Chapter 5
The coasts

Denmark is characterised by the length of its coastline - a total of 7,300 km - i.e. approximately 1.5 m of coast per inhabitant.

The coasts undergo constant development and change as a result of the action of the sea; they are therefore the most dynamic and genuine nature that we possess in Denmark. The coastal areas contain a multitude of nature types that are linked naturally into a cohesive network. The coastal zone is therefore a vital ecological corridor for plants and animals. At the same time, the Danish coasts are vital as routes for many migratory birds.

The Danish coastal zone contains several areas of international significance. Of European dune areas, Denmark has more than one tenth and they are among the best preserved. Denmark also has considerable, intact, parts of the North-West Atlantic dune heath. The coastal zone's tidal flats are very important as resting and foraging areas for migrating water birds. Many rare species of plant also grow in the coastal zone.

Status

Geographical and geological conditions

The constant effects of the sea's wave motion and currents, wind and rain, etc., are responsible for the dynamics of the coastal zone. These agents are responsible for the equalisation coasts, the intertidal coasts, the steep lines of cliffs, and isthmus and spit formations. At the local level, windbreaks are also important to the formation of cliffs and the erosion and depositing of sand on land.

The Danish coast is unique due to its great geological variation - the cliffs, rocky shores, sandy beaches, stony beaches, sand and rock banks, coastal reed beds or coastal meadows. They also give rise to wide variation in the soil's composition of nutrients, minerals and water absorption which, together with the sea's variations in salinity, are decisive to nature types and the assemblage of flora and fauna; see Fig. 5.1.

Flora and fauna

The living conditions of the flora and fauna along the coast are special in many ways and many life forms are dependent on the coastal zone; see Chapter 11.

The outermost zone of the foreshore is the link between the two different ecosystems, i.e. the sea and land area. The paucity of plant and animal life illustrates the difficulty of living in such a zone. The animals that live here are rarely intermediate forms but, rather, either marine or terrestrial creatures that possess secondary adaptation to the coastal zone.

The conditions of life in other parts of the coastal zone, such as in the dunes, can be compared to the conditions of a sandy desert in other parts of the world. Species occur here that exhibit the same adaptations that can be found in desert plants and animals, such as the ability of plants to withstand drought and a peculiar diurnal rhythm in insects; see Fig. 5.2.

The coast is the resting place and breeding ground of seal and several species of bird, such as the bar-tailed godwit, of which 10% of the total west Pal-

aearctic population rests on the coastal meadows and tidal flats along the west coast of Jutland in the spring.

The differing nature types encountered along the coast are the habitats of many rare plants, which Denmark has an international responsibility to protect.

Environmental impact

Coast defence

Today 6% of the coast is protected by dikes or is included in harbour areas. Long stretches of the coast are also protected against erosion by breakwaters or other constructions, such as stone sea walls or concrete structures. These constructions change the state of nature along our coasts and are, therefore, an expression of a conflict of interests between the protection of the authentic vegetation and coastal dynamics and the need to safeguard socio-economic interests.

Land reclamation

Over 1,000 km, corresponding to 14% of the original coast, have disappeared over the last 125 years, typically as a result of the diking and draining of fjords, bays and coves. To a very great extent, the underlying reason has been the extension of cultivable land.

Major reclamation works have for the most part now ceased and there are even several examples where diked areas have been returned to nature. However, small-scale reclamation is still in progress, e.g. in connection with urban areas, where there may be conflicts between the inherent value of the landscape and the interests of open-air activities. Land reclamation has also been discussed in Chapter 4.

Modified agriculture

Of the coastal nature types, the coastal meadows, in particular, have been used by agriculture, typically for pasture or hay mowing. The total area of the coastal meadows is estimated to have been reduced by between 50 and 75% over the last 100 years as a result of changed agricultural methods and diking. It is therefore significant to the maintenance of biodiversity that we reach a decision on the methods to be used in our low-lying coastal areas.

Preventing sand drift

From around the year 1500, sand drift became a serious problem for society, as much arable land was destroyed. Now that we have sand drift under control we need only devote limited effort to this matter.

The dwarf mountain pine in particular has spread from dune plantations to the adjoining dune areas through self-seeding, and clearing is constantly in progress to safeguard the nature and landscape of the dune areas. Clearing should however be extended to include part of the current plantations, to restore some of the dune heath.

Water catchment

Some of Denmark's purest water table resources lie in the coastal zone. Increasing pollution of the water table will increase the pressure to take advantage of the water table resources of the coastal zone. Water extraction in the dune areas could lower the level of the water table and dessicate such valuable nature types as dune-slack fens and dune-slack pools. In addition, extensive abstraction will increase the risk of salt water penetrating the water table and, thus, of changing the conditions of life of plants and animals.

Pollution and eutrophication

The vegetation of the „grey dunes" (fixed dunes with herbaceous vegetation) and dune heaths consists of dwarf scrub with a wide representation of various lichen species. These groups of plants are characteristic in their adaptation to the low nutrient conditions prevailing in grey dunes and the dune heath. For this reason, the introduction of even minor

Fig. 5.1
Coastal nature types
Together with physical and chemical conditions, geographical, geological and culture-historical factors create the different nature types, thus forming the basic conditions of the variegated plant and animal life of the coastal region.

Nature type	Occurrence and description
Reedswamp	Occurs along naturally-protected coasts, where the sea is less saline, and often in association with freshwater outlets. Climax vegetation, dominated by a few, predominant species.
Coastal meadow	Occurs along naturally-protected intertidal coasts. The plant cover consists of cohesive herbaceous vegetation, which varies in the richness and assemblage of its species according to its location in the country and, thus, the tides, salinity, climate and cultural influences. The total area of saltmarsh and coastal reed bed amounts to about 40,000 ha.
Coastal grassland	Succeeds coastal meadow vegetation above the winter high water line, where there is less salt. Plant cover is distinguished by herbaceous vegetation, rich in species and open to light.
Shingle beach	Occurs along exposed coasts and is dominated by deposits of pebbles and boulders, which can be incorporated into apposition banks. The distribution of vegetation depends on wave and tidal action, which create the distinction between the different zones.
Sandy foreshore	Occurs along exposed coasts. The outermost zone is exposed to wave and tidal action. This zone often lacks vegetation. Alluvial deposits of marine material which, depending on seed quantities and germination conditions, house a vegetation that is poor in species and that consists of salt-tolerant annual species.
Sand dune	Occurs above the sandy foreshore along exposed coasts, where the sand is transported by the wind to form dunes. Plant cover varies, from the outermost nutrient-rich white dunes, characterised by stiff grasses on more chalky land, over dune-slack grassland, characterised by vegetation frequently rich in species, to the low-nutrient grey dunes, characterised by few species of vascular plant and dominated by different species of lichen.
Dune slack	Occurs between dune ridges. It can be caused by wind erosion and extend down to the level of the water table. Depending on the lime content and nutrient content of the soil, and on the level of the water table, extremely species-rich vegetation can be found in such slacks.
Dune heath	Occurs on leached sand behind dune ridges. The vegetation is characterised by dwarf scrub and mosses and lichens adapted to low-nutrient sandy soil. The type is climax vegetation on dune sand.
Steep foreshore	Occurs in places where rock faces and slopes raise themselves above the surface of the sea. Cliffs and slopes are often characterised by erosion, which keeps them free of vegetation. In places where erosion has ceased, plant cover can be rich in species, depending on the substrate, climate and salinity.

(Sources: Gravesen, 1976; Petersen & Vestergaard, 1993; Vesselbo, 1994.)

quantities of nutrient will affect the vegetation assemblage. It has been observed in recent years that the lichens of these areas have been damaged in various ways. One of the causes could be the deposition of nitrogen.

Open-air activities and tourism

The sea and coast have a great attraction value for open-air activities and tourism. Increasing recreational pressure has been brought to bear on the coastal areas in recent decades.

Increased public access results in damage to the dunes and dune heaths, especially around parking places, hotels, camping sites and summer-cottage areas. The attrition of dune vegetation can result in sand drift, and frequent rambling in dune heaths is sufficient to destroy lichen vegetation.

Several birds and seals have their breeding grounds along the coasts. Many of these creatures are especially shy and vulnerable to disturbances caused by man in the breeding season. Seals, for instance, have largely been forced away from our foreshores and only breed nowadays on isolated islets and suchlike.

Current protection performance

The provisions on the foreshore protection line and dune conservation line of the Nature Protection Act (along most of the west coast of Jutland) have brought a general prohibition against altering beaches and other stretches of coast, e.g. by building, plantation or fencing. In 1994, this coastal zone was extended from 100 m to 300 m from the start of cohesive terrestrial vegetation. This extension will become effective through a statutory order, when a special beach protection commission has determined the line and has made its recommendations to the Minister of Environment and Energy.

According to the provisions of Section 3 of the Nature Protection Act, coastal meadows (which in the sense of the law include coastal grassland and reed-swamp that have an area of 2,500 m^2 or greater are protected. This means that their state cannot be changed unless the local county council grants exemption.

The Planning Act has been amended to include rules on a 3 km coastal proximity zone. The object of this zone is to provide general protection against the planning of new areas for urban, holiday and recreational purposes, against con-

Box 5.2

Adaptation of plant life in the coastal zone

The adaptation of plants to the extreme conditions existing along the coast takes different forms. Apart from the fact that growth conditions of the plants depend on either high or low nutrient concentrations, there are also adaptations in the form of:

- *deep roots, to provide an anchor and to increase water intake;*
- *rapid growth, as a defence against the accumulation of sand deposits;*
- *thickened surface tissue, for protection against the strong winds, the heavy wear caused by the bombardment of grains of sand and for insulation;*
- *succulence, as a defence against dessication and increased salt concent rations;*
- *involute leaves, deeply recessed stoma and the formation of cushions, to reduce evaporation.*

Glasswort is adapted to the life conditions prevailing in the coastal zone, since it tolerates total immersion in salt water as well as total dryness.

structions, and to reduce the need for coastal defence and reclamation of areas in our territorial waters. The coastal proximity zone does not preclude the possibility of new construction, although the underlying idea is that new areas for urban development and for construction in rural areas be located as far as possible from the coastline and preferably behind existing built-up areas or areas designated for urban or recreational development.

The Nature Protection Act and the Planning Act have been amended in order to attain more effective protection of areas close to the coast, for instance, by requiring the Ministry of Environment and Energy to supervise county-council and local-council planning for the coastal proximity zone. We have thereby improved our chances of preserving the nature of our coastal areas.

According to the Coast Defence Act, the administration shall give consideration to the environment. All coastal defence projects shall be approved by the Coastal Inspectorate, under the Ministry of Transport. The Coastal Inspectorate submits applications for permits for the establishment of coastal defence constructions to the county councils and - if the matter is considered to be of especial interest - to the Danish Forest and Nature Agency, under the Ministry of Environment and Energy.

The State, county and local authorities only finance coastal defence on especially exposed stretches. This mainly covers the coast of Jutland, where coastal defence is carried out to maintain the present coastline or to bring erosion under control.

Tangible protection measures

Some of Denmark's most precious coast stretches are *protected* through conservation orders. Much of this protection has been implemented as a means of attaining the goal of preserving their peculiar geology or to protect unique flora or breeding, foraging or resting places for marine mammals and birds.

In compliance with the terms of the *Ramsar Convention*, areas have been designated for the protection of wetlands that are of international importance in

our territorial waters. Several of the adjoining coastal and land areas are covered. The same applies in the case of *EC Bird Protection Areas*, in which several coastal regions are also included; see Chapter 4.

Many nature types along the Danish coast are potential protection areas under the terms of the *EC Habitats Directive*, which was mentioned in Chapter 4. The draft for the designation of areas proposes to designate, for instance, apposition banks, mobile dunes, wooded dunes, grey dunes (fixed dunes with herbaceous vegetation) and dune slacks, as Danish EC Habitat Areas. Of these areas, *grey dunes, decalcified fixed dunes with crowberry and dune juniper thickets* are classified as high priority nature types and will be the object of special protection provisions.

When the designation of EC Habitat Areas has been completed we will have a legal basis for the protection of some of the nature types that are not covered by the general protection provisions of current legislation. Increased scientific knowledge and awareness of the state of the various nature types and flora and fauna in coastal regions can lead to the designation of additional areas, since the initial designation of EC Habitat Areas is not final.

Rules can be set to *restrict public access*, either in the form of special statutory orders or as provisions in preserved areas and wildlife reserves and, in part, by the local Chief of Police, under the provisions of the police regulations.

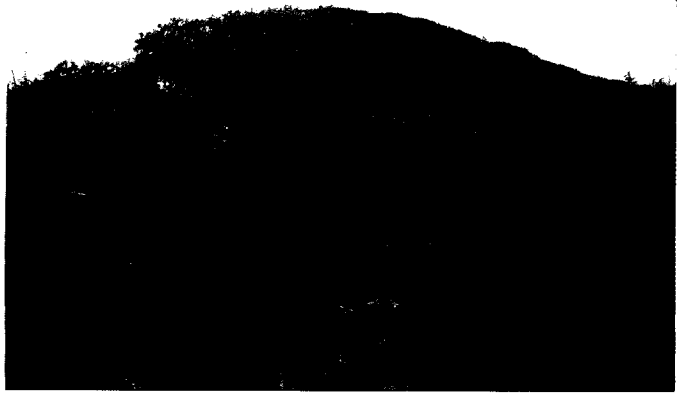
Forthcoming efforts

Increased coastal dynamics

The different nature types and the special flora and fauna that exist along the coast are to a very great extent dependent on the influence of the adjoining sea. The sea creates a dynamic landscape in which demolition, erosion and depositing constantly give rise to new living conditions for plants and animals.

Social development over the last few centuries has set requirements on safeguarding of the coastal regions. This has resulted in the establishment of constructions that limit the sea's influence on these regions and in extensive dune control works.

The trend in coastal defence today is towards increasing our attention to nature. The use of breakwaters has thus been restricted because of their impact on nature.



The oak scrubs, Store Løvklit and Lille Løvklit, on the west coast of Jutland, are the residue of the virgin deciduous forests over which sand has drifted due to the population's overexploitation of the natural vegetation.

Studies show that many of the smaller trees have joint trunks and root systems and are, in fact, large trees of great age. The individual trees are capable of growing upwards stepwise with the depositing of sand.

Take great care in the dunes!

Attempts are being made today to use other, more nature-oriented methods of coastal defence, such as feeding with sand, instead of more massive fixed constructions. This trend should be encouraged. Similarly, consideration should be given to replacing the existing massive constructions with more nature-oriented techniques. Finally, an increased effort is needed in the removal of the illegal coastal defence constructions.

Greater emphasis must be placed on consideration for factors important to biodiversity in the future maintenance and extension of coastal defence constructions.

To the extent that they do not represent a threat to their surroundings, sand dunes should be considered as a dynamic nature type, i.e. sand-drift prevention should be avoided.

Nature restoration

Some of the diked fjords, bays and coves are today only marginal arable land. Such land offers potential for nature restoration as mentioned in Chapter 4. By recreating the original nature of these diked areas, it will be possible to re-establish some of the approximately 180 islands that have been lost in connection with land reclamation.

One goal of nature restoration in the coastal regions is to restore 8,000 ha of salt marsh over a 30-year period.

Similarly, several dune heath areas on the west coast of Jutland should be restored by clearing unproductive coniferous plantations. The goal for the Ministry of Environment and Energy's property is to clear 2,000 ha of such plantations before the year 2030.

Consideration should be given to whether or not nature restoration should also be done for grey dunes, since this nature type is not encompassed by present nature restoration.

Restricting wear and tear

Many of the coast's most valuable nature areas are the object of intensive recreational use. The local wear and tear on vegetation can be so great that special measures are necessary, e.g. in the form of reinforced foot-paths or other methods of channelling the traffic. It may even be necessary to prohibit public access in certain cases.

In order to ensure the continued existence of these valuable nature areas, we must devote more attention to balancing the conflicting interests of utilisation and conservation. What is also important when seen in the light of the Government's goal, as expressed in the *Tourist Policy Report 1994*, is that the number of overnight stays in Denmark will increase from about 50 million in 1993 to about 64 million by the year 2000. However, according to the report, this shall take place under observation of the greatest possible consideration for environmental qualities.

Restriction of fertilisation and afforestation

Summer-cottage areas are a special problem. They are often laid out as natural plots but become gradually changed through planting and increased use of compost.

The soil conditions change from low-nutrient to nutrient-rich. This means that the conditions of life of the plants - and thus the animals - that have lived in close association with the low-nutrient soil of the coastal region disappear. Informative material, explaining how care of the area can include consideration for the nature of the coast, should be produced and distributed to the owners of summer cottages.

Accumulation of scientific knowledge

Future efforts for the conservation of biodiversity should be based on increased knowledge of the flora and fauna of the coastal regions and the state and development of ecosystems.

Goals should be set for the state and development of the individual nature types and analyses should be performed of the external conditions and factors that can affect these goals.

A number of areas should be laid out in appropriate places for dune reserves, which should be kept free from intensive public access and use and the resulting wear and tear. Suitable parts of these areas could be covered by the monitoring programme for the European dune areas, as proposed by the European Union for Coastal Conservation.

Target areas

- Reinforcing consideration for the coastal zone's scenic and natural value in the planning of county councils and local councils, through the adopted amendments to the Planning Act.
- Continuing restriction of coastal defence and dune control and, thus, restoration of the natural dynamic coastal regions.
- Increasing nature restoration in the coastal regions through:
  - restoration of the nature, including islands and islets, of previously diked areas;
  - re-establishment of 8,000 ha of saltmarsh before the year 2025;
  - re-establishment of sand dunes and dune heaths, in part through clearance before the year 2030 of 2,000 ha of unproductive coniferous plantations on land owned by the Ministry of Environment and Energy.
- Developing coastal defence technology with a view to increasing consideration for the natural processes that take place along the coast.
- Increasing the accumulation of knowledge on biodiversity in coastal regions.
- Increasing the distribution of information, e.g. to the owners of summer cottages, on nature-oriented care of summer-cottage areas.

Chapter 6
Fresh waters

The ecosystems we find in and around our fresh waters contain a degree of biodiversity that must be conserved and the conditions of which must be improved.

The freshwater systems form the link between the land area and the sea, they serve as ecological corridors for flora and fauna and, therefore, hold a key position in relation to the other environments.

Status of lakes

Most of Denmark's natural lakes were formed when the ice melted after the last ice age. They vary greatly with regard to their origins, size and form, water exchange, chemical properties of water, etc. In the unpolluted state, nearly all of them hold clear water.

Over the course of time, many of them became marshes as a result of natural filling and overgrowth processes. Also, since the middle of the 1700s man has, with increasing intensity, reduced the number and area of the lakes by lowering their water levels and draining them.

New lakes have also been formed, particularly small ones, e.g. through damming and the excavation of raw materials.

20 large, previously drained lakes, with a total area of 900 ha, have been restored during the period 1989 to 1994. During the same period, the country's local authorities have excavated 1513 new water holes, of which 420 alone were established in 1993. Moreover, many water holes and smaller lakes are being cleaned and extended, by both private and public interests, and new ones are being excavated. However, no statistics are available on the growth trend over the years in the number of lakes and their total area. The total area of lakes with areas of greater than 10 ha was estimated at about 36,000 ha in 1994.

When focusing on their significance to biodiversity, it is easiest to classify Danish lakes according to the assemblage of their vegetation mantle; see Box 6.1.

Lakes are more vulnerable to pollution by nutrients than are watercourses. This is due in part to their low water exchange. It is generally accepted that phosphorus is decisive to their condition.

In general, the nutrient-salt content of Danish lakes has risen. This is due especially to the discharging of waste water and airborne pollution and to the percolation and leaching of nutrients from arable land. Moreover, pollution from trout farming has played a significant part in the nutrient loading of certain lakes.

Despite intervention over the discharging of waste water and nutrient loading, the condition of the Danish lakes has not improved in general over the last 10 to 15 years. Their water is still largely turbid as the result of unnaturally high quantities of plankton algae.

It is possible to set specific goals for the desired water quality on the basis of water clarity measurements. In 1992, only about 30% of the lakes investigated had attained the goal set for water clarity, and 57% of those lakes held very turbid water.

Current protection performance

Protection of lakes

Natural lakes are protected according to the Nature Protection Act if they have a

minimum area of 100 m″. The same applies to artificial lakes that have developed natural flora and fauna.

Thus, the scope of this protection also covers most artificial lakes, such as peateries and marl pits, gravel pits, dammed lakes, etc. According to the terms of protection, any action that can result in a change in the natural state of lakes can only be carried out subject to special permission from the county council.

The area criterion has been gradually reduced, from 1,000 m″ in 1978, through 500 m″ in 1984, to the present limit of 100 m″ in 1992. This was done in recognition of the great importance of small ponds to natural plant and animal life.

Regardless of their size, lakes in forest reserves are protected by the provisions of the Forest Act.

Lakes larger than 3 ha also have a protection zone that extends 150 m from the shores. No building of modification of the terrain within this zone can be carried out without the permission of the county council.

A number of lakes are also protected or covered by various forms of preservation, reservation, etc., which often means that there are restrictions on the types of disturbance that can be generated, such as by motor boats and windsurfing.

Box 6.1

Classification of Danish lakes on the basis of their vegetation

Clean lakes. *These generally exhibit a rich variety of plant and animal species. The underwater plants that grow in pondweed and lobelia lakes usually occur in belts that depend on the depth, and often down to depths of several metres. About 5% of all Danish lakes are clean.*

Pondweed lakes. The water is clear and pondweed and other underwater plants flourish. Pondweed lakes are associated with moraine landscapes and were the most common lake type in Denmark, until pollution changed their state. They are also known as naturally eutrophic lakes.

Lobelia lakes. The water is clear and lobelia and other rosetted plants flourish on the bottom. Lobelia lakes are associated with lean, sandy districts, especially dunes and heaths. This was the normal type of lake in West Jutland before pollution changed the situation. They are also known as oligotrophic lakes.

Dystrophic lakes. The water is turbid because of suspended humus material, which comes from the bogs around the lakes. Few or no submerged plants occur in the water, apart from mosses and algae. Dystrophic lakes have always been rarities.

Polluted lakes. *The pollution of lakes started in earnest at the end of the last century in step with the influx of waste water from households. Today, over-fertilisation with nutrients is the most significant source of pollution.*

The water is turbid to a greater or lesser extent and green in the summer. The visibility depth is reduced by the increased quantity of nutrient substances. Nutrients increase the production of a few species of algae in the top layers of the water, which gives rise to homogeneous societies of plankton. The submerged vegetation disappears, together with the animals that depend on it. The plant and animal life of polluted lakes has become homogeneous and poor in species, for which reason their biodiversity is greatly diminished in comparison with the clean lakes.

About 95% of Denmark's lakes are polluted. Polluted lakes are also known as eutrophicated lakes.

Box 6.2

Lake Hald - an example of successful restoration

Lake Hald was formed during the last ice age. It has a surface area of 3.5 km² and its present depth is 31 m. Up to the mid-1930s the greatest depth was 34.5 m, but deposits of organic material, in the form of sludge, have raised the bottom. This lake has a modest catchment area of 84 km².

Lake Hald was classified until 1980 as clean and poor in nutrients, for which reason plants and animals also flourished in its deeper parts. About 10 species of underwater plant and about 120 species of animal have been observed.

A radical change took place in the beginning of the 1980s, when vigorous efflorescence of microalgae was observed several summers in succession. This efflorescence was due to the increased influx of fertilisers, in part from agriculture, through the water table, and in part, with waste water from villages and fish farms. The villages of Dollerup and Skelhøje lie in the catchment area of the lake, whereas fish farms had been established at the south end and along several feeder streams.

Council rescue plan

Waste water from the villages was led past Lake Hald to the central sewage treatment plant at Viborg. The fish farms were purchased by Viborg County Council and their basins filled to restore the feeder-spring areas and streams. All farms in the catchment area of the lake were checked for discharges of black liquid and silage juice.

In order to ensure better conditions for the animal life of the lake, pure oxygen has been pumped into its bottom every summer since 1985. This helps to prevent the occurrence of deoxydised conditions in deep water and to prevent the release of phosphorus from the bottom sludge.

The oxygenation conditions of the bottom water have been improved, which means that sediment disturbances caused by gas releases are avoided and that the release of phosphorus from the bottom sludge is now under control. Background pollution by phosphorus has been halved, so that the lake's water has become clearer, and algal efflorescence is now avoided, to the benefit of the natural plant and animal life, which can once more colonise the deeper parts of the lake.

(Source: Viborg County Council, 1993.)

Nutrient loading

The Government's Action Plan on the Aquatic Environment (adopted in 1987) prescribes a reduction of 50% and 80%, respectively, in the quantities of nitrogen and phosphorus discharged.

The monitoring programme of the Action Plan on the Aquatic Environment (started in 1988) was the first implementation of a systematic, nation-wide monitoring programme.

This programme has shown that the concentration of *nitrogen* in our lakes has not, in general, dropped in recent years.

On the other hand, the concentration of *phosphorus* in the lakes has generally diminished as a result of improved waste water treatment. But this reduction has not had the desired effect on the state of the lakes, in part because the phosphorus that has been deposited on the lake bottoms (the sediment) is only released slowly. Apart from phosphorus, the sediment of some lakes also contains other pollutants, such as heavy metals. These substances have been borne in industrial effluent. Limits have now been set on the permissible quantities of heavy metals in waste water.

In certain lakes, attempts have been made to remove the sediment or to improve their state through biomanipulation; see Box 6.2. The long-term effects of such attempts are still unclear.

Acid rain

The action taken to reduce the smoke gases emitted by different sources (especially sulphur dioxide and oxides of nitrogen), which cause acid rain, have not yet brought about any improvement in the ecological balance of the lakes. This could be due to the fact that a large proportion of airborne pollution does not originate in Denmark, but in the surrounding countries.

Most of the Danish lakes have a high natural lime content, which serves as a buffer that can, to some extent, neutralise acid rain. Lakes of low lime and nutrient content are particularly sensitive to the effects of acid rain. Their acidity is increased, which has a detrimental effect on their ecological balance.

Forthcoming efforts

Safeguarding cleanest lakes

The most important and most threatened part of lake biodiversity is associated with our remaining clean lakes. It is from these that flora and fauna spread when other lakes have been cleaned. Thus safeguarding against the impairment of the clean lakes is of the greatest significance to biodiversity.

The few remaining clean lakes are in forests or on heaths and are characterised by the small extent of the catchment area of the water table. Rational forestry and agriculture are practised in the catchment area in certain cases. A target-oriented effort must be made to ensure that the operation of the clean lakes' catchment areas does not have any detrimental effects on the lakes.

Lightly polluted lakes are normally capable of *cleaning themselves* once the influx of nutrients has been reduced to the natural level. As it has proved difficult to clean heavily polluted lakes, our efforts to give the lightly polluted lakes a chance to *clean themselves* should be intensified. This can probably be achieved by preventing additional impact from the catchment area.

Reducing nutrient loading

We must continue reducing the influx of waste water from urban areas and industry in order to reduce the quantity of phosphorus, in particular. It is also important to trace and restrict discharges from areas that lack sewers, and minor sources of pollution in open country, such as the effluent from individual buildings, rainwater overflow and fish farms. The contribution from diffuse sources, including the surface run-off from agriculture, should be reduced.

Restoration

The Ministry of Environment and Energy has started an overall assessment of the restoration work carried out in different types of lake. This will strengthen the basis on which decisions will be made as to when restorative action will be taken in some of our highly polluted lakes.

Conceivable restorative action includes biomanipulation, the removal of sediment and oxygenation; see Box 6.2.

The funds reserved for national nature management under the Finance Act make it possible to restore lakes, etc.; see Chapter 7. Since many of our restored lakes are free from pollution and hold pure, clear water, the effect on biodiversity will be considerable.

Designation of protective zones

Support is available for set-aside and other extensification of areas close to lakes and areas in which there are many small lakes under the terms of the EU Common Agricultural Policy (CAP) accompanying measures, which are administered by the Ministry of Agriculture and Fisheries; see Chapter 7.

The designation of uncultivated or ex-

tensively cultivated areas is desirable, particularly in the vicinity of *clean* or lightly polluted lakes. Together with the legally-required 2 m zones along lakes and watercourses where there are several riparian owners, such areas can become valuable habitats and ecological corridors for the species that depend on fresh water. Such areas will also help to contain and degrade nutrients leached from the intensively-cultivated surrounding land.

Small lakes and ponds
The landscape has become poor in small ponds that lack fish but that can contain a great variety of amphibians and aquatic insects. The cleaning and excavation of new small lakes and ponds in recent years has, therefore, been beneficial to the preservation of aquatic flora and fauna, as has been the fact that new ponds have been created by the cessation of draining.

The excavation of new lakes should not take place, however, if it would be at the expense of established natural resources. As a main rule, such excavation should only be undertaken outside natural areas that are already protected, unless the effect of constructing new lakes in protected areas would be insignificant, or in cases where new lakes in such areas would bring a significant improvement in the conditions of life of particularly endangered or vulnerable species living in the area.

The cleaning and extension of small lakes is also beneficial where the removal of waste, polluted bottom sludge, etc., is concerned. Undisturbed natural overgrowth should, however, be permitted to take place to a greater extent. The risk of impairment of the conditions of species in need of protection should be included in any assessment of planned action.

Finally, the county councils should be aware of the fact that, when working on marshes, previous marsh areas and hitherto untouched lakes, damage can be caused to the records of vegetation history and other historical assets. The organic layers' deposits of the remains of plants and animals often conceal information on the development of the landscape since the last ice age; see Box 3.1. It is also well-documented that bogs often conceal such relics as stone-age dwellings.

Protection of freshwater flora and fauna and genetic diversity
See Chapters 10 and 11 concerning the protection of our lakes' plant and animal species and their genetic variation, e.g. from the standpoint of the release of fish and other organisms.

Status of watercourses

All Danish watercourses have been affected by human activities, such as water catchment, discharging of waste water and physical intervention (realignment, laying of pipes, draining, maintenance and blocking). Such intervention has meant that most watercourses are far removed from their optimum environmental states.
It is seldom sufficient to restrict pollution when seeking to improve the environmental condition of watercourses - *watercourse quality*. It is also necessary to ensure a sufficient flow of water and a physical condition that is as close to the natural as possible.

Discharges
High concentrations of nutrients only have a limited direct effect on the plant and animal life of watercourses. On the other hand, the watercourses themselves play an important part in transporting nutrients to lakes and the sea.

However, the discharging of organic substances does have a detrimental effect on watercourse quality and, thus, on plants and animals. One of the reasons for this is the high oxygen consumption that occurs when bacteria degrade the organic material discharged in household

and industrial waste water and in discharges from agriculture and fish farming.

In Jutland especially, the draining of meadow areas has impaired watercourse quality since ochre is often formed in conjunction with draining. Ochre vitiates the living conditions of the natural plant and animal life in a watercourse. In general, however, the ochre situation in the counties of Jutland has improved in recent years.

The Government's Action Plan on the Aquatic Environment of 1987 resulted in extensive investment in waste water treatment and storage capacity for the manure of domestic animals. In turn, this has resulted in a marked reduction in the pollution of many watercourses.

Water flow

The water flow of watercourses is affected by the water catchment that takes place, either through pumping the water to fields from the watercourse itself, which results directly in a reduction of the flow, or through the abstraction of water from the water table, particularly for drinking water or industrial purposes. The latter can result in lowering of the water table, which causes periodic drying up of watercourses in certain places. This problem is particularly noticeable on the island of Zealand.

Maintenance and restoration

Nature-oriented maintenance of watercourses, i.e. a form of maintenance that considers not just the water-carrying abilities but also the natural characteristics, is of great importance to the physical condition of our watercourses. Thus, maintenance that tries to approach the condition of natural watercourses as closely as possible is carried out in many public watercourses where the goal is to attain high watercourse quality; see Box 6.3. This is achieved by cutting back aquatic plants (waterweeds) manually instead of with machines, which have a much harsher impact on watercourses. It was estimated in 1990 that environmentally-oriented maintenance is carried out on 37% of all public watercourses. This modified practice is also gaining ground in private watercourses.

In the case of certain watercourses it is necessary to undertake *restoration* in order to attain the desired watercourse quality. A number of watercourse restorations have been carried out for this reason. Realigned watercourses have been relaid in their original courses, watercourses that were formerly piped have been re-established and the spawning conditions of salmonids have been improved. Denmark's counties have restored more than 57 km of watercourses since 1989. As an example of a particularly grand restoration project, it is worth mentioning the work involved in returning the regulated River Skjern delta to a more natural state. There is still a great need for the restoration of watercourses. This is apparent from the many applications for subsidies for such projects received by the Ministry of Environment and Energy. The funds available are not sufficient to satisfy the desires of all interested parties.

Current protection performance

Legislation

Denmark has about 40,000 km of watercourses that are divided into regional, local and private watercourses, depending on who is responsible for their maintenance. About 28,000 km of watercourses, public and private, are protected by the Nature Protection Act. Designation is carried out by the county councils and approved by the Minister of the Environment according to principles that were introduced when the Nature Conservation Act was amended in 1978. Protection of the watercourses means that (apart from normal maintenance) no changes must be made to their natural condition without the permission of the local county council.

Regardless of their size, watercourses in forest reserves are protected by the provisions of the Danish *Forest Act*.

Pursuant to the Watercourse Act, the county councils or local councils shall draft watercourse regulations for regional and local watercourses, with provisions governing flow characteristics, maintenance, restoration measures, etc. About 19,800 km of watercourses are covered by watercourse regulations. When drafting new watercourse regulations, consideration shall be given to the quality goals set for the watercourses.

According to the Planning Act, the county councils shall set *quality goals* for watercourses; see Box 6.3. Such goals have been set for about 24,000 km of watercourses. Of this, goals have been set for about 1,500 km as areas of especial scientific interest, fishing water goals have been set for about 17,000 km, whereas adapted water quality goals have been set for 5,500 km. Goals have thus been set for all public, and some of the private, watercourses. As the establishment of goals for private watercourses is not mandatory, the extent to

Box 6.3

Goals for watercourse quality

The Ministry of Environment and Energy has established a system of guidelines for the specification of goals for watercourses.

Watercourses governed by stringent requirements

A: Areas of special scientific interest. Typically applied to watercourses that are unaffected by human activities, where there is a desire to preserve unusual plant and animal life or where there is particular interest in preserving geological, hydrological, culture-historical or scenic resources.

Watercourses governed by base requirements
(Goals for fishing waters)

B1: Spawning and nursery waters of salmonids.
B2: Salmonid fishing waters.
B3: Carp fishing waters.

The choice between goals for fishing waters is governed by the size of the individual watercourse, flow velocity and other physical conditions, including the degree of pollution. This includes an assessment of whether or not the physical quality of the water can be improved through more environmentally-oriented maintenance or by direct restoration.

Thus, the base requirement is that the environmental quality shall be so high that the watercourses can contain a natural assemblage of plant and animal life, with the main accent on naturally occurring fish.

About 80% of the watercourses for which goals have been set have one of the above three fishing water goals.

Watercourses governed by adapted requirements

C: Watercourses that will only be used for the discharge of water.
D: Watercourses affected by waste water.
E: Watercourses affected by the extraction of water from the water table.
F: Watercourses affected by ochre.

The adapted requirements apply in cases where it is considered that, due to use by man or to the impact of the surroundings, the fishing water goals cannot be attained for a watercourse within the period specified by the county council.
(Source: the Ministry of the Environment 1994f.)

which this has been done varies from county to county. The quality goals for individual watercourses are set after an assessment of each watercourse's present and future suitability as a habitat, for instance, for fish. If the goals have not been attained, they are set with a view to attainment within a certain period.

The goals set for the quality of a watercourse also form the basis for processing applications for permission to carry out various types of action. This applies, for instance, to permission to discharge waste water, draining in areas where there is a risk of problems with ochre, and it also applies to changes in the physical state of a watercourse (regulation, etc.). Applications are materially assessed by the county councils from the standpoint of effects on the quality goals set for the specific watercourse. Today, we have been attained the watercourse quality goals set for about 40% of the watercourses for which goals have been set.

Improvements in the environmental state of watercourses may very well have been made, even if the goals have not yet been attained. Thus, a study of 17,000 watercourse assessments carried out over the past 22 years in the county of Vejle has shown an improvement of at least a whole pollution class at 29% of the watercourse stations studied. This did not, however, represent an increase in the percentage of watercourses for which the set goals had been attained.

The Ochre Act has helped to prevent further ochre pollution as a result of draining. In addition, several county councils have started directing purposeful efforts at reducing the ochre impact, by carrying out watercourse restoration and undertaking ochre removal in individual watercourse systems.

The use of pesticides in cultivated areas can result in their presence in watercourses. Pesticides can be transported to watercourses by the wind, surface run-off or through the water table. For this reason a minimum distance of 10 m to lakes and watercourses has been set on the use of approved pesticides that are considered to be toxic to aquatic organisms. Current scientific knowledge of the effects of pesticides on the living organisms of watercourses (and lakes and the sea) is, however, still insufficient.

Maintenance of watercourses

According to the objective provision of the Watercourse Act, it is a requirement that *watercourse maintenance* preserve, and possibly improve, the physical environmental quality of watercourses so that they satisfy the set quality goals; see Box 6.3.

Due to their age, many regulations cannot be used to demarcate the framework of sufficiently environmentally-oriented watercourse maintenance in the watercourses for which high quality goals have been set. In these cases, the county councils and local councils shall revise the regulations so that they are brought into line with the quality goals set for the watercourses.

No-cultivation zones

A 2-metre broad no-cultivation zone along all watercourses was introduced with the amendment of the Watercourse Act. This was the first step towards improving the significant interaction between our watercourses and their neighbouring areas. No-cultivation zones will, for instance, reduce the erosion of watercourse banks caused by heavy agricultural machinery. This will also reduce the sand drift in our watercourses, which destroys, for instance, the spawning banks of salmonids. The vegetation of these zones is also important to the conditions of life in the watercourses themselves, in part because many watercourse insects mate there.

Fauna barriers

Dams, waterfalls created by watercourse regulation, the draining of stretches of watercourses by pumping water for fish

farms, etc., the so-called *fauna barriers*, have in many places radically altered the opportunities for migration and spreading available to the animal life in and along our watercourses.

The *Watercourse Act* prescribes that impoundment constructions, or other constructions that can prevent the free flow of water or can otherwise be harmful to a watercourse, must not be erected or modified without the permission of the watercourse authorities.

A major effort has already been made to solve the problems that fauna barriers have caused for the animal life of watercourses. We should, however, still give consideration to the culture-historical assets associated with the different types of barrier.

Water catchment

The regulation of water catchment is provided by the *Water Supply Act*. Catchment requires the permission of the local authorities, who base their decision on a catchment plan that combines considerations of supply with considerations of water-table quality and quantity and with considerations of water quality in watercourses and lakes.

Under the *Zealand Water Plan*, seven regions cooperate on future catchment and on consumption patterns that go a long way towards satisfying the requirements on the quality of these freshwater areas. In parallel with this, a national effort is being made to decrease water consumption.

Forthcoming efforts

Continued fight against pollution

We must continue the struggle to reduce the pollution of our watercourses by nutrients. This must be done because the watercourses are active transporters of nutrients to lakes and the sea. We must carry out a material investigation to determine where the need is greatest for intervention against the remaining sources of discharge of organic substances into fresh waters.

The ochre impact is expected to diminish in the future in step with the reduction in draining activities. Environmentally-oriented watercourse maintenance and nature restoration of drained low-lying areas will also reduce the impact of ochre compounds. However, the need will still remain to reduce the level of ochre pollution from present sources in many watercourse systems. This can be achieved through active ochre removal.

Natural watercourses

The on-going fight against pollution should proceed hand-in-hand with an increased effort to improve the physical condition of watercourses.

One of the most vital targets is to return cultivated and straightened watercourses to a more natural, varied and winding form. This can be attained merely by allowing the dynamic watercourse processes to act more freely. In many cases, however, restoration will be necessary.

A more natural path for watercourses will also mean that the water in them flows more slowly. In turn, this means that more nutrient salts will be degraded in the watercourses, thus reducing the eutrophication of the marine environment and contributing to the increased retention of ochre.

Nature-oriented management and maintenance

Over the coming years we can expect improvements in the conditions of plant and animal life in many watercourses in step with the establishment of more nature-oriented management and maintenance, as is now being worked into amendments to the regulations governing public watercourses. For this reason, it is important to heighten our efforts towards the further extension and reinforcing of modified practices. The goal should be to make the mechanical cutting of wa-