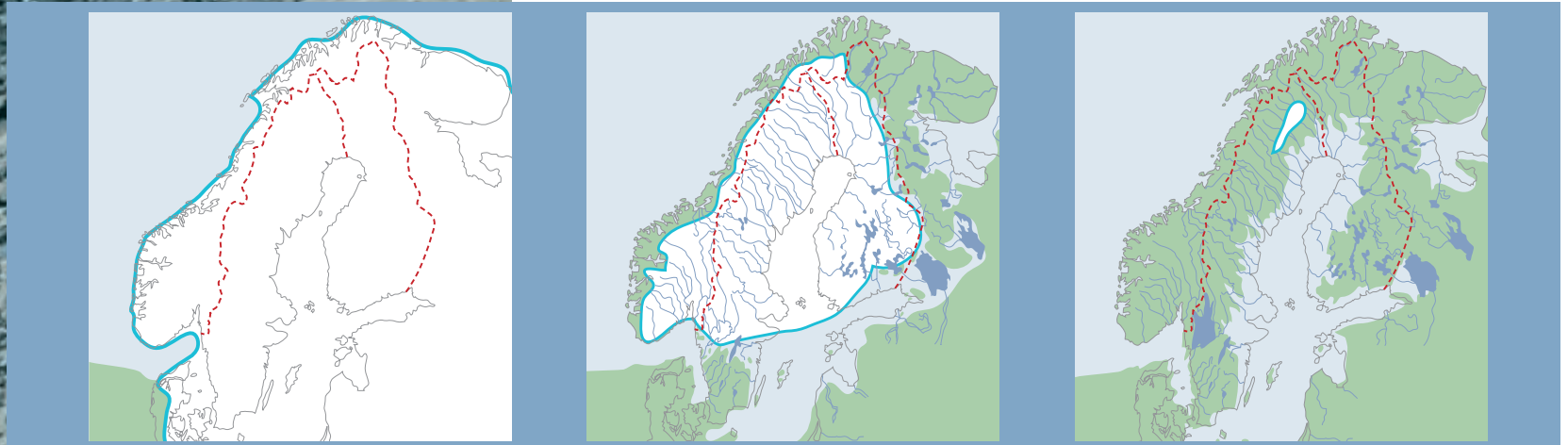
Planet earth is around 5 billion years old. The historical development of the climate has been partially reconstructed from marine sediments, ice cores, bogs, etc. This construction shows that there have been a number of pronounced climate changes over time, caused by events such as volcanic eruptions and continental movements.

Around two million years ago, our planet entered the current era of ice ages; in which we still live. During this era, there have been eight ice ages, each lasting around 100,000 years. The periods between the ice ages, called the interglacial periods, lasted 10,000 to 20,000 years.

The end of the last ice age

16,000 years ago, rising temperatures ended the last ice age (fig. 1). At that time, the predecessor of the Baltic Sea was a freshwater lake. Four of the seven big mammal species that previously lived in the Nordic region became extinct. The mammoth (*Mammuthus primigenius*), the woolly rhinoceros (*Coelodonta antiquitatis*), the steppe bison (*Bison priscus*) and the Irish elk (*Megaloceros giganteus*) all became extinct with the disappearance of the mammothstep; a unique ecosystem of this ice age which completely disappeared.

Figure 1
The withdrawal of the ice after the last ice age – selected periods (After Hultén 1971).



It was not the climate change alone however that caused the animals to become extinct; even at this early time, man played a decisive role.

The landscape left by the receding ice was naked, light and open. The soil was poor. The first plants that invaded the region from the south and east were robust species that did not require much richness in the soil.



Photo: Ole Malling

The melting poles

With the increasing temperatures, the poles began to melt, causing the sea level to rise 120 m above the lowest point during the ice age. The temperature rose continuously, the soil was reduced to vegetable mould, the vegetation became denser, evaporation increased and lakes and bogs became overgrown. The forest that eventually appeared



Photo: Ole Malling

was light, with a ground cover of herbs. Animals such as red deer (*Cervus elaphus*), wild boar (*Sus scrofa*) and roe deer (*Capreolus capreolus*) proliferated. This period had summers with higher temperatures than today, and winters like our winters. The ice was reduced to a number of scattered spots of glaciers in the northern parts of Norway and Sweden.

The sea level rose as the ice melted.



Photo: Peter Brandt

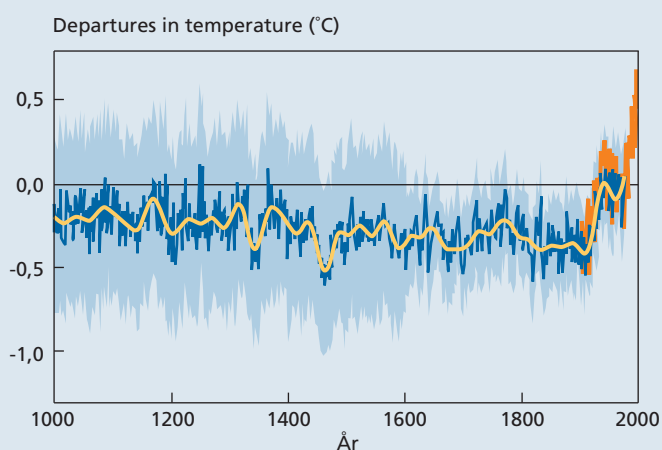
Humans already in early days left visible signs in their surroundings. Here a 3.000 year old rock carving from Sandvig, Bornholm (far left).

The red deer immigrated naturally after the last ice age with the rising temperatures (left).

Man's increasing impact on nature

As time passed, the average temperature dropped by 1 °C. The postglacial warmth ended, and was followed by a period with cold weather and a great deal of precipitation during the Bronze Age. Man and his activities had an increasing impact on the way nature developed. In the beginning, hunting and fishing dominated the activities, but these were slowly replaced by farming, which was introduced from the Middle East. The success of farming had a great impact on the forests, which were cut down and replaced by farmland and meadows for cattle, goats and other domestic animals.

Figure 2
The temperature in the northern hemisphere the last 1,000 years (After IPCC 2001).
Orange: data from termometers.
Blue: data from three rings, corals, ice cores and historical records.
Yellow: 50-years average.
Light blue: the 95 % confidence range.



The pheasant was introduced to the Nordic countries during the 15th century (right).

Some plants and animals are tightly connected to cultural nature types like e.g. old fashioned hay harvest (far right).

Man's new form of life meant that wild animals now also became hunted, due to their threat to, or competition with, domestic animals.

A number of wild animals immigrated, and some species that lived so far away as to prevent natural immigration, were introduced by man. These included the rabbit (*Oryctolagus cuniculus*), the fallow deer (*Dama dama*) and the pheasant (*Phasianus colchicus*), which were introduced to the region during the period between 1200 and 1500.

In the beginning of the 19th century, there was a marked cooling. This was related to the eruption of volcanoes – such as the volcano on Tambora Island in Indonesia in 1815, which resulted in “the year without

a summer” in the United States, with snow and freezing temperatures in July and August (Robock, 1994).

The current distributional pattern

As mentioned earlier, it is not only the climate that determines the range of flora and fauna. Man also has a great impact: directly by means of hunting, and the introduction of new species, pollution, etc., and indirectly by means of land use, which has a substantial impact on nature. A number of animals and plants in the southern part of the Nordic countries are common to cultural types of nature such as meadows, dry mea-

Apart from climate, human activities play an important role in the range of flora and fauna, both directly and indirectly.



Photo: Peter Brandt



Photo: Ole Andersen

Since the middle of the 19th century the global average temperature has been rising in line with the industrialisation.

dows and bogs. These include the butterfly species, meadow brown (*Maniola jurtina*) and purple-edged copper (*Lycaena hippothoe*), which appears to be withdrawing from the northern parts of their distributional area. An analysis of this tendency shows that the butterflies are closely linked to dry meadows – a type of meadow that is declining fast. Over the past 300 years, the area covered by meadows in Skåne, in the southern part of Sweden, has declined from around 65% to just half % today. This clearly illustrates the impact of land use on flora and fauna.

Recent developments

Since the middle of the 19th century, the temperature has increased in line with in-

dustrialisation. The average temperature is now 0.6 °C higher than it was 150 years ago. The biggest change in temperature has taken place over the past few decades. The precipitation has also increased – by 10% in the southern part of the Nordic countries, and by 30% in the northern part, although there has been a slight decrease in precipitation in Finland (Parry 2000) (fig. 3).



Photo: Peter Brandt

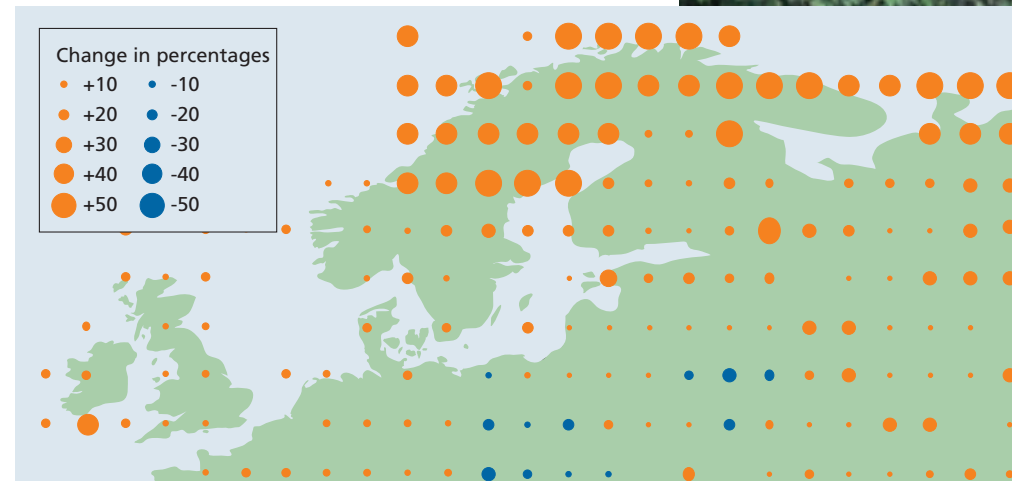


Figure 3
Tendencies in the yearly precipitation pattern expressed in changes in percent during the 20th century (After ACACIA 2001).



Photo: NASA, Goddard Space Flight Center

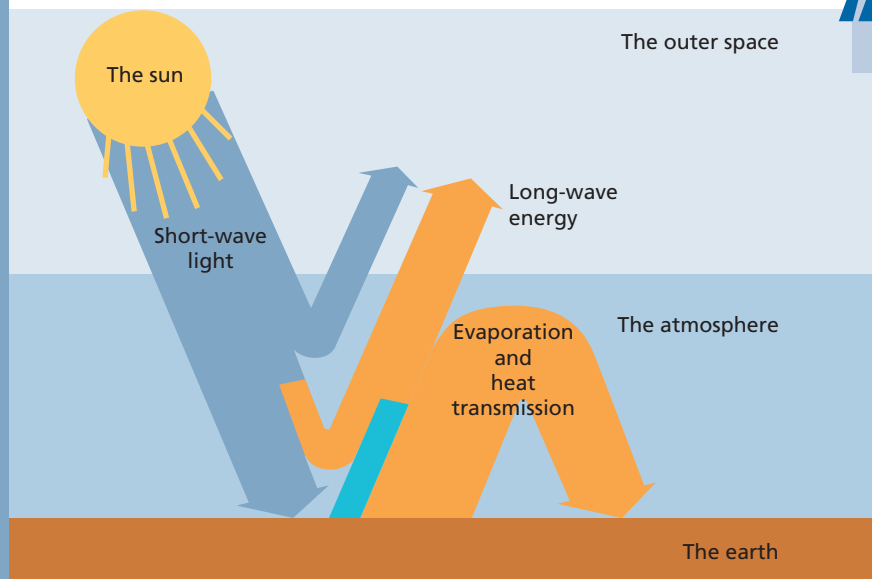
Figure 4

A simple description of the greenhouse effect. Short-wave light easily penetrates the atmosphere and heats up the Earth. The energy is returned to space, however the Earth is colder than the Sun, and the returning of the energy takes place at a longer wavelength which is partly absorbed in the atmosphere and reirradiated in all directions. The energy that is irradiated will heat the earth until a new balance is reached.

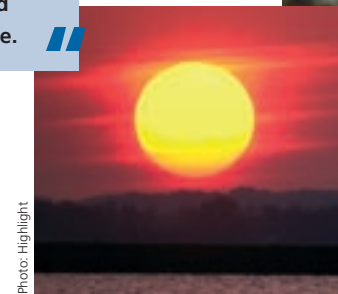
The increasing greenhouse effect

The climate varied over time, even before man started influencing it. The reasons for these climate variations are only partly understood, although there are many possible explanations. Some of these include changes in the earth's movement around the sun (Milankowich cycles), the drift of the continents and volcanic activities. Another explanation of the changing climate may be the changes in the magnetic field around

the sun that affects the period of sunspots. This influences the amount of cosmic particles reaching the earth, and thereby the formation of clouds and the heat balance on earth. However, the greenhouse effect is a very important element in the heat balance (fig. 4). The greenhouse effect is a natural phenomenon that increases the average temperature on earth by 33 °C, by means of molecular processes in the atmosphere, such as water vapour and carbon dioxide. Thus, the greenhouse effect is a very important factor for the existence of life on earth.



// The climate has always varied – also before human influence. //



The greenhouse gas methane is e.g. produced by internal fermentation in cattle.

Photo: Ole Malling



The human role in the greenhouse effect

Since the beginning of the 19th century, three parameters have been of vital importance for human impact on the environment: our standard of living; the technology we use; and the number of people using it. Until 1800, the number of people on earth increased slowly to around 1 billion, but since then the number of people has risen with increasing speed. Today, there are more than 6 billion people on earth. The global energy consumption has increased even more rapidly – especially after World War 2. So far, most of the energy has been produced by burning fossil fuels such as coal, oil and gas. The predominant end product of these burning processes is carbon dioxide (CO_2), which is why the emission of this greenhouse gas has increased correspondingly. Similarly, the increase in global agri-

In 1997 there were more than 600,000,000 cars in the world – one car per 10 people (After <http://hypertextbook.com/>).



Photo: 2. maj/Sonja Iskov

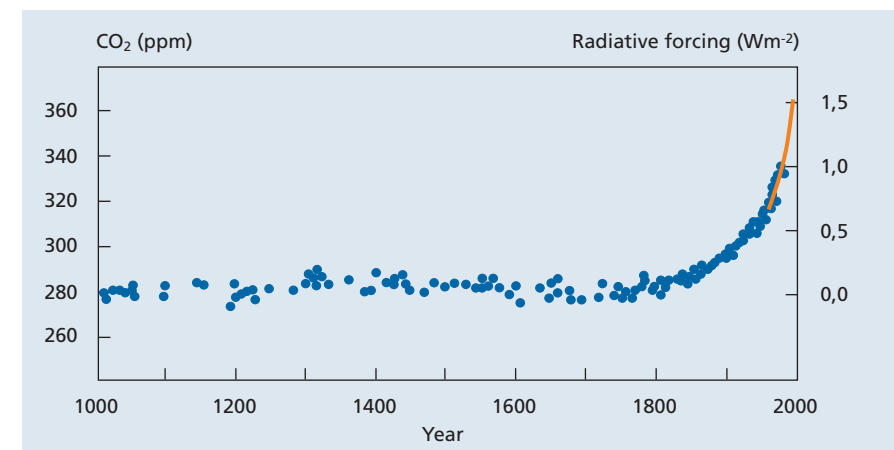
cultural production has resulted in a growing emission of other greenhouse gases such as methane (CH_4) and laughing gas (N_2O). The concentration of the greenhouse gases CO_2 , CH_4 and N_2O in the atmosphere over the past two hundred years has increased by 31%, 250% and 17% respectively, and none of them are showing any sign of stabilising (IPCC 2001).

The problem is that this accumulated increase in emissions of several greenhouse

gases increases the total concentration in the atmosphere, which enhances the greenhouse effect, so the temperature in the atmosphere also increases, ultimately changing the climate. The IPCC, the international climate panel, has by the use of very advanced climate models showed that the past few decades of warming have almost certainly been caused by the increasing concentrations of greenhouse gases in the atmosphere.

3.8 tons CO_2 per capita per year is emitted into the atmosphere (World Bank Atlas 2003).

Figure 5
The CO_2 -concentration in the atmosphere during the last 1,000 years (After IPCC 2001).



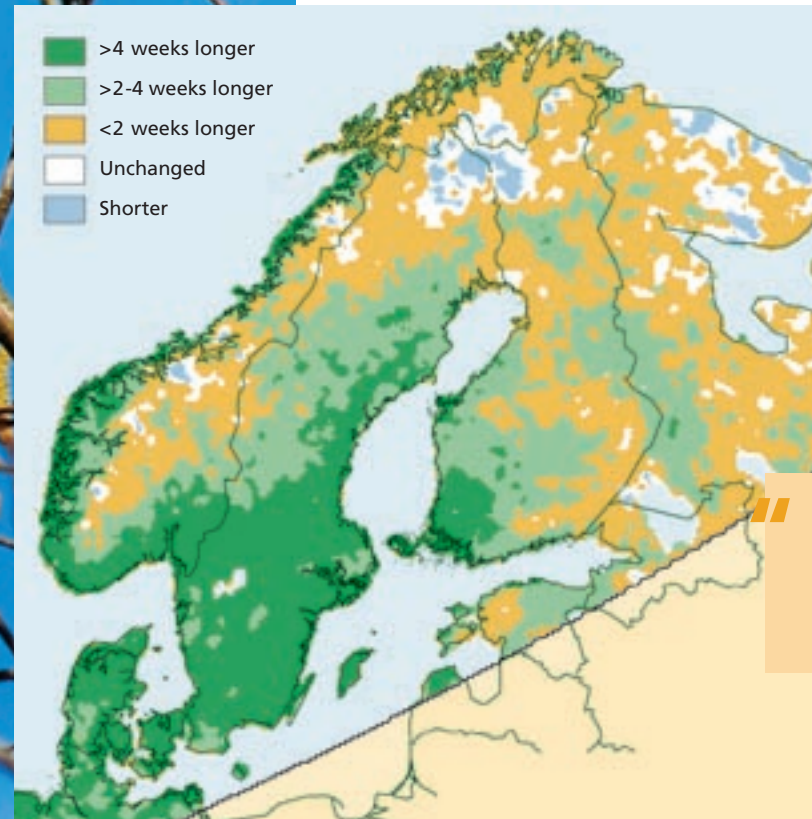
2 Climate effects in the Nordic nature

The climate forms the basis for how nature works and functions. One might therefore ask what effect the past couple of decades of climate change, in the form of changing temperatures, heat records, mild winters, change in precipitation patterns, etc., has had on nature? A number of examples of changes that have been observed in the Nordic nature, and which may be due to

this climate change, are given below. We do not know whether these changes have been caused by the changing climate, but we do see changes we cannot explain, and where the climate may play a part.

The extension of the growing season

Records of the beginning and end of the growing season show a possible climate effect. The growing season is monitored by satellite. The satellite registers the changes in the vegetation index, NDVI (Normalised Difference Vegetation Index). Given the amount and density of the vegetation, the index indicates the photosynthesis activity. This index shows that the growing season, overall, has been prolonged by 4 weeks in the period from 1982 to 1999. This prolongation can be seen in most of Denmark, in



The length of the growing season and the onset of spring have great impact on the primary production, species composition and the range of species.

Figure 6
Changes in the growing season
in the period 1982 to 1999
(After Norut, <http://www.itek.norut.no/>).

– examples

the southern part of Sweden, along the coast of Norway south of the Lofoten islands, and in the south-western part of Finland (fig. 6) (Høgda & al., 2001). In some parts of the mountains, on the other hand, spring starts later, and the growing season here has been shortened. This may be due to the milder winters, which at these latitudes often bring more snow, and so longer periods with snow cover. The length of the growing season and the onset of spring have great implications for the primary production, the composition of ecosystems and the range of species present.

The pollen season has advanced

Another possible climate effect is the change in the length and period of the pollen sea-

son. The product of male reproduction is pollen. The flowering date and the emission of pollen vary from species to species, and are primarily regulated by temperature. The species with the earliest flowering date of the wind-pollinated species, the hazel (*Corolys avellana*), flowers as early as February in the Nordic countries. One of the latest species to flower is the mugwort (*Artemisia vulgaris*), which flowers in August/September. Thus, pollen is found in the air half of the year, and, at the same time, the amount of pollen, i.e. the concentration of pollen, is increasing (fig. 7). Because of the widespread pollen allergy among people, pollen has been monitored for the past 20-30 years in Finland, Sweden, Norway and Denmark. This monitoring shows that the pollen season is beginning earlier and earlier (fig. 8). Since 1978, the pollen season has

advanced by almost 3 weeks. The phenomenon of plants changing their flowering period is a phenological phenomenon (see box). Phenology is a useful tool for identifying and monitoring climate effects (Walther & al. 2002).



Photo: Highlight

Phenology

Phenology is a branch of natural science that describes the relationship between recurrent biological events and the climate. Registering and comparing the dates of different events in nature, such as the arrival and departure of migrating birds, flowering, the end of amphibians' hibernation, and so on, forms the basis of phenology.

Figure 7
The increasing amount of pollen in the air in the period from 1977 to 2002 in three Finnish cities (After Aerobiology Unit, University of Turku).

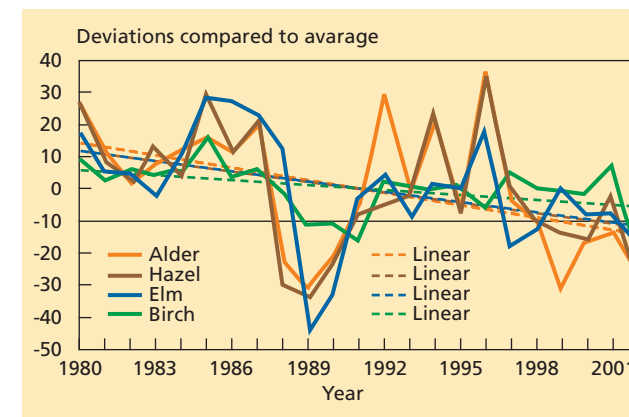
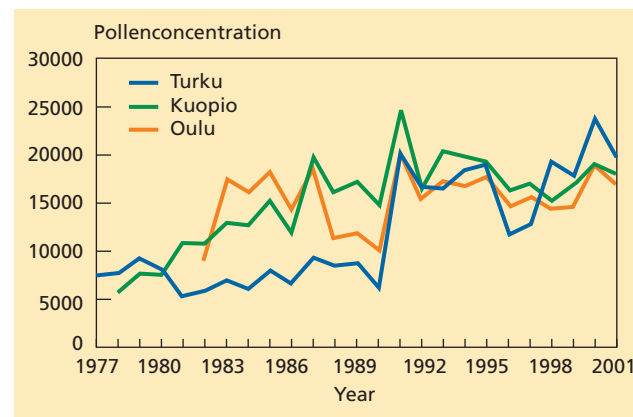


Figure 8
The pollen season starts earlier and earlier (Carsten Ambelas Skjødt on the basis of pollen data from the Astma-Allergy Foundation and DMI (2005)).



Photo: Maria Mikkelsen

The stair step moss.

The palsa is melting

Another possible climate effect can be seen in the habitat type known as palsa. The palsa is a type of bog characterised by permanently frozen lumps (called palsa) found in the northern hemisphere. There is an unusually diverse bird life in a palsamyre and its characteristic mosaic of different habitats (Luoto & al., 2004). The temperature change over the past 150 years has had an impact on the palsamyres. The melting of the palsa has been superseded by its reconstruction. In the Laiva Valley in Sweden, for example, half of the palsas have disappeared. In Finland, a third have disappeared, and the same pattern can be seen in Norway (Hofgaard, 2003). One of the preconditions for the construction of a palsa is an adequately thick layer of peat, so thick that it can remain permanently frozen (Zuidhoff, 2003). The palsa is protected by the EU Habitats Directive as a species that has been given priority importance.

Stair step moss is advancing

The range of stair step moss (*Hylocomium splendens*) is also associated with climate change. A Norwegian monitoring programme has revealed a marked advancement in stair step moss in two areas in Sørlandet between 1989 and 2003. The scientists ascribe the mild and humid winters as one the main reasons for this change (Hofgaard, 2004). An analysis of Swedish data ("Standorts-karteringen") shows that the coverage of stair step moss increased in all of Sweden except the southernmost part from 1984 to 1991 (Grandin, unpublished). In Finland, however, the moss has retreated. This is interpreted primarily as a result of modern forestry.

Reptiles, amphibians and birds are breeding earlier

Other examples of possible climate effects can be seen if we look at the biology of the species. A Danish-Norwegian study shows that a number of reptiles, amphibians and birds are breeding earlier, in a pattern closely correlated to the North Atlantic Oscillation (NAO, see box). This tendency has been consistent throughout the past 20 to 30 years. This pattern emphasises the importance of the climate on flora and fauna, and indicates a future where an unpredictable, non-linear development of the climate may have a great impact on nature.

A number of reptiles, amphibians and birds reproduce earlier and earlier.

Brown frog (*Rana sp.*) (right) and the butterfly peacock (far right).



Photo: Peter Brandt

Butterflies as climate indicators

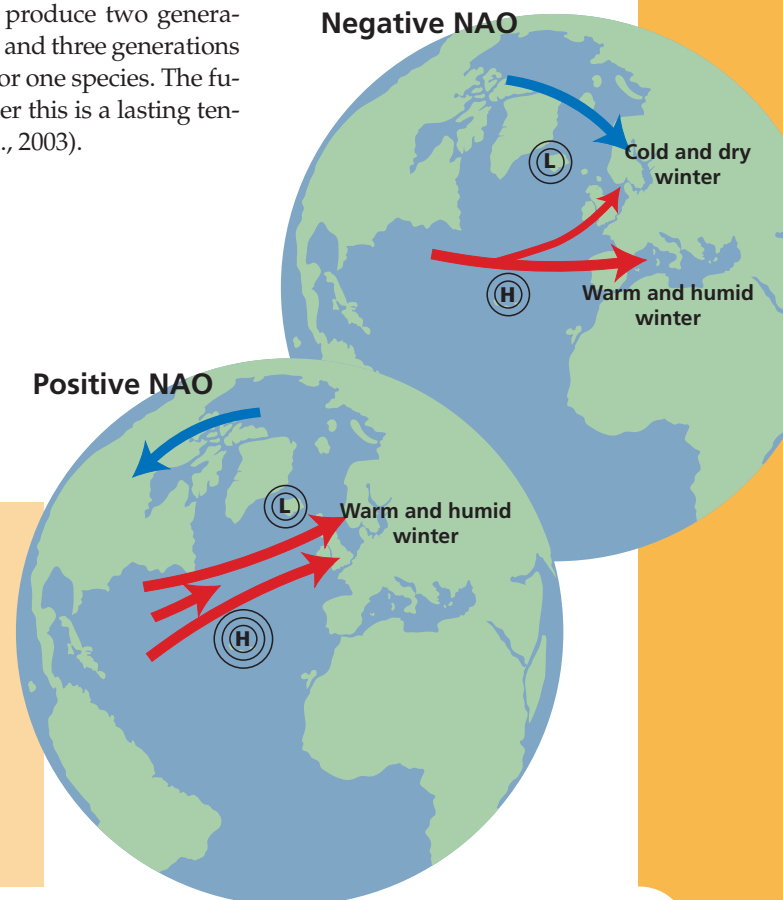
Butterflies, like the organisms described above (Ryrholm 2003), change their habitat range too. Like birds, butterflies and other flying organisms are capable of reacting quickly to things such as changes in temperatures, by moving and changing their area of distribution. A European study shows that 63% of 35 butterfly species have moved their distribution limit 35 to 240 km northwards over the past century. Only 3% of the species have relocated to the south (Parmesan & al., 1999). One of the species in the study is the common species, peacock butterfly (*Inachis io*). At the beginning of the last century, the peacock butterfly was widely

dispersed up to Stockholm. Over the next 100 years, the butterfly changed its northern limit concurrently with the variation in the temperature. In just a decade, from the 1980s to the 1990s, this species extended its northern limit 600 km northwards, which is today still the northern limit for its distribution. In Norway, a similar change has been observed in the butterfly fauna. In 2000, 11 new butterfly species were observed, in 2001 this figure was 15, and in 2002, 13 new species were registered. Most of these butterflies are small and insignificant southern species, common to Central Europe, Denmark and the southern part of Sweden (Arvik pers. comm., www.toyen.uio.no/norlep). A similar trend has been observed in Finland, where 14 to 21 new species were regis-

tered each year from 2000 to 2004. Again, all of the species came from more southeasterly latitudes.

In addition, the breeding pattern shows new trends. Finnish butterflies have been monitored since 1993. In this period, there have been several warm, dry summers. Analyses of the data show that there is an increasing tendency to produce two generations during summer, and three generations were even observed for one species. The future will show whether this is a lasting tendency (Leinonen & al., 2003).

Figure 9
The North Atlantic Oscillation simplified.



....63% of 35 butterfly species have moved their range northwards.



Photo: Sarah Brandt

The North Atlantic Oscillation – NAO

The North Atlantic Oscillation is a climatological phrase describing the gradient of atmospheric pressure above Iceland and the Azores. The difference in the two atmospheric pressures produces “a motor” that drives hot air from the south northwards. A big difference between the two atmospheric pressures results in winds bringing hot air containing lots of water vapour up to the south-eastern part of the Nordic countries. This is called a positive NAO – and gives the Nordic countries mild, wet winters. In contrast, a small difference between the atmospheric pressures will give a negative NAO, and cold, dry winters in the eastern Nordic countries (fig. 9).



Photo: Bjarne Jensen

The great tit is one of the bird species that adapts the time of arrival and egg laying to the climate.

A change in the behaviour of migrating birds

A change in the phenology/behavioural pattern of migrating birds has also been observed over the past 30 years. This has been shown by a number of studies (Forchhammer & al., 2002; Stervander & al., in press; Crick & al., 1997; Thomas & Lennon, 1999; Framstad & al., 2003). A Danish study from 2004 (Tøttrup) shows that 25 Passerine, that winter in the south and migrate to the north for breeding, arrive on average 6 days earlier today than they did during the 1970s. A Finnish study of 81 migrating birds finds the same pattern during the period 1970-1999 (Vähätalo & al., 2004). As mentioned earlier,

it seems that the migrating birds adapt their date of arrival to the NAO. A positive NAO with mild and humid winters makes the birds arrive earlier – whereas a negative NAO, with cold and dry winters, makes the birds postpone their arrival. British studies of great tits (*Parus major*), blue tits (*Parus caeruleus*) and flycatchers (*Muscicapidae*) all point in the same direction. Most of the birds adjust their time of arrival, date of egg-laying and numbers of eggs laid to the climate (Visser & al., 2003; Both & al., 2004).

There is no doubt that most bird species react to changes in climate. One problem posed by this flexibility is that other parts of the ecosystem do not necessarily adapt at the same speed. If a less flexible part of the ecosystem is important at a crucial time in

the birds' breeding season, this can have great implications on the success of the breeding. This is called a match/mismatch problem (Stenseth & Mysterud, 2002, see box).

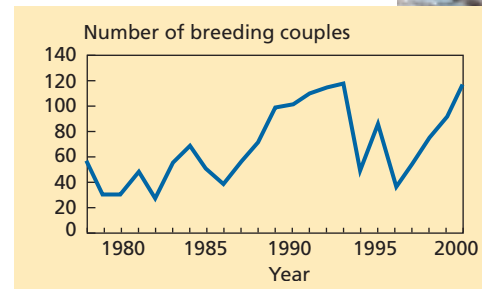
An increasing number of dippers survive the winter

Another example of a species that is sensitive to the climate is the dipper (*Cinclus cinclus*) in Norway. In the southern part of Norway, the dippers have increased in numbers, coinciding with the warming of the climate. This result was found by a Norwegian study of the dipper in an area of Sørlandet in the period 1978 to 2000 (Sæther & al, 2000).

Match/mismatch

A match/mismatch develops when different parts of an ecosystem get out of phase, whereby years and years of well established patterns and correlated mechanisms are disrupted, thus weakening the ecosystem. One example of this is when the great tit's chicks hatch earlier than normal, in reaction to the milder climate, but their main source of food – the winter moth larva (*Operophtera brunrata*) – does not adapt at the same speed. So the larvae of the winter moth have not yet been hatched, when the chicks of great tit are hatched (Visser & al., 1998).

Figure 10
The numbers of dipper couples reproducing from 1978 to 2000 in the Sørlandet in Norway (Sæther & al. 2000).



The dipper benefits from mild winters with less ice cover.

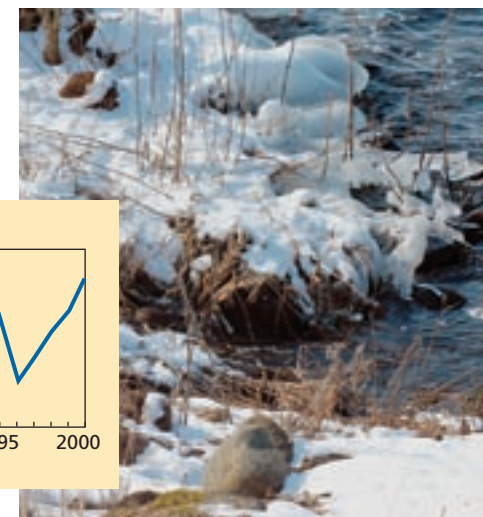


Photo: Maria Mikkelsen

The probable explanation for this is that the milder winters lead to the ice cover becoming thinner, or even absent, which gives the dipper a better chance to forage on water insects during the winter. Consequently, more dippers survive the winter, and will be able to make it to breeding time (fig. 10).

The exotic stork of the North is increasing in numbers

The spoonbill (*Platalea leucorodia*) is another species that reacts to the climate with great mobility. In 1996, the spoonbill returned to Denmark after having been absent for almost 30 years. Every year since then, the spoonbill has increased in number in the Danish bay areas. Normally, the spoonbill does not inhabit areas as far north as Denmark. Nevertheless, Denmark has had breeding spoonbills three times before, during the 1920s, the 1940s and the 1960s. During these periods, the summers were warm and dry, and there was a surplus of birds in the nearest colony in the Netherlands. Time will show whether or not Denmark will become a permanent breeding ground for the spoonbill (Skriver, 2002).

Guests from the south, or new citizens?

Yet another possible climate effect can be seen in the sea. Every year for the past 15 to 20 years, tropical fish have advanced northwards in the North Sea by 50 km. More and more southern fishes have been observed during this period, including species such as the horse mackerel (*Trachurus trachurus*), the anchovy (*Engraulis edentulus*), the thick-lipped grey mullet (*Chelon labrosus*) (fig. 11) and the cuttlefish (*Illex illecebrosus*). Synchronously with this advancement of southern fish, there has been a decline in cold water species such as the cod (*Gadus morhua*) and the plaice (*Pleuronectes platessa*) (MacKenzie & al. 2002).



Photo: Highlight

Figure 11
Landings of the thick-lipped grey mullet from Skagerak and Kattegat (MacKenzie unpubl. data).

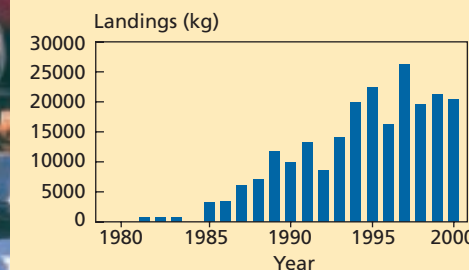


Photo: Maria Mikkelsen

Photo: Jan Skriver

During the last 15 to 20 years tropical fishes have moved their range northwards with 50 km a year.

The polar fox in decline

The polar fox (*Alopex lagopus*) has undergone serious decline since the start of the 20th century. In the 19th century, the polar fox was a common species in the Nordic mountain regions. The number of foxes varied with the cyclical variation in the numbers of rodents.

In good years, there were around 5,000 individuals in the Swedish mountain regions (fig. 12). Today, the number is estimated at 50 adult individuals in Sweden – individuals that, moreover, are intimately related, thus increasing the risk of inbreeding (Linnell & al., 1999; Kaikusalo & al., 2000; see

box). The polar fox is threatened in Fennoscandia, and is protected by the EU Habitats Directive.

At the start of the last century, intensive hunting and the distribution of poison against wolves (*Canis lupus*) and wolverines (*Gulo gulo*) substantially reduced the numbers of polar fox. In the 1920s, the polar fox had disappeared from large parts of the Nordic mountain region. This resulted in the protection of the polar fox in Sweden, Finland and Norway. Nevertheless, the polar fox is still threatened throughout the area. A similar reduction has been seen in Canada (the Canadian Council of Ministers of the Environment, 2003). This decline has been

examined in detail in the Nordic countries, without any isolated cause being found. A number of changes could be to blame for the decline, either isolated or together (Angerbjørn & al., 1995; the Norwegian Directorate for Nature Management, 2003). E.g. a genetically narrow population, the breeding individuals having difficulty in finding one another in a fragmented landscape – a so-called Allée effect (see box), or competition from the red fox (*Vulpes vulpes*) (Tannerfeldt & al., 2002). The red fox has increased in numbers in the same region, which may be a result of climate conditions.

The polar fox
(*Alopex lagopus*)
– this one is from
Greenland.

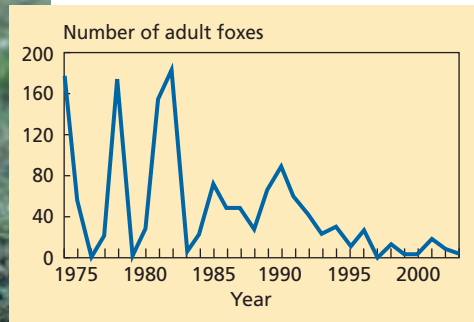


Figure 12
An example of the decline in polar
foxes in the period 1974–2003
(SEFALO; [www.zoologi.sv.se/
research/alopex/](http://www.zoologi.sv.se/research/alopex/)).

Inbreeding depression

Inbreeding depression arises when the genetic material is too limited, and the risk of breeding between two related individuals is high – there is an overrepresentation of individuals with a high frequency of different kinds of handicaps. This means that there is a higher risk of offspring with deformities, diseases, small litters, reduced reproductive capacity and lower bodyweight.

Trout in the mountain region

As mentioned earlier, it is not only warmer temperatures that indicate a change in climate. In several mountainous regions in Norway, the climate change can be seen in the form of increased precipitation – snow – in winter (Høgda & al., 2001). This has lead to an increased reflection of the sun's rays from the snow and ice cover, which, in turn, has lead to a shorter growing season for fish such as the trout (*Salmo trutta*). Over the past 20 years, the trout's reproduction in these waters has been greatly reduced (Borgstrøm, 2001).

General effects

The examples given above come from different habitats, different parts of the region in question, and different flora and fauna. All the examples illustrate changes in nature that are not immediately explainable by our normal, previously known standards of reasoning. Together with the changes in climate, these examples help to form a picture of nature already affected by a changing climate.

The Allée effect

If a plant or animal that is dependent on cross-fertilisation is scarce in number, there is a risk that individuals of different sexes will not meet. This leads to reduced reproduction, which in turn leads to the species becoming even more threatened. Allée first described this phenomenon in 1931.

We see changes in nature that we cannot immediately explain by the usual line of reasoning.

A longer period of ice cover on the Norwegian mountain lakes has lead to a shorter growing season and a reduction of the brown trout populations.

Photo: Maria Mikkelsen



3 The future climate

Photo: Ole Malling

The way that the climate has developed, and the effects we ascribe to it, is one thing – what the future will bring, is another thing entirely. We do not know exactly how natural events such as volcanic eruptions will have on the development of the climate, but one thing we can do, is to look at how they have influenced the climate in the past. This effect can be “subtracted” from the climate changes that have been observed, to give an idea of the human influence to date. This has been done by the IPCC (2001) using models, which showed that natural causes did play a role in the 20th century. However, it also showed that a

substantial portion of the climate changes that have been observed over the past couple of decades are anthropogenic (Hassel, 2004).

From observations to projections

The climate constitutes a very important basis for nature and man. With the current development in climate, we are experiencing a course of events. Human activities lead to increased emissions of greenhouse gases. The concentration of greenhouse gases in the atmosphere rises. In this way, the greenhouse effect also increases, thus affecting the earth and the atmospheric system. This results in climate changes. The climate changes have a primary effect on nature, farming, fisheries, etc., and a secondary effect on international trade, global security, human migration, etc. (fig. 13).

In practice, there are a number of complicated feedback mechanisms between the individual processes. For example, the climate changes influence the amount of energy consumed for heating and cooling, thus indirectly influencing the emission of anthropogenic greenhouse gases. Furthermore, climate changes influence the production of water and wind energy, the decomposition of organic material, and thereby the emission of natural greenhouse gases. In addition to this, we should mention the interactions with technological, social, economic and other factors.

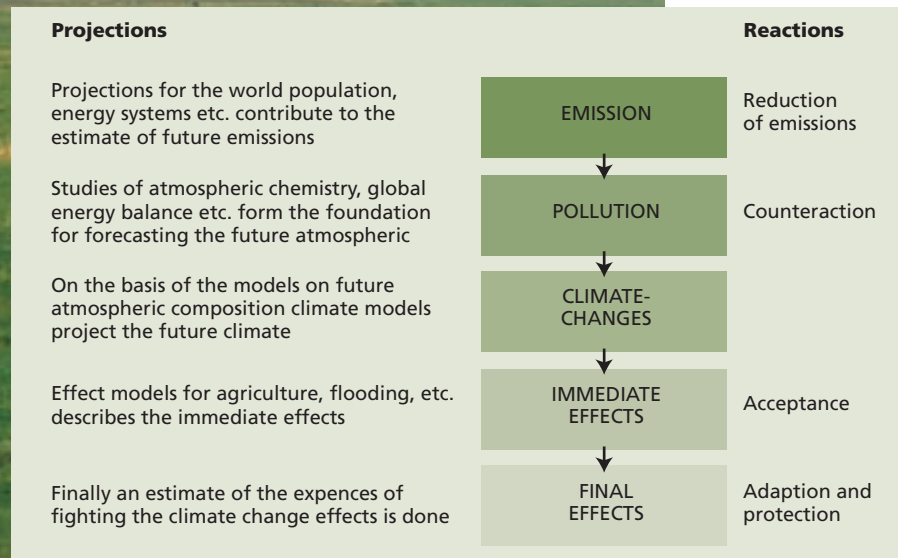


Figure 13
The chain of events in anthropogenic climate changes. The uncertainty grows by every step (After Fenger & Torp 1992).

As we move from observations of the past to projections of the future, the conclusions will become increasingly uncertain for each step, based on complicated model calculations. The publication of the IPCC's third and latest assessment in the summer of 2001 provides convincing argumentation that the increase in the greenhouse effect brought about by humans will lead to climate changes of some sort. How extensive these will be, at what rate they will happen, and how the different regions on earth will react, depends on how successful we are at reducing our emission of greenhouse gases.

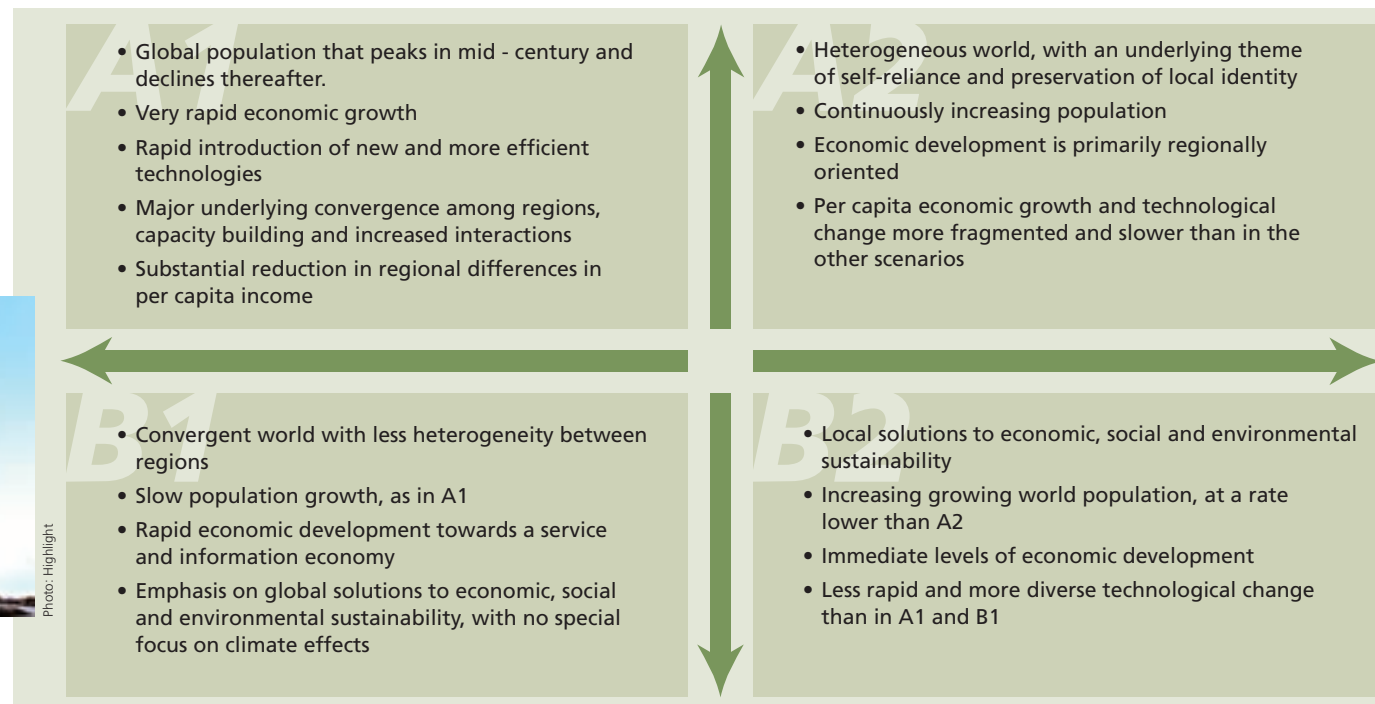
Nobody knows with great certainty how the world will develop technologically and socially. Nevertheless, we can create more or less probable scenarios (see box). Detailed emission and climate scenarios do not ex-

tend more than 100 years in the future. This is due to the uncertainty with which, we are able to assess the technological and social development, and the current limits of computer capacity.

Figure 14
IPCC operates with four different scenarios regarding the development of the world (After Nakicenovic & al. 2000).

Emission scenarios

The IPCC (2001) has created a number of scenarios (called reference scenarios) for the economic, social, technical and demographic development until the year 2100. The scenarios are divided into 4 "families" or story lines (fig. 14), depending on whether emphasis is put on the economy or the environment, or a regional or global-oriented development. Scenario A1, at the one end – describes a world with fast economic and population growth, and the development of new and efficient technology. In addition, scenario B2, at the other end – describes a world with continuous but slow population growth, and more diverse technological development. Even though some of the more optimistic scenarios include a decrease in the emission of greenhouse gases, they all lead to an increase in the concentration of greenhouse gases, from 370 PPM (parts per million) to between 500 to 1000 PPM around the year 2100. To this, the uncertainty in the development of the emission of other greenhouse gases must be added – which follows a similar pattern. Only in one of the 4 scenarios (B2) does the CO₂ concentration stabilise within the next 100 years.



The technological development is of great consequence for the future climate and nature.

Figure 15

After CO₂-emissions are reduced and atmospheric concentrations stabilize, surface air temperature continues to rise slowly for a century or more. Thermal expansion of the ocean continues long after CO₂-emissions have been reduced, and melting of ice sheets continues to contribute to sea-level rise for many centuries. This figure is a generic illustration for stabilization at any level between 450 ppm and 1,000 ppm, and therefore has no units on the response axis.

Climate scenarios

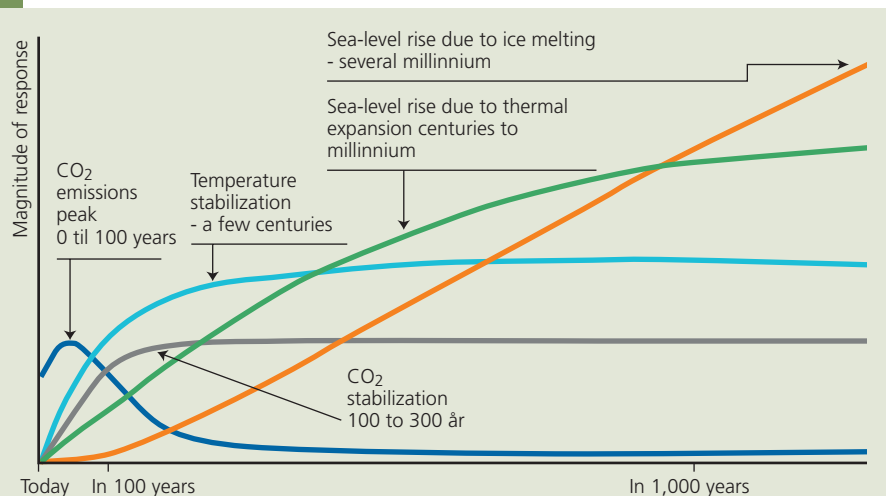
Based on the reference scenarios for global development, the corresponding rise in temperature can be calculated using climate models. The results of these calculations indicate average temperature changes of between 1.4 °C and 5.8 °C up to the end of 2100. The minimum increase in temperature is found in the scenarios where growth is based on non-fossil energy sources, and the biggest increase is found in the scenarios with the biggest growth based on the burning of fossil fuels.

It should be emphasised that none of the

scenarios shows the warming stopping by 2100. E.g. with the rising temperatures, the sea level will rise, because of glacial melt, and because heat makes water expand. These oceanographic processes are much slower than the atmospheric warming. By the year 2100, the sea level may have risen by 9 to 88 cm. The effect of this rise in sea level will depend on the natural vertical movements of the continents. There is great uncertainty in this respect, but the core values in the individual scenarios do not differ that much (30-50 cm). Under all circumstances, the sea level will rise continuously over the next couple of centuries (fig. 15).

Stabilization in the long run

If the climate is to stabilise, the concentration of CO₂ must be stabilised. Stabilisation at 550 PPM, which corresponds to a doubling of the natural level, will lead to development as shown in fig. 14. The other scenarios do not show any stabilisation this side of 2100. Not even in the scenarios where the concentration of CO₂ is stabilised will the temperature increase stop. Stabilisation at 550 PPM will give an estimated temperature change of 2.2 °C in 2100, and a final increase of 3.5 °C.



By the year 2100 the water level will have risen between 9 and 88 cm – and it is expected to continue to do so for many centuries.

Low lying coastal areas in particular will be vulnerable towards a rising sea level and storms.

Photo: Maria Mikkelsen

Surprises in the greenhouse

As mentioned above, the earth has previously undergone extensive and rapid climate changes due to natural causes. For this reason, there have been discussions about whether an increase in the greenhouse effect might trigger extensive and rapid changes, e.g. by affecting the big ocean currents. In the long run, without any reduction in the emission of greenhouse gases, non-linear development cannot be excluded. The weakening of the Gulf Stream by meltwater from the Greenland icecap is one topic that has been discussed in particular. This would imply a colder climate for northern Europe, in an otherwise warmer world. Changes in the ocean's currents will also lead to changes in local sea level. However, most of the model predictions (IPCC, 2001) indicate that we will not see any bigger changes over the next 100 years, although it is important to remember that the mechanisms that form the ocean's currents are not fully understood.

Regional differences and effects

Although all of the IPCC's scenarios involve a general warming of the earth, there will be considerable regional differences, with the biggest changes occurring at the higher latitudes. Simultaneous changes in the precipitation pattern are expected. As warmer

air can contain more water vapour, the total amount of precipitation will probably increase. However, this is unlikely to be enough to make up for the increase in evaporation also brought about by the increasing temperatures. In general, an increase in precipitation during winter, and a reduction during summer, is expected outside of the tropics. In the tropics, the effect will be more varied. Around the poles, a great increase in precipitation is expected, whilst a more moderate increase is expected in the temperate regions. Moreover, the intensity of the precipitation and the seasonal distribution will change, and more precipitation will fall as rain and less as snow, except in the high mountains, where more precipitation during the winter will mean more snow. These are all elements that influence the plants' accessibility to water. A rise in temperature can also influence the wind systems, and give regional differences in rising sea levels. Added to this is the risk of extreme weather that is of great importance for the effects.

Global security aspects

Climate changes will give both positive and negative effects. The bigger the changes, and the faster they appear, the more the negative effects will dominate. They will predominantly hit the tropical and subtropical regions, and thereby many developing countries which, for economic and technological reasons, are less able to adapt.

A moderate warming of the earth is unlikely to make living conditions in general less optimal, but regional differences can imply great problems. The projected climate changes may result in millions of people having to move from areas that are no longer able to feed them, or from areas that have been flooded. As the possibilities for food production in the Nordic region will probably improve in comparison to the more southerly regions, there may be an increased demand for food production in this region.



Photo: Maria Mikkelsen

The extreme weather events are central to the consequences of the climate change.

A general increase in the precipitation is expected.

Photo: Highlight

The Nordic climate in the future

More detailed projections of climate changes involve great uncertainty. Moreover, the global model grids are too general to give a precise picture of smaller regions like the Nordic countries. Global models have a resolution of 300-500 km, but this may be improved by integrating detailed descriptions of the region.

When making such models, the results depend not only on the assumption of global development – the choice of models for downscaling also affects the result. The

result of the detailed analyses of the future climate and development is very interesting from a scientific point of view, but it is of little value for the formation of an adaptation strategy. In this situation, the entire spectrum of possible developments is of interest. Our adaptation strategies need to process a number of general instructions, and plan nature management with a great deal of flexibility.

The result of a Swedish model, SWECLIM, is shown here as an example of a local model (fig. 16 and 17) (Bernes, 2003). Finland and Norway have also processed national scenarios, FINSKEN and RegClim. Figure 16 shows the average temperature in Europe from 1961 to 1990 and the estimated temperature levels for the period 2071 to 2100. The rise in winter temperature is 3 °C to 6 °C, and the rise in summer temperature is 2 °C to 4 °C. As the temperature gradient in Europe is weaker in the summer than in the winter, the changes correspond to a 500 km to 1,000 km northwards shift in the thermoclines in flat terrain. The most remarkable result is the very great increase in the summer temperature in the south-western

and central parts of Europe. This gives a large increase in the difference or gradient in the temperature level in south-western and central Europe on the one side, and northern Europe on the other. The result of this will be that the large area in the middle of Europe, that today has summer temperatures of between 15 and 18 °C, will not only shift northwards, it will also be reduced in size.

However there are still big differences between the models. In Europe, the two models from Germany and Great Britain differ considerably. For this reason, they are presented separately, in order to illustrate the uncertainty in the results depending on the choice of model. The English model shows an average rise in precipitation for the Nordic region of 10–20%, while the German model presents increases of up to 60% in the summer precipitation on the west coast of Norway. The greatest difference between the models is their projection of precipitation during the winter. Which of the models ends up giving us a picture of precipitation levels that is closest to the truth will be of crucial importance to features such as the

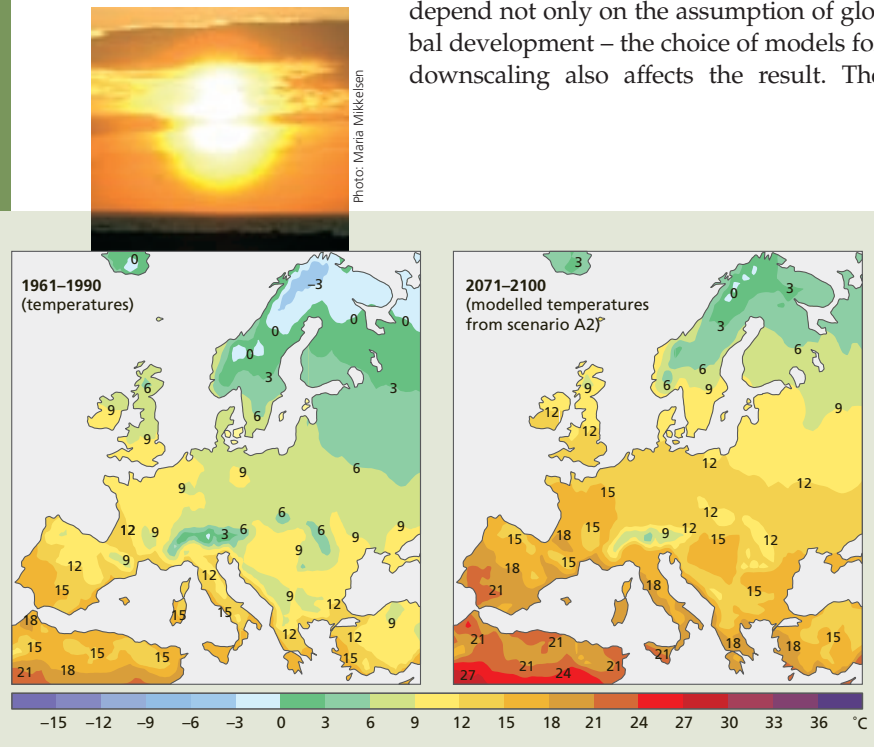


Figure 16
Average temperatures
in Europe in the two periods
1961-1990 and 2071-2100
(After Bernes 2003).

glaciers in the mountainous regions. Will climate change lead to a total melt-down, or to possibilities for continuous existence due to its favourable position in the winter? This is also the case for the northwards shift of the vegetation zones in the same region. Both of the models show a decrease in summer precipitation of around 10 to 30% in the southern part of the North, and almost no change or a slight increase in the northern part. As mentioned above, the German model shows an extensive increase in summer precipitation along the Norwegian west coast (fig. 17).

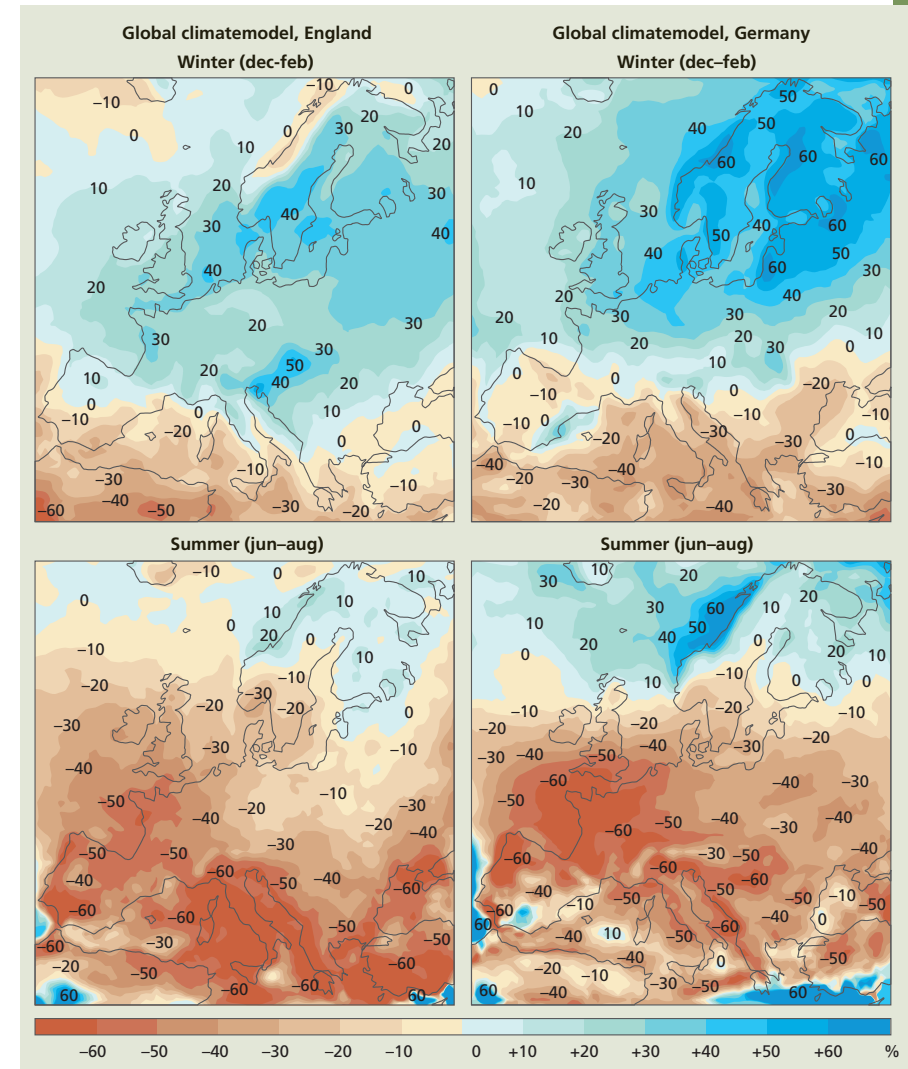
Even if the rising temperatures stimulate evaporation, there will be increased run-off in the northern part of the North – naturally the biggest increase is seen in the German model. In the southern North, where there is little run-off in the summer, levels may rise in case of a major summer draught where the watercourses dry out.

There will be a considerable increase in wind in the northern countries, according to the German model, whereas the English model predicts a smaller increase in wind in the Gulf of Bothnia.



Photo: Highlight

One very important element in predicting the future climate is the occurrence of extreme weather conditions, which is likely to increase in frequency and strength. This may produce much greater effects than the effects of the average values, and are thus very important to include in the planning.



A climate adaptation strategy must take the whole range of possible climate developments into account – including the most extreme.

Figure 17
The change in summer and winter precipitation according to two models – the English model to the left and the German model to the right (After Bernes 2003).

“ One important effect of the climate change is the north- and upwards movement of the vegetation zones. ”

Regional predictions are uncertain – we do not know the future emission levels, and different models give different results from the same input (cf. the preceding chapter). There are, however, a number of general tendencies;

Sweden, Norway, Finland and Denmark cover a large geographical area with five vegetation zones and four climate zones. Thus, the background is heterogeneous, and so are the effects. An average rise in temperature of 1 °C can be compared to moving 150 km closer to the equator. 4 °C corresponds to 600 km, or to the difference between Copenhagen and Frankfurt. It is important not to attach too much weight to this picture – partly because the altitude of the sun and the soil remain the same, and partly because extreme values in temperature, precipitation, wind velocity and sea level are of greater importance or impact than average values. The speed with which changes happen have a great say in the effect on flora and fauna. If flora and fauna could move freely, and were not pressed for time, the ecosystems would have a better chance to adapt by means of migration and natural selection. This is not, however, the case today.

Photo: Peter Brandt

Possible tendencies in the development of different ecosystems are outlined below, in order to give an impression of the very complex scenarios that should be integrated into the management and conservation of nature and nature resources. No one particular climate scenario has been used as a basis for the outline, because there are substantial uncertainties with regards to both effects and assumptions. What is interesting is to look at the outlines of the possible effects of the changes in precipitation, temperature and extreme events, as well as their possible combined effects.

Any division or categorisation of nature would be inadequate and unnatural. Nevertheless, we have chosen to describe possible tendencies for a number of ecosystems, from mountainous regions to the marine environment, undergoing a change in climate.

Effects on the mountainous ecosystems

One primary effect of the climate change on mountainous ecosystems may be a shift in the vegetation zones upwards topographically, and northwards. This would stimulate the overgrowth of the treeless mountainous landscape. The tree line is primarily determined by the average summer temperature. One study indicates an upward shift topographically of around 230 to 650 m within the next 100 years in the Swedish mountain region. This would leave the Swedish mountain heaths reduced by 75–85% (Moen

ains to the sea

& al., 2004). The "Kungsleden" hike would become a walk through the forest. Skiing areas like Sälen and Åre would lose their alpine character. This tendency has already been observed in some areas, where the tree line has shifted upwards by about 200 m since the end of the 19th century (Kullman, 2001). However, this effect may be reduced by an increased accumulation of snow during the winter, and more cloudy and windy weather during the summer (Dalen & Hofgaard 2005) (cf. chapter 3, the German model) and vice versa. Other elements that may mitigate the shift in the tree line include an expected increase in attacks by insects, diseases and a change in grazing pressure (Hofgaard, 1997).

Biodiversity

The biodiversity in mountainous regions is also expected to change with a change in climate. The number of different species in the mountainous regions is comparatively low in the higher zones, although some groups, such as the vascular plants in certain low alpine habitats, and lichens in high alpine systems, are relatively diverse. The total number of species is therefore expected to increase, due to species migrating from lower lying ecosystems with a greater diversity of species.

The threat to the biodiversity of the mountainous region is not a local decline. The threat is the loss of species in a regional or global perspective, because some species

that are unique to the mountains will lose a substantial part of their habitat, thereby rendering the populations non-viable.

The most threatened groups of species are species from the middle and high alpine zones, as these zones will probably be reduced in size, or disappear. Species found in the mountainous region that require a certain amount of space will also be threatened by the fragmentation of the treeless landscape (Sonesson & Lilliesköld, 2000).

Glacier buttercup
(*Ranunculus glacialis*)
grows in the mountains
near the ice edge, far
away from the woods.



Photo: Hans Ohrt

"Kungsleden" a walking path in the mountains, which might end up being a walk through the woods.

The main threat towards the mountainous nature probably is the reduction of the treeless zone.



Photo: Peter Brandt



Photo: Maria Mikkelsen

The forest – industry and nature

The forests in the Nordic countries are currently primarily managed from an economic point of view, whereby they express not just climate and geological propositions, but also social and commercial interests. This blurs the possible climate effect somewhat.

General effects

A general effect that has already been observed is the extension of the growing season. This implies increased primary and biomass production, improved possibilities for the growing of new species, and an increased risk of pathogens and frost injuries (Hänninen, 1991). Competition will change, and new species from the south and east have better conditions to establish themselves. Moreover, the frequency of forest fires due to summer draughts will probably rise (Suffling, 1992).

/// In the forests the competition will change and make room for new species. ///

Based on the prolonged growing season, it is projected that the net primary production for certain species and regions will increase by up to 20%. Increases in the net primary production will apply to most of the primary producers in the forest. This means that the wild plants and herbs will, for example, form an enhanced threat to the newly planted forest.

The prolonged growing season also produces an increased risk of frost injuries, because the increment in the early springtime brought about by the higher temperature may be harmed by nights with temperatures below freezing point. This has already been observed, but the frequency of nights with temperatures below freezing point is expected to increase. In forestry, the rotation age is normally 60 to 130 years. However, with the prolonged growing season it is expected that the rotation age will be shorter. This has several positive effects for the industry, but not necessarily for biodiversity. For the industry, the turnover of wood will be faster, and there will be increased flexibility in terms of the changing climate. One might expect that the industry would afforest with more southern species, or species that are new to the region. The introduction of new species, more frequent rotation and the working of the soil will have an impact on the existing flora and fauna. Moreover, rotation that is more frequent will contribute to acidify the soil by removing nutrients from the forest's ecosystem.

Pathogens

As mentioned earlier, a rise in diseases and pathogens is expected, due to the change in precipitation, draught stress and possible changes in wind patterns. Together, these will stress the forest and make it more receptive to pathogens and pests.

Forest fires

As the summer precipitation decreases, the risk of draught and forest fires increases. A study (Suffling, 1992) shows that a 2 °C increase in temperature in July/August will increase the risk of forest fires by a factor of 5. A higher frequency of forest fires will benefit species that have adapted to fire, at the expense of species requiring great continuity.

A higher fire frequency than the current level is, however, a natural element of the boreal forest. Previously, the normal fire frequency was between 50 and 200 years (Zackrisson, 1977). The reason for the big variation in frequency is found in the variation of the natural forest, with parts of it being humid or wet, and other parts being drier, and therefore more liable to burn. So-called fire refuges develop in those areas that never, or very seldom, burn. The current nature management and forestry strategy, however, is based on a system where fires are fought. This has produced a species composition in the boreal forest that is different to the natural, fire-adapted flora and

fauna. The absence of forest fires has resulted in a change, primarily in the species composition of the vegetation, but also in the composition of insects.

The large herbivores of the forest

The change in temperature, and the changes that may follow in the forests, will affect the large herbivores living in the forest. The diminishing snow cover and the shorter winters will probably increase the population density of roe deer, red deer and fallow deer (introduced from Asia Minor in around 1200) in their northern range. The moose (*Alces alces*), on the other hand, which is restricted by high summer temperatures, and prefers cooler winters (Andersen & Sæther, 1996) will probably gradually disappear from its southern ranges.

Like the moose, the reindeer (*Rangifer tarandus*) found in mountainous regions may become negatively affected by a milder climate. Results from a study undertaken by the International Tundra Experiment (ITEX) in Abisko and Alaska have shown that the vegetation in the range of the reindeer changes from being dominated by berry-bearing bushes, lichens and grasses, to a more high-bushes system. As the reindeer primarily lives on lichens and berry-bearing bushes, this kind of change may affect the range of the reindeer.

However, there is one type of reindeer that lives in the forest all year round. This forest type of reindeer has a different food composition than the reindeer that grazes in the high mountains during the summer. The reindeer living in the forest will not be affected by the transformation of the mountain heath to a more bushy landscape. If the summer grazing disappears due to an overgrowth of the mountain heath, it is probable that the traditional Same business will be more greatly affected than the reindeer itself.

Wild boar

The wild boar is a so-called key species for the forest in a large part of Europe south of Scandinavia, and in the forests in southern Sweden. The wild boar grubs the forest floor and eats whatever it finds, i.e. roots, insects and nuts. The wild boar influences nature to almost the same extent as the beaver (*Castor fiber*), for example. In a changing climate, the wild boar might be expected to spread further northwards, with consequences for the forest and the flora and fauna here.

One threat to the reindeer and other herbivores, however, is the increase in the depth of the snow. This hampers both grazing and mobility. Another risk involves an increased probability of sheets of ice, because of alternating thawing and snowing. This sheet of ice may cover herbs and lichens, and complicate feeding for the grazing animals. Moreover, the sheet of ice will also lead to the disappearance of the space under the snow inhabited by the rodents. Consequently, the hunting possibilities for predators on the prowl under the snow are limited.

The footprint of a moose – the moose prefers colder climate and may retreat northwards in a warmer climate (top).

The fallow deer is one of the species that probably will benefit from a warmer climate (bottom).



Photo: Maria Mikkelsen



Photo: Maria Mikkelsen

The wolverine (bottom) that is connected to the tundra and the boreal forests (top) is vulnerable towards changes in these habitats.



Photo: Talvi Mäsema



Photo: Peter Brandt

The large carnivores

The range of three of the large carnivores, the bear (*Ursus arctos*), the wolf and the lynx (*Lynx lynx*) is not likely to change much as a consequence of a milder climate.

The bear and the wolf already live in a wide range of different habitats, such as forests, mountains and tundra. The total range is reduced today, compared to the original area. The most important reason for this reduction is several hundred years of hunting. As both species are typical generalists, they are not expected to experience problems with a changing climate.

The lynx differs from the bear and the wolf by residing in rocky areas with large surrounding forests. Recently, the lynx has broadened its range to include more cultural landscapes, and is now spread over most of Sweden and Norway, except in the most intensively cultivated parts. Outside the Nordic countries, the lynx inhabits areas such as virgin forest in Poland and Belarus. This indicates that the lynx is not favoured by intensive farming, but prefers large areas of forest, even in a milder climate.

The wolverine on the other hand, which lives in the boreal forest and tundra, is expected to react to any change that might develop in these biotopes. The wolverine is very shy, and requires large, preferably deserted areas with virgin nature. Because of intensive hunting, the wolverine strain

has been small, but this has changed recently. Until now the wolverine has typically lived in the reindeer's grazing areas, but now the wolverine is slowly re-colonising parts of the coniferous forest. A climate effect on the range of the coniferous forest will presumably have a direct influence on the range of the wolverine (<http://www.de5stora.com/rovdjurscentret>).

Terrestrial nature types

Most of the terrestrial environment in the Nordic countries that can be developed is utilised for farming, forestry and building activities, in the form of urban areas, industry and transportation. A small part of the area that is used for farming and forestry is in a semi-natural form, preserved only by extensive cultivation or use in the form of grazing or hay harvest. The remaining land is covered by natural ecosystems such as raised bogs, mountain heath land, etc., all ecosystems which are typically poor in nutrients.

In general, the terrestrial ecosystems will react with an increase in the primary production, conditioned by an increase in temperature and carbon dioxide – depending on which element is the limiting factor. This will have consequences on the distribution of species, the diversity and functionality (Bazaz & Fajer, 1992). However, the interaction between carbon dioxide and temperature is complicated (Mortensen, in prep.). Experiments show that the photosynthesis



activity in the leaves rises as the temperature rises, up until a certain point, where the activity falls even if the temperature continues to rise. However, this optimum temperature is not fixed. With an increase in the concentration of CO₂, the optimum temperature rises. Thus, the concentration of CO₂ apparently determines the photosynthesis reaction to a change in temperature (Norby & Luo, 2004). As CO₂ appears to have a fertilising effect on systems that are poor in nutrients, such as dry meadows and raised bogs, these systems will be exposed to great changes in vegetation and function.

A number of experimental projects (CLIMATE, CLIMOOR, VULCAN, etc.) are stu-



Photo: Maria Mikkelsen

The primary production in peat bogs will probably increase with a warmer climate.

dying the reactions of different habitat types to temperature changes, a rise in CO₂ and changes in the precipitation pattern. Therefore, at this time, it is only possible to outline some general, uncertain tendencies for the terrestrial habitat types.

Some experiments have, however, already presented some big surprises. For example, an experiment in Colorado, USA, showed that 16 years after an experiment of giving a test area nitrogen and water was ended, an overrepresentation of intro-

duced species was found in all the test areas, whereas no introduced species were registered in the control spots. This may indicate that the experiments had pushed the ecosystems over the edge into a new position (Milhunas & Leurenroth, 1995).

The experiment showed that, in a changing climate, the long-term effect of any given exposure does not necessarily end with the end of the experiment (Mooney & Cleland, 2001).



Photo: Peter Brandt

Great sundew
(*Drosera anglica*)
– frequent in
peat bogs.



Photo: Maria Mikkelsen

Peat cutting – an old method of management of peat bogs.

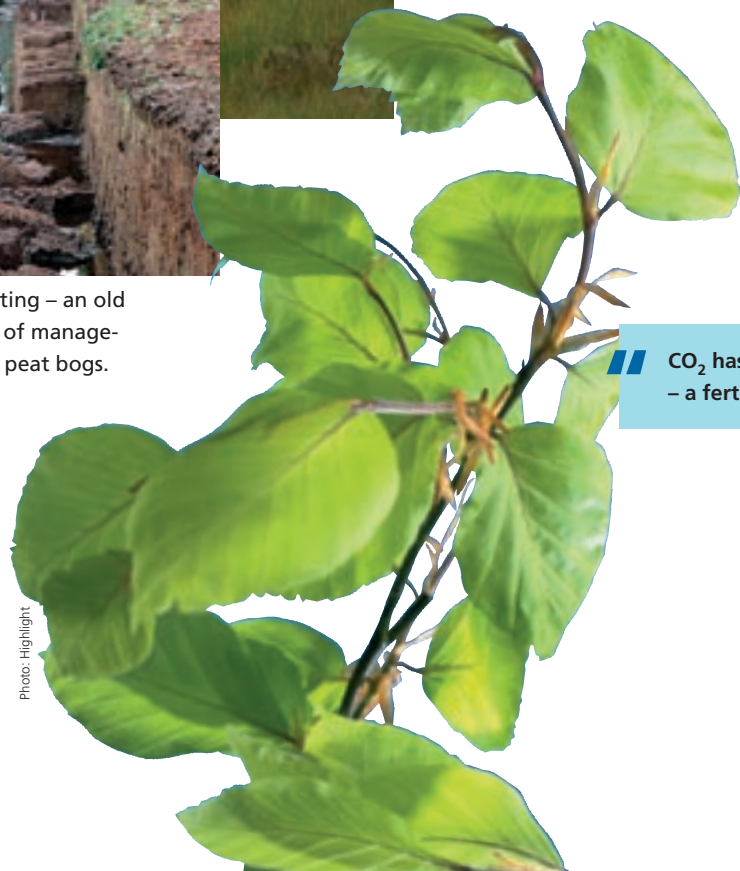


Photo: Highlight

CO₂ has – until a certain limit – a fertilizing effect.

Watercourses are well circulated water systems.

Watercourses – temperature sensitive ecosystems

Watercourses are characterised by being shallow watered, well-circulated ecosystems with a ready exchange of oxygen and heat between water and air. Thus, watercourses are vulnerable to temperature changes. Like in the other ecosystems, a general reaction to rises in temperature is an increased turnover and growth. Combined with the fact that warmer water binds less oxygen, the temperature rise results in an increased need for oxygen due to the rise in decomposition, which gives a generally poorer quality of water.

Organisms that are very sensitive to temperature can be severely affected by even minor temperature changes. However, a number of insects are winged in the adult form, and thus more mobile as such. Organisms such as fish and amphibians will be more dependent on good migration possibilities.

Moreover, a rise in temperature in the summer months will imply increased eva-

poration, and reduced flow, water quality and desiccation, with great consequences for the flora and fauna (Opdam & Wascher, 2004). Changes in the flow will change the times and impact of flooding. This could lead to watercourses running dry during the summer in parts of Norway, Sweden and Finland, with the resultant impact on fish and other organisms living in the watercourses. Impacts on erosion, and thereby water quality and the physical form of the watercourses, are also possible.

The macro-fauna

Temperature and the provision of nutrients from the catchment affect aquatic macro-fauna. In catchments dominated by coniferous forest – as is the case for most of the Fennoscandinavian area – the watercourses are poor in nutrients, with simple ecosystems and few different species. An increase in the deciduous forest in this area will also increase the number of leaves in the water, and thereby also the number of decomposers and other species. Thus, a rise in temperature will lead to more complex ecosys-

tems with more different species if the deciduous forest is allowed to spread northwards. This might, at first sight, appear to be an advantage for the biodiversity, but in the greater perspective, on a regional level, it may lead to an impoverishment of the biodiversity (Poff & al., 2002).

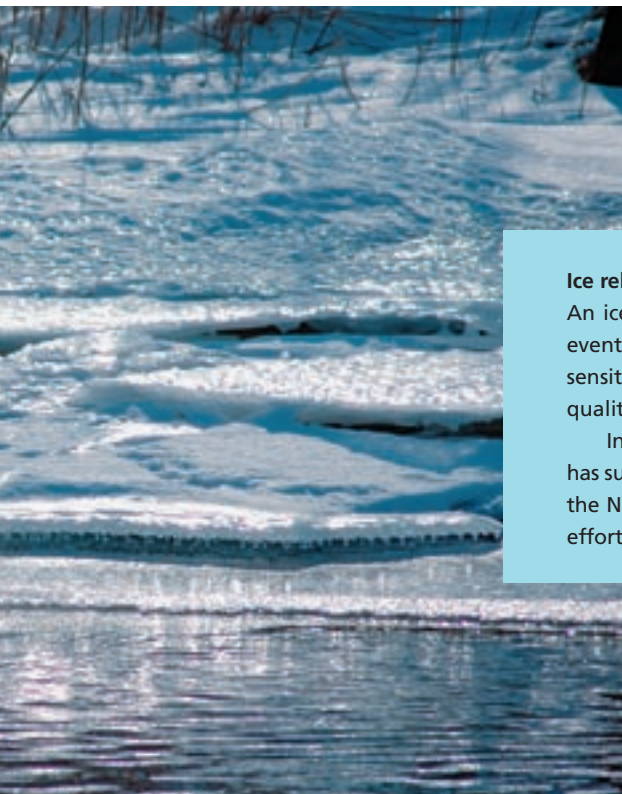
Lakes

The Nordic countries have many lakes. For the lakes, the temperature change, change

The temperature rise, the changes in ice cover and precipitation patterns are the primary climate changes affecting the lakes.

The ice cover period is important for the primary production of the algae in the lake.

in ice cover and change in precipitation pattern are the predominant factors of the projected climate changes. If the growing season is extended, it will probably lead to an increase in the primary production, and a change in the trophic levels and the stability of the lake. As with other ecosystems, the change in precipitation pattern will lead to an increase in the leaching of nutrients and organic matter, and thereby obstruct the primary production that is dependent on light. The effect of the above will be



influenced by a number of factors that are not directly connected to climate change, such as the depth of the lake, the size and form of the catchment and the nutrient stressing (Jeppesen pers.com.).

The temperature rise in nutrient-rich lakes

A eutrophic lake is typically rich in nutrients such as nitrogen and phosphorus. The nutrients stimulate the growth of algae, which leads to a decrease in the permeability of light, thus affecting the water plants, the macrophytes. A reduction in macrophytes will, in turn, result in a reduction in predatory fishes such as pike (*Esox lucius*) and perch (*Perca fluviatilis*), which thrive among the plants. A reduced pressure from the predatory fish on non-predatory fish such as

bream (*Abramis brama*) and roach (*Rutilus rutilus*) will lead to an increase in these populations, thus also increasing the grazing on zoo plankton. The number of algae will increase, and the circle of pollution will be cemented, resulting in a muddy lake, rich in nutrients (Carpenter & al., 1992).

The season with pycnocline, which separates the surface water from the bilge water, is also expected to be extended in the lowlands, thus producing a risk of deoxygenation in the bottom layer. Deoxygenation has a great impact on the composition of species, including fish, demersal organisms and macrophytes. This may lead to an increase in the release of heavy metals, nutrients, etc., found in the sediment. The consequences of this, and the mechanisms involved, are not fully understood.



Photo: Maria Mikkelsen

The pike is one of the fish species that might have its life potential reduced with a warmer climate.

Ice relicts in the lakes and on land

An ice relict is an organism that lived in the former Glacial Ocean, and that was caught in the lakes that eventually emerged as a result of the ice melting and the upheaval of the land. Invertebrate ice relicts are sensitive to low pH values and a low oxygen concentration, and are therefore excellent indicators of the quality of the water.

In the terrestrial environment, the saxifrage plant species (*Saxifraga hirculusa*) is an example of a plant that has survived the end of the Ice Age in springs where the water temperature is constantly low all year round. In the Nordic countries, the saxifrage is found in the mountainous region, primarily in Finland. The amount of effort that should be put into conserving this special saxifrage in Denmark is a matter of discussion.

The Carp

The characteristic fish the carp (*Cyprinus carpio*) will probably experience increased success in the southern parts of the Nordic region in the event of a temperature change. This will have extensive consequences for the lakes involved, due to the carp's way of life. The carp rubbles the sediment when it forages, which results in the lake becoming muddy and less permeable to light. This will stress the macrophytes and species of predator fish that rely on sight for hunting.

The uncertain future of the nutrient-poor lakes

The reaction of lakes that are poor in nutrients to a changing climate is not fully known either. On the one hand, the extended growing season will lead to an increase in the macrophytes' water rinsing capacity. On the other hand, it could lead to an increase in algae production, and the leaching of nutrients and organic matter, thus making the lake richer in nutrients (Weyhenmeyer unpubl.).

The fishfauna

The flora and fauna will probably change. One possible reaction would be a migration of species from the south to the north. The speed and extent of this migration would depend on the migration possibilities in the form of watercourses, and any physical barriers that might hinder the migration (Poff & al., 2002).

The effects of the climate changes on lakes are complicated by cumulative, non-linear, coupled feedback mechanisms. The

extent and effect of the climate change will thus vary considerably from one region to another. As with the other ecosystems, there is a great deal of uncertainty surrounding the development of lakes in a changing climate.

Coastal ecosystems

The expected future development of the coastal regions in a changing climate will probably lead to a loss of coastal habitats, a change in water quality and changed fishing

// The future of the lakes is uncertain. //



Photo: Maria Mikkelsen

The lakes of the coniferous forests

The lakes of Sweden, Norway and Finland are found in the boreal coniferous zone. This, and the rocky ground, is the reason why the lakes are acidic and poor in nutrients. If the deciduous forest moves northwards, the degree of acidification will be reduced, and the nutrient concentration of many lakes in the coniferous forests will be increased.

conditions. The rise in sea levels will put low-lying coastal nature under great pressure, with a considerable part of the salt marsh and the like probably disappearing under the sea. The possibilities of compensation inland are limited, because of the intensive land use in most of these areas. In addition, the mobilisation, transport and retention of organic matter will be influenced. This will affect the transportation of nutrients and water in the ecosystems (Kronvang & al., 1999), and have a considerable impact on the flora and fauna in these areas. With the greatest expected rise in sea levels, species such as the hawthorn (*Hippophae rhamnoides*) in the Gulf of Bothnia, and the endemic plant tufted hair grass (*Deschampsia botnica*), will be greatly reduced or even disappear.

Many of the habitats and species found in the coastal zones are often of international or national importance, which makes the coastal ecosystems especially important (Vestergaard, 2001).

Marine ecosystems

Marine ecosystems are primarily influenced by changes in temperature and in wind pattern. The climate change is expected to involve a general increase in eutrophication, due to an increase in leaching and an increased rate of decomposition. In this case, it will lead to greater risks of oxygen depletion and decreasing salinity, with extensive effects on marine organisms. Another effect that is expected to be seen is an increase in the primary production, because of a rise in CO₂ (Hein & Jensen, 1997).

The pycnocline shifts

As with lakes, the pycnocline forms a very important basis for the dynamics and function of the sea. The bottom and top layers of water differ in temperature, salinity and/or direction of current (Christensen & al., 2004). The pycnocline will probably be lowered by 0.5 to 1 m, and will

probably be strengthened. The effect this will have on oxygen depletion, bottom turn-overs and the release of the very powerful greenhouse gas methane, heavy metals and organic matters such as dioxin (Verta & al., in prep.) is not fully known.

“ The primary production is also expected to rise in the oceans. ”

Like for the lakes a strengthening of the pycnocline in the oceans is expected with a cascade of effects in the rest of the ecosystems.

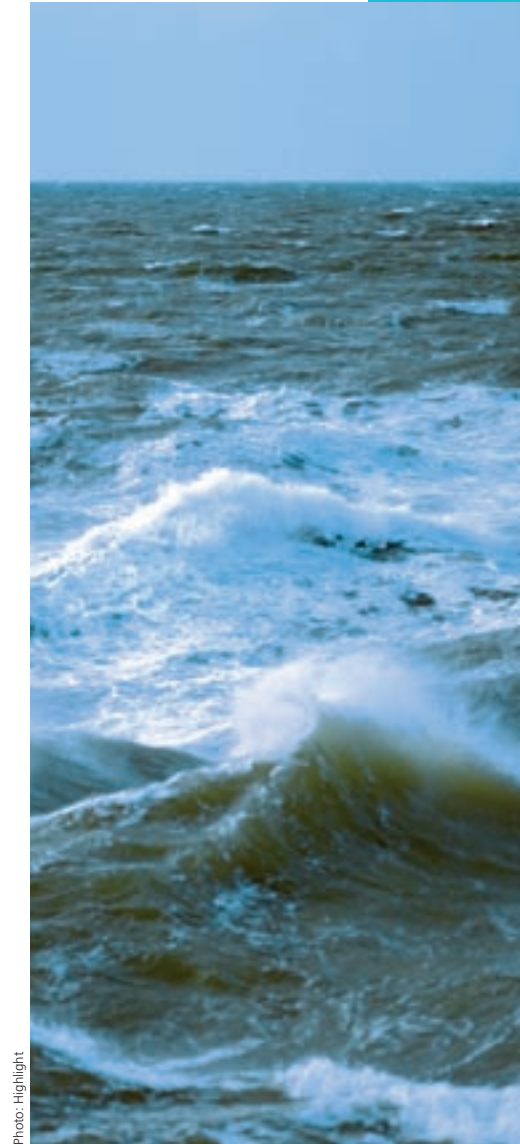


Photo: Highlight

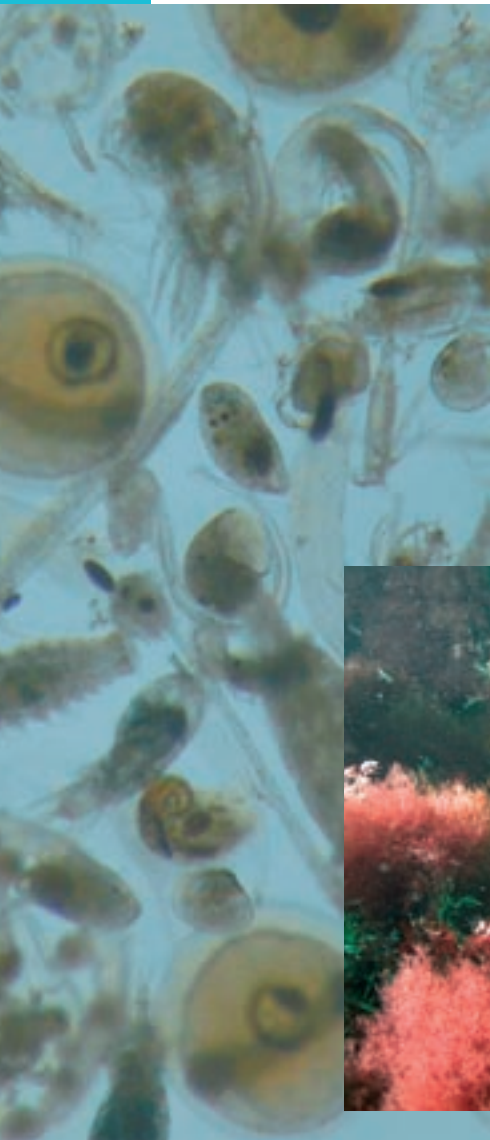


Photo: Suree Sarapoomin

Photo: Karsten Dahl

Flora and fauna

Marine flora and fauna will be influenced both directly and indirectly. As in other ecosystems, a rise in temperature will increase the speed at which biological processes take place. Moreover, the temperature affects things such as the range of the individual species, the competition status between the species and their functions.

Algae – one of the lowest organisms in the food chain – are, due to the increased leaching of nutrients from the soil, expected to increase the primary production. This will enhance the effects, as has already been

seen from the effects of eutrophication on macrophytes. The number of species decreases in line with decreasing salinity, increased nutrient concentrations and decreased permeability of light through the column of water.

Consequences for fishes

An increase in temperature and a shift in salinity will have serious consequences for fish. It is difficult to project the consequences for the individual species and populations, but the following tendencies are expected:

- Survival, growth and reproduction will change, some species will probably benefit from the changes and some will not, so various systems will experience changes in the composition of species found
- A migration of new species from the south, which may mean increased competition for the native species
- The living conditions of flora and fauna that are introduced anthropogenically by means of ballast water, for example, may be enhanced with the climate change, which will increase their competitiveness in relation to the native species
- A shift in the trophic layers, affecting things such as the relationship between the pelagic and demersal fish species. Higher temperatures and lower salinity will result in an extended primary production season, and favour the species that graze on algae in contrast to the demersal species such as plaice, Dover sole (*Solea solea*) and other flatfish.

In general, the species that will be influenced the most are the species living at the edge of their range, such as cod, sprat (*Sprattus sprattus*) and plaice (MacKenzie, & al., 2002).

There is no simple answer to the question, how the ecosystems in the oceans will react to a change in climate.

The Baltic Sea

The Baltic Sea is particularly vulnerable. A Swedish study (Graham, 2004) describes the change in the inflow from rivers. All the scenarios for climate change project an increase in the inflow from rivers in the northern part of the Baltic Sea, and a reduction in the southern part. It is difficult to conduct an environmental impact assessment of the change in nutrient inflow, but the reduced inflow from the southern, more intensively farmed areas, may produce a positive effect on the nutrient balance in the Baltic Sea. An increase in the northern, more extensively

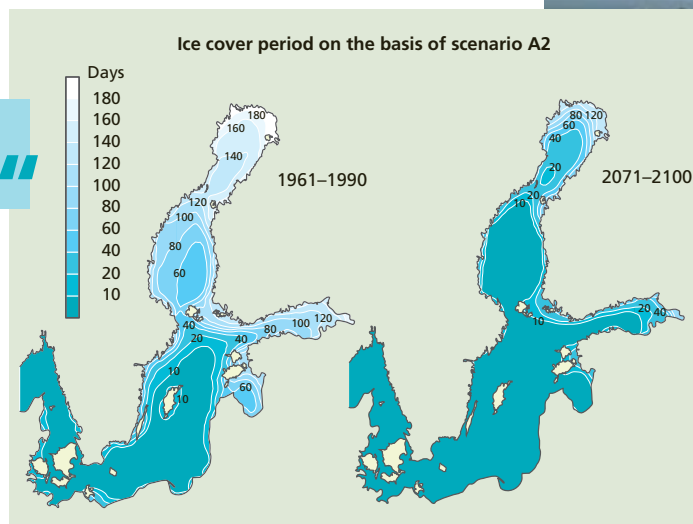
used area will not increase the inflow of nutrients. However, the climate change may very well lead to a change in farming and land use, and increase the leaching in the winter months, thereby neutralising the above effect.

The future for nature is thus uncertain, as biological systems are complex, and their dynamics and mechanisms are non-linear. This complicates the management and sustainable use of nature and its resources. One solution may be to manage the areas with an expectation of a wide range of possible future developments for nature and the climate.

The Baltic seal and the Saimaa ringed seal

There are two subspecies of the ringed seal in the Baltic region, the Baltic ringed seal (*Phoca hispida botnica*) and the Saimaa ringed seal (*Phoca hispida saimensis*). The latter is endemic to Lake Saimaa in Finland. The reproductive success of both species is dependent on a stable ice cover. Projections of the future ice cover show an average reduction of 83% (fig. 18). The Gulf of Bothnia, the Finnish Bay, the Bay of Riga and the outer parts of the Finnish archipelago are projected to become free of ice in the future. The only area with a stable and suitable ice cover for the seals will then be in the northern part of the Gulf of Bothnia. This will be fatal for the Saimaa ringed seal, and critical for the Baltic ringed seal (Markus Meier & al., 2004).

Photo: Ole Malling



Figur 18

The ice cover period – today and in 70 years (After Bernes 2003).

Ice cover models for the Baltic Sea foresee dramatic changes.

Realising and acknowledging the anthropogenic influences on biodiversity helps to clarify the possibilities of preserving and sustaining biological diversity. The following outlines the motive and reason for sustaining and protecting the biodiversity of nature.

Biodiversity and ecosystem services

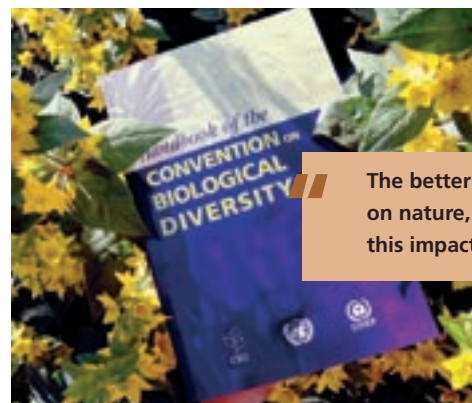
The Convention on Biological Diversity (CBD) defines biological diversity as the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part (CBD Handbook 2003).

Ecosystems provide many goods and services that are essential for human survival and wellbeing. Ecosystem services can

be classified in many ways. One classification system adopted by the Millennium Ecosystem Assessment is shown at the end of this chapter. The relative importance of various ecosystem services varies from region to region, but they are of crucial importance to human existence in all areas. Ecosystem services are worth billions of dollars annually (Costanza & al., 1997). However, most of the services are not traded in markets, and carry no price tags to alert society about their supply, or even their loss. The economies of the Nordic countries are also based on ecosystem goods and services, and ultimately the biodiversity behind them.

The relationship between different components of biodiversity and ecosystem services is very complex. Ecosystem functioning may be sensitive to biodiversity at some levels and scales, while being insen-

Photos: Marna Mikkelsen



The better we understand our impact on nature, the better we can control this impact.

sitive at other levels and scales. For example, the relationship between species diversity and ecosystem productivity is still debated. In addition to species diversity, genetic diversity within populations is also important for allowing continued adaptation to changing conditions by means of evolution, and ultimately, for the efficient provision of ecosystem goods and services. Likewise, diversity among and between habitats, and at the landscape level, is also important in multiple ways for allowing adaptive processes to occur.



Photo: Ole Malling

Resistance and resilience

Highly functional ecosystems with great diversity may be better able to adapt to climate change and climate variability than functionally impoverished ecosystems. As ecosystems are degraded or lost, these communities become more vulnerable, because their options for change may be diminished. Experimental studies have indicated that intact, non-intensively managed ecosystems and high-diversity forestry and agricultural systems may cope better with

longterm climate variability than biologically impoverished, intensively cultivated land. Although there is a consensus that at least a minimum number of species are essential for ecosystems to function, and that a larger number of species is likewise essential for maintaining the stability of ecosystem processes in changing environments (Loreau & al., 2001), there is growing evidence to suggest that the effects of biodiversity on ecosystem processes are also heavily dependent on given levels of functional diversity, as well as the total number of species (Chapin & al., 2000). In addition, the larger the number of functionally similar species within the ecosystem (e.g. several species of trees), the greater the probability that at least some of the species will survive changes in the environment, and maintain their vital properties.

Resistance and resilience are the two elements that are essential to ecosystem functioning. Resistance is the ability of a system to avoid change, or its capacity to stay in the same state in the face of disturbance. Resilience is the rate at which the system returns to its former state after being displaced by perturbation. The ability of ecosystems to persist depends on their resilience, their resistance to change, and their capacity to migrate as a reaction to changing environmental conditions. The dominance

Biodiversity is low in the intensively cultivated land.



Photo: Maria Mikkelsen



Photo: Maria Mikkelsen

Genetic diversity is of crucial importance for the adaptability (top).

The pasque flower (*Pulsatilla vulgaris*) (bottom).



Photo: Ole Mølling

The competition for land is escalating – here the building of a road...

of long lived (e.g. trees), slow growing, stress-tolerant plants favours resistance, but their resilience in changing conditions may be low. In contrast, many types of grassland with annual plants exhibit low resistance but high resilience.

The degree of genetic variability within species can be important for maintaining ecosystem performance, and for allowing continued adaptation to changing conditions. The loss of genetic variation within species may also lead to instability in the face of a changing environment (Joshi & al., 2001). Grime & al. (2000) reported that herbaceous communities composed of genetically uniform populations appear to lose more species over time than those with more genetically heterogeneous populations. Crops with high genetic diversity tend to be more resistant to pests, etc.

Current human impacts on biodiversity

The earth is subjected to many human-induced and natural pressures that have significantly altered, degraded, displaced and fragmented habitats, often resulting in biologically impoverished landscapes (Dias & al., 2003).

The impact of these pressures varies greatly among regions and countries. On a global level, the most severe threats are ha-

– and here mining and quarrying activities.

bitat loss and degradation due to land conversion and exploitation, and invasive alien species. There is also variation in the threats in the Nordic countries. In Denmark, southern Sweden and, to a lesser extent, southwestern Finland and Norway, agricultural environments dominate a great deal of the landscape. In these areas, many natural habitats (forests, bogs and other wetlands) are often fragmented or isolated, and several of the species that are found there are rare or threatened. Building activities, several kinds of chemical pollution and the eutrophication of habitats (due to nitrogen and phosphorus) are also common. In large parts of northern

Sweden, Finland and Norway intensive forestry, the drainage of mires and the overgrowth of various grasslands and shores are common, whereas building activities are more localised. Invasive alien species are also common in the Nordic countries (Weidema 2000; <http://www2.skovognatur.dk/nobanis>).

Sala & al (2000) developed scenarios of biodiversity change for the year 2100 based on changing scenarios of atmospheric carbon dioxide levels, the climate, vegetation, land use and the known sensitivity of biodiversity to these changes. They proposed that for terrestrial ecosystems, a change in



Photo: Peter Brandt

land use followed by a climate change would probably have the greatest effect on biodiversity, while in freshwater ecosystems, biotic exchange (i.e. both unintentional and intentional introduction of organisms) would have the greatest effect. The authors stressed that the level of change in biodiversity will depend on interactions among the various drivers of the change in biodiversity. On the other hand, insufficient knowledge of these interactions represents one of the greatest uncertainties for projecting the future of biodiversity.

The survival of populations in fragmented landscapes

The distribution of species in natural, fragmented landscapes can be analysed using ecological models such as the island biogeographical model, the source-sink model and metapopulation dynamics. **Island biogeographical** theory predicts the relationship between the size of an island (or a generally isolated area surrounded by unfavourable environment) and the number of species.

The island biogeographic model also has implications for terrestrial ecosystems,

particularly with regards to the fragmentation of previously contiguous habitats. This model has been utilised when estimating the number of species disappearing as a consequence of deforestation in the tropics, for example (e.g. Groombridge, 1992). In the southern parts of the Nordic countries, forests are often like islands in a sea of agricultural lands or urban areas, whereas in the north, old-growth forests are embedded by a matrix of managed production forests. In both cases, the amount of available habitat and their ability at dispersal are important for species preferring special forest habitats. The density of populations of specialised forest species increased as the size of their habitat increased, suggesting that viable populations prefer large forest areas (e.g. Virkkala & al., 1994).

Photo: Ole Malling

The natural conditions can still faintly be seen in the intensively cultivated land.



Photo: Ole Malling

90% reductions of a certain nature reserve will half the number of species in the reserve.

A fragmented landscape.

The ratio between area and number of species

In general, the number of species increases by the area-species equation $S = cA^z$, where A is the area and S is the number of species. C and z are constants that depend on things such as the groups of organisms considered. In general, a tenfold increase in area (= amount of resources available) doubles the fauna and flora, i.e. a tenfold decrease in area causes the number of species to halve.



Photo: Maria Mikkelsen

Watercourses are well suited for migration.

Another model for the migration of species is the so-called **stepping-stone model** (Kimura & Weiss, 1964), a close cousin to the island biogeographic model. The stepping-stone model presumes that species only migrate to the nearest, most suitable habitat, whereas the island biogeographic model assumes that species migrate freely between all available habitats. The stepping-stone model is often used in genetics to explain and understand the genetical differences between populations.

According to the **source-sink model**, sources are demographically viable sub-populations, whereas sinks are demographically unviable sub-populations of a particular species. Sinks will ultimately become extinct unless they receive immigrants from the source. Preserving source populations is of utmost importance.

A fourth important ecological model is **metapopulation dynamics**. Metapopulation is a collection of local populations of a species that interact by means of individuals moving among populations (Hanski, 1998; Hanski & Gilpin, 1997). The fragmentation

of habitats may cause a metapopulation structure comprised of local populations in isolated habitat patches of a previously continuous landscape. A metapopulation experiences continuous extinction and re-colonisation of the local population on the various patches. The number of habitat patches available should, however, be much greater than the number of inhabited patches at any particular time. The metapopulation persists if the colonisation rate of patches exceeds the extinction rate.

In general, ecological theories predict that there are **critical thresholds** for the preferred habitat of a given species. Only some of the habitat patches preferred by a species are occupied at any given time (metapopulation dynamics). This means that the number of habitat patches or areas available must be considerably greater than the number of patches or areas actually inhabited at any given time. The quality of the inhabited patches is important. If all of a species' inhabited patches are sink populations, the



Photo: Ole Malling

A monoculture in the form of a field of wheat.

population may not survive without recruits from a source population (the source-sink model). A decrease in habitat area causes a decrease in the numbers of species preferring this habitat (the island biogeographical model or species-area dependence). The survival of a species is largely dependent on the ability of a species to disperse, i.e. the capacity of individuals to move into the habitat where survival is high and offspring production is possible.

In a world dominated by humans, na-



Some researchers stress that the fragmentation of habitats worsens the effects of climate change.

tural or semi-natural ecosystems are embedded in tracts of unsuitable landscape, and populations of species restricted to these habitat types are spatially dissected. Such populations often display characteristics of a metapopulation structure, which is an indicator of a moderate degree of fragmentation (Opdam & Wascher, 2004). Opdam & Wascher (2004) conclude that fragmentation multiplies the impact of climate change on the integration of metapopulations by means of several mechanisms. Fragmentation causes population decline and extinction, loss of genetic diversity, etc. The effects of large-scale disturbances are also greater in more fragmented habitats, causing temporary extinction at the regional level. Smaller densities and a lower percentage of habitat occupation all decrease the resilience of populations to increased environmental disturbance, including climate change. Fragmented landscapes can block a population's responses to climate change by hindering its dispersal to more favourable habitats, thus leading to local extinction (Opdam & Wascher, 2004).

Especially in fragmented landscapes, extra attention needs to be paid to land use and cultivation methods in the matrix, in order to strengthen the connections between the habitats. A more extensive use of forests and wetlands would, for example, support migration possibilities between major nature reserves.

One of nature's goods and services – recreation.



Ecosystem services

The most crucial ecosystem services provided by biodiversity are:

- **Supporting services** (services that maintain the conditions for life on earth): Soil formation and retention; nutrient circulation; primary production; pollination and seed dispersal; the production of oxygen; the provision of habitats
- **Regulation services** (benefits obtained by regulating ecosystem processes): the maintenance of air quality; climate regulation; water regulation; flood control; erosion control; water purification; waste treatment; detoxification; human disease control; biological control of agricultural and livestock pests and diseases; storm protection
- **Provisioning services** (products obtained from ecosystems): Food; wood fuel; fibre; biochemicals; natural medicines; pharmaceuticals; genetic resources; ornamental resources; fresh water; minerals; sand and other non-living resources
- **Cultural services** (non-material benefits obtained from ecosystems): Cultural diversity and identity; spiritual and religious values; knowledge systems; educational values; inspiration; aesthetic values; social relations; a sense of place; cultural heritage; recreation and eco-tourism; communal; symbolic

(Ref: Millennium Ecosystem Assessment 2003 Report.

6 Guidelines and recommendations

A temporary technical group of experts on climate and biodiversity, AHTEG (Ad Hoc Technical Expert Group 2003), identified in a report in 2003 several possibilities for adaptation to climate change that reduce the negative impacts of climate change on biodiversity. The adaptation options include activities aimed at conserving and restoring native ecosystems, managing habitats for rare, threatened and endangered species and protecting and enhancing ecosystem services.

Nature's goods and services are numerous, and of considerable importance for human survival. However, there is also extensive pressure on nature. The climate change, with its unpredictable and complicated effects, is increasing this pressure. The climate effects mentioned in chapter 4 include an imbalance in the ecosystem, the immigration of new species; enhanced living conditions for introduced species, increased erosion, match/mismatch, increased emission of nutrients, etc.

Photo: Peter Brandt

There are a number of possibilities to reduce the negative effects of climate change.

International conventions and directives such as the Convention of Biological Diversity, the EU Habitats Directive, the Bonn and Bern Conventions commit the signatory countries to protecting and preserving the designated species and habitat types. Indirectly, this means that politicians and managers have to relate to, and deal with, the climate change and its effects. The question is how, and to what extent, the countries should relate, adapt, mitigate and plan for the possible future effects of the climate change (Meir & al., 2004).

It may well be necessary to prioritise the management of nature and its resources in a way that integrates the climate, in order to support nature, or at least to avoid undermining its resistance, resilience and dynamic development.

Activities

With the uncertainties that exist in relation to climate development, many economists recommend long-term, flexible planning, especially with regards to investments in building and construction with a lifetime way into the future, etc. The point is to ensure sustainable functioning under a wide range of climate conditions, and in extreme weather situations (Tol & al., 1998).

View from Torgatten, Brønnøysund, Norway.

The same guiding principle applies to nature management. We must apply caution when managing nature and its resources, in order to optimise nature's resistance, resilience and adaptability in relation to both the gradual climate changes and to extreme weather situations. This should be done by minimising other stress factors on nature, by preserving the present biodiversity (Wuetrich, 2000), by increasing the integration of biodiversity considerations in administration and legislation, and by securing migration possibilities for flora and fauna in a changing climate.

Adaptation strategies

The above-mentioned prioritising and adaptation strategies are called "planned adaptation" (Carter & al., 2003). A more passive adaptation strategy, where the adaptation is planned and implemented *ad hoc*, as the climate effects emerge, is called "reactive adaptation".

An example of planned adaptation is the creation and preservation of migration corridors between nature reserves. The corresponding reactive adaptation would be the active translocation of the species to more suitable habitats, or to *ex situ* conservation, perhaps for later introduction to a suitable habitat. Planned adaptation may reduce the

negative effects of the climate change, whereas the results of the reactive adaptation strategy would seem more uncertain. A rise in sea level, with serious consequences in the event of extreme weather, is another example where it would be wise to apply planned adaptation. By keeping coastlines free of buildings and other installations, the coast can provide migration possibilities for nature, and a buffer zone for the rising sea, thus reducing the negative impact of the rise in sea level (Fankhauser, 1999).



Photo: Maria Mikkelsen

Coastal zones should be kept as buffer zones in case of sea level rise.

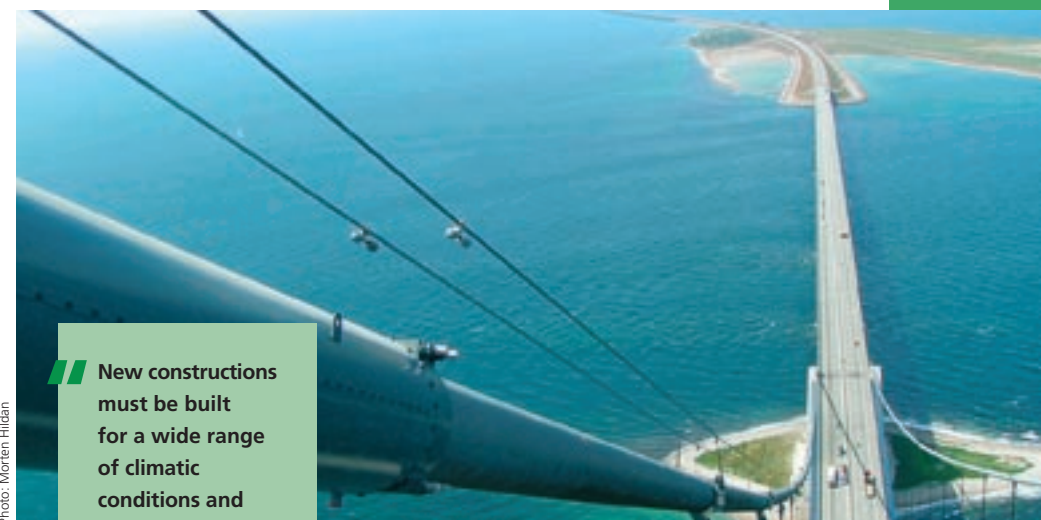
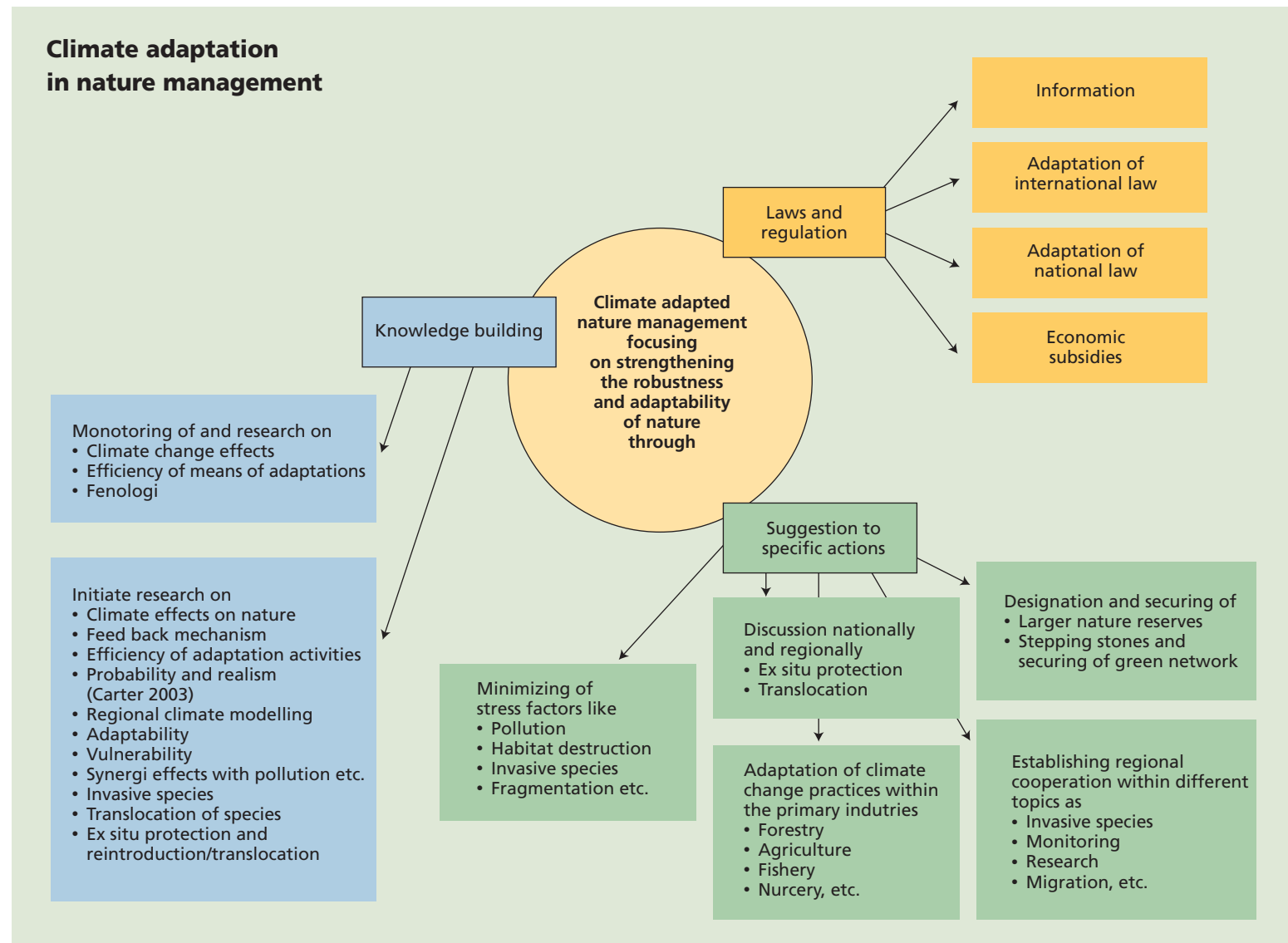


Photo: Morten Hildan

New constructions must be built for a wide range of climatic conditions and extreme weather.

Figure 19
Possibilities for climate adaptation within nature management and the primary industries – including research, adapted practice, legal work etc.



Planned adaptation

Figure 19 illustrates a number of possible actions and strategies for adaptation to climate change by means of direct and indirect strengthening, or at least less weakening, of nature. The suggestions are directed towards all kinds of nature managers and politicians. Most of the suggestions require more knowledge about efficiency, prices and feasibility in relation to prioritising resources and strategy planning (Carter & al., 2003). This economic assessment lies outside the scope of this report. The suggestions should be seen as a first attempt at drawing up a catalogue of ideas on how to integrate climate change into the management and use of nature and its resources.

The suggestions are categorised into four groups:

- **Research and knowledge building**, which closely monitors the development of the climate and its effects, and thus adds to the relevance and topicality of different adaptation initiatives.
- Proposals for tangible **actions** which directly or indirectly support the development of nature's resistance, resilience and adaptability.
- The adaptation of **laws and regulations** that regulate behaviour and practice in the direction of a more desirable behaviour with regards to climate changes.
- The establishment of **regional cooperation** in order to coordinate the work on adaptation strategies and the monitoring of climate changes.

Knowledge and research

More knowledge improves modelling and projections on climate changes and their effects, as well as the development and testing of adaptation strategies and technologies (Fankhauser, 1999). It is crucial to test the adaptation activities in order to assess their efficiency. This can only be done by testing them against long-term series of relevant indicators (Pullin & al., 2004). Moreover, studies of earlier climate effects are also relevant in the processing of projections and models for the future development of the climate (Næss & al., 2004). There is a need for knowledge about the different ecosystems' reactions to a changing climate, especially that of the sea (Richardson & Schoeman, 2004). It is important to identify indicators and key functions that are sensitive to the climate, and the effect the climate change has on them, on the functionality of the ecosystems, and on dynamics and structure. Furthermore, there is a need for knowledge about:

- The interaction between climate change and other pressures on nature
- The dynamics of potentially invasive species and invasive species (Dukes & Mooney, 1999)
- The economic and biological consequences of invasive species
- The functionality of ecosystems
- The function and physical form of biological corridors

- The consequences of the translocation and/or reintroduction of species
- The climate sensitivity of chosen species as an illustration of the effect and tendencies
- The processing of a sensitivity index for ecosystems, species and genetic resources
- The population biology and dynamics of species
- The identification of isolated natural areas offering no possibilities for migration
- The processing of ideas for solutions and tools for policymakers, nature managers and stakeholders, for the development of a multifunctional landscape (Opdam & Wascher, 2004.)

Time series are important for the analysis and assessment of adaptation actions.

The climate change challenges researchers and others to re-evaluate.



Photo: Maria Mikkelsen

Designation of larger nature reserves

The traditional tools for nature conservation include the designation of national parks, nature reserves and conservation areas. A change in climate will affect the range of a number of species and ecosystems, thus changing the value of a given area as a guaranteed preservation of species and ecosystems (Burns & al, 2003; Rodrigues & Gaston, 2001).

The size and geographical range of nature reserves must be discussed in light of the effect the changing climate will have. The IUCN (The World Conservation Union) recommends that 10% of a country's land

Climate change demands a more dynamic and interactive form of nature protection.



Photo: Peter Brandt

be conserved as a nature reserve. Few countries have followed this recommendation – a recommendation that the climate change has made even more relevant (Kramer & al., 1997). One element that should be considered is that climate change can leave a habitat unsuitable for the species or ecosystems it was originally designated to preserve. This situation changes the predictability of the traditional idea of nature conservation, and requires a far more dynamic and interactive form of nature management. Three elements should be considered when developing nature reserves and initiatives for local and/or regional nature conservation:

- Sufficiently dense networks, distributed along the most important natural geographical gradients – especially climate gradients
- Nature reserves of a size that allows the climate gradients to be given the best possible representation within the area – this is especially relevant in areas with topographical gradients such as in the western and northern parts of Norway
- Connecting corridors along the climate gradients.

Nets of nature reserves along the most important nature geographical gradients contribute to securing migration possibilities in the landscape.

Securing connecting corridors

As already mentioned, the adaptation of flora and fauna to climate changes by means of migration to more suitable habitats in a fragmented landscape – which in prehistoric times was plants' normal reaction to a changing climate (Bradshaw & McNeilly, 1991) – requires migration options along the climate gradients (CBD report no. 10). These possibilities for migration usually exist in the form of stepping-stones, or corridors that make it possible for species to move to new habitats, but the migration possibilities for flora and fauna can also be enhanced by optimising the matrix, or the intervening land, as suitable surface for migration. If consideration is given to biodiversity when managing the matrix, this consideration to biodiversity and nature's need for migration possibilities can be combined with the use of the open land for forestry, farming and urbanisation.

Different organisms and species make different demands on stepping-stones or corridors, depending on their individual ability to spread, and on their biology (cf. the island-biogeography theory) (Opdam & Wascher, 2004; Hannah & al., 2002). Connecting corridors also support nature's abi-

lity to adapt by securing the exchange of genes between populations, and thus the genetic basis for evolutionary adaptation. However, each individual species has individual demands for the form a connecting corridor should take in order for it to actually work as a corridor (Haddah & al., 2003).

Marginal types of land, such as humid areas in river valleys and other low-lying areas, could be designated and managed as

connecting corridors. These areas are often potentially rich in biodiversity. Moreover, humid land is a source of CO₂ when the soil is turned over for drainage, and it is known to be rather expensive to keep in use because of the continued need for drainage. Thus, using humid areas as connecting corridors could produce a win-win situation, as it would reduce expenses for drainage, reduce the emission of CO₂ and meet a demand for connecting corridors.



Photo: Maria Mikkelsen

Isolated species regardless of climate change

The stag beetle (*Lucanu cervus*) used to be widespread in Denmark and the southern part of Sweden. The stag beetle's larva inhabits old oak or beech trees for 5 years, after which time the larva pupates and transforms into the adult form. The fully-grown male measures around 9 cm, and the female 5-cm. The beetle only exists in its adult form for one month, during which time it needs to mate and lay eggs in old trees.

The stag beetle has now disappeared from Denmark, but a few populations remain in the southern part of Sweden. The reasons for this decline are that land with deciduous forest has been reduced in favour of coniferous forest, and that old trees are increasingly rare.

New, or rather re-established, populations in Denmark and Sweden would come from the few populations in the southern part of Sweden, or the populations found in the forests in Germany. Due to its adult size and limited lifetime, the stag beetle is not able to move far from the specific tree where it lived as a larva. Therefore, even if a climate change helps the survival rate of the beetle, the stag beetle will have problems re-establishing itself in suitable habitats because of its limited ability to spread. If there was limited space between its potential habitats, the species would have much better opportunities to spread, and might inhabit the entire region.



Photo: Maria Mikkelsen

It has become harder for the stag beetle to spread in a modern landscape with distances between the old oak trees – here a possible exception north of Copenhagen in “Dyrehaven” with many old oak trees.

Preservation of species

Translocating species

Actively moving endangered species from one area to another in order to preserve them is a tangible option called translocation. Previously, this option has been looked at with great scepticism, because the consequences are difficult to control, and even more difficult to predict. The basic objective of translocating a given species might result in quite different effects than originally anticipated. This is still a crucial uncertainty, and one of the major drawbacks of this option. However, with the fast and unpredictable development of the climate, and the effects thereof, translocation may prove to be a last resort in preserving a given species or ecosystem. It is therefore important that nature managers debate this possibility, and the risks it entails.

The habitats of the mnemosyne butterfly will probably be reduced significantly.



Photo: Ole Andersen

Two examples of introduced invasive species in the Nordic countries – rugosa rose (*Rosa rugosa*) (left) and arion lusitanicus (far left).

One example is the mnemosyne butterfly (*Paranassius Mnemosyne*) which inhabits forests in Germany and the Netherlands. This zone is expected to be somewhat reduced by the climate change, thereby posing a threat to the butterfly. The zone will decrease as the climate envelope shifts north to Denmark and southern Sweden. In such cases, a translocation might be considered. However, this would require extensive evaluation of the risks, preparation and monitoring, during and after the translocation, in a regional cooperation.

Introduction of new species

The current flora and fauna in the Nordic countries can be separated into two groups: species that have immigrated naturally and species that have been introduced by man. The former group is called native species,

and the latter group is called introduced species.

Some of the introduced species may be harmful, if they suppress native species, or if they have extensive economic consequences for society. It is said that species like these, act invasively or are invasive. Species have been introduced for, as long as there have been people in the Nordic countries. Nevertheless, the speed with which species have been introduced is now faster than ever, because of increased global trade and transportation. Most introduced species do not have much chance of survival in the wild, but there is a chance that a climate change might create suitable living conditions for some of them. History shows that an introduced species may live in an area for a long time before exploding in numbers and acting invasively.

One such Danish example is the giant



Photo: Maria Mikkelsen



Photo: Maria Mikkelsen

hogweed plant (*Heracleum mantegazzianum*), which had been in the country for about 100 years before it started acting invasively. Today this plant is causing enormous trouble financially, botanically and because it is poisonous on contact. Other examples of invasive species are species such as the gastropod, *Arion lusitanicus* (*Arion lusitanicus*), which is widely dispersed in the Nordic countries and still spreading.

With a climate change leading to increasing temperatures and an imbalance in the ecosystems, more and more introduced species can be expected to experience improved living conditions, and may act invasively.

Minimising other stress factors

It is generally assumed that the adaptability and resistance of a species or an ecosystem is the result of the total stress on that species or ecosystem. Just like humans, other species are more or less susceptible to diseases and pests depending on their general condition.

One species of water beetle (*Dysticidae*), for example, inhabits small ponds of low water quality found within its main range. In the periphery of its range, however, the beetle is very sensitive to nutrients, and inhabits only ponds of very high water qua-

lity (Holmen pers. com.). This illustrates the importance of minimising other stress factors, in order to strengthen the resistance and adaptability of nature.

The impressive, but invasive giant hogweed.



Photo: Maria Mikkeisen

More than 20 million DKK (Euro 2.7 million) and 25 man-years are used every year to fight the giant hogweed in Denmark.



Photo: Highlight

Adjusting common practice in relevant industries

It would be a good idea to adjust the common practice within relevant primary sectors such as farming, forestry and fisheries to sustain the foundation for both businesses and nature. Farming is likely to require an increased use of pesticides against infesters and weeds because of the longer growing season, the immigration of new pests, new crops, etc. Fisheries will need to discover adapted species to catch, which may mean that their tools and fishing seasons will need to be adjusted. The forestry sector may need to use more mechanical rinsing of weeds, because of the increased spreading of pests and the change in crops (MICE, 2004).



Photo: Highlight

The fishery industry and agriculture may very well benefit from adapting to the changing climate.

Before such climate-dependent changes are implemented, however, we should bear in mind that these industries depend on nature's continuous dynamism and functionality. It ought therefore to be in the industries' interest to adjust common practice to a changing climate by taking biodiversity and nature into consideration as a functional basis.

Forestry is an industry that is attentive to climate change. The industry already includes the possible effects of a climate change in its planning. A study from 1999 shows that 11 % of the private forest owners in southern Sweden have made changes in their planning in anticipation of a changing climate (Blennow & Sallnäs, 2002). In Denmark, climate changes have been integrated in the national forestry strategy in order to produce a more sturdy and profitable forest (The National Forest and Nature Agency, 2005).

Adapting legislation and regulations

In Norway, a new bill on nature conservation has been submitted (NOU 28:2004). This law will replace the current "Protection of Nature Act", parts of the "Act on Game"

and the "Act on Fishery and Salmon", but it has a much wider target, and includes the use of all nature. With this new law, Norway will have regulation that is abreast of the other Nordic countries in respect of the protection of nature, and a better instrument for managing nature under changing conditions (Hessen, 2005).

Another example of legislation in need of revision is the "EU Habitats Directive" (92/43/EEC). According to article 6, 2: the "Member States shall take appropriate steps to avoid the deterioration of natural habitats and the habitats of species in the special areas of conservation, as well as disturbance of the species for which the areas have been designated, in so far as such disturbance could be significant in relation to the objectives of this Directive". The Member States are committed to protecting and restoring a "favourable conservation status" for the species and habitats that are included in the directive. The corresponding protection of wild birds is accomplished in the "EU Birds Directive" (79/409/EEC). The effects of climate change on nature complicate the attainment of the objectives of these directives. The Member States and the Commission are aware of this, and expect to discuss this topic in the near future.

Moreover, the demands made of different national regulations, such as the various forms of Environmental Impact Assessments, may need to be revised. It is especially important for long-term structures and initiatives to adapt to a changing climate and to extreme events. It is suggested that a national synopsis of the relevant laws and regulations needing to integrate climate effects be drawn up. This should be one of the first steps on the road to climate-integrated nature management.

Mitigation

Mitigation activities cover activities that aim to reduce the concentration of greenhouse gasses in the atmosphere. This can be done by measures such as developing clean technology (CDM), adjusting common practices, or by creating so-called sinks that use or bind CO₂. In connection with such expensive and comprehensive initiatives, it is very important to pay due attention to biodiversity. In order to ensure conservation and the sustainable use of nature, is it im-

portant to identify the political initiatives and subsidies that generate unwanted effects. Such initiatives and subsidies must be reviewed and changed in relation to climate changes.

A potential synergy effect may be obtained by coordinating the various different mitigation activity initiatives and projects. As a minimum, however, it is important to make sure that the activities do not counteract the objectives of other conventions. One example of an action that has an unintentional negative effect on nature, is when bogs are afforested to create a CO₂ sink with great harm to the biodiversity. The afforestation of a fallow field would not give the same negative effect at all, as the biodiversity in a fallow field can, and will, easily be replaced elsewhere.

Climate adaptation and nature considerations should accompany each other – including economic programmes, clean development activities etc.

There are still very clear signs of the last “storm of the century” in January 2005.

From coniferous to deciduous after a storm

A storm in Denmark and Sweden in December 1999 brought down an extensive part of primarily coniferous forest. Subsidies were subsequently given to private forest owners in Sweden, to afforest deciduous forest in areas that were formerly covered with coniferous forest. This contributed to a shift from coniferous forest to deciduous forest, which was the original type of forest in this area. Thus, this occurrence of extreme weather contributed to a shift in land-use benefiting biodiversity and nature.



Photo: Peter Brandt



Photo: Maria Mikkelsen

// The possibilities for connecting support programmes with climate adaptation initiatives are obvious. //

Subsidies

A number of primary industries in the Nordic countries are given financial support. These subsidies impose certain conditions on the industries. However, none of these subsidies currently includes an integrated climate policy. This field of economic support presents an obvious opportunity for integrating climate change into activities directly or indirectly involving biodiversity and nature. Countries should cooperate on a regional level, such as within the Nordic Countries or under the auspices of the EU, to establish lists of subsidies where the integration of climate effects and nature conservation is relevant. Demands that may be made of subsidies could, for example, include non-cultivation and/or non-pesticide use zones along watercourses, nature reserves, paths, and prehistoric monuments. Such zones already exist, but need extending and securing in view of the climate change.

Regional co-operation

Several of the above-mentioned tools and initiatives may be successfully solved in a regional co-operation, for example:

- The development of regional climate models to form a basis for projections and planned adaptation activities.
- The development of relevant climate indicators and monitoring.
- An analysis and follow-up of adaptation activities, including the prevention and control of invasive species, experiments and follow-up, the translocation of species, etc.

The climate change and the climate effects are global, regional and local, and should be solved at these levels (Hannah & al., 2002).

An example of an existing regional collaboration is the “Fennoscandinavian Green Belt” between Russia and Finland. This project includes the development of several trans-boundary nature reserves on the Russian/Finnish border. The long chain of nature reserves will cover all the bio-geographical zones from the archipelago in the Bay of Finland and Lake Ladoga, to the boreal zone and up to the sub-arctic region. This belt, covering more than 1 million ha., forms the backbone of the preservation of Fennoscandinavian boreal nature; not least in relation to climate change. This kind of trans-boundary regional initiative should be encouraged, and the matrix ought to be managed so as to enhance the possibilities of migration, thus ensuring effective connections between the nature reserves.



Photo: Magnus Fröderberg

Regional cooperation
– Nordic session in Stockholm 2004.

Conclusion

This report has presented a number of general recommendations on how to initiate planned adaptation strategies in nature management in response to climate changes. The recommendations are based on the existing and potential climate effects as listed above, and are as follows:

1. More **research** is needed, and **knowledge** needs to be acquired, about certain mechanisms of nature, including:
 - The interactions between climate change and other stress factors on nature, and the feedback mechanisms between nature, land-use, and climate. This information is essential in order to optimise projections of climate changes and nature's development, and to plan for a sustainable use of nature and natural resources.
 - Migration biology and functionality as a necessary basis for nature management, in order to secure the ability of flora and fauna to adapt by means of migration.
2. There are a number of possibilities for strengthening nature's resistance, resilience and ability to adapt by means of **tangible activities**, some of which require a certain degree of preliminary study and research. These include the minimisation of other stress factors, the securing of migration possibilities, and the adaptation of practices in relevant industries.
3. Consideration should be given to potential climate effects in the reviews and revision of **laws, regulations and subsidies**, in order to ensure, improved legislation that includes the general goals of the climate policy.
4. Most of the above "planned adaptation" activities will be optimised if they are implemented on a **regional level**. Nature management during climate changes is a trans-boundary problem, so there will be a potential boost and synergy effect with regards to knowledge, efficiency and use of resources if the regions join forces.

// Regional cooperation optimizes the effect of climate adaptation initiatives – also within nature management. //

The bluebell bellflower
(*Campanula rotundifolia*).

Photo: Maria Mikkelsen





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Conservation of Nordic Nature in a Changing Climate

Seeing that e.g. –

- plants bloom at an earlier time
- the growing season is extended
- butterfly species from more southern parts of Europe show up in the Nordic nature
- the fishermen more frequent get tropical fishes in their nets
- cold-water species like cod and plaice are reduced in numbers in the North Sea

– we observe signs of possible climate effects on nature.

Management and adaptation

If this climate change – as is the common opinion – is partly anthropogenic then this development in climate will continue towards higher temperatures, change in precipitation pattern and more extreme weather. Thus, this report suggests that nature managers and policy makers adapt the administration and management of nature and its resources to this climate development.

Tangible actions

Is it then possible to adapt to the changing climate in line with minimising the negative effects the climate change may have on nature? Yes, there are a number of possibilities. From securing the possibilities of adaptation through migration for flora and fauna; to keep the coastal zones as buffer zones and migration routes against the rising water level; to plant trees from a milder climate, but without introducing foreign species from other continents and so on.

This report points out some more or less tangible tools for adaptation, but first and foremost it addresses the advantage of, at this early point, to take the climate change and its effects on nature into account in the management and administration of nature's goods and services.

