Forestry Commission Scotland
Coimisean na Coilltearachd Alba

Managing forests as red squirrel strongholds

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Practice Note

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Stronghold forests are large areas of coniferous and mixed forest identified as having the potential to sustain resilient and healthy populations of red squirrels (*Sciurus vulgaris*) over the long-term. With suitable planning and management the woodland composition and layout should provide the native red squirrel with a competitive advantage over the introduced North American grey squirrel (*S. carolinensis*) and strongholds should be defendable if grey squirrels arrive. Strongholds would therefore act as red squirrel refuges even if grey squirrels continue to extend their range in Scotland. This management guidance follows five general principles which support the defining aim of strongholds – to use woodland management to maintain a healthy self-sustaining population of red squirrels. It outlines management objectives and options with regard to tree species choice and forest operations but the suitability of specific options will need to be decided locally for individual strongholds.

Introduction

This practice note offers guidance to forest managers and landowners on conservation management options for red squirrels in stronghold forests in Scotland. The red squirrel strongholds programme is a non-statutory scheme, led by Forestry Commission Scotland (FCS) as part of the Scottish Government's strategy to secure the future of the red squirrel in Scotland. Further information on how the programme complements the work of Forestry Commission Scotland and others to protect the red squirrel can be found at www.forestry.gov.uk/redsquirrelconservation

Strongholds for red squirrels cover a wide range of different forest habitat types such as spruce dominated forests in the south and west, pine dominated woodlands in the north and east of Scotland, and island woodland habitat on Arran. The aim of this guidance note is to provide a general overview of management options that should in all cases be followed by the development of site-specific management plans for each stronghold. However, management options for red squirrel conservation differ between woodland habitat types. We therefore distinguish and provide guidance for these three broadly different types.

Forestry Commission Scotland will help forest managers in stronghold areas to develop site-specific plans. We will follow this practice note when managing the national forest estate and will encourage it to be followed for planning and operational activities in private stronghold forests.

Background to the red squirrel strongholds programme

A set of 19 potential red squirrel stronghold forest areas were identified following public consultation in 2009. An updated map of stronghold sites and the interim strategic priorities for red squirrel conservation in Scotland is available at www.forestry.gov.uk/redsquirrelconservation

The vulnerability of red squirrels in Scotland means that it is important to evaluate the impact of the strongholds programme over time, which Forestry Commission Scotland will do every five years. The strongholds programme needs to be sustainable over the long-term and we look forward to working closely with organisations and individuals to improve our advice.

Management priorities in a stronghold

The defining aim for strongholds is to maintain a healthy, self-sustaining population of red squirrels through woodland management. Management outcomes should therefore be designed to favour red squirrels and discourage grey squirrels.

Although stronghold sites were identified to minimise conflicts with other objectives, for example by avoiding sites with a high proportion of large-seeded broadleaved species (which would provide grey squirrels with an advantage), the challenge for forest managers will be to integrate red squirrel conservation measures with other forest management objectives.

This will apply to wider landscape management decisions too, such as establishing habitat networks. These can bring positive benefits for some species, but can also have negative impacts. For example, woodland networks can facilitate the dispersal of grey squirrels across landscapes. A future shaped by climate change must also be considered, and the availability of resources. Forest managers are encouraged to seek the advice of Forestry Commission Scotland in balancing these objectives.

This guidance has been prepared specifically for stronghold forests but the management principles and tools referred to will help create good red squirrel habitat in other areas too.

General principles for managing red squirrel strongholds

No systematic assessment of the benefits and disadvantages for red squirrel populations of different silvicultural systems has yet been possible. What is well known, though, is that both red squirrels and wider biodiversity will benefit from a diversity of tree species and age structures. How this is best achieved without also encouraging grey squirrels will depend on local circumstances and long-term forest objectives.

Five principles guide the options for red squirrel conservation management (see Box 1).

Figure 1 View looking towards the South Rannoch stronghold.

Box 1 – Principles for managing a red squirrel stronghold.

1. Manage the forest to maintain a dependable food supply
2. Seek to resolve conflicts with other management objectives without compromising the success of red squirrel strongholds
3. Plan for red squirrels at the landscape scale
4. Plan forest operations to reduce short-term impacts on populations and sustain long-term resilience
5. Establish a monitoring system and a review process

Urgency of measures

Management options for red squirrel conservation need to be decided and implemented as soon as possible because a forest's long-term carrying capacity depends on planning decisions made now. This guidance suggests how a management actions can address three risk factors in particular:

Suitability of current and future habitat for red squirrels

The aspiration for stronghold areas is that red squirrels are considered at or near the top of the management decision hierarchy. It means that stronghold forest managers should consider red squirrel requirements in their long-term plans by appropriately enhancing the diversity of tree species and age structures to provide a dependable seed food supply; and by reviewing current felling plans to ensure suitable habitat provision is maintained.

The increasing incidence of disease outbreaks (such as those caused by Dothistroma Needle Blight (DNB) and Phytophthora species) may mean that planting preferences have to change, with implications for managing a stronghold site. We will update our guidance on this on our website.

Risk of grey squirrel incursion from the surrounding landscape

Strongholds were selected with the intention that their size and character would make them resilient for red squirrels even if grey squirrels are nearby. Most strongholds are located far from known grey squirrel areas but some were selected in areas closer to greys to get a spread across Scotland. Hence a wise precautionary approach is to anticipate their possible arrival in adjacent areas.

The spread of grey squirrels across Scotland depends on a number of factors such as the patterns of tree seed crops, levels of natural predation and the availability of dispersal pathways (usually wooded river corridors or woodland networks). They are sometimes illegally released by individuals too. Once grey squirrels are present, population levels can increase rapidly in suitable habitats, so grey squirrel control may be considered a high priority in some stronghold areas. The success of these efforts will depend on sustained commitment, resources and targeted control efforts (see Principle 3 for more guidance).

Risk of grey squirrels transmitting disease to the red squirrel population

Like all wild mammal species, squirrels can carry and be afflicted by a variety of infectious agents. Currently the greatest threat is from squirrelpox virus (SQPV). Grey squirrels can carry the disease with no symptoms, but if passed to red squirrels it is normally fatal. Prospects of success in containing the spread of pox across Scotland are not yet clear so vigilance is needed in all stronghold areas where grey squirrel incursion is a risk.

Figure 2 Red squirrel and grey squirrel.

Box 2 – Grey squirrel control.

Scottish Natural Heritage (SNH) has developed an interim Grey Squirrel Control Strategy for Scotland, which identifies priority areas for grey squirrel control. It views habitat management as the mainstay of red squirrel conservation, but targeted grey squirrel control may help to prevent the spread of grey squirrels and squirrelpox virus into new regions. Work is on-going to assess the costs and benefits of targeted grey squirrel control. Where aligned with priority areas, this may be used to support red squirrel strongholds where necessary. Monitoring will show when this is needed – for example when there are significant changes in grey squirrel distribution or when there is evidence of the squirrelpox virus spreading. This approach will allow forest managers to take a flexible and responsive approach to monitoring and control in and around strongholds.

Resources and financial help to maintain a stronghold

Most stronghold forests are fully or partly on the national forest estate – land managed by Forestry Commission Scotland on behalf of Scottish Ministers. Red squirrel conservation is a key priority for FCS, and the strongholds programme is central to our plans to use habitat management to achieve this. Strongholds on the national forest estate will therefore be resourced in line with other core, on-going work programmes.

Financial support is available to private landowners under the Scottish Rural Development Programme (SRDP) through grants such as the Woodland Improvement Grant for restructuring a forest or the options for long-term forest planning or controlling invasive non-native species (grey squirrels). Under the SRDP scoring system, managing a forest as a red squirrel stronghold will contribute towards delivering regional priorities for the conservation of priority species under the UK Biodiversity Action Plan. Management actions include work to improve the quantity, quality and consistency of red squirrel food supplies, and where necessary, grey squirrel control to protect stronghold sites. Forestry Commission Scotland can advise on relevant grants, and technical guidance on how SRDP supports red squirrel conservation is available on our website.

FCS works with various regional and local red squirrel conservation projects to support management planning in stronghold forests, and grey squirrel control programmes where required. We will consider the need for any further resources to support this work and what, if any, additional support might be appropriate for the next SRDP cycle (2014–2020).

Stronghold Management Guidance

Principle 1 – Manage the forest to maintain a dependable food supply

Carrying capacity

Manage the stronghold's carrying capacity – the variety and availability of food for red squirrels – rather than the red squirrel population itself.

Red squirrel populations fluctuate naturally, largely in response to food supply, and are capable of recovering quickly so this is the most critical aspect of stronghold conservation efforts. The number of squirrels that can be supported by a forest is known as its carrying capacity.

Populations can be made more resilient by managing the forest so that it has a potentially high carrying capacity which is more stable through time. A higher carrying capacity is maintained by having a diverse tree species composition and age structure, so by choosing these, managers can influence the variety and availability of food for red squirrels. Forest plans should consider tree species composition, diversity and age structure, to provide a dependable seasonal and year-to-year food supply in the future.

Figure 3 Red squirrel feeding in winter.

Red squirrels follow food sources throughout the year and across a forest. Their main diet is tree seeds but they will also eat buds, shoots, tree flowers and fungi. They forage optimally, so their preference for particular types of food will change between seasons and years. Seed shedding patterns and seed crop cycles will affect the seasonal and between-year distribution and abundance of seed food, and thus habitat use

and squirrel numbers. Management choices should therefore consider the coning patterns of different tree species and the availability of other food sources.

Table 1 shows how the food sources available for red squirrels in a forest can be mapped to create and maintain a diverse forest that yields a dependable food supply within and between years. Diversifying the age structure will create a varied pattern of seed cropping and shedding across seasons and between years.

Box 3 – Managing a forest's carrying capacity for red squirrels.

Guidance on how to use information on forest type, tree species, age class and squirrel density to estimate a forest's carrying capacity is given in Forestry Commission Practice Note 11 *Practical techniques for surveying and monitoring squirrels* (2009), available on the Forestry Commission Scotland website.

For example, a conifer forest that consists of stands of Norway spruce, Sitka spruce and lodgepole pine may hold 1 squirrel per 2.5 ha in an average seed year but only hold 1 squirrel per 10 ha in a poor seed year. This variation illustrates why red squirrels need extensive and diverse food sources beyond relying on tree seeds, and why stronghold forests need a carrying capacity that is stable and resilient over time.

Scots pine forests in Scotland can support up to one red squirrel per 1.25 ha. Hence managing the habitat and food supply to benefit red squirrels is important in strongholds.

Age structure

The tree age classes in a stronghold will ideally be: less than one-third of trees younger than 15 years, with the rest (two-thirds or more) to be thicket and mature trees, most of which should be of cone-bearing age.

These proportions are an informed attempt to reconcile the demands of wood production, broader biodiversity and landscape values with the needs of red squirrels who will find a greater food supply in older crops. The seasonality of different tree species is illustrated in Table 2.

Figure 4 Mixed age woodland.

Table 1 Seasonal pattern of food availability and red squirrel feeding behaviour.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TREES	Sitka spruce cones												
	Cones of other conifers												
	Broadleaved seeds												
	Catkins												
	Flowers												
	Buds												
	Shoots												
	Bark/sap												
Cached seeds													
Berries/rosehips													
Insects													
Fungi													
Lichens													

Table 2 Average age to first good seed crop and interval between good seed years for red squirrel food trees. Note that in some upland areas the intervals between seed crops may be longer.

Tree species	Age to first good crop (years)	Average interval between good seed crops (years)	Seed available to squirrels*
Scots pine	20–25	2–5	June – late spring (Two-year seed maturation cycle)
Lodgepole pine	20–25	2–3	July – late spring (Two-year seed maturation cycle)
Sitka spruce	30–35	3–5	August to January
Norway spruce	30–35	3–11	August to late spring; in years of mast crops seed available for > 12 months
Larch	20–25	3–5	July – following spring (Important food plant in years of low pine and spruce seed crops)
Douglas Fir	30–35	4–7	September onwards

*Approximate estimates, precise period will vary with overall seed crop size and weather.

Existing felling plans should be assessed in relation to age structure and species diversity to ensure a favourable habitat is maintained. It is recognised that an ideal age structure within a forest may be difficult to achieve within an existing rotation especially in some western spruce forests. Future long-term forest plans should introduce sufficient young and middle-aged trees to provide a sustainable succession of cone crops.

Low impact silvicultural systems (sometimes called continuous cover forestry) offer an alternative to clear felling silviculture to achieve varied age structure. These systems should be considered in sheltered areas of stronghold forests (where they are suitable) as this scale of operations is likely to favour red squirrels, and can provide other landscape, biodiversity and recreation benefits too. Further guidance on transforming even-aged stands to continuous cover management is available from Forestry Commission Scotland.

Forest species composition

Manage the stronghold so that it is composed of diverse species that benefit red squirrels and do not offer greys an advantage.

Broadleaved trees and shrubs should be included in a stronghold forest because they help provide a diverse food supply throughout the year. However, large-seeded broadleaved species may give grey squirrels a competitive advantage so stronghold planning should favour small-seeded broadleaved species.

To help find a balance, Table 3 indicates which tree species are preferable to support a red squirrel population.

Table 3 Tree species that benefit red squirrels ('Favoured'), trees and shrubs which provide some benefit ('Secondary'), trees and shrubs that do not give grey squirrels an advantage ('Neutral'), and species which may provide grey squirrels with a competitive advantage ('Discouraged'). Species which are native in at least part of Scotland are in italics.

Favoured	Secondary	Neutral	Discouraged
Douglas fir	*Bird cherry*	*Alder*	Beech
Larch (all types)	*Blackthorn*	*Ash*	Chestnuts
Pine (Corsican, Scots, Lodgepole)	*Bramble*	*Aspen*	*Hazel*
Spruce (Norway, Sitka, Omorika)	*Dog rose*	*Birches*	*Oaks*
Yew	*Hawthorn*	Cypress	Sycamore
	Wild cherry	Fir (Grand, Noble, Silver)	
	Wych elm	*Holly*	
		Juniper	
		Rowan	
		Western hemlock	
		Western red cedar	
		Willows	

Key ways to diversify the composition of forest species to benefit red squirrels are:

- In non-native conifer strongholds, at least 20% of total cover should be made up of a range of other favoured (or secondary) species.
- In native woodland strongholds, diversification should use native species.
- Encourage spatial diversity by planting in mixtures or groups.
- Encourage good seed production by planting favoured species on south-facing aspects and long south-facing edges to east/west rides, and in irregular shapes to increase the periphery edge.

- If established large-seeded broadleaved species are aiding the colonisation of a stronghold by grey squirrels, consider a phased removal of trees over 30 years old (mast-bearing age).
- Restrict large-seeded broadleaved species to less than 5% of the stronghold. [Note: this figure is only a guideline – definitive knowledge is not yet available but it is recognised that the **spatial distribution** of large-seeded broadleaved trees should also be taken into account. Concentrated patches (greater than 0.5 ha) of oak, beech, chestnut or hazel may support a resident population of grey squirrels when the same number of trees dispersed over a wider area would not.]

Native broadleaved woodlands and designated sites

Look for ways to satisfy both native broadleaved woodland or designated site objectives and red squirrel objectives.

Red squirrel strongholds were selected to avoid forests where a large proportion of the forest is designated or has the regeneration of native large-seeded broadleaved woodland as a priority. Advice on how best to resolve potential management conflicts for stronghold areas is given under Principle 2.

In other forests that contain a large native broadleaved woodland component or designation, options for red squirrel management may be limited in terms of conifer species diversity and reducing suitability for grey squirrels. Red squirrels can thrive in broadleaved woodlands in the absence of grey squirrels and efforts to help local populations should manage for a diverse seed food supply, with targeted grey squirrel control if needed.

Climate change

Use tree species that are adapted to both current and predicted future climates.

Because red squirrel strongholds are for the long-term it is important to consider how climate change might affect the forests they are in. Impacts will not be the same everywhere but it is expected that some tree species will no longer be suited to some locations, in turn altering a forest's composition and structure and its ability to support a viable red squirrel population. Sitka spruce, for example, is predicted to have increased productivity in a wetter south-west Scotland but a reduced yield in drier south-eastern areas. Some broadleaved species are predicted to expand in southern and eastern Scotland.

Box 4 – Some implications for red squirrels of projected climate change effects on Scottish forests.

- Changes in rainfall patterns, leading to drier summers in the eastern and south-eastern Scottish lowlands but wetter winters in the west, which may alter planting preferences.
- Increased risk of storm damage, which may reduce the number of seed-bearing trees and the amount of red squirrel habitat.
- Possible greater prevalence of new tree diseases, which may change planting preferences.

To maintain a dependable seed food supply in the future, there may be a need to move towards planting drought-tolerant conifer and broadleaved species in some eastern/central areas and to take account of any potential restrictions arising from disease risk. Conifer diversification may need to include a broad range of species that are not commonly used at the moment. This will have consequences for the type and patterns of food available to red squirrels, and new research will need to assess the suitability of these species for red and grey squirrels as well as other wildlife.

Forestry Commission Scotland will continue to update its advice for woodland managers on the effects of climate change on forestry and stronghold forests.

Management objectives for spruce-dominated forests

In spruce-dominated strongholds the distribution and diversity of conifer species is crucial.

Spruce stands can provide good habitat for red squirrels and they favour the dense crowns of spruce for building dreys. However, single species forests may suffer cone crop failure or provide insufficient food throughout the year. Sitka spruce, for example, has an early seed shed so strongholds dominated by this species will need to have other species such as pine or larches to both offer food at other times of the year and to mitigate against cone crop failures in the dominant species. Additional food sources should therefore be introduced or maintained to give a dependable food supply that supports the resident red squirrel population. Tables 2 and 3 (above) should be used to guide planning.

Figure 5 Mixed age spruce forest.

Management actions to support a spruce-dominated stronghold are:

- In plantations dominated by Sitka spruce, include other tree species that will provide food for red squirrels, preferably 'favoured' species such as larches, Douglas fir, Norway spruce, Scots pine and lodgepole pine. The precise tree species choice will depend on local conditions but a minimum cover of 20% of the stronghold by other favoured or secondary species is best;
- Long-term retentions of non-Sitka conifers could be considered to maintain current habitat suitability until younger plantations become mature;
- Well in advance of operations, review felling plans so that the availability of red squirrel food is not reduced by changes to the proportions of mature conifers;
- Long-term forest design plans should integrate conifer species diversity and age structure; seed crop cycles should therefore be considered when determining tree species diversity; it is important to plan for a dependable food supply.

Management objectives for pine-dominated forests

In pine-dominated stronghold forests providing other food sources is highly beneficial. In forests managed as native pine woodland, diversification should use native species.

Scots pine-dominated woods in strongholds should be treated according to whether they are native pinewood priority habitat areas or not. This national and European priority habitat type includes both semi-natural pinewoods and planted pinewoods within the native range of Scots pine in the Highlands. Comprehensive information on these areas is being collected in the Native Woodland Survey of Scotland (see Forestry Commission Scotland website).

Native pinewoods are a natural habitat for red squirrels in Scotland. They typically have associated components of birches, rowan, and juniper; and pockets of willows, holly, alder, bird cherry, aspen, oaks and hazel can occur on the more fertile stream sides. These are nearly all 'favourable', 'secondary' or 'neutral' food sources (Table 3). Studies in Scandinavia indicate that red squirrels are absent from old-growth pine forests for two out of ten years, perhaps because of reduced cone production. It would therefore be beneficial to provide other native food sources to maintain a viable resident red squirrel population. Again, Table 3 should be used to guide planning.

Figure 6 Native pinewood.

Management actions to support a pine-dominated stronghold are:

- In native pine stronghold areas, diversify red squirrel food sources by encouraging a wide range of characteristic native trees and shrubs which can help red squirrels as well as the wider native pinewood ecosystem. Oak and hazel should be kept to below 5% (about their natural level in pinewoods in any case).
- For Scots pine stands outside the native range, and also in pine plantations in the Highlands that are managed for timber, there is scope to include a minority of non-native conifer species to improve food supplies for red squirrels. This may not normally apply to PAWS sites, however, as the aim there is likely to be restoration towards native woodlands (see Principle 2).
- Lodgepole pine stands can be a valuable food source as a minority component in stronghold forests.

Management objectives for island strongholds

In an island stronghold the most important requirement is to prevent grey squirrels being introduced and established on the island.

Islands such as Arran require some different management actions from mainland sites. The most important requirement is to prevent grey squirrels being introduced and established on the island. Beyond that, forest managers should focus on providing a dependable seed food supply (see advice above) but also work to prevent the resident red squirrel population becoming extinct through population fragmentation or significant changes in habitat.

Ideally, red squirrels on islands should be managed as an interlinked group of local populations, so woodland connectivity is important. A similar approach may also be applied on a smaller scale to isolated mainland habitat where internal connectivity would enhance the long-term viability of the local red squirrel population.

Management actions to support an island stronghold are:

- Make links between woodland areas, including hedge links, to encourage red squirrel dispersal and enhance population viability;
- Use an appropriate mix of tree species and shrubs in these habitat links;
- Large-seeded broadleaved species can be a significant part of the overall tree species diversity, on the assumption that grey squirrels can be excluded.

Box 5 – What if grey squirrels arrive in an island stronghold?

It is vital to have an integrated contingency plan for the island as a whole. This should include:

- An overall aim (e.g. to maintain the island as free from grey squirrels);
- Target objectives (e.g. level of surveillance under normal circumstances; effort required if greys are reported; timeframe for grey squirrel eradication if needed);
- An assessment of resources available for grey squirrel control;
- Monitoring (a way to evaluate success or what further measures are needed).

Principle 2 – Seek to resolve conflicts with other management objectives without compromising the success of red squirrel strongholds

Identify and resolve any conflict with other management objectives inside or immediately adjacent to a stronghold.

Stronghold sites were chosen in forests that were least likely to have conflicting management objectives. The management conflict most likely to arise in a stronghold will be over the presence and proportion of large-seeded broadleaved trees, which encourage grey squirrels to colonise but may be important components of designated sites, native woodlands, ancient woodland restoration projects, habitat networks, or scenically and culturally important woodlands in and around stronghold sites. For example:

- The objective of timber production may become more important, for example if the landowner or market conditions change, and this will need to be factored into the overall management of the stronghold.
- Designated sites such as Sites of Special Scientific Interest bring a statutory obligation to manage them so they are maintained or brought onto favourable condition, and this takes precedence over managing for red squirrels.
- Native woodlands and Plantations on Ancient Woodland Sites (PAWS) may contain a high proportion of interconnected areas with large-seeded broadleaved species. The scope for tailoring tree species and age class distributions in these woods to suit red squirrels will be constrained by national priorities and targets for maintaining and improving the ecological condition of existing native woods and restoring PAWS partially or completely to native woodland ecosystems. Restoring PAWS to varying degrees is also a requirement of UKWAS certification (www.ukwas.org.uk). The main constraints to optimising for red squirrels in native woods and PAWS are that non-native species should generally be removed or phased out; and conversely the removal or restriction of large-seeded native broadleaves to discourage grey squirrels may not be desirable in these cases. However, the very low proportion of PAWS in the various stronghold sites means that even their full restoration is unlikely to have a significant effect on the viability of the stronghold sites.
- Forestry Commission Scotland policy is for native woodland creation and expansion to be focused to help develop habitat networks, but developing a native woodland network within or adjacent to a stronghold can bring both benefits and problems to resident red squirrel populations. A network increases the connectivity between patches of habitat, which can improve the linkage between favoured red squirrel habitat and help populations thrive, disperse and adapt

to processes such as climate change. However, networks with large-seeded broadleaved trees as a significant part can encourage grey squirrels to the area and so increase competition and the risk of disease.
- New native woodlands have a significant proportion of open ground to create a diverse character, and this could inhibit long-term use by red squirrels which prefer contiguous canopy cover. Similarly objectives to support other woodland or woodland edge species might sometimes conflict with the ideal actions to support red squirrel populations, for example to support species that need a high proportion of open ground or large clear felling patches.
- Broadleaved or mixed woods can be important for landscape or cultural reasons and Forestry Commission Scotland is committed to maintaining and enhancing landscape quality. Where these contain large-seeded broadleaves this may encourage grey squirrels into strongholds.

Figure 7 A woodland habitat network.

The local management plans drawn up for each stronghold will identify, compare and prioritise the different objectives for each site, so that decisions can be made on how best to achieve them.

It is the case that managing for red squirrels usually brings benefits to a wide range of other species.

- An increased emphasis on production can be achieved without compromising the stronghold's viability by ensuring that restructuring and harvesting are undertaken according to this guidance, and that remaining areas are prioritised to retain a high carrying capacity for red squirrels.
- Designated sites – the requirements arising from the designation should be complied with but subtle adjustments of the forest design and species composition to provide more native food sources and habitat favoured by red squirrels may be possible, for example by varying the mix of native species that are characteristic of a site designated as a native woodland feature.
- Large-seeded broadleaved species can be avoided or phased out if other objectives allow, in favour of small-seeded broadleaved and other native species. Where large-seeded broadleaves have to be retained (for example to regenerate existing native woods or to form a nationally-important linkage in a habitat network), plant and manage them in such numbers that they make up no more than 5% of the stronghold forest area. The stronghold should then retain a carrying capacity that overwhelmingly favours red squirrels and not greys. It should also reduce the potential need for grey squirrel control measures in the stronghold.
- Management for red squirrels will also diversify the forest for many other species, but some local conflicts with open ground and edge species may occur. In stronghold forests the national importance of the site to such species should be assessed to guide resolution of any conflicts. They are unlikely to occur over a whole stronghold forest and careful zonation should allow both red squirrels and open species to be accommodated.
- Where strongholds contain broadleaved or mixed woods that are important for landscape or cultural reasons, a similar range of measures can be considered to those for native woods to alter composition away from large-seeded broadleaves and reduce their influence on the stronghold.
- Native woodlands are defined as woods with at least 50% of their canopy composed of species native to the location. It is national policy to maintain and enhance these woods as native woodland ecosystems, especially for semi-natural woods and new native woodlands. This generally means that the full range of native species characteristic of the site should be encouraged and that non-native species should not be introduced or, if present they should be phased out. But the extent and pace of these adjustments should depend on circumstances. For mature *planted native woods* that are located outside ancient woodland sites there is more scope to retain a long-term mix of native and non-native species depending on the owner's objectives.

Some ways to achieve both red squirrel stronghold and native woodland objectives include:

- Phase out and remove *non-native* large-seeded broadleaved trees, to help prevent grey squirrels gaining a competitive advantage over red squirrels should they arrive at the stronghold.
- Adjust the proportions of native large-seeded broadleaved species (oaks and hazel) within the range of composition that is characteristic of the priority native woodland habitat type. This can be quite wide, which gives considerable scope. For example the natural proportion of oaks in *upland*

oakwoods and *lowland mixed deciduous woods* can be much less than the current share which is often a result of historical management, for example in former oak coppice woods. Indeed there may be cases where upland oakwoods can be gradually transformed through natural regeneration toward birchwoods (of the same National Vegetation Classification type: W11 or W17) with just a small proportion of oak or none at all. Decisions should, however, take account of the other values of each wood, including the particular importance of oak and hazel for biodiversity or cultural heritage.

- Where native woodland in a stronghold contains non-native conifers that are to be removed to improve the native woodland, the manager may plan their removal to have least impact on red squirrels in the short to medium term. This could be done by, for example, retaining the best coning trees/species for longer and removing the others, although the invasive potential of each species should also be taken into account.
- New native woods in strongholds can be designed to encourage red squirrels, by making linkages between stands or groups of trees.

PAWS sites

- Full restoration to native woods may not always be appropriate on PAWS sites and this can be assessed during the creation of the stronghold management plan and any subsequent Forest Plans. For both partial and full restoration there is scope to retain trees and species useful to red squirrels for longer by selective thinning and other management choices, as above. This can be planned to allow time for other parts of the stronghold to develop a higher carrying capacity for red squirrels

Habitat Networks

- Developing native woodland habitat networks can be combined to some degree with red squirrel stronghold objectives by planning woodland composition as above, and also constraining the overall area of large-seeded broadleaved trees and the degree of linkage of patches containing these species to the stronghold.

Principle 3 – Plan for red squirrels at the landscape scale

Defend the stronghold forest against grey squirrel incursion from adjacent areas.

The wider landscape around a stronghold plays an important part in its success as a safe haven for red squirrels by providing a defence against grey squirrel incursion. The role of Forestry Commission Scotland will be particularly important here. Forestry Commission Scotland will lead local management plans and will encourage a co-ordinated approach to managing the boundary. Forest managers should also follow advice in the Forestry Commission Practice Guide *Forest design planning: a guide to good practice* (1998).

Box 6 – Grey squirrel incursion through the landscape.

Managing for red squirrels at the landscape scale needs to consider whether adjacent forested areas will attract grey squirrels – this will influence the defendability of the stronghold and reveal which management approaches are most appropriate. For example, large-seeded broadleaved woodland a 1 km or more beyond could be an important source of grey squirrels dispersing into the stronghold and competing with red squirrels. The likelihood and frequency of this will be influenced by the number of dispersal corridors into the stronghold, and the degree to which grey squirrels are established in the adjacent woodlands. Grey squirrel control may therefore be an appropriate management option around some stronghold forests.

Stronghold forest managers can work with neighbouring landowners to plan how to best manage adjacent woodlands to meet other objectives whilst still maintaining suitable red squirrel habitat. Planning for red squirrels at the landscape scale will need to reflect the circumstances at each site but management actions could include:

Manage the stronghold boundary

- Manage the boundary according to its geography (natural barriers such as coastline or mountains), local landowner support and defendability from grey squirrel incursion;
- Avoid planting large-seeded broadleaved trees in areas that link the stronghold with other wooded areas beyond. If large-seeded broadleaved trees are essential to a designated habitat or species, then any connection to the stronghold should be restricted to a small proportion of the stronghold's edge which can be monitored for grey

squirrel incursion. The internal design of the stronghold should then focus on deterring grey squirrels from colonising it.

- Consider an 'area of influence' close to and adjacent to a stronghold in which to target any grey squirrel monitoring or control. The size and shape of this area will reflect the local geography, the functional habitat of woodland cover within it, and the degree of connectivity to the stronghold via possible incursion corridors;
- Identify pinch-points and potential invasion routes for grey squirrels. Any potential corridors that do exist should be broken or phased out where possible. In some areas it may be important to control greys before they enter the stronghold to prevent competition or disease transmission;
- In some locations road traffic mortality may be significant – warning signs may be appropriate.

Figure 8 Inshriach red squirrel stronghold.

Minimise grey squirrel competition

- For strongholds with habitat where grey squirrels may thrive, Forestry Commission Scotland will encourage adjacent landowners to favour small-seeded rather than large-seeded broadleaved species.

Monitor and control grey squirrel populations

- Grey squirrel control efforts can be made by more effective by landowners joining regional monitoring or sightings schemes;
- A rapid reaction plan should be drawn up in case grey squirrels are found – landowners can work with local squirrel groups to prepare a contingency plan to monitor grey squirrel incursion;
- Landowners should be prepared to allow grey squirrel control to take place on their land, if needed. To be effective, control efforts must be planned and costed in relation to manpower and resources so they can be sustained over the longer term.

Box 7 – Managing disease risk for red squirrels.

Disease surveillance is vital to discover outbreaks of known viruses such as SQPV as well as emerging or undetected diseases, and to monitor the patterns and spread of diseases. See page 14 for contact details for some relevant regional groups. Key actions to protect red squirrel stronghold populations from disease risk are:

- In line with best practice guidance, if an outbreak of SQPV is confirmed in red squirrels all feeders should be removed and supplementary feeding should cease indefinitely.
- Wear disposable gloves when handling dead squirrels.
- Dead red squirrel bodies can be sent for post-mortem examination, to further our knowledge on the conservation, welfare and diseases of red squirrels. Further advice is available at: www.red-squirrels.org.uk/pmortem.asp

Principle 4 – Plan forest operations to reduce short-term impacts on populations and sustain long-term resilience

Minimise the population level effects of operations where possible.

Felling and regeneration is essential in planted forests to create and maintain good red squirrel habitat and long-term carrying capacity, as well as to meet other objectives. Nevertheless, routine operations such as thinning and harvesting can potentially have a detrimental short term effect on local red squirrel populations by removing suitable habitat. For example, forced dispersal across open, felled habitat is likely to increase mortality and reduce overall population viability. A planned and maintained improvement of habitat for red squirrels is important for their long-term conservation so forest plans should be translated into a work plan process, so that operations have a defined volume or area to work with.

Detailed operational guidance on forest operations and red squirrels in Scottish forests is available from Forestry Commission Scotland, to reduce the risk of forest managers committing an offence by damaging red squirrel dreys or disturbing red squirrels at their dreys.

Figure 9 Thinning operations in a spruce forest.

Forest operations in strongholds should aim to:

Maintain canopy cover or linkage as far as possible

- Red squirrels find it difficult to cross large areas of open ground. Where clear fell patches are necessary, try to leave linkages between remaining neighbouring areas of mature forest as far as possible.
- When harvesting, maintain a dispersal route for as long as possible via contiguous canopy cover to the wider forest.
- Heavily thinned and open structures are an important part in the range of managed forest habitat types for restructuring, recreation and wildlife purposes but should not become a dominant habitat component in stronghold areas.
- Felling (e.g. for a windfarm development) should not significantly reduce overall forest size.

Increase seed production

- A light thinning regime will give older trees more space, encouraging them to produce more seed.

Avoid fragmenting the red squirrel population

- Ensure that planned harvesting does not fragment the resident red squirrel population and maintain some internal connectivity within the stronghold to allow widespread foraging and dispersal.

Principle 5 – Establish a monitoring system and a review process

A monitoring plan will help to assess the success of management actions and respond to changes in squirrel distribution, population trends or outbreaks of potentially fatal disease.

A monitoring plan will help managers assess how effective the stronghold's management approach is in maintaining a viable red squirrel population, and to indicate if anything needs to change. Having sufficient resources to maintain a consistent level of monitoring over the years is important so, where possible, efforts should be integrated with existing monitoring programmes.

There are different options suitable for monitoring a stronghold. The techniques used should be easy, repeatable and ideally of sufficient sample size to give confidence in the observed changes. This will help produce a distribution map of red (and where needed, grey) squirrels and a repeatable index to show any significant population change in red squirrels.

The monitoring strategy for each stronghold will need to address specific habitat types and management choices but will have the following objectives:

- to monitor changes in the stronghold's carrying capacity. This will be based on the proportion of food-source tree species and the proportion of different age classes for each;
- to monitor the presence / absence of red squirrels and grey squirrels across the forest and – if possible – adjacent areas. This can record sightings, other quantifiable evidence such as eaten cones (if only red squirrels are present), or hair tube results (if reds and greys are present). For this, methods must be standardised and repeated at regular intervals (e.g. every year);
- to monitor the response to trapping, if this is being carried out. Trapping data should reveal the number of grey squirrels trapped and the trapping effort (number of trap days) employed. A blood sampling programme will show the presence of squirrelpox virus (SQPV).

Advice on monitoring can be found in the Forestry Commission Practice Note 11 *Practical techniques for surveying and monitoring squirrels*, available on the Forestry Commission Scotland website, and we will develop further guidance on monitoring strongholds in due course. The techniques described in Practice Note 11 and as applicable to monitoring a stronghold are summarised in Table 4.

Table 4 Monitoring methods suitable for red and/or grey squirrels. Y = Yes, suitable; N = No, unsuitable.

	Presence and absence only			Quantity trend	
	Red only	Red & grey	Greys only	Red only	Grey only
Sightings	Y	Y	Y	N	N
Visual transects	Y	Y	Y	Y	Y
Drey counts (transects)	Y	N	Y	Y	Y
Cones	Y	N	N	Y	N
Hair tubes	Y	Y	Y	Y	N
Feeder boxes	Y	N	Y	N	N

Please note that current advice is to discontinue the use of feeder boxes in red and grey squirrel areas if SQPV is present in order to reduce the risk of disease transmission. SQPV can be tested for by blood sampling (ELISA antibody test) or by testing swab or tissue samples for viral DNA (qPCR).

Figure 9 A red squirrel feeder box.

Useful sources of information

Publications

Forestry Commission Information Note (FCIN069)
Climate change and British woodlands

Forestry Commission Practice Note (FCPN011)
Practical techniques for surveying and monitoring squirrels

Forestry Commission Practice Note (FCPN005)
Red squirrel conservation

Forestry Commission Practice Guide (FCPG014)
Restoration of native woodland on ancient woodland sites

Online resources

Forestry Commission
www.forestry.gov.uk/redsquirrelconservation
Forestry Commission Scotland works on the national forest estate and with partners on private land to manage wooded areas to benefit red squirrels and to control grey squirrels.

Forest Research
www.forestry.gov.uk/fr/climatechange
Information on the implications of climate change in forestry.

Scottish Natural Heritage
www.snh.gov.uk/about-scotlands-nature/wildlife-and-you/red-squirrel
SNH works to protect the red squirrel through legislation, advice and partnership working.

Saving Scotland's Red Squirrels
www.scottishsquirrels.org.uk
SSRS aims to halt the decline of red squirrel populations in key parts of north Scotland.

Red Squirrels in South Scotland
www.redsquirrels.org.uk
RSSS works to co-ordinate red squirrel conservation and grey squirrel control in the Scottish Borders, Dumfries & Galloway and Ayrshire.

Red Squirrels of the Highlands
www.redsquirrelsofthehighlands.co.uk
This group works to encourage red squirrel conservation in the Highlands of Scotland.

The UK Forestry Standard
www.forestry.gov.uk/ukfs

UKFS Guidelines on Forests and Biodiversity
www.forestry.gov.uk/ukfs/biodiversity

Scottish Rural Development Programme (SRDP)
www.scotland.gov.uk/srdp

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