Chapter I:
Overview of Biodiversity Status, Trends and Threats in Denmark
Introduction
It is simply impossible to give a complete and comprehensive account of the status and trends of biodiversity in Denmark for several reasons. Firstly, the issue is almost intractable due to the complexity of biological systems and the diversity of wild species. Even the comparatively simple task of recording the number of species has not been completed for Denmark. Second, biodiversity has not traditionally been considered as important enough to justify statistical monitoring of status and trends. Under these limitations, the present chapter gives an overview of known status and trends of habitats and species based on reported assessments, sample-based estimates and expert judgements. A short summary of biodiversity in Denmark is provided below, followed by a more detailed review of diversity, trends and threats for the major ecosystems of Denmark and their species.

Summary

Status
The status of biodiversity in Denmark reflects the country’s high population density and a long history of intensive commercial exploitation of her raw materials, soils, timber, water and stocks of wild species. The vast majority of the country is covered by highly modified urban, silvicultural and arable areas, where construction, cultivation and logging restricts biological diversity to a number of widespread opportunistic species that are tolerant or able to adapt to the disturbance regimes and the limited variation and abundance of natural substrates and habitats. However, the long protected coastal line, the extensive sea territory and more recent regulations to protect birds and mammals from unsustainable hunting has helped to protect large areas of important habitats and their biological diversity, including large populations of birds.

From a biodiversity perspective, forests hold the largest number of Danish species and also the largest number of threatened species. Forests cover 12% of the Danish terrestrial land area, the vast majority of which is intensively managed logged plantations with few old growth habitats and forest glades for endangered species.

The coastal and marine ecosystems must be considered the most important Danish contribution to European biodiversity, as Denmark holds a major proportion of the areas of dunes, saltmarsh and shallow marine waters, of crucial importance for specialised lichens, plants, fungi and invertebrates, as well as waterbirds, of which Denmark hosts a large globally important share of many flyway populations, e.g. East-Atlantic population of light-bellied brent goose (100%), Svalbard population of pink-footed goose (100%) and the Baltic-Wadden Sea population of common eider (86%).

Trends
Among the most important positive trends in biological diversity are the population increases shown by a number of bird and mammal species, following complete or local bans on hunting and/or an ability of these species to utilise increasingly available nutrient-rich and abundant terrestrial or amphibian vegetation (e.g. winter green fields). The enhanced abundance and nutritive quality of terrestrial vegetation owes much to the combination of increasing winter temperatures, decreasing snow cover and the high nutrient status of fertilised fields and nutrient-polluted pastures, meadows, ponds and lakes. Species falling into this category include roe deer, red deer, otter, cormorant, swans, geese and birds of prey.

Notable positive trends also relate to the area and quality of freshwater bodies. The emphasis during recent decades on the restoration of lakes and meandering streams, combined with reductions in organic and inorganic pollution, has led to positive improvements in freshwater habitat quality. Despite this general trend, the majority of Danish streams and associated terrestrial wetlands remain physically modified, polluted by nutrients and disturbed by canalisation for water diversion and drainage. The area of forest is also increasing, but despite an increasing emphasis on old growth habitats, it is questionable whether this has had
any positive impact on the amount of old growth habitat or on the diversity of woodland habitat specialist species to date.

A large number of habitat specialists have experienced long-term declines and there are no indications that this decline has been halted or reversed yet. This includes species of:

- plants, invertebrates, fungi and birds of infertile grassland, heathland, meadow, mire, fen, spring and bog habitats
- invertebrates, fungi and epiphytic lichens and bryophytes associated with dead wood and veteran trees.
- invertebrates of warm and dry bare soil habitats in fields, grasslands, heathlands and dunes.
- invertebrates, plants and epiphytes in forest glades and associated small scale biotopes, including ponds, streams, dead wood and their native vegetation of bushes, trees and herbs.
- plants, invertebrates and molluscs in oligotrophic lakes and streams.
- birds, plants and invertebrates in the fields and small biotopes of the agricultural landscape.
- marine benthic fauna.

In conclusion, the best current estimate is that biodiversity is still declining in Denmark. It should be stressed that it is a challenging task to reverse population declines that follow decades of declining habitat area and quality. First, there is a marked delay in the population response to habitat destruction for most species, especially perennial and sedentary species which may survive long after de facto habitat destruction. When habitats are restored or conditions improved, the recovery delay may be even longer, especially for species with poor dispersal ability and highly fragmented populations.

**Threats**

The major threats to biodiversity are all directly related to human land use, and include:

- Abandonment, cessation of grazing and overgrowth of open semi-natural habitats, including forest glades
- Nutrient pollution of oligotrophic habitats by leaching from agricultural fields and atmospheric deposition of nitrogen
- Logging of trees in forests and plantations
- Drainage of wetlands
- Cultivation or afforestation of remnant patches of semi-natural vegetation in the agricultural landscape and in forests
- Fragmentation and isolation of remnant habitats
- Commercial fishing (especially trawling)
- Climate change

In conclusion, the major threats to biodiversity in Denmark are continuously declining habitat quality due to eutrophication, abandonment, intensification of agricultural practices, trawling and continued high-intensity logging in forests and plantations. Climate change may advance on the list in the future, but is currently considered subordinate to the above-mentioned threats.

**Values**

There is, beyond doubt, a positive correlation between biodiversity hotspots and recreational hotspots in the Danish landscape. Extensive areas of grassland and heathland, old broadleaved forests, coastal ecosystems of dunes, saltmarsh, grasslands, beaches and lakes, streams and seas are all favoured areas for recreation, but at the same time support the majority of Denmark’s biodiversity. Despite this fact, it is hard to establish the significance of biodiversity per se, to recreational use and its value to the public. Greater value seems to be associated with the accessibility and naturalness of these ecosystems than with their biodiversity as such. On the other hand, wild species seem to hold a value to the public in themselves, being appreciated to the extent of people’s knowledge. In general, public concern
increases along a gradient from small invisible creatures to large and better known species of birds and mammals. It is not obvious that biodiversity is synergistic with commercial use. In most cases commercial use imposes the most obvious threats to biodiversity. Over the last few centuries, the extraction of food, timber and water has increased in agricultural, silvicultural and urban landscapes causing a crash in diversity. An important exception to this general pattern is the coincidence between the demands of biodiversity and society for clean drinking water and clean surface waters in streams, lakes and seas for fishing and swimming. In this case however, it is not the value placed on biodiversity per se that underlies environmental concern.

In conclusion, the major value of biodiversity to society, resides in its importance for recreation, embracing ethical, aesthetic and spiritual dimensions in their broadest sense.
Forest ecosystem

Forests cover approximately 12.4% of the Danish land area, and of this area 53% is covered primarily by conifers and 43% by deciduous trees (Nord-Larsen 2008).

Native forests types in Denmark are primarily deciduous with *Fagus sylvatica* and *Quercus robur* as the most abundant dominant trees on well-drained soils and *Fraxinus excelsior*, *Alnus glutinosa* and species of *Betula* and *Salix* in moist or wet forests. *Pinus sylvestris*, once native, disappeared regionally from Denmark, before being reintroduced and planted extensively, together with *Picea abies*. Common alien conifers include *Abies alba*, *Abies normanniana*, *Picea sitchensis* and *Pinus nigra*. *Pinus contorta* and *Pinus mugo* are important invasive species in dunes and heathlands.

Ecosystem and habitat diversity

The conservation status of 10 different forest types included in the Annex 1 of the Habitats Directive has been reported from Denmark, most recently to the EU in 2007 (Anon. 2007). The general favourable assessment reflects an assessment with particular emphasis on vascular plants. The assessment was completed for the two European biogeographical regions that Denmark has a share of.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Assessment Atlantic region</th>
<th>Assessment Continental region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wooded dunes (2180)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Luzulo-fagetum beech forest (9110)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Atlantic acidophilous beech forests with Ilex (9120)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Asperulo-Fagetum beech forests (9130)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Medio-European limestone beech forests (9150)</td>
<td>Not present</td>
<td>Unknown</td>
</tr>
<tr>
<td>Sub-Atlantic and medio-European oak forests (9160)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Galio-Carpinetum oak-hornbeam forests (9170)</td>
<td>Not present</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Old acidophilous oak woods with Quercus robur (9190)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Bog woodland (91D0)</td>
<td>Unknown</td>
<td>Unfavourable Inadequate</td>
</tr>
<tr>
<td>Alluvial forests with Alnus glutinosa and Fraxinus excelsior (91E0)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
</tbody>
</table>

Table 1. Reported conservation status of 10 forest habitat types in Denmark (Anon. 2007).

Forests and plantations also include habitats for highly specialised species, the most important being coarse woody debris (CWD), old veteran trees and forest glades. These habitats are not exclusively coupled to specific habitat types, as they are rather linked to trees and forest dynamics in general. For example forest glades may occur even in coniferous plantations, and old trees and CWD may occur in any forest type and even in semi-natural habitats of the open landscape.

The amount of CWD in Danish forests is generally low, with an average figure for 2006 of 4.7 m$^3$ per ha for Danish forests as a whole (Nord-Larsen 2008). Furthermore, there is a strong bias towards dead wood in early decay classes, a result of continuous removal of dead wood from the forest floor (Nord-Larsen 2008). In deciduous forests within NATURA2000 the average figures are considerably higher, ranging from 4.4 m$^3$ in wooded dunes to 30.9 m$^3$ per ha in acidophilus beech forest with Ilex (median 12.8 m$^3$, Ejrnæs et al. 2009). The amount of CWD in the majority of Danish forests is thus low compared to current calculations of habitat thresholds for saproxylic species (Ranius & Fahrig 2006). The most demanding saproxylic species are unlikely to thrive in logged forests, so protected reserves are needed to secure sites with near natural quantities of CWD (Ranius & Fahrig 2006). Approximately 1.4% of the Danish forest area is protected forest reserve without logging.
Large living veteran trees (i.e. those old individuals with rotten parts and hollows) are important habitats for saproxylic (decomposing wood) insects and fungi, for epiphytic (growing on tree surfaces) lichens and mosses and for hole nesting birds and mammals. The density of large trees in Danish forests is generally low. In habitat types of the Habitats Directive within NATURA2000, the mean density is 5 large trees per ha, and the median density 3 large trees per ha (Ejrnæs et al. 2009).

Forest glades, i.e. open areas inside forests with ponds, fens, meadows, grasslands or heathlands are particularly important sites for biodiversity because many species are adapted to the warm sheltered microclimate and the combination of flowering shrubs and species-rich herb flora associated with such places (Honnay et al. 2004). Likewise, many epiphyte species are adapted to the combination of high humidity and sunlight found around small wetlands surrounded by forest. Approximately 0.6% of the Danish forest area is currently managed by grazing or hay cutting in order to promote and maintain forest glades.

**Species diversity**
The forest ecosystem must be considered the most diverse Danish ecosystem. The species richness is considerable and so is the number of threatened species. Forest constitute 52% of the habitat affiliations for red-listed species (IUCN-categories: NT, VU, EN, CR, RE) in the most recent update of the Danish Red Data Book (Anon. 2008). Deciduous forests hold most red-listed species, and particularly old growth forest, forest reserves and forest glades. 25% of the red-listed species in forests have habitat affiliations with either of heathland, dry grassland, meadow or mire, stressing the importance for biodiversity of forest glades and ecotones from forest to open semi-natural habitats. Coarse woody debris is a habitat for more than 100 red-listed species in itself. From 2006, 25 selected indicator species of epiphytes and saproxylic fungi selected for their commonness and indicator value for old-growth forest habitats have been monitored in Habitat directive forests within NATURA2000 sites. The indicators were found with an average frequency of approx. 1 species per 1000 m² (Ejrnæs et al. 2009) indicating a general scarcity of old-growth habitat.

**Trends in diversity**
The forest area in Denmark has been steadily increasing from 1881 to 2006. Until 1990, this increase was entirely due to conifer plantations, but from 1990 and onward the increase has been mainly in deciduous forests and plantations. It is not given that the increase in area leads to increasing diversity of forest inhabiting species, as the particularly species-rich forest habitats such as forest glades, old-growth forests, wet forests, large trees and CWD need not follow the overall increase in area. Although the forest area increased by approx. 100% from 1800 to 2000, a recent investigation indicates a simultaneous decrease in the area of natural forest with old-growth qualities (Ibsen 2003). We have no current data-based trends for these habitats, but over the last century, extensive drainage and intensification of forestry for timber production has led to a significant net decrease in open forest glades, forest wetlands and structures related to old growth forests (Wesenberg-Lund 1939, Rune 1997).
Denmark has no long-term monitoring of species biodiversity in the forest ecosystem. Habitats directive monitoring of forest types started in 2006 and will provide trends for vascular plants and selected indicator species in the future. The only monitored species group for which we can provide long-term trends is forest birds, and for this group a composite index reveals a 16% population index increase from 1976 to 2006, but with a stable trend over the last 15 years. Compared to saproxylic species, ectomycorrhizal fungi and epiphytes, many forest birds may be considered generalists, and may therefore have benefited from the increase in the forest area over the past 15 years.

The lack of monitoring data for species-rich habitat specialist groups of the forest ecosystem, such as epiphytes, saproxylic invertebrates and fungi, ectomycorrhizal fungi and thermophile invertebrates, means that no firm conclusions can be reached with regard to trends in species diversity of the forest ecosystem. Based on expert judgment however, it is likely that the rare specialist species are declining due to a delayed negative response (extinction debt) to a long-term loss of habitats for these species, and due to a general scarcity of old growth habitats in the forests and plantations of the present day. Common species of birds and plants may be stable or even increasing due to the increase in forest area, a conversion to deciduous forest and increased emphasis on natural regeneration and sustainable forestry.
Threats to forest biodiversity
The most frequently cited threat to red-listed forest species is by far logging and removal of
trees and dead wood (mentioned for 600 species), followed by soil cultivation (229), closing
of open spaces (forest glades) by planting or dereliction (172), eutrophication (154) and
drainage (125). It may seem counterintuitive that logging and afforestation are both important
threats, but it is important to understand that both processes may destroy habitats that cannot
readily be restored. Logging does not usually produce forest glades and nor does afforestation
create old growth habitats, and if so, only after centuries. Eutrophication by nitrogen
deposition strikes forests particularly hard as they filter the air currents effectively leading to
depositions ranging from approx. 10 kg N/ha to above 25 kg N/ha, highest for coniferous
forests in high-emission regions. Despite a general decrease in nitrogen deposition, the
monitored deposition in forests is stable and usually above estimated critical loads (Nord-
Larsen 2008). The deposition in forest edges and small forests may be even higher. N-
deposition may lead to acidification, leaching of nitrate and loss of typical communities of
plants and ectomycorrhizal fungi.

Values for society
Forests are among the most important ecosystems for recreation in Denmark and therefore
also for public health. Close proximity to forests may improve the quality of life as well as
house prices: house owners’ willingness to pay for living in proximity to forests has been
found to be significant and positive, and in most circumstances exceeds the costs of
afforestation (Præstholm et al. 2002, Hasler et al. 2002). Nielsen et al (2007) found that the
public was willing to pay for replacement of stands of even-aged conifers (i.e. with no dead
trees left for natural decay) with a mixture of conifers and broadleaved trees of varying
heights, and leaving a few dead trees for natural decay.

Forest visitors benefit from the stocks of wild berries (Vaccinium spp., Rubus spp.,
Fragaria vesca, Sambucus nigra), wild edible herbs and edible mushrooms, and forests are
important hunting grounds for roe deer, red deer and fox. Forests are also important for the
collection of raw materials (such as moss, lichens, cones etc.) for hand crafts and decoration
(especially for Christmas). Forests also provide timber and firewood for society, filter clean
water to ground water stocks and may act as carbon sinks. There are, however, few proven or
straightforward links between these ecosystem services and forest biodiversity. Wood
production clearly implies the removal of an important substrate and habitat, and intensive
forestry is generally highly detrimental to biodiversity. While species-rich swamp forests may
act as effective carbon sinks, inundation on the other hand, may obstruct recreation and
logging. Features such as old and large trees and forest glades have important simultaneous
value for people and diversity.

Dry grassland/heathland ecosystems
The dry grassland and heathland ecosystems occur on infertile and well-drained soils where
recurrent disturbance prevent succession towards forest. Today, these ecosystems cover
approximately 1-2 % of the Danish land area, depending on the interpretation of “openness”
and “infertile”. Agricultural statistics have never been accurate compiled on these marginal
agricultural areas and before 1950, it was not always easy to distinguish between dry
grassland or heathland and former fields colonised by wild plants. A conservative estimate
would be that this ecosystem covered 25% of the land area in the 19th century. The ecosystem
may develop on the full range of Danish soil types, including shallow soils over rocks in
Bornholm, leached acidified sands of central Jutland, Eocene clays of E Jutland, limestone
and cretaceous chalks of S Zealand and N Jutland and the full range of moraine soils found in
Eastern Denmark. The most decisive factors for the development of different subtypes of this
ecosystem are topographical climate (slope and aspect), local climate (range of 450-800 mm
annual precipitation) and soil pH (range of 3-8). In historical times traditional husbandry,
farming and heathland management kept the areas open, but since 1800 large areas have been converted to arable land, and today the remaining fragments are facing abandonment and succession toward scrub and forest.

**Ecosystem and habitat diversity**

Eight habitat types designated under the Habitats Directive belong to this ecosystem type, and the conservation status of these was reported to EU in 2007 (Anon. 2007). Conservation status of the seven open habitat types was reported as unfavourable-bad, whereas the status of Juniper scrub was reported as unknown. Cited reasons for unfavourable status were loss of habitat due to abandonment, and unfavourable structures and functions due mainly to eutrophication and lack of recurrent disturbances, particularly grazing (Anon. 2007).

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Assessment Atlantic region</th>
<th>Assessment Continental region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry sand heaths with Calluna and Genista (2310)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Dry sand heaths with Calluna and Empetrum nigrum (2320)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Inland dunes with open Corynephorus and Agrostis grasslands (2330)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>European dry heaths (4030)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Juniperus communis formations (5130)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Xeric sand calcareous grasslands (6120)</td>
<td>Not present</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Semi-natural dry grasslands and scrubland facies on calcareous substrates (6210)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Species-rich Nardus grasslands (6230)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
</tbody>
</table>

Table 2. Reported conservation status of 8 dry grassland and heathland habitat types in Denmark (Anon. 2007).

The remaining patches of open grasslands are small and fragmented implying a risk of local extinction of populations of rare species with limited dispersal potential (fig. 3). The median size of a Danish grassland habitat inside NATURA2000 is 0.7 hectare and half of the habitat area is found in localities less than 8 hectare in extent (www.naturdata.dk, see also Fredshavn & Ejrnæs 2006). A general feature of the remaining localities is that only a minor proportion of the protected areas are in a good semi-natural condition, the remaining being impoverished due to historical ploughing or fertilization or due to ceased grazing.
Additional important habitats for biodiversity include open decalcified sand grassland, grassland-forest ecotones with thermophile fringe vegetation and specialised habitats such as herbivore dung, bare soil and solitary trees. The general scarcity of these habitats is linked to changes in agricultural practices over the last century, resulting in a general abandonment of less productive semi-natural habitats, leading to a loss of herbivore dung and open gaps of bare soil and sand for thermophile invertebrates and short-lived vascular plants (Hansen 2009). Nitrogen deposition has further forced this development, stimulating the development of denser and taller swards. Even where grazing has continued, herbivores usually now graze only in summer, when they compete with herbivorous invertebrates, but not in winter when trampling is more likely to produce gaps, and where the large herbivores switch partly to feeding on woody species.

Species diversity
After forest, the dry grassland and heathland ecosystems hold the highest number of red-listed species - 18% of all habitat affiliations mentioned for red-listed species (IUCN-categories: NT, VU, EN, CR, RE) in the most recent update of the Danish Red Data Book (Anon. 2008). The ecosystem is particularly important for invertebrates, fungi, lichens and vascular plants. Certain species groups of the ecosystem have a disproportionately large number of rare and red-listed species. Among these are butterflies, thermophile invertebrates of bare sand, dung-inhabiting invertebrates, saprophytic fungi of infertile grasslands and stress-tolerant vascular plants. While migratory species of the Birds Directive are generally in favourable conservation status with few exceptions, breeding bird species are doing less well, especially species confined to semi-natural habitats kept open by grazing – e.g. grassland, heathland, meadow, salt meadow and open mires (Pihl et al. 2003).

Diversity trends
Monitoring of the area of grasslands and heathlands only started in 2004 and does not yet provide a representative assessments of trends over time. The long-term trend is negative for certain, but the estimate of the magnitude of the decline is uncertain due to necessary
interpretations and assumptions of the available area statistics. The area of dry grassland and heathland has been estimated to approx. 15% in 1881-1888 (Levin & Normander 2008) and approx. 1-2% today as our best current estimate based on the mapping of Habitat Directive vegetation types and extrapolation to the national area (Anon. 2007). The current trend is unknown, but we suspect that the observed trend of succession from heather to grass cover in dry heaths is continuing (Fig. 4, Degt 2006) and that there is an ongoing loss of small areas (<2500 m²) within the agricultural ecosystem due to conversion of small biotopes to arable land. An additional loss of grassland and heathland is also suspected to result from abandonment and natural regeneration of forest. The area or availability of specialised habitats such as dung and bare soil is also likely to be decreasing due to abandonment and cessation of grazing as well as increasing productivity due to nitrogen deposition and global change.

![Graph showing trends in the relative cover of three major vegetation components in a Danish dry heathland from 1954-2005. Trends are derived from visual inspection of aerial photographs. Source: Degt H.J. 2006.](image)

The habitat quality of areas covered by the ecosystem is considered to be declining due to cessation of grazing and increased productivity leading to a succession towards tall herb communities, scrub and forest with loss of habitats for specialised species. Repeated inventories of grassland habitats confirm this assessment (Mønster 2005, Jelnes & Lange 2002). Scrubs of thorny bushes are an important habitat that typically occurs in mosaic with open grassland, and such scrub is the only grassland habitat type that has shown an increasing trend (Mønster 2005). Increasing efforts to reintroduce domestic grazers in the ecosystem only partly counteracts the impacts of abandonment and eutrophication.

There is a general lack of long-term datasets showing trends in the diversity of key species groups representing the diversity of the ecosystem. A focused inventory of grassland habitats on the island of Funen in 2004, revealed that 14 out of 38 covered red-listed vascular plants should now be treated as regionally extinct, and the inventory also revealed a dramatic decline of selected indicator species (Vinther & Tranberg 2005). Arnica montana, an indicator species for species-rich acidic grassland that was previously known from 41 localities, only survives now at one locality (Vinther & Tranberg 2005). The national monitoring programme was only started in 2004, so although this can be expected in the future to reveal trends in indicator species among vascular plants. However, for other important species groups such as
butterflies, dung beetles, thermophile beetles, bryophytes, fungi and lichens, future trend estimates will have to rely on regular updates of the Red Data Book. A best guess estimate would be that rare species confined to the infertile end of the ecosystem as well as habitat specialists of dung and bare ground are continuing to decline leading to a net loss of diversity.

**Threats**
The most prominent threats to red-listed species from the ecosystem as revealed from the Danish Red Data Book are abandonment and succession towards forest (mentioned for 263 species), cultivation (167) and eutrophication (156). In general, eutrophication reinforces the impacts of abandonment, leading to rapid increases of biomass, changes in soil temperatures and loss of thermophile invertebrates and stress-tolerant low growing plants, bryophytes and lichens. Other disturbances than grazing may counteract these processes, especially in dry heaths where the regeneration of heather requires recurrent disturbance, e.g. by burning or sod cutting. Such disturbances have also diminished as they are no longer part of normal agricultural practices.

Climate change may be expected to lead to considerable northwards distributional shifts of native species, and due to the fragmented habitats of the ecosystem, there is a severe risk that losses by local extinction will exceed gains by immigration. A net loss in the case of Denmark is however not certain, as the northern latitude of Denmark implies that the potential species pool should be expected to increase with increasing temperatures.

Increasing temperatures, a lengthier growing season and increasing CO₂ content of the atmosphere may also have negative effects on the diversity in the ecosystem, as it may reinforce the competitive exclusion of stress-tolerant plant species by more competitive generalist species.

**Values for society**
Grasslands and heathlands are popular recreational areas in Denmark. They are generally accessible to the public and especially the larger heathlands and grassland complexes of some regions are among the most frequently visited natural areas in Denmark. Apart from recreation and physical exercise, the ecosystem also provides stocks of wild berries, mushrooms and game animals. The ecosystem also provides grazing for livestock, especially robust breeds of sheep and cattle and infiltration of clean water to ground water stocks. In fact, a larger proportion of the precipitation infiltrates to ground water in grasslands and heathlands than under a canopy of trees, especially evergreen conifers.

The value of these habitats, of the landscape itself, can be appreciated reasonably well by members of the public, and preservation of such landscapes is highly valued (Jacobsen et al 2008). Biodiversity protection apparently contributes a minor amount to this value. However, by simply naming and hence ‘iconising’ only a few species, dramatically higher value estimates were obtained than when using just a quantitative description of the area preserved (Jacobsen et al 2008).

This conclusion indicates that there is no straightforward link between the landscape and habitat value and biodiversity. This is also the case with ecosystem service: livestock productivity is low when grazing is restricted to infertile swards, and additional feeding may lead to unwanted eutrophication. A recent positive trend in the formation of local grazing unions by volunteering caretakers is an excellent example of potential synergies between biodiversity and the ecosystem services of biodiversity. But for the majority of livestock owners the conflict between biodiversity and growth targets prevails, with the consequence that biodiversity conservation using reintroduced commercial livestock depends on significant agricultural subsidies.
Wetland ecosystem

The wetland ecosystem includes all moist to wet terrestrial areas that are not under cultivation. Forested wetlands are included in the forest ecosystem and coastal wetlands in the coastal zone. Agriculturally improved meadows are not included in this chapter, but considered as part of the agricultural ecosystem. The Habitats Directive types (Table 3) cover most of the variation in Danish wetland ecosystems, with the exception of acidic fens and naturally nutrient-rich meadows and reed beds. Non-forested wetlands occur in areas where a periodically or permanently high water table, nutrient deficient ground water and/or grazing and mowing promotes wetland herbs and mosses and prevents the succession towards forest. The ecosystem may be naturally species-rich as in alkaline fens or species-poor as in raised bogs, Cladium fens and wet heaths. Wetlands have been extensively drained and presently occupy only a fraction of the hydrological potential.

Ecosystem and habitat diversity

The conservation status of the Habitats Directive types was reported as unfavourable except for tall herb fringes where lack of data led to unknown status. The estimated national area of these protected wetland types amounts to 0.6% of the Danish land area (Anon. 2007). The area of meadows and mires mapped according to the Danish Nature Protection Act amounts to 4.4% of the land area, but this estimate is far too high as it also includes wooded mires, willow scrubs and agriculturally improved meadows (BLST 2009).

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Assessment Atlantic region</th>
<th>Assessment Continental region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Atlantic wet heaths with Erica tetralix (4010)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Molinia meadows on calcareous, peaty or clayey-silt-laden soils (6410)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Hydrophilous tall herb fringe communities (6430)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Active (and degraded) raised bogs (7110/7120)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Transition mires and quaking bogs (7140)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Depression on peat substrates (7150)</td>
<td>Unfavourable Inadequate</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Calcareous fens with Cladium mariscus (7210)</td>
<td>Not present</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Petrifying springs with tufa formation (7220)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Alkaline fens (7230)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
</tbody>
</table>

Table 3. Reported conservation status of 9 wetland habitat types in Denmark (Anon. 2007).

The diversity of wetlands is closely related to the hydrological regime, and particularly the amount of pure unpolluted ground water and rain water. The Danish landscape is extensively drained, such that large quantities of water are led directly to freshwater streams and that the retention of fresh water by small local upland mires has disappeared as a feature of most agricultural landscapes. Water abstraction in densely populated areas approaches or even exceeds the estimated sustainable resource (fig. 5). Rain water is polluted by nitrogen oxides and ammonia, and the deposition of nitrogen exceeds the critical loads of oligotrophic wetland habitats such as raised bogs, transition mires and wet heaths. The implication for the wetland ecosystem of these pressures is that both the area and the habitat quality of Danish wetlands are seriously impacted by suboptimal quantities of clean water.
Species diversity
Terrestrial wetlands are important habitats, especially for specialised vascular plants, mosses, invertebrates and birds. Approx. 10% of the habitat affiliations for red-listed species (IUCN-categories: NT, VU, EN, CR, RE) in the most recent update of the Danish Red Data Book refer to terrestrial wetlands (Anon. 2008). Particularly vulnerable groups include plants, mosses and invertebrates of alkaline springs and fens, invertebrates of bogs and transition mires as well as specialised wetland bird species.

Diversity trends
Habitat statistics on trends in the area of infertile terrestrial wetlands are not available. A best guess would be a present decline of open meadows, mires and bogs due to abandonment of grazing and hay cutting and invasion of tall herbs and woody species. In many places a suboptimal hydrological regime due to ditching, evergreen plantations, water abstraction and eutrophication by surface water and nitrogen deposition aggravates the situation. Water abstraction has been stable at 600-700 mill m$^3$ per year for the last 7-8 years and this is approx. 25% lower than in the 1990’s. With regard to water chemistry, nitrate and pesticide are found frequently as ground water pollutants, but whereas nitrate content shows a small decline from 1990’s to 2006 in the upper ground water layers, pesticides are found more frequently today.

From 1990 to 2009 wetland restoration has been prioritised in the national environmental management programme. In this period, an area of wetlands amounting to 0.4% of the total Danish land area has been restored. A major part of this area has been restored as lakes or meandering streams, but terrestrial wetlands have also been restored.
Documentation of the precise effects of restoration programmes on biodiversity is sparse. A recent report covering restored terrestrial wetlands show that 45% of the affected terrestrial area was previously considered as terrestrial meadows and mires, and of this area almost 90% was considered agriculturally improved (Hoffmann et al. 2006). It is doubtful whether inundated former fields and improved meadows will eventually support specialised species confined to infertile wetland habitats. On the other hand, generalist species, including mammals, such as otter and the reintroduced beaver, as well as wetland birds thriving in the transition zone of lakes and fjords may benefit from the expansion in area of wet habitats. Preliminary monitoring indicates a significant short-term increase in the bird fauna diversity following wetland restoration, including the immigration of a number of rare birds, but it is not well documented that this increase will persist on a long-term basis (Hoffmann et al. 2006).

It is worthwhile mentioning a recent positive trend caused by a reduction of local water abstraction by closing of commercial fish farms. These are typically located in the vicinity of alkaline springs, which represent many of the richest ground water discharge points in the Danish landscape.

Denmark has no long term monitoring programme to assess the trends in species diversity of the wetland ecosystem. However, a number of recent inventories may be compared with previous evidence of species distribution and thereby provide reliable assessment of the trend direction. Saxifruga hirculus is a stress-tolerant plant species and an important indicator of undisturbed alkaline springs with a steady release of clean, cold ground water into the spring area. The species was once widespread over the country with 90 documented localities (presumably only a fraction of the real number) of which 15 were on the islands. Today the species only persists in 7 localities, all in Jutland (Wind 1999, Anon 2000). The species has disappeared from 20 localities within the last 20 years and its population trend within the remaining 7 localities has been assessed as declining in 3 localities, stable in 3 localities and unknown in 1 locality. Saxifruga hirculus is restricted to open alkaline spring areas, and its decline may be seen as a long-term response to habitat destruction and deterioration by drainage, water pollution, abandonment and water abstraction. The trend indicated by Saxifruga hirculus is reflected in a recent wetland inventory of the island of Funen, which revealed that out of 188 mire areas that were formerly known as localities for red-listed plant species, only 57 localities remain as such (Vinther & Tranberg 2002). The decline does not only apply to red-listed species, but also more common species sharing the characteristics of a vulnerable species: slow-growing species of low stature, confined to infertile soils. Trollius europaeus, once a widespread species, was found to have disappeared from 72% of 88 formerly known localities.

While migratory species of the Birds Directive are in favourable conservation status with few exceptions, breeding bird species are doing less well, especially species confined to semi-natural habitats kept open by grazing – e.g. grassland, heathland, meadow, salt meadow and open mires (Pihl et al. 2003). The overall assessment is thus a declining trend for biodiversity in the wetland ecosystem.

**Threats**

The most important threat to the wetland ecosystem is lowering of the water table by drainage and water abstraction. This is also reflected in the Red Data Book, where this threat is the most frequently mentioned (148 species) followed by cultivation (81), abandonment and succession toward scrub and forest (52) and eutrophication (42). It is likely that the threat from eutrophication is underestimated in the Red Data Book as this threat is more difficult to detect by visual inspection of habitats than the other threats. The claimed threat of cultivation on the other hand is surprising, as remnant valuable localities ought to be protected against cultivation by the Nature Conservation Act. Nevertheless, sample-based evidence indicates that small remnant wetlands are still being taken into cultivation, sometimes without the required permission (www.naturbeskyttelse.dk).

There is a long tradition of excavation of sphagnum peat in bogs and mires, and this activity continues today in a number of degraded bogs. In Northern Jutland the average
excavation of bog peat over the past 16 years amounts to 300,000 m$^3$ per year, primarily in areas neighbouring active raised bogs and degraded bogs with opportunities for regeneration (Mortensen 2008). While the excavation does not take place in existing active raised bogs, the threat certainly applies to degraded bogs, as the removal of preserved peat layers obstructs the opportunities for future bog regeneration.

**Values for society**
Wetlands are important habitats for broadly valued wildlife including birds, mammals, plants and butterflies, but also for less known species of invertebrates and mosses. Acidic mires and bogs also provide wild edible berries (Vaccinium spp.). The intact peat layers of bogs and mires are important archives of prehistoric landscapes and historical changes are reflected in the composition of the peat and its content of well-preserved pollen and macrofossils as well as archaeological artefacts. Wetlands with well-developed peat layers also constitute important carbon-stocks, and actively accumulating peat lands are important carbon-sinks. Furthermore, the retention of water in the landscape in upland mires as well as brook valleys and flood plains may prove an important part of future adaption to climate change in order to avoid flooding of farmland and urban areas.

While there is a definite positive synergy between ecosystem service and biodiversity when it comes to reduction of the drainage of existing wetlands, there is also a potential conflict if wetland restoration is implemented by flooding of terrestrial wetlands with nutrient-polluted surface water. A particular conflict resides in the large areas of low-lying cultivated fields and pastures. In these areas, considerable economic interests are linked to the deposition of manure from livestock, in order to comply with the demands for harmony between livestock and area. With respect to the ground water dependent terrestrial ecosystems, there is a direct conflict between biodiversity and the society’s need for abstraction of clean drinking water.

The results of a Danish valuation study of wetland restoration in the Store Aamose area indicate that the value of restoration is high, but also that the value of access to this particular wetland area is low for people not living in close proximity. This indicate that people may find it valuable to know of a high nature content in an area or in wetlands in general, even if they do not themselves visit these areas (Lundhede et al. 2005.)
Coastal ecosystem

The Danish coastal ecosystem is unique and diverse. It is unique because of the 7,000 km long dynamic coast line, continuously reshaped by erosion and deposition, with succession in build up areas, lagoons and salt lakes. Also, the extensive areas of open dunes and salt marshes constitute a major proportion of the European area of these systems. The coastal ecosystem is highly diverse, as most of the variation in inland habitats is also present here, in addition to the specific shifting dunes, shingle beaches and salt marshes.

Habitat diversity

The coastal zone includes 14 primarily terrestrial habitat types of the Habitats Directive, and the area of these has been estimated to cover 2% of the land area (Søgaard et al 2008). Conservation status is unknown or not evaluated for 7 types due to lack of data, favourable for 2 types and unfavourable for 5 types.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Assessment Atlantic region</th>
<th>Assessment Continental region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual vegetation of drift lines (1210)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Perennial vegetation of stony banks (1220)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Vegetated sea cliffs of the Atlantic and Baltic coasts (1230)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Salicornia and other annuals colonising mud and sand (1310)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Spartina swards (1320)</td>
<td>Not evaluated</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Atlantic salt meadows (1330)</td>
<td>Unfavourable</td>
<td>Unfavourable</td>
</tr>
<tr>
<td>Embryonic shifting dunes (2110)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Shifting dunes along the shoreline with Ammophila (2120)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Fixed coastal dunes with herbaceous vegetation (2130)</td>
<td>Unfavourable Inadequate</td>
<td>Unfavourable Inadequate</td>
</tr>
<tr>
<td>Decalcified fixed dunes with Empetrum nigrum (2140)</td>
<td>Unfavourable Inadequate</td>
<td>Unfavourable Inadequate</td>
</tr>
<tr>
<td>Dunes with Hippophae rhamnoides (2160)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Dunes with Salix repens ssp. argentea (2170)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Humid dune slacks (2190)</td>
<td>Unfavourable Inadequate</td>
<td>Unfavourable</td>
</tr>
<tr>
<td>Coastal dunes with Juniperus spp. (2250)</td>
<td>Unfavourable Inadequate</td>
<td>Unfavourable Inadequate</td>
</tr>
</tbody>
</table>

Table 4. Reported conservation status of 14 coastal habitat types in Denmark (Anon. 2007).

Among the reasons compromising the conservation status of the coastal ecosystem is anthropogenic modifications of the natural dynamic processes involving erosion and deposition by waves and wind. These natural processes create the unique features and habitats of saltmarsh, shorelines, cliffs and dunes.
Grazing by large herbivores is important for the maintenance of species-rich habitats in e.g. saltmarsh, dune slacks and dune grassland. Abandonment of grazing in the coastal zone has led to extensive re-growth and a scarcity of open infertile habitats as well as feeding areas for coastal birds. This process reinforces the dampening of erosion processes by plantations and invasions of invasive conifers and deliberate planting of Ammophila in order to stabilize shifting dunes. Salt meadows have been extensively drained by ditches, protected by dikes and agriculturally improved by fertilization, resulting in species poor habitats of limited value to plants, invertebrates and birds (with the exception of geese and swans).

**Species diversity**
The coastal zone is particularly important for specialised birds feeding in shallow water, lichens in grey dunes, herbs in dune slacks, saltmarsh and steep coastal slopes and specialised invertebrates and fungi of the open dune and grassland habitats. Approx. 8% of the habitat affiliations for red-listed species (IUCN-categories: NT, VU, EN, CR, RE) in the most recent update of the Danish Red Data Book refer to coastal ecosystems (Anon. 2008), but this is likely to be underestimated, as species-rich habitat types such as calcareous grassland, alkaline fen, xerothermic scrub and coastal slope forest are not included in this estimate.

**Diversity trends**
Over the past 30 years changes in food availability (winter green fields), mild winters and also adaptation of wild species to increased terrestrial foraging, has led to increasing numbers of geese, swans and cormorants in the coastal zone. The development is not positive for all groups of wild birds: while migratory species of the Birds Directive are in favourable conservation status with few exceptions, breeding bird species are doing less well, especially species confined to semi-natural habitats kept open by grazing – e.g. grassland, heathland, meadow, salt meadow and open mires (Pihl et al. 2003).

A recent regional investigation of saltmarsh in Funen (Vinther & Tranberg 1999) revealed an extensive decline of rare plant species. Of 33 investigated red-listed species previously recorded in the region, 8 were found to have disappeared, 22 to be declining and 3 species to increasing. Common to the increasing species was a lack of adaptation to grazed saltmarsh, 50% of the investigated localities had lost previous populations of red-listed species.

With regard to the invasive scrub Rosa rugosa, monitoring of fixed coastal dunes with herb vegetation revealed a significant increase of the frequency of the invasive rose from
2004–2007 (Ejrnæs et al. 2009). This result stresses that the extensive expansion of the rose in the coastal zone over the last 50 years is far from over.

A changing attitude to natural dynamics over the last decades has led to increasing restoration by removal of plantations and invasive conifer scrub in dunes as well as a general relaxation in the construction of physical barriers and maintenance of anthropogenic measures against erosion along the coast line. The full effect of these changes remains undocumented however and it is unknown whether it counteracts the spontaneous colonisation of dunes and cliffs by invasive as well as native woody species.

**Threats**

Among the most important threats to the coastal ecosystem biodiversity is loss of natural disturbance caused by marine and wind erosion as well as cessation of grazing. Climate change imposes a particularly grave future threat because expected sea level rise may lead to significant loss of low altitude coastal habitats. Furthermore the protection of private property by the construction or enforcement of dikes may lead to coastal squeezing with partial or complete loss of the terrestrial low-lying part of the coastal ecosystem. Agricultural improvement by drainage and fertilization continues to be a threat to habitat quality and nitrogen deposition is a threat to the infertile dune habitats. In some areas water abstraction and lowered ground water tables may be a threat to ground water fed fens and meadows along the coast.

The expansion of invasive species, particularly Rosa rugosa and Pinus mugo remains a threat to herbaceous dune and grassland habitats and their associated invertebrate fauna. Disturbance by humans and dogs and predation by fox of remote coasts are important threats to birds and seals breeding near the coast (e.g. Holm & Laursen 2008).

**Values for society**

The coastal zone is important for recreation. The entire Danish population uses the coasts for swimming, playing and celebration in the summer time. In other seasons, coasts are popular for long promenades. The extensive coastal dunes and plantations are important areas for collection of wild berries and mushrooms and for hunting. The coastal zone is important for educational purposes including biology and geology and they are important areas for research in ecology and geomorphology. The coastal ecosystem provides opportunities for grazing of livestock in saltmarsh and dune grasslands. Considerable economic interests are represented in the coastal zone, with its importance for tourism and for values associated with houses situated in the coastal zone. While there is a positive feed back between recreational value, natural dynamics and biodiversity, there are also a number of conflicts between biodiversity and acknowledged values. These include the disturbance of nesting and feeding birds by tourists, unrestrained dogs and hunting (Holm & Laursen 2008), and the threat that natural processes of wind and wave erosion poses to private property. This conflict between biodiversity and private interests should be predicted to intensify with expected sea level rise. Also the invasive Rosa rugosa, while threatening coastal biodiversity, has added utility value to the coasts, as the fruits and perfumed petals are very popular for domestic use.

**Marine ecosystem**

The Danish marine ecosystem spans the brackish Baltic Sea to the salty North Sea and covers twice the area of the terrestrial territory. Marine waters exhibit considerable variation in depth, salinity, turnover of water and exchange of gases with the atmosphere. Large areas also have restricted water renewal rates and consequently are vulnerable to eutrophication and oxygen depletion. The marine ecosystem provides important habitats for fish, birds, marine mammals, zooplankton, phytoplankton, macroalgae and benthic invertebrates.

**Habitat diversity**
Eight habitats of the Habitats Directive are primarily marine, and their habitat distribution is estimated to cover approx. 10% of the marine territory (Table 5). The conservation status was assessed as unfavourable for 6 types, favourable for 1 and unknown for 1 type (Anon. 2007). The unfavourable assessment is mainly due to low habitat quality caused by eutrophication, oxygen depletion zones and physical disturbances by e.g. trawling or stone fishing. Denmark has a major share of unique marine areas, namely the shallow Wadden Sea the brackish Baltic Sea, and the shallow waters around the Danish islands.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Assessment Atlantic region</th>
<th>Assessment Baltic/Continental region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandbanks which are slightly covered by sea water all the time (1110)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Estuaries (1130)</td>
<td>Favourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Mudflats and sandflats not covered by seawater at low tide (1140)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Coastal lagoons (1150)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Large shallow inlets and bays (1160)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Reefs (1170)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Submarine structures made by leaking gases (1180)</td>
<td>Unfavourable</td>
<td>Unfavourable</td>
</tr>
<tr>
<td>Submerged or partially submerged sea caves (8330)</td>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Reported conservation status of 8 marine habitat types in Denmark (Anon. 2007).

Species diversity
The most important species are overwintering migratory waterbirds of which a major part of the global flyway populations of several species of swans, ducks and geese use the Danish sea territory and adjacent coasts. Breeding birds feeding on mussels, fish, seaweeds and sea grass in the shallow waters, pelagic fish, algae, benthic invertebrates and marine mammals are also important components of species diversity. Three resident marine mammals of the Danish sea territory are protected by the Habitats Directive, namely grey seal, harbour seal and harbour porpoise. The conservation status of these were assessed as favourable for harbour seal and unfavourable to the two other species of which the harbour porpoise show a significant declining trend. Species richness of invertebrates in marine areas is very high, in the Danish inner waters, >500 species, although there are major variations between local areas (Josefson and Hansen, 2004). Unfortunately only a part of these species habitats are embraced by the Habitats Directive.

Diversity trends
Eutrophication of the marine ecosystem has been in decline over the last 20 years, but this decline has not yet resulted in a significant improvement of marine habitats or their species diversity (Dahl & Josefson 2009). In general, oxygen depletion zones are still abundant in the inner water bodies, Secchi depth is unchanged, and the vertical and horizontal distribution of sea grass does also not show a positive response. The lack of obvious positive recovery may be due to a significant recovery delay time or the influence of increasing water temperatures. The local species diversity, alpha richness, of the benthic fauna in Kattegat, Øresund and Bælthavet has decreased by 50% during 1994-2007. The cause has yet to be determined, but the reduction is not related to low oxygen concentrations. The possibility remains that it could be due to changes in the cycling and deposition of organic material or to physical disturbances from trawling activities (Dahl & Josefson 2009). Populations of water birds feeding on mussel beds and/or sea grasses and sea weed where these remain intact are generally thriving, but the submerse vegetation in several shallow fjords show indications of habitat loss.
Threats to marine diversity
The major threats to marine macro-organism species diversity are eutrophication, commercial fishing and by-catches, physical disturbances of habitats by trawling, hunting and climate change. Increasing temperature may for instance speed up oxygen consumption and increase the risk of oxygen depletion in the bottom of the water column.

Values for society
The marine ecosystem has considerable economic value for commercial fishing, and in addition recreational value for water sports and leisure activities, including non-commercial fishing and hunting as well as sailing and swimming. There is a strong synergy between the protection of ecosystem functioning by reduction of eutrophication and the commercial and other values associated with the biodiversity of the ecosystem. However the human exploitation of the ecosystem also creates a significant pressure on biodiversity components, most notably fish stocks, reefs and bird populations. The disturbance by humans at sea (sailing) and in the transition zone of sea and land, also conflicts with the breeding of birds and seals.

Freshwater ecosystem
The freshwater ecosystem comprises ponds, lakes and streams. The variation in the abiotic environment in terms of size of water bodies, turnover of water, nutrient content, pH and the quantity and fluxes of water in streams cause a significant variation in habitats and species composition. Anthropogenic modifications of streams and eutrophication of lakes have been decisive for the shaping of diversity.

Habitat diversity
The Habitats Directive include 5 types of lakes and one type of stream (Table 6), all of which were assessed to be in unfavourable conservation status in 2007 (Anon. 2007). These 6 habitats cover the majority of the freshwater ecosystem in Denmark with regard to area as well as variation. The estimated area of habitat types in Denmark amounts to 2%, with the streams travelling a total distance of 64,000 km.

Due to physical modification and eutrophication, the rare examples of unmodified streams and oligotrophic lakes hold a particularly large number of species that have otherwise disappeared from the freshwater ecosystems.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Assessment Atlantic region</th>
<th>Assessment Baltic/Continental region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligotrophic waters containing very few minerals (3110)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Estuaries Oligotrophic to mesotrophic standing waters (3130)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Hard oligo-mesotrophic waters with benthic vegetation of Chara spp. (3140)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Natural eutrophic lakes (3150)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Natural dystrophic lakes and ponds (3160)</td>
<td>Unfavourable Bad</td>
<td>Unfavourable Bad</td>
</tr>
<tr>
<td>Water courses of plain to montane levels (3260)</td>
<td>Unfavourable Inadequate</td>
<td>Unfavourable Inadequate</td>
</tr>
</tbody>
</table>

Table 6. Reported conservation status of 6 freshwater habitat types in Denmark (Anon. 2007).

Species diversity
Freshwater habitats are important for invertebrates including molluscs, dragonflies, beetles, benthic invertebrates, amphibians, vascular plants, fish and bats. A relatively large proportion
of the Danish Habitats Directive species are freshwater species, indicating the heavy pressure by anthropogenic pollution and physical modification there has been on these habitats. The assessment of conservation status of freshwater species reveals that common generalist species of amphibians, fish and mammals are generally in favourable status, while rare and more specialised species of invertebrates, molluscs and fish are primarily in unfavourable status (Anon. 2007).

**Diversity trends**

Danish freshwater habitats are in a process of recovery following long-term efforts to reduce organic and chemical pollution as well as nutrient loads. As a consequence, the nutrient concentration in Danish lakes is generally decreasing, and the Secchi depth and distribution of macrophytes plants is increasing, all indicating improving habitat quality (Jørgensen et al. 2009). The improvement is however significant mainly for the most polluted lakes, indicating the major challenge in further nutrient reduction and restoration of natural nutrient levels. Furthermore available trends are from large lakes, and a recent inventory of smaller lakes revealed low habitat quality as measured by nutrient and chlorophyll content of the water (Jørgensen et al. 2009). Much the same positive trend has been observed for streams where the stream fauna index revealed a significant increase in species indicative for clean oxygen-rich water. From 1990 to 2009 wetland restoration has been prioritised in the national environmental management programme. In this period, an area of wetlands amounting to 0.4% of the total Danish land area has been restored. Besides the increased area, wetland restoration also involved the removal of barriers for fish migration in streams, and restoration of the physical properties of streams. Some of the generalist freshwater species are responding positively to the improved habitat quality and increasing wetland area, e.g. otter, and common bird and amphibian species (e.g. Anon 2005). Despite the overall positive trend in the freshwater ecosystem, habitat quality is still heavily impacted by eutrophication and physical modification and barriers in most Danish lakes and streams, and a large number of macrophytes and animal species have disappeared from their former localities and not been able to recover and reproduce again following environmental improvements (e.g. Riis & Sand-Jensen 2000).

**Threats**

Judged from the Red Data Book, the most important threat is drainage, possibly due to a number of species living in ponds vulnerable to drainage and levelling. Other important threats mentioned are eutrophication, cultivation and fragmentation. Physical modification and obstructions of streams are other important threats to biodiversity. Climate change is an important future threat, as increasing water temperature may impose a direct threat to a number of cold water species and an indirect threat through its impacts on primary productivity and food webs in lakes. Invasive alien mammals, such as the American mink and the raccoon dog, pose a particular threat to the diversity of wetland birds and native mammals.

**Value for society**

Freshwater bodies have important values in terms of fishing, hunting and recreation. Canoeing and lake promenades are popular activities as well as swimming in clean lakes. Freshwater resources also serve as drinking water for grazing livestock. Another ecosystem service of streams, lakes and ponds is the humidification of the local climate, not only for humans, but also for neighbouring terrestrial habitats and species vulnerable to desiccation such as lichens, fungi and epiphytic bryophytes. The ecosystem service of the most obvious commercial interest today is the drainage and diversion of water from low-lying agricultural fields and agriculturally improved meadows, and this service is in direct conflict with the habitat quality and habitat area of streams and mires in the stream valley. Another potential conflict relates to livestock grazing that on the one hand supports the diversity of grazed fens, mires and grasslands, and on the other hand implies a risk of increased soil erosion to streams and lakes.
Agricultural ecosystem

The agricultural ecosystem covers approx. 60% of the Danish land area (Levin & Normander 2008). Rotational fields cover the major part of this area, but set aside fields and small biotopes such as hedgerows, dikes, field boundaries, scrubs, solitary trees as well as improved meadows and grasslands constitute the habitat backbone for most of the biodiversity of the ecosystem.

Habitat diversity

Habitat diversity of the agricultural landscape is today closely related to the coverage and habitat quality of uncultivated small biotopes. This situation has changed dramatically over the last 50-60 years, where increased nutrient content, pesticides, improved cultivation techniques and high-yielding crops has constrained the abiotic variation in rotational fields to an extremely narrow interval. Few rotational fields today suffer from nutrient limitation and water stress or inundation, and crops are consequently high, dense and monotonous, leaving few opportunities for wild species. The vegetation composition of permanent pastures has also been agriculturally improved and consists now of a few reseeded high-productive species of grass and clover. Remnant habitat patches are heavily impacted by nutrient pollution from neighbouring fields, and biodiversity hot spots are often very small, and therefore vulnerable to changes in land use. Among the important habitats of the ecosystem are xerothermic sandy set aside fields, permanent pastures and meadows lining or surrounding wetlands, ponds and coasts, small woodlands, solitary trees, large stones in dikes, and ponds. Besides these specialised habitats, the agricultural landscape, because of its large extent, remains an important habitat for space-demanding species of birds of prey and mammals.

Species diversity

Of all the red-listed species habitat affiliations, agricultural habitats constitute 3.5% (anon 2009). The majority of the species are associated with the small biotopes, surrounding cultivated fields. Particularly well-represented among the red-listed species are bumble bees, beetles, birds and lichens. Species associated with bare soil caused by inundation or desiccation and species associated with other infertile habitats are still important components of the agricultural landscape but they have become increasingly uncommon.

Diversity trends

The quest for large rational fields has led to a rapid turnover in small biotopes with destruction of old biotopes and creation of new. The net loss of hedgerows and ponds has been reversed, but the overall loss of habitat continuity is difficult to cope with for plants and invertebrates with limited dispersal ability. Also conversion of remnant small biotopes to new ones implies a risk of increased nutrient status, when new biotopes are established on former agricultural fields.

Repeated inventories of small biotopes neighbouring rotational fields has revealed an extensive loss of grassland, heathland and meadow species and increased abundance of competitive and ruderal species as well as woody species (Jelnes & Lange 2000, Tranberg et al. 2002). The reported causes for these changes are eutrophication and cessation of grazing and the result is a dramatic change in the species pools of the Danish landscape with long-term consequences for successional processes and cascade effects through the following trophic levels.

Farmland birds show a long-term decline to 60% of the population sizes 30 years ago. Reported causes for this decline are intensified cultivation, effective chemical and mechanical control of weeds and insects, long-term loss of wet biotopes and eutrophication.

In 2008, changed agricultural policy led to the re-cultivation of 80,000 ha of former set aside, and this area is expected to increase in 2009. There are no data on the biodiversity...
of these set aside areas, but it is obvious that resumed cultivation will lead to further decline of biodiversity in the agricultural ecosystem (Berthelsen et al. 2008).

The agricultural ecosystem has always been important for generalist species, especially large space-demanding species such as roe deer, red deer and birds of prey. While the deer species show a long-term increasing trend, other specialised farmland species such as hare and partridge show alarming declines. The decline of the little owl has driven it close to national extinction.

Among the positive trends in the agricultural ecosystem are the increasing area of deciduous hedgerows with high frequency of native woody species, the increased number of restored ponds and the area of organic farming that has resumed a positive trend in 2007 after five years of decline.

Based on the documented trends for farmland birds, for brown hare and for vascular plants of small biotopes, and the anecdotal trends of declining populations of butterflies, bumble bees and beetles, it is reasonable to conclude that there is an ongoing negative trend in the biodiversity of the agricultural ecosystem.

Fig 7. Trend in the population index based on 22 farmland bird species using the criteria proposed by EBCC’s (European Bird Census Council). Source: Danish Ornithological Society (DOF), 2007.

**Threats**
For the 12 red-listed bumble bees, changed agricultural practices and cultivation of habitats are listed as common threats. The rapid turnover of small biotopes may be detrimental to these species due to the destruction of nesting sites and the change in the composition of the vegetation. In general the most important threats are eutrophication, abandonment of formerly grazed semi-natural habitats, pesticide application and mechanical weed control, rapid turnover of small biotopes and re-cultivation of former uncultivated areas.

**Values to society**
The main ecosystem service of the agro-ecosystem is food production. It is however a very narrow range of wild species in the ecosystem that supports this production, including the soil fauna and microbiota thriving in nutrient-rich and heavily disturbed agricultural soils and providing the ecosystem service of nutrient cycling. The vast majority of species are severely limited in diversity by the intensive production, and declining diversity is closely coupled to increasing productivity. A number of generalist species are thriving in the nutrient-rich agricultural landscape, e.g. deer and geese, and to an extent where they induce conflicts due to harmful effects on crop productivity. A related conflict is the hostility of the pig industry...
towards wild populations of wild boar and the obstruction of re-introduction or de-domestication of horse, cattle and European Bison in natural reserves by agricultural policies.

**Urban ecosystem**

There is no such thing as a well-defined urban ecosystem. Areas covered with infrastructure, buildings, parks and lawns also provide habitats for wild species, but these habitats are typically analogues to the habitats described from the other ecosystems. Urban areas occupy approx. 10% of the land area in Denmark, and the total area of road verges is comparable to the remnant area with semi-natural grassland, and much less fragmented (Jelnes & Lange 2002).

**Habitat diversity**

Urban areas are often less intensively used than rotational fields and forest plantations, except for areas of concrete and asphalt. Important habitats for wildlife are old parks with old scrubs and veteran trees with hollows, gardens with a variety of native bushes, large solitary trees along roads, ruderal areas free of pesticides, large stones in dikes and around gardens, as well as open sheds and towers for nesting of mammals and birds. The exposed infertile mineral soils of abandoned quarries and new highways offer opportunities for species of open grassland habitats. Parks and gardens have the potential of a forest glade, as trees and bushes surround the open sunlit spaces inside gardens and parks. The forest glade potential in gardens and parks is unfortunately rarely realised, as the controlled mown lawns are species-poor and the woody species are often alien species with limited value for biodiversity. Despite this, the frequency and diversity of native shrubs and trees as well as the opportunity for nesting and hibernation sites may often exceed that of plantations and arable landscapes.

**Species diversity**

Urban areas constitute 2.5 % of the habitat affiliations of the red-listed species (anon. 2008), almost as much as the agricultural landscape, despite its lesser distribution. Urban areas are important for rare invertebrates, fungi and birds. Urban areas are also important for mammals such as bats, hare, squirrel, fox, and beech marten. Abandoned quarries are important as realised and potential refuges for forest glade and grassland species that have declined dramatically in the commercial forests and agricultural landscape, e.g. thermophile insects, including saproxylics (butterflies, beetles, hoverflies, bees). Also, fungi associated with rich, undisturbed mull soils that develop in warm microclimates in old scrubs have important hot spots in gardens and parks. The partial or complete absence of hunting in combination with the heterogeneous urban landscape offer good opportunities for birds and mammals, such as hare, fox, squirrel and beech marten.

**Diversity trends**

Urban areas are steadily increasing in extent, but there is no monitoring of the trends of diversity within urban areas. Assumed positive trends relate to increased awareness about the value of native trees and bushes, the value of old trees and to restrictions on the use of pesticides in gardens and public parks. A well-documented trend is the significant recovery of epiphytic lichens on solitary trees following the decline of acidifying sulphur dioxide emissions from power plants. There is also anecdotal evidence of increasing populations of brown hare and fox in the urban landscape.

**Threats**

Threats to biodiversity include effects of pollution, disturbances and intensively controlling garden practices in parks and gardens. The logging of solitary trees and removal of scrub with old-growth qualities in parks and gardens are amongst the major threats to urban biodiversity. Also the deliberate re-seeding of un-vegetated areas with lawn grasses seriously limits the
diversity of urban areas. In some urban or suburban areas, the density of free ranging domestic cats is so high that it effectively limits the diversity of small mammals, breeding birds and reptiles.

Values to society
There is a considerable societal value associated to the wild plants and animals as well as the open natural spaces (mires, lakes, parks, woodlands) of the urban landscape. The biodiversity and natural habitats of the urban landscape are essential for recreation and public health.

However, not all urban biodiversity is synergistic with public value. Among the potential conflicts is the correlation between the density of wild mammals and the risk of passing of serious infectious diseases to humans. Also the invasion of houses by mammals (bats, mice, rats, marten) and the invasion of urban areas by colonies of noisy birds (e.g. rooks) cause frequent conflicts.

Literature
Anon. 2007. Danmarks bidrag til EU i henhold til artikel 17 i EF Habitatdirektivet:
http://www.blst.dk/Naturbeskyttelse/Beskyttedeomr/Naturtyper/Arealopgoerelse_over_beskyttede

Literature
Danish Ornithological Society (DOF), 2007.


