Ecological restoration and management in boreal forests
– best practices from Finland

Maarit Similä and Kaisa Junninen (eds)

Metsähallitus – Natural Heritage Services

The first controlled burning for restoration purposes in Finland – and possibly also anywhere in Europe – was done on a small wooded island in Patvinsuo National Park in 1989. Twenty years later, the burnt site is a real hotspot for polypore fungi, hosting 18 red-listed species. PHOTO: MAARIT SIMILÄ.

Twenty years of experience

An extensive Guide for Forest Habitat Restoration and Management compiled by Metsähallitus Natural Heritage Services was published in October 2011. This guide was based on the wealth of information and experiences that has been accumulated over the last 20 years relating to the restoration and management of forest habitats in protected areas in Finland. The guide particularly examined the restoration of heathland forests and habitat management work in herb-rich forests, white-backed woodpecker habitats, nemoral broadleaved forests and sunlit habitats.

The guide was primarily produced to support the effective management of protected areas, but the methods it features can also be usefully applied in commercially managed forests. The guide aims to increase understanding of the ecological factors behind the restoration and management of forest habitats, and enhance the effectiveness of future actions. Its publication was funded by the Finnish Ministry of Agriculture and Forestry as part of a project promoting ecological forest management and the conservation of biodiversity, within the wide-ranging METSO Forest Biodiversity Programme for Southern Finland.

The material in the guide has mainly been produced by conservation biologists and planning officers from Metsähallitus Natural Heritage Services, and the five members of the guide's editorial board. Many other experts from Finnish universities and research institutes also helped by producing the guide's factual insets which will hopefully be translated into English at a later date.

This English-language publication is a summary of the most important contents of the lengthier Finnish-language guide. We would like to warmly thank everyone who has contributed to the original guide and this summary version.

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Maarit Similä and Kaisa Junninen
Editors
Metsähallitus Natural Heritage Services

Maarit Similä
Metsähallitus Natural Heritage Services
maarit.simila@metsa.fi

Kaisa Junninen
Metsähallitus Natural Heritage Services
kaisa.junninen@metsa.fi

Translation: Fran Weaver
Layout: Marianne Katainen

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1 Introduction

Kaisa Junninen and Maarit Similä

Habitat restoration and management work should always be based on plans that set out the grounds for the conservation of a site and its relevant characteristic features. On this basis, targets for restoration are set and methods for restoration are described. Plans also specify how impacts will be monitored.

Ecosystem restoration has become an internationally significant means to maintain ecosystem services and curb the impoverishment of biodiversity. Its importance has been increased by the EU's new Biodiversity Strategy (European Union 2010). Habitat restoration was also highlighted as a way to speed progress towards the objectives of the UN Convention on Biological Diversity (CBD) at the CBD's 10th Conference of Parties in Nagoya in 2010.

Land use histories, geographical conditions and restoration methods vary from country to country, so definitions related to restoration also differ (Society for Ecological Restoration International 2004). In this guide the term **habitat restoration** refers to measures taken in forest ecosystems in protected areas that have been degraded or damaged due to human activity, aiming to help recreate conditions as close as possible to the natural state more quickly than would happen under natural processes alone.

The **ecological management** of protected areas refers to measures taken to enhance or maintain certain biotopes or the favoured habitats of particular species requiring protection. Examples include measures to maintain the species assemblages of herb-rich forests dominated by broadleaved trees (largely by curbing the spread of Norway spruce trees into such biotopes), or measures to preserve the characteristic species of sunlit habitats by preventing overgrowth in such areas.

Only about a quarter of the forests inside protected areas in southern Finland are in their natural state or a close-to-natural state.[1] Most of these forests have been commercially managed at some time in the past, before they were designated for protection. The Assessment of Threatened Habitat Types in Finland and the Finnish Red List indicate that the main threats to natural heathland forests and their characteristic species are insufficient quantities of decaying wood, unfavourable changes in the age-structure and tree species assemblages of forests, the scarcity of natural forest fires, eutrophication, and the fragmentation of forest habitats (Raunio et al. 2008, Rassi et al. 2010).

Many herb-rich forest habitat types and species are also classified as threatened. The most important causes of their decline are the clearance of forests to create fields, the spread of Norway spruce, and a shortage of deadwood. Other factors include building developments and erosion as a consequence of recreational use.

Forest ecosystems have been managed to promote biodiversity in Finland's protected areas for decades, but the extensive restoration of heathland forest habitats was initiated only in 2003 through related EU LIFE projects and the METSO Forest Biodiversity Programme for Southern Finland. The need for forest habitat restoration is greater in southern Finland than in the north, where protected areas tend to be much more extensive, and their forests have been less intensively utilised in the past.

In 2003 a forest habitat restoration group identified a need for restoration measures in areas totaling 38,600 ha within protected areas run by Metsähallitus (see info box 1). Between 2003 and 2011 forest habitats with a total area of 16,400 ha were restored, mainly in areas selected for the METSO Programme. During the same period ecological management work was carried out in herb-rich forest sites totaling 650 ha, white-backed woodpecker habitats with a total area of 750 ha, and sunlit habitats totaling 100 ha. Smaller areas of forest and mire habitats have been restored and managed in privately owned protected areas. Ecological management and habitat restoration work are still continuing in Finland, enabled by METSO and LIFE funding.

INFO BOX 1

METSÄHALLITUS NATURAL HERITAGE SERVICES MANAGES FINLAND'S PROTECTED AREAS

The Finnish State owns about 125,000 square kilometres of land – amounting to about a third of Finland's total land area (figure 1, page 4). Finland's state-owned lands and waters in are administered by Metsähallitus.

Metsähallitus's Forestry Business Unit administers commercially managed forests in these areas; whereas Metsähallitus Natural Heritage Services is responsible for the ecological management of protected areas.

Natural Heritage Services manages areas totaling 70,000 sq km, of which 39,000 sq km consist of land and 31,000 sq km are marine and inland waters. In addition to these state-owned protected areas, Metsähallitus Natural Heritage Services also carries out habitat restoration and ecological management work in many privately owned protected areas around Finland.

METSÄHALLITUS

1 This figure, based on Metsähallitus's geographical data as of March 2011, describes the total area of protected heathland forest currently classified as Western Taiga (habitat type 9010 in Natura 2000) as a proportion of the total area of forest inside protected areas that would be classified as such if these forests were all in their natural state.

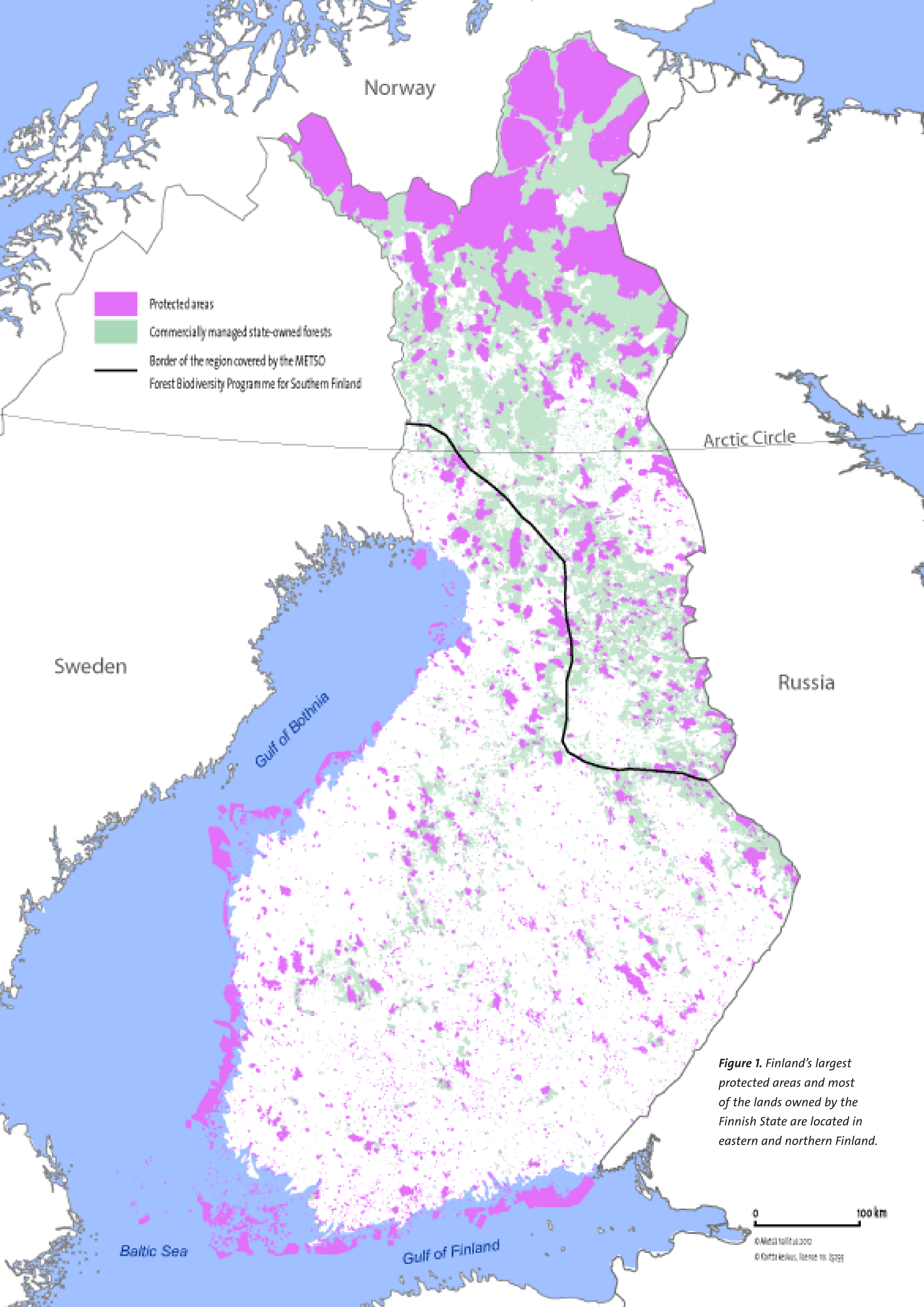

Figure 1. *Finland's largest protected areas and most of the lands owned by the Finnish State are located in eastern and northern Finland.*

2 Restoring heathland forest habitats

2.1 Emulating natural processes

Maarit Similä, Kaisa Junninen, Esko Hyvärinen and Jari Kouki

Habitat restoration measures' short-term aims are to halt the decline of forest species, and to increase the populations of threatened species. In the longer term, the aim is to safeguard the species diversity of self-sustaining forest ecosystems where interventions are no longer needed.

2.1.1 Different dimensions of diversity

The *structural diversity* of forests is mainly based on the living and dead trees they contain, together with their other vegetation. This diversity is also affected by simultaneous and intermittent processes such as the growth and decay of living and dead trees, and the successional shifts of forest stands. Some of these successional processes involve large-scale disturbances, like forest fires, while others are more gradual, such as the growth and ageing of trees. These forces and the consequent structures of forests in combination with their resident biota together constitute forests' *functional diversity*.

It can be stated as a rule of thumb that forests whose structures and functions remain closer to the structures and functions of forests in their natural state will be more valuable in terms of the species they host (figure 2). Although forests' functional diversity does not always result in high *numbers of species*, it does result in the *naturally typical biota* of the respective habitat type. Scots pine forests on dry heathland soils, for instance, naturally host fewer species than herb-rich Norway spruce stands; but on a larger scale than the stand scale both biotopes are equally important in terms of preserving wider forest biodiversity.

Diverse dynamics involving change and disturbance create different combinations of resources and structures that biota can utilise. Irregular natural disturbances of varying extent can be caused in boreal forests by fire, wind (figure 3), water and snow, insects, and mammals (mainly moose, beavers and other large herbivores). More frequent, smaller-scale disturbances, such as the death or falling of a single tree or a small number of trees, can maintain diverse forest structures in the same way as larger but less frequent disturbances, and sometimes even more evidently (Kuuluvainen 2009). Since disturbances change habitats, they also affect the abundance of different species.

***Figure 2.** Natural forests, like these in the Vesijako Strict Nature Reserve in southern Finland contain many kinds of decaying wood.* PHOTO: JARI KOSTET.

2.1.2 Striving to preserve natural diversity

The goal of forest habitat restoration in forests that have been affected by human activity is to speed up the redevelopment of the characteristic processes and structural features of natural forests.

Habitat restoration measures are realised at the forest stand level. The background to such measures should nevertheless relate to species conservation objectives set for a larger area, such as a protected area or a network of protected areas. This enables choices to be made between alternative sites for restoration. It is particularly important to maintain species, ecological communities or biotopes that are rare on the national or regional level, and to give lower priority to species and biotopes that also occur in other protected areas in the same region.

It is also important to safeguard the regional connectivity of habitat types. A national network of protected areas should be considered as part of all forest ecosystems in the area. Ecologically restorative controlled burnings, for instance, are mainly conducted within a national network of forest fire continuity sites (figure 4), but such measures can also be carried out in forests outside this network.

2.1.3 Recovery takes time

The best way to reach the goals of habitat restoration is to attempt to replicate the disturbances that would naturally modify forest habitats. The diversity of restored forests nevertheless differs from that of natural forests. For example, large and slowly grown decaying trees only exist where trees have been able to grow for centuries before they die. Hollow trees and trees dying and decaying in different ways will also appear only as tree stands age.

← ***Figure** 3. In August 2004 strong winds blew down almost all the trees in an area of 25 hectares in a protected area on the island of Jouhteninen in North Karelia. This created more than 3,000 m3 of decaying pine wood. By October 2009 many birch seedlings were growing in the resultant clearing.* PHOTO: MAARIT SIMILÄ.

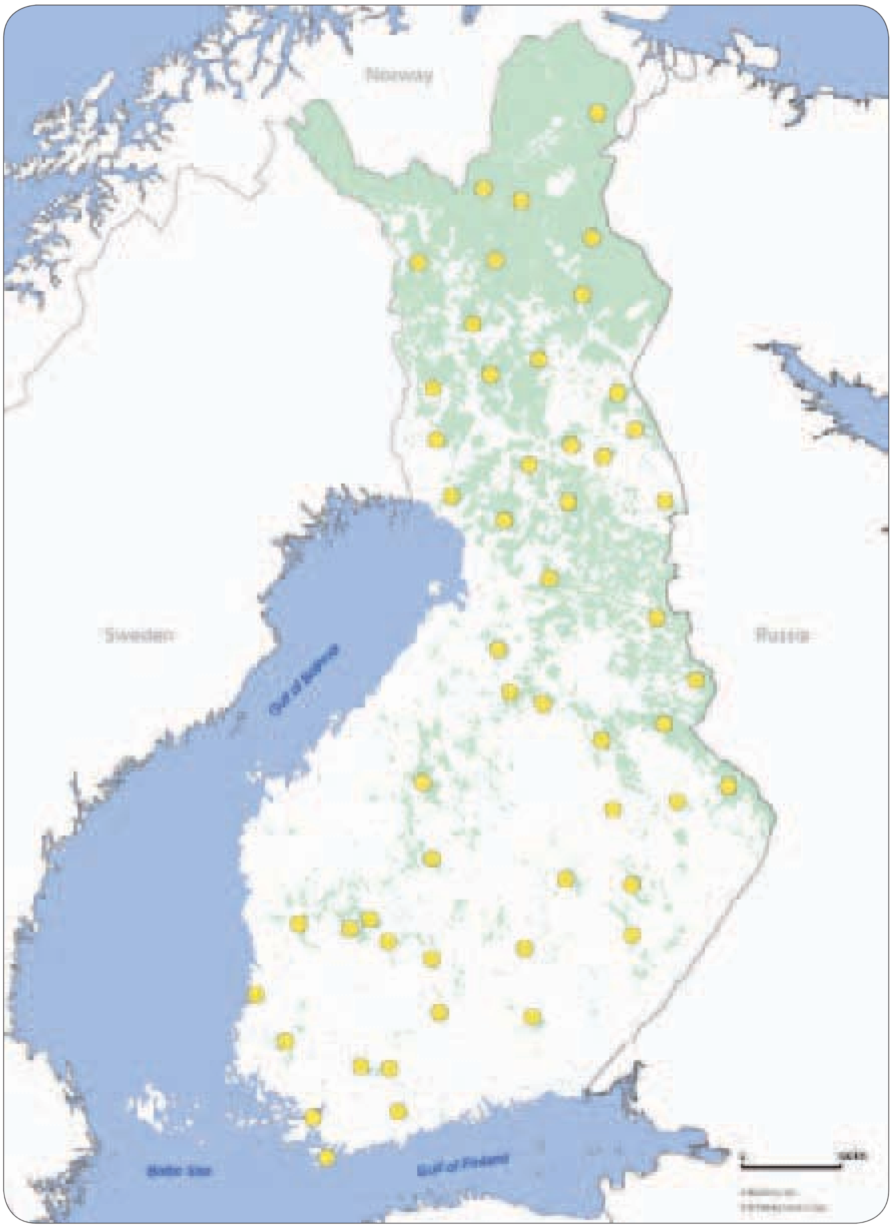

***Figure 4.** A network of 52 forest fire continuity sites has been designated in protected areas and some commercially managed forests between these areas. Selected areas of forests in these sites are burnt at intervals of 3–5 years. The areas run by Metsähallitus are shown in green.*

The effectiveness of restoration depends on whether the target species will be able to spread into areas of restored habitat (Kouki et al. 2012). The ability of these species to spread and the proximity of viable populations are therefore crucial factors.

Restoration work has been seen as a one-off action, designed to create space for natural disturbance processes to take over. Increasing the quantities of deadwood and creating small clearings by felling trees, for instance, inevitably make trees in adjoining sites more vulnerable to wind, so "natural" wind damage processes can then take over the process of creating a succession of decaying wood where the restoration work left off. To achieve the goal of restoring natural processes in practice, however, this idea of one-off measures is not always applicable or effective enough. For example, to provide continuous supply of diverse deadwood, restoration measures may need to be repeated at intervals of 5–10 years.

To achieve restoration goals it is important to understand the essential differences between natural forests and commercially managed forests (see table 1). Being aware of the structural features and resources required by rare or threatened characteristic species in natural forests, facilitates efforts to steer the development of formerly commercially managed forests in ecologically favourable directions. It is generally easier to restore structural features than to recreate forests' natural functional diversity.

The impacts of forest habitat restoration in Finland's protected areas are continuously monitored (see section 7), aiming to ensure that they achieve the desired results also in the longer term.

Table 1. *Differences between the structures and dynamics of commercially managed and natural forests, with examples of measures to restore the related natural or near-natural features in heathland forest habitats.*

	Natural forests	Commercially managed forests	Restoration methods
Living trees	– Diverse tree species assemblages – Trees of various ages, incl. large, old trees – Trees spatially aggregated, resulting in variations in the canopy cover	– Stands dominated by a single tree species – Trees mainly of similar age – Trees evenly or randomly spaced – Trees grow rapidly and uniformly	– Controlled burning – Creation of canopy gaps – Protection of aspen seedlings
Dead trees	– Plenty of deadwood in early stages of forest succession as well as in mature forests – Many kinds of deadwood by tree species, diameter and degree of decay – Stumps and snags of different heights – Continuity in the availability of deadwood	– Little deadwood – Dead trees only of limited diameter, with no continuity – Stumps may even be totally absent in sites where energy wood has been harvested	– Controlled burning – Creation of deadwood (– Creation of canopy gaps)
Soil conditions	– Soil structure varied due to fire and windthrows – Varied degree of upheaval due to disturbances of varying intensity – Decaying trunks form a good substrate for seedlings	– Soil treated uniformly during the regeneration of stands – Very few fallen trunks or areas of exposed mineral soil in mature forests	– Controlled burning – Trees felled with their root systems uprooted
Hydrological conditions	– Natural streams, springs, groundwater seepage areas and moist hollows create variety in forest microclimates	– Springs, groundwater seepage areas and moist hollows often drained; streams cleared artificially to speed drainage	– Restoration of natural hydrological conditions, e.g. by filling in ditches and restoring natural stream courses
Species	– Species adapted to natural forest habitats and disturbance regimes – Species with specialised habitat requirements – Species assemblages change radically following major disturbances – Many species that utilise deadwood – Species that require long-lasting habitats and substrates – Fire-dependent species in burnt areas	– Generalist species – Many species deadwood-dependent species are absent. – Species assemblages change greatly after clear-cutting	– Creation of valuable habitats and substrates by burning sites and increasing the amounts of deadwood – Reintroductions of species into restored areas
Nutrients and carbon storage	– Nutrients and carbon are stored in living wood, dead wood and the soil	– Thinnings, site preparation and the harvesting of energy wood speed up the nutrient cycle and reduce the amounts of carbon stored in trees and the soil – The use of fertilisers on tree stands intensifies eutrophication	– The impacts of habitat restoration on the nutrient content of forest soils and the carbon cycle are not yet well understood
Disturbance dynamics	– Disturbances occur irregularly and on many scales. – Major disturbances such as forest fires and serious storm damage are rare – Small and moderate disturbances such as the deaths of single trees or groups of trees are more frequent. – Dead trees decay in the forest	– Regular and predictable man-made disturbances, usually at the stand scale: e.g. logging and site preparation – Most trees killed in disturbances are removed from the forest	– Repeated measures may be needed to restore and maintain natural dynamics: e.g. controlled burning, measures to increase the amounts of decaying wood, and the creation of canopy gaps – Restoration designed to emulate natural disturbance dynamics at the area scale
Structure of the forest landscape	– Mature and closed-canopy forests dominate landscapes – Forest stands merge into each other with no clear boundaries – Connectivity of habitats preserved due to natural disturbance dynamics	– Even distribution of stands of different age-classes, with high proportions of seedling stands and young forest areas – Clear artificial boundaries between managed stands with trees of different species and ages – Specific habitat types, e.g. habitats for species dependent on decaying wood, often fragmented and isolated	– All forest habitat restoration methods improve the connectivity of habitats

2.2 Controlled burning to emulate natural forest fires

Rauli Perkiö, Mika Puustinen and Maarit Similä

Controlled burnings aim to reintroduce fire and its ecological impacts to the dynamics of forests in protected areas. Forest fires provide habitats for fire-dependent species, increase the amounts of charred and decaying wood, affect the quality of wood in living trees, and diversify the tree structure of forests.

Figure 5. *A Scots pine forest 14 years after an intense fire raged through the canopy and the burnt area was then designated for protection. The forest had been thinned before the fire. It today contains about 80 m3 of dead wood per hectare.* PHOTO: MAARIT SIMILÄ.

2.2.1 The many impacts of controlled burning

Forest fires are one of the crucial factors that shape natural boreal forests. In former times man created many more fires than would occur naturally, but due to modern fire prevention measures very few extensive fires affect Finland's forests nowadays. Controlled burning is clearly the most effective way to restore or increase the diversity of heathland forests.

Forests selected for restoration are burnt with their trees still standing. Suitable conditions for burnings usually occur only on a few days a year between mid May and the end of August. During rainy summers controlled burnings may not be feasible at all; and in dry summers the risk of a fire getting out of control may be too high.

Natural forest fires seldom rage strongly enough to destroy entire tree stands by spreading through the canopy (Pitkänen & Huttunen 1999) and create open habitats with plenty of decaying wood (figure 5). Less intense fires do not kill the sturdiest trees, though they do significantly change the structure of the forest in the longer term, since trees will subsequently grow more slowly and become more fibrous and resinous. Controlled burnings aim to leave 25–75% of the trees in the prescribed area alive after the fire, and some patches within the burnt area, such as moist marshy hollows, may not show any effects of fire at all.

The objectives and impacts of controlled burning vary between different sites and different regions of Finland. In southern Finland most sites consist of young, previously commercially utilised coniferous forests, where the main goal of burning is to diversify the structure of the forest. Burning the moss layer and inducing the death of trees facilitates the growth of new seedlings. This diversifies the structure of tree stands and increases the proportion of broadleaved trees (figure 6).

In the north and the east there is more scope for burning also older forest, resulting in large decaying trees. Forest fires and the controlled burning of stands with large trees particularly affect insect species assemblages (Wikars 2002, Hyvärinen 2006). Many polypore fungi also benefit from fire damage, but the impacts occur more slowly (Junninen et al. 2008).

Controlled burning can initiate a continuity of decaying wood, with fire-damaged trees gradually dying over the years following a fire. In forests dominated by Scots pine, fires serve to kill off undergrowth and maintain the predominance of pines. Following an intense fire, young successional stages with plenty of deadwood will be formed. Such habitats have almost vanished from Finland's forests during past decades.

Figure 6. *Five years after burning, a thicket of young aspens has sprung up.* PHOTO: RAULI PERKIÖ.

Figure 7. *Especially in forests with younger trees, piles of burnable material tend to increase the intensity of fires greatly, and even uncontrollably. This area was burnt in Repovesi National Park.* PHOTO: JUHA METSO.

2.2.2 Species considered during preparations for burning

In young, even-aged, formerly commercially managed forests, there is little risk that rare or threatened species will be harmed by controlled burning. The areas restored through burning are so small that the occurrences of forest species are not harmed even on a local scale, let alone the national scale. But the presence of valuable species should certainly be considered when planning to burn older forests.

If an area of forest to be burnt has plenty of old trees and large decaying trees, the moss, lichen, polypore and insect communities living on their trunks should be surveyed beforehand. Any trunks hosting threatened species may need to be excluded from the area to be burnt, or protected from burning (fallen trunks), unless the same species also occurs in neighbouring forests.

Any forest where an inhabited nest of a threatened bird of prey species has been observed should not be burnt. During the breeding season it is important to keep a distance of more than a kilometre from the nests of threatened bird species such as golden eagles or peregrine falcons.

Black grouses and capercaillies also nest in forests suitable for restorative burning. If a nest of such a game bird species is found, it should be protected or excluded from the area to be burnt.

2.2.3 Controlled burnings must be planned with care

In sparsely wooded forests over 50 years old the cost of burning a smaller area (less than five hectares) is similar to the cost of burning a larger area of ten hectares or more, so it is more cost-effective to designate larger areas for burning. In younger forests, and especially in topographically varied forests, several factors affect costs more than the extent of the area to be burnt, including the tree cover, the precise delineation of the area to be burnt, and the necessary safety precautions.

The need for fire extinguishing equipment should be worked out well before burning is scheduled. Ideally plenty of water should be available nearby to control and extinguish the fire. Areas for burning should be defined to utilise any suitable adjoining features such as forest roads, lakes, rivers or wet mires as natural or pre-existing firebreaks.

To optimise burning, biomass materials ready for burning (ranging from moss to tree trunks) should be either piled up or removed, to either increase or reduce the intensity of the fire as desired (figure 7). The amounts of burnable material in the field layer can be increased in advance by felling trees 2–18 months before burning. The nature of the burnable material will affect the behaviour of the fire considerably. Finer organic material such as moss, needles and twigs will readily catch fire, but then burn rapidly and with low intensity. Thicker branches, crowns and small trunks can significantly increase the intensity of a fire. Larger trunks mainly prolong the duration of a fire (Lindberg et al. 2011).

In young, dense forests it may be necessary to remove trees beforehand to make it easier to control burning, or to speed the drying out of the area to be burnt. But no more trees should be removed than is necessary for safety reasons or to enable burning.

Where necessary, the area to be burnt should be delineated with the help of firebreaks. Wider firebreak corridors 5–25 metres wide can be created by felling trees and if necessary removing them. Firebreak corridors are not needed where natural firebreaks already exist. They are not always needed even inside forests. In sparsely wooded mature pine stands, for example, the spread of fire can often be halted by watering the ground around the margins of the area to be burnt (figure 8).

Narrower firebreaks can also be created by removing the vegetation from a narrow strip of the ground around the area to be burnt (figure 9). This limits the spread of fire over the ground during the burning and fire extinguishing phases. Such firebreaks can be created independently of wider firebreak corridors.

In old forests, sites chosen for burning must meet the following criteria:

- They are not in their natural state (e.g. lacking in deadwood); have traces of earlier forest fires; or have characteristics that naturally facilitate burning.
- They must be largely bounded by natural firebreaks, so that there is no need to dig artificial firebreaks.
- There is no need to add burnable material to the field layer.

If any cultural heritage sites (see section 7) are known to exist in an area to be burnt, or are discovered during preparations for burning, it is important to assess the risks of damaging or destroying the sites, and take into consideration these values in the delineation of the area to be burnt.

Protective buffer zones should be left unburnt alongside water bodies, since burning increases the leaching of nutrients into adjoining waters. In esker forests situated in areas with important groundwater reserves there is also a risk that groundwater could become contaminated (see section 5.3.3).

Figure 8. *In pine forests with large trees and little burnable material in the field layer, the area to be burnt can be delineated by watering the ground around its margins. At Tohlinsuo mire in eastern Finland, trees were felled to increase the amounts of burnable biomass in the field layer in the central parts of a 20-hectare site designated for burning.* PHOTO: MAARIT SIMILÄ.

2.2.4 Many ways to organise controlled burnings

Controlled burning may be initiated when a site's ground and field layers have dried out sufficiently. This can be determined by removing a small piece of the ground vegetation and testing its combustibility. If it only takes a few matches to set it on fire and burn it, the site should be sufficiently dry.

The day chosen for burning should ideally be dry with winds of favourable and predictable direction and speeds of less than 5 m/s. Strong winds should not be forecast for the following day. The best time to start burning is often in the afternoon or evening, when the wind direction stabilises and the wind speed starts to calm.

There are as many different ways to organise burning as there are sites to be burnt. The choice of the method and the desired intensity of the fire should be determined by the objectives of the burning; the shape, size and topography of the site; the amounts and nature of burnable biomass; and the availability of workers, equipment and water to put out the fire.

Fires spreading into the wind are usually easy to control, but they spread slowly, so it may take a long time to burn larger areas in this way. The process can be speeded, however, by burning the area along several parallel fronts into the wind simultaneously. It is easier to control several smaller fires than one large one. The method of burning into the wind is often used together with other methods, when an area needs to be created to prevent the further spread of fire.

Figure 9. *Narrow firebreaks created by removing ground vegetation usually only need to be 0.5–3 metres wide, depending on how vulnerable the terrain is to fire.* PHOTO: RAIMO IKONEN.

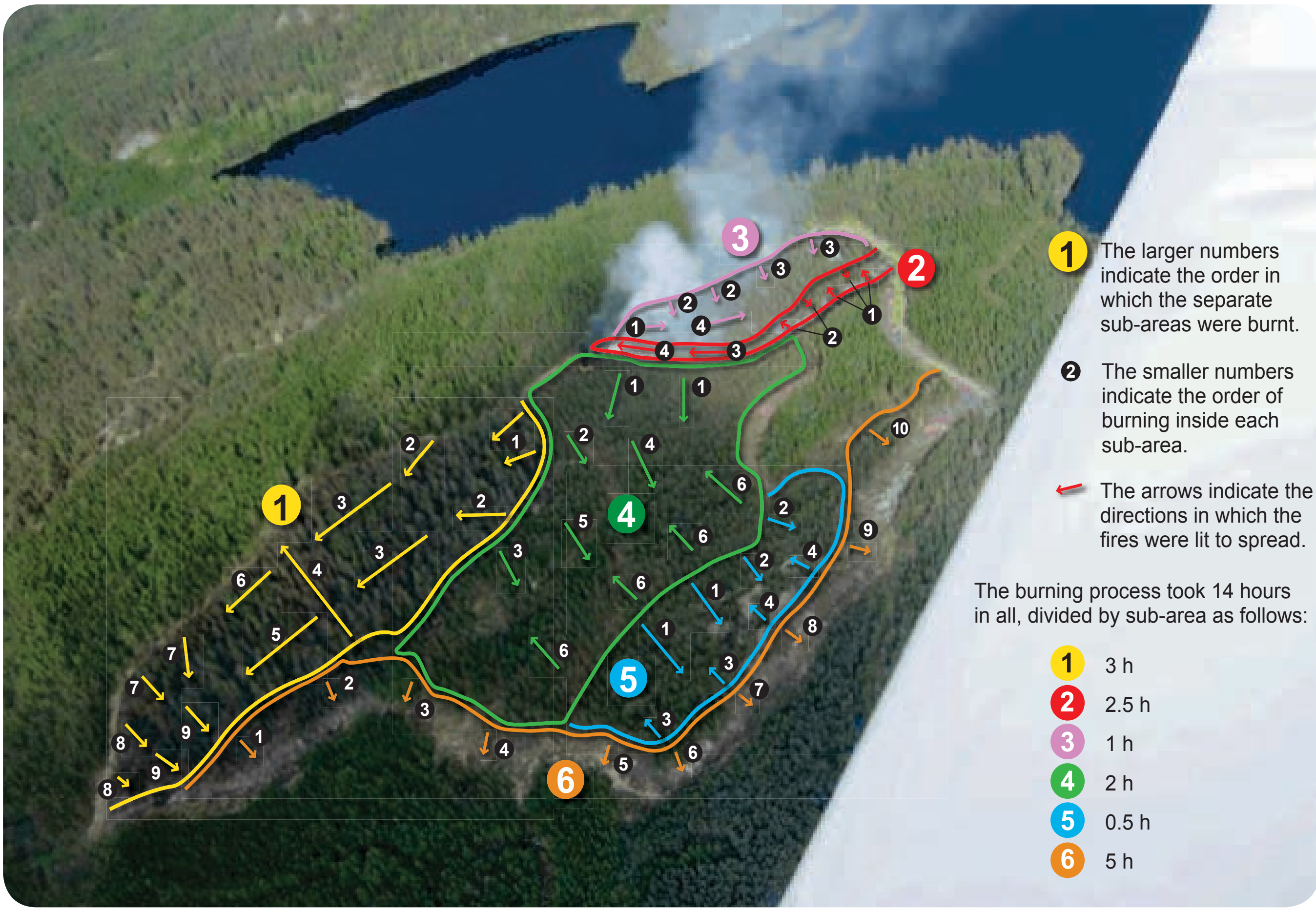

Figure 10. *This 12-ha site was burnt in several phases to make it easier to control burning in its young, dense forests and varied relief.*

Forests can also be burnt downwind if there is not too much biomass to be burnt and there is little risk that the fire could rage out of control. Fires spreading downwind are often harder to control if problems arise.

The horseshoe-burnings traditionally carried out for forestry purposes involve initially burning a 15–20-metre-wide strip of ground into the wind, and then lighting further fires into the wind from both ends of the initial strip, to create a horseshoe-shaped front of fire. The two ends of the fire are then joined together upwind. This method is not the best alternative for restorative burnings, however, since it tends to make old forests burn only patchily, and in younger forests such fires easily become too intense. It is suitable, however, in larger, sufficiently dry areas where burnable biomass is evenly spread, and the risks of the fire becoming uncontrollably intense or spreading beyond the designated burning area are low.

An area to be restored can be burnt in several parts if necessary (figure 10). It is generally worth burning the "difficult" parts separately first, and then the remaining areas. Areas worth burning separately include steep slopes, areas with a lot of burnable biomass, the edges of sites designated for burning, and any smaller areas that project out of the main area. If some feature inside an area has to be protected against burning, such as a fallen tree trunk with polypore growths, a game bird's nesting site or an occurrence of some other significant species, it may be worth burning its surroundings separately.

2.2.5 Care needed to extinguish fires and guard recently burnt areas

Sufficient equipment must be left available at burnt sites to enable any later outbreaks of fire to be extinguished. Extinguishing work using water can already be commenced from outside the edges of the area to be burnt while the fire is still burning. Features that particularly need attention during extinguishing work include anthills, decaying and resinous stumps, and smouldering fallen logs, snags and dead standing trees. Smouldering features should be sprinkled or sprayed with water or dug up and smothered with sand excavated from the surrounding ground. When fires have been extinguished around the edges of the burnt area, firefighters should move on to put out any smouldering features throughout the site.

The best time to extinguish fires is usually at night, when conditions tend to be calmer. Dew also helps to slow the spread of fire. The most critical phases of extinguishing and patrolling a burnt site are the morning and day after burning, when winds typically strengthen again, and isolated hotbeds may reignite.

After any remaining hotbeds have been extinguished, burnt areas must still be patrolled. This should continue until there is certainty that the whole area is free from fire, or the area has received at least 10 mm of rain.

2.3 Varied measures to increase amounts of decaying wood

Päivi Virnes, Maarit Similä and Kaisa Junninen

Measures to increase the amounts of decaying wood in formerly utilised forests where deadwood is scarce can strengthen the populations of species dependent on decaying wood, and help to increase the amount of dead wood closer to the amount typical of natural forests. The aim is to enable the preservation and spread of deadwood-dependent species until decaying wood becomes more abundant due to natural processes.

2.3.1 Improving the quantity, quality and continuity of decaying wood

Forests in Finland's protected areas contain an average of 13 m3 of deadwood per hectare (Ihalainen & Mäkelä 2009). This is almost three times the average for commercially managed forests, but considerably less than the amount in corresponding natural forests, which in Finland would average 40–120 m3/ha (Tonteri & Siitonen 2001). The amounts of deadwood in protected forests less than 100 years old are particularly low. Most of these forests have been commercially managed in the past, and not enough time has elapsed since their protection for natural deadwood dynamics to become established.

More than four thousand species – about a quarter of the forest species found in Finland – are directly or indirectly dependent on deadwood (Siitonen 2001). Most of these species are fungi, beetles, dipterans and hymenoptera, but decaying wood is also important for many mosses and lichens. Dwindling quantities of deadwood are the most significant single factor threatening forest species in Finland. This factor is listed as a reason for the decline, Red List status or disappearance of more than 600 species primarily found in forest habitats (Rassi et al. 2010).

The amounts of decaying wood in forests need to be much greater than the present average figure to ensure that threatened deadwood-dependent species can thrive (Junninen & Komonen 2011). In addition to the local availability of decaying wood, deadwood-dependent species also require continuity in the availability of wood at different stages of decay at the regional level. If this continuity is broken over wider areas, creating even large amounts of deadwood at a local scale will not enable the more demanding species to recover, due to the absence of source populations near enough to enable their spread.

Figure 11. *Pale-coloured, flat fruit bodies of the polypore fungus Skeletocutis odora tend to grow on the sides or undersides of large fallen aspen or spruce trees.* PHOTO: JARI KOSTET.

The characteristics of decaying wood are also significant for the related species diversity (figure 11). Qualitative factors include tree species, trunk diameter, the causes of tree deaths, the time elapsed since trees died, and the other species that the dead trees host. Snags, fallen trees and dead standing trees each host their own specialist species communities. Fallen conifers and aspens are particularly valuable for mosses and polypore fungi. Dead standing trees provide favourable habitat for many insects and lichens. Larger decomposing trunks host more species than smaller trunks, partly because they decay more slowly and store moisture more effectively. Environmental factors including the amounts of direct sunlight, shadow and moisture also affect species assemblages.

2.3.2 Determining where more deadwood is needed

In deciding whether to create more deadwood in an area, it is important to assess both the probability that the continuity of deadwood within a single protected area or a network of areas will be broken without such measures; and how quickly it would naturally begin to appear in forests where it is in short supply.

If a protected area's core zone, still preserved in its natural state, is too small to ensure continuity in the availability of decaying wood, it may be necessary to create deadwood in its surroundings. If deadwood is in short supply throughout the forests in a protected area, and there are no natural forests with occurrences of demanding deadwood-dependent species within tens of kilometres, the benefits of creating more deadwood might be limited to species that are already common. The natural increases in the availability of deadwood that occur as the succession progresses will generally suffice to meet the conservation goals defined for such sites.

In Finland the most favourable forest stand types for creating more deadwood include mature forests where the trunks of the dominant trees are at least 20 cm in diameter, where deadwood is in short supply (less than 10 m3/ha) due to previous commercial utilisation, and where tree deaths would be unlikely over the next couple of decades under natural conditions.

Figure 12. *Measures to increase the amounts of decaying coniferous wood can also be planned to create more space for aspens and other broadleaved trees.* PHOTO: PHILIPPE FAYT.

Even in forests undergoing restoration, dense thickets of trees should be left standing, as this will later naturally result in the development of deadwood through a self-thinning process. If broadleaved undergrowth or individual broadleaved trees are present in an area where the amounts of deadwood are to be increased, wood decay should be promoted in groups of trees around concentrations of broadleaved trees by felling or ring-barking coniferous trees (figure 12).

In scenically significant sites or sites with stable microclimates such as spruce mires, stands along streams, moist herb-rich woodlands and stands beneath crags, decaying wood should be created by treating only single trunks or groups of a few trees.

2.3.3 Qualitative considerations

In protected areas it is recommended that deadwood should be created to build up the overall stand-level quantities of decaying wood to 15–30 m3/ha, including any naturally occurring deadwood. If repeated measures will be needed to ensure continuity, the amounts of deadwood created at one time should be smaller.

A maximum of 10–15% of the total volume of living trees in a stand should be treated, to ensure that enough living trees remain in the forest to ensure continuity in the availability of decaying wood in the future. Where amounts of deadwood are to be increased gradually, lower percentages than this should be treated at a time. Damaged or weakened trees should not be treated, since their natural development will soon produce deadwood in any case. The oldest trees in a forest should not be treated either, since they will eventually form slowly grown wood that will also die and decay slowly and naturally.

Deadwood created for restoration purposes is qualitatively different from naturally decaying wood, since restoration measures kill healthy trees which would otherwise not die for a long time (figure 13). Restoration measures also kill trees faster than most natural processes like ageing, disease or insect damage. These factors may reduce the habitat value of artificially created decaying wood, especially for many threatened deadwood-dependent species.

The most favourable increases in the amounts of decaying wood occur when trees are killed by natural disturbances such as storm damage, forest fires, flooding by beavers, or the combined effects of insect damage and drought. Even large amounts of deadwood created in protected areas by such events should not be removed, except in exceptional cases, e.g. where fallen trees may endanger an occurrence of a threatened plant species.

2.3.4 Ring-barking particularly suitable in pine stands

When creating deadwood, the aim is to reproduce the kinds of decaying wood that would naturally occur in the particular site. Natural pine stands, for instance, often have plenty of dead standing wood, so ring-barking trees is a good way to create the kinds of deadwood that would naturally exist in dry heathland forests (figure 14).

Debarking a wide section of a trunk will kill a pine within a few years. Varying the number of narrow grooves cut around a tree (1–3 grooves) can make a pine tree die sooner or later. More grooves will make a tree die more quickly and more conclusively. One groove cut with a chainsaw is usually enough to kill a spruce or a birch.

The depths and uniformity of grooves also affect the likelihood and speed of a tree's death. Deep cuts kill trees faster, and a few years later trunks often break where deep cuts had been made. For this reason deep-cut ring-barking should be avoided in forests often used for recreation.

Trees ring-barked with shallow or incomplete cuts may be able to grow a bridge of bark over the ring. This means that ring-barking might not ultimately

Figure 13. *The amounts of decaying wood in this protected area have been increased by felling and ring-barking pine trees.* PHOTO: MAARIT SIMILÄ.

Figure 14. Dead standing trees can be created by ring-barking trunks using a chainsaw. Narrow grooves can be cut around a tree (a), or a wider strip of bark can be removed (b). Narrower cuts are less conspicuous initially, but they will be obvious for longer after the bark of dead trees falls off. Trees with wider debarked rings are visible from a long distance at first, but not after the debarked part of the trunk turns grey. PHOTOS: JUHA SIEKKINEN.

kill a tree, but it will still affect the quality of its wood. Some species benefit from trees in a state of slow recovery, and rich in resinous wood.

Trees can also be ring-barked using a barking bar, a tree-marking-knife, a machete or an axe (figure 38 p.108). These tools are especially useful where restoration work is done by volunteers rather than professional foresters.

Broadleaved trees should not be ring-barked, with the exception of birches, since they begin to decay naturally while they are still alive. Ring-barking prevents the sprouting of new aspen trees from older trees. It is therefore undesirable, since the poor regeneration of aspens in protected areas is a recognised problem in Finland.

2.3.5 Uprooted trees resemble windthrown trees

Natural spruce stands tend to contain more decaying uprooted trees than dead standing trees, so in spruce stands deadwood should be created by uprooting trees. The best way to fell trees is to knock them down with the bucket of an excavator. This method can also be applied to emulate natural windthrow clearings in pine stands (figure 15).

Figure 15. Dead trees felled with excavators resemble windthrown trees. PHOTO: JUHA SIEKKINEN.

Uprooting trees in this way exposes bare mineral soils, facilitating the growth of new tree seedlings. Uprooted trees are typically left with some of their roots still in the ground, which slows their death and delays the decomposition of their fallen trunks.

Clearings can be made to resemble naturally windthrow areas by felling trees in roughly the same direction. If some of the felled trees are left on top of each other, parts of their trunks will remain off the ground, creating a wider range of microhabitats for deadwood-dependent species.

Creating deadwood using an excavator is less costly than using manpower, and the resulting fallen trees do not differ from naturally windthrown trees. When using such vehicles, however, care should be taken to avoid damaging any pre-existing decaying trees in the forest.

2.3.6 Felling trees with a chainsaw becoming less common

In Finnish protected areas many trees were felled in the early 2000s using chainsaws to create deadwood on the ground (figure 13). Observations of polypores, however, indicate that particularly where spruce trees are felled in this way, an unbalanced community of decomposers may result, with one species – *Trichaptum abietinum* – gaining a crucial competitive advantage at the expense of other, rarer pioneer decomposers. Since these early-stage decomposers affect the development of subsequent species assemblages, the initial predominance of a single species could also reduce species diversity among decomposers in the longer term as the wood decays further. It is therefore recommended that deadwood should not be created in protected areas by simply felling trees with a chainsaw.

Figure 16. *The use of explosives can result in large surface areas of splintered and cracked wood, creating the kinds of deadwood that would result from lightning strikes, storm damage or breakages caused by heavy snow burdens. Restoration work using explosives requires special expertise and the sealing off of danger areas. Studies of the species found on decaying wood created by explosives have so far not indicated that this method should be used more widely.* PHOTO: HELENA LUNDÉN.

2.3.7 Experimentation worthwhile

In some special cases deadwood has been created by felling and shattering trees with explosives (figure 16), inoculating mycelia of certain polypore species (*Fomes fomentarius, Piptoporus betulinus*) onto living birch trees, or burning the bases and trunks of pine trees with a blow torch. These methods are generally not suitable for more widespread use, however.

It is worth keeping an open mind with regard to any new methods that could be developed or tested to create more decaying wood. There is particularly a need to develop alternative methods to fell trees together with their roots in sites where the use of excavators is not possible.

Sometimes it may even be necessary to bring decaying wood of a certain type into a site – for instance if a rare species is likely to disappear from the site due to a temporary break in the availability of decaying aspen or wood of a scarcer hardwood tree species. This kind of temporary break in deadwood continuity may exist where a site's living trees will in future provide the right kind of decaying wood, but only in a few decades time. It is, however, important to ensure that the site from where the dead hardwood is taken will not consequently suffer from a break in its own deadwood continuity. Heavy equipment is needed to move trunks. This work is most easily done in the winter.

2.3.8 The risk of promoting insect damage

Any natural disturbance or artificial measure that creates deadwood can in theory increase the abundance of potentially harmful insects. In Finland the most destructive insect pests in forestry terms are the pine shoot beetles *Tomicus piniperda* (figure 17) and *T. minor*, and the spruce bark beetle *Ips typographus* (figure 18).

Bark beetles prefer host trees on open, well-lit and warm sites. Consequently they rarely cause serious damage in forests with closed canopies such as those typical in habitat restoration sites (Annila 1969, Martikainen et al. 1996, 1999).

Pine shoot beetles can damage pines in the immediate vicinity of restoration

Figure 17. *Adult pine shoot beetles feed on new growths on the crowns and branches of pine trees, reducing the growth of the trees. The beetles reproduce in dead and weakened trees, so they do not usually kill healthy trees.* PHOTO: ESKO HYVÄRINEN.

Figure 18. *Spruce bark beetles may eventually kill host spruce trees where they proliferate.* PHOTO: ESKO HYVÄRINEN.

sites, but at a distance of a hundred metres such impacts are no longer evident (Komonen & Kouki 2008). In protected areas the reduced growth of trees is not problematic, but to protect neighbouring commercially managed forests measures to create more decaying wood should not be realised within 100 metres of the boundaries of protected areas.

Risks related to spruce bark beetles vary with the amounts of dead spruce wood and conditions during the beetles' breeding season. Risks can be reduced by producing less than 20 m3/ha in a single year, by creating deadwood only in late summer, by avoiding felling larger trunks, and by not creating deadwood in warm sites adjoining more open areas. Spruce bark beetles have so far not caused any significant damage in northern Finland. In protected areas with spruce stands in their surroundings in southernmost Finland, protective belts at least 200 metres wide are left untreated around areas where dead spruce wood is created.

Burning reduces the suitability of deadwood for the most important insect pests, so insect damage is unlikely in sites restored through controlled burnings, even where they contain a lot of deadwood.

2.4 Creating canopy gaps to diversify forests

Maarit Similä, Rauli Perkiö and Kaisa Junninen

Creating canopy gaps in heathland forests can increase their structural diversity by improving conditions for the growth of deciduous trees and for the regeneration of both deciduous and coniferous trees.

2.4.1 Measures to favour broadleaved trees

In Finland the presence of broadleaved trees like birches, goat willow and particularly aspen, greatly increases the species diversity of forests. Although aspens only make up a small proportion of Finland's forests by timber volume (<3 %, Finnish Statistical Yearbook of Forestry 2011), they are important for many specialised and red-listed species, including many beetles (Tikkanen et al. 2006). Aspens regenerate only poorly in forests with closed canopies; and large aspens, which are particularly valuable for their associated biodiversity, are becoming scarce in many Finnish protected areas, especially in eastern regions. This can today be considered as one of the most serious ecological problems in Finland's network of protected areas (Kouki et al. 2004).

Small canopy gaps are created to increase the proportions of broadleaved tree species in forests by enhancing conditions for both the growth of existing trees and the regeneration of new seedlings. In nature reserves, canopy gaps are most often created in younger forests whose previous commercial management involved sowing or planting spruce or pine, and clearing other seedlings (figure 19).

The creation of canopy gaps is a habitat restoration and management method that can be widely applied, not only in restoring young heathland forests, but also in managing herb-rich forests (section 3), forests with nemoral deciduous tree species (section 4), white-backed woodpecker habitats (section 3.4) and sunlit slopes (section 5). This method may also be used as part of preparations for controlled burning (section 2.2) and in the removal of alien tree species (section 2.5). The boundary between measures designed to create canopy gaps and those used to create decaying wood (section 2.3) is unclear, since the methods used to increase the amounts of deadwood also tend to form canopy gaps. This section focuses on the creation of canopy gaps in heathland forests.

2.4.2 Canopy gaps do not have to be treeless clearings

Clearings of various sizes arise naturally in forests due to disturbances such as storms, insect damage, heavy snow burdens or forest fires. Such disturbances provide models for the restoration of small gaps.

Gaps in the canopy layer can be created by felling, ring-barking or otherwise damaging coniferous trees around deciduous trees, by creating clearings of various sizes, and even by clearing whole stands if they mainly consist of a tree species sown or planted where it would not naturally grow.

The sites chosen for creating gaps should already contain seedlings or deciduous trees (figure 20). The trees

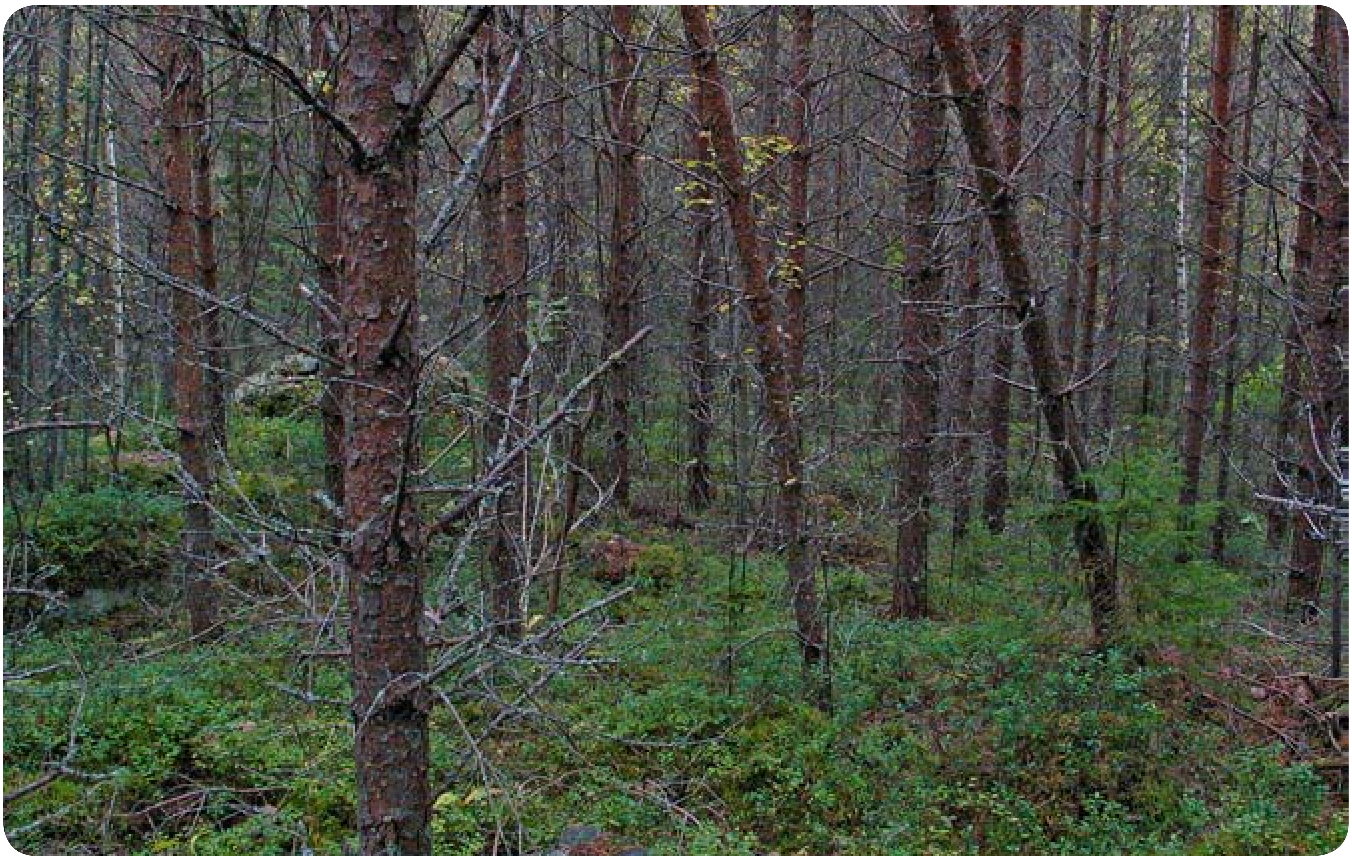

Figure 19. *In young commercially managed forests conifers dominate and trees are of even age, size and spacing.* PHOTO: MAARIT SIMILÄ.

***Figure 20.** Deciduous trees left in canopy gaps will grow faster if any coniferous trees around them are removed.* PHOTO: MAARIT SIMILÄ.

left in the gap should be of a size that they are no longer vulnerable to damage by moose. Any large conifers or rows of coniferous trees that compete for canopy space with deciduous trees should be felled in the gap. Care should be taken to avoid damaging seedlings, deciduous trees or any decaying trees. In principle all of the trees felled and ring-barked in such sites should be left in situ to decay in the forest.

Trees left in and immediately around sufficiently large cleared canopy gaps will grow more rapidly than those elsewhere, adding diversity to the size distribution of trees in a forest. A suitable diameter for such a clearing may be 2–5 times the height of the growing trees, or even larger in some areas. In addition to deciduous trees, some coniferous trees may be left in larger cleared areas in locations where their presence will not prevent restoration goals being reached. In special sites, e.g. where spring pasque flowers (*Pulsatilla vernalis*) or wild thyme (*Thymus serpyllum*) occur, controlled burning may also be implemented in canopy gaps (section 6).

It is important to create gaps that vary in shape and location. Their edges should be indistinct. Gaps should not be spaced too regularly or treated uniformly, as it is preferable to create a variety of forest habitats including unevenly thinned areas and untreated thickets (for descriptions of such variable density thinning, see Carey 2003).

In young pine stands with hardly any broadleaved trees, the benefits of creating canopy gaps are limited, and it is often worth considering whether controlled burning would be possible in such sites (section 2.2). If the primary goal of clearing small canopy gaps is to promote regeneration, a combination of clearing and controlled burning seems to produce the best results.

2.4.3 Excavators suitable for clearing canopy gaps

The methods used to clear gaps should be chosen according to the ecological objectives for the site. In even-aged stands with a predominant tree species or other forests where the goal is to promote seedling growth in canopy gaps, the best method is to knock trees down with an excavator during a time when the ground is not frozen (figure 21). This exposes mineral soil beneath the root systems of felled trees, enabling tree seeds to germinate more readily than on moss-covered ground. Bare ground will also be exposed along the excavator's tracks. Planning excavators' routes and the directions in which trees are felled can help to create gaps that resemble natural gaps. Excavator tracks can be covered with felled trees. It is not always possible to use excavators, however, e.g. in sites that are inaccessible due to rocky terrain, their distance from any roads, or natural barriers such as mires or streams.

Small clearings can also be created with a chainsaw by felling or ring-barking competing trees in young stands that already have trees or seedlings in the understorey, and where there is no need to encourage new seedlings for the sake of structural diversity. In such locations clearings are created to give space to existing young trees or seedlings – usually of deciduous species.

2.4.4 Light and protection for aspen seedlings

In natural forests aspens regenerate most effectively after forest fires or other large-scale disturbances that kill many trees, since they benefit where light becomes more available, heathland soils are exposed, and large quantities of fallen trees keep elk away from their seedlings. But such large-scale disturbances occur only rarely in Finland's

***Figure 21.** A small clearing created by an excavator in Repovesi National Park.* PHOTO: MAARIT SIMILÄ.

Figure 22. *Lodgepole pines have been felled in this herb-rich heathland forest site to make space for native tree species and typical plant communities to take over.* PHOTO: PETRI SILVENNOINEN.

small protected areas. It may therefore be necessary to ensure the regeneration of aspens through measures that do not exactly emulate any natural disturbances, but which will nevertheless eventually recreate natural forest structures by enabling aspens to regenerate.

In nutrient-rich forests with many aspen trees, creating small clearings can speed the growth of larger aspens and ensure continuity in the presence of aspen by also enabling the growth of young aspens. Since aspens often grow in clusters and regenerate almost exclusively from their root suckers, small clearings should be made in the immediate vicinity of existing aspens. Because the most important requirement for their regeneration is the availability of enough light, it is important to ensure that the field layer in small clearings will be well lit.

In areas with dense moose populations the only way to enable aspen seedlings to survive is to fence off such clearings. This is labour-intensive and costly, however. Tested fencing materials include metal meshes and poles made of small trees cut from the site itself. The condition of fences should be checked regularly, as falling trees, heavy snow and the decaying of wooden poles may break them.

2.5 Keeping alien species out of protected areas

Maarit Similä

In Finland commercial forests are mainly regenerated using native tree species. Certain exotic tree species, mainly Siberian larch (*Larix sibirica*) and lodgepole pine (*Pinus contorta*) have been planted in small areas throughout the country, however, and these species consequently grow in limited numbers also in protected areas. Since introduced exotic tree species are also able to spread naturally under local conditions in Finland, they should usually be removed from forests in protected areas (figure 22). The felled trees can be removed and sold to cover the related costs, or used as firewood or to make duckboard trails. Limited amounts of wood may also be left in the forest to decay.

After trees of exotic species are removed or felled, the forest is usually left alone to enable seedlings of native tree species to spring up naturally. The untreated ground may be taken over by seedlings only slowly, but, space will nevertheless be created for native trees in the understorey to thrive. Controlled burnings are counterproductive as restoration methods, at least where lodgepole pines have been growing, since forest fires enhance the germination of lodgepole pine seeds.

Restoring native species in areas where exotic tree species have been growing can be a long process. Measures may be required many years after larger trees have been removed, in places where seeds that have dropped into the ground sprout, creating new seedlings. Aggressively regenerating alien tree species include balsam fir (*Abies balsamifera*) and sycamore (*Acer pseudoplatanus*). Their seedlings may have to be cleared or totally uprooted for many years.

For details of how exotic herbaceous plants that have spread from gardens and parks should be removed from protected areas, see section 3.

2.6 Dismantling unnecessary roads in protected areas

Maarit Similä and Helena Lundén

Forest roads fragment otherwise unbroken areas of forest, increase the disturbance caused by motor vehicles, and affect the natural hydrological conditions in mires. In protected areas any roads that are no longer necessary, and especially those that cause problems, should be closed and dismantled.

Suitable ways to close off minor roads include moving large rocks onto them, felling trees across them, excavating a section of road, or narrowing the entrance to the road to keep vehicles out. Lighter methods tend to be less costly, and they are suitable for roads made of locally sourced materials which have already begun to become overgrown with seedlings and other plants. If necessary, road surfaces can also be scarified to promote the overgrowth of seedlings.

If a road has been built by banking up earth excavated alongside it or bringing in vehicle loads of gravel, the earth removed from the roadbed should be spread over the surrounding ground considering its natural landforms. Any piles of earth or rocks piled up behind ditches alongside a road should also be relocated accordingly.

Concrete culverts can be crushed using an excavator bucket and covered with earth. Any intact metal or plastic culverts and drains may be taken away for reuse. It is also worth digging up any broken metal or plastic culverts and drains and relocating them in a place where they will not disrupt flows of water through mire or forest sites after they have been covered with earth.

Excavated road surfaces provide suitable sites for tree seedlings to grow, and seedlings usually start to spring up within a couple of years. Small trees can also be moved onto the bed of the former road using an excavator (figure 23). Some of these trees will take root and help to erase traces of the road.

When removing traces of roads from peatlands and around streams, it is important to ensure that natural hydrological conditions can be restored. Earth masses should be removed from the surroundings of streams or small marshy areas and left appropriately in nearby areas with mineral soil. If roads run for longer distances through marshy areas, and it would be costly to move roadbed material to areas with mineral soil, they should be dug up at sufficiently regular intervals to the level of the surface of the marsh or below, so as to enable water to flow over these stretches and seep through the gravelly road bed.

Figure 23. *A forest road before and after measures taken to remove its traces from the forest landscape. The line of the road has been landscaped by shifting spruce and alder seedlings onto the road bed using an excavator. Trees moved in this way often successfully take root.* PHOTOS: HELENA LUNDÉN.

3 Managing herb-rich forest habitats

Mikko Siitonen, Aulikki Alanen and Maaret Väänänen

3.1 Why are herb-rich forests managed?

3.1.1 Herb-rich forest plants threatened by the spread of spruce

In Finland's boreal forest zone, herb-rich forest habitats are only found in small patches within larger areas of nutrient-poorer heathland forest habitat. Herb-rich forest soils arefertile, neutral (pH 5.5-7.0) brown soils with thick mull layers, whereas heathland forest soils are acidic (pH < 5.0) podzol soils. Herb-rich forest plants are most abundant in a hemiboreal zone in the southwest where oak trees occur naturally, and in a few other small concentrations around the country (Info box 2). Most of these areas are associated with alkaline bedrock and favourable local climatic conditions.

In Finland's natural herb-rich forests, trees regenerate in small clearings created by storms or the death of individual old trees. Forest fires have seldom spread into such areas, especially moist areas with many herbaceous plants, though heat damage from intense fires and the spread of fire through the canopy layer may have sometimes killed trees in herb-rich forests, even in moist sites. In boreal herb-rich forests, the ecological succession generally involves a deciduous stage, followed by gradual increases in the proportions of spruce trees. Spruce eventually gains predominance until groups of spruces fall, creating space for deciduous trees again. Spruce trees are particularly common in moist herb-rich forests with peaty soils or moderate nutrient levels.

The spread of spruce into herb-rich forests is slowed by the buffering capacity of their characteristic soils, which is highest in areas with alkaline bedrock or subsoil. The structure of vegetation communities in some herb-rich forests may also have this effect. Spruces cannot easily take root and thrive in areas with broadleaved nemoral tree species, hazel groves, or other areas with dense vegetation, where their shoots are easily smothered by the abundant leaf litter.

Spruce is widely favoured for commercial forestry in Finland today in areas with nutrient-rich soils (figure 24), even in the south. Where the plants of herb-rich forest habitats occur near the northern climatic limit of their distribution, they often struggle to compete with spruce trees.

***Figure 24.** Ecological management is most needed in herb-rich forests in protected areas where the natural tendency for spruce to take over has been artificially accelerated for forestry purposes (e.g. through plantings, thinnings, or seedling stand management favouring spruces).* PHOTO: JARI KOUKI.

In Finland the ecological management of herb-rich forests always involves interventions in the ecological succession in broadleaved forests, which in small, isolated sites used for commercial forestry may not have been left to run its natural course for a long time. The most common method involves clearing space to enable rare and declining light-dependent herb-rich forest species to thrive while shade- and moisture-dependent species decline. Such measures are taken most often to ensure the survival of demanding and threatened herb-rich forest species that need light and warmth. However, most of the herb-rich forests in Finland's protected areas are left unmanaged to enable their ecological succession to develop naturally.

Shady spruce trees reduce the availability of light for light-dependent herb-rich forest plants and many other species. Because spruce stands have lower evaporation levels than broadleaved stands, they have cooler, moister and more uniform microclimates, and the ground thaws out more slowly in the spring. Spruce needles create more acidic litter on the forest floor, acidifying the ground and changing the chemical consistency and structure of the topsoil. This weakens decomposition activity in the soil, which reduces the availability of nutrients for plants. Light- and nutrient-demanding plant species consequently suffer, and may be replaced over time by species associated with heathland forests and spruce mires. Spruces also replace herb-rich forest species through competition for root space. However, spruces also have positive biodiversity impacts even in herb-rich habitats. They provide vital shelter and food for birds and flying squirrels, and living space for many more species. Many herb-rich forest fungi are dependent on spruce, and older spruce-dominated herb-rich forests can host valuable decomposer species assemblages.

3.1.2 Invasive garden plants problematic

Invasive alien species represent a particularly serious threat to natural plant communities in herb-rich forests (figure 29). Many of these aliens are exotic plant species that have spread from gardens. The most widespread and problematic of these plants in Finland include Himalayan balsam (*Impatiens glandulifera*), which can spread rapidly especially along streams; and garden lupin (*Lupinus polyphyllus*), which readily proliferates along road verges, even in protected areas, and is hard to eradicate. The most difficult invaders of all are the rapidly proliferating giant and Persian hogweeds (*Heracleum mantegazzianum* and *H. persicum*), which spread thousands of seeds into the soil each year from their prolific blooms. Particularly in the surroundings of built-up areas, many other ornamental plants and shrubs may spread into herb-rich forests, including dwarf serviceberry (*Amelanchier spicata*), knotweeds (*Fallopia spp.*), golden-rods (*Solidago spp.*), Sorbaria spp and Spiraea spp. Some herb-rich forests near settlements may also contain ornamental trees including apple trees, cherry trees and broadleaved limes (*Tilia platyphyllos*).

Finland has prepared a national strategy to combat harmful invasive alien species and prevent new threats (Ministry of Agriculture and Forestry 2012). The aim is to eradicate harmful invaders at as early a stage as possible, to maximise ecological effectiveness and minimise costs. The strategy's ambitious objectives include the goal of eradicating the giant hogweed from Finland within 10–20 years.

Some of the above-mentioned alien species originate from distant regions in completely different natural vegetation zones, where they share their native habitat with quite different insect and fungi communities. The most prolific invasive species should be eradicated from herb-rich forests and entire protected areas whenever possible. Because red-berried elder (*Sambucus racemosa*) and the rapidly spreading small balsam (*Impatiens parviflora*) are native to Europe, efforts should only be taken to eradicate them in special cases, for example where their spread endangers threatened herb-rich forest species.

INFO BOX 2.

NORTHERN AND SOUTHERN HERB-RICH FORESTS

Finland's herb-rich forests can be categorised by their moisture conditions into three main types: dry (figure 26), mesic (moderately moist) (figure 27) and moist (figure 28). These main categories can be further subdivided into dozens of herb-rich forest types (Hotanen et al. 2008).

When considering the need for habitat management, Finland's herb-rich forests are divided into two groups: southern herb-rich forests in the hemiboreal and southern boreal zones; and northern herb-rich forests in the middle and northern boreal forest zones.

Herb-rich forests in the hemiboreal and southern boreal zone may be naturally dominated by either deciduous trees or spruce. In the hemiboreal zone they are characterised by the presence of plant species that need light and warmth, which spread into Finland from the temperate deciduous forest zone before spruces arrived here. Many of the same species also occur in herb-rich forests in the southern boreal zone. Herb-rich forests in the hemiboreal and southern boreal zone are often also characterised by traces of their former traditional uses, some of which are

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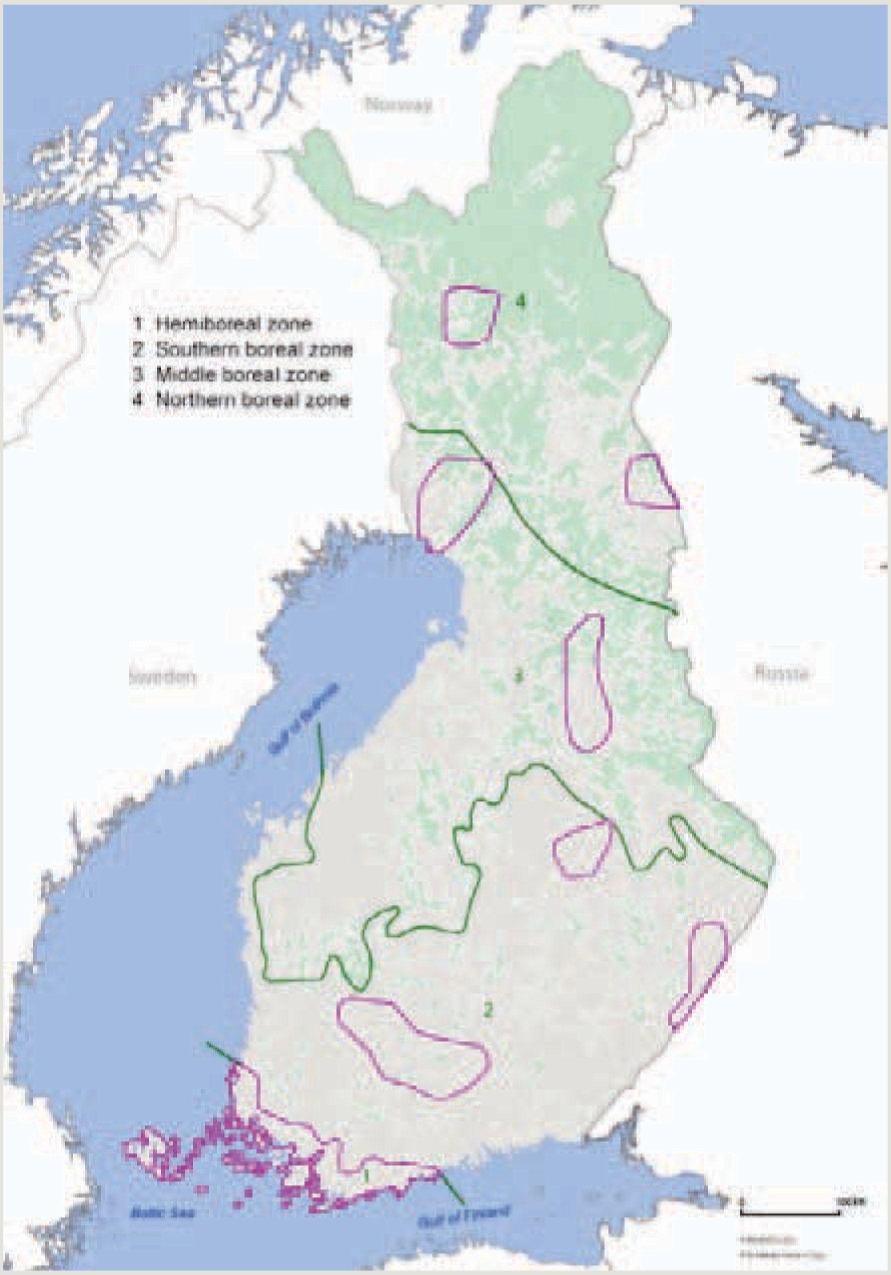

Figure 25. *Concentrations of herb-rich forest habitat around Finland and forest vegetation zones (according to Rassi et al. 2010). Copyright Metsähallitus 2012, Finnish Environment Institute 2012.*

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closely linked to their ecological value. In coastal areas affected by land uplift, herb-rich forest biotopes at different stages of the primary succession can uniquely be found in zones that have emerged from the sea over different periods of time.

Herb-rich forests in the middle and northern boreal zones naturally tend to consist of spruce-dominated mixed forest or herb-rich birch stands in upland regions in the north. Their vegetation communities are relatively well established. Most species in the field layer can tolerate shade. More southerly light-dependent species that grow in the spring are almost invariably absent, although light-demanding calypso (Calypso bulbosa) and lady's slipper (Cypripedium calceolus) orchids may occur in calcium-rich herb-rich forests in the north. Where old spruce trees fall, broadleaved trees and herb-rich forest undergrowth occupy the resulting clearings, and management measures are not needed, except where the habitats of light-demanding orchids need to be maintained. Other exceptions include areas that were previously dominated by broadleaved trees due to traditional slash-and burn farming or grazing practices, but which are now being taken over by spruce trees.

Figure 26. *Dry herb-rich forests are found particularly on the south-facing slopes of eskers and moraine ridges, in areas with calcium-rich soil and on islands. They typically consist of well-lit, semi-open slopes with broadleaved trees, Scots pines and large aspens. Their field layers feature grasses and legumes. Heathland forest plants may also be abundant. The shrub layer is usually sparse.* PHOTO: HELENA LUNDÉN.

Figure 27. *Most of Finland's herb-rich forests can be classified as mesic (moderately moist) in terms of their soil moisture conditions. They may be naturally dominated by broadleaved trees or Norway spruce. Vegetation layers are well developed and diverse. Those with diverse tree structures dominated by broadleaved species have very high levels of species diversity in their plant, bird and invertebrate communities.* PHOTO: MAARIT SIMILÄ.

Figure 28. *Moist herb-rich forests can be found in all regions of Finland. They typically consist of spruce-dominated mixed forest, birch stands or alder stands. The shrub layer is often well developed, and the field layer is dominated by tall herbs or ferns. The best preserved natural examples are found along streams, in the vicinity or mires and springs, in regularly flooded alluvial sites, and elsewhere along shores.* PHOTO: KAIJA EISTO.

3.2 Varying objectives for habitat management

The most important objective of the management of herb-rich forests in Finland is to preserve the diversity of their ecosystems by safeguarding the regional and ecological variability in their biotopes and species assemblages. Another goal is to enable their characteristic species to spread through a network of herb-rich forest sites.

The ecologically valuable features of herb-rich forests include their rare or notable species, entire biotic communities, their characteristic vegetation, their structural features, the preservation of traditional agricultural biotopes, or cultural and landscape values. Extensive or structurally varied sites can be managed to enable species that require shade and moist microclimatic conditions to thrive alongside light-demanding species. Parts of such sites can be left to develop naturally for the purposes of monitoring the impacts of management, and in line with the precautionary principle.

Different objectives are prioritised in the management of herb-rich forest biotopes in Finland's different vegetation zones (Info box 2). But one common goal in all these biogeographical regions is to preserve diverse herb-rich forest ecosystems in both the short and the long term.

If the habitat management requirements of two rare or threatened species or species groups conflict, their regional conservation statuses should be assessed, and measures favouring the species with the less favourable conservation status should be chosen. In many sites it may be possible to plan ecological restoration to meet the needs of both species groups. In making such choices, priority should be given to threatened species and other notable species, such as those listed in Annexes II and IV of the EU Habitats Directive or Annex I of the Birds Directive, and species whose occurrences and populations in the site to be managed are very important at the regional or national level.

Increasing the availability of light is particularly important when managing habitats for southern spring-blooming vascular plant species, and in the north-

Figure 29. *In SW Finland attempts are being made to eradicate Siberian dogwood (Cornus alba) where this exotic plant has spread into protected areas.* PHOTO: JOHANNA RUUSUNEN.

ern herb-rich forest habitats of lady's slipper (*Cypripedium calceolus*), rattlesnake fern (*Botrychium virginianum*) and sweetberry honeysuckle (*Lonicera caerulea*). Managing the habitats of herb-rich forest plants also benefits the insects that feed on them. Many of these insects depend on certain species. Increasing the availability of light also improves the prospects for nemoral broadleaved tree species and the species that depend on them, which include many gnats, true bugs, other insects, and molluscs that thrive in their leaf litter. Contrastingly, many of the fungi, mosses and lichens found in herb-rich forest habitats require the moist conditions associated with shady sites.

In southern Finland it is often necessary to choose whether to continue to manage a site in ways that reproduce its traditional cultural utilisation, or in ways that will enable it to revert to herb-rich forest. Traditional agricultural biotopes used until fairly recently as wooded pastures are easy to recognise, and can be designated for similar management again. If it is a long time since they were grazed, decisions on their management should be made carefully. Factors to consider include the value of their species and ecosystems, and the occurrence and representativeness of herb-rich forest biotopes and traditional agricultural biotopes on a wider scale. Choices may also be made on the grounds of cultural and landscape values, or practical considerations such as the availability of grazing animals.

3.3 Ecological management methods

3.3.1 Removing spruce trees to favour broadleaved trees

Management measures often need to be repeated several times to effectively alter or maintain the structural features of herb-rich forest habitats. In all types of herb-rich forest one goal should usually be to enable nemoral broadleaved tree species, goat willows and aspen to grow and thrive.

It is necessary to reduce the numbers of spruce trees in sites where they would not naturally grow, or where their presence has detrimental effects on nemoral broadleaved tree species, on vulnerable light-demanding species, or on other valuable features needing protection (figure 30). Such species may only be able to thrive in herb-rich forest habitats. If a continuity of deadwood from large spruce trees has already naturally developed or is now developing, however, herb-rich forest sites should preferably be left to develop naturally without management.

If spruces in a herb-rich forest make up a closed canopy layer in a stand where they were planted as seedlings, most of them should usually be removed (figure 31). If a planted spruce stand has grown so densely that the natural ground and field layer of a herb-rich forest site has mainly vanished, the best option is to fell the spruce stand and remove most of the trunks and logging residues, before leaving the site to be taken over by natural seedlings.

Spruce trees growing in clusters or here and there in different canopy layers may also be removed where necessary. In young planted forests where broadleaved trees grow among spruces, conifers can be removed from beside and between the broadleaved trees.

In hazel groves, stands with nemoral broadleaved trees, aspen stands or other herb-rich forest sites dominated by deciduous trees, some 90–95% of the spruce trees growing in lower layers

Figure 30. *The trunks of planted spruce trees have been piled up in this herb-rich forest in a protected area where they had almost totally inhibited the growth of natural herb-rich forest vegetation. The smoke visible in the background comes from burning piles of logging residues.* PHOTO: VILLE VUORIO.

should be removed. Where herb-rich forests are truly dominated by deciduous trees, especially nemoral species, they should not easily be reoccupied by spruces.

In Finland it is preferable to fell trees in herb-rich forest sites during the winter, when the vegetation in the field and ground layers is protected under the snow. If trees are felled using forest harvesters, this should be done only while the ground remains frozen, at least in mesic and moist sites, to avoid damaging the soil. On steep slopes, in sites with very valuable species, and in scenically sensitive sites, it is preferable to fell trees manually. In some sites it may be useful to combine mechanical and manual work.

It is often important to remove spruce logging residues from herb-rich forest sites to reduce acidification and shade (figure 32). Decomposition processes in herb-rich forests are often rapid, however, so such measures may not always be needed. Where suitable, the spruces to be felled may initially be ring-barked to make their needles fall directly on their roots, and not spread more widely. Some of the trunks of felled spruces should always be left to decay on the site.

Figure 31. *Where herb-rich forest habitats are to be restored in sites with planted spruce stands, many spruce trees may need to be removed. Where necessary, they can be felled using machinery, and the logging residues can be burnt.* PHOTO: ESKO TAINIO.

Figure 32. *Where dense stands of planted spruces are thinned or removed, it is usually worth destroying logging residues, for instance by burning them.* PHOTO: VILLE VUORIO.

When working in small protected areas and close to the edges of protected areas it is important to minimise the risk of future damage by the spruce bark beetle Ips typographus in surrounding commercially managed forests (see section 2.3.8). Felled spruces should be transported away from any sites where there is a risk of bark beetle outbreak. Large spruces should preferably be ring-barked and felled gradually, to reduce this risk.

It is not usually necessary to remove deciduous trees or pines when restoring herb-rich habitats in Finland. In dense aspen seedling thickets it may be worth promoting the growth of larger aspens by removing competing neighbouring trees. It is also worth creating growth space around seedlings of nemoral deciduous tree species or larger individual trees. Birches or pines planted at regular intervals in a herb-rich forest may be thinned irregularly. Any felled deciduous trees should be left to decay in situ.

3.3.2 Long-term measures needed to combat invasive alien species

The need to eradicate an alien species largely depends on whether it represents a present or future threat to a herb-rich forest site's conservation values. Trees of exotic species that are able to spread should be removed from protected herb-rich forests, unless they need to be preserved for cultural reasons (see section 6). Trees of native species but of non-native genetic origin should only be removed when their origin is known and when there is an evident risk that they will spread competitively in a herb-rich forest.

The methods used to combat invasive alien species should be chosen with careful consideration given to local conditions in a protected area, notably species assemblage, hydrology, relief and location in relation to settlements. Methods should also be suitable given the characteristics of the species to be eradicated (perennial or annual, flowering time, propagation method) and the age and extent of its local populations. Timing can be crucial: actions should be implemented before plants flower and seeds mature. Measures to remove invaders from a herb-rich forest site may need to be repeated several times during each annual growing season for several years (at least 5 years). Even years after such actions it remains important to monitor whether the species has truly been eradicated from the site or whether further actions are needed.

Mechanically removing invasive plants is an effective but laborious method. It is most vital to remove their roots and any mature inflorescences from which they could spread again. Invasive species may be dug up from their roots (individual giant hogweeds and lupins), have their main roots broken (giant hogweed), be pulled up by hand (balsams), be mown (golden-rods, extensive growths of lupins and balsams) or be broken and then have their exposed parts treated with herbicide (red-berried elder and other shrubs). Giant hogweeds, for instance, can rapidly grow back from any root fragments left in the soil, so mowing is not an effective way to eradicate them. When working with giant hogweed it is important to remember to protect workers' skin against the effects of their sap, which can cause burn-like skin rashes when exposed to sunlight. The leaves of invasive alien plants may be composted or buried, but their roots and seeds should be destroyed by burning.

Herbicides may be the only effective and reasonably inexpensive way to eradicate alien plants in cases where other methods have failed. Giant hogweed, for instance, can be combated by treating growths repeatedly with a glyphosate solution, sprayed or spread directly onto their leaves to ensure that only the targeted plants are killed. Herbicides should not be used near open water or in areas where groundwater is utilised, however.

Other methods that can be used to combat alien invaders include covering their growths (figure 33), ring-barking trees and shrubs, and the use of grazing animals. Growths may be covered for several years with durable dark plastic sheets. This may be done to ensure, for instance, that giant hogweed roots and seeds in the topsoil die off in the absence of light.

3.3.3 Special consideration for certain species and small-scale features

Where herb-rich forest sites are managed specifically to improve conditions for occurrences of an individual (threatened) species, these occurrences should be mapped in detail during the initial planning phase. Management measures should target the structural features of habitats that are most important for the target species. Such features may include certain kinds of decaying wood, hollow deciduous trees, or the host plants that provide nutrition for specialist insects. The measures taken to manage the habitat of a threatened species must never put occurrences of the target species at risk.

Surveys of important species groups should be conducted in herb-rich forest sites designated for ecological management before measures are planned, even if the primary goal is to manage the biotope rather than the occurrence population of any particular species.

Sites designated for management often contain ecologically valuable small-scale features such as crags, brook-sides, springs and groundwater seepage areas with moist microclimates favourable for mosses, lichens and ferns. Management measures should generally not be imple-

Figure 33. *Attempts may also be made to eradicate growths of giant hogweed outside herb-rich forest sites, to prevent their spread into a protected site. In this case, attempted clearing had proven ineffective, and the remaining growth has now been covered with durable black plastic to keep off light and smother the plants' growths. Herbicides cannot be used in this site, because of a nearby water supply intake.* PHOTOS: MAARET VÄÄNÄNEN.

mented around such features, to ensure that their shady conditions and stable moist microclimates are preserved.

Contrastingly, sites may also contain outcrops of calcium-rich bedrock, sloping shores, patches of meadow habitat and other small features important for light-demanding species. Such features should be kept open or semi-open. It may also be necessary to remove any overhanging shady trees, shrubs and sometimes even dwarf shrubs and ground layer vegetation to improve conditions for plants that require plenty of calcium.

Spruce thickets with slow-growing trees or trees of different ages should be preserved even in herb-rich sites dominated by broadleaved trees. Where spruce trees grow beside large aspens, such groups of trees should be preserved particularly to provide suitable habitat for Siberian flying squirrels (*Pteromys volans*).

3.3.4 Restoring natural hydrological conditions

Measures to restore natural hydrological conditions are sometimes needed in herb-rich forests. In many places, especially in moist herb-rich forests, streams have been cleared or springs and groundwater seepage areas have been artificially drained. The terrain may also bear traces of ploughing, mounding, or the deep tracks of heavy vehicles. Measures to restore natural hydrological conditions should be carefully planned and implemented on the basis of surveys of sites' moss species assemblages.

Ditches can be filled in using the same methods as in spruce mires. Several dams reinforced with wood and filter cloth may have to be built across stretches of ditches that are sloping, rocky, or otherwise vulnerable to erosion. It may also be necessary to use machines to reduce the drainage impacts of old ploughed furrows. Other measures may be realised at the same time as ditches are filled in, e.g. felling trees across the former ditch to provide growth sites for mosses.

Figure 34. *A male white-backed woodpecker by his nesting hole, beneath a growth of the chaga fungus Inonotus obliquus.* PHOTO: LASSI KUJALA.

3.4 Creating well-lit deciduous forest habitat for white-backed woodpeckers

Timo Laine and Pekka Heikkilä

Forest habitats can also be restored or managed specifically to protect a single species. In Finland hundreds of hectares of forest habitat in protected areas have been managed specifically to benefit the white-backed woodpecker (Dendrocopos leucotos), though these measures also favour many other deciduous forest species and deadwood-dependent species.

3.4.1 The white-backed woodpecker in Finland

Finland is home to seven woodpecker species, including the white-backed woodpecker (figure 34), which is classified as nationally endangered (Rassi et al. 2010) and in need of special protection. The species' Finnish population has increased recently thanks to conservation measures, habitat management and the spread of birds from Russia. In the early 1990s, their Finnish breeding population was estimated at just 30–50 pairs (White-backed woodpecker working group 1992, Virkkala et al. 1993). Surveys conducted during the breeding season in 2011 found that pairs had established territories in almost 150 localities, and more than 100 broods were raised for the first time on record.

White-backed woodpeckers thrive in well-lit forests dominated by deciduous trees. In Finland they are typically found in forests with many birch, aspen and alder trees, though pine and spruce trees may also be present (figure 35). Spruce trees are typically scarce or absent in the understorey. The woodpeckers' territories often encompass moist heathland forests with some herb-rich forest features, or open, dry herb-rich forests. Their distribution is centred on eastern and southeastern regions, where almost half of their breeding territories have been found, and where their numbers have increased steeply.

Figure 36. Caterpillars of the fungus moth (Scardia boletella) grow in the fruit bodies of tinder fungi (Fomes fomentarius) and in birches decomposed by these fungi. Adult moths emerge from cocoons that may be seen on the surface of the fungi or the birch bark. PHOTO: PETRI MARTIKAINEN.

Breeding white-backed woodpeckers require territories that include about 50 hectares of mainly deciduous forest with plenty of standing and fallen deadwood. Since there are hardly any extensive areas of unfragmented habitat of this kind left, their territories today usually encompass several smaller areas of suitable habitat scattered over a wider area.

White-backed woodpeckers excavate a new nest hole every year in a decaying deciduous tree – most often in a birch snag, or in aspens, grey alders or common alders with hollowing trunks.

The same forests that suit white-backed woodpeckers also provide optimal habitat for many other species (figure 36), including threatened deadwood-dependent beetles (Martikainen et al. 1998), and rare mosses and polypore fungi. Siberian flying squirrels (*Pteromys volans*) also breed in many sites protected for white-backed woodpeckers.

3.4.2 Removal of spruce trees

White-backed woodpeckers are adapted to thrive in forest habitats at a successional stage dominated by deciduous trees, which provide plenty of suitable food and nesting sites. Most of the most favourable sites in Finland today developed where traditional slash-and-burn cultivation was practised, or where animals were grazed in the forest. Such land use practices have declined greatly, and the intensive management of forests favouring conifers has also worsened the prospects for white-backed woodpeckers around Finland. The features that the woodpeckers require can also be safeguarded in commercially managed forests.

White-backed woodpeckers largely feed on the insects that live in decaying deciduous trees, and they also find food on dead fallen trees, around the bases of deciduous trees, and among leaf litter. Nutrient-rich deciduous forest habitats suitable for white-backed woodpeckers are naturally taken over by spruces as the succession progresses, leaving the field and ground layer vegetation in permanent shade. In shady sites fallen trees emerge from under the melting snow only in late spring, and insects become active later than in open sites. Dense spruce growths in the understorey also facilitate predators' surprise attacks on woodpeckers feeding at ground level.

White-backed woodpecker habitat is managed to preserve, increase and enhance its special characteristics and features. In planning management for the short term, the focus should be on enhancing the quality of existing habitat, whereas longer term plans should aim to create suitable conditions for the future development of new areas of favourable habitat. Management measures should be prioritised considering factors including the location of a site within the white-backed woodpecker's distribution, its location in relation to known woodpecker territories, and the structure and successional stage of the forest.

Removing spruce trees increases the penetration of light and warmth to the forest floor, making it easier for the woodpeckers to find food. In white-backed woodpecker habitats it is usually necessary to clear spruce from the understorey in addition to thinning, felling or ring-barking mature spruce trees (figure 37). This work is mainly done using machinery. In small or inaccessible sites manual forestry work may produce better results and be more cost-effective, however. Manual work is also preferable if the cleared undergrowth or fallen trees are to be left in the forest.

In areas of woodpecker habitat where demanding herb-rich forest species are present, the cleared spruce understorey or logging residues may be removed or burnt on the site, to ensure that their acidity has no detrimental effects on conditions for herb-rich forest species or the growth of new deciduous trees.

Figure 35. Well-lit forests near shores, dominated by deciduous trees and containing abundant deadwood, provide favourable habitat for white-backed woodpeckers. PHOTO: MICHAEL MÜLLER.

***Figure 37.** Spruce in the understorey and mature spruces have been cleared in this site to create habitat for white-backed woodpeckers. Harvesters have also been used to break birch trees at a level just below their lowest living branch, to create more deadwood. The crowns and upper parts of the birch trunks may be left on the forest floor to decay.* PHOTOS: JOUNI ELONEN.

In other situations material from the cleared understorey may be left on the forest floor. Trunk decay can be accelerated by partially or completely pruning the felled trees.

It may also be necessary to clear rowan trees, since their low foliage creates shade and reduces visibility at ground level. Clearing rowans also creates more space for other deciduous trees to occupy. Rowans should be removed while they are still in leaf to inhibit sprouting, and to facilitate the scaling of such measures.

3.4.3 Creating decaying birch wood

Large quantities of deadwood only need to be created in woodpecker habitat where none is present and there are no signs that trees are likely to start decaying naturally. The amounts of deadwood should be increased gradually to ensure continuity in the availability of deadwood. Using currently available restoration measures, it is, however, difficult to create the kinds of deadwood used by white-backed woodpeckers (figure 38). Ring-barked birches die and dry out more rapidly than trees that die naturally, which delays the emergence of decomposing fungi. It may take 7–8 years before white-backed woodpeckers can find food on a ring-barked birch.

Felled birches often remain hidden by grasses in herb-rich sites, making it hard for white-backed woodpeckers to benefit from them. Trunks can be lifted off the ground onto stones or mounds to make them more visible and accessible to the woodpeckers.

3.4.4 Continuous management needed

White-backed woodpecker habitat management work should not disturb the woodpeckers' courtship or choice of nest sites. In Finland such measures should therefore be scheduled in autumn or during the winter before the beginning of March. The removal of spruces and rowans can start in early September, after the end of the woodpigeon nesting season. To minimise damage, machinery should only be used when the ground is covered by snow.

In practice, managing white-backed woodpecker habitat means acting against the natural succession. Management actions must therefore be repeated at intervals of 10 years or so, to combat the sprouting of rowans and new spruce seedlings. The use of grazing animals is always favourable, since livestock inhibit the growth of grasses and brushwood in cleared areas, and also trample most spruce seedlings.

3.4.5 Converting young forest into woodpecker habitat

Young, mainly deciduous forests in protected areas can be managed at an early stage to gradually make them into suitable habitat for white-backed woodpeckers (figure 39).

The first actions in new sites involve strongly favouring deciduous trees. Space is cleared around larger deciduous trees to speed their growth. Dense growths of aspen saplings can be thinned in selected patches to promote the growth of thicker trunks. Young mainly deciduous forest should be left to grow quite densely, however, to enable the natural formation of deadwood and the development of more spacious forest structures. It may take decades for this process to be completed.

__Figure 38.__ Four methods for ring-barking birch: a) with a barking bar, b) using a tree-marking knife, c) cutting grooves with a chainsaw; and d) removing a strip of bark with a chainsaw. PHOTOS: TIMO LAINE.

In young forests managed to create white-backed woodpecker habitat, spruce trees should account for less than one third of the total volume of timber. It is not worth eradicating spruces altogether, since leaving a few conifers will provide shelter from birds of prey for other woodland birds. Conifers – especially spruces – also provide vital shelter for Siberian flying squirrels. A protective group of spruce trees should always be left beside any aspen tree with flying squirrel nest holes.

→ *__Figure 39.__ Young mixed spruce and birch forest has here been selectively cleared favouring birches. This site is located near existing areas of white-backed woodpecker habitat.* PHOTO: JARMO HALONEN.

4 Ecological management in nemoral broadleaved forests

Esko Tainio and Mikko Siitonen

4.1 Nemoral broadleaved tree species in Finland

Trees of nemoral broadleaved species occur in Finland at the northernmost limits of their distributions. They spread into Fennoscandia during a warm climatic phase after the Ice Age, and were most abundant about 6,000 years ago, before Norway spruce spread into Finland. As spruce spread and the climate cooled, the limits of their ranges shifted south to where they are today. But some of their occurrences have survived as relict populations, mainly in sites with favourable microclimates and soil conditions.

The nemoral broadleaved tree species naturally found in Finland are English oak (*Quercus robur*), small-leaved lime (*Tilia cordata*), common ash (*Fraxinus excelsior*), Norway maple (*Acer platanoides*), wych elm (*Ulmus glabra*) and European white elm (*Ulmus laevis*). The common hazel (*Coryllus avellana*) is also sometimes considered to be in the same category. The most favourable growth sites for these trees are well-lit herb-rich forest habitats on south-facing slopes. Oak forests occur naturally in Finland only within the hemiboreal vegetation zone, but all the other species may also be found in the southern boreal zone. In terms of conservation biology, forests containing these trees are significant habitats in Finland.

As human settlement spread through Finland hardwood trees were increasingly utilised, and their growth sites were often cleared to create farmland. As commercial forestry intensified, conifers were preferred, and nemoral species were cleared from commercially managed forests. Even in recent decades nemoral broadleaved forests are estimated to have shrunk by 30–50% overall, and they have also deteriorated greatly in qualitative terms. These trends are largely due to a commercial preference for spruce, and an increase in building developments. In Finland nemoreal broadleaved forests are now considered to be endangered habitat types (Tonteri et al. 2008).

***Figure 40.** The hollow trunks of old nemoral broadleaved trees contain mulm, which is made of wood fragments, insect faeces and other debris. Mulm provides habitat for many rare fungi and insect species.* PHOTO: HEIKKI KIURU.

***Figure 41.** Dead oaks provide growth substrate for many lichens and polypore fungi including the oak mazegill (Daedalea quercina).* PHOTO: HEIKKI KIURU.

Nemoral broadleaved trees, especially oak, can be described as key species in their ecosystems. They provide growth substrates, breeding sites, food and shelter for many other species (figure 40). In terms of biodiversity, the most valuable trees are the largest decaying trees, the oldest trees with the widest canopies, and also thriving trees that will eventually grow into sturdy but hollow trees containing mulm in their hollows. The total numbers of species found in such habitats rise into the hundreds, or thousands if soil organisms are counted, including many species that are threatened in Finland. Even small stands of decaying broadleaved nemoral trees may represent valuable oases of biodiversity (figure 41).

Nemoral broadleaved trees are also found in traditional agricultural biotopes, especially in the hemiboreal zone of Finland. Such biotopes may become well-developed boreal broadleaved woodland habitats with slowly decaying wide-canopied oaks (figure 42), ash trees earlier used to provide leafy fodder, and birches. Their field layers feature species of herbaceous plants and grasses that are typically found in herb-rich forests, as well as those characteristic of traditional agricultural biotopes. Traditional agricultural biotopes with many nemoral broadleaved trees are widely managed in Finland as a combination of herb-rich forest and traditional agricultural biotope, to benefit their nemoral broadleaved trees.

Very few areas of naturally developed nemoral broadleaved forest remain in Finland. They are mainly in inaccessible locations such as islands, boulder fields or steep slopes. Their natural dynamics no longer function in small fragmented areas: small canopy gaps do not form, the trees do not regenerate, and their genetic diversity declines. Commercial forestry favouring spruces in their surroundings also gradually changes them into spruce stands. For these reasons some of the remaining areas will only survive if they are managed by removing spruces and other competing tree species.

Figure 42. *Oak trees need space for their crowns to spread, so grazed woodland pastures provide good growth sites.* PHOTO: HEIKKI KIURU.

The shrub layer typically contains hazel, other shrub species, and in moist sites particularly bird cherry. The presence of an understorey and shrub layer evens out forest microclimates, reducing frost damage and the drying effect of wind.

The canopy layer in Finnish nemoral broadleaved forests may contain trees of any of the coniferous and deciduous species native to Finland. Nemoral broadleaved trees thrive best among slow-growing, short-lived or shorter trees such as rowan, goat willow, bird cherry, common alder and grey alder. Pines, which only produce limited shade and consume little water, can generally be tolerated alongside nemoral broadleaved trees; but the presence of birches, aspen and spruce may be detrimental (figure 44).

The conservation values of nemoral broadleaved forests increase as their trees age and time passes since they were last managed by foresters. Their tree structure gradually becomes more natural and the amounts of decaying wood increase (figure 45). Living nemoral broadleaved trees of different sizes, hollow trunks and a diversity of decaying wood all maintain diverse habitats for threatened and demanding species.

4.2 Layering characteristic of nemoral broadleaved forests

Mature and old-growth nemoral broadleaved forests have a layered structure like other kinds of herb-rich forests (figure 43). The canopy layer mainly includes sturdy limes, oaks, maples, ashes as well as varying amounts of other deciduous and coniferous species. A fairly well developed sub-canopy layer and a diverse shrub layer grow beneath the canopy. The understorey layer typically contains shade-tolerant trees including lime, maple, elms, bird cherry, rowan and spruce, though where light conditions are favourable oak, ash, birches, alders and aspen may also thrive. In younger forests the trees tend to be more uniformly aged and strongly competitive, and layering has generally not yet become evident.

Figure 43. *Conditions will become more natural in this genetic reserve lime forest in eastern Finland as natural processes such as the formation of deadwood proceed.* PHOTO: PETRI SILVENNOINEN.

Figure 44. Dense spruce thickets in the understorey should be removed, since they compete with lime trees for water and nutrients, slow the thawing of the frozen ground in the spring, and produce too much shade for herb-rich forest plants. PHOTO: ESKO TAINIO.

Figure 45. Large decaying trees add to the structural and species diversity of nemoral broadleaved forests. The artist's bracket fungus (Ganoderma applanatum) grows on decaying oak wood. PHOTO: HEIKKI KIURU.

↓ *Figure 46.* Natural oak seedlings have grown into young forest in this site where a shady spruce stand was felled in the 1970s and subsequent measures have prevented the spread of spruce. PHOTO: HEIKKI KIURU.

4.3 Promoting deadwood continuity and habitat connectivity

At the regional level the ecological management of nemoral broadleaved forests aims to safeguard these habitats and maintain and enhance flows of genetic material between populations by ensuring the connectivity of forest patches.

The goal at the stand level is to preserve the diversity of nemoral broadleaved trees and the species and ecological communities that directly or indirectly depend on them.

In managing individual trees, the aim is to keep the most valuable trees for biodiversity alive as long as possible, and ensure that new generations of trees thrive and exhibit diversity in the structures of their crowns and trunks.

The prioritisation and intensity of ecological management measures should be defined on the basis of these key factors: the proximity of a stand to other nemoral broadleaved forests; the age, health and regenerative capability of its trees; and the viability of local populations of characteristic species.

Stands with trees that vary in age and structure, with deadwood present, where most of the broadleaved trees are thriving and capable of regenerating naturally, should be left to develop naturally.

The areas where nemoral broadleaved trees occur may be increased and their connectivity improved by expanding existing forests or establishing new stands. Trees and stands may be planted as seeds or seedlings, and by utilising natural seedlings and offshoots. However, nemoral broadleaved trees should be planted outside their natural ranges only in exceptional cases.

4.4 Enhancing the diversity of nemoral broadleaved forests

4.4.1 Management scaled to suit the age and health of trees

Management measures should safeguard the vitality of nemoral broadleaved trees and diversity in the structure of their trunks, enhance the layered structure of stands, and create more deadwood. This is typically a continuous process, and measures need to be repeated.

Measures mainly focus on providing more space for nemoral broadleaved trees by ring-barking or felling other trees that detrimentally affect them (figure 46). Nemoral broadleaved trees often lose out in competition, especially with fast-growing trees such as spruce, aspen or birch. If a stand only contains

Figure 47. Spruce trees need to be removed urgently from this forest, where they are overshadowing 150–200-year-old oak trees. PHOTO: HEIKKI KIURU.

a few nemoral broadleaved trees, even every single tree might be managed in this way. In stands with many nemoral broadleaved trees, the intensity of management may be varied, with some trees left to compete naturally with trees of other species.

Measures to remove competing trees should not be delayed so long that a site's nemoral broadleaved trees suffer too much and their crowns shrink (figure 47). Mature trees particularly take time to recover if their canopies suffer, since they use an increasing proportion of their resources just to stay alive and produce seeds. Space should be gradually created over a period of perhaps 4–15 years for broadleaved trees older than 55 years that have long been affected by shade. For younger trees (including those in the understorey) or trees with healthy crowns, more space can be created through one-off measures.

Especially in young forests care must be taken to ensure that the field layer does not receive too much light, since this may promote the spread of grasses to the detriment of sensitive herb-rich forest plants, and also intensify the sprouting of trees that will compete with the nemoral broadleaved trees.

Ring-barking is a good way to remove competing trees, since the slow death of ring-barked trees evens out changes in the microclimate, and makes it easier for the remaining trees to adapt to new conditions. Ring-barked deciduous trees become snags which collapse section by section, while conifers dry out and fall as whole trees. Competing trees may also be felled where necessary.

4.4.2 Use of machinery or manual forestry methods

Manual forestry work is preferable in many nemoral broadleaved forest sites requiring management. In seedling stands and young forests this is the only option, but such methods are also to be favoured in mature forest sites with valuable vegetation and threatened species that may be sensitive to erosion or disturbance. The best time for manual work is in the autumn, when trees can still be recognised by their leaves, but the birds' nesting season is over.

If too many competing trees are present to be left in the forest, or where they are difficult to fell (e.g. if the trees that need to be removed lean towards nemoral broadleaved trees, or have decaying bases), they may be felled using harvesting machines. This process is fast, and the removed trunks and branches can be piled up if necessary (figure 48). In Finland such work should be scheduled for the winter, when the frozen ground and snow cover limit damage to tree roots. Care should be taken during such work to avoid damaging old or hollow nemoral broad-leaved trees and large living or dead branches, but minor damage generally does not harm a site's nemoral broadleaved trees, and may even increase the site's overall diversity.

If necessary, sensitive areas where harvesters should not enter (e.g. moist habitat patches, gorges, occurrences of rare species, concentrations of deadwood) should be delimited. Some of the trees to be removed, especially more robust trunks, should be left in the forest to decay. In herb-rich sites felled spruces should have their branches stripped to ensure that their needles do not cause acidification.

4.4.3 Deadwood of nemoral broadleaved tree species

Nemoral broadleaved forests in Finland often contain only limited amounts of deadwood, even in protected areas, due to the young age of the trees or the ways sites were earlier used. Deadwood will form naturally over time, and this is usually sufficient in most protected areas. But where this process will be so slow that it endangers the survival and conservation status of dependent species, deadwood may have to be artificially created, for instance by ring-barking selected nemoral broadleaved trees or bringing in suitable deadwood from sites outside protected areas (e.g. trees felled in urban parks).

Deadwood may also form as a consequence of management measures, for instance where young nemoral broadleaved trees are ring-barked in the vicinity of old hollow trees containing mulm or in planted stands to break up their uniform structure.

Nemoral broadleaved trees can also be deliberately damaged (e.g. with a chainsaw), to make them decay slowly. Some of the damaged trees may later provide habitat for the species that live in mulm.

Figure 48. The branches and crowns of spruce trees harvested in this herb-rich forest site have been piled up to be later sold as energy wood or burned on site. About 10% of the spruce trunks, mainly larger trunks, will be left to decay on site. The objective here has been to create space for the seedlings of nemoral broadleaved trees, hazel and other herb-rich forest vegetation. PHOTO: ESKO TAINIO.

5 Ecological management in sunlit habitats

Harri Tukia and Maarit Similä

5.1 Sunlit habitats and their species under threat

***Figure 49.** This sandy depression in the Rokua National Park is one of Finland's largest fluvioglacial kettle hole[3] features. Its sunlit habitats, which host valuable species, remain open due to erosion caused by the park's visitors.* PHOTO: PÄIVI VIRNES.

Sunlit habitats can be found in very different locations around Finland, from sandy shores to the tops of treeless arctic fells. Sunlit habitats can also be found inside forests in sites such as the south- and southwest-facing slopes of esker ridges[2] and on crags. Sunlit habitats endure extreme conditions: on sunny days they are hot and dry, whereas at night they are colder than their surroundings. Vegetation, which would even out temperature differences, tends to feature intermittent gaps. Sunlit habitats will only persist where there are external disturbances such as forest fires, erosion and weathering due to wind, water and ice, grazing, mowing or trampling (figure 49). Some sunlit habitats will naturally remain open, while others need to be managed. The total area of sunlit habitats with valuable characteristic species in Finland is estimated at around 1,200 hectares. This section focuses on measures for managing sunlit habitats on forested eskers.

***Figure 50.** This 130-year-old pine forest is on the southwest slope of an esker. The trees are not sparse enough to favour plants that thrive in sunlit habitats, and little deadwood is present.* PHOTO: HARRI TUKIA.

Sunlit habitats naturally occur on esker slopes mainly during the initial stage of the forest succession, in sites affected by forest fires or storms. Smaller areas of sunlit habitat may also develop in older forests, or temporarily in any forest habitat as a consequence of fire or other disturbances. In more nutrient-poor sites and in sites more exposed to extreme conditions, the impacts of fire on the ground layer will last longer, and the tree canopy will stay open longer. In pine-dominated forests on sandy soils in the middle and northern boreal forest vegetation zones, for instance, the impacts of a strong single

2 Eskers are long, narrow, winding ridges of sand or gravel originally deposited by glacial streams flowing under an ice sheet. Following the melting of the ice sheet, eskers are left as prominent landscape features with special ecological, physiographical and hydrological characteristics.

3 Kettle holes are large hollows in sandy glacial deposits that originally formed where a large mass of ice was left inside the deposits, and later melted. They often contain lakes, ponds or marshes.

disturbance event may last as long as several decades.

In Finland today there are hardly any geomorphologically intact esker forest habitats with fairly natural mature and old forest conditions. Esker forests have been managed with an emphasis on landscape aspects, and this has impoverished their biodiversity (figure 50). Pines are typically predominant, and forests are often structurally monotonous. Dwarf shrubs dominate the field layer and there is little deadwood. The ground layer is covered with a blanket of thick litter and raw humus even on steep slopes. Esker forest habitats have also become less diverse due to the absence of natural disturbances, and because of eutrophication caused by atmospheric nutrient deposition.

Species adapted to sunlit habitats (figure 51) may still be found alongside paths, road verges, power lines, and even old anthills. But species characteristic of the initial successional phase and poorly competitive species cannot thrive or spread in esker forests with closed canopies unless their habitats are actively managed.

Almost 200 species associated with esker forests are classified in Finland as threatened or near threatened (Rassi et al. 2010). The most typical species of sunlit habitats in Finland include vascular plant and insect species that are adapted to dry and sunlit habitats and pronounced variations in microclimatic conditions. The seeds of such plants germinate best where the ground is sandy or gravelly. The sizes of their occurrences naturally vary from an isolated cluster of a few individuals to sparse growths over an area of a few ares or a few dozen ares. More extensive occurrences usually develop only in habitats that have been artificially created and maintained by repeated human activity, such as gravel pits or airfields.

Insect species adapted to the life cycles of the plant species of sunlit habitats typically survive or disappear on a local scale as their host species thrive or decline.

5.2 Targeting surviving populations of characteristic species

The ecological management of sunlit habitats aims to preserve existing areas of such habitat, increase their representativeness, and restore sunlit biotopes in sites where they would naturally occur. Management ensures the vitality of populations of rare species associated with sunlit habitats, and makes it easier for them to spread.

It is ecologically most justifiable and cost effective to manage sunlit sites that still host their characteristic species. Sites suitable for such management within overgrown and densely wooded esker forests include south- and southwest-facing esker slopes within a few hundred metres of existing occurrences of typical sunlit habitat species (in areas of natural or artificial habitat). Management may be also justified by historical records indicating that such species have previously occurred in the site concerned.

Figure 51. *Wild thyme (Thymus serpyllum) thrives on sunlit slopes.* PHOTO: HARRI TUKIA.

***Figure 52.** Habitat for rose-winged grasshoppers (Bryodemella tuberculata) and rattle grasshoppers (Psophus stridulus) is managed by clearing dwarf shrubs, lichens and tree seedlings.* PHOTO: ANTTI BELOW.

Since sunlit habitats and their characteristic plants typically occur in small patches, management measures may also be implemented on a small scale, focusing on a suitable part of an esker slope.

In the short term (less than 5 years) the most important objectives are to increase the amounts of sunlight by thinning out trees, and to expose mineral soil by removing undergrowth. The special requirements of the target species should also be considered on a site-by-site basis (figure 52).

In the longer term (more than 5 years) management should ensure the preservation of sunlit habitats and ecological connections between such sites and occurrences of their characteristic species. It is important to include sunlit sites at different developmental stages in conservation networks.

Rattle grasshoppers live in dry sunlit habitats in southern Finland. PHOTO: ANTTI BELOW.

5.3 Different management phases

5.3.1 Reducing shade by removing trees

The most important element of the ecological management of sunlit habitats on south- and west-facing forested esker slopes is to clear canopy gaps. Gaps should be created in sites that will receive direct sunlight for at least ten hours a day during the summer. Cleared sites resemble the treeless or sparsely wooded successional stages that occur following natural disturbances. Trees should be chosen for removal so as to reduce shade as much as possible. This is best done on a sunny day when it is easiest to see which individual trees cast the most shade over the slope. It is usually more important to remove trees that cast shade over the lower parts of a slope, since if they were left to grow their shade would also affect higher parts of the site (figure 53). Any large broadleaved trees and dead trees should always be left standing for the sake of biodiversity and landscape considerations. It is also worth sparing any exceptionally large individual pines.

Trees should be cleared in groups to create variety in the structure of the forest, with both clearings and groups of

Figure 53. *Young dense tree growths were beginning to cast shade over the sunlit slope and bottom of this kettle hole feature, which nevertheless still hosted many typical species. Trees were then felled on the parts of the kettle hole with the most valuable occurrences of the typical plants of sunlit habitats. Trees and logging residues were mainly cleared away, though larger trunks were left in place to decay.* PHOTOS: HARRI TUKIA.

standing trees. Removing trees simultaneously over a wide area could have detrimental impacts even for species that require sunlit habitats.

Trees can be felled manually or using machines. Steep esker slopes can be problematic for forestry machines, however, and it may be necessary to fell trees manually and then use a winch or other equipment to move trees to the top or bottom of a slope for further transportation. The use of harvesting machinery breaks up the ground vegetation and raw humus, which means there is less need for separate measures to break up the soil humus layer. The related risk of erosion must nevertheless be considered when planning measures to manage sunlit habitats, especially on steep slopes, since it is important that loose sand and gravel remain on the slope.

When esker forests are managed by clearing trees, in addition to the pre-existing dead trees, some felled and ring-barked trees should always be left to decay in the resulting sunlit habitats. Branches should be stripped off felled trees where necessary to reduce shade impacts. Logging residues including branches and crowns may be removed from the site or piled up and burnt.

5.3.2 Clearing undergrowth and exposing mineral soils

Removing dwarf shrubs, moss, lichen, litter and the humus layer is an essential part of the ecological management of sunlit habitats in esker forests. This can be done using a brush saw, rake or mattock, for instance. In sites with thick humus layers, mineral soils can be exposed using machinery. Without exposing mineral soils the benefits of management for the species of sunlit habitats will be limited. Poorly competitive plant species will spread onto exposed soils vegetatively or from seeds. It is relatively easy to spread plants such as wild thyme (*Thymus serpyllum* ssp. *serpyllum*) into sunlit habitats using its seeds.

Mineral soils should be exposed by hand, perhaps using a mattock, alongside existing growths of the target plant species. This is the best way to ensure that these plants themselves do not become uprooted when competing plants are removed. Particularly just above and below the growths of the target plant species such measures should only expose small patches of ground, to reduce the threat of erosion.

If a site to be managed does not yet host typical sunlit habitat species, the soil can be scalped so that between a fifth and a half of the total area of the ground will be exposed. Patches of exposed ground should be at least a square metre in size, though they can also be much larger. The plant species of sunlit habitats benefit from small-scale erosion, but to reduce the risk of larger scale erosion, exposed patches should be aligned along the contours of a slope.

Nutrient-rich sites may become overgrown with grasses soon after the ground is exposed. Particularly reed grasses can smother other lower-growing species such as wild thyme (figure 54). Methods for removing grasses include mowing, burning, or the brief introduction of grazing animals in sites that have been grazed at some time in the past.

Figure 54. *Reed grass may take over sites where wild thyme grows.* PHOTO: TEIJO HEINÄNEN.

The rapid growth of thickets of aspen clones is a typical phenomenon in sunlit hollows in Finland. This may cause problems for other species of sunlit habitats, since aspens cast shade over the vegetation on slopes even when they are very young. To prevent sprouting, the largest aspens should be left standing in sites to be managed. In sunlit habitats old aspens can also benefit rare and threatened species (figure 55).

The fastest way to remove aspen brushwood is to use a brush saw. To limit further sprouting, such measures should be repeated every 5–10 years. Aspen seedlings may also be pulled or dug up with their roots in sandy sites. Uprooter accessories for forest harvester machines have also proven to be suitable for such work where seedlings are 0.5–4 metres in height.

If logging and clearing residues are left on a slope, they will cover and smother the target species and increase nutrient levels for long periods. Such residues and organic material removed from the ground and topsoil should be piled up and burnt, composted or removed from the site.

Figure 55. Surveys of insect populations in sunlit habitats in Rokua National Park indicated that the presence of aspens increases insect species diversity. PHOTO: PÄIVI VIRNES.

5.3.3 Controlled burning

Natural forest fires no longer occur on esker slopes in Finland due to effective fire prevention. Restoring fire impacts in esker forests is an important aspect of the ecological management of protected areas. It may be difficult to burn areas of sunlit habitat in esker forests where slopes are steep (figure 56). Burning should only be conducted in almost wind-free conditions, since wind could easily drive a fire spreading uphill out of control. Good times for burning are immediately after the snowmelt or in late autumn.

Burning particularly promotes the spread of species of sunlit habitats when the ground vegetation and the humus layer are also burnt. However, humus usually only burns completely in nutrient-poor sites with little organic topsoil. If a very thick humus layer has formed in a site, and has to be burnt in a semi-moist state for fire safety reasons, only a shallow surface layer of the organic topsoil may be burnt. Unburnt humus may effectively protect reed grass roots, for instance, so it is worth pulling up reed grass and its roots before burning. After successful burnings, the characteristic vegetation communities of sunlit habitats may continue to thrive in open sites for up to a decade.

In Finland many protected eskers are located in or near areas where groundwater is used in the local water supply. There is a risk that burning in such areas could lead to the contamination of groundwater, and this must particularly be taken into account in sites near water intakes.

Figure 56. Fire is here being used as a tool for the ecological management of an esker forest. Spruce trees in the understorey have been felled to provide fuel for the fire at the field layer. PHOTO: HELENA LUNDÉN.

5.3.4 Introducing typical species into managed sunlit habitats

The characteristic species of sunlit habitats should primarily be conserved by managing their existing occurrences, but if a population of a threatened species is threatened with extinction, it may be justifiable to bring individuals from other locations into managed sites. In Finland special permits are required for such measures involving threatened species. Even where more abundant plant or animal species are moved, it is important to ensure that this does not threaten their source populations.

If it is known that a sunlit site earlier hosted typical species that have since disappeared due to overgrowth, attempts can be made to reintroduce them as plants or seeds. These plants or seeds should be procured from locations as near as possible to the site. Subsequent exceptionally dry or wet periods may reduce the likelihood of success, and make it more difficult to predict future trends. Reintroductions may also fail if the management of a site cannot later be continued.

The best time to sow seeds for reintroductions is when a plant would naturally shed its seeds, often in June and July (Kittamaa et al. 2009). Seeds may germinate immediately after they are shed, or later during the next spring. The seeds of some species will germinate only after enduring winter conditions.

In Finland the best time to transplant plants into sunlit habitats is during the autumn. Plants already in or entering dormancy for the winter can successfully put down their roots under moist autumn conditions with no need for watering (Kittamaa et al. 2009). When transplanting individual plants it is important to also move enough soil together with a plant, and avoid breaking their roots when digging up the ground. The roots of such plants can extend to depths of tens of centimetres in sandy soils.

Attempts have also been made to transfer living insects between areas of sunlit habitat, but this has proven to be difficult. Individuals may be moved as adults or larvae from populations that are reproducing well.

6 Considering cultural heritage during ecological restoration and management

Henrik Jansson

Valuable cultural heritage sites can often be found in the same protected areas where forest habitats need to be restored or managed. In planning measures for such areas, care should be taken to consider all of their valuable features that require conservation.
To ensure the conservation of ancient sites and historical relics, it is generally sufficient to be aware of their existence and location, and plan measures accordingly.

Figure 57. *This natural rock formation is known as the Croft Church. According to local tradition, masses used to be held here and communion was given to local people. In Finland such natural formations associated with folkloric traditions can be officially designated as legally protected ancient monuments.* PHOTO: RIIKKA MUSTONEN.

6.1 Habitats shaped by man over the ages

People have used Finland's forests for millennia. From the Middle Ages into the 19th century settlers shaped the forests by clearing fields and farmyards, practising slash-and-burn cultivation, and using timber for building or to make tar and charcoal. Ironworks and other industrial settlements then sprang up, using the forests more intensively. In Finnish Lapland, human impacts on forests remained limited until the second half of the 20th century. All these activities have left traces which remain as valuable cultural heritage, providing insights into past livelihoods and lifestyles.

Cultural landscapes reflect the historical phases of human activity, and interactions between man and nature.

Figure 58. *Unusual patches of vegetation (with different trees and dwarf shrubs) may reveal the location of an old charcoal pit.* PHOTO: JOUNI TAIVAINEN.

Finland's National Board of Antiquities defines cultural heritage as including the spiritual and material heritage created through human activity. If people have shaped an area's biological features, but left no other traces, the results can be described as biological cultural heritage.

Archaeological sites in forests include various kinds of structures, traces of human activity visible in the landscape, or natural features that are associated with folklore (figure 57). A site's value and significance do not directly correlate with its age. The foundations of a logging camp from the early 20th century may be as valuable as traces of a Stone Age settlement. Some archaeological sites still remain clearly visible. Traces of old round tar-burning pits and swidden fields and barns endure for long periods, for instance. Contrastingly, it may be hard for anyone but an expert to notice traces of a Stone Age settlement or old charcoal pits (figure 58). Particularly on river banks and lakeshores by old waterways, for instance, traces of prehistoric settlements may be hidden in the ground.

6.2 Avoiding damage to cultural heritage sites during restoration work

When planning ecological restoration and management work it is important to find out whether a site contains any known cultural heritage sites. During initial fieldwork it is also worth remembering the possibility that a site may contain ancient relics. If a site to be restored includes ancient relics or other cultural heritage sites, the planned management measures need to be approved by a cultural heritage expert.

Controlled burning

Little research has been done in Finland about the impacts of fire on ancient relics. As a rule of thumb, controlled burnings should therefore be avoided in sites containing ancient relics. Impact studies nevertheless indicate that brief overburning of a site does not raise temperatures in the ground very significantly, so in some sites burning may be an option even if they contain ancient relics. However, certain types of archaeological object, such as ceramics and metal objects, are sensitive to temperature variations. Stone structures are also liable to crack or crumble when affected by fire.

Other restoration and management measures

Measures taken to create small clearings or increase the abundance of deadwood can detrimentally affect structures in cultural heritage sites in various ways. Valuable sites could be covered with a layer of decomposing material; layers of sediment could be mixed; or the movement of tree roots could damage them. For these reasons trees must not be felled by knocking them down with a machine in such sites.

Pits and stone structures generally remain better preserved if any trees growing in or on them are removed (figure 59). It may be harmful to leave individual trees standing on such structures if surrounding trees are felled, since the cultural heritage structures may be damaged if the remaining trees are later blown down in a storm.

If deciduous trees have to be removed from structures, care should be taken to ensure that they do not sprout again over the next few years after the site is managed. One option is to ringbark deciduous trees and only fell them several years later. Another alternative is to clear away any deciduous trees growing and sprouting on such a relic site repeatedly during the beginning of the growth season until they stop sprouting. Any trees whose roots extend onto or into relic features are liable to damage them over time.

The use of forestry machines may directly damage structures or the layers of sedimentary material around them. Machines must never be driven through or over cultural heritage relics.

Removing non-native tree species

Some protected areas contain trees of species that are not native to Finland. It is often desirable to remove such trees. In some instances, however, such trees may be linked to local cultural history. For example, they should not be automatically removed where they remain as traces of an old garden or farmyard that subsequently became overgrown by forest.

Figure 59. *Trappers used to dig pits to catch game animals such as deer and elk from the Stone Age until the 19th century. Some of these pits are still visible as shallow depressions, even though material has accumulated inside them over the intervening years. The biggest trappers' pits can be five metres in diameter and more than a metre deep. Such pits are legally protected in Finland as ancient relics.* PHOTO: EIJA OJANLATVA.

7 Monitoring the impacts of habitat restoration

Kaisa Junninen

The impacts of forest habitat restoration measures are monitored to assess how well the restoration objectives have been realised. For this purpose an extensive network of monitoring sites has been set up around the country (figure 59). The network includes restored sites in moderately moist and semi-dry heathland forests together with a parallel set of control sites set up either in an unmanaged part of the same stand, or in a similar stand nearby. Monitored variables include living and dead trees, beetles and polypores at sites where deadwood has been created, and living trees and tree seedlings where small canopy gaps have been opened.

***Figure 59.** A network of 24 forest restoration monitoring sites has been set up by Metsähallitus Natural Heritage Services. The black line denotes the northern boundary of the region covered by the METSO forest biodiversity programme.*

7.1 Monitoring of living and decaying wood

In sites where measures have been taken to create more deadwood, trees are monitored to examine how the formation of decaying wood is progressing. At each monitoring site three stands in mature or older forest are monitored. At each site 2–4 concentrations of deadwood have been set up per hectare, with the amount of deadwood increased by at least 15 m3/ha. Within these concentrations of deadwood, and in control sites, circular monitoring plots with a radius of 10 metres have been established (figure 60) around permanently marked central points. The central points of the monitoring plots are located at least 50 metres from the edge of a stand. No measures that could affect the monitored parameters will be carried out in the control site or within 50 metres of its central point.

In monitoring sites, the living and dead trees have been measured before and after increasing the amounts of deadwood. Measurements are repeated in both the managed sites and the control sites at five-year intervals.

7.2 Beetle monitoring

Beetles are a key species group in the context of monitoring the impacts of forest habitat restoration. About 800 of the beetle species found in Finland are dependent on deadwood or other species that live on deadwood, most commonly fungi (Siitonen 2001). Many of these beetle species are threatened or rare (Rassi et al. 2010). The impacts of restoration on beetle assemblages are monitored in sites where the amounts of deadwood have been increased, since such measures directly affect the availability of resources that are vital for deadwood-dependent beetles.

Beetles are trapped in monitoring sites using freely hanging flight-intercept window traps. Two traps are placed in each of the circular monitoring areas in both the managed sites and the control sites (figure 60). The most favourable season for trapping beetles is between mid May and mid August, when it is possible to obtain data on most species.

Beetle specimens were trapped for the first time in monitored sites in 2006

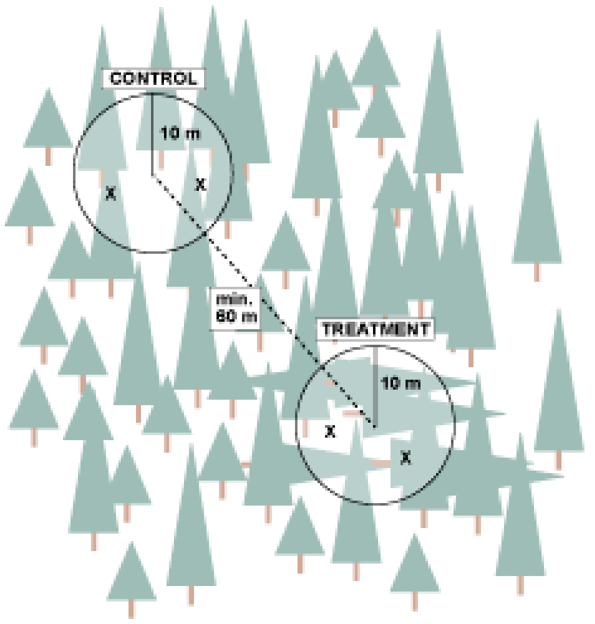

Figure 60. The locations of circular monitoring plots and beetle traps (X) in a site managed to increase the amounts of deadwood.

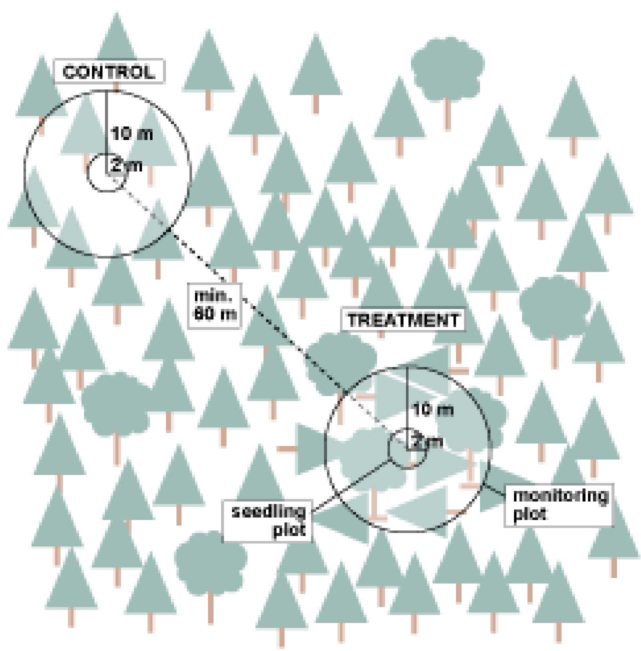

Figure 61. The locations of tree and seedling monitoring plots in stands where canopy gaps have been created.

and 2007 after measures were implemented to create more deadwood. The second monitoring round will be realised in 2009-2012, and monitoring will be continued at five-year intervals for as long as necessary.

7.3 Polypore monitoring

Polypore fungi are also a key species group for monitoring the success of forest restoration. Declining quantities of decaying wood in forests is specified as a threat factor for more than 70% of Finland's red-listed polypore fungi (Kotiranta et al. 2010). The decaying wood that has formed due to the restoration work is monitored to assess progress in the succession of polypore species assemblages, and to see whether the artificially created deadwood provides growth sites for threatened and rare species. Polypore monitoring is a long-term project. It may take decades for trees to decay to the extent that they provide suitable substrate for polypores, enable the polypores' mycelia to develop into spore-producing fruit bodies, and facilitate a succession of polypore species.

The resultant monitoring data is also useful in relation to beetle monitoring, since it describes a factor that greatly affects beetle populations. Polypores are monitored in all restored sites where trees and beetle species are monitored. Polypore species are inventoried in the same circular plots as the trees at five-year intervals after treatment.

7.4 Monitoring of sites where small canopy gaps have been created

Trees and tree seedlings are monitored in sites where canopy gaps have been created in young pine-dominated forests Three circular monitoring plots with a radius of 10 metres have been established around permanently marked central points in the treated and control forests. Inside each circle, smaller seedling plots with a radius of 2 metres are defined (figure 61). Control sites, with similarly defined tree and seedling monitoring areas, have been selected randomly, and located at least 50 metres away from the edge of the canopy gap. The central points of the managed sites and the control sites designated for monitoring are at least 50 metres from the edge of a stand. No measures that could affect the monitored parameters will be carried out in the control site or within 50 metres of its central point.

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Ecological management and restoration

have been widely practiced in forests in protected areas in Finland over the last 20 years. This guide is based on the wealth of information and experiences accumulated during that period. It gives an overview of the practical methods applied in the ecological management and restoration of forest habitats in Finland. Controlled burning and the creation of deadwood and small canopy gaps are the main means used in protected areas to restore natural structural features in forests that have previously been utilised commercially. Herb-rich forests, white-backed woodpecker habitats, nemoral broadleaved forests and sunlit habitats are ecologically managed in order to maintain habitats for rare and threatened species. In addition to providing practical guidelines for such actions, the guide also explains the ecological factors behind the restoration and management of forest habitats, aiming to enhance the effectiveness of future actions.

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