Rold Skov – Active measures aiming at integrating nature conservation elements in a multifunctional forest

C3

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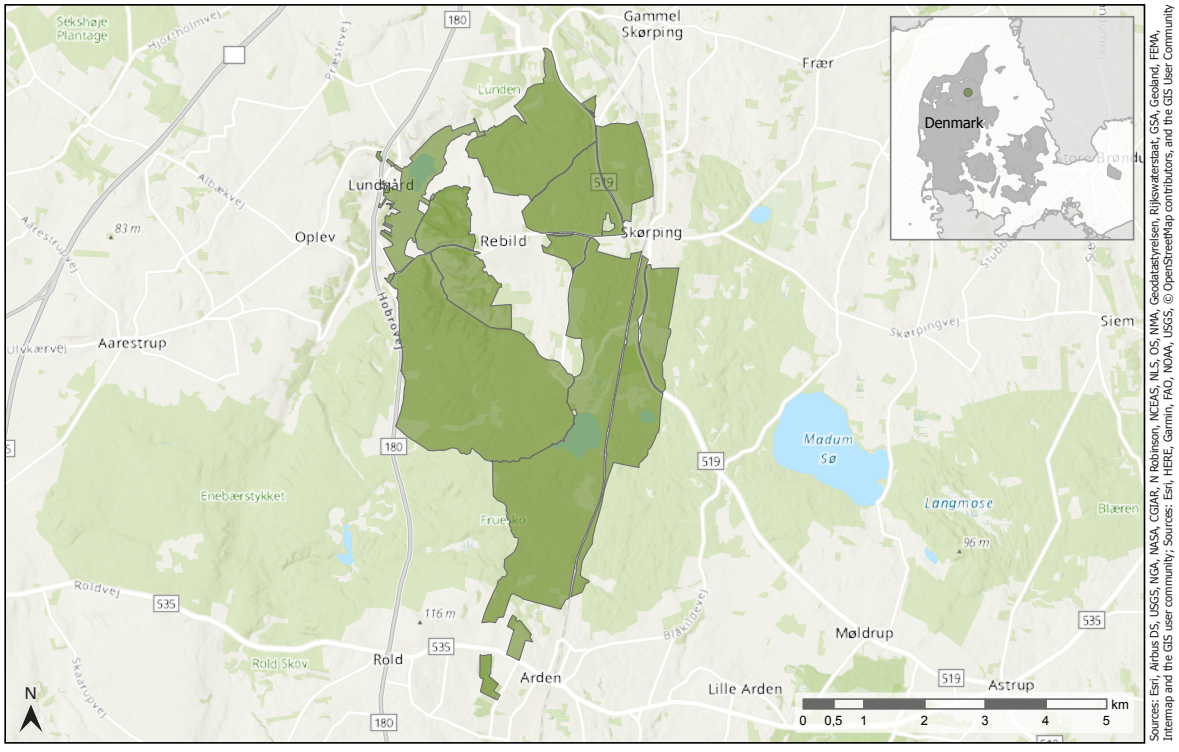
Introduction to the Nature Agency – Himmerland and Rold Skov

The Nature Agency Himmerland is one of the 16 local departments of the Danish Nature Agency (Danish: Naturstyrelsen) and manages a total of 5700 ha of forest and open nature areas. Approximately half is open nature and half is forest.

Rold Skov (Rold Forest) is the largest forest complex in Denmark with a total area of more than 8000 ha. It is located in central Himmerland about 25 km south of the city of Aalborg. The state forest



< Fig. C3.1. Natural regeneration of spruce. The shallow gravel and sandy soils provide very good growth conditions for a variety of both European and Northwest American coniferous tree species (Photo: Karen Poulsen).

Statement

"The developments described for Rold Skov will continue for decades to come. The objective is to develop an ecologically and economically stable forest with a solid base of large old trees in all stands with continuity in forest ecosystem and forest cover and with a variety of recreational forest and nature experiences for the public."

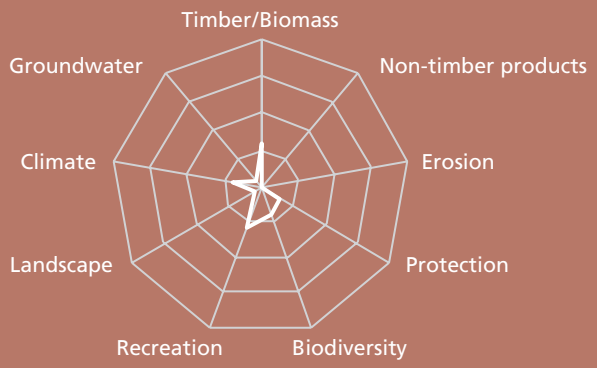


Table C3.1. General information on the forests of the State Forest Rold Skov.

Total state forest area	2300 ha (500 ha is open nature types and 400 ha set-aside forest area; timber production on 1400 ha)
Main management types	Irregular group shelterwood, group and single-tree selection systems
Total volume	230 m³/ha (568.000 m³ in total)
Annual growth	9.7 m³/ha/a (24 000 m³ in total)
Annual cutting rate	8.0 m³/ha
Deadwood	no inventory on forest level
Ownership	State forest
Climate	8.6 °C mean annual temperature, 790 mm mean annual precipitation
Soils	Gravel moraine sandy, well drained, and with a relatively low nutrient content. In the northern part calcareous subsoil is found close to the ground surface.
Protected area	600 ha forest set-aside including open nature types
Natura2000 area	The whole of Rold forest is Natura2000

area covers 2300 ha and is managed by the Danish Nature Agency. Three major private estates own the rest of the forest, the Nørrelund Estate to the west, the Lindenborg Estate on both sides of the state forest area, and the Villstrup Estate to the southeast. Of the 2300 ha which the Nature Agency manages, 1800 ha has forest cover. The following paper focuses on the state-owned part of Rold Skov.

Rold Skov is considered old forestland, which has 'always' been covered with forest. However, documents from 1826, when the state took over the area, state that only a third of the area was covered with forest/trees, most of which was thicket, including beech *(Fagus sylvatica)* thicket and poor beech stands (fig. C3.5), while the rest of the area was open landscape such as heathland and dry grassland. Local farmers had free-ranging livestock grazing the area.

Today, the forest is predominantly the result of the previous 200-year effort to rehabilitate the forest. However, until 2004 most of the forest had been replanted with exotic conifers including Norway spruce *(Picea abies)* and larch *(Larix x eurolepis).* Scots pine *(Pinus sylvestris),* which is the only conifer considered to be a natural part of the vegetation in Denmark, is not common in Rold Skov. Instead North-American conifers have been planted, including, Douglas fir *(Pseudotsuga menziesii),* Grand fir *(Abies grandis),* and Sitka spruce *(Picea sitchensis).* The first Douglas fir to be planted in Denmark was planted in 1849 and can still be found in the forest. Today, large-size Douglas fir timber is sold for special purposes at high prices (fig. C3.3).

The soils in the area are sandy and gravel moraine, well drained, and with a relatively low nutrient content, providing good growth condi-

Fig. C3.2a and b. Beech is common in Rold Skov, though on the northern limit of its European distribution. Beech contributes to two main objectives in the Rold Skov: (1) it is a stabilising element in coniferous dominated production forest, and (2) it constitutes the main species in forest set aside for biodiversity conservation (Photos: Naturstyrelsen).

tions for conifers. In 1998 the tree species distribution was 70 % conifer and 30 % broadleaved tree species. Forest management was very intensive, and these areas were utilised optimally for forest production including draining wet soils for further afforestation. Only very few areas (some meadows, mires, and small lakes) were left open without trees.

The majority of the old beech stands found in the forest in 1826 are still present in the forest today. Rold Skov contains the largest concentration of old (>200 years) beech stands in the state forest. This is one of the reasons why the forest has been designated a Natura 2000 area.

Water and chalk

The northern Rold Skov is dominated by the Lindenborg River, a stream fed by several springs. Unique habitats are associated with these springs and the calcareous soils on the edge of the river valley.

Rifts in the chalk enable very rapid, horizontal, underground water flow towards the steep slopes of the valley. Here the water pushes out near the foot of the steep slope as abundant springs, which are among the largest in Northern Europe.

The calcareous subsoil in the Rold Skov also explains the so-called sinkholes. When rainwater

Fig. C3.3. The first Douglas fir was planted in Denmark in 1849 and such old Douglas fir can still be found in the forest. The forest development type Douglas fir with spruce and beech is an import part of the forest. Today, large-size Douglas fir timber is sold for special purposes at high prices (Photo: Naturstyrelsen).

Fig. C3.4. In 2004, the state began to restore the drained raised bog west of the Great Økssø lake (see the clearing in the bottom of the picture a) from above. A mature stand Sitka spruce (26 ha) was cut down and a dense system of drainage ditches was blocked to retain the water a) from above and b) from the ground (Photos: Naturstyrelsen).

permeates the forest soil, it is acidified by humic acids. The acidified water seeps down through the rifts in the soil and dissolves the chalk. When the chalk is dissolved, holes are formed which may suddenly collapse. Holes of 4–5 m in diameter are common in the Nørreskov forest.

In 2004, the state began restoring the drained raised bog west of the Great Økssø lake. A large area of Sitka spruce was cut down and a dense system of drainage ditches was blocked to retain the water (fig. C3.4).

Fig. C3.5. Part of the very old beech forest was exposed to coppice and grazing more than 200 years ago. The most well-known is also known as the 'troll forest'. The forest is protected set aside forest and is part of northern large set-aside forest see the map figure C3.3 (Photo: Naturstyrelsen).

Biodiversity

Some of the old beech trees are multi-stemmed (fig. C3.5), crooked, and gnarled with cavities caused by cutting and grazing in earlier times. These provide numerous tree microhabitats for insects and fungi as well as for cavity nesters such as tits (Paridae), bats, and a large population of the rare stock dove *(Columba oenas).* The black woodpecker *(Dryocopus martius)* and the stock dove are mostly seen in old broadleaved forest. Other birds present in the forest, and listed in the annexes of the Birds Directive include red kite *(Milvus milvus),* kingfisher *(Alcedo atthis),* honey buzzard *(Pernis apivorus),* woodlark *(Lullula arborea),* and red-backed shrike *(Lanius collurio).*

Also, the old trees host a number of rare epiphytic mosses and lichens including the rare tree lungwort *(Lobaria pulmonaria)* (fig. C3.5). Especially in the centre of the forest (Fællesskov), the level of nutrient discharge from the air is low and there is a favourable environment for mosses and lichens. Fifteen species of lichens found in Rold Skov are classified on the Danish Red List as threatened. Mosses include buxbaumia moss *(Buxbaumia viridis),* leucobryum moss *(Leucobryum glaucum),* and fringed bogmoss *(Sphagnum fimbriatum),* which are listed in the annexes of the Habitats Directive.

Endangered plant species include two orchids: the lady's-slipper orchid *(Cypripedium calceolus),* which is only found at this location in Denmark, and the red helleborine *(Cephalanthera rubra),* is only known from two locations in Denmark

Fig. C3.6. In the centre of the forest (Fællesskov), the level of nutrient discharge from the air is low and there is a favourable environment for mosses and lichens. Fifteen species of lichens found in Rold Skov are classified on the Danish Red List as threatened. Here the rare tree lungwort *(Lobaria pulmonaria)* on beech (Photos: Naturstyrelsen).

(fig. C3.7). Both plants grow on the calcareous soils in the northern part of the forest (Nørreskov). Several rare fungi species are also present here. A total of 48 species of fungi found in Rold Skov are on the Danish Red List and considered as threatened. Most of these species depend on old broadleaved forest growing on calcareous soils or on deadwood for their habitat.

Out of the 17 Danish species of bats, eight are found in Rold Skov. The forest is attractive to bats because of the combination of watercourses and lakes in the forest (which provide good opportuni-

Fig. C3.7. Endangered plant species include two orchids: the lady's-slipper orchid *(Cypripedium calceolus)* (a), which is only found at this location in Denmark, and the red helleborine *(Cephalanthera rubra)* (b), which is only known from two locations in Denmark. Both plants grow on the calcareous soils in the northern part of the forest (Photos: Naturstyrelsen).

ties for food), and the hibernation sites in the Thingbæk limestone mines near the forest, as well as the numerous tree cavities. The bat species in Rold Skov include: serotines *(Eptesicus serotinus),* noctules *(Nyctalus noctula),* long-eared bats *(Plecotus auritus),* pond bats *(Myotis dasycneme),* Daubenton's bats *(M. daubentonii),* Natterer's bats *(M. nattereri),* Brandt's bats *(M. brandtii),* and pipistrelles *(Pipistrellus pygmaeus).*

Other mammals include one of the oldest races of Danish red deer *(Cervus elaphus).* The forests red deer population is estimated at 900 animals. Also, the otter *(Lutra lutra)* and pine marten *(Martes martes)* are found in Rold Skov.

Multipurpose and close-to-nature forestry

Since the 1990s, the multifunctional forest concept came increasingly into focus because of a new national forest law, the Rio Convention on the Conservation of Biodiversity (1992), and the subsequent introduction of the sustainability concept.

Close-to-nature forest management

The frequency of storms with severe impact on Danish forests have increased during the last 50 years. In 1967, 1982, 1999, 2005 and 2013 more than one mill. m³ of wood has fallen at each of these storms. The worst hurricane struck in 1999 (3.4 mill. m³ fell) and was a so-called once in a 100 years event. This event highlighted the need for a more robust and resilient forest development. Thus, the decision to implement close-to-nature forest management was seen as a long-term strategy towards achieving these aims. The decision was part of the first national forest programme (Skov- og Naturstyrelsen 2002). In 2005 an action plan was launched to apply close-to-nature forest management principles in all state forests. This was a radical change from previous state forest management. A transformation over the next 100 years was envisioned.

The management concept of the Nature Agency changed from a classical 'high forest, mono-species, and even-aged management system with clear felling to a close-to-nature forest management concept with no clear felling and characterised by more single tree and group management, incorporating and supporting natural regeneration and structural differentiation as well as more integration of biodiversity and outdoor recreation. For a more comprehensive description of the concept, see Larsen (2012).

Rold Skov was hit by another storm in 2005. It flattened 120 ha of spruce stands and damaged a further 340 ha in the state forest part of the forest. This again highlighted the vulnerability of the uniform stands to wind throw and potentially other calamities. It was decided to turn this calamity for wood production into a positive beginning for the new forest management regime.

A new management plan was made for the forest. Open nature types were restored on substantial parts of the cleared forestland. Furthermore, new management targets were defined for the forested area, laying out new forest development types (FDT) based on local growth conditions and soil mapping. In accordance with the management plan, forest areas have been converted from spruce to broadleaved tree species, to increase the coverage of broadleaved tree species; in particular, beech was planted in cleared patches. In addition, the area of open habitat has increased and contribute to more diverse habitats in the forest including areas with more light and transition zones between open and closed forest. Figure 3.8. shows the change in area distribution over the last 30 years.

In Rold Skov, where the beech is naturally present and conifers grow and regenerate profusely, the FDTs are mainly targeted at beech mixed with broadleaved tree species (on the better soils) or beech mixed with conifers to a greater or lesser extend (on more sandy soils). The beech generally has a stabilising function while the conifers constitute the primary forest production. Table C3.2 provides an overview of the FDTs used. The title of the FDT indicate the main species mix, though more tree species are included in all FDTs. An important feature of the Danish concept is the integration of FDTs with nature conservation as the primary objective. FDT 91, 92, 93, and 94 all focus on nature conservation and they are an integral part of the forest matrix. Coppice and forest with grazing also include an element of preserving cultural and historic management methods. Figure C3.9 shows the distribution of the FDT in Rold Skov.

Table C3.2. Forest Development Types (FDT) in the Danish State forests.

FDT No.	Forest type	FDT No.	Forest type
11	Beech *(Fagus sylvatica)*	52	Sitka spruce *(Picea sitchensis)* and pine (*Pinus sylvestris* and *P. contorta*) with broadleaved trees
12	Beech with ash *(Fraxinus excelsior)* and sycamore *(Acer pseudoplatanus)*	61	Douglas fir, Norway spruce *(Picea abies)* and beech
13	Beech with Douglas fir *(Pseudotsuga menziesii)* and larch *(Larix x eurolepis)*	71	Silver fir *(Abies alba)* and beech
14	Beech with spruce (*Picea* spp.)	81	Scots pine, birch and Norway spruce
21	Oak *(Quercus robur)* with ash and hornbeam *(Carpinus betulus)*	82	Mountain pine *(Pinus mugo)*
22	Oak with lime *(Tilia cordata)* and beech	91	Coppice
23	Oak with Scots pine and larch	92	Forest with grazing
31	Ash and alder *(Alnus glutinosa)*	93	Forest meadow
41	Birch *(Betula pendula, B. pubescens)* with Scots pine *(Pinus sylvestris)* and spruce	94	Set-aside forest – strict reserve
51	Spruce with beech and sycamore		

Note: FDTs no. 92, 93 and 94, are all forest development types set aside for nature conservation.

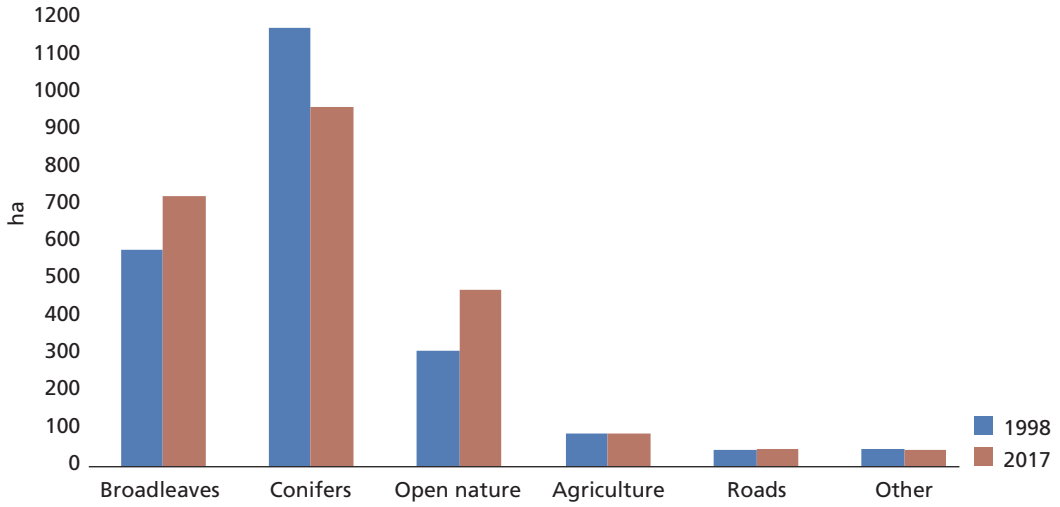


Fig. C3.8. Changed area distribution (ha) from 1998 to 2017.

Activities integrating nature conservation element over the past 15 to 20 years

Integrating nature conservation elements in the production forest matrix

- In 2015, the area with domestic broadleaved tree species as main tree species had increased by 25 % and the area of conifers as the main tree species had decreased by 18 %.
- An increase in variation of mixed stands has taken place. Either with two or more tree species or two or more forest layers by: (1) planting under an older canopy, (2) group plantings, and (3) by natural regeneration.
- Retention of high stumps, single dead trees and scattered wind felled trees in the forest matrix, to increase the amount of deadwood.
- Retention of LifeTrees (habitat trees) and veteran trees in all stands to increase long-lived and large trees, natural tree death, and decay. A minimum of five trees per hectare are retained over time.

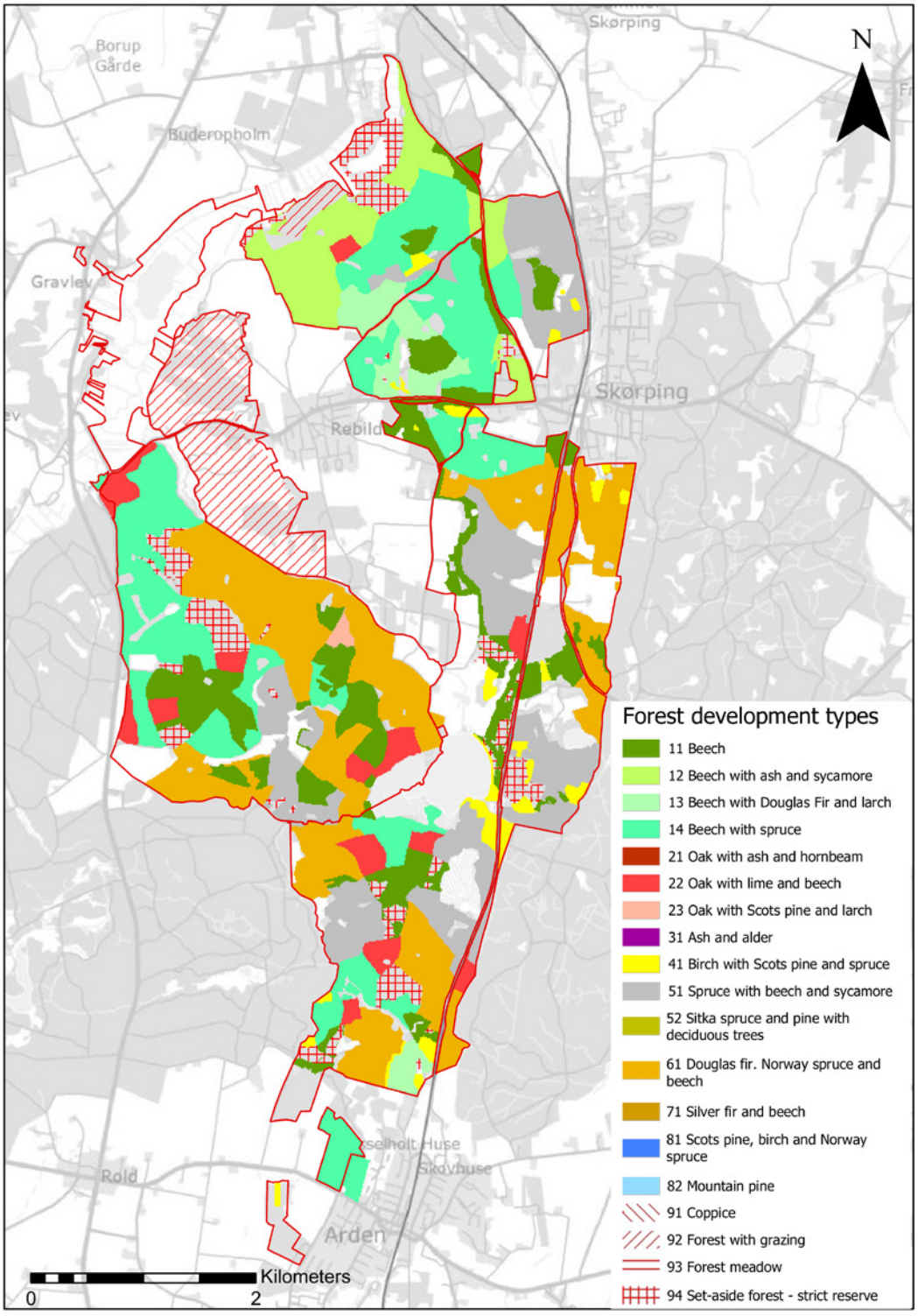


Fig. C3.9. Map of the planned forest development types in Rold Skov. See table C3.2 for an explanation of the numbers on the FDTs used in the legend of the map.

- Trees with woodpecker holes or nests made by birds of prey are painted with a big F for bird tree (Danish: fugletræ) to prevent the trees being felled by accident.
- Uncommon or rarer tree species are retained to increase variation and secure microhabitats for species living on these trees: willow species (*Salix* spp.), aspen *(Populus tremula),* oak *(Q. robur),* Norway maple *(Acer platanoides),* mountain ash *(Sorbus aucuparia)* and crab apple *(Malus sylvestris),* etc.

Integration of set-aside areas for new habitats in the production forest matrix

- 50 new small lakes and ponds have been established
- A large number of draining ditches have been closed to restore the natural hydrology.
- The total area of open areas in the forest including inner forest edges and transition zones have increased from 300 ha to 470 ha. This area is mainly meadows and restored mires.
- 404 ha of forest area have been set aside for nature conservation (strict protection) mainly divided in two large areas (22 % of the forest cover). Selection is based on the presence of threatened red list species and old beech forest patches.
- More than 180 prehistoric sites such as burial mounds, burial chambers, rocks, and dykes are managed as small open areas in the forest and contribute to a varied forest structure.

Set-aside forest for nature conservation

Segregated forest areas for nature conservation is an integral part of the multipurpose forest in the state forests. Since 1995 107 ha of old-growth forest has been set aside for nature conservation in the state forest of Rold Skov and mainly consist of smaller old beech stands spread all over the forest (6 % of the forest cover). Selection of areas was part of the first national effort for forest biodiversity conservation and linked to the Danish adoption of the UN Convention of Biodiversity agreed in Rio 1992.

In 2016, a further 297 ha was set aside in two major areas, Nørreskov and Fællesskov. Nørreskov to the north is predominantly an old beech forest on calcareous soils. Very rare species of fungi and orchids are found here and are associated with these soils (see Biodiversity section). Also, sixteen rare species living on deadwood are found in these two forest areas as well as rare insects associated with open forest meadows (Buchwald 2018).

The new set-aside areas bring the total forest area for nature conservation up to 380 ha, equal to 22 % of the forest cover. This was part of a government decision called the 'Nature Package'. See details in Box B3. The newly selected areas for conservation will undergo forest restoration. Measures include restoration of previously drained water systems; artificially promoting microhabitats on trees and increasing the amount of deadwood. Harvest of trees will take place with the aim of, reducing or even eradicating non-native tree species and may include clear felling promoting open areas for natural succession. These actions will increase the structural variation in the forest.

Parts of the forests set aside for nature conservation are already open habitats (e.g. forest meadows and wet habitats). Some of these open areas (including some of the areas to be clear felled) are to remain open as they host rare species and play an important role creating transition zones between the closed shaded forest and open sunny habitat. To prevent the transition of open habitats into forest, some of these areas are grazed with domestic animals e.g. cattle and horses. Restoration of natural water regimes will increase the area of shallow wet soils and is another strategy to prevent open habitats from growing into forest. Figure C3.10 shows a map of the selected areas to be set aside and their distribution of forest cover and open habitat.

The new set-aside areas cover a total area of 380 ha. The areas include patches of previously set-aside forest already set aside in 1995 as part of the first national strategy to set a side forest for biodiversity: Untouched forest (60.4 ha), forest with grazing (21.6 ha) and 0.4 ha of coppice. The new set-aside areas add 257 ha forest, 15.9 ha protected open habitat covers, and other open areas cover 24.7 ha. The forest area is mainly composed of beech (110.3 ha), oak (42.3 ha), Norway spruce (47 ha), and non-native species (mainly Douglas fir, grand fir, and Sitka spruce) (36.8 ha). The protected open habitat consists of bogs (5.9 ha), meadows (6.4 ha), semi-natural grasslands (2.5 ha), and lakes (and other water) (1.1 ha). Other open areas consist of grassland (14.9 ha), forest roads (7.5 ha), agriculture (0.2 ha), and unplanted areas (2.1 ha).

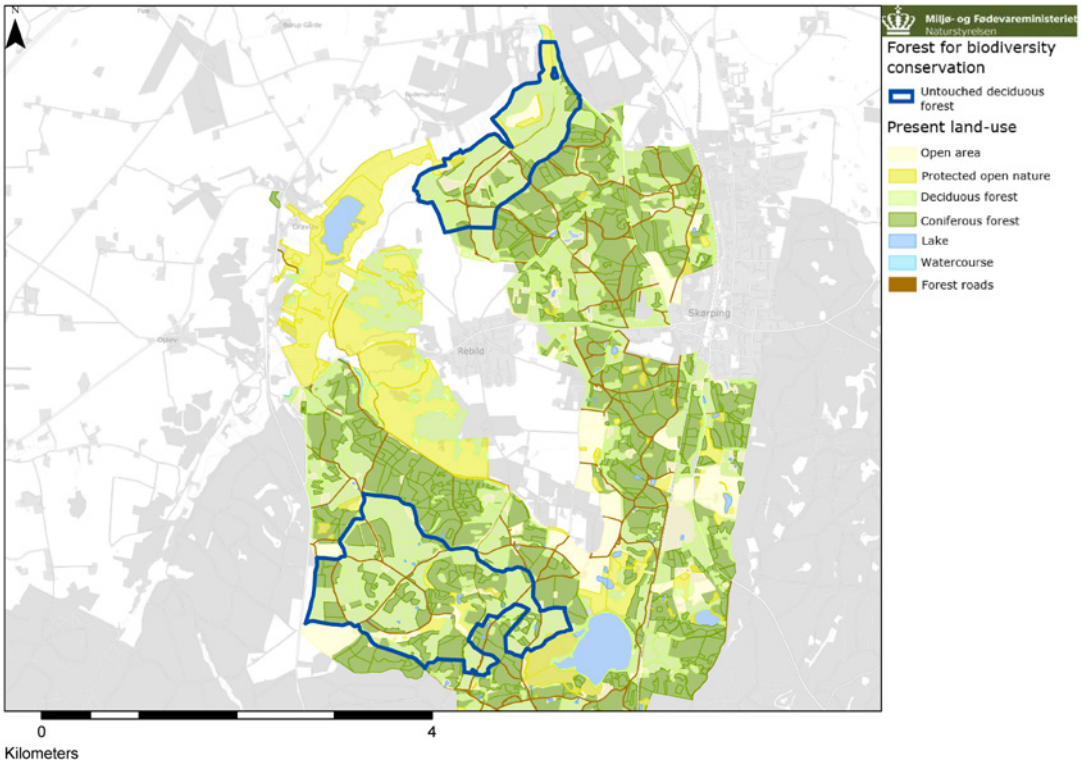


Fig. C3.10. Present land use in the new set-aside areas (marked by the dark blue line). Open areas are divided into: (i) protected natural areas and (ii) other open areas.

Outdoor recreation and tourism

Rold Skov attracts visitors all year round for outdoor recreation. Hiking and running is possible on 60 km of marked routes, though not restricted to the tracks. Access is open all over the publicly owned forest. Other rules apply in the privately owned part of Rold Skov. Horses and dogs are also welcome in the forest. Horse riding is unrestricted in the northern part of the forest and restricted to marked bridleways in the southern part. In general, dogs must be kept on a leash in the forest. The two off-leash dog parks are very popular among dog owners. The undulating terrain is very popular with mountain bike enthusiasts. Since 2004 one of Denmark's most comprehensive networks of mountain bike routes has been developed here. There are now three routes including Denmark's longest downhill track. The tracks are established and maintained in close collaboration with volunteers from the local mountain bike club. The recreational opportunities do not only attract locals, but also visitors from Aalborg, which is the third largest city in Denmark and beyond. There are varied options for accommodation for visitors, including hostels, 'bed and breakfasts', and hotels in the area and these provide easy access to the forest. Some of these specialise in sports and active holydays and arrange tours and renting out of mountain bikes, etc.

Conclusion

Site-adapted silviculture with multispecies and multilayer forest provide the basis for dynamic forest development and diversifying the risks from climate change and calamities. Thus, ensuring continuous forest growth even when calamities occur. Integration of segregated set-aside forest for biodiversity in the forest matrix is part of multifunctional strategy. The forest management aims have changed over time according to the changing needs of society – from production of timber, to

Fig. C3.11. Rold Skov has one of Denmark's most comprehensive networks of mountain bike routes (Photo: Mads Krabbe).

multifunctional forest services, to set-aside for biodiversity or carbon storage. Thus, it is vital for the forest management applied to be able to adjust to changing circumstances such as climate change and changing objectives required by society. This also ensures more options for future generations as they may have other priorities for the forest.

Over the last 25 years, the management of the state-owned part of Rold Skov has worked intensely to develop the forest away from the intensive production that had been practiced during the previous 150 years, towards a stable forest with a high level of integration of biodiversity and outdoor recreation, though still with a high annual growth and thus high carbon sequestration. About 22 % of the forest will have biodiversity as the primary objective, while the rest of the forest will develop further under close-to-nature forest management, thus integrating numerous small key habitats and single elements with high value for biodiversity within the forest matrix. As a whole, the forest will promote multiple services, including timber production, biodiversity, cultural heritage, landscape, protection of groundwater sources, and also, the latest very highly prioritised objective, to store carbon in the forest.

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