Photo: CDanmark

4.3 Biological diversity

4.3.1 Introduction

Denmark is one of the countries whose nature is most affected by intensive land use. In an historical perspective this is the result of developments over the past 100-200 years, with the decline of Danish nature being primarily attributable to expansion of farmland and forest acreage and intensification of management, but also to expansion of built-up areas, the road system and quarries at the cost of the natural ecosystems in particular.

Many areas have thus radically changed character due to effectivization of agriculture, including the drainage of wetlands and arable land, conversion of extensively grazed grasslands to cultivated fields and the enhanced use of commercial fertilizers and pesticides. To this can be added an indirect effect of more intensive agriculture, namely atmospheric deposition of nitrogen, which has contributed to overall deterioration in the state of the countryside.

The natural conditions are an important co-actor in this development. Denmark lies on the border between two bioclimatic regions, the Atlantic and the Continental. The country forms the threshold between the Baltic freshwater and brackish water areas in the east and the salty marine areas in the North Sea and Atlantic Ocean in the west. The shallow marine waters are bottlenecks on the bird migratory routes between the summer breeding grounds in the north and the southern winter quarters. Within close proximity of each other, the country also contains varied landscape elements and soil conditions of different quality. In addition, the climate is changeable with considerable regional differences. As a consequence of these conditions, Denmark contains a large number of different plant and animal species relative to its size. It is thus estimated that there are about 30,000 native and anthropogenically introduced or adventive species, excluding bacteria, unicellular algae and certain lower animal groups.

During the period 1960–1990, nature management in Denmark was characterized by a growing understanding that nature and natural resources could not tolerate society's markedly intensified use of the land. The industrially oriented exploitation of our natural resources for agriculture, forestry and fishery led to acknowledgement of the need for active conservation of biodiversity, both internationally and nationally. At the international level, that period saw the adoption of a number of conventions aimed at protecting wetlands, birdlife and other animals and plants. The past decade has been greatly influenced by the debate on sustainable development.

The efforts of the international community to conserve nature led to the 1992 Rio Convention on biological diversity, which was also strongly influenced by the sustainability approach. The EC Habitats Directive and the Danish Protection of Nature Act represent more specific and binding implementation of the sustainability concept in the nature area. In Denmark, formulation of a national action plan for the protection of biological diversity was initiated based on the work of the Wilhjelm Committee. In order to ensure more responsible management of the natural resources, the EU Summit Meeting held in Gothenburg in 2001 decided to "protect and re-establish habitats and natural ecosystems as well as to halt the loss of biological diversity by 2010".

4.3.2 Background and issue

The Biodiversity Convention sets the overall framework for formulation of Denmark's national strategy for conservation of biodiversity. The term is defined as follows:

> *"Biodiversity is understood to mean the diversity of living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological structures of which they are part: The diversity thus encompasses both the variation within and between species and the diversity of the ecosystems".*

Biodiversity is thus the variation of life-forms in our surroundings irrespective of whether these are natural or man-made. The term is understood to mean not only the number of different species, but also the variation in the different levels the species are part of: The variation in the genetic pool within a species or population; the complex of species that help define an ecosystem; the biotopes and ecosystems that comprise major geographic landscape units; and at the upper level, the whole of the global biosphere, the stability of which the underlying levels completely depend on. Conservation of a species' genetic variation can thus be a precondition for its future possibilities to adapt in a changing environment. However, it will often be the adaptability, stability and changes to the ecosystem of which the species is a part that determine whether its evolutionary potential has the chance to be expressed.

From a global and evolutionary perspective, the majority of the species that have existed on the Earth over the ages have become extinct. Species adaptation, extinction and the development of new species through natural selection ensure life and the maintenance of nature's stability. In the long term, then, preventing species from becoming extinct is not a goal in itself. What is currently the cause of concern is rather the markedly enhanced rate at which the extinction of species is progressing due to increased human activity, enhanced exploitation of natural resources and the narrowing of many species' genetic variation, which deteriorates their adaptability and evolutionary potential. On the global scale, the trend is towards increasingly regulated nature and less wild nature to tell the story of evolution and the succession that takes place when man does not intervene.

Photo: NERI/Anna Bodil Hald

Biodiversity can be considered a valuable natural resource that is at our disposal, and which is a precondition for human activity. Others consider all life-forms as equal, and protection of them should be prioritized so as to avoid loss of species. One can also consider man as an integral part of the surrounding nature, however, and view biodiversity as a product of man's impact on the Earth over the millenniums. In relation to the latter view, the present and future challenge is to ensure that this co-existence can continue in a sustainable manner.

The protection of nature and biodiversity is thus not solely a question of protecting plant and animal species. Protection of nature is also a question of ensuring well-functioning ecosystems that provide society with a number of services. Examples are the water cycle, recirculation of nutrients, degradation of waste products, climate regulation, pollination of cultivated plants, production of fertile topsoil, etc. In other words, nature conservation and protection of ecosystems are necessary steps in sustainable development aimed at meeting the needs of present and future generations.

The nature quality concept

There is no objective opinion as to which species or habitats are most worth preserving. Internationally, however, the consensus is that there should be room for considerable biological diversity at all levels as a "biological precautionary principle", and that there should be room for nature's own processes to unfold.

According to the EC Habitats Directive, Denmark is required to ensure a "favourable conservation status for a number of habitat types and species". This is a formulation that implicitly presumes agreement on which quality criteria can or should serve as the basis for defining a favourable conservation status. In the Habitats Directive, this is defined as follows:

The conservation status of a natural habitat will be taken as “favourable” when:

- its natural range and areas it covers within that range are stable or increasing, and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable as defined below.

The conservation status of a species will be taken as “favourable” when:

- population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

Section 3 of the Protection of Nature Act provides general protection of habitat types such as bogs, meadows, heaths, lakes and dry grasslands. The Act does not specify criteria for determining when Section 3 habitats have a biological quality that justifies their conservation, however.

Criteria for nature quality are being developed in order to be able to determine the value of natural elements in relation to the conservation of biodiversity. One proposal contains four criteria describing the properties of nature that emphasize the natural, spontaneous processes and the significance of time and space for the expression of these processes (*Box 4.3.1*).

Criteria for nature quality

Wildness

- Free progression of natural processes, i.e. the absence of anthropogenic pressure on the flora and fauna.

Continuity

- **Temporal:** The period during which the locality has been free of either direct or indirect intervention by modern agricultural practice.
- **Spatial:** Extent and spatial coherence of the unaffected area.

Originality

- The natural habitat types of the native flora and fauna.

Authenticity

- Genuineness, i.e. that the nature content of the habitat has developed through natural processes and has not been “helped on its way” by planted species, released game, etc. and thus reflects the habitat’s history rather than human efforts to promote a particular type of nature content.

Box 4.3.1
Proposed criteria for nature quality.

The time perspective for these criteria is that of evolution, or at least very long, and the criteria are specially developed for conditions where it is meaningful to speak of the absence of human intervention in the state of nature as the reference point. With the term nature quality, biodiversity can be said to be supplemented by the term biological integrity: We have to give nature more space to develop on its own premises.

Biodiversity and nature quality are thus related terms, but biodiversity understood as species diversity is rarely an adequate measure of quality since species-poor ecosystems such as heaths and raised bogs can also have a high nature quality. In these systems, increased species diversity can even indicate disturbances or pollution and hence a lower nature quality.

While biodiversity includes the collective diversity across hierarchical levels (genes, species, populations, ecosystems), the term nature quality – among other means by including the time factor – attempts to add a dynamic and process-oriented dimension (*Box 4.3.2*).

In principle, the term and its criteria encompass the whole of nature and all habitat types, but has hitherto only been operationalized for the open habitat types such as heaths, meadows, bogs and dry grasslands, where botanical quality has been used as the foundation for the criteria and as an indicator of overall quality.

Photo: NERI/Jørn Pagh Bertelsen

The temporal dimension – *continuity* – is very important as far as concerns the quality of the habitats for biotope-specific species as it is very easy to spoil a given quality. In contrast, changes back towards a more undisturbed state are very slow, among other reasons because depletion of nutrients and colonization by extinct species occur very slowly. This phenomenon is called "ecological inertia".

Originality challenges one's attitude to nature: When is something native? How far back in time do we go? In addition, there is a clash of interests as regards man as a part of nature: On the one hand we are part of it, and on the other hand we have to curtail our intensive use of nature. *Wildness* also necessitates taking a position on the question: How wild shall/should nature's processes be? After all, the very basis of our existence is utilization or control of nature, while extensive utilization provides relatively good nature protection. All seminatural habitats entail an in-built paradox in that while wildness has high priority from the biological point of view, we must concomitantly accept that the habitats have to be managed in order to protect the existing biodiversity. This paradox necessitates an evolutionary-historical perspective in order to explain why the open habitat types are so biodiverse, and why they cannot maintain themselves in our cultural landscape.

Authenticity or genuineness is also a difficult term. Many people think that biodiversity can be established at will, and that we are obliged to repair the damage we have done to nature by re-establishing and creating replacement habitats and releasing or planting animals and plants. This only reduces authenticity, however. Other people are adherents of natural and spontaneous colonization when the quality of the habitat is otherwise satisfactory – even though the time horizon may be long. The nature quality debate has flamed up in recent years in connection with eradication of the wild pig population and the almost simultaneous reintroduction of the beaver into the Danish countryside.

Biodiversity and nature quality can also be considered on larger scales. At the *landscape scale*, man will always be part of nature as we affect every landscape in Denmark. Man's cultural landscape can be said to be our "nature" where, for example, the open semicultural societies are examples of our preservation-worthy "human nature". Perception of nature at the landscape scale can include ecosystem function, e.g. nutrient turnover, production of food and pure water and extinction and colonization of species, but just as much the aesthetic quality and quality of the experience nature provides, and which for many people is the very essence of nature. The landscape's qualities can also be analysed by working with landscape elements, structures, land use, multi-functionality, etc. In other words, it will be possible to describe man's impact on nature and its resulting state very differently.

Box 4.3.2
Nature quality and biodiversity are mutually supplementary terms.

4.3.3 Denmark's nature – status and trend

Introduction

With many species and habitat types, it is difficult to find quantitative investigations demonstrating the overall trend in Danish nature. The existing data nevertheless indicate some clear tendencies, as described below. The present section thus attempts to describe the trend over the past 50–100 years as well as the tendencies in recent years/decades.

A number of nationwide surveys have been made of the distribution of various habitat types in Denmark, including registration of habitats encompassed by Section 3 of the Protection of Nature Act carried out by the Counties in the early 1990s. No time series are yet available, though. The list of habitat sites of Community importance prepared pursuant to the Habitats Directive only includes priority habitats and species. Moreover, this list of 194 sites is not based on comprehensive field assessment of their state (*Figure 4.3.1*).

The sites largely coincide with the previously designated bird protection sites and Ramsar sites, although a number of terrestrial sites have been added such that a total of 6% of the land area has been designated as habitat sites.

Habitats of the open countryside

A large number of the so-called hardy plants that presently characterize the habitat types in the open countryside, including the semi-natural areas, have been associated with the open countryside for longer than the 6,000 years agriculture has been practised in Denmark. During the course of history, these have become increasingly dependent on different forms of agricultural management. Today our open semi-natural habitat types such as meadows, dry grasslands and salt marshes are completely dependent on agriculture's extensive grazing and grass cutting practices. In the hunter Stone Age, before peasant farmers occupied the land and gradually cleared the forest, a number of the open habitat types were already present and comprised an estimated 15–25% of the area of Denmark.

At the beginning of the 19th century, the amount of the open habitat types dunes, heaths, salt marshes, meadows, dry grasslands and bogs peaked at about 75% of the total area of the country. Today these areas cover less than 9% of Denmark, corresponding to a 70–90% reduction (*Table 4.3.1*).

As is apparent from the regional distribution of the protected habitat types, the heaths are located in areas with sandy, less fertile soils, which are mainly found in western Jutland (*Figure 4.3.2*). On the more fertile moraine plains of eastern Jutland and the island part of Denmark, they are replaced by the dry grasslands.

Open habitat types	Area (ha)	Percent of Denmark
Meadows	104,000	2.4
Salt meadows	44,000	1.0
Bogs	90,000	2.1
Dry grasslands	26,000	0.6
Heaths	82,000	1.9
Dunes*	30,000	0.7
Total	**375,000**	**8.7**

Table 4.3.1
Area of the various open habitat types.
*The figure for dunes is uncertain as it is an estimate. The remaining areas are based on registration and charting of habitat types carried out by the Counties in 1996.

Figure 4.3.1
Chart of the 194 habitat sites in Denmark of relevance for the European Community.
(Source: Danish Forest and Nature Agency, 2001).

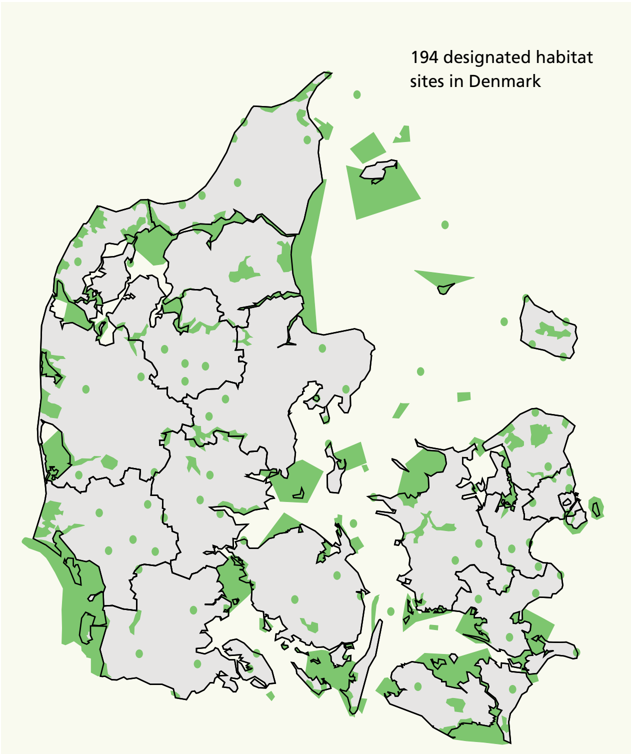
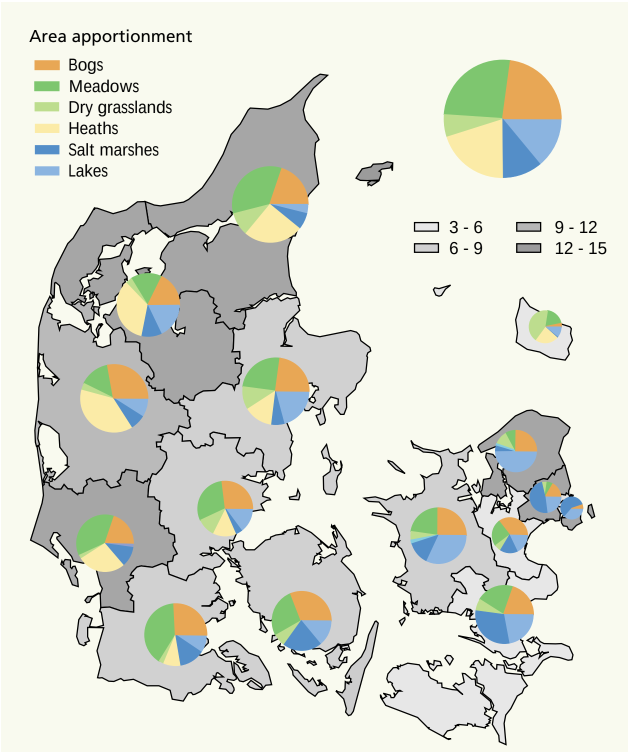


Figure 4.3.2
Relative distribution of the natural habit types in the Danish counties together with the percentage of the county area accounted for by natural habitat types.
(Source: National Environmental Research Institute, 1997).



The marked areal decline of the open habitat types is explicable by the fact that they have lost their former major economic importance as grazing areas for livestock. As a consequence, agricultural management of most of them has been intensified and the remainder have been abandoned. Intensification has resulted in large areas of open habitat types being converted to cultivated land, either fertilized grasslands or forest. In other areas, management has ceased and they have become overgrown. Cultivation and afforestation were the characteristic fate of these areas up to the mid 1980s, whereas cessation of management has predominated during the past couple of decades.

While agricultural interest in the open habitat types is decreasing, increased competition for land has enhanced interest in the use of these areas for other purposes. Examples are establishment of summer cottage districts and other recreational facilities in dune areas, management of bogs and ponds whereby they are allowed to become overgrown etc., and the release and feeding of ducks to satisfy hunting interests.

The nature restoration projects carried out in recent years have also resulted in the creation of new areas of natural habitats, however. Thus between 1989 and 1998, just under 7,800 ha of new natural habitats has been established (excl. afforestation). Some of these are completely new, some comprise existing natural habitats whose quality has been markedly improved. The biodiversity of the newly established meadows and dry grasslands is often no greater than that of the former semi-natural grasslands, however. Whether they can develop greater biodiversity in the long run depends on the possibilities for the habitat character species to migrate in from old meadows and dry grasslands.

Small biotopes in the open countryside

The small biotopes can be defined as small areas of uncultivated land in the open countryside. They can be subdivided into two main groups: Linear biotopes such as hedgerows, dykes, field boundaries, ditches and field tracks, and non-linear biotopes such as ponds, small bogs, burial mounds, small forests, coverts, quarries, etc. The presence of small biotopes is of decisive importance to the existence of numerous wild plants and animals in the arable landscape. Together with small natural habitats, they serve an important function as dispersal corridors or as "stepping stones" between the larger natural habitats.

No nationwide survey of the areal distribution or development of small biotopes exists. A major study carried out by Roskilde University Centre of 25 localities throughout the country revealed that small biotopes presently occupy about 3% of Danish arable land, but that there is considerable local variation. In some landscapes small biotopes thus only account for 1%, while in others they account for up to 6%. The study also showed that the number of small biotopes is generally smallest on the large farms, and that the areal percentage accounted for by small biotopes decreases with increasing field size.

Photo: CDanmark

As a general tendency, many small biotopes have been removed from the open countryside up through the 20th century, in particular many field boundaries, hedgerows and ponds. An increase in the area of small biotopes in Danish arable land cannot be demonstrated until the period 1986–91. This increase is mainly attributable to the planting carried out for landscape and game management purposes. The increase in area has continued in recent years under the hedgerow scheme with the establishment of multi-rowed hedgerows of broadleaf trees and of ponds. In the season 1999–2000, just under 1,000 km of hedgerow was planted. The majority of this is three-rowed, predominantly consisting of broadleaf species of which approx. 80% are indigenous. In addition, 4–500 ha are planted annually under the game coverts scheme. The coverts are primarily established on existing cultivated land that is difficult to farm. Three quarters are established in non-linear form, and one quarter as hedgerows. Only plants on a specific species list are provided and wherever possible, only indigenous species are used.

A study of the fate of small biotopes at five selected localities on Funen and Zealand over the 100 years since 1884 shows that in addition to a reduction in the total number of small biotopes, the number has also fluctuated considerably over the past century, thereby reducing the number of biotopes with a long continuous history. Subsequent updating of the study up to 1996 confirmed the general picture that the trend in small biotopes has stabilized, although with two exceptions:

- Small forest biotopes have been advancing over the past 25 years
- The number of biotopes with permanent grass or other plant cover continues to decline (*Figure 4.3.3*).

The trend in the total area of small biotopes veils a pattern of considerable variation, however. Valuable old biotopes are eliminated and replaced by more homogenous biotopes.

The small arable land biotopes are the potential habitat of more than 600 species of plants, 1,500 species of insects, 65 species of birds and 20 species of mammals and reptiles.

The small biotopes are generally extremely affected by field management. Several studies have shown that the ground flora in hedgerows, field boundaries and along field tracks has changed character in many places. Just 50 years ago, these small biotopes housed a varied flora with species from fields, meadows, dry grasslands and forest. Nowadays they virtually only consist of competitive and pioneer species such as the common nettle, cow parsley, couch grass, ground elder, creeping thistle, orchard grass, meadow grass, tall meadow oat, mugwort and goosegrass.

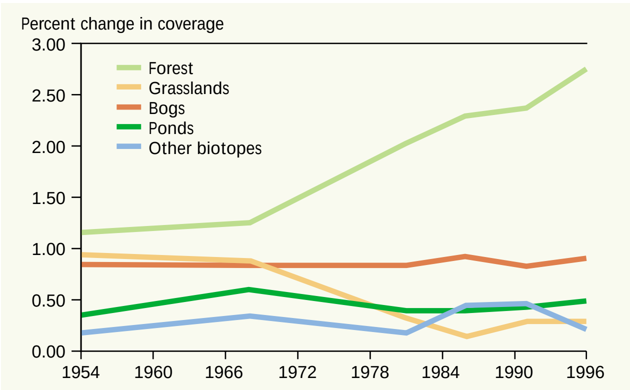
Among other things, this trend is attributable to the fact that the number of agricultural holdings has fallen from 200,000 to 60,000 since 1940. Moreover, mechanization has resulted in larger fields, elimination of field boundaries and hence also of hedgerows, dykes and ponds. A general feature of small biotopes is that their suitability as habitats increases markedly with age. Thus small biotopes with a long continuity cannot simply be eliminated and re-established without this considerably reducing their biodiversity. Clearance of old hedgerows cannot be balanced by the planting of new hedgerows, for example. As there is a large contact surface between small biotopes and the cultivated fields, the border effect is of great significance for the small biotopes. Fertilization, pesticide spraying and other disturbances from neighbouring areas therefore markedly affect the many small biotopes.

Photo: CDanmark

Figure 4.3.3

Development in selected small biotopes over the period 1954–1996 for five selected localities on Funen and Zealand indicating the percentage change in coverage in 1954. The small biotope "Grasslands" refers to localities with permanent grass. "Forest" encompasses woods, game coverts and thickets.

(Source: National Environmental Research Institute, 2001; Brandt and Holmes, 2001. Agger et al., 1986).



The open countryside flora and fauna

The Danish landscape currently appears as a mosaic-like cultural landscape comprised of many different fragments of nature surrounded by cultivated land. The most visible man-made barriers in the landscape are roads and railroads, which can comprise complete or partial obstacles to the dispersal of plant and animal populations. Increasing traffic and new roads enhance fragmentation of the landscape and hence the number of animals killed by traffic. The opportunities to cross the roads are diminishing, and hence the possibilities for the animals to exchange genes. The impact on genetic variation is particularly great in cases where movement between isolated localities ceases completely. Dispersal between habitats is clearly diminished, thus making restoration or establishment of areas of natural countryside difficult. Many organisms that are linked to specific types of habitat find it difficult to colonize such new potential habitats in the open countryside.

The marked decrease in the total area of open natural habitat types and the decline in the quality of the remaining localities as a result of drainage, fertilization and cessation of extensive management have led to the disappearance or marked reduction of a large number of plant and animal species in Denmark, and the same fate now awaits many others. Out of 343 species that have become extinct in Denmark since 1850, 109 species (approx. 1/3) are associated with open habitat types, of which 63 alone are associated with dry grasslands. The existing studies of the trend over the past 20 years also indicate that most species have been on the decline during the period, with only very few species having gained ground.

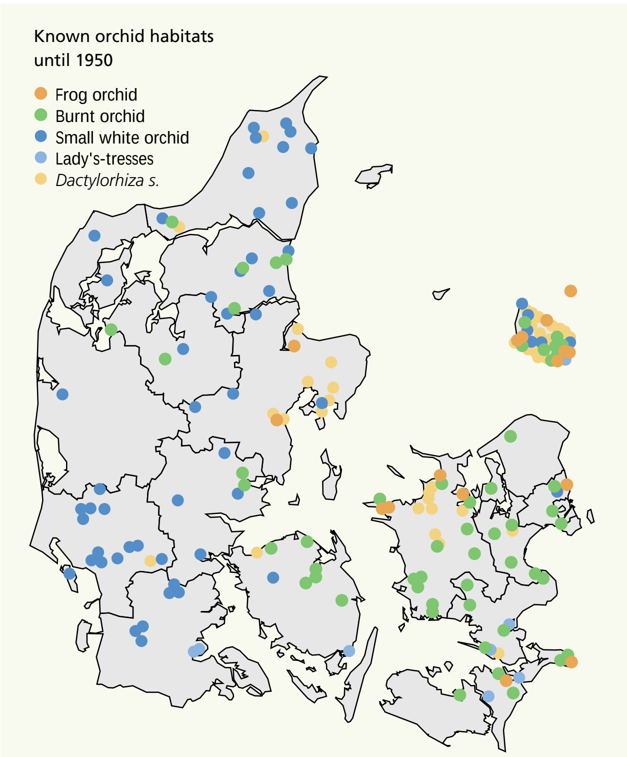
Plants: The decline among the plants inhabiting the open natural habitats has particularly affected the so-called hardy plants associated with the naturally nutrient-poor localities, both the previously widespread species such as star sedge, heath bearberry and arnica, and the more rare species, e.g. many species of orchid. On the other hand, species that are naturally more limited in distribution have now become more common in the landscape. This applies to species adapted to nutrient-rich and/or disturbed environments. Thus, the picture has changed from one of many rare plants to one of a few common plants.

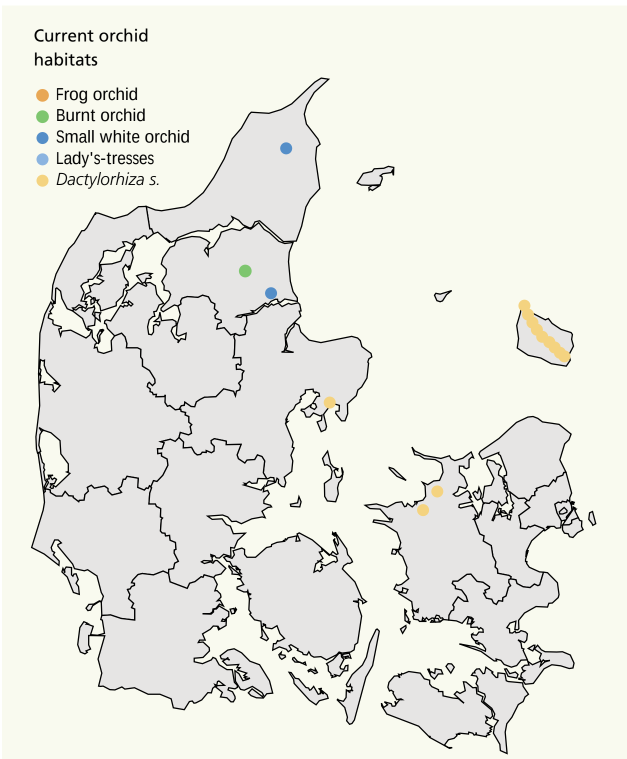
Butterflies: A third of the Danish butterflies are associated with the open natural habitats and are included on the Danish Red List. Since 1950, many of these have been declining markedly. Nine species in all have become extinct, of which 6 were associated with the open natural habitat types. This marked decline seems to

Figure 4.3.4

The charts show the decline of five rare orchids associated with old dry grasslands. The left-hand chart shows the known habitats until 1950, while the right-hand chart shows their few remaining habitats. The decline is attributable to cultivation, fertilization of heaths and dry grasslands, and the cessation of grazing.

(Source: National Environmental Research Institute, based on Løjtnant and Worsøe, 1977).





be attributable to a combination of several factors, especially the fact that many open natural habitats have become overgrown as a result of enhanced nutrient input, pesticide spraying, drainage and cessation of extensive grazing and hay making. Two species of butterfly currently found in Denmark are covered by the EC Habitats Directive, namely the marsh fritillary and the common blue butterfly. The conservation status of both species is unfavourable.

Birds: The tendency for bird species associated with the open natural habitats has been investigated by determining a bird index for eight selected species characteristic of open natural habitats based on annual bird census data for the period 1982–2000 (*Table 4.3.2*): Oyster catcher, lapwing, common snipe, redshank, skylark, meadow pipit, whinchat and red-backed shrike.

A marked and statistically significant decline is evident in the combined breeding population of these birds, although with considerable inter-species differences. This confirms that conditions for the birds associated with open natural habitats are becoming increasingly difficult in Denmark. A marked decline is seen with the lapwing, but also with the redshank, meadow pipit and whinchat. In contrast, the common snipe seems to be gaining ground during the period 1993–2000, although with considerable inter-annual variation. The populations of red-backed shrike (index only available for 1995–2000) and the skylark have remained largely unchanged or are slowly gaining ground. The red-backed shrike is favoured by the habitats becoming overgrown as it thrives on dry grasslands and heaths with scattered thickets.

The decline could reflect deterioration in the bird's Danish habitats, i.e. the open natural habitat types, but other factors such as conditions in their winter quarters can also play a role. However, since the bird index is comprised of species with very different migratory habits, winter quarters and preferred food, it is probable that the overall decline seen with these species reflects a general decline in their habitats here in Denmark.

Of the rare and almost extinct bird species, the corncrake and crane are gaining ground. The advance of the corncrake population is presumed to be largely due to the advance of the population in Eastern Europe. Other rare bird species have declined, for example the white stork, which has decreased from 25 to 2 pairs over the past 25 years. The black grouse has completely ceased breeding in Denmark. In contrast, the black stork and the peregrine falcon have started to breed in Denmark again.

Amphibians: There are 14 species of amphibians in Denmark. Of these, six are included on the Danish Red List, and the remaining are on the Yellow List as requiring attention. All amphibians are protected in Denmark, but have generally declined markedly throughout the 20th century. During the 1990s, considerable conservation efforts were directed at many amphibian species. This seems to have halted the decline of several species, among others the smooth newt, common toad, common frog, jumping frog and the more rare green toad. With three species – the Alpine newt, the green tree frog and the fire-bellied toad – the decline has been successfully reversed, and they are now increasing. Other amphibians are still declining, however, including the common spadefoot, marsh frog, moor frog, edible frog and natterjack, and possibly also the crested newt.


Photo: NERI/Jørn Pagh Bertelsen

Table 4.3.2
Indexed trend in breeding bird populations in open habitat types.
Note that new species are ascribed an initial index value corresponding to the sum index so that their entry into the index does not per se affect the sum index vlaue.
(Source: Danish Ornithological Association, Ellemann et al., 2001).

Open habitat types	1982	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Oyster catcher	100	97	106	99	97	85	82	78	116	101	112	95	125	112	122	131	103	100	74
Lapwing											93	73	65	68	59	65	48	37	31
Common snipe											93	79	66	108	113	117	87	128	123
Redshank						108	65	62	55	51	46	43	43	41	52	52	44	46	58
Skylark								85	113	105	108	130	131	126	128	119	109	105	99
Meadow pipit						108	76	106	113	89	95	77	91	87	72	65	56	95	77
Whinchat		97	76	81	89	131	101	96	82	94	104	103	76	52	58	68	54	59	49
Red-backed shrike														85	82	75	92	97	102
Sum index	**100**	**97**	**91**	**90**	**93**	**108**	**81**	**85**	**96**	**88**	**93**	**86**	**85**	**85**	**86**	**86**	**74**	**83**	**76**

Hares: The game bag statistics provide a good indication of the trend regarding the hare population. The annual game bag has fallen from around 400,000 in the 1940s and 1950s to approx. 100,000 at the end of the 1990s. The outbreak of fox mange in Jutland and on Bornholm led to a minor, transient increase in the early 1990s. The decline of the population over the past 40 years is probably attributable to structural changes and increasing mechanization in the agricultural sector, including changes in crop mix, increasing field size and elimination of hedgerows and small biotopes.

Causes of the changes in the open natural habitats

The majority of the open natural habitat types have been legally protected since 1992, while bogs have been protected since 1978 and heaths since 1984. For quite some years they have thus been protected against encroachment and new measures. This does not necessarily ensure protection of the quality of the localities, however. Spot checks thus indicate that no more than half of the open natural habits are in a state worthy of the description "natural".

There are several reasons for this decline in the quality of the open natural habitats. Becoming overgrown has already been described. Another important reason is eutrophication. The open natural habitats receive nutrients indirectly via deposition of ammonia from local livestock holdings and fields, through spillage of fertilizer from neighbouring areas and as nitrogen oxides from the combustion of fossil fuels (*Section 2.4.2*).

Deposition of airborne nitrogen has decreased from 21 to 15 kg per ha per year over the period 1990–1996. The natural background level for N input from the air is believed to be 3–7 kg N per ha per year. Relative to the international critical loads for the individual open natural habitat types, it appears that the total deposition clearly exceeds the critical loads for raised bogs and is equivalent to or above the critical loads for dune heaths, dry grasslands and inland heaths. Some of the open natural habitats are also fertilized directly as it is permitted to continue fertilization of a habitat to the same extent as before the area became encompassed by the Protection of Nature Act.

By far the majority of wild species in Denmark are adapted to nutrient-poor conditions. Eutrophication enhances pressure on these hardy species, a pressure that is clearly illustrated by the fact that these species are over-represented on the Red List (*Figure 4.3.5*).

The use of pesticides detrimentally affects habitat conditions for wild plants and animals, not only on production land, but also on neighbouring areas. The poor habitat conditions are due in part to the direct toxicity of the pesticides and accumulation up the food chain, and in part to the scarcity of the food resource of those species that live off the plants and insects eliminated by the pesticides (*see Section 4.5*).

Fragmentation and consequent isolation of habitats and plant and animal populations affect both their occurrence and their possibilities to disperse. Fragmentation enhances the significance of the border effects, and affects the genetic variation of the populations. Border effects can be in the form of wind drift of fertilizer and pesticides from adjacent fields. Natural habitats near plantations can be subjected to increased seed pressure from species that are not naturally occurring, thereby enhancing the risk that

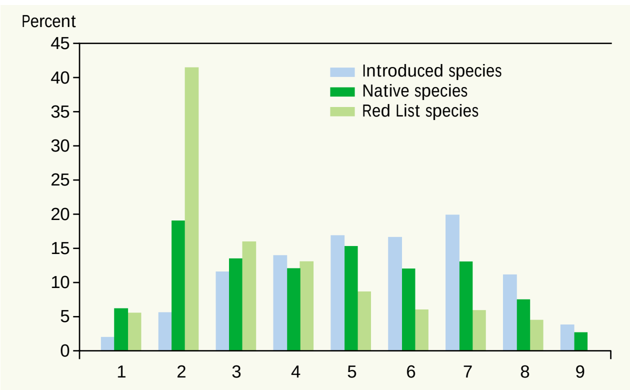


Figure 4.3.5
Preference of Danish plant species for habitats with different nitrogen levels. The height of the columns indicates the percentage of introduced species, Red List species and the remaining native species that prefer the nutrient level in question. The values along the abscissa are such that 1–4 (–5) covers the variation in seminatural habitats of low productivity, while categories 6–9 encompass fertilized fields and naturally productive habitats (e.g. seaweed embankments and reed swamps). (Source: Ejrnæs, 2000).

they will become overgrown, while those near major livestock holdings are subjected to enhanced levels of ammonia deposition.

Marked lowering of the groundwater table has been detected in many of the open natural habitats. This has a direct effect on the flora and fauna, and the drying-out enhances the rate at which they become overgrown. No overall information is available as to how great a percentage of the open natural habitats are affected by lowering of the water table, and what changes this has caused. The existing data indicate that around half of all bogs and salt marshes are directly affected by drainage. In addition, there are the indirect effects of drainage of neighbouring areas and lowering of the groundwater table as a result of water abstraction. In Funen County, for example, a survey thus shows that little salt marsh remains that is only minimally affected by drainage. In Copenhagen County, where the groundwater table in some areas has sunk by 10–15 m since the 1980s, water abstraction is considered to be the main factor negatively affecting the bogs.

Breaks in continuity – both temporal and spatial – can have major consequences for the open natural habitats, and are even a contributory cause of their quantitative and qualitative decline. If dry grassland is fertilized, for example, this flower- and insect-rich habitat gradually changes to a homogenous grass field. Once dry grassland has become converted to a grass field, it takes 50–100 years of impoverishment of the soil and recolonization by hardy plants before it once again resembles dry grassland. In other words, the changes are almost irreversible within a manageable time frame, and restoration depends on the presence of other localities from where biotope-bound organisms can immigrate.

An example of a break in continuity is the temporal development of meadows and bogs at Dallerup near Horsens (*Figure 4.3.6*). The area of meadows and bogs there decreased considerably from the early 1800s to 1996 concomitantly with an increase in the area of urban and arable land. This in itself does not show the dynamic relationship between the different areas, though. Thus, closer examination of the pattern of meadow and bog development reveals that the meadow and bog area in 1876 had decreased by 66% relative to 1800. Moreover, 85% of the meadow and bog existing in 1887 was also meadow and bog in 1800. The present area of meadow and bog is 87% less than in 1800, and of the remaining 13% meadow and bog, one third can be characterized as undisturbed relative to 1800.

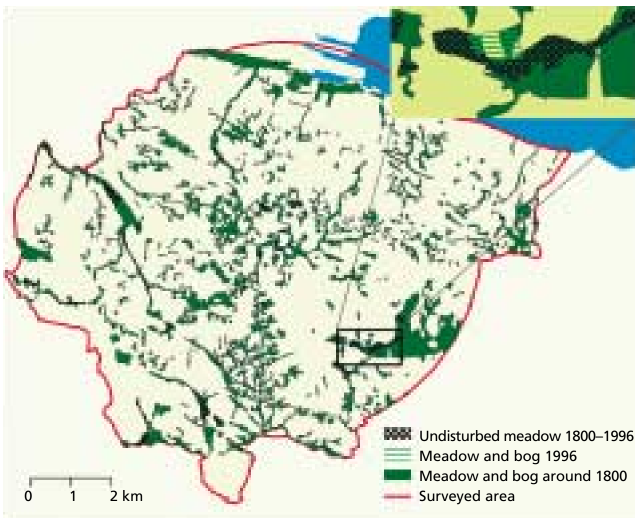


Figure 4.3.6

Development of meadow and bog in the Dallerup area near Horsens from approx. 1800 to 1996. The chart is based on various old maps and recent registration of protected natural habitat types.

(Source: Eigaard, 2001).

The forests

The forests possibly contain some of the country's most valuable natural habitats. Denmark was originally a forest country, and half of our native plant, fungi and animal species are originally forest species. The forests have always been affected by man. Due to great demand for wood and arable land, the forests were reduced to around 4% of the area of Denmark around 1800. Wood for timber, fuel and fencing became in short supply. New forest was planted, and the Forestry Act was passed in 1805 to protect the remaining forest. The forests gradually became managed efficiently and systematically to produce wood, and the natural dynamics of the forest became of secondary importance. Around 1850, extensive afforestation was initiated which doubled the forest area to 8% within 70 years. This trend has continued, although at a slower pace, and 10% of Denmark is presently covered by forest.

Over the past decade the emphasis in forestry has shifted from productional optimization to more versatile land use. The forest has to "produce" goods other than just wood to satisfy society's needs – goods such as pure groundwater, possibilities for outdoor activities, and not least biodiversity. At the same time, the forest has to blend into the landscape as an integral part of the whole.

In view of the fact that forest acreage is increasing and has been doing so for almost 200 years, the Danish forest is not threatened. The question, though, is what type of forest one wants to carry on into the future. During the same period, the area of broadleaf forest has not increased correspondingly and now only occupies 4% of the country. In addition, conifers have been planted on much of the land that was formerly broadleaf forest. Despite a slight increase in the broadleaf forest acreage since the beginning of the 19th century, there is now considerably less broadleaf forest acreage with a long continuity.

The break in continuity can be exemplified by the forest pattern at Dallerup near Horsens during the 19th and 20th centuries (*Figure 4.3.7*). The statistics show that there was 968 ha of forest in 1800 and 1,035 ha in 1997, i.e. forest acreage increased slightly during the period. The figures veil dynamic changes, however, although these are much less than the dynamic changes in meadows in the same area (*Figure 4.3.6*). Of the 1,035 ha of forest that exist today, 642 ha (66%) are undisturbed forest, i.e. have been forest since the 1800s. The analysis also reveals that considerable forest clearance and planting have been undertaken between the 1800s and the present day. There has not been any differentiation in the switch between broadleaf forest and conifer forest or in relation to clearance and planting within the individual forests. In this context, undisturbed forest thus must not be confused with natural forest as defined in the 1992 Natural Forest Strategy.

Over the past 10 years the area of broadleaf forest has increased from 143,000 to 163,000 ha (*see Section 1.5*), i.e. the proportion of broadleaf forest has increased from 34% to 37%, largely due to an increase in the area of oak forest. In contrast, the area of beech forest has remained largely constant. The area of actual virgin forest is unknown, but probably only comprises a modest part of the long-standing broadleaf forest acreage. The oak coppices in Jutland are an example of a special type of natural forest that mainly occurs on the sandy soils of northern and western Jutland, as well as on the hill islands of western Jutland (*Box 4.3.3 and Figure 4.3.8*).

Photo: NERI/Britta Munter

Oak coppice in Jutland

Oak coppice is a special type of transitional nature – a succession stage – between heath and timber forest. It was included in the Forestry Act in 1996 and has since been registered throughout the country. Oak coppice is a form of natural forest, i.e. self-sown forest consisting of oak and varying amounts of aspen, mountain ash, birch, small-leaved linden and possibly also common alder, ash or beech, often with an undergrowth of alder buckthorn and juniper. On clayey soils it may also include hawthorn and hazel. Open oak coppices often have a dense ground vegetation of grasses and such species as cow wheat, blueberry, may lily, lily of the valley and wild honeysuckle.

Many oak coppices are located on the poorest soils between the villages, in outlying fields, where it has previously been too troublesome or unprofitable to clear the forest completely and cultivate the soil. Many oak coppices are therefore a living historical testimony of the harsh living conditions that formerly prevailed in western Jutland.

Typical oak coppices are generally low, and the trees are often crooked or multi-stemmed. Their form is due to being bitten by game and livestock, pollarding, growth under particularly frosty or windy conditions and an impoverished soil.

The most valuable oak coppices from the natural history point of view have an unbroken history as forest far back in time. This applies among other things to coppice where small-leaved linden is naturally occurring. Other species, for example certain species of butterfly, depend on some degree of clearance through felling, grazing or actual pollarding.

The preservation of oak coppice requires various types of intervention, and nature preservation can be combined with various other types of useful purposes by allowing grazing in the forest, by carrying out selective felling or by pollarding.

Grazing with livestock in the forests is an old forest management practice that is presently being revived, among other places in certain oak coppices with a view to preserving biological and landscape diversity. Interesting similarities have been found between the effects of the large forest grazers of the past (e.g. aurochs) and present-day cattle and the growing populations of red and roe deer. Many of the forest plant species are adapted to grazing and resist it to various extents such that a varying grazing pressure can provide variation in the forest picture. Under certain circumstances, forest grazing can thus affect soil formation and the associated vegetation, thereby promoting the formation of humus rather than raw humus. At the same time, the many organisms associated with the large ungulates find new niches in the grazed areas of forest. Old grazing forests and dry grasslands contain many species and from the biological point of view are some of our richest communities.

Box 4.3.3
Oak coppice is a special type of natural forest.

Figure 4.3.7
Development of forest in the Dallerup area near Horsens from approx. 1800 to 1997.
The chart is based on various old maps and recent registration of protected natural habitat types.
(Source: Eigaard, 2001).

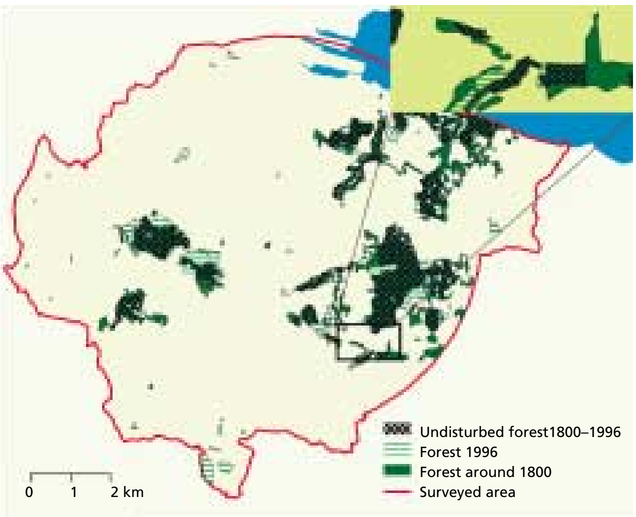
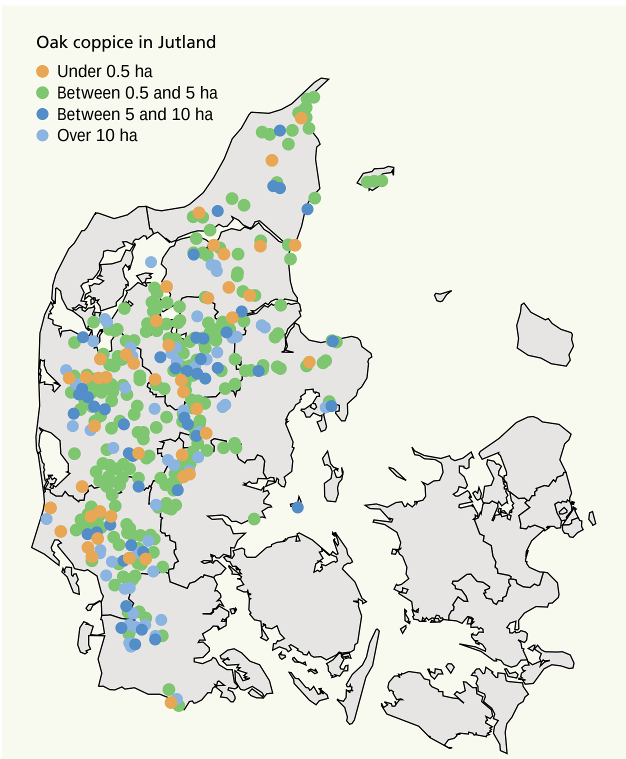


Figure 4.3.8
Distribution of oak coppice in Jutland apportioned by size category.
(Source: Danish Forest and Nature Agency, 2001).



Forest flora and fauna

The natural vegetation in most of Denmark is mixed broadleaf forest. The majority of the original Danish wild animals and plants are therefore species associated with broadleaf forest. The forests are thus of great significance for biodiversity in Denmark. It is estimated that at least half of the 30,000 species native to Denmark – the majority of which are insects and other arthropods – are directly associated with the trees in the forest. As the natural forest ecosystem is not limited to tree stands, but also encompasses bogs, watercourses, lakes, clearings, etc., it is open to discussion how many of the other species should be considered "forest species".

Due to extensive drainage and intensive forest management, which has primarily aimed at wood production, a wealth of plant, fungal and animal species and their habitats has disappeared from the forests. The forest has become increasingly "homogenized" in order to simplify management and optimize wood production, thus leading to the disappearance of many habitats and ecological niches. As a consequence, and because the majority of Danish wild species are associated with forest, over half the plant and animal species on the Red List are forest species (*Table 4.3.3*). These species are particularly associated with old forest, undisturbed forest, dead wood, large old trees, undisturbed soils, high humidity and wetlands.

Mammals: The original Danish deer species, the roe deer and the red deer, are both advancing significantly. In contrast, several species of bat are declining, largely due to a lack of suitable habitats such as hollow trees.

Birds: Over the period 1976–1999, the populations of several forest birds have increased considerably, including the wood pigeon, tree pipit, blackcap and chiffchaff, while the populations of the cuckoo, hedge sparrow, icterine warbler, lesser whitethroat, wood warbler, willow warbler, pied flycatcher and nuthatch are on the decline. A bird index for nine cavity-nesting birds for the period 1976–1999 reveals that the combined breeding population of these species declined from 1976 to 1986, but has since been improving somewhat. For the period as a whole a slight decrease may be detectable, but the tendency is not significant. Finally, the populations of birds of prey are generally stable or increasing, although the goshawk population is unnaturally low in a number of private forests in eastern Denmark compared with western Denmark and the state forests in eastern Denmark.

Insects: A large proportion of threatened insects comprise species associated with old forest, virgin forest and forest clearings. Many insects primarily inhabit dead wood and hollow trees. Several of our butterfly species associated with forest biotopes have disappeared from large parts of the country or have become rare in large areas of the country. Some of these are threatened by drainage of moist areas in forests, while others depend on the pioneer plant community that is often eliminated in connection with pesticide treatment and fertilization of newly planted forest. This applies for example to violets, which are a food plant for butterflies such as the silver-washed fritillary, high brown fritillary and pearl-bordered fritillary.

Plants: No overall information is available concerning the state of the forest plant communities. It is nevertheless possible to describe the trend as regards forest vascular plants. During the 19th century, the open forests were replaced by more closed tall forests. As a consequence, forest floor plant species preferring shady sites have been favoured at the cost of species preferring more open sites. Species associated with wet soil have also declined as a consequence of the considerable drainage of the forests. Nutrient-demanding species have ousted hardy plants as a result of eutrophication. Many species of lichen have disappeared, and many are considered to be threatened. A large number of fungal species associated with the forest environment are considered to be acutely threatened or vulnerable.

Table 4.3.3
Summary of plant and animal species on the Danish Red List apportioned by Red List category and habitat category.
(Source: Ministry of Environment and Energy, 1998).

	Extinct	Endangered	Vulnerable	Rare	Total
Forest fringes and clearings	46	52	99	80	277
Old forest	64	154	181	96	495
Broadleaf forest	67	82	169	171	489
Conifer forest	16	33	64	109	222
Swamp forest	1	12	35	29	75
Virgin forest	29	90	161	238	518
Wood	**2**	**0**	**8**	**7**	**17**
Forest, total	**155**	**299**	**547**	**698**	**1,699**

Pressures on the forests

The biodiversity of the forests is affected by the various forest management forms. The choice of tree species is also decisive, both as regards the actual mixture of tree species at any one time and the historical continuity. Switching between pure cultures of different tree species is particularly detrimental to the development of biodiversity, especially a switch from broadleaf to conifer forest. The species naturally associated with the different tree species differ markedly, as does their contribution to the forest food chains. The forest trees that most enhance biodiversity are native species, although introduced species can also make a positive contribution to biodiversity. The choice of tree species is also of great significance for forest water balance, light conditions and soil development, thereby also affecting biodiversity. A forest stand consisting of a mixture of many different tree species also creates many different habitats and satisfies the requirements of a greater number of different species than monocultures.

The greater the age variation that exists among and between the various stands, the greater the number of habitats present. A wide age range can also ensure a constant supply of dead wood if this is not continually removed by forest management. If periods arise during which there is absolutely no dead wood, many organisms will not be able to survive in the forest ecosystem, but will have to re-invade if possible once dead wood is present again. In principle, this applies to all organisms associated with any age of forest. This process takes time, and many organisms will constantly be lacking in a forest devoid of age variation.

Water is a decisive precondition for life and growth in forests, not just for the forest trees themselves, but also for all the flora and fauna belonging to the forest communities. The use of fertilizer in forestry has been decreasing for some years and at present is mainly used in connection with Christmas tree and ornamental greenery production, as well as on some poor-quality soils in connection with afforestation or replanting (*see Section 1.5.1*). Pesticide consumption in forestry is also low compared with agriculture, for example, and in the case of state forests is currently being reduced even further. Pesticide consumption in connection with Christmas tree and ornamental greenery production also comprises a significant pressure on the environment that can be reduced by the development and use of alternative forms of pest control. It should be noted, however, that mechanical weed control can affect the flora and fauna more than careful pesticide application, and can concomitantly lead to considerably enhanced nitrate leaching.

The sea and coastal areas

The total area of Danish marine waters is approx. 105,000 km^2 and the total coastline is more than 7,000 km long. The Danish marine waters are unique due to the interplay between the marine life forms and the decreasing salinity moving from the North Sea to the Baltic Sea, the low water depth and the interaction with the coastal landscapes.

The marine flora and fauna

Fortunately, there are only few examples of species and natural habitats that have completely disappeared in Danish marine waters, although the sturgeon and the Gudenå salmon are two. On the other hand, there are numerous examples of species that have decreased in number, and of natural habitat types whose area has diminished and/or where qualitative changes have occurred in species composition.

The number of plant and animal species in the Danish marine waters is highly correlated to the salinity. In the marine waters around Bornholm, where salinity is low (8‰), only 150 animal species are present. In the North Sea, in contrast, where the salinity is high (35‰), the figure is 1,500.

The first measurements of phytoplankton biomass in the Kattegat were made in the 1950s. Since then the biomass has almost doubled, although a relatively clear fall in primary production has been detected in the coastal waters, except the North Sea, since 1989. Since nutrient loading started to become significant in the 1950s, changes have also taken place in species composition. Changes such as frequent algal blooms have been recorded in all Danish marine waters, including blooms of potentially toxic algae in the Baltic Sea and the Kattegat. Eelgrass is the dominant macrophyte in Danish estuaries and coastal waters, where it occurs on sandy bottoms from the coast and as far offshore as light conditions permit. The depth distribution of the eelgrass has decreased markedly since the beginning of the last century, but has remained largely unchanged over the past 10 years at 1–6 metres in general.

The depth distribution of macroalgae has also decreased significantly since the beginning of the last century. The distribution has not changed significantly over the past 10 years in coastal waters, though, although local blooms of eutrophication-dependent species occasionally occur.

Photo: NERI/Peter Bondo Christensen

Comparison of data from the open marine waters in the Kattegat and Skagerrak for the period 1970s–1990s with those from the beginning of the last century reveals that benthic faunal biomass increased until the mid 1980s, mainly due to an increase in brittle star and bristle worm biomass as a result of eutrophication. In areas with poor oxygen conditions, especially in the southern Kattegat, the benthic faunal communities have declined. The development of the benthic fauna in the estuaries and coastal waters has generally been in accordance with that in the open marine waters, but with a further increase in the biomass of species able to survive in eutrophic, hypoxic areas. The common mussel has become particularly dominant in the estuaries.

The populations of a number of aquatic birds have been improving, largely due to the conservation efforts resulting from Danish implementation of the Ramsar Convention, the EC Bird Directive and the Bonn Convention for migratory species. As a result of designation of the Ramsar sites and the EC Bird Protection sites in the 1970s and 1980s and regulation of hunting in the 1980s and 1990s, hunting exploitation is now largely ecologically sustainable. Recent development in the populations is not wholly positive, however, as both the breeding and overwintering populations of several species have declined. Examples of breeding populations that have been growing, are the cormorant and eider. The population of eider breeding pairs increased markedly between 1930 and 1990, but has declined slightly since 1995. The populations of several other wading birds are declining, e.g. the Kentish plover, avocet and redshank. Several species of gulls and terns are also on the decline.

The situation as regards the migratory and overwintering birds has been positive for a number of years. Since 1995, though, there have been signs of decline in a number of populations, in particular the seaducks. The number of overwintering eider has thus halved between 1990 and 2000. The reasons for this are as yet unknown.

No overall national data are available describing the state and trends for the coastal fish populations. Based on the available information, however, it is clear that the fish populations in the coastal waters have declined considerably during the past few decades. Catches of salmon, cod, eel, plaice, turbot and flounder and seasonal species such as lumpsucker, herring, garfish and mackerel have decreased considerably in estuarine fisheries. The wild salmon population in the Baltic Sea is considered to be threatened and has been placed on the Red List, primarily because of a lack of breeding grounds in the watercourses. Thus only approx. 10% of the current population consists of wild specimens, the remainder being released fish, although derived from the original Baltic Sea population (*see Section 1.5.2*).

Three or perhaps four species of marine mammals breed in Danish marine waters – the porpoise, harbour seal, white-beaked dolphin and grey seal. In the previous century, the grey seal was the most common seal species in Denmark. It was hunted so much, though, that only approx. 50 grey seals are estimated to remain in Danish marine waters at present. It is unknown whether the grey seal permanently breeds in Danish localities. A lack of permanently undisturbed resting and breeding grounds, especially during the breeding season, seems to limit the occurrence of the grey seal in Danish marine waters. The Danish population of harbour seal has been monitored since 1976, when there were approx. 4,000 animals. In 2000, the population had grown to approx. 11,500 animals. In recent years the growth of several of the populations has fallen, however. At present the main factors limiting the harbour seal are disturbance of the breeding and resting grounds, an inadequate food resource and exemptions allowing culling in certain areas.

The porpoise is widespread throughout Danish marine waters. There are an estimated 305,000 porpoises in the North Sea and 37,000 in the Kattegat/Skagerrak/inner Danish marine waters, while it has not been possible to estimate the population in the Baltic Sea. While the Baltic Sea population has declined markedly, it is unknown whether the porpoise populations in the other Danish marine waters are declining or advancing.

Photo: NERI/Jonas Teilmann

Causes of the changes in the marine waters

The nature and biological diversity of the sea are affected by a large number of anthropogenic pressures. Among the most important is discharge of nutrients. These primarily derive from agriculture, but also from wastewater, traffic and a number of other societal sectors (*see Chapter 3*). The direct and indirect effects of fishery are also of importance (*Section 1.5*).

Hazardous substances and heavy metals are input to the sea through diffuse loading via watercourses, direct discharges, marine currents and deposition from the atmosphere. Hazardous substances occur dissolved in the seawater, but many substances also bind to particles and suspended organic matter and hence can be taken up by and affect all marine organisms – from bacteria to fish to mammals. In Denmark, the antifouling agent TBT used in hull paints and its degradation products are examples of substances that have spread throughout the marine food chains. Due to the dense ship traffic, these tin compounds are ubiquitous in Danish harbours and accumulate up the marine food chains (*see Section 3.8*).

Oil pollution comprises a permanent threat in cases of major oil spills that occur in the wrong place at the wrong time. By monitoring species diversity and biomass together with concentration levels at operational oil platforms it has even been possible to demonstrate a causal relationship between exposure and effect (*see Section 1.3.1*).

Fish stocking has been known for centuries, but has only been carried out on a larger systematic scale in Denmark over the past 50 years, in particular following the implementation of fish management in 1987. Changes in population composition can pose a problem in connection with fish stocking if the natural carrying capacity is exceeded. In the marine waters it is difficult to assess whether, for example, sea trout derived from stocking impose competition for food on other species. Moreover, fish stocking can reduce the genetic variation of the fish species, transfer disease, replace the gene pool of the wild fish population with the gene pool of the farmed fish, and breed specific characteristics into the wild fish populations. The available data indicate, for example, that upstream migration of Baltic Sea salmon in the rivers of western Sweden is of a magnitude that can have significant harmful effects on the natural salmon population.

Introduced species are foreign species whose existence in Danish waters is solely attributable to man's activity. Foreign species can be introduced into new areas by release or through the current practice of discharging large amounts of ballast water from distant seas. Among the introduced species, those that are able to establish themselves and displace other species in nature are termed invasive. In Danish marine waters there are approx. 30 well-documented cases of introduced animal species that have established permanent populations. In many cases these introductions do not seem to have had negative consequences, e.g. the slipper limpet, the jackknife mussel and the ascidian *Styela clava*. In contrast, three invasive eel parasites of Far Eastern origin cause harm to the eel populations.

There are only a few examples of invasive plant species. Townsend's cord-grass was introduced into the Wadden Sea 60 years ago and has since been transplanted to or spread to other localities. This has had significant effects on the species composition of the natural plant community, among other things resulting in glasswort being displaced. Certain phytoplankton species able to form (toxic) blooms have also been introduced.

Photo: CDanmark

Watercourses and lakes

In Denmark there are about 64,000 km of watercourse. About 75% of the total length of watercourse consists of watercourses less than 2.5 m wide (*Table 4.3.4*). Approximately 90% of the watercourses have been channelized, culverted or regulated in some other way over the years. There are approx. 22,500 km of public watercourse, of which just over 3,000 km are culverted.

In Denmark there are 120,000 registered lakes. By far the majority are ponds and small lakes, however, and only just over 2% are lakes larger than 1 ha. The important inland wetlands also include small ponds, bogs, raised bogs and periodically flooded meadows (*see Sections 3.3 and 3.4*). The number of lakes has been decreasing for many years as a result of agricultural and urban development. This has mainly affected the small lakes, but the number of large lakes has also declined considerably. The trend has reversed recently, however, as the Counties are granting permission for the establishment of several hundred new lakes and concomitantly refusing most applications to eliminate lakes.

The majority of shallow-water calcareous lakes used to have extensive vegetation. As a result of eutrophication, however, these lakes have become rare in Denmark (less than 10 in the country as a whole). The clearwater heath and dune lakes on nutrient-poor sandy soils with dense vegetation of rosulate plants (lobelia, shoreweed and quillwort) have also become rare (less than 20 in the country as a whole). It is estimated that 80% of the lakes had sufficiently clear water to house a variable submerged vegetation 100 years ago as compared with only 15% today. Both types of lake are rare and valuable – also at the European level. The same applies to the unregulated and unpolluted watercourses, which together with the lakes can serve as reference localities.

Freshwater flora and fauna

Overall, the inland waters are rich in species, and one finds representatives of most major groups of freshwater animals and plants. It is estimated that the number of freshwater species (algae, macrophytes and animals) in Denmark is approx. 10,000, i.e. around one third of all known Danish species. A large part of the groups of organisms investigated are included on the Danish Red List.

The trend over the past 100 years has been towards plant and animal communities characterized by fewer but more robust and pollution-tolerant species. Comparisons of former and present surveys of the watercourse flora thus show that many formerly common species have now disappeared. Of 16 species of pondweed found at 13 localities in 1896, only 7 were found in a similar study in 1996 (*Figure 4.3.9*). The number of submerged macrophytes has also fallen markedly over the past 100 years. However, as a result of the focus on and efforts to improve the aquatic environment over the past 20–30 years a

Watercourse width	0–2.5 m	2.5–8.0 m	> 8m	Total
Watercourse length	48,000	14,500	1,500	64,000
Percent of total	75	23	2	100

Table 4.3.4
Total watercourse length (in km) apportioned by watercourse width.
(Source: Wilhjelm Committee, 2001).

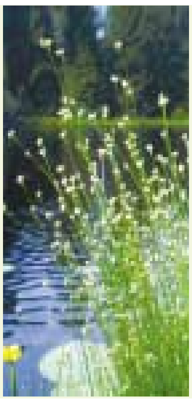


Photo: NERI/Peter Wind

Photo: NERI

	Extinct species	Threatened/ rare species	All species
Dragon flies	4	17	50
May flies	5	15	42
Stone flies	2	8	25
Caddis flies	10	44	167
Buffalo gnats	0	7	24

Table 4.3.5
Distribution of extinct and threatened/rare Danish species of freshwater insects.
(Source: Ministry of Environment and Energy, 1998).

number of clean-water species have started to re-appear in the Danish freshwater environment.

The populations of a number of mayflies, dragonflies, stone flies and caddis flies have declined considerably in Danish watercourses over the past 100 years. Many recorded Danish freshwater insect species are therefore either extinct or threatened (*Table 4.3.5*). Among the 42 known species of mayflies in Denmark, five are extinct and eight are considered to be endangered. The situation for many insects is closely associated with the nature quality of the riparian areas on which they are dependent.

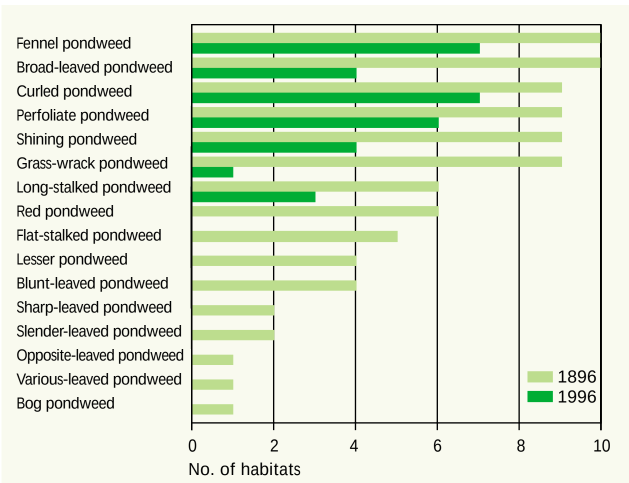
In the past 10–20 years, however, a number of species have started to spread again and establish larger populations. After many years on the decline, several clean-water insects such as the majority of mayflies and stone flies are now advancing. A 1998 survey thus shows that 9 species of mayfly and 11 species of stone fly are advancing, while two species of mayfly and one species of stone fly have been rediscovered after having been declared extinct.

The Danish freshwater fauna contains 38 native fish species, of which 15 (40%) are included on the Red List. Of these, the sturgeon and the miller's thumb are considered to be extinct. The allis shad, twaite shad, pond loach, loach and salmon are considered to be endangered, while the thick-lipped grey mullet, vendace, houting, Siberian bullhead, belica trout, lake trout, brown trout and sea trout and grayling are considered to be rare. The three forms of trout are also considered to be rare because their habitats have been destroyed.

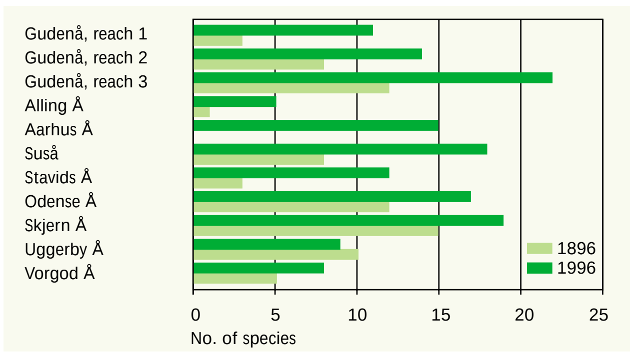
The last population of North Sea houting in the world inhabits the river Vidå. The North Sea houting is included under Annex II of the Habitats Directive as a priority species. Genetically it is a very special population that differs from a smaller population in the Baltic Sea. Recovery of the North Sea houting has been promoted through artificial rearing and stocking in the river Vidå and nearby rivers flowing into the North Sea. The population as a whole is increasing and, despite the small size, it is no longer considered to be acutely threatened. The wild Danish salmon has declined markedly during the course of the 20th century. The salmon was formerly common in the river Gudenå as well as in a number of large rivers in western Jutland.

Of the Danish species of mammals on the Red List, the main species associated with inland waters are the otter, the rough-legged water bat and Daubenton's bat. In the mid 1980s the otter was considered to be acutely threatened with a population of only 200. The otter is now increasing, and the population has reached between 660 and 825 individuals. In 1995 it was thus rediscovered on Zealand, and progress has been detected in most of Jutland.

Figure 4.3.9
Lower left: Number of localities where various species of pondweed were found in 1896 and 1996.
Lower right: Reduction in the number of submerged species over 100 years at a number of localities.
(Source: Riis and Sand-Jensen, 2000).



Watercourse



Causes of the changes in watercourse and lakes

Regulation of watercourses has considerably affected the ecological state of the riparian areas. The physical conditions together with the generally poor water quality of the watercourses are thus among the main reasons for the present state. This is attributable to hard-handed maintenance. Both wastewater discharges from sparsely built-up areas and degradation products from pesticides and hormone-like substances are increasingly reported to affect watercourse animals and plants (*see Sections 3.3 and 4.5*).

The decisive factor for biological diversity in the majority of Danish lakes is the degree of eutrophication – in particular with phosphorus, but also with nitrogen. Water level regulation, shading and pesticide input (especially in small lakes and ponds) can also be decisive. In a number of lakes, large amounts of phosphorus have accumulated in the sediment over the years. In these cases, internal loading from the sediment phosphorus pool can keep the lakes in a turbid state despite a reduction in external phosphorus loading to acceptable levels (*see Section 3.4*).

4.3.4 Objectives and policy measures

International conventions and directives

The 1992 United Nations Conference on Environment and Development in Rio de Janeiro saw the signing of both the Convention on Biological Diversity and the Agenda 21 global action plan. Denmark ratified the Convention on Biological Diversity in December 1993. In order to comply with Article 6 of the Convention and to follow up on Agenda 21, a status report and strategy for biodiversity in Denmark were drawn up in 1995. The strategy specifies that nature restoration is one of the most important means of ensuring biodiversity.

Pursuant to the *Ramsar Convention* on the protection of wetlands, 27 sites together encompassing 740,000 ha have been designated in Denmark. Under the *EC Bird Directive*, the objective of which is to protect a number of threatened or vulnerable bird species, 111 sites together encompassing approx. 980,000 ha, including the whole of the 27 Ramsar sites, have been designated.

The EC Bird Directive and the *EC Habitats Directive* comprise the foundation for nature management and conservation in the EU. Together the two Directives are intended to protect Europe's wild animals and plants and natural habitats.

The provisions of the Habitats Directive only concern species and habitat types of Community interests. Habitat types of Community interest are those that are either in danger of disappearing in their natural range, have a small natural range or present outstanding examples of typical characteristics of one or more of the five biogeographical regions into which the Directive subdivides Europe.

Species of Community interest are species that, in the five above-mentioned biogeographical regions, are either endangered, vulnerable, rare or endemic and requiring particular attention. These species encompass much of the nature present in Denmark, although a large proportion of the species on the Danish Red List are still not encompassed by the Directive. Neither does the Directive specifically encompass "ordinary" nature in the landscape.

Member States are required to designate conservation sites for the species and habitat types encompassed by the Directive. A proposed list of Danish sites for conservation has been drawn up encompassing 194 sites covering a total of approx. 100,000 ha, of which 23% is terrestrial. At these sites, measures have to be taken to avoid the deterioration of natural habitats and the habitats of species as well as the disturbance of the species for which the sites have been designated. Any plan or project that might affect the sites has to be subjected to appropriate assessment of its implications for the site. If implementation of a plan or project will negatively affect a site, it may only be permitted for imperative reasons of overriding public interest. The sites are not only to be protected against deterioration, however. Where necessary, Denmark must implement active administrative measures to re-establish or ensure a favourable conservation status for the natural habitat types and species for which the sites have been designated. This can be achieved through management plans, nature restoration projects, voluntary agreements and issuance of protection orders.

The essence of the Habitats Directive has been implemented through previously existing Danish legislation, namely the Protection of Nature Act, Environmental Protection Act, Town and Country Planning Act, Game Act, Watercourse Act, Forestry Act and Raw Materials Act.

Under the *Bern Convention*, Denmark is duty bound to protect wild plants and animals and their natural habitats. A 1991 Statutory Order (most recently amended in 1997) on the conservation of reptiles, amphibians, invertebrates and plants is a step in the fulfilment of these obligations.

Through the *Washington Convention*

and the associated EU regulations, threatened species are protected in the form of restrictions or bans on trade. The Convention is mainly aimed at trade in tropical species, but encompasses several Danish plant and animal groups, e.g. orchids, tuberous and bulbous plants and birds of prey.

Under the *Bonn Convention* on the protection of migratory species of wild animals, signatory countries are obliged to protect those species most in need of protection. The Convention is based on international agreements, usually dealing with one or a few animal species or groups. Denmark participates in agreements on the protection of seals in the Wadden Sea, of bats in Europe, of small whales in the North Sea and the Baltic Sea, and of aquatic birds that migrate between Europe/Asia and Africa.

Denmark is a member of the global nature conservation organization IUCN (originally the International Union for Conservation of Nature – now called World Conservation Union). The IUCN draw up guidelines and definitions for nature conservation work, among other things for the preparation of Red Lists of threatened species and for the reintroduction of species. The organization operates with some more closely defined categories of protected nature such as national parks, nature reserves, etc. In the EU, the European Environment Agency collates information on this from Member States, including Denmark. Under the category "national parks", Denmark in 2000 notified the following sites as fulfilling the IUCN's criteria for national parks: Wadden Sea, Lyngby-Lodbjerg Heath-Fladesø, Fanø, Mols Bjerge, Randbøl Heath, Haldsø-Dollerup Hills-Stang Heath and Rebild Hills and Gravlev Valley.

National Acts and regulations

Several national Acts lay down instruments regulating exploitation of the country's natural resources. Among others these include:

- The Protection of Nature Act. This provides general protection to a number of habitat types provided they exceed a certain size. The rules on protected habitat types are administrated restrictively and have largely had the intended effect. The Protection of Nature Act also includes the necessary instruments to protect nature in the open countryside and in the forests through designating specific areas as protected. A total of around 4.6% of Denmark is protected land. Through the protection orders it has been possible to preserve these areas – with a mosaic of natural, cultural and landscape interests – in the desired condition. From 1992 to 2000, 89 protection orders have been issued encompassing a total area of approx. 15,000 ha.

- The Game Act. The management of wild mammals and birds is primarily undertaken pursuant to the Game Act. The purpose of this Act is to ensure diverse and numerous game populations and to provide the basis for sustainable administration of the populations. Among other things, this takes place through special protection of game in the breeding season, through regulation of hunting and through the establishment of game reserves. In Denmark, 100 reserves have thus been established with a combined total area of 330,288 ha. Of this, 293,740 ha are located in Danish marine waters and 29,766 ha on land.

- Since the mid 1970s, spatial planning through the Town and Country Planning Act has been an important instrument with which to safeguard not only the aesthetic qualities of the landscape, but also the habitat conditions for the plants and animals inhabiting the open countryside. The Town and Country Planning Act and spatial planning regulate part of land use – in particular building and construction activities, and to some extent afforestation.

- The Watercourse Act aims to ensure that the watercourses can be used for drainage purposes, though while showing consideration for the individual watercourse quality objectives stipulated in the Regional Plans. The watercourse authority can carry out restoration of the watercourses if their quality does not correspond to the quality objective stipulated in the Regional Plan, for example through re-meandering, laying out spawning gravel and establishing fauna passes around obstacles.

- The Forestry Act ensures that areas protected as forest are to remain as forest. It is estimated that approx. 90% of the forest area in Denmark is protected forest. The Act also contains provisions on the protection of other types of habitat. Thus watercourses, bogs, meadows, salt marshes and swamps, heaths and dry grasslands situated in protected forest must not be cultivated, drained, planted or changed in any other way irrespective of their size.

- Regulation of fishery and the protection of fish populations, crustaceans and molluscs takes place through the Fisheries Act and the EU fisheries regulations. For each fish species, minimum sizes, fishing seasons and quotas are stipulated.


Photo: NERI

National strategies and action plans

One of the aims of the Strategy for Biodiversity (1995) is by the year 2005 to re-establish 30,000 ha of lakes and watercourses, plant 150,000 ha of forest, re-establish 2,000 ha of dune heath and 8,000 ha of salt marsh, and considerably increase the area of permanent grass. Even though nature restoration and afforestation have been in focus for the past 10 years, we are still far from reaching the target.

With the completion of the two major projects, the River Skjern Restoration Project and the Varde River Valley Restoration Project, the state will have established and restored at least 12,000 ha of natural habitats in the period 1989–2003, i.e. approx. 1,000 ha per year. To this should be added the management work carried out at existing natural habitats and the work carried out by the Counties, amounting to initial conservation work on 20,000–25,000 ha of natural habitats during the same period. As there are approx. 375,000 ha of open natural habitats outside the forests in Denmark, Danish nature is still hard pressed.

In order to strengthen efforts in the nature area, the Wilhjelm Committee was established in 2000 with the task of determining the need for future efforts to meet Denmark's national and international commitments regarding biodiversity.

The aim of the Natural Forest Strategy is to preserve the biodiversity of the forests. The short-term objective for 2000 has been fulfilled with more than 5,000 ha of virgin forest and more than 8,500 ha under traditional forestry management (coppice forest, grazing and selective felling).

In the longer term, the aim is to ensure the existence by the year 2040 of at least 40,000 ha of virgin forest and forest managed using traditional forestry practices, to designate areas that can be left to become overgrown naturally and thereby help enhance the area of natural forest, and to establish better possibilities for the dispersal of threatened forest plants and animals.

Finally, it should be mentioned that a number of action plans in the environment area are of importance for the state of nature and hence can be indirectly considered as instruments of nature management, namely Action Plan on the Aquatic Environment II (*see Section 3.8*) and the Pesticide Action Plan and the Ammonia Action Plan (*see Section 1.2.1*).

Photo: Highlights

4.4 The terrestrial environment

4.4.1 Introduction

Increasing attention is now being paid to protect the terrestrial environment and the animals, plants and man, which are dependent on good soil quality. High soil quality is difficult to define unambiguously. First and foremost, the soil serves as the physical foundation for the majority of our activities and is the basis for much of our food and raw materials production. The soil functions as a natural filter and transport medium for many substances. In the short or long term, therefore, soil contamination can lead to pollution of inland waters or comprise a threat to our groundwater resources. It is relevant to discuss whether the objective should be to ensure that all soil is of sufficiently good quality to enable multifunctional use, or whether different quality objectives should be established for different land uses.

Irrespective of which soil quality criteria or objectives are focused on, it is often difficult to define and quantify deterioration in soil quality. Some of the pressures that comprise a short- or long-term threat to animals, plants and man are examined below. In addition, a brief insight is given into the state of the terrestrial environment by describing selected environmental indicators. Finally, current Danish environmental initiatives in areas of relevance for soil contamination are outlined.

Large numbers of man-made chemical substances are in use in Denmark. Moreover, man's activities often lead to naturally occurring substances such as heavy metals and tars being discharged into the environment in concentrations far exceeding the natural background levels. Finally, a large number of substances not in use in Denmark can find their way to the environment via airborne long-range transport of pollutants.

Some of these substances will end up in the terrestrial environment, for example through air pollution and through the use of pesticides, fertilizer, lime or other soil improvers such as sewage sludge and manure slurry. If the substances end up in the aquatic environment, they can either degrade, bind to the soil, be taken up by plants and animals or leach to the groundwater and inland waters.

The arable soil, which accounts for the majority of the Danish land area, receives contaminants from the following major sources:

- Atmospheric deposition
- Commercial fertilizer and agricultural lime
- Manure
- Sewage sludge

These sources are therefore examined separately with the main emphasis on the temporal trends and comparison of the relative magnitude of the sources. Finally, the problem of contaminated sites located outside farmland areas is briefly described.

Photo: Highlight

4.4.2 Heavy metals in the terrestrial environment

Lead

Lead consumption in Denmark has been declining significantly. The main uses were vehicle batteries, roofing, flashing, cable shielding and glass. Since 1945, an estimated 150,000–200,000 tonnes of lead have been laid out in the soil in the form of electric cables. No overall estimates are available as to how much of this has been removed after cessation of use. Little lead is expected to have leached from the cables, however. Waste deposition and scrap metal are considered to comprise two additional but lesser sources of lead input to the terrestrial environment. Petrol as a source of lead pollution has effectively ceased with the ban on leaded petrol.

Cadmium

The total cadmium consumption in 1996 was estimated to be 43–71 tonnes. This includes the unintended consumption of 5.4–9.5 tonnes cadmium present as an ancillary substance in coal, oil, cement, commercial fertilizer, agricultural lime, etc. In addition, 12–25 tonnes cadmium were deposited in slag and fly ash, among other things as construction filler in roads, dams, etc. Cadmium consumption is currently estimated to be stagnating. The primary source of cadmium in Danish society in 1996 was still cadmium-nickel batteries. In 1995, the Danish Parliament placed a levy on cadmium-nickel batteries and passed a law concerning refund of the levy in connection with collection of used batteries. In the long term, the levy will probably promote the sale of less harmful types of battery.

Copper

The calculations of the mass flow of copper in Danish society are based on old data. In 1992, total consumption was thus estimated to be 35,000–43,000 tonnes, of which 20–30% derived from recycling. The main consumer areas were electrical conductors and other live equipment, valves, fittings, copper goods and building materials. Other sources of copper input to the terrestrial environment include leaching from pressure-impregnated timber and deposition of waste and scrap. Over the period 1960–1992, some 350 tonnes copper are thus estimated to have been lost to the environment from pressure-impregnated timber. How much of this is lost to the terrestrial environment is unknown, but it is presumed that copper disposed of in waste pressure-impregnated timber will mainly end up in landfill percolate or waste incineration residues. An unknown amount ends up in private incineration and recycling, however. The loss of copper from pressure-impregnated timber continues, and has possibly increased since the use of chromium and arsenic for timber impregnation has been banned since 1992.

Manure is another major source of copper input to the terrestrial environment. A large part of the copper that is either naturally occurring in the feed or has been added as a growth promoter, will end up in the animals' faeces and urine. Figures from 1995–1996 thus show that a total of around 450–600 tonnes copper were input to arable land via manure each year. However, more stringent control and changes in the way farmers use feed mixtures, inclusion of the natural copper content of the feed and greater awareness of the problem in the agricultural sector mean that the loss is probably less nowadays.

Mercury

The latest mass flow calculations for mercury in Danish society are also old. In 1992/1993, mercury consumption in Denmark ranged from 0.64 to 0.95 tonnes. This is roughly half of the figure for 1982/1983. In addition, recent environmental policy measures can be expected to support this trend. The main uses were electrodes in electrolysis plants, dental amalgam and batteries.

Nickel

The consumption of nickel in 1992 amounted to approx. 5,400–7,800 tonnes. Stainless steel products accounted for 80% of the total consumption, with the most important products being pipes and tanks. More than 250 tonnes nickel were in the form of ancillary substances in coal, oil, fertilizer, lime and livestock feed.

Atmospheric deposition

Measurements of atmospheric deposition and ambient air concentrations of heavy metals over the past 10 years indicate a clear fall (*see Section 2.4*). The fall in lead input to the terrestrial environment is particularly notable. Much of the deposition derives from long-range transport of pollutants. Thus cadmium deposition on Denmark is many times greater than Danish emission of cadmium to the atmosphere. Despite the constant fall, atmospheric deposition still accounts for a considerable part of the total input of heavy metals to arable land (*Table 4.4.1*).

Commercial fertilizer and lime

The cadmium content of commercial phosphorus fertilizers has been reduced through regulatory control in recent years.

Cadmium is naturally occurring in the phosphorus-rich raw materials, which contain from 1 mg to more than 600 mg Cd per kg phosphorus. All in all, approx. 50 kg cadmium was applied in the form of commercial fertilizer in 1996, and a further 890 kg Cd in the form of agricultural lime. Expressed on an areal basis the input is relatively low because it is spread on a large area (*Table 4.4.2*). The input has probably fallen since then because an increasingly smaller amount of commercial fertilizer is being used. Over the past six years, consumption of commercial fertilizer has fallen by almost 200,000 tonnes to approx. 1,177,000 tonnes in 2000, which was 2% less than in the preceding year. Consumption of agricultural lime has also fallen steadily for the past many years. Sales of lime products thus fell to approx. 621,000 tonnes in 2000, which was 11% less than in the preceding year.

In 1994 it was estimated that 135–140 tonnes of copper were applied to fields as commercial fertilizer, and a further 2 tonnes in the form of agricultural lime. The corresponding figures for 1997 were 86 tonnes and 3.6 tonnes, respectively. Given the continuing decline in consumption of commercial fertilizer and agricultural lime, the figures for copper input can be expected to be even lower today. Copper is also an impurity in phosphorus, and is added as a micronutrient to aid crop growth. As regards the other heavy metals, commercial fertilizer and agricultural lime only comprise minor sources.

Manure and sewage sludge

In order to enhance recycling, nutrients from organic waste from livestock and man are recirculated via arable soil. Both waste products contain heavy metals and can therefore comprise a potential risk to the environment and health when applied in large amounts. The main source of copper input to the terrestrial environment is manure as the majority of the copper that is added to the livestock feed as a growth promoter ends up in the manure. The most recent studies of the copper content of pig slurry are from 1995–1996. The measured copper and zinc concentrations ranged from 18 to 33 g Cu and 48 to 68 g Zn per tonne pig slurry and around 8 g Cu per tonne cattle slurry. Expressed in terms of dry matter, the copper content of pig slurry was approx. 520–650 g per tonne, and the zinc content was 900–2,060 g per tonne. As a consequence, around 450–600 tonnes Cu and 1,200 tonnes Zn are input to arable land each year via manure alone. However, part of this represents a returned contribution to the soil derived from copper and zinc uptake by fodder crops. On arable land receiving all its fertilizer as pig slurry, copper input amounts to approx. 750 g per ha per year. The crops only remove 50–100 g per year. This yields a net input of at least 600 g Cu per ha per year. As the copper content of cattle slurry is considerably lower, the national average for land fertilized with manure is considerably lower (*Table 4.4.1*).

Manure is also expected to be a major source of nickel input to the terrestrial environment. Nickel derives from coarse fodder and concentrates, as well as from feed fat. Nickel input to arable land via manure totalled approx. 32–99 tonnes at the beginning of the 1990s. In 1995, the Danish Plant Directorate issued a directive setting a maximum

Table 4.4.1

Annual inputs of heavy metals to Danish arable land from various sources. The areal inputs shown are scaled up to a total farmland area of 2.3 million ha, thus excluding permanent grass and set-aside acreage.

(Source: National Environmental Research Institute).

Source	Lead		Cadmium		Copper		Chromium		Nickel		Zinc	
	t/yr	g/ha/yr	t/yr	g/ha/yr	t/yr	g/ha/yr	t/yr	g/ha/yr	t/yr	g/ha/yr	t/yr	g/ha/yr
Atmospheric deposition	23.0	10	0.70	0.3	18.5	8	3.0	1.3	4.6	2.0	184.0	80.0
Commercial fertilizer and lime	4.5	4	0.90	0.8	90.0	40	3.0	2.1	6.0	4.7	23.5	18.5
Manure	2.7	3	1.40	1.5	520.0	575	7.5	8.2	15.0	16.0	1,165.0	1,290.0
Sewage sludge	4.0	51	0.12	1.5	18.9	220	2.1	25.0	1.8	22.0	55.7	650.0

Table 4.4.2

Heavy metals content of soils from Danish seminatural/natural areas, forest and farmland.

The values are medians in mg/kg.

(Source: National Environmental Research Institute, 1996).

	Arsenic	Lead	Cadmium	Copper	Chromium	Mercury	Nickel	Zinc
5% fractile	0.9	4.5	0.036	0.8	2.7	<0.01	0.9	5.8
Median (*n*=393)	3.3	11.3	0.16	7.0	9.9	0.04	5.0	26.8
95% fractile	8.4	19.2	0.45	15.9	30.4	0.12	15.1	59.7
Sandy soils (*n*=226)	2.6	10.5	0.13	5.6	6.4	0.03	2,9	18.4
Clayey soils (*n*=167)	4.1	12.1	0.22	9.0	17.1	0.05	9.6	43.3
Arable land (*n*=311)	3.6	11.3	0,18	7.8	10.7	0.04	5.7	29.1
Forest soils (*n*=68)	2.3	12.1	0.09	2.8	7.0	0.04	2.9	18.9
Uncultivated soils (*n*=14)	1.3	8.7	0.07	0.9	3.8	0.01	1.5	7.7

nickel content for feed fat. As a consequence of that alone, nickel input for manure can now be expected to be less than 25 tonnes per year. This is nevertheless considerably more than the 1.8 tonnes Ni that was spread on arable land with sewage sludge in 1999.

Mapping of heavy metals

The heavy metals content of Danish soils has been analysed with the aim of mapping the background level of heavy metals (*Table 4.4.2*). Urban areas and contaminated sites are not included in the survey as these areas comprise a special problem. The highest concentrations were generally found on clayey and humus-rich soils and are generally attributable to natural conditions. The lower content of heavy metals in the natural ecosystems relative to arable land and forests is primarily because the natural ecosystems are mainly associated with sandy soils, whose natural content of heavy metals is low.

Comparison of the average background concentrations in arable land with the estimated inputs (*Tables 4.4.1 and 4.4.2*) reveals that the annual input of copper and zinc together with atmospheric deposition of the two metals comprises more than 1% of the average background content in the topsoil in cases where slurry or sludge is used as the only fertilizer. All other sources comprise considerably less than 1% of the background level. As an unknown amount of heavy metals concomitantly disappears from the soil through leaching and uptake by plants, it will take many years before any increase would be measurable.

If the copper content of pig slurry remains at the level last measured in 1995/1996, it will take between 70 and 120 years before the soil copper content reaches a level equivalent to the soil quality standard set to protect the environment and agricultural production (30-40 mg per kg dry matter) in the case of the soils with the highest background levels (*Table 4.4.2*). In the case of the average soil types, it will take approx. 50 years longer.

These calculations are based on the assumption that up to 150 g Cu per ha is removed each year in the crops and in feed. It is therefore feared that it will only take a couple of generations of pig farmers before there is a real risk that the soil content of copper will reach a level that is critical for the most sensitive crops. On the other hand, it is certain that if the critical levels of heavy metals are exceeded on arable land, it will take many centuries, perhaps even millennia, before the content once again falls to acceptable levels. Farmers and feed companies are well aware of the problem.

Whereas the majority of slaughter pigs were formerly fed throughout their lives with piglet feed, where the limit value for copper is five-fold greater than in feed for slaughter pigs, this practice has now ceased for an increasing proportion of pig production. In the first quarter of 2001, the Danish Plant Directorate detected exceedance of the current limit values for copper of 35 and 175 mg Cu per kg pig feed in 13% and 6%, respectively, of complete feed mixtures for slaughter pigs and piglets. The limit value for zinc (250 mg per kg) was exceeded in 12% of complete feed mixtures for piglets.

Photo: NERI/Britta Munter

4.4.3 Organic waste and agriculture

In Denmark, there is broad political support for recirculating nutrients to the greatest extent possible. The action plan "Waste 21" thus stipulates goals for exploitation of sewage sludge and organic domestic waste. It is expected that it will be possible to attain the goal of recycling half of all sewage sludge and a minimum of 150,000 tonnes of organic domestic waste by 2004.

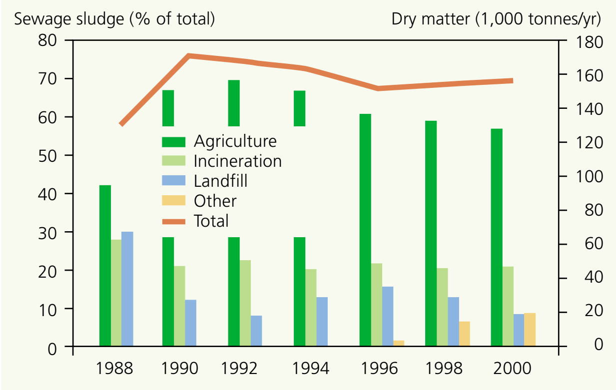
In the towns of the future, waste management can be organized in such a way as to prevent mixing of the waste streams. This will obviate the need to remove nutrients from the wastewater, which can then be treated locally using soakaways, etc. Preliminary studies indicate that waste products generated by alternative yet sanitary management of toilet waste and organic domestic waste will be well suited as fertilizer. However, because of the major investments associated with the present waste system, it will take a long time to change the urban infrastructure to enable nutrient cycles to be re-established – at least 50–100 years. In other parts of the world, where investments in functioning systems have not yet been made, the process can take place more rapidly. Before management of our waste can be radically changed, the societal consequences for health, technology, environment and agriculture will have to be thoroughly investigated. There is some potential in the utilization of nutrients from households (*Table 4.4.3*). However, present agricultural consumption of commercial fertilizer is so great that urban waste will only be able to substitute for a minor part, i.e. approx. 10% of nitrogen consumption and 20% of phosphorus consumption. As the lack of manure can curtail development towards a greater share of organic farming, urban waste products will be able to meet a greater share of agriculture's nutrient requirements since the use of sewage sludge on organic farms is not presently permitted. Before then, though, as mentioned earlier, a large number of technical problems will have to be solved, and attitudes changed.

Despite – or perhaps actually due to – effective sludge treatment at more than 1,500 Danish wastewater treatment plants, residues of most of the chemical substances used in industry and households are found in the sludge. Following preliminary treatment, approximately 40% of the sludge is treated anaerobically in biogas reactors at the wastewater treatment plants. A number of hazardous substances are only partially degraded by this treatment, however. Apart from the heavy metals it is the large amounts of detergents and plasticizers (phthalates) in the sludge that cause concern.

In order to facilitate safe exploitation of sewage sludge as fertilizer, limit values for these substances and the polyaromatic hydrocarbons (PAH) were stipulated per 1.7.1997 in the Statutory Order on the use of waste products on arable soils. Since their introduction, these limit values have been tightened and are now as follows:

- 1,300 mg per kg dry matter for the detergent LAS
- 50 mg per kg dry matter for the plasticizer DEHP
- 3 mg per kg dry matter for the polyaromatic hydrocarbons (PAH)
- 30 mg per kg dry matter for nonylphenol.

Figure 4.4.1
Sewage sludge production over the period 1987–1999 apportioned by fate. (Source: Danish Environmental Protection Agency).



The requirements in the Action Plan on the Aquatic Environment concerning the upgrading of the Danish wastewater treatment plants has resulted in a marked increase in the production of sewage sludge from the mid 1980s to the mid 1990s. The percentage of sewage sludge used for agricultural purposes fell during the period 1996 to 2000, among other reasons due to the new limit values for hazardous substances (*Figure 4.4.1*). In total, 25% less sludge was applied to fields in 2000 than in 1996. The more stringent limit values that entered into force on 1.7.2000 will probably lead to a further reduction in the percentage of sludge applied to arable land. If the voluntary phase-out of nonylphenol does not have the desired effect, the percentage of sludge used in agriculture will decrease even further when the limit value for nonylphenol is reduced to 10 mg per kg in July 2002. As a result of the tightened quality standards, a cautious estimate is that only approximately half of Danish sewage sludge will be suitable for agricultural use in the future. This is in accordance with the objectives stipulated in the action plan "Waste 21". The percentage of sludge that is incinerated or sent to landfill will probably remain unchanged since new uses have arisen since 1997. These include the use of sludge in mineralization plants and the use of the inorganic matter content of the sludge in cement and sandblowing agents.

The quality of Danish sludge has regularly been improved. Due to the general phase-out policy and im-

Table 4.4.3
Waste and fertilizer quantities in Denmark (1996) together with the potential for utilization of solid organic domestic waste, garden waste, faeces and urine. If urine and faeces are separated from the sewage sludge, its fertilizer value will decrease.
(Source: Eilersen et al., 2001).

	Dry matter	Carbon	Nitrogen	Phosphorus	Potassium	Sulphur
Commercial fertilizer			300,000	22,000	83,000	
Sewage sludge	162,000	45,000	7,000	5,100	500	1,200
Compost	190,000	-	1,700	400	700	450
Pig manure	930,000	500,000	125,000	25,000	45,000	7,000
Cattle manure	2.500,000	1.000,000	155,000	18,000	130,000	17,000
Organic domestic waste	160,000	69,000	3,000	600	750	400
Garden waste	270,000	133,000	1,500	300	1,500	150
Faeces	63,000	45,000	1,800	900	1,800	400
Urine	110,000	15,000	20,000	2,700	4,500	1,800
Urban waste in % af commercial fertilizer			**8.8**	**20.5**	**10.3**	
Urban waste in % af of manure			**9.3**	**10.5**	**4.9**	

proved source tracking in the Municipalities, the heavy metals content has fallen markedly over the last few decades. Conversely, no major decrease in heavy metals content is detectable for the period 1994–1999 (*Table 4.4.4*). More than 90% of the sludge meets the current limit values for heavy metals.

With respect to the four groups of hazardous substances that have been monitored in sludge since 1997, no major change has been detected for the PAHs, while the sludge content of DEHP and nonylphenol and its ethoxylates has decreased, and the LAS content has increased (*Figure 4.4.2*). Campaigns against LAS in detergents and the eco-labels for LAS-free detergents will probably lead to a decrease in the consumption of LAS, which is in accordance with the pattern seen in Sweden. In spring 2001, the major detergent manufacturers thus decided to remove LAS from their products. A voluntary agreement with the branch organization aimed at stopping the use of nonylphenol in numerous products should also lead to a decrease in the nonylphenol content of Danish sewage sludge.

4.4.4 Manure

Manure is spread on arable land in amounts that clearly exceed the amount of sewage sludge, etc. Annual manure production by Danish pigs and cattle amounts to 35 million tonnes (3–4 million tonnes dry matter). The hazardous substances in manure derive from numerous sources, the most important of which are cleaning and disinfecting products, udder care products and pest control agents for use in livestock housing. Air pollutants such as PAHs and heavy metals are present in small amounts in feed and will there-

Table 4.4.4

Concentration of heavy metals and hazardous substances in Danish sewage sludge (mg/kg dry matter). The values are the medians with the 5% and 95% fractiles in parentheses. In the case of lead, cadmium, mercury and nickel, phosphorus-related limit values also exist. Sewage sludge producers must comply with either the dry matter-related or the phosphorus-related limit values.
* The data are not nationwide, only encompassing analyses from 19 Danish sewage treatment plants.
(Source: Danish Environmental Protection Agency, 1996e).
[1] 25.7 [2] 760.0

	Limit value	1994	1995	1996	1997	1998	1999
Arsenic		-	5.1	6.5	3.9	10.1	8.0
			(0.5-8.5)	(2.4-231)	(0.04-4.97)	(3.3-11.3)	(2.7-10.0)
Lead	120	71.0	72.0	52.0	58.0	57.0	56.0
		(25-123)	(26-155)	(20-107)	(20-183)		21-256)
Cadmium	0.8	1.5	1.5	1.2	1.4	1.3	1.4
		(0.8-2.3)	(0.8-6.0)	(0.7-2.1)	(0.7-2.1)	(0.8-7.4)	(0.7-6.4)
Copper	1,000	260.0	298.0	275.0	247.0	270.0	25.0
		(85-500)	(100-512)	(93-515)	(100-492)	(84-464)	(81-487)
Chromium	100	26.0	34.0	25.0	28.0	29.0	29.0
		(8-55)	(10-108)	(10-65)	(10-60)	(10-85)	
Mercury	0.8	1.2	1.4	1.2	1.2	1.1	1.0
		(0.4-2.7)	(0.3-3.1)	(0.3-2.6)	(0.4-3.0)	(0.3-3.1)	(0.3-2.9)
Nickel	30	21.0	[1] [redacted]	18.0	19.0	190	21.8
		(8-42)	(10-141)	(9-55)	(8-44)	(8-53)	(10-58)
Zinc	4,000	[2] [redacted]	878	767.0	783.0	7200	758.0
		(300-1,360)	(312-1,610)	(297-1,303)	(336-1,078)	(280-1,204)	(342-1,201)
DEHP	50	-	24.5	-	220	240	21.4
			(9-151)*		(4,3-64)	(4.7-65.7)	(5.2-42)
LAS	1,300	-	420	-	3100	3740	490.0
			(13-13,725)*		(50-3,100)	(50-3,100)	(50-3,500)
Nonylphenyl	30	-	8.0	-	16.0	8.1	10.4
			(0.3-61)*		(1.5-133)	(0.8-76.2)	(1.1-56.3)
PAH	3	-	0.7		1.8	1.8	2.0
			(0.1-4.9)		(0.4-5.1)	(0.4-5.0)	(0.4-4.9)

fore reappear in the manure. Finally, medication of livestock can lead to the presence of medicine residues in the manure.

Only a few good studies are available of hazardous substances in manure. A major Danish study involving analyses from more than 30 holdings in Jutland revealed that the LAS, DEHP, nonylphenol and PAH content was generally low in both cattle slurry and pig slurry. The average concentrations expressed in mg per kg dry matter were below 50 mg LAS, 1 mg DEHP and 0.1 mg PAH. Nonylphenol was not found in concentrations above the detection limit. All in all, the input of the four substances per hectare was therefore far lower for slurry than for sewage sludge. The manufacturers of agricultural cleaning agents that contained LAS in 1997 have stated that they have subsequently replaced the LAS in their products with other tensides. The present LAS content of slurry can therefore be expected to be very low.

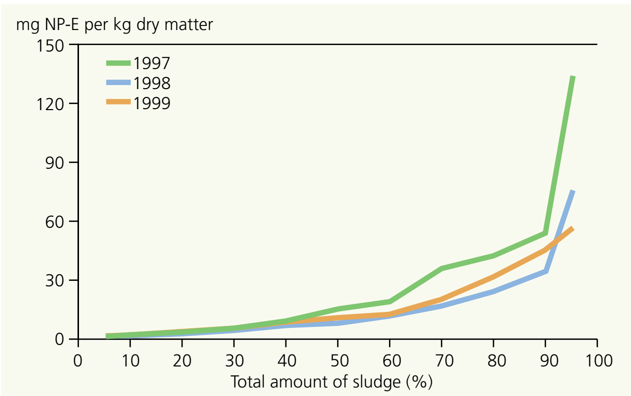
There are no comprehensive studies of the concentrations of pharmaceuticals and growth promoters in manure. The so-called therapeutic consumption of antibiotics amounted to more than 40 tonnes in 1997. At the same time, more than 14 tonnes of medicine was used on animals with metabolic disorders or digestive problems. Medicines are also used to treat other types of disease, but the consumption of these is generally low. Certain types of growth promoters are still in use, although consumption of antibiotic growth promoters has fallen considerably due to voluntary agreements. Thus the consumption of growth promoters fell from more than 105 tonnes in 1996 to less than 12 tonnes in 1999, of which antibiotics only accounted for 2.6 tonnes. In 2000, consumption of antimicrobial growth promoters had virtually ceased (*Figure 4.4.3*).

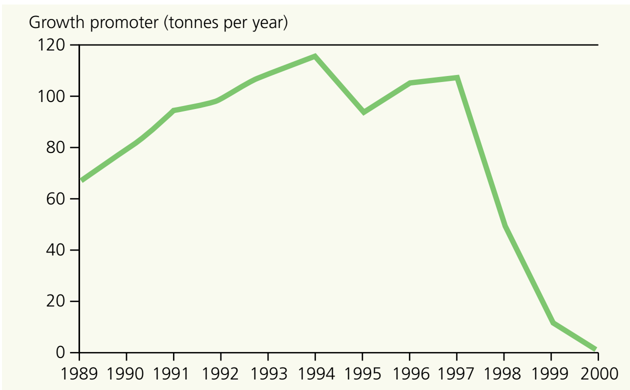
Consumption of coccidostatics, which are primarily used as parasiticides in slaughter chickens, amounted to 16 tonnes in 2000, representing a fall compared to 25.5 tonnes the preceding year. The marked fall in consumption of antibiotic growth promoters appears to have led to only a minor increase in the consumption of antibiotics for combating disease. From 1997 to 1999, consumption of medicine prescribed by veterinary surgeons thus only increased from 55.7 tonnes to 61.9 tonnes.

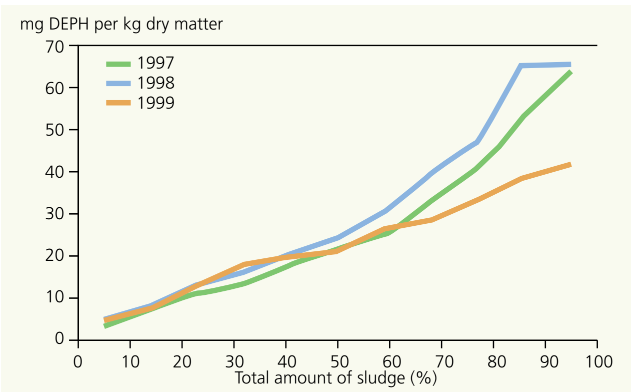
Very little is known about the fate of medicine and growth promoters in slurry containers and in the soil. However, as not all the medicine is metabolized in the livestock, medicine residues must be detectable in the slurry containers,

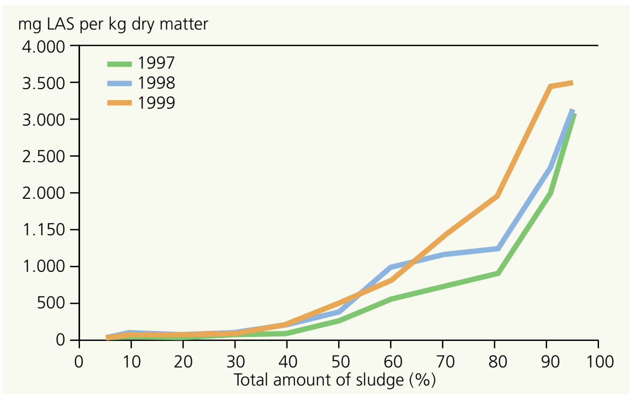
Figure 4.4.2 (a, b, c)
Concentrations of DEHP, LAS and nonylphenol (+ ethoxylates) in fractiles of the total amount of sewage sludge in 1997, 1998 and 1999.
(Source: Danish Environmental Protection Agency, 2001, 2000b, 1999a).

Figure 4.4.3 (below)
Consumption of growth promoters in Denmark over the period 1989–2000.
(Source: Danish Plant Directorate, 2001).









where some metabolism and degradation takes place. In accordance with the conditions at the wastewater treatment plants, it is unlikely that all the substances are degraded completely, however, and some of the substances will therefore end up on the arable land when the manure is spread.

The above section has shown that with the current regulations and quality standards, there are no grounds for major concern about the recycling of organic waste. Consideration should be given to the possibility of reducing consumption of copper and zinc in feed mixtures for pigs, and our knowledge of the fate of veterinary medicines after the animals have been treated should be improved. Finally, efforts should continue to reduce society's consumption of potentially hazardous substances so as to reduce their concentrations in sewage sludge such that use of the sludge as an agricultural fertilizer remains acceptable.

4.4.5 Persistent pollutants in arable soils

A common property of substances such as dioxins, polychlorinated biphenyls (PCB) and brominated flame retardants is that they are persistent in the environment and can accumulate in organisms. Because of this and their unfortunate toxicological properties, they pose a problem even at very low concentrations. High levels of these substances are therefore generally undesirable in our arable soils.

Certain dioxins and PCBs are extremely carcinogenic, and brominated flame retardants are suspected of causing hormonal disturbances. The brominated flame retardants have many of the same harmful effects on health as the more well-known PCBs, DDTs and dioxins. In contrast to DDT and PCB, however, which have long been banned in the EU, and to dioxins, which only arise unintentionally during the combustion of fossil fuels or other forms of fire, the brominated flame retardants are deliberately incorporated in electronic products. The substances can thus be measured in the blood of PC users. They are teratogenic and suspected of oestrogenic effects. In addition, they form dioxins during fires. Brominated flame retardants are not produced in Denmark, but we import 320–660 tonnes annually, mainly in the form of raw plastic or as laminates for printed circuit boards.

The mass flow analyses of brominated flame retardants are based on an extremely small amount of data, very little of which is Danish. Brominated flame retardants can volatilize from the materials in which they are used. The emitted compounds will rapidly bind to particles, whereafter they can disperse into the environment, either immediately or during subsequent dismantling or disposal of the appliances. Little is known about their further fate in the environment, and no estimates are available of atmospheric deposition on the soil.

The annual atmospheric input of dioxins to the terrestrial environment is estimated to be in the order of 120 g I-TEQ. New Danish measurements show that, like dioxins etc., the brominated flame retardants are also detectable in very low levels in sewage sludge. Input of dioxins and brominated flame retardants to Danish arable land via sewage sludge is modest, though, i.e. of the order of 1.7 g I-TEQ per year for dioxins and 30–300 kg per year for brominated flame retardants. This can be compared with for example the input of PAHs to the terrestrial environment in sewage sludge, which amounted to approx. 140 kg in 1999. As regards dioxins and brominated flame retardants, atmospheric deposition is therefore the predominant source. Tars such as PAH can also be present in high levels in contaminated sites, for example in connection with former gasworks, landfills, petrol filling stations, etc.

4.4.6 Contaminated sites in towns and in uncultivated countryside

Apart from the surface loading that results from agricultural use of fertilizers (see above) and pesticides (*see Section 4.5*), there are also numerous sources of soil contamination in towns and urban areas. Point-source contamination can also be found in the uncultivated countryside, e.g. disused timber impregnation sites. The problem of contaminated sites in the towns is examined in *Section 5.3*.

Soil contamination has hitherto been regulated through a large number of laws and regulations, e.g. the Waste Deposits Act and the Environmental Protection Act, as well as certain other laws and regulations within the environment, agriculture and energy sectors. A new Contaminated Sites Act entered into force in 2000. This is the first regulation aimed at diffuse contamination from so-called surface sources. The problems associated with the normal use of pesticides, sewage sludge, etc. will still have to be solved through other legislative areas, however, as diffuse contamination under the Contaminated Sites Act typically derives from traffic, smokestack emissions and construction fillers.

The Contaminated Sites Act prioritizes public efforts in areas where contamination is considered to threaten the groundwater or to pose an acute threat to health, i.e. those cases where the soil can have a harmful effect on man in areas that are presently used for housing, child-care centres or public playing grounds. The Act also encompasses the possibility of public efforts in relation to contamination that can have a more general negative impact on the environment. However, the Act presumes that these considerations will only exceptionally result in publicly financed remediation. Responsibility for prioritizing the remediation efforts lies with the Counties.

One set of ecotoxicological soil quality standards and two sets of quality standards are in force that aim to protect man from the risks posed by contaminated soil (*Table 4.4.5*).

4.4.7 Legislation and regulation

In cooperation with the Danish EPA, the Counties' Soil Contamination Information Centre has collated the existing data from studies of diffuse soil contamination in the database Dif-Jord. The data derive from more than 50 reports from 12 Counties or Municipalities in Copenhagen and encompass more than 3,000 analysed soil samples. The diffuse contamination typically derives from air pollution associated with traffic or large industrial enterprises or from contamination of the surface soil in areas located on non-contained filler deposits such as old city centres, i.e. not including sites encompassed by the Waste Deposits Act or similar sites. The same applies to sites contaminated by point sources. These are instead registered in the Danish EPA's register of waste deposits.

The terrestrial environment is regulated directly or indirectly by a large number of legislative complexes and associated statutory orders, circulars and guidelines, e.g. the Environmental Protection Act (1998), the Contaminated Sites Act (1999), the Protection of Nature Act (1998), the Chemical Substances and Products Act (1997), the Agricultural Holdings Act (1999), the Forestry Act (1996), the Agricultural Use of Fertilizer and Vegetation Cover Act (1998), the Organic Farming Act (1999) and the Structural Development of Agriculture and Organic Farming Act (1996).

The primary aim of the Contaminated Sites Act of 2 June 1999 is to prevent, remove or limit soil contamination or hinder or prevent the harmful effects of soil contamination on groundwater, human health and the environment in general. The Act contains provisions stipulating the responsibility of the polluter to take the necessary steps to remediate the effects of soil contamination and to re-establish the state that existed prior to the contamination. In cases where the polluter cannot be held accountable, the site becomes the responsibility of the public remediation efforts. The Act also contains provisions regulating the contamination of the environment in connection with the use and disposal of soil.

Diffuse contamination of the soil is prevented through such means as setting limit values for the content of hazardous substances in commercial fertilizer, sewage sludge and compost used for agricultural purposes.

Pesticides must be approved by the Danish EPA before they can be imported, sold or used. In addition to groundwater and working environment protection, the risk to the environment is an important factor in the approval procedure. Since pesticides are not unnaturally toxic to certain organisms, the approval procedure primarily focuses on their unacceptable side effects on non-target organisms.

At the EU level, a directive is being drawn up concerning the biological treatment of organic waste. The early drafts of this directive indicate that obligatory source separation of organic domestic waste will be introduced in the long term.

Photo: NERI/Patrik Fauser

	Health-based soil quality standards	Health-based threshold values	Ecotoxicological soil quality standards
Arsenic	20	20	10
Lead	40	400	50
Cadmium	0.5	5	0.3
Copper	500	500	30
Chromium (III)	500	1,000	50
Chromium (VI)	20	-	2
Mercury	1	3	0.1
Nickel	30	30	10
Molybdenum	5	-	2
Zinc	500	1,000	100
PAH (sum)	1.5	5	1.0
Benz(*a*)pyrene	0.1	1	0.1
Dibenz(*a,h*)anthracene	0.1	1	-
Chlorophenols (sum)	3	-	0.01
Pentachlorophenol	0.15	-	0.005
DEHP	25	-	1.0

Table 4.4.5
Danish soil quality standards (mg/kg dry matter).
(Source: Danish Environmental Protection Agency).

Photo: Danish Institute of Agricultural Sciences/Henny Rasmussen

4.5 Theme – Pesticides

Pesticides are used to combat weeds, pests and fungal infections, especially in agriculture. They are also used in market gardens, on sports grounds, alongside roads and railroads, and in private gardens. Pesticides can be unintentionally spread to other parts of the environment through wind drift, long-range transport or via leaching from the soil. In Denmark and other countries, pesticides have thus been detected in groundwater, inland waters and rain water. The pesticides can be harmful to a number of animals and plants, as well as to human health.

4.5.1 Pesticide consumption and application frequency in Denmark

Each year, the Danish EPA publishes national statistics for pesticide consumption and pressure on the environment expressed in terms of application frequency.

While the figures for the amount of pesticide used (*Table 4.5.1*) reflect consumption, they do not directly reveal anything about the magnitude of the environmental pressure. The pesticides differ considerably in how effective they are. A simple, meaningful measure of pressure on the environment is the so-called application frequency. This indicates how many times a plot of arable land is sprayed with the recommended dose, and is calculated from the national figures

Table 4.5.1
Pesticide consumption in Denmark over the period 1992–2000 apportioned by pesticide category.
(Source: Danish Environmental Protection Agency, 2001)

	Amount per year (tonnes)								
Pesticide category	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Herbicides	2,824	2,632	2,685	3,281	2,915	2,726	2,619	1,892	1,982
Growth regulators	281	331	247	310	87	104	175	221	204
Fungicides	1,333	1,033	892	1,055	631	794	770	715	614
Insecticides	128	107	95	163	36	51	55	46	41
Total	**4,566**	**4,103**	**3,919**	**4,809**	**3,669**	**3,675**	**3,619**	**2,874**	**2,841**

for pesticide sales and the recommen-ded doses (*Table 4.5.2*). By way of example, the application frequency for herbicides in 1992 was 1.28. This means that Danish fields were sprayed with herbicide an average of 1.28 times assuming that the recommended dose was always used. This figure naturally hides the fact that some fields were sprayed more than others, 1.28 being the estimated average.

Effective pesticides are used in relatively small doses, while less effective pesticides are applied in higher doses. If the recommended dose is low, not much of the pesticide needs to be used to spray one hectare of field. This means that each time one kg of an effective pesticide is sold to the agricultural sector, it will be sprayed on a greater area and hence contribute more to the application frequency than one kg of pesticide with a higher recommended dose. When calculating the application frequency, one can therefore say that the more effective pesticides count more than the less effective pesticides. An effective pesticide is characterized by the fact that relatively small amounts can affect biological processes. This means that one kg of an effective pesticide affects the environment more easily than one kg of a less effective pesticide. The application frequency can therefore be considered as a measure of the environmental impact, but a very simple measure of a very complex environmental effect.

The level of consumption has generally decreased slightly over the years, but the application frequency has not decreased to quite the same extent. This is due to the fact that smaller amounts (weight) of pesticides are being applied at the same time as the agents are becoming more effective. As mentioned earlier, this means that they are weighted more in the calculation of the application frequency. However, it is very difficult to detect any clear trend from year to year, in part because the need for pesticides varies, and in part because the figures are based on pesticide sales and not on actual consumption. The goal is an overall application frequency of 2.0 by the year 2002. As the application frequency was 2.0 in 2000, the goal has been attained 2 years ahead of schedule. The application frequency varies considerably from year to year, however, and it is therefore difficult to use a single figure as the goal (*Table 4.5.2*). For example, if 2002 becomes a year with a low application frequency due to climatic and other conditions, it will be far easier to attain the goal. Conversely, it could easily be difficult to attain the goal if 2002 becomes a year in which the climate and pest attacks enhance the need for a relatively high application frequency.

The various crops are treated with pesticides differently, so the environmental impact varies considerably from crop to crop (*Table 4.5.3*). In order to smooth the rather large inter-annual variations, the table shows the 3-year averages for the years 1997, 1998 and 1999.

If the application frequency is calculated jointly for the different pesticide types, the assumption has to be made that a treatment to combat for example weeds affects the environment in the same way as a treatment to combat insects. It can therefore be advantageous to keep the different types of pesticide separate when assessing the individual crops in relation to environmental impact. It is evident (*Table 4.5.3*) that winter cereals are sprayed with growth regulators far more frequently than the other crops, and that potatoes and vegetables are sprayed relatively frequently with fungicides. In contrast, the use of herbicides and insecticides is more evenly distributed.

The figures can be taken as an expression of the environmental impact on the individual field, but it can also be interesting to know the magnitude of the impact of the various crops on the Danish environment in general. As a measure of this, one can use the area sprayed with the recommended dose for each individual crop and for each individual pesticide. An example of a typical calculation is: If one tonne of a pesticide has been sold for a particular crop, and if the

Table 4.5.2
Pesticide application frequency over the period 1992–2000 apportioned by pesticide category. (Source: Danish Environmental Protection Agency, 2001).

	Application frequency								
Pesticide category	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Herbicides	1.28	1.24	1.28	1.72	1.28	1.67	1.43	1.33	1.28
Growth regulators	0.13	0.15	0.12	0.15	0.04	0.05	0.09	0.11	0.10
Fungicides	0.71	0.57	0.53	0.58	0.38	0.47	0.51	0.59	0.45
Insecticides	0.61	0.61	0.58	1.04	0.21	0.3	0.24	0.3	0.18
Total	**2.73**	**2.57**	**2.51**	**3.49**	**1.92**	**2.49**	**2.27**	**2.33**	**2.00**

recommended dose is 1 kg per ha, then the sprayed area for that crop is 1,000 ha. This corresponds to multiplying the application frequency for a crop by the area cultivated with the crop. Summating the sprayed area for each crop and for each pesticide type then provides an impression of how much each crop impacts upon the environment expressed in terms of the number of sprayed hectares (*Table 4.5.4*).

Apportionment of the total pesticide-treated area (*Figure 4.5.1*) reveals that cereals dominate relative to other crops. From this it is apparent that even if a cereal field is treated less frequently than for example a potato field (*Table 4.5.3*), so much cereal is grown in Denmark that cereals are nevertheless the crop responsible for the greatest pesticide impact on the environment. The most notable exception from this rule is potatoes in relation to fungicides, where potatoes account for approx. 25% of the impact even though they only account for 6.7% of the cultivated area.

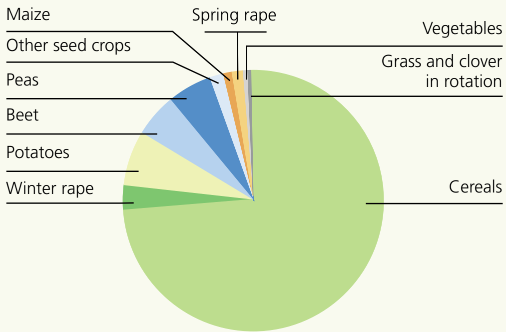


Figure 4.5.1
Pesticide-treated area apportioned by crop type (winter and spring crops are combined in the case of cereals). (Source: Danish Environmental Protection Agency, 2001).

Table 4.5.3
Pesticide application frequency for the various types of crop apportioned by pesticide category. The values are the means for the years 1997, 1998 and 1999. (Source: Danish Environmental Protection Agency, 2001).

	Herbicides	Growth regulators	Fungicides	Insecticides	Total for the crop
Winter cereals	1.63	0.19	0.81	0.26	2.89
Spring cereals	0.85	0.01	0.25	0.23	1.34
Winter rape	0.87	0.00	0.08	0.65	1.60
Spring rape	0.89	0.00	0.01	0.68	1.57
Other seed crops	0.81	0.08	0.04	0.24	1.17
Potatoes	1.84	0.00	6.84	0.27	8.95
Beet	1.85	0.00	0.07	0.77	2.70
Peas	2.15	0.00	0.19	0.56	2.90
Maize	1.17	0.00	0.00	0.11	1.28
Vegetables	3.27	0.02	3.23	1.10	7.62
Grass and clover in rotation	0.03	0.00	0.00	0.04	0.07

Table 4.5.4
Sprayed area (ha) of the various types of crop apportioned by pesticide category. The values are the means for the years 1997, 1998 and 1999. (Source: Danish Environmental Protection Agency, 2001).

	Herbicides	Stem shorteners	Fungicides	Insecticides	Total for the crop
Winter cereals	1,456,533	168,883	710,350	228,003	2,563,770
Spring cereals	595,230	4,590	178,140	165,010	942,970
Winter rape	74,603	0	7,443	57,900	139,946
Spring rape	25.483	0	173	20,273	45,929
Other seed crops	64,140	7,420	2,806	18,480	9,846
Potatoes	69,070	0	251,520	10,120	330,710
Beet	182,026	0	7,216	76,150	265,393
Peas	196,413	0	17,576	48,173	262,163
Maize	53,426	0	0	4,840	58,266
Vegetables	17,752	110	17,681	5,973	41,517
Grass and clover in rotation	7,453	0	0	8,206	15,660
Total for each pesticide category	**2,742,132**	**181,003**	**1,192,908**	**643,129**	**4,759,173**

4.5.2 Impact on arable land animals, plants and fungi

The impact of the use of pesticides on plants and animals in arable land depends on how the individual pesticides are used, their fate in the environment and the nature of their toxic properties. The effect on the individual plant or animal species depends on where the species lives, and how sensitive it is to the pesticide used (direct effects), and how much the species in question is affected by the effects of the pesticide on other species (indirect effects).

As the purpose of pesticides is to kill something living, it must be expected that plants, fungi and insects are generally less abundant in pesticide-treated fields. This effect will rub off on organisms that live off the affected species. It has thus also been shown that insects that feed on weeds are considerably less abundant on land treated with herbicides, and that insects that eat fungi are less abundant in areas sprayed with fungicides.

The application frequency can thus be used as an indicator of both the direct and indirect effects of pesticide use.

There is one problem with the application frequency, though, namely that it is calculated on the basis of the recommended doses. The real number of treatments is therefore underestimated since many treatments are conducted using less than the recommended doses. The problem is that a reduced dose does not necessarily mean that the ecological effect is reduced correspondingly. For example, fungicide treatment of cereal crops is largely carried out using so-called split doses, i.e. instead of applying the recommended dose once, one third of the dose is applied 2–3 times. This can easily enhance the ecological effect even though the application frequency may actually decrease. No general record of the use pattern based on interview surveys and the like are kept at present, although such a system is being developed by Statistics Denmark.

It is unclear to what extent the use of reduced doses of herbicides improves the conditions for flora and fauna in Danish fields. In general, there are reasons for believing that weeds that are not completely killed by pesticides can serve as a food resource for parts of the fauna. This is unlikely to be the case for all insects, however. For example, the well-being of bumblebees and other insects that visit flowers is affected by whether or not the weeds flower. The use of reduced doses could be expected to leave more weed plants in Danish fields. However, there is no clear evidence that the amount of weeds has increased, at least not when calculated as the amount of weed in the harvest. Thus farmers have become better at spraying optimally, thus achieving the same effect with reduced doses. The effect of changes in the spraying pattern on seasonal development of weeds have not been studied. It is possible that weed biomass is in some cases higher for a long period after spraying with reduced doses. The goal of reducing the application frequency stipulated in the Pesticide Action Plan will increase the incentive to reduce the dose further, which will in turn increase the probability that the amount of weeds in Danish fields will increase.

A step higher up the food chain, indirect effects of pesticide treatment have been found. The majority of the pesticides used in Denmark are most toxic to organisms belonging to the same group as the pest. Thus in the doses used, herbicides are most toxic to vascular plants, fungicides are most toxic to fungi, and insecticides are most toxic to insects and other arthropods. The effects on the higher fauna are largely attributable to indirect effects on the ecosystem's food chains. Common arable land bird species such as the partridge, pheasant, yellowhammer and skylark breed less successfully in pesticide-treated fields compared with untreated or organically farmed fields, even though the pesticides used are not directly toxic to the birds in the doses used. Everything indicates that the effect on the birds is due to a decline in their food resource.

Less intensive pesticide treatment, which is one of the objectives of the Pesticide Action Plan, can therefore benefit arable land bird species, even if we do not know exactly how much it has to be reduced in order to have a beneficial effect on bird life.

Photo: NERI/Anna Bodil Hald

Photo: NERI/Niels Elmegaard

4.5.3 Occurrence of pesticides in watercourses, ponds and lakes

Pesticide inputs to the aquatic environment derive from:

- Deposition on the water surface from spray clouds
- Direct spraying when driving too close to the water body
- Deposition from the air following long-range atmospheric transport
- Leaching to drains and onwards to surface waters
- Leaching to the groundwater and subsequent upwelling to surface waters
- Surface runoff following heavy rain and melting snow
- Contamination from point sources, e.g. equipment cleaning sites and buried packaging, via discharges, drains or groundwater.

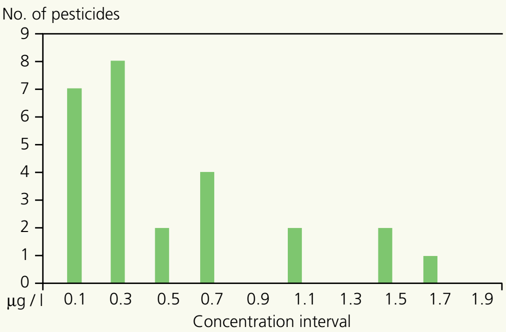


Figure 4.5.2

Number of pesticides for which the highest measured concentration lies within the indicated intervals (0.1 µg/l corresponds to the interval 0–0.2 µg/l, 0.3 µg/l corresponds to the interval 0.2–0.4 µg/l, etc.). With a further three pesticides the highest concentration exceeded 2 µg/l (3.6, 4.3 and 23 µg/l, respectively).
(Source: Bichel Committee, 1999).

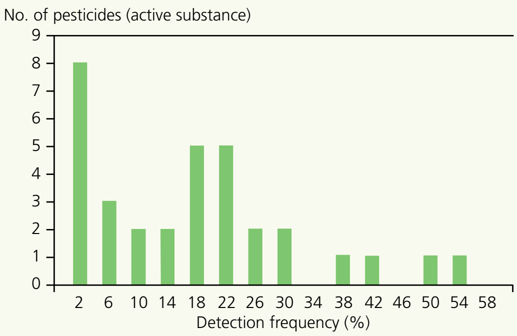


Figure 4.5.3

Number of pesticides detected in the samples examined with a detection frequency within the indicated intervals (2% corresponds to the interval 0–4%, 6% corresponds to the interval 4–8%, etc.).
(Source: Bichel Committee, 1999).

These various transport pathways seem very different. Under certain circumstances, deposition from spray clouds (wind-drift) can have a considerable impact on a pond as the pesticides from the spray cloud will tend to lie on the water surface in enhanced concentrations, partly because of poor mixing conditions in standing water, and partly because standing water forms a surface film where the lipid-soluble pesticides tend to concentrate. Some effects can be extreme, but perhaps occur relatively rarely. Examples are when the spraying equipment comes too close to a watercourse or a pond and sprays directly onto the water surface, or when water containing pesticides runs from equipment cleaning sites into drains and onwards to watercourses. In contrast, upwelling from groundwater has a more steady and less severe impact, although more permanent. Depending on the conditions prevailing, drains can result in both short-lasting severe impacts and more steady, long-lasting impacts. It is therefore difficult to determine whether a substance occurs "a lot" or "a little" in nature. Some substances appear suddenly and have a major impact, but occur rarely. Other substances do not occur in high concentrations, but are often present as they may have contaminated large parts of the environment far down into the groundwater. Both of these types of occurrence are undesirable.

The greatest impact can be described by means of the maximum concentration detected in the environment. In contrast, the steady and long-lasting impact is described by means of the detection frequency, i.e. how often the substance is detected in environmental samples. It thus seems reasonable to describe occurrence by means of two figures, i.e. the maximum concentration and the detection frequency. Data for the detection of 33 pesticides in Danish watercourses is presented in *Figures 4.5.2 and 4.5.3*.

The fact that a pesticide is frequently detected does not necessarily mean that it is detected in high concentrations (*Table 4.5.3*). Herbicides dominate the pesticide-positive samples, which correlates with the fact that they are the most used pesticides (*Table 4.5.1 and Figure 4.5.4*).

Several different pesticides may be present in an individual watercourse at the same time. They can be present at all times of the year, but are most frequently detected in the spraying season and during periods of high runoff after rain. The detection frequency and concentration of pesticides are generally greatest in agricultural catchments on clayey soil. Some of the pesticides only occur in a few percent of the samples, while others are found in up to 55% of the samples. The detection frequency is greatest during the spraying season and when the amount of water increases after storms. Much indicates that a lot of the pesticide present in the watercourses derives from drainage water. In addition, pesticides are also discharged into watercourses with urban wastewater. Based on observations made over a 10-year period, Funen County estimates that over 200 km of watercourse corresponding to approx. 20% of the watercourses investigated have been exposed to acute damage resulting in the death of large numbers of crustaceans and aquatic insects.

It is important to point out that some pesticides have been more thoroughly investigated than others, and consequently there is a certain degree of uncertainty about some pesticides. Not all pesticides are included in the investigations. Moreover, those that are included are pesticides that are frequently detected, and those whose presence is to be expected. The 33 pesticides included in these investigations thus do not necessarily provide an overall impression of how much pesticide is present in the environment. Data from the ongoing Danish Aquatic Monitoring and Assessment Programme (NOVA-2003) are expected to reduce this uncertainty.

No systematic data on the occurrence of pesticides in Danish lakes and ponds are yet available, and those that are available are not considered to be representative for Denmark as a whole. The available data on standing water bodies encompass findings from two studies, both of which concern field ponds on clayey soils. Many field ponds have neither an inlet nor an outlet, and the residence time of the pesticides in such ponds can thus be expected to be longer than in watercourses and the risk posed to aquatic organisms consequently greater. Approx. 15 of the 17 pesticides analysed for were detected in one or more water samples. The highest concentration of an individual pesticide detected was 11 µg/l. The studies encompassed several ponds in the Køge area and on the island Avernakø, and were carried out at the beginning of the 1990s. The samples were mainly collected in the spraying season. The concentration levels in lakes seem to be somewhat lower than the corresponding concentrations in watercourses.

The five substances most frequently detected

- (Glyphosat (herbicide))
- Mechlorprop (herbicide)
- Dichlobenil (herbicide) (As metabolite: BAM)
- Isoproturon (herbicide)
- Atrazine (herbicide)

The five substances detected in the highest concentrations

- Primicarb (insecticide)
- Bentazon (herbicide)
- Metamitron (herbicide)
- Mechlorprop (herbicide)
- Hexazinon (herbicide)

Table 4.5.5

The five pesticides most frequently detected and detected in the highest concentrations. The pesticide category is indicated in parentheses. Note that only mechlorprop occurs on both lists. Glyphosat is shown in parentheses because the finding is based on a very small number of samples and hence is subject to considerable uncertainty. Of the pesticides listed, the following are now banned: Dichlorbenil, isoproturon and atrazine. The use of mechlorprop has been cut back.

4.5.4 Occurrence in groundwater

The majority of the groundwater abstracted for drinking water in Denmark was formed after 1950, and is therefore affected by man's activities to some extent. Half of the upper groundwater, down to a level of around 40 m, is contaminated with nitrate and pesticides, mainly derived from agriculture.

The Groundwater Monitoring Programme now encompasses 45 pesticides or pesticide residues, and of these, 39 have been detected. In addition, an extended analytical programme carried out by the Counties has detected a further 10 pesticides that are not encompassed by the monitoring programme.

Additional pesticides and pesticide residues have also been detected in water supply abstraction wells, although predominantly at concentrations below the limit value for drinking water. Thus a total of approx. 90 pesticides and possible pesticide residues have so far been detected in the groundwater. Over the past seven years, pesticides and pesticide residues have been detected in 26% of abstraction wells, with the limit value for drinking water of 0.1 µg/l being exceeded in 9.6%. Monitoring of the subsurface groundwater under cultivated fields has also frequently detected the presence of pesticides. The analysis results from two national monitoring systems and from the waterworks' in-house control of abstraction wells differ markedly from each other:

- In the **Agricultural Catchments Monitoring Programme (ACMP)**, where the subsurface groundwater is monitored, virtually all the pesticides detected are or have been used in agriculture.

- In the **Groundwater Monitoring Programme (GMP)**, the pesticide degradation product BAM has been detected. BAM derives from dichlorbenil, a now banned herbicide previously used on paved areas, for example roads and courtyards. Many other pesticides have also been detected, though. Thus the pesticide categories "triazines and their degradation products", "phenoxy acids and their degradation products" and others account for more than 2/3 of the pesticides and pesticide residues detected.

Photo: NERI/Anna Bodil Hald

- The picture for the **waterworks' in-house control of abstraction wells** is dominated by detection of BAM, especially when only considering wells in which the pesticide level exceeds the limit value. This is not unexpected because many abstraction wells are located close to paved areas, and because some waterworks have used pesticides near the abstraction wells. The waterworks' wells are therefore more often affected by the use of pesticides near and in the towns and by point sources than the wells included in the Groundwater Monitoring Programme, which are often located under cultivated fields.

Pesticides have been found in more than half of the filters in the agricultural monitoring catchments. Moreover, the limit value for drinking water was exceeded in approx. 20% of the filters investigated (*Table 4.5.6*). During the period 1993–2000, pesticides were detected in 26% of the abstraction wells tested under the waterworks' in-house control, while the limit value was exceeded in approx. 10%. It is important to remember, though, that the waterworks often mix water from several wells, and that the waterworks have closed down many wells in recent years due to exceedance of the limit values for pesticides and pesticide residues. On a yearly basis the limit value for individual pesticides in drinking water is 0.1 µg/l on average.

The pesticide content of water samples collected in the Groundwater Monitoring Programme has changed over the past eight years (*Figure 4.5.4*). Just under 10% of the investigated filters were pesticide-positive in the period 1993–95, with the figure increasing to 29% in 1998 and thereafter falling again to approx. 21% in 2000. The number of filters exceeding the limit value has remained almost constant over the period 1999–2000. The marked increase in the number of pesticide-positive filters in the latter part of the period is due to the fact that the number of pesticides analysed is being increased, that degradation products of among others triazines such as atrazine are being detected, and that the degradation product BAM is being detected frequently. An analysis of BAM concentrations in groundwater reveals a weakly falling tendency.

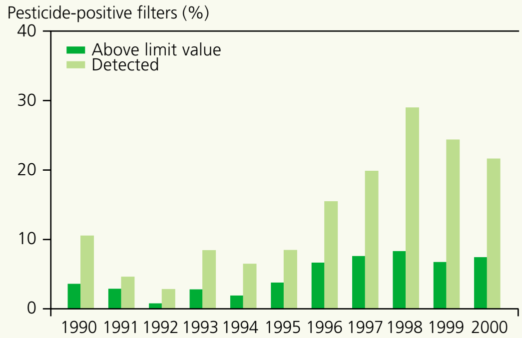


Figure 4.5.4
Percentage of tested filters in which pesticides or pesticide residues were detected in the Groundwater Monitoring Programme over the period 1990–2000.
(Source: Geological Survey of Denmark and Greenland, 2001).

Analysis of the occurrence of pesticides at different depths during the period 1993–2000 reveals that pesticides were detected in approx. 50% of the filters located in the depth interval 0–10 m below ground surface, and that the limit value was exceeded in approx. 15% of the filters (*Figure 4.5.5*). The detection frequency decreases with increasing depth, but the decrease is not the same for filters exceeding the limit value.

The high detection frequency in the subsurface groundwater is predominantly due to BAM and the degradation products of triazines and phenoxy acids. The combined impact on the groundwater in the period 1993-2000 shows how great a share of the investigated wells are vulnerable to pesticide contamination. If the number of pesticide-positive filters is calculated for the year 2000 alone, the trend is close to the accumulated trend for the whole period of investigation. This particularly applies to the vulnerable

Table 4.5.6
Filters testing positive for pesticides or pesticide residues during the period 1993–2000. Waterworks in-house control refers to control of drinking water abstraction wells.
*Filter is here understood as the section of the well from which the groundwater is abstracted. The filter usually consists of a slit plastic tube separated from the surrounding waterbearing formation by filter sand or gravel.
(Source: Geological Survey of Denmark and Greenland, 2001).

Pesticides and degradation products in 1993–2000	Substances detected	Filters analysed*	Filters with pesticide		Filters with pesticide >0.1µg/l	
	No.	No.	No.	%	No.	%
Groundwater Monitoring Programme	49	1,085	395	36	133	12
ACM Programme	35	122	74	60	25	20
Waterworks in-house control	52	6,105	1,606	26	588	10

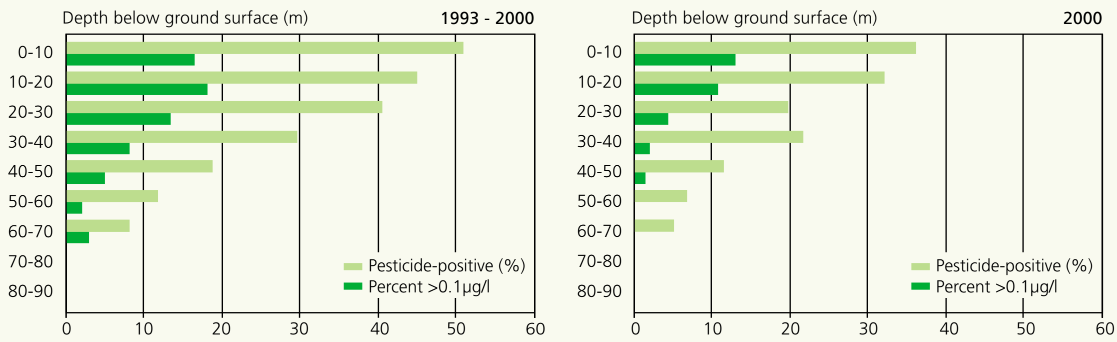


Figure 4.5.5

Samples testing positive for pesticides and pesticide residues at various depth intervals measured in metres below ground surface for the period 1993–2000 (left) and in 2000 only (right). The youngest water is mainly found in the interval 0–10 m. The number of pesticide-positive filters in the same interval increases to more than 50% if all filters testing positive for pesticides and pesticide residues during the period 1993–2000 are included. As only a few water samples from the interval 70–150 m have been analysed, the positive samples have not been included here.
(Source: Geological Survey of Denmark and Greenland, 2001).

groundwater located close to the ground surface, where pesticides or pesticide residues were detected in more than 40% of the analysed filters in 2000, although a high degree of vulnerability also exists at depths of more than 30 metres (*Figure 4.5.5*).

The degradation product 2,6-dichlorbenzamid (BAM) and the mother substance dichlorbenil comprise the most frequently detected group of substances in groundwater. Dichlorbenil is a broad-spectrum herbicide that has been used in urban habitations, alongside roads, railroads and on courtyards. BAM is detected alone or together with other pesticides in approx. 24% of water supply wells. The limit value for drinking water is exceeded in just under 10% of the investigated wells. The group comprising the triazines and their degradation products are also frequently detected, but their occurrence differs in that they are primarily detected in agricultural areas. In the agricultural monitoring catchments, triazines and their degradation products account for almost half of all pesticides and pesticide residues detected, and in this case BAM is rarely found.

Table 4.5.7

The ten pesticides/pesticide residues most frequently detected in the Groundwater Monitoring Programme (GMP), the Agricultural Catchment Monitoring Programme (ACMP) and in the waterworks in-house control (WWC). The number of filters/wells investigated over the period 1993–2000 is shown together with the percentage of positive samples. The wells included in the Groundwater Monitoring Programme can have several filters installed at different depths. The GMP and ACMP figures are thus filter-based, whereas the WWC figures are well-based. The table only includes the most frequently detected substances ranked in descending order of detection frequency for each of the three data sources.
(Source: Geological Survey of Denmark and Greenland, 2001).

No.	***GMP***			***ACMP***			***WWC***		
	Pesticide	**No. of filters**	**% with pesticide**	**Pesticides**	**No. of filters**	**% with pesticide**	**Pesticide**	**% of wells**	**% with pesticide**
1	**BAM**	992	18.3	**Deethylisopropylatrazine**	31	41.9	**BAM**	4,956	24.3
2	**Deethylisopropylatrazine**	838	6.2	**Deisopropylatrazine**	85	22.4	**Atrazine**	5,979	4.1
3	**Deisopropylatrazine**	982	5.8	**Bentazon**	94	20.2	**Deethylatrazine**	4,517	3.6
4	**Deethylatrazine**	982	5.7	**Glyphosat**	46	17.4	**Simazine**	5,992	2.2
5	**Atrazine**	1,076	4.9	**AMPA**	46	17.4	**Deisopropylatrazine**	4,434	2.9
6	**Bentazon**	983	3.8	**Deethylatrazine**	91	16.5	**Mechlorprop**	5,994	2.1
7	**Dichlorprop**	1,076	3.5	**Metamitron**	85	11.8	**Dichlorprop**	5,993	1.9
8	**Mechlorprop**	1,076	2.8	**Mechlorprop**	109	11.0	**Bentazon**	4,522	2.0
9	**Hydroxyatrazine**	917	2.2	**Isoproturon**	94	9.6	**Hexazinon**	4,614	1.7
10	**Simazine**	1,076	2.1	**MCPA**	109	9.2	**MCPA**	5,993	0.6

Photo: Photodisk

The Agricultural Catchment Monitoring Programme includes analysis of glyphosat and its degradation product AMPA in young and subsurface groundwater under cultivated fields. Glyphosat and AMPA have been detected in eight filters, the majority of which are located in one locality on Funen. A study of transport of glyphosat at the same locality shows that its presence is due to natural infiltration of glyphosat through moraine clay via worm holes, root canals and fissures down to the filters, which are located at a depth of 1.5–5 m.

The pesticides/pesticide residues presently most frequently detected in the groundwater are often banned or regulated by the Danish EPA. They are nevertheless still found in the groundwater and will continue to be found for a long time in the future (*Table 4.5.7*).

4.5.6 Current measures to limit pesticide consumption

The Danish strategy for reducing pressure on the environment from the use of pesticides over the past 15 years is laid out in two Pesticide Action Plans. The first Pesticide Action Plan was published in December 1986. In March 2000, it was replaced by Pesticide Action Plan II, which was drawn up on the basis of assessments initiated by a committee chaired by S. Bichel, the so-called Bichel Committee. The various initiatives to curb agricultural use of pesticides during the period 1986–2000 are summarized in Section 1.2.1 (*Box 1.2.2*).

The Bichel Committee was established in 1997 to assess the overall consequences of a phase-out of pesticide use in agriculture. The Committee's task was to carry out an assessment of the productional, economic, legal, health, employment and environmental consequences of a complete or partial phase-out of the use of pesticides. The results of this work were taken into account when drawing up Pesticide Action Plan II.

Among other things, the Bichel Committee recommended a three-pronged strategy for the reduction of pesticide use. The strategy entails a general reduction in pesticide use, a reduction in pesticide exposure of biotopes, and increased conversion to organic farming. The question, then, is how the strategy can be implemented. This was subsequently investigated by examining the possibilities for using a levy to reduce total pesticide use. The existing pesticide levy was to be raised considerably in order to reduce pesticide consumption.

The investigation also showed that pesticide quotas could be used to reduce consumption. However, the administrative costs of quota systems are somewhat uncertain and need to be investigated before such a system can be established. Moreover, it is necessary to define specific figures that concretize the reduction targets for the individual farmer, and to enhance awareness amongst farmers of methods to reduce pesticide consumption.

The Bichel Committee also recommended that market gardeners and fruit growers should be included in a coming plan for reducing pesticide use, but that these branches needed to be evaluated further before reduction targets could be set.

Pesticide Action Plan II

The introduction to Pesticide Action Plan II states that the Bichel Committee's analyses show that agricultural consumption of pesticides far exceeds that necessary for profitable cultivation, and that impact on the environment and health can be reduced by eliminating the excess consumption of pesticides.

Pesticide Action Plan II is based on a three-pronged strategy that was recommended by the Bichel Committee. The plan stipulates some goals that are set stepwise. Thus subgoals have been set until the end of 2002, whereafter the plan will be re-evaluated and new goals set for the next three years.

The first goal is that the application frequency on treated land should be as low as possible. The subgoal here is an application frequency of under 2.0 by the end of 2002. The application frequency is used because the Bichel Committee considered it to be the best indicator of environmental impact at the present time.

The second goal is the protection of certain areas, including the introduction of a no-spray border zone alongside watercourses and lakes exceeding 100 m^2 for which quality objectives have been set by the Counties. The goal is the establishment of 20,000 ha of no-spray border zone by the end of 2002. Particularly pesticide-sensitive areas, e.g. areas where the risk of pesticide contamination of the groundwater is high, are also to be protected.

The third goal, as also stipulated in the Action Plan on the Aquatic Environment, is to ensure that the total area of organically farmed land reaches 230,000 ha by 2003.

In order to attain these goals, a large number of initiatives have been financed by Government Budget appropriations in 1999 and 2000. Pesticide Action Plan II will be evaluated at the end of 2002. This will encompass evaluation of whether the various goals have been attained, of the economic consequences of the Pesticide Action Plan, and of the initiatives implemented. The evaluation will also include proposals for new goals and any necessary revision of the measures for the subsequent 3-year period.