Handbook 08/2007

The Norwegian Forest and Landscape Institute

FOREST DAMAGE

A Guide to the Identification of Damage Causes - Norwegian National List.

Gro Hylen, Paal Krokene, John Y. Larsson, Halvor Solheim, Volkmar Timmermann

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ISBN 978-82-311-0024-9

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NORWEGIAN FOREST AND LANDSCAPE INSTITUTE

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(a = all tree species, b = birch, f = Scots pine, g = Norway spruce)

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Preface

Knowledge about and registration of forest damage has a very long history in Norway because of the great importance of the forests for the forestry and wood products industries. For the forest owner, healthy forest is a precondition for income. Modern forestry values both tree quality and the forest ecosystem, and the forest is important for the Norwegian population as a whole. When it was believed that acid precipitation could lead to extensive forest damage early in the 1980s, the European forest monitoring programme ICP Forests was established. This programme is based on the Geneva Convention on Long-range Transboundary Air Pollution (LRTAP). The Norwegian Monitoring Programme for Forest Damage started in 1984. In the initial phases there were only a few, simple registrations made. Gradually, the registrations increased in extent, so that we have today a scientifically based measurement and analysis programme for forest health in nearly 40 European countries. The programme includes harmonised registrations of causes and symptoms of forest damage due to fungi, insects and abiotic causes (e.g. meteorological factors and nutrient deficiency). The results from the European forest monitoring are included in the evaluations that are used to obtain healthy conditions in our forests in the long term, for the benefit both of those who have their source of income there and of the general public who use the forests for recreation and inspiration.

In a time in which the climatic conditions affecting the forests are changing, it will not be less important to have knowledge of forest damage. If the forest is to form a basis for renewable biologically based energy, it is a precondition that it is healthy and can produce that which is desired. We must also be aware that fungi and insects are part of the diversity of nature that it is important to preserve, with specific roles in the forests. Data from forest damage registrations will therefore be useful in other forest policy contexts, for example the question of sustainable forestry.

Ås, April 2007

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Introduction

The Norwegian Monitoring Programme for Forest Damage (OPS) has since its start registered damage to selected trees. The aim of the registrations has been to explain variations in crown density and crown colour. In 2005, ICP Forests introduced a standardised reporting of tree damage from all countries participating in the European forest monitoring programme. Such a harmonisation will in the course of time give a better picture of the range and occurrence of insects, fungi, meteorological conditions and other factors, as well as the effects they have on European forests. Without this information, it will be very difficult to interpret the crown vitality results.

In answer to international requests, the Norwegian Forest and Landscape Institute has prepared a short guide to the determination of the most common forms of damage found in Norwegian forests, with the emphasis on coniferous forests. This handbook presents the most important fungi, insects, grazers, meteorological conditions and other factors that can affect forest trees. If you find injuries that you wonder about, you can visit *Skogskader på internett* on the home page of the Norwegian Forest and Landscape Institute: www.skogoglandskap.no/skogskade (only in Norwegian).

Text and photos are taken from several sources: *Skogskader på internett*; *Veiledning i overvåking av skogskader* (Aamlid et al.), Finn and Helga Roll-Hansens *Bildeband om Skogsykdommer* (all these are available at www.skogoglandskap.no), the Norwegian Forest and Landscape Institute's photo archive and *SkogsSkada* at the Swedish University of Agricultural Sciences (www-skogsskada.slu.se). The photographs are marked with initials underneath each picture, and a complete list of initials and names is given under the Contents. The first edition of the handbook (NIJOS håndbok 02/05) was edited and put together by Paal Krokene, Halvor Solheim, Volkmar Timmermann, Gro Hylen and John Y. Larsson. In this revised edition, some new descriptions and more pictures have been included, and some improvements have been made in the text. The revisions have been made by Paal Krokene, Halvor Solheim and Volkmar Timmermann, and have been translated into English by Nicholas Clarke.

Deer

Winter grazing by elk can cause great damage to Scots pine regeneration.

Bark damage on Scots pine caused by elk.

Occurrence:
European elk (or *moose*) (*Alces alces)* is widespread in forested areas over the whole country, except for a few municipalities in western Norway, Lofoten and the coast of Troms and Finnmark. *Red deer* (*Cervus elaphus*) has its main range in western Norway, but has spread to southern and eastern Norway and northwards to Nordland County. *Roe deer (Capreolus capreolus)* is distributed over most of Norway as far north as Bodø, although stocks are scattered in central western Norway.

Grazing damage:
Elk prefer coniferous forest with plenty of deciduous trees. Because of their large food consumption, elk can cause great damage, for example in areas with Scots pine propagation. Scots pine tolerates grazing quite well, but in the areas with most winter grazing, grazing pressure can be so high that the development of young trees can be retarded. *Red deer* graze Norway spruce and Scots pine only when little other food is available. The damage done by red deer to forest is normally small, but in severe winters damage can be extensive when the animals gnaw bark and graze on shoots of Norway spruce and Scots pine. *Roe deer* prefer deciduous trees such as rowan and willow species, while Scots pine and Norway spruce are only exploited when the snow conditions make little other food available. When roe deer graze on trees and bushes, the twigs are torn off. The damage done by roe deer in coniferous forest is normally small.

Rubbing damage:
Arises when deer rub their antlers during the rutting season. The bark is removed, and sometimes the whole top of the tree can be broken by the antlers. The damage can be on the trunk between whorls, but often a larger part of the trunk is affected. Roe deer rub their horns in the spring, elk and red deer in August - September. The most extensive damage on single trees is caused by elk. Roe deer rubbing is normally conducted on smaller trees/plants. One cannot clearly distinguish between damage caused by elk, red deer and roe deer.

Bark damage on spruce caused by red deer.

Beaver

(Castor fiber)

Large aspen felled by beaver. (JYL)

Beaver damage to birch. (SLU)

Occurrence:
Stocks of European beaver have increased in Norway since the end of the 19th century from 60-120 individuals to ca. 70 000. Through natural expansion and reintroductions, the species can now be found in most of the country south of Saltfjellet, except for some quite large areas of western Norway. It has been observed in Finmark. Fast-growing stocks have in the last years caused far more conflicts than previously, because the animals have to a large extent occupied more marginal areas. Because of their way of life, beavers can cause conflicts in relation to e.g. forestry and agriculture.

Symptoms:
Felling of and gnawing of bark on birch is common in the whole of the range, but can also occur with Norway spruce and Scots pine. Norway spruce, Scots pine, birch and other deciduous trees are felled by the beaver gnawing the trees in its characteristic fashion, leaving a conical stump with a similar end on the felled trunk. Beavers can fell trees of all dimensions, but most often it is the smaller trees that are felled. On standing Scots pine trees, the bark can be gnawed furthest down on the trunk, at a height of a couple of dm. The trunk can also be ringbarked so that the tree dies.
Ponding and flooding of forest occurs over the whole range. If water in the dammed area cannot drain away, the trees will die after a while due to suffocation of the roots.

Ponding caused by beaver, with a dead and a dying Norway spruce tree. (SOH)

Ponding of forest caused by a beaver dam. If the water does not drain away, the trees will die. (SLU)

European pine sawfly

(*Neodiprion sertifer*)

European pine sawfly can attack on a large scale over large areas.

When the larvae are disturbed, the front parts of their bodies rise upwards.

Occurrence:

Widespread in Scots pine forest up to Nordland. Attacks trees of all ages. The Norwegian sawfly species that most often attacks on a large scale over large, continuous areas. Attacks are often spread over thousands of hectares and last for years. The species does not exhibit periodic fluctuations.

Symptoms and description:

The eggs hatch in May – June. The newly hatched larvae have black heads and grey-black bodies, while older larvae have grey-green bodies with dark or light longitudinal stripes. They reach 20-25 mm long. They form colonies (5-6 larvae/needle) around the last year's needles and eat these (ca. 50 larvae on each shoot). When disturbed, the front parts of their bodies are raised outwards from the twig. The larvae eat along the edges of the needles on the shoot on which the eggs were laid. If there are many larvae, there may not be enough food even if all the older needles are eaten, and the larvae can then crawl up to the current year's shoots and eat the new needles. They do not normally have time to eat the needles all the way down to the growth point before they pupate. Because the larvae finish eating before the current year's needles are fully developed, the damaged needles will continue to grow until the middle of August. As a rule, this needle growth will be enough to ensure survival of the tree. In the worst case, the trees will still have one year's shortened needles left. Thus, the forest which seemed completely brown and lacking needles in the middle of June will once again have a touch of green in the late summer. The adult wasps are 7-9 mm long. The female is red-brown with threadlike antennae. The male is black (apart from the legs and the underside on the back part of the body, which is red), has featherlike antennae and is smaller and slimmer than the female. The life cycle takes one year.

The newly hatched larvae have black heads and grey-black bodies.

European pine sawfly, male on left and female on right.

European spruce bark beetle

(*Ips typographus)*

The European spruce bark beetle is capable of killing large numbers of trees during an outbreak.

Fresh attacks are most easily seen in the dust that the beetles remove from their galleries.

Occurrence:

Widespread throughout the country where Norway spruce grows naturally, and also in some plantations. Causes the greatest damage of any insect to older forest in Norway, as it can kill enormous numbers of healthy trees during an outbreak. The beetles are normally too few in number to do this, and they breed in windfallen trees, coarse felling residues and timber lying in the forest when the beetles swarm. They can also attack weakened trees, for example those that are exposed at the edges of new clear-cuts. Large-scale attacks can arise after severe drought or large storm fellings that give the beetles good breeding grounds. The increased beetle population can later attack completely healthy trees.

Symptoms and description:

The beetle is about 6 mm long, black or brown-black with brown antennae and legs. The back parts of the elytra form a hollow with several large teeth on each side. The life cycle takes one year, swarming occurs from the middle of May and through the summer. The temperature should be 18-20°C for swarming to start fully. The galleries are developed in the trunk of the tree, often up until the stem diameter is about 5 cm. *The main galleries always run longitudinally* and are up to 10 cm long. However, they can be shorter, especially when the boring density is high. The larval galleries run outwards from the main galleries, and are up to 5-10 cm long. The larvae build their pupal chambers in the bark. Boring density varies greatly, but 4-6 borings per dm^2 of bark surface is not unusual. Fresh attacks are most easily discovered from the dust that the beetles remove from the galleries. Massive attacks arise most easily after large storm fellings, which give good breeding conditions. The beetles carry blue-stain fungi, which grow into the wood and stop water transport so that the trees die. The larvae are commonly fully developed from the middle of July. They leave the mother tree in August-September and spend the winter in the forest floor.

Adult European spruce bark beetle

The main galleries are up to10 cm long and always run longitudinally. The larval galleries run outwards from the main galleries and are shorter.

Six-toothed spruce bark beetle

(*Pityogenes chalcographus*)

Six-toothed spruce bark beetle can occur in such large numbers that they can kill living trees. (RUA)

The six-toothed spruce bark beetle has star-shaped galleries. (RUA)

Occurrence:

The species occurs over the whole natural range of Norway spruce in the country, and is probably the commonest bark beetle here. It is found in natural Norway spruce areas at Voss, but not in the plantations of western Norway. When the beetle population is large and the trees have been weakened, for example by drought, they can attack and kill living trees. This is especially the case in years with spring and early summer drought. It is normally completely secondary and reproduces in felling residues or in windfallen trees and branches, and it exploits the upper parts of Norway spruce trees that have been killed by the European spruce bark beetle (*Ips typographus*).

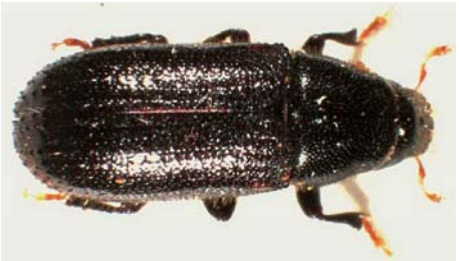
Symptoms and description:

The beetle is about 2 mm long. The head and thorax are dark brown while the elytra are red-brown. The life cycle takes one year: swarming occurs primarily in May, but can continue throughout the summer. It builds *star-shaped galleries*, where 4-10 females live together with a male. The larvae eat their way out of the main gallery, leaving larval galleries in the bark. They pupate in the bark and the new generation often spends the winter in the mother tree. The larvae are generally fully developed in July - August, but because the species swarms throughout the summer it is possible to find larvae nearly throughout the year.

Common pine shoot beetle

(*Tomicus piniperda*)

Damage to Scots pine caused by common pine shoot beetle.



Common pine shoot beetle.

Occurrence:
Common where Scots pine grows. Feeds on shoots, and can therefore considerably reduce tree growth. Destruction of the shoots can lead to the stem form becoming damaged in younger trees. One of the most important pest insects in the forest. It does not kill healthy trees, but reproduces in dead and greatly weakened trees, windfalls, stored timber, and residues from thinnings and fellings. During feeding, a beetle can bore into 2-3 shoots during late summer and autumn. Most of the shoots will die, break off and fall to the ground.

Symptoms and description:
The beetle is 3-4 mm long. It is black with brown feelers and brown legs. The life cycle takes one year: swarming is predominantly in the spring (March - June), often when there is still snow on the ground. The female lays eggs along both sides of an 8-10 cm long main gallery running longitudinally in the wood. The main gallery is placed in the inner part of the bark under coarse bark. The first part of the main gallery can be at an angle to or transverse to the wood's longitudinal axis, and the galleries can be reminiscent of a *walking stick*. The larvae eat their way out of the main gallery, building long larval galleries that often wind irregularly between the bark and the wood. In southern Norway, larval development takes place in May and part of June. The new generation of beetles leaves the mother tree from the beginning of July and feeds on the current-year or last year's shoots, in which it hollows out the pith to a length of 2-3 cm. The beetles spend the winter in cork bark at the root collar of larger Scot pine trees.

Galleries of common pine shoot beetle.

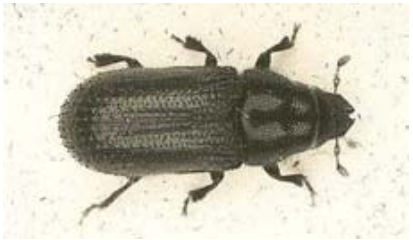
Risks for misidentification:
The lesser pine shoot beetle is similar and lives in a similar manner. However, the galleries are very different; the lesser pine shoot beetle builds two main transverse galleries and short larval galleries (2-3 cm), while the common pine shoot beetle has a single main longitudinal gallery and long, winding larval galleries.

Lesser pine shoot beetle

(*Tomicus minor*)

After leaving the mother tree, the lesser pine shoot beetle feeds on current-year or last year's shoots.

Galleries of lesser pine shoot beetle.



Lesser pine shoot beetle.

Occurrence:

The lesser pine shoot beetle is found in lowland areas of southern Norway (< 400 m a.s.l.) It occurs primarily in eastern Norway and along the coast northwards to Sør-Trøndelag, but is found sporadically in Trøndelag and once in Saltdal. It feeds on Scots pine shoots in the same manner as the common pine shoot beetle and has a similar way of life, but is less common and therefore less important as a pest. Injuries to the trees due to feeding lead to growth reduction.

Crown thinning after an attack of lesser pine shoot beetle.

Symptoms and description:

The beetle is 3-4 mm long and is very similar to the common pine shoot beetle. The head and thorax are black, while the elytra, antennae, and parts of the legs are dark red-brown. The life cycle takes one year: swarming occurs in the spring (April - June), simultaneously with or slightly later than the common pine shoot beetle. The main gallery is divided into two parts, which run transverse to the longitudinal axis of the wood and can resemble the *silhouette of a flying gull*. The larvae eat their way out from the main gallery, building short larval galleries (2-3 cm) that finish in small holes in the wood. Blue-stain fungus always develops strongly in the sapwood in connection with the galleries. The fungus serves as food for the larvae. After the new generation has left the mother tree, they feed on current-year or last year's shoots during late summer and autumn. They spend the winter in the forest floor.

Risks for misidentification:

The common pine shoot beetle is very similar and has a similar way of life. The galleries are, however, very different; the lesser pine shoot beetle has two main transverse galleries and short larval galleries (2-3 cm), while the common pine shoot beetle has a single longitudinal gallery and long, winding larval galleries.

Moths on birch

Large-scale attacks of autumnal moth occur every 8–10 years.

Larvae of autumnal moth eat birch leaves in early summer.

Several moth species eat birch leaves. The most important are three species which have characteristic caterpillars with three pairs of true legs and two pairs of prolegs at the back of the body. All the species can occur together and cause similar damage due to the caterpillars eating the leaves. To separate them, one has to study the caterpillars, but these are only present for a few weeks from leaf break in the spring to early summer.

Autumnal moth (*Epirrita autumnata*)

Occurrence:

The species is found on birch over the whole of Norway, but is most common in northern Norway and mountain forests in southern Norway. It can eat up large continuous forest areas. Large-scale attacks in mountain forest occur every 8-10 years. The population is built up over a three-year period and remains on a high level for several years before the attacks are reduced again. In cases of complete denudation for several years, the trees can die, especially in old forest. Large-scale attacks can influence the local climate and lead to the forest line being displaced downwards.

Symptoms and description:

The caterpillars are green with light green longitudinal stripes, and can reach 20 - 25 mm long. They eat the birch leaves in early summer, and during large-scale attacks can denude large areas of forest.

The adult moth is grey-brown with very variable nuances of colour. The front wings have grey, wavy transverse lines, while the back wings are whitish. The wingspan is 25-40 mm. The life cycle takes one year. The moth swarms in September - October and lays 200-300 eggs singly or in small groups in cracks in the bark or other uneven places on the branches of the birch trees. The eggs spend the winter there and hatch in the spring when the leaves break. The caterpillars eat the birch leaves during the early summer before crawling down and pupating in the forest floor. The adult moths appear in September.

Adult autumnal moth.

Caterpillars of autumnal moth (HEM)

Winter moth (*Operophtera brumata*)

Occurrence:

This species is found over the whole of Norway and is very common on several different broadleaved trees. The winter moth can occur in large numbers in both southern and northern Norway. It can occur together with the autumnal moth (*Epirrita autumnata*) and can also be responsible for the denudation of mountain birch forest. Large-scale attacks on birch also occur in the lowlands of eastern Norway, although in this area denudation leads only to loss of growth and only rarely to tree death. This species can also cause serious damage to orchards.

Symptoms and description:

The caterpillars are dark green to green-black with a thin dark stripe on the back and three clear light longitudinal stripes on each side of the body. The caterpillars eat the leaves of several different broadleaves in early summer and often hide in leaves that have been spun together. The female's wings are just 2-3 mm long stumps and she can not fly. The male's front wings are light brown with a weakly reddish tinge and a broad, dark band in the middle. The back wings are lighter and more evenly coloured. The wingspan is 20-28 mm. The life cycle takes one year: mating occurs in September - October and the female lays her eggs in the tree tops. The eggs spend the winter there and hatch in the spring. The caterpillars eat leaves in the early summer, before crawling down to the forest floor and pupating. The adult moths appear in the autumn.

Male winter moth.

Northern winter moth (*Operophtera fagata*)

Occurrence:

The species is distributed over most of Norway. Northern winter moth has, together with autumnal moth (*Epirrita autumnata*), occurred in large numbers and denuded birch over large areas, but its importance as a pest is still somewhat unclear.

Symptoms and description:

The caterpillars are first green-black with whitish lines along the body and black head. They become gradually more yellow-green with white longitudinal stripes and brown-black heads. The caterpillars begin to eat the birch leaves right after bud break in the spring. In cases of severe attacks, birch can be denuded over large areas. Like the winter moth, the female does not have fully developed wings. The male's wings are very thin. The front wings are grey-brown with a wavy brown-black crosswise band, while the back wings are uniformly greyish. The male swarms in the late autumn and mates with females that have climbed to the tops of the trees. The female lays her eggs furthest out on the birch twigs. After spending the winter there, the eggs hatch in the spring at the same time as the birch leaves come out. The larvae are fully developed later in the summer and pupate in the forest floor. The adult moths appear in the autumn.

Male of northern winter moth

Spruce needle rust fungus

(*Chrysomyxa abietis*)

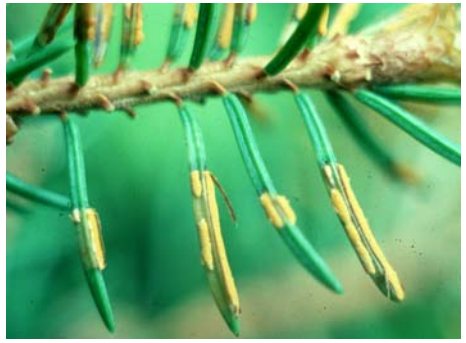
Spruce needle rust fungus on current-year needles. (SOH)

Spruce needle rust fungus on last year's needles. (SOH)

Occurrence:
The whole country. Primarily on younger Norway spruce. Other spruce species can also be attacked. The disease causes insignificant damage, but with severe attacks, a whole year's needles can be lost. After repeated attacks, this will lead to loss of growth.

Symptoms:
In late summer, the affected needles first show yellowish patches; later, larger yellow patches or clearly limited yellow transverse bands. In severe attacks, whole needles can become yellow. The affected needles do not fall off before the spores have been dispersed in the next spring/early summer. The life cycle takes one year without alternate host. The young spruce needles are infected in the spring as soon as they appear.

Risks for misidentification:
Spring and summer frost. In cases of frost, the needles most often first become yellowish and then rapidly turn brown. The needles fall off after a short time.
Spruce needle cast/blight first discolours the needles in the spring of the year after they are attacked, and they then turn brown. The fruit bodies are long and black, and are first mature in the spring two years after the attack. The needles also form a black transverse band at the base.



Spruce needle rust fungus: mature fruit bodies with yellow spores. (SOH)

Spruce needle rust fungus attack on current-year needles of young Norway spruce. (SOH)

Resin top fungus

(*Cronartium flaccidum* and *Endocronartium pini*)

Resin top on old Scots pine. (AAD)

Resin top fungus, aecidia. (FRH)

Occurrence:
The whole country. Resin top is caused by two fungi, *Cronartium flaccidum* and *Endocronartium pini*. The first of these alternates hosts with e.g. white swallow-wort, peony and small cow-wheat. *E. pini* is spread directly from pine to pine without an alternate host. Scots pine trees become more susceptible to infection as they grow older, but young Scots pine trees can also be attacked.

Symptoms:
The classical symptom is the dead tops of older Scots pine trees. At the place where the tree is girdled and a bit further down on the stem there is ample discharge of dark resin. Before the tree is girdled, oblong wounds with abundant resin discharge can be observed. These can be up to several metres long. Occasionally, one can see branches in the crown that have been attacked and killed. Smaller trees can also be attacked. In connection with the canker, there is a resin discharge and often abundant fruit bodies, yellow-white sacks with orange spores. If the fungus girdles the tree, the area above the infection will die and the typical symptom with a dead tree top will appear. Girdle formation can take many years.

Old Scots pine attacked by resin top fungus. (JYL)

Risks for misidentification:
Drought can in some cases lead to a dry top, although this is rare.
Phacidium coniferarum: This fungus infects wounds and can lead to cankers. This is more common in younger forest and in connection with pruning. *Phacidium coniferarum* is not as aggressive and seldom girdles trees. However, if all twigs in a whorl are infected it can probably also girdle trees.
Lightning and other electrical discharges can cause top death on Scots pine trees on clear-cuts with seed trees left standing, especially if the trees stand on high ground. The injuries look very like resin top fungus damage, but are most often caused by lightning. Resin discharge is rare in these cases.

Brunchorstia dieback / Scleroderris canker

(Gremmeniella abietina)

Brunchorstia dieback on young Scots pine. (SOH)

Occurrence:
Common in the whole country. Most common on Scots pine, but Norway spruce can also be attacked, especially when growing together with Scots pine. Trees of all ages can be attacked.

Symptoms:
The symptoms are different for Norway spruce and Scots pine. On *Scots pine*, buds and shoots are attacked and killed, most often the last year's shoots. In spring, the needles on affected shoots start to be a little grey-green. As the fungus gradually kills these needles, they will become brown from the base. This symptom can be seen in May or June, depending on when spring starts. The injuries first become visible when the needles turn brown. The needles remain on the trees as a rule throughout the summer, so the damage is clearly visible then. Brown-black or black 0.5-1.5 mm fruit bodies can be seen with a magnifying glass. In some situations, especially at higher altitudes, the fungus will cause cankers. This occurs when the fungus has established itself in wounds, or if the fungus from a side branch reaches a main branch or the trunk. On *Norway spruce* it is most often the leading shoot that is affected, more seldom side shoots. In the spring, shoot growth at the top does not occur. Gradually the needles become grey-green, later turning brown, and then fall off. Typically, the whole leading shoot and some of the most recent year's shoots wither. In a small area far down on the next to last year's shoot, the fungus has girdled the tree and the top has dried out above this. In the affected area, the bark is dark brown and filled with resin. The dead shoots are straight. Side shoots replace the leading shoot and there are often double tops.

Brunchorstia dieback. (SOH)

The leading shoot is killed and side shoots replace it. (SOH)

Lophodermium needle cast

(*Lophodermium seditiosum*)

Lophodermium needle cast attacks primarily the oldest needles on young Scots pine trees. (SOH).

Occurrence:

Common in areas of Scots pine propagation in southern Norway, and very common in nurseries across the country. If the weather is advantageous for the fungus and disadvantageous for the pine, there can be large-scale attacks. A lot of rain in summer and autumn promotes spore dispersion. The fungus can cause a lot of damage in nurseries, but in Norway is considered to play a minor role in the forest. However, there have been some attacks in southern Norway in recent years.

Symptoms:

The fungus has a one-year life cycle. Small, pale patches can be observed on infected needles in the autumn that they are infected. Early the next spring they become first mealy red-green, then red-brown. Later in the summer they become more grey-brown. The needles on older seedlings and trees will most often fall off early in the summer before the fruit bodies are formed. Needles of all ages are attacked, but primarily the oldest needles. In seedlings, the whole plant is often attacked. Otherwise, the attack is generally on the lower branches. In severe attacks, whole 4-5 m high Scots pine trees can be attacked. The buds are not damaged, so even if all the needles are attacked, new shoots and needles will be formed. In whole-plant attacks, seedlings and small trees can be killed.

Needles attacked by Lophodermium seditiosum turn red-brown after a while. (SOH).

Risks for misidentification:

Lophodermium pinastri is a closely related species that can be observed on most dead Scots pine needles. The safest way to tell it apart is the evident black transverse stripes formed on the needles of *L. pinastri*. The openings on the fruit bodies also have different colours: reddish in *L. pinastri* and greenish in *L. seditiosum*.

Common snow mold (Phcaidium infestans) normally only causes damage beneath the snow. Needles of all ages are attacked. Normally, the needles do not fall off before the next spring, and the fruit bodies are round and break open with lobes.

Birch leaf rust

(Melampsoridium betulinum)

Birch leaf rust. (AAD)

Uredinia of birch leaf rust on the underside of a leaf. (FRH)

Occurrence:
Common on all birch species, including dwarf birch, in the whole country up to 1350 m a.s.l. It does not normally cause great damage in the forest, but large-scale attacks occur in some years. With subsequent large-scale attacks, growth can be reduced. Trees attacked by the fungus can be more easily injured by frost.

Symptoms:
The life cycle takes one year. The fungus spends the winter in birch buds. During bud break, the young leaves can become infected. Yellow uredo-spores (summer spores) are formed on the underside of the birch leaves. These can impart a yellowish colour to e.g. water or cars during large-scale attacks. In the autumn, dark brown crusts are formed on the undersides of the leaves. The birch leaves turn yellow already in the late summer, and fall off earlier than normally. Small-scale attacks of birch leaf rust fungus occur nearly every year. Large-scale attacks occur if there is a wet early summer followed by a warm, humid late summer. There are clear differences between different trees' susceptibilities.

Risks for misidentification:
Drought: at a distance, the yellowing of the birch leaves can appear similar to the effects of drought. However, with drought one does not see the yellow uredinia on the undersides of the leaves.

Birch trees attacked by birch leaf rust. The tree in the middle has been severely attacked, while the tree to the right has only experienced a mild attack. (SOH)

Yellow covering of birch leaf rust spores on a fjord (TJS)

Spruce needle cast/blight

(Lirula macrospora)

Spruce needle cast fungus with long, black fruit bodies on the underside of the needles. (AAD)

Spruce needle cast fungus on Norway spruce needles. The black transverse band at the base of the needle is characteristic. (FRH)

Occurrence:
Common in spruce forest over the whole country. Attacks many different spruce species, primarily at an age of 10-40 years. The fungus can spread most severely in young dense stands and on suppressed trees. The needles are susceptible for a short period in early summer. The weather in this period is a decisive factor in the development of the infection. Attacks are favoured by light deficiency and damp conditions.

Symptoms:
The last year's needles turn brown in the spring, and at the base of the needle a characteristic transverse black band develops when the needle dies. The anamorph stage, with small, oblong, light-coloured pustules, becomes quickly visible. In the autumn a construction for fruit bodies starts to form; this is far more conspicuous. The long, black fruit bodies are mature in the spring two years after the start of infection. The dead needles do not fall off, but remain attached for a long time inside of the healthy green current-year needles and turn gradually greyish. Attacks occur as a rule on the lower branches. From a few to all of the needles on the shoot can be attacked.

Risks for misidentification: *Snow blight (Lophophacidium hyperboreum).* Here it is the current-year needles that are attacked, rather than last year's, as is the case with spruce needle blight. In addition, the fruit bodies mature in the autumn and are not black.

Spruce needle rust. The needles turn yellow already in the first autumn. In the spring of the second year the fruit bodies are mature and can be seen as longitudinal yellowish elevations. The spruce needle blight fungus has black fruit bodies that are not mature before the third spring.

Lophodermium piceae has black, oval, shiny fruit bodies. Characteristic black transverse stripes often occur on the needles, which also have a dark transverse stripe at the base. Young and old needles are infected in the summer. In the case of *Lirula macrospora*, last year's needles turn brown, followed by the formation of long, black fruit bodies on the dead needles, which also have a clearer black needle base and no other black transverse stripes.

Branch attacked by spruce needle cast fungus several years in a row. Last year's needles are now red-brown, while previous years' needles are pale brown. Older needles have also been attacked. (SOH)

Lophodermella pine needle cast

(Lophodermella sulcigena)

Lophodermella pine needle cast on twigs. (SOH)

Lophodermella pine needle cast on needles. (SOH)

Occurrence:
The whole country. Primarily, 10-30 year old Scots pine trees are attacked, but also younger and older trees. Attacks are common in nutrient-rich soil, i.e. on typical Norway spruce land. The weather is important: a wet early summer is a precondition for a more extensive attack. Primarily, trees at stand edges or inside broken-up stands are attacked. Repeated attacks lead to lower growth, but otherwise the fungus has little effect.

Symptoms:
Current-year needles that are attacked in early summer start to turn grey-brown towards the end of summer, often with a violet tinge. Well into the winter and spring, the colour becomes paler, more greyish. Some needles are killed completely, but most often the needle base remains green. Often only one needle in each pair is attacked. This variation means that the tree obtains a motley appearance. There are large individual differences in resistance. In some trees, attacks cover the whole crown, while neighbouring trees are not attacked at all. The fungus has a one-year life cycle. Young needles are infected in the early summer. In the spring of the year after the attack, long grey-brown fruit bodies start to appear. These open in damp weather and the spores can then be dispersed, most often in June.

Lophodermella pine nedle cast on a young Scots pine. (FRH)

Risks for misidentification:
Lophodermium needle cast. In the spring, attacks can appear similar to those of the Lophodermium needle cast fungus, which is characterised by small, pale patches that can be seen on infected needles in the same autumn that they are infected. Early next spring they become first a mealy red-green, and then red-brown. In the course of the summer they become more grey-brown. Often the needles fall off early in the summer. Lophodermella pine needle cast on the other hand is characterised by a greyish colour on the needles and a green needle base, by many needles not being killed over their whole length, and often by only one of the needles in each pair being attacked.

Honey fungi

(*Armillaria* spp.)

Honey fungus. (SOH)

Honey fungus, mycelial flake. (SOH).

Honey fungus, rhizomorphs. (FRH).

Occurrence:

The whole country. All tree species are attacked, both conifers and broadleaves. Honey fungi fruit in late summer and autumn. There are several species of honey fungus that are difficult to tell apart.

Symptoms:

In small trees, shoot growth is first reduced and the tree turns yellow before dying. Seedlings and small trees can die one to two years after infection. In larger trees, the process may take several years. In these there is also reduced shoot growth, especially in the top of the tree; the tree turns yellow and dies from the top down (top decline). As the fungus gradually kills the root system, one can find white mycelial flakes between the bark and the wood. There is often a severe resin discharge in the root collar. Further out in the root system, one can find flat rhizomorphs (mycelial strands), which are later also formed in the root collar. The rhizomorphs are first light brown to reddish, later becoming black. With the help of the rhizomorphs the honey fungus can spread from an infected stump or root to the roots of weakened trees or woody plants nearby. It can infect through wounds or directly through the root bark. Weakening due to stress makes trees susceptible to honey fungus attack.

Honey fungi lead to reduced shoot growth and the tree dies from the top down. (SOH)

Risks for misidentification:

Annosus root and butt rot (*Heterobasidion annosum)* attack can resemble attack of honey fungus. The root and butt rot is different as it is neither black nor cavity-forming, nor does it form white mycelial flakes or rhizomorphs like honey fungi do.

Drought: on larger trees in particular, acute drought can lead to top decline that can easily be confused with top decline caused by honey fungi. In drought, top decline is more acute in the drought year, and reduced shoot lengths are rare.

Six-toothed spruce bark beetle can attack in the tops of drought-weakened trees (early summer drought), leading to top death. However, the dying off happens more rapidly than after attack of honey fungi.

Snow

Wet, heavy snow in the crown can cause stem breakage. (FRH)

Birches in September that are still bent after the last winters' snow. (TIV)

Even though trees growing at high latitudes have crowns that are adapted to large amounts of snow, extreme conditions can still cause considerable forest damage. (JYL)

Occurrence:
Damage caused by heavy, wet snow can occur over the whole of Norway, but is most common at high altitudes and northern forests. Wet, compact snow that is caught in the crown can break branches and stems. This is especially serious when the wet snow freezes in the crown and is subjected to strong wind. Mature trees in northern areas therefore have a crown that is adapted to tolerate large amounts of snow.

Symptoms:
Snow pressure: The stems and branches are bent by the weight of snow and ice. This can result in branch and stem breakage. Younger trees in plantations can be uprooted. When there is a crust on the snow, branch and stem breakage can also occur at snow level on young, weak trees, and double stems or tops can be formed.

Drifting snow: On stems and branches of young trees, shiny light areas can develop above the snow level on the side exposed to the wind. The needles can also be damaged and fall off. Drifting snow occurs due to strong winds, when snow blows along the surface, grinding the bark and damaging the layer of wax on the needles. The risk of drying out is increased in the current-year needles, which find it difficult to develop during the short summer at higher altitudes in the north. In the case of needle damage, temperature fluctuations around freezing point may play a role.

Breakage due to snow on young Scots pine. (FRH)

Drought

Withered Norway spruce, old tree on left (SOS) and young tree on right. (SOH)

Withered Scots pine on left and birch on right. (SOH)

Occurrence:
On dry ground with a thin soil and insufficient groundwater, or on moist ground that dries out in the summer. Young planted trees and older trees exposed to sun and wind are most affected. Most common in Norway spruce and birch, but also in Scots pine on very dry and shallow soils.

Symptoms:
In *Scots pine*, damage is limited to brown current-year needles and needle loss. In *birch*, the leaves hang down and turn yellow during the summer before the autumn colours arrive. In *young Norway spruce* the needles turn brown, as a rule in the upper part of the crown at the base of the current-year shoots. Growth of the current-year shoots is poor, and sometimes the needles are shorter than usual. The number of needles is not affected. It is common with large variations between the trees in a stand. In *older Norway spruce*, crown thinning can be seen at a distance. This thinning is often greatest under the healthy top part. Drought causes an unusually large number of brown needles and needle fall earlier in the autumn than normal. With binoculars, the following observations can be made:

***** *Needle fall and needle discolouration* towards the branch tips, in a severe drought all the way to the tips and to the top.

***** *Dead branches*, i.e. side branches wither and later break off, so that gaps appear.

***** *Short and often discoloured leading shoots*. If the tree is sufficiently vital, secondary shoots develop on the top sides of the injured branches in the following year. In the case of several dry seasons in a row, the secondary shoots will also be small and dispersed.

Effect of spring drought on Norway spruce. (AAD)

Risks for misidentification:
Honey fungi. Drought can destroy the root system in a similar way to honey fungi. On slightly larger trees in particular, drought can cause top decline that can easily be confused with top decline caused by honey fungus attack. In the case of drought, top decline is generally more acute in the drought year itself, and reduced shoot lengths are rare. *Brunchorstia dieback*: Drought can, especially on small Norway spruce trees, damage leading shoots and sometimes some of the top side shoots, which then wither and die. The symptom is, however, not as regular as when *Gremmeniella abietina* attacks Norway spruce.

Drought in frozen soils

Occurrence:
Can occur in stands where oxygen deficiency can arise in the roots, caused by ice in the soil until late in the spring (for example in dense Norway spruce stands on land previously used for agriculture where there is little solar radiation). The soil is characterised by poor drainage.

Root suffocation due to drought in frozen soils; mild damage on the left, severe damage on the right.

Symptoms:
Injured trees are spread throughout the stand, but are mostly concentrated in the lower areas. Initially, older needles turn brown. Short annual shoots can develop over the whole crown, and are a sign of rapidly decreasing growth. Extensive needle fall can lead to quick tree death. This can happen before or after the start of shoot growth.

Causes:
In *Norway spruce*, the extent of the damage depends on whether the fine roots die due to lack of oxygen. The risk is increased in dense stands with little solar radiation and a thick, insulating litter layer. The frozen layer in the soil acts as a seal. Air cannot penetrate and the water-saturated soil becomes anaerobic. The roots of Norway spruce are sensitive for oxygen deficiency. Under anaerobic conditions, iron (III) is reduced to iron (II). This is taken up easily by the trees but is removed from solution in the tree trunk, giving rise to a blue-black discolouration in the wood that can be observed after felling of a damaged tree.

Blue-black discolouration of wood (FRH)

In *Scots pine* growing in mountainous areas, drought in frozen soils can occur in connection with very cold winters when the ice does not disappear from the soils. The trees wither and die, as water uptake is impossible.

Effect of drought on frozen soil on Scots pine at the edge of a bog (FRH)

Frost

Occurrence: can occur in all seasons and can strike all tree species at all developmental stages. There are several types of frost damage. See also oxygen deficiency/drought on frozen soils.

Autumn and winter frost on shoots:
In late autumn and winter, trees are normally highly resistant to low temperatures. Despite this, poor maturation of last years' shoots can lead to diverse autumn and winter injuries.

Winter frost causes red-brown needles with a well-defined border to green areas. (SOH)

Symptoms:
The whole needle or the part nearest the tip changes colour to straw yellow or yellow/red-brown. The marked red-brown colour has a well-defined border to the green areas. The colour is retained in the growing season. The needles fall off gradually. The shoot tip and the whole shoot can be damaged; the sensitive current-year shoot is normally most damaged. If the buds survive, new green shoots are formed at the tips of the brown shoots. The entire current-year shoot can be killed, or only the shoot tip, or the parts of the tree that are not covered by snow. The damage is often not a pure frost injury, but can be due to an interaction of frost and drought (see frost-induced drought).

Winter frost on Scots pine results in straw-yellow tops (SOH)

Risks for misidentification:
Frost-induced drought. Dead buds and needle fall caused by *Argyresthia glabratella*, *Pine bud moth* and *European pine shoot moth*, but with these the buds, shoot tips and shoots are hollowed out. The first stages of needle discolouration are

reminiscent of *Lophodermium needle cast* and *Lophodermella pine needle cast*.

Summer frost leads to hanging shoots, which gradually develop brown needles that finally fall. (FRH)

Spring and summer frost:
Most common on young Norway spruce trees and seedlings. Very variable injuries. Injuries arise in open areas, especially in low-lying terrain and hollows where cold air masses lie. An important factor is radiation of warmth from open terrain on clear nights without wind. Injuries arise especially on young trees and seedlings during shoot growth, when the shoots are particularly sensitive, but also in summer if there should be night frost.

Symptoms:
With a severe frost, young, delicate shoots become yellowed quickly and die. The phenomenon is common in young Norway spruce, where dead, hanging shoots with brown needles remain hanging through the rest of the summer. In the next year, the bare, bent axils are often still present. If this is repeated for several years in a row, especially in younger trees, the trees will become bush-formed. Mild frosts before the shoot is fully developed can result in downwardly bent leading shoots without obvious discolouration. When the shoot is more mature, damage will be limited to browning of the needles, often in the shoot tips.

If Scots pine is subjected to a severe frost, the damage will commonly be limited to bleaching of the shoot tips and slightly bent shoots. Spring frost damage on Scots pine needles affects primarily the growing base, while later summer frost damages primarily the needle tips.

Risks for misidentification: Bent shoots in Norway spruce due to frost can be confused with the effect of drought. Yellow-brown needles in early summer can be due to insect or fungal damage, for example the first symptoms of *Brunchorstia dieback, Lophodermella pine needle cast* on Scots pine and *Chrysomyxa needle rust fungus*.

Frost-induced drought:
Appears largely on younger trees that are exposed to sunlight late in the winter or in spring, and that are exposed to large fluctuations in temperature between night and day.

In frost-induced drought, the needles turn brown because they start to transpire while the soil is still frozen. (SOS).

Symptoms:
The needles turn brown due to desiccation, because they start to transpire without a water supply because the soil is frozen. Damage is most obvious on south- and southwest-facing slopes at forest edges, on free-standing trees, or in the parts of the crowns that are not covered by snow. All years' needles can fall, although this is most often the case for the latest years' needles. Buds and twigs normally survive, and can therefore produce new shoots.
Risks for misidentification: *Salt damage. Winter frost.*

Frost cracks:
Longitudinal cracks in the trunks of deciduous trees, in particular oak but also elm, ash, beech and lime. Due to old, closed wounds that open due to large falls in temperature during the winter. After several years' repeated closing and opening, longitudinal frost cracks are formed on the trunk.

Bark frost:
The bark cracks during tree growth in the summer due to frost damage on the

Frost cracks (FRH)

sunny side of the tree. Especially common in thin-barked trees such as Norway spruce, beech, aspen and poplar.

Red belts:
Occur on wooded hillsides and along the sides of valleys.
Symptoms:
Red belts can be observed as brown, horizontal belts of variable dimensions on wooded hillsides in the spring when the trees have started seasonal adaptation. Damage arises when cold air accumulates in the valleys or lower areas and when warm air forms a layer over this cold air. Small movements up and down of the boundary between the two air masses give large, rapid changes in temperature that damage the trees' needles. New shoots are normally affected.

Red belts can also occur as patches in the stand at sites exposed to frost. (SOH)

Red belts can be observed as brown-coloured, horizontal belts on wooded slopes in the spring. (SOH)

Lightning

Lightning damage occurs most often on trees standing on high ground. (SOH)

Occurrence:
Can occur in the whole country on trees (especially Scots pine) standing on high ground, especially on seed trees on clear-cuts.

Symptoms:
In cases of powerful discharge, trees can be splintered or vertical mechanical damage going down to the roots can be caused. When the discharge is weaker, only the top is damaged, which then dies without there being resin outflow.

Risks for misidentification:
Resin top fungus: Lightning damage is very similar to resin top damage, which also causes dead tops on older Scots pine trees. However, resin top damage causes oblong wounds with ample outflow of resin.

Dead tops with no resin outflow are characteristic for lightning damage. (SOH)

Salt damage

Salt damage after spring tide. (VEK)

Leaf edge discolouration and spots on birch leaves from sea spray. (AAD)

Occurrence:
Salt damage occurs either along roads due to use of de-icing salt or along the coast due to storms (sea spray) or spring tides. Sea spray damage is most important for forests. This damage is common at forest edges by the coast, although it can also be observed several tens of kilometres from the coast after heavy storms. All tree species can be damaged after summer storms, while winter storms cause damage to conifers. Sitka spruce is resistant to salt injuries.

Symptoms:
Needles and leaves become red-brown or pale red-brown. Where damage is slight, needle tips are discoloured. In deciduous trees, leaf edges become discoloured, often with some spots towards the centre of the leaf. Where there is a lot of damage, whole needles and leaves become discoloured. In cases of sea spray, damage is greatest on the side that is exposed to the wind and the sea. Very damaged needles and leaves fall from the tree eventually.

Risks for misidentification:
Frost-induced drought: the needles, especially on younger trees, become brown after desiccation, because they begin to transpire without water supply due to frozen soil.

Nutrient deficiency

Nitrogen deficiency. All years' needles are yellowed and shoot length is reduced (AAD).

Potassium deficiency where whole needles are yellow. Last years' needles are green. (AAD)

Occurrence:
Needle yellowing can be caused by nutrient deficiency. Nitrogen, potassium and magnesium deficiency can cause yellowing in trees. Deficiency in the latter two nutrients can occur at the same time and then in general together with below-optimal values for calcium. Nutrient deficiency is uncommon in Norwegian forests, but can occur on poor, sandy soil or on bogs and similar places. We have most experience with coniferous trees, especially Norway spruce, and the symptoms described below are those found in this species, even though Scots pine has in general the same symptoms.

Symptoms:
Nitrogen deficiency leads first to light green needles, after which the needles become yellow-green and finally nearly completely yellow. In conifers, all years' needles most often become equally discoloured, but the younger needles often become slightly lighter than the older.
Magnesium deficiency starts as needle tip discolouration in the last years' and older needles. With greater deficiency, large areas of the needles turn yellow, although the base of the needle generally remains green. There is a fairly clear, characteristic transition between the green needle base and the yellowish discolouration. In the case of mild deficiency, the most recent years' needles remain green. Deficiency symptoms do not appear on the underside of branches or on branches that lie in the shadow of other branches.
Potassium deficiency is similar to magnesium deficiency and starts with discolouration of the needle tips. The transition to the healthy areas is more diffuse, and most often whole needles gradually turn yellow. The most recent years' needles remain green for a long time. The symptoms also arise in shaded areas of the trees.
The needles may die or develop necrotic tips in cases of long-lasting deficiency or severe deficiency of any of the nutrients. Growth is also affected.

Risks for misidentification:
It can be difficult to distinguish between the different deficiencies, and several deficiencies may be present at the same time.

Typical magnesium deficiency with discolouration of the needle tips. (AAD)