



# COMMISSIONED REPORT

---

Commissioned Report No. 089

## **Identification of priority woodlands for red squirrel conservation in North and Central Scotland: a preliminary analysis**

(ROAME No. F02AC334)

*For further information on this report please contact:*

Dr. Mairi Cole  
Species Group  
Scottish Natural Heritage  
2 Anderson Place  
EDINBURGH  
EH6 5NP  
Telephone: 0131-446 2068  
E-mail: [mairi.cole@snh.gov.uk](mailto:mairi.cole@snh.gov.uk)

*This report should be quoted as:*

*Poulsom, L., Griffiths, M., Broome, A. & Mayle, B. (2005). Identification of priority woodlands for red squirrel conservation in North and Central Scotland: a preliminary analysis. Scottish Natural Heritage Commissioned Report No. 089 (ROAME No. F02AC334).*

---

This report, or any part of it, should not be reproduced without the permission of Scottish Natural Heritage. This permission will not be withheld unreasonably. The views expressed by the author(s) of this report should not be taken as the views and policies of Scottish Natural Heritage.



## Identification of priority woodlands for red squirrel conservation in North and Central Scotland: a preliminary analysis

Commissioned Report No. 089 (ROAME No. F02AC334)

Contractor: Forest Research

Year of publication: 2005

### Background

The red squirrel (*Sciurus vulgaris*) is native to Britain and was formerly widespread throughout England, Scotland and Wales. It is now restricted primarily to Scotland, the north of England, and small pockets in Wales and southern England (Pepper *et al.*, 2001). The identification of key sites where management to benefit red squirrels will be a priority is central to the maintenance of viable self-sustaining populations of red squirrels in the future. This report presents the results of analysis to apply the criteria proposed by Reynolds & Bentley (2001) to identify such sites across Scotland.

Phase 1 of this study used information on woodland size and composition (broadleaf or conifer) and squirrel distribution to select blocks of woodland which conformed to the criteria. These were identified throughout Central and North Scotland and thereby supplement the previous analysis for Dumfries and Galloway and Borders region (Poulsom *et al.*, 2003).

The aim of Phase 2 was to identify and rank sites for red squirrel conservation management within these regions.

### Main findings

- Data quality was variable for squirrel distribution/presence, woodland composition and management plans. This influenced methods of data analysis.
- 12 scoring factors were used in the ranking process. No region scored highly for every factor, with the woodlands of each region having particular strengths and weaknesses.
- 192 woodlands were initially selected as suitable priority areas for red squirrel conservation. Woods were rejected due to lack of red squirrels or presence of grey squirrels. 127 woodlands were included in the final analysis and ranking.
- All woodlands were in Grampian, Highland, Strathclyde, Central, Fife and Tayside. There were no woodlands in the Lothians in the final ranking list.

- A higher proportion of woods were in private ownership (52); compared to Forestry Commission ownership (45). The remaining 30 woods were jointly owned.
- With the exception of Strathclyde south, high ranking woodlands were found in each region.
- The work identified three vulnerable areas for the spread of grey squirrels along Deeside and Donside, in Grampian, and at the top of the Cowal and Kintyre peninsulas, in North Strathclyde. Grey squirrel control targeted at these areas would significantly impede the spread of grey squirrels into currently vulnerable red squirrel populations.
- Improved data on squirrel distribution is required.

---

*For further information on this project contact:*

**Dr. Mairi Cole, Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP.  
Tel: 0131-446 2068**

*For further information on the SNH Research & Technical Support Programme contact:*

The Advisory Services Co-ordination Group, Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP.  
Tel: 0131-446 2400 or **ascg@snh.gov.uk**

---

## **Acknowledgements**

The authors would like to thank the following people for all their help in providing information and comment on this report:

Louise Sing, Dave Tracy, Andy Kennedy, Glen Brearley, Chris Brown, Colin McNair, Bruce Taylor, Charles Bushby, Tom Pearson, Stephen Tong, Tom McLellan, John Little, Neil McKay, Ian Collier, Gavin Legge, Malcolm Wield, Peter Walling, David Jardine, Lorne Campbell, Hugh Clayden, Norman Davidson, Howard Davies, Lesley Halsall, Simon Hodge, Colin Leslie, Chris Nixon, Nick Mainprize, Brian Allison, Steve Brown, Ken Smith, Laura Wright, Roger Wilson, David Whitaker, Tracy Brown, Ken Thomson, Charlie Taylor, Rob Coope, Emma Stewart, Janie Steele, Rob Soutar, Mic Canham, John Spittall, Geoff Shaw, Iain McNichol, Paul Raisbeck, Keith Miller, Juan Arkotxa, Miller Harris, Alistair Lumsden, Patrick Porteous, Stuart Wilkie, Stuart Blackhall, Gordon Donaldson, Andy Greathead, Robin Dixon, Arnold Bijlsma, David Dewar, Gareth Wyman, Will Anderson, Stuart Taylor, Mr C MacBrayne, Doug Glenny, Stuart Connolly, Fergus Tickell, Glenn Heggs, Mr A Dickson, Jamie Cowie, Kenny Wright, Ian McLellan, Mr Sherrill, David Robertson, Gordon Robertson, Bob Furniss, Tessa Jones, Diane Holman, Marina Curran-Colthart, Graham Taylor, Polly Freeman, Alan Ross, Ian Cornforth, Shirley McGowan, David Anderson, Colin McLean, David Kennedy, Lucy Sumsion, Helen Docherty, Phil Hoare.

The maps shown in this report have been created from the National Inventory of Woodlands and Trees: Interpreted Forest Type. This data set was completed in July 2000 and is based on aerial photography and Ordnance Survey mapping with permission of the Controller of Her Majesty's Stationary Office. (c) Crown copyright – Forestry Commission Licence No. 100025498.



## **Contents**

### **Summary**

### **Acknowledgements**

<b>1</b>	<b>INTRODUCTION</b>	<b>1</b>
<b>2</b>	<b>METHODS</b>	<b>3</b>
2.1	Data sources and data quality	3
2.2	Data analysis approach	5
<b>3</b>	<b>RESULTS</b>	<b>10</b>
3.1	Woodlands excluded from the analysis	10
3.2	Woodlands included in the analysis and ranked for suitability as priority areas for red squirrel conservation	12
3.3	Results by region	12
<b>4</b>	<b>DISCUSSION</b>	<b>23</b>
4.1	Discussion of the ranked woods in the 5 regions of Scotland	23
4.2	Woodland management policy influences on habitat	25
4.3	Regional analysis	27
<b>5</b>	<b>CONCLUSIONS AND RECOMMENDATIONS</b>	<b>34</b>
<b>6</b>	<b>REFERENCES</b>	<b>36</b>
<b>APPENDICES</b>		
<b>Appendix 1</b>	<b>Scoring sheet for red squirrel reserves proposed by Reynolds &amp; Bentley (2001)</b>	<b>37</b>
<b>Appendix 2</b>	<b>Questionnaire for the regional contacts, woodland owners and agents</b>	<b>39</b>
<b>Appendix 3</b>	<b>Protocol for assessing presence of red squirrels in woodlands</b>	<b>41</b>
<b>Appendix 4</b>	<b>List of 127 woodlands ranked by priority for red squirrel conservation</b>	<b>43</b>
<b>Appendix 5</b>	<b>Tables showing woodland rankings per region</b>	<b>47</b>
<b>Appendix 6</b>	<b>Red and grey squirrel distribution at the 10km<sup>2</sup> scale for Scotland</b>	<b>51</b>
<b>Appendix 7</b>	<b>Location of the 192 priority woods in North Scotland and grey squirrel distribution</b>	<b>52</b>



## 1 INTRODUCTION

The red squirrel (*Sciurus vulgaris*) is native to Britain and was formerly widespread throughout England Scotland and Wales. The red squirrel has been displaced from much of its former range since the introduction of the North American grey squirrel between 1876 and 1920's (Middleton, 1931). Over the last 30 years the range of the red squirrel has contracted dramatically and it is now restricted primarily to Scotland, the north of England, and small pockets in Wales and southern England (Pepper *et al.*, 2001). Scotland is now most probably the stronghold for at least 75% of the UK population (Harris *et al.*, 1995).

The red squirrel is listed in Appendix III of the Bern Convention and is protected by Schedules 5 and 6 of the Wildlife and Countryside Act, 1981 and Schedules 5 and 6 of the Wildlife (Northern Ireland) Order 1985. It has been identified as a Priority species in the UK Biodiversity Action Plan. Proposed actions under the Red Squirrel Species Action Plan identify the preparation and implementation of site management plans for all sites with viable populations to safeguard their future. Delivery of the Species Action Plan is achieved through the UK Strategy for Red Squirrel Conservation. Two main aims are:

1. to maintain viable self sustaining populations of red squirrels where populations are healthy and grey squirrels are rare or absent; and
2. to maintain or expand red squirrel populations which are currently threatened because of isolation, small size or proximity to grey squirrel populations.

The identification of key sites where management to benefit red squirrels will be a priority is central to the delivery of these aims.

The red squirrel appears to have a competitive advantage over grey squirrels in large areas (>200ha) of coniferous woodland, particularly where there are no large-seeded broadleaf trees (Gurnell & Pepper, 1993). Reynolds & Bentley (2001) proposed a method by which priority sites for red squirrel conservation management could be identified based on the proximity of grey squirrels, habitat size and suitability, site defendability, site management and socio-economic criteria (Appendix 1).

Mayle *et al.*, (2002) used GIS analysis to identify potential priority areas for red squirrel management throughout Scotland based on information on squirrel presence (at the 10km<sup>2</sup> scale), and woodland size and composition (broadleaf or conifer). Woodland composition data was derived from data in the 'National Inventory of Woodlands and Trees' (NIWT) (Anon., 1995) but as NIWT only identifies woodlands as conifer or broadleaf, identification of areas of large-seeded as opposed to small seeded broadleaf trees was not possible. For this reason all woodlands with more than 5% broadleaf presence were excluded from the priority areas.

To allow ranking of sites within the 'priority' areas identified, further analysis using detailed information on tree species and the other criteria identified by Reynolds & Bentley (2001) was required. Red squirrel officers in the Scottish Borders and Dumfries and Galloway have already obtained the necessary information and applied the more detailed analysis to identify potential woodlands for red squirrel conservation in these areas. The aim of this project is to identify and rank sites for red squirrel conservation management within the priority areas across the rest of Scotland (divided into the following regions: Highland, Grampian, Strathclyde, Central, Tayside, Fife and the Lothians and hereafter, termed the 5 regions) based on the criteria

outlined by Reynolds & Bentley (2001). Given the uncertainties about squirrel distributions and woodland composition, this was not anticipated to provide a definitive list but to establish a transparent and repeatable process. Where possible, the analysis was to consider conflicts that may arise with other priority species and habitats for which Action Plans have been developed and priority areas identified, or where, for economic reasons, owners may not wish to restock woodland following felling, leading to deforestation.

The initial phase of this project was completed in June 2003. This involved mapping grey squirrel records by six figure grid reference to provide an indication of the level of grey squirrel presence rather than just presence or absence at the 10km<sup>2</sup> scale (red squirrel data was used at the 10km<sup>2</sup> scale). The current Scottish Squirrel Database (SSDB) provided the most up to date information for this task. NIWT and Interpreted Forest Type data for Scotland was then used to select continuous areas of woodland greater than 200ha in size and with less than 5% broadleaf trees. Woodland blocks in the 5 regions, within the distribution range of the red squirrel, which met the criteria above and which had no record of a grey squirrel in that woodland block were selected and ranked by size. A map was produced identifying potential sites for red squirrel conservation management by ownership (Forestry Commission or private). A strategy was also prepared for Phase 2 work including further analysis using additional data sets, local area and landowner/manager knowledge, and collation of information on potential management conflicts to allow a final priority ranking to be completed.

This report details the results of Phase 2 and provides a final ranked list of woodland sites where management to benefit red squirrel conservation will be a priority within the 5 regions of (north and central) Scotland. Details of the final scoring and ranking analysis are provided in the Appendices.

## **2 METHODS**

### **2.1 Data sources and data quality**

Initial priority woodland selection was based on squirrel distribution data from the SSDB, and woodland composition and size from NIWT. Further detailed information on the woodlands, their surroundings and their management, necessary for the analysis, was obtained from other data sets (see Table 1) and from local contacts. Data was collected from local contacts via a questionnaire (Appendix 2), which was either sent out or followed during the meeting/phone call, to ensure consistency in data collected. Key to this process was consultation with regional Red Squirrel Groups or other relevant contacts eg from SNH, Farming and Wildlife Advisory Group (FWAG), Forestry Commission and other interested parties, over the initial selection of priority woodlands. This also provided the opportunity for other woodlands to be put forward. Other local contacts consulted included FC woodland officers, woodland agents, LBAP officers or other conservation organisations such as The Woodland Trust.

There were a number of problems related to the quality of the data available for the analysis from both the data sets used in the initial GIS analysis (NIWT and SSDB) and the information available from local sources.

#### **Quality of datasets**

In NIWT, the 'conifer' category refers to woodland composed of at least 80% conifers. Therefore, it was possible for the priority woodlands to include a broadleaved component of up to 20%. Data from the SCDB and anecdotal information was required to determine the actual broadleaved component of the woodlands. NIWT also tended to split woodlands into separate polygons even where woodland blocks are only separated by a narrow gap such as a road or a wayleave, which squirrels are quite capable of crossing. Consequently, woodlands which might function as one unit in terms of squirrel habitat may have been analysed as separate, smaller woodlands with possible implications for ranking position.

The SSDB may not represent the true distribution of red and grey squirrels in Scotland, as data are based on a variety of sources rather than on systematic survey of the whole country. Under these conditions, records could be biased towards the areas where recorders were active. Data on red squirrel distribution was only available at the 10km<sup>2</sup> resolution raising the possibility that the individual priority woodlands, although within the red squirrel range, might not contain red squirrels.

#### **Data received from the questionnaires**

Throughout Scotland, the levels of activity amongst local Red Squirrel Groups varied and this influenced how well red squirrel presence could be verified in the selected woodlands. For example, in Ayrshire there is a well co-ordinated and active Red Squirrel Group with members representing a range of conservation organisations, with extensive knowledge of squirrel presence in their area. This contrasted with the Lothian region where there is no recognised Red Squirrel Group, leading to difficulties in ascertaining the most appropriate person to discuss the woodlands selected. The extent of local knowledge also affected the number of potential woodlands suggested for inclusion in the analysis. For example, a contact point for red squirrel conservation in Central region was not available to discuss the woodlands and hence no additional woodlands were included from this area. It is unclear to what extent, this has led to under representation of woodlands in this area.

**Table 1 Data gathered and sources**

<b>Data</b>	<b>Sources</b>
Presence of grey and red squirrels in the woodland	Questionnaire responses
Nearest grey squirrel	Questionnaire response and Scottish Squirrel Database (SSDB)
Species composition of the woodland	National Inventory of Woodlands and Trees (NIWT) for Phase 1, questionnaire responses and Forestry Commission (FC) Sub compartment database (SCDB) for Phase 2
Age structure of the woodland block	Questionnaire response and SCDB
Proportion of large-seeded broadleaves in 5km buffer	Questionnaire response, Land Cover Map2000 (LCM 2000) and NIWT
Human population size in 5km buffer	Questionnaire response, LCM 2000 and Scottish Census data
Woodland ownership	Questionnaire response and FC Woodland Grant Scheme GIS layer(WGS)
Landowner support for red squirrel conservation	Questionnaire responses
Ownership security	Questionnaire responses
Felling regime	Questionnaire responses
Other species of conservation interest	Questionnaire responses
Potential management conflicts	Questionnaire responses

The quality and availability of data varied quite significantly between the privately owned and FC owned woods, with the co-ordinated data management approach across the whole FC estate ensuring a consistency not available for the private woodlands. With regard to species composition and age of the woodlands, for example, the SCDB lists all species planted, whereas the data from the private woodlands may be limited to the main species planted. As one of the scoring categories used was number of conifer species present, it can be argued that the level of detail available in the SCDB could bias woodland quality analysis.

For some woodlands, information on population stability, landowner support, ownership security, species composition, woodland age, felling regime and development potential was not available. In such cases, assumptions or interpretations were made. For example, if no information was available on security of woodland ownership it was assumed to be secure as potential woodland sales or clearance was usually highlighted. Similarly, where no information was provided on landowner support for red squirrel conservation, it was assumed that support was forthcoming. Only, in very few cases were owners found to be unsupportive. Also, in the absence of information that owners were proactively supportive, the middle ground of 'supportive' was adopted.

There were also incidences where data were provided in a very imprecise format for categories such as species composition, tree age and felling regime. In these cases, a score was ascribed based on knowledge obtained from adjacent woodlands and from general knowledge of the area, which had been built up in the course of this study. In all, only about 25% of all woodlands analysed required some interpretation of this kind and less than 10% of the woodlands required more than two factors to be estimated. The availability of data on percentage of broadleaves that were large-seeded within the 5km buffer zone was so patchy that it has been excluded from the final scoring process. For five of the woodlands there was insufficient data available to justify inclusion in the study and these were removed from the analysis.

## **2.2 Data analysis approach**

Data from the sources described above were brought together in a single analysis. Twelve factors were used as the basis of the analysis and scores were allocated to each (Table 2). Where quantitative data was available the range of values was split into five or more categories, subjectively assessed factors, eg landowner support for red squirrel conservation were assigned a maximum of three categories. This put less weighting on the factors that were difficult to categorise and to avoid subjectivity. The 12 factors reflect the categories employed by Reynolds & Bentley (2001), but expand on them in a number of areas (see below). Each woodland, considered in the analysis, was scored for all factors, the scores were summed and the higher the overall result, the better the woodland was deemed for red squirrel conservation. From these scores a ranked list was produced (Appendices 4 and 5).

The Reynolds & Bentley (2001) method was developed for use in England and Wales and has, up until now, only been applied at a local or regional scale in Scotland. In applying it to such a wide area of varying character, it was necessary to adapt the methodology to make the interpretation of the data more quantitative, to allow woodlands with very different characteristics to be compared and to clarify the assumptions behind the analysis. The result is a more repeatable process that may be extended to other woodlands. Obtaining quantitative data was more time consuming and, for this reason, parts of one assessment criteria has been omitted (see 'Socio-economic/other considerations' section, below). However, on the whole the refinements have improved the methodology for application in Scotland and, in some parts, added more information and resolution to the interpretation.

**Table 2 Factors used in the scoring analysis showing rules and scores**

<b>Reynolds and Bentley Criteria</b>	<b>Factor</b>	<b>Rules</b>	<b>Score</b>
Magnitude of threat	Distance to nearest grey (km)	< 1km	1
		1 – <5km	2
		5 – <20km	3
		20 – <50km	4
		> 50km	5
Extent and suitability of habitat	Woodland size (ha)	200 – 500	1
		501 – 1000	2
		1001 – 2000	3
		2001 – 5000	4
		5001 – 10000	5
		>10000	6
	Number of conifer species present	(number of conifer species present with 1% cover or more)	
	% Cover of all conifers other than Sitka spruce	0 – 20%	1
		21 – 40%	2
		41 – 60%	3
61 – 80%		4	
81 – 100%		5	
% of trees between 30–60 years old	0 – 20%	1	
	21 – 40%	2	
	41 – 60%	3	
	61 – 80%	4	
	81 – 100%	5	
Red Squirrel population stability	Unstable, unhealthy, declining	1	
	Stable	2	
	Stable, healthy and increasing	3	
Site defendability	Landscape Defendability	Results of the defendability analysis were divided by 10 to avoid excess weighting compared to other factors	See text
	Human population in 5km buffer	>10000	1
		5001 – 10000	2
		1001 – 5000	3
		501 – 1000	4
100 – 500		5	
<100		6	
Landowner support for red squirrel conservation	Not supportive or indifferent	1	
	Supportive	2	
	Proactively supportive	3	
% of broadleaves in 5km buffer zone that are large-seeded species	Summarised by region as not available for every woodland Not used as a factor in analysis	Not scored	
Socio-economic/ other considerations	Management – Felling regime (% cover clearfell)	81 – 100%	1
		61 – 80%	2
		41 – 60%	3
		21 – 40%	4
		0 – 20%	5
	Management – Site Development	Actual development	1
		Development planned at some point	2
		No development planned	3
Ownership of woodland security	Ownership not secure	1	
	Ownership secure	2	
Other species of conservation interest	Summarised by region. Not used as a factor in analysis	Not scored	

## **Magnitude of threat**

The magnitude of threat criteria is based on whether red and grey squirrels are present and at what levels. Reynolds & Bentley (2001) recommend considering woodlands that have reds and only a few greys present. Due to the differences in squirrel distributions between England and Scotland, this analysis uses more stringent criteria, only considering woodlands that have red squirrels and are grey squirrel free. This factor is not scored as it is taken as the baseline condition, ie–minimum criteria. Including all woodlands that were in the red squirrel range and had the potential to be colonised would have added many more woodlands to the analysis and required an assessment of their connectivity and an understanding of land use changes that could impact upon woodland connectivity. This extra work was beyond the scope of the present contract. Ascertaining that only red squirrels and not grey squirrels were known to be present in the woodlands was of key importance to the analysis, as any of the priority woodlands (identified in the initial GIS analysis in Phase 1) that did not match this criterion were rejected. Squirrel status of the priority woodlands as indicated by the SSDB, was confirmed by local contacts, including woodland owners/managers. Where this information was not available in red squirrel only areas, a field survey for squirrel signs was carried out by Forest Research Technical Support Unit (TSU) (see survey method in Appendix 3). Six woodlands in Highland were surveyed in this way. Assumptions that the SSDB records for red squirrel presence and grey absence within a woodland were correct were only made when local contacts could not help and where use of the squirrel signs survey was precluded due to the woodlands occurring within the range of both squirrel species. Nine woodlands were included based on this assumption.

For the magnitude of threat criteria, the distance (km) of the nearest grey squirrel to the woodland was measured as an alternative interpretation of Reynolds' & Bentleys' 'greys are expected to appear soon' judgement. Distance to nearest grey squirrel was scored (Table 2) and used as the first of 12 factors in the analysis.

## **Extent and suitability of the habitat**

Reynolds & Bentley (2001) use two factors to assess the extent and suitability of the habitat: 'woodland type & size' and '% of mature large-seeded broadleaves'. In this analysis woodlands were only included if they were greater than 200ha in size and either a) conifer woodlands containing less than 5% large-seeded broadleaves, or b) conifer/birch woodlands containing less than 5% large-seeded broadleaves. In the initial GIS analysis (Phase 1), woodlands in NIWT were selected which matched (a) and were within the range of red squirrel but with no record of grey squirrel. This rule was relaxed to include woodlands described in (b) when suggested for inclusion by local Red Squirrel Groups/contacts. As this was the baseline it has not been used as a factor in this analysis. Verifying what proportion of the broadleaf content of the woodland was large-seeded (ash, beech, oak, hazel, sycamore) or small seeded (birch or alder) by checking the SCDB or by local contacts was essential as NIWT only categorises woodlands as broadleaved or coniferous.

Woodland size was used as the second factor in the analysis. Reynolds & Bentley (2001) class woodland size as 200-2000ha and greater than 2000ha. The size range of woodlands encountered in this analysis was often much bigger than 2000ha so further categories were added to capture this variation, giving this factor extra weight (Table 2). This was done by dividing the range of woodland sizes recorded into six size classes, three of which cover woodland from 2000 to greater than 10,000ha in size.

Three extra factors were added into the assessment of 'extent and suitability of the habitat' criteria: conifer species diversity (number of different conifer species planted), proportion of different conifers present and the food potential of the woodland based on the % conifer area at cone-bearing age (30–60 years old). Table 2 gives the number of categories for each of these factors and how they have been scored.

Rather than interpreting population persistence from woodland size and composition, a more direct measure of this was sought by enquiring if the red squirrel populations in the woodlands were known to be increasing, stable or declining. This also avoided using the same information on woodland size and diversity twice in the analysis. However in most cases people didn't know about population status but assumed they were stable. There were some examples where declines or increases had been noticed and this information has been captured in the analysis.

### **Site defendability**

Site defendability, in the Reynolds & Bentley method, is a combination of landowner support, landscape defendability, buffer size and surrounding woodland cover. In this analysis the last three factors were combined into one GIS analysis. The method adopted was a cost-distance analysis, within ArcView 8.3 (ESRI, 2003) to assess the defendability of each of the priority woodlands identified. This method takes into account the landscape surrounding the woodlands and combines both the cover composition of the surrounding landcover and the orientation and distribution of landscape features to give a picture of the ease of intrusion by grey squirrels into a woodland, and hence its relative defendability. Each land cover type, as identified from the Land Cover Map 2000 (LCM2000), was given a value relating to the resistance of the habitat to the movement of grey squirrels. This reflected how far a grey squirrel could travel through a particular land cover type, ie high movement through woodland, low movement through open fields, and barriers to movement created by, for example, open water. A 'cost layer' composed of the resistance values for the landscape surrounding the woodland, accumulated up to a maximum of 10km, was calculated for every route a grey squirrel might follow from the woodland edge. Routes might range from straight out from every point along the woodland perimeter into whatever habitat was adjacent, to least-cost routes, eg following shelterbelts or riparian corridors. The accumulated 10km cost limit of each route defined the area of the 'cost buffer'. This was large where the landscape was permeable to grey squirrels but small when impermeable. This area was expressed as a proportion of the full 10km buffer zone, as re-scaling allowed comparisons to be made between woodlands of different sizes. The cost buffers allowed identification of woodland networks that appeared to be functionally connected for grey squirrels. Further analysis was conducted using these woodland networks, rather than the individual woodlands.

The GIS defendability analysis was carried out using LCM2000 dataset, which does not distinguish between large and small seeded broadleaves within the broadleaved woodland category. As large-seeded broadleaves are considered to provide the best habitat for grey squirrels, an attempt was made to find out what proportion of the woodland in the surrounding landscape was made of this woodland type. This information was obtained from local contacts and was sometimes not available. It has been used in this analysis only to add to the discussion of the merits of the different woodlands and not in the quantitative part of the analysis.

Land owner support for red squirrel conservation within the woodland and human population size in the 5km buffer zone surrounding the woodland, have been used as two separate factors in the assessment of site defendability criteria.

### **Socio-economic/other considerations**

For socio-economic/other considerations, Reynolds & Bentley methodology assess 5 factors: future age structure of woodlands, future species composition, felling regime, development and land-use changes, and security of ownership. Data on future conditions of the woodlands is available only occasionally in the form of long term management plans and the analysis of these is complex. To obtain this type of information consistently across the 192 woodlands analysed would have been an enormous task and beyond the scope of this contract. Good information was obtained on felling regime (proportions of woodland that was to be clearfelled or subject to other management such as continuous cover forestry or long term retention), landuse changes and ownership security and these three factors have been included in the analysis (Table 2). In addition, information was sought on the presence of other species of conservation interest, such as black grouse, whose active management may be indirectly detrimental to red squirrels. These data have been used when discussing the priority woodlands.

### **3 RESULTS**

144 woodlands were selected in the initial analysis (Phase 1) in Highland, Grampian, Strathclyde, Central, Tayside, Fife and the Lothians. The 144 woodlands were not evenly distributed between the five regions of Scotland. Strathclyde had the most (45 woodlands covering 149,000ha), followed by Highland (38 covering 71,000ha), Grampian (29 covering 75,000ha) and Central, Fife & Tayside (26 covering 34,000ha). Only four woodlands were identified in the Lothians. There were slightly more privately owned woodlands than FC woodlands selected, and just over a quarter were in joint ownership.

Following the regional liaison meetings, Red Squirrel Groups and contacts suggested 48 additional woodlands for inclusion. With the exception of the Lothians, between nine and 14 new woodlands were suggested for each region. No new woods were identified for the Lothians. Just over half of the new woodlands were in FC ownership, the rest being in private ownership.

In total, 192 woodlands were assessed for suitability as priority areas for red squirrel conservation.

#### **3.1 Woodlands excluded from the analysis**

Two woodlands had to be rejected as they were found to be mapping errors created in the GIS analysis of Phase 1. Five more woodlands were omitted from the analysis due to lack of information on woodland, composition, management and squirrel status. For these woodlands the only source of information was the woodland owner/agent who either could not be identified or who did not respond to any enquiries or return any information that could be analysed in time for inclusion in the report. Four of these woodlands were in Strathclyde and one in Highland.

An attempt was made to only include woodlands where red squirrel presence and grey squirrel absence, as indicated by the SSDB information, was verified by a local source. Local contacts confirmed there were no records of red squirrels in 37 of the woodlands that occurred within the red squirrel range, and grey squirrels were present in 21 woodlands for which the SSDB gave no records of greys (Table 3). For 14 of the latter, red and grey squirrels occurred together. The majority of woodlands where red and grey squirrel occurred together were in Central, Fife and Tayside. Most of the woodlands where red squirrels were not recorded were in Strathclyde and Highland. In total 58 woodlands were excluded due to the presence of grey squirrel and/or absence of red squirrel, and their distribution is shown in Figure 1.

A further nine woodlands (seven in Strathclyde and two in Central, Fife and Tayside) could have been excluded as the local contacts were not able to confirm the squirrel status indicated by the SSDB. A decision was made to retain these woodlands in the analysis, as there was more likelihood of survey and monitoring in the future, which would help to confirm squirrel status.

**Table 3 Excluded woodlands broken down by region and reason for exclusion**

	<b>Strathclyde</b>	<b>Highland</b>	<b>Grampian</b>	<b>Central, Fife &amp; Tayside</b>	<b>Lothian</b>	<b>Total</b>
No red squirrel	14	16	0	6	1	37
Grey squirrel only	5	0	0	1	1	7
Grey and red squirrel	3	0	2	7	2	14
<b>Total</b>	<b>22</b>	<b>16</b>	<b>2</b>	<b>14</b>	<b>4</b>	<b>58</b>

Figure 1 Woodlands excluded from the analysis



### **3.2 Woodlands included in the analysis and ranked for suitability as priority areas for red squirrel conservation**

127 woodlands were included in the final analysis. Most woodlands were in Grampian, Highland and Strathclyde (36, 33 and 33, respectively), and in Central, Fife & Tayside (25). There were no woodlands in the Lothians. Ownership of the woodlands was fairly evenly divided, though slightly more were in private ownership (52); compared to Forestry Commission ownership (45) and the rest (30) were jointly owned.

The 127 woodlands were ranked based on the suitability scores of the 12 factors used in the analysis (Table 2). The overall suitability scores for the 127 woodlands ranged between 43.1 and 25.8. The top ranking woodland (no. 6 – Ordiequish/Whiteash/Ben Agin) was in Grampian and the lowest ranking woodland (no. 119 – Gryfe Forest) was in Strathclyde. Half of the woodlands in Highland, Grampian and Central, Fife & Tayside achieved scores in the upper 50% of the score range. Woodlands in Strathclyde ranked relatively poorly with 80% of the woodlands being placed in the lower half of the score range. The top 10 ranking woodlands were in Highland (six) and Central, Fife and Tayside (three). No. 6 was the only woodland in Grampian that occurred in the top 10 ranked woodlands. Woodlands ranking in the bottom 10 were predominately in the southern part of Strathclyde region but were also to be found in each of the other regions and one woodland on the Isle of Arran was ranked in the bottom 10. For the nine woodlands for which unconfirmed data on red squirrel presence and grey squirrel absence was available, and the SSDB was assumed to be correct, all ranked at or below 59th position.

The best-defended woodlands occurred in West Argyll and on the Knapdale peninsular. The woodlands that were furthest away from grey squirrel were mainly in Highland and Strathclyde.

The largest woodlands occurred in Strathclyde. Woodlands with the greatest diversity of conifer species (in terms of number of species planted) tended to be found in Highland and Central, Fife & Tayside, whereas woodlands with the greatest proportion of area planted with conifers other than Sitka spruce were in Highland and Grampian. Woodlands with the most appropriate age structure for red squirrels (30–60 year old crops) were well represented in Grampian and Central, Fife & Tayside. Alternatives to clearfell management regimes were practised or were going to be used for more woodlands in Highland and Grampian. For the majority of woodlands, ownership was secure with only four out of the 127 likely to be sold.

### **3.3 Results by region**

#### **Highland**

The distribution of the 33 selected woodlands in Highland region is displayed in Figure 2.

The woods were distributed from near Lairg in the north to Ballachulish in the south, but were primarily concentrated around Speyside and to the west of the Great Glen. The highest ranked wood was number 8 (Rothiemurcus) which was ranked second overall in Scotland and the lowest ranked wood was number 99 (Abriachan) which was ranked 119th.

No woodlands were excluded from the analysis for the presence of greys but 16 were excluded due to the lack of reds. Woodland 39 (Inveroykel Estate/Rossal Wood), although scoring well appears to be at the

Figure 2 Priority woodlands in the Highlands



northern-most range for the red squirrels, while the westward range for reds declines markedly with increased distance north. There were no greys reported within 5km of any of the selected woodlands in the Highlands, and only one woodland (number 36, Glen Duror) had greys reported between five and 20km away. The validity of this grey sighting appears to be questionable due its extremely isolated location at the top of Loch Etive, although there was anecdotal evidence of release or escape of captive animals. For the remainder of the woods, 13 had grey squirrels over 20km away and the remainder had grey squirrels over 50km away.

Woodlands were evenly distributed between the six woodland size classes used in the analysis, with 24 woodlands between size scores of two and four (500–5000ha). There was an equal number of woodlands in each of the five age classes. Woodlands 43 and 61 had the greatest range of conifer species (8) while four woodlands only consisted of one species of conifer. However for all of these woodlands this conifer species was Scots pine. Only three woods contained greater than 80% Sitka spruce and all three of these were located south west of the region where Sitka spruce is better suited to the climatic and soil conditions. Woodlands 115 (Strathconon) and 177 (Strathgarve) were deemed to be worst defended woodlands but both woods scored 5 on the distance to nearest grey (>50km) so this acted well in their favour. The best defended woodland was number 16 (Tulloch/Curroul), reflecting its isolated position from centres of human population and the mountainous nature of the surrounding landscape. However, its population of red squirrels is said to be declining, which again maybe a factor of its isolation.

In all but four of the woods in the Highlands the population of red squirrels was believed to be stable and the ownership of the woodland secure. For 30 out of the 33 woodlands the human population in the surrounding 5km was less than 5000, reflecting the increasingly sparse human population in this region. Large-seeded broadleaves made up 0–90% of the broadleaved component in the 5km buffer, with oak being the predominant species. Woodlands 179 and 180 were located on the southern boundaries of Argyll and their high large-seeded broadleaf component reflects their location on the northern edge of the 'Atlantic oakwood region'. Beech increasingly became a component in woods towards Grampian.

Over one-third of the woods in the region were due to have more than 80% of their area clearfelled, but 13 woods had proposals for 60% of their area or more dedicated to continuous cover forestry (CCF) or non intervention. Only six out of the 33 woodlands were due to be developed in some way, with small scale housing (four woodlands) and windfarm developments (two woodlands). Four of the woodlands had owners who were unsupportive or indifferent to red squirrel conservation. However, in all of these cases this was due to concerns being raised over species-specific conservation with landowners preferring instead to focus on a habitat-based conservation approach. Three of the woodland owners were proactively in favour of red squirrel conservation.

A number of other species of conservation interest were noted in the woodlands, with black grouse and capercaillie widely distributed as well as occasional records for wood ants and pearl bordered fritillaries. A number of raptor species were also noted including ospreys, goshawk, hen harriers and merlin, and pine martens were widely reported.

## **Grampian**

The distribution of the 36 selected woodland in Grampian is shown in Figure 3. The distribution map shows two reasonably distinct groups of woodlands, those in northern Grampian along the coastal plain between Nairn, Elgin and Huntly and those concentrated along the valleys of the Dee and the Don.

Figure 3 Priority woodlands in Grampian



The highest ranked wood was number 6 (Ordequish/Whiteash/Ben Agin) which was ranked first overall in the five regions, and the lowest ranked woodland was number 122 (Kildrummy Estate/Clova) which was ranked 126th.

From the original 192 woodlands selected only two from Grampian were excluded from the analysis, but unlike Highland both of these were removed due to the presence of greys (woodland 131 located on the banks of the Don and wood 146 on the banks of the Dee). Three of the woodlands had grey squirrels reported less than 1km from their boundaries, these three being woodland number 17, on the banks of the Don and woodlands 147 and 148 in the Dee valley. Another nine woodlands have grey squirrels between one and 5km of their boundaries, again along the Dee and the Don valleys. None of the woodlands are more than 50km away from their nearest grey squirrel.

None of the woodlands in Grampian exceeded 10,000ha, but nearly two-thirds of the woodlands were bigger than 1000ha. Five out of the 36 woodlands only contained two species of conifer but in all but one case Scots Pine was the dominant species. 30 out of 36 woodlands contained between three and seven species of conifer. Only three woodlands contained greater than 80% Sitka spruce cover and 29 of the woodlands contained between 41% and 100% conifer cover other than Sitka spruce. Nearly half the woodlands had 60% of their trees at effective cone bearing age (between 30 and 60 years old).

The red squirrel population was thought to be stable in all of the woodlands selected, with the woodland ownership secure in all cases. Woodland 114 (Todlaw) had the lowest defendability score of all the 127 woodlands selected. The top defendability score for Grampian was shared by 14 woods possibly reflecting the uniformity of landscape. However, the top defendability score for Grampian of 2.8 was nearly half of the top defendability score overall of 4.5. Beech was the predominant large-seeded broadleaf species present, with sycamore also strongly represented and oak and hazel occasionally. While the proportion of large-seeded broadleaves in the 5km wide buffer zone ranged from 0% to 75%, for the vast majority of woodlands, the large-seeded component of the broadleaves in their buffer was less than 20%. Two of the woodland owners were indifferent to red squirrel conservation, three were positively in favour and were prepared to actively modify their management techniques to benefit red squirrels and the remainder of landowners were generally supportive. Out of the 36 Grampian woodlands finally chosen, six had human populations exceeding 10,000 in their 5km buffer zones with five in close proximity to Banchory and outlying villages. 26 of the woodlands had less than 5000 people in their buffer zone.

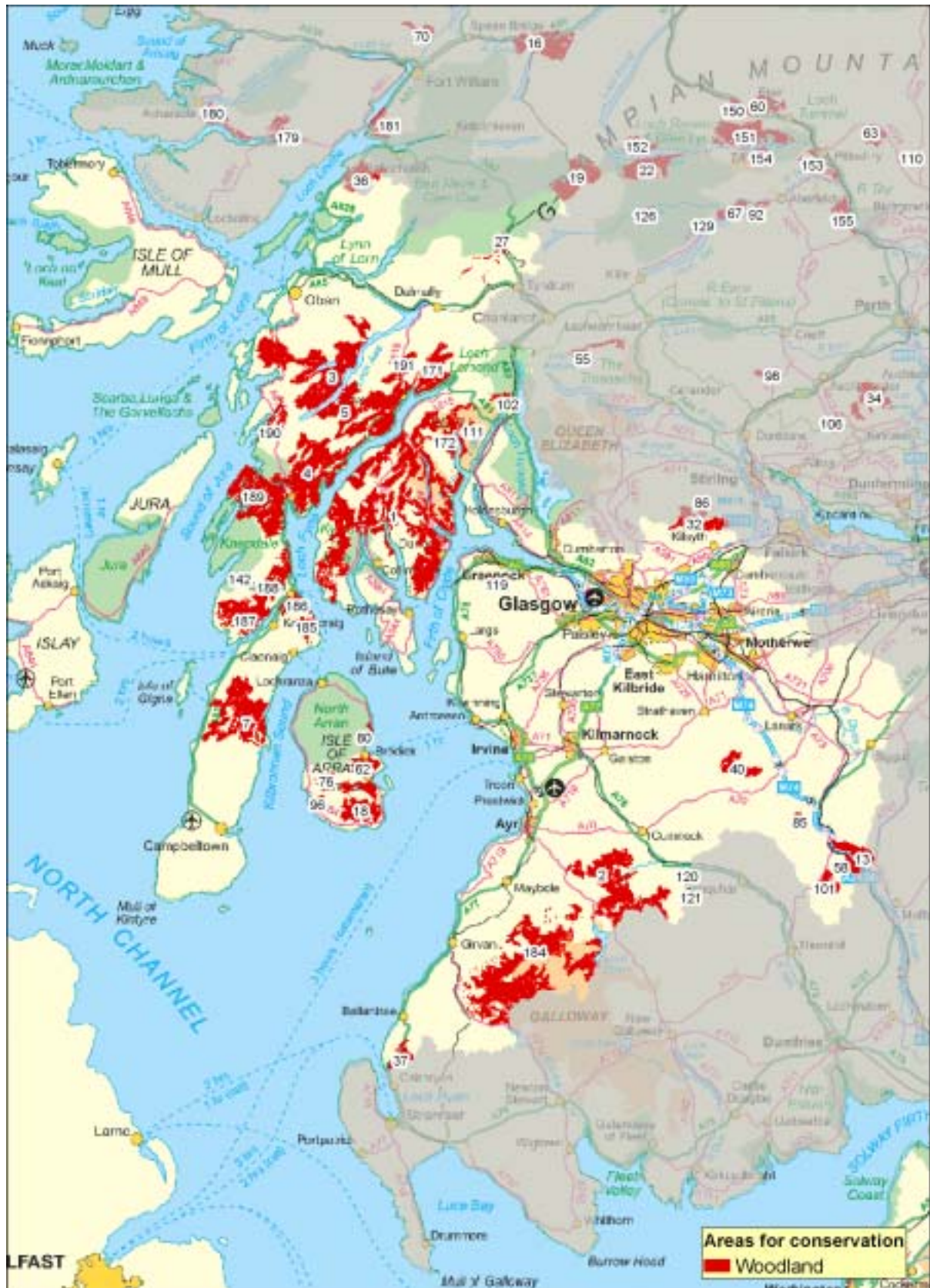
Nine woodlands were designated for clearfelling on over 80% of their area, but for a further 20 woodlands, CCF and long-term retentions was to be applied to at least 60% of the land. No actual development was being planned or carried out on any of the woodlands in Grampian. Capercaillie were widely distributed throughout Grampian, but only two woodlands reportedly contained black grouse. One of the woodlands reportedly contained otters.

## **Strathclyde**

The distribution of the 33 selected woodlands in Strathclyde region are shown in Figure 4.

The woodlands are concentrated in the north and in the far south of the region and these two areas will be dealt with separately as they are different in character.

Figure 4 Priority woodlands in Strathclyde



### **Strathclyde north**

Priority woodlands were concentrated in Knapdale and Cowal peninsulas, West Argyll and the Isle of Arran. The highest ranking woodland was number 7 (the most southern woodland on the Knapdale peninsula) which was ranked in 23rd position, and the lowest ranking was number 172 (Arkanglass estate) on the Cowal peninsular. A band of woodlands running along Glen Lochy, Strath Fillan, Glen Dochart and Glen Ogle were excluded due to the absence of red squirrel, as were woodlands on the south end of Knapdale peninsular. Woodlands along the west shore of Loch Lomond and near Helensburgh were rejected due to the presence of grey squirrels.

The woodlands in north Strathclyde were some of the largest in Scotland. Only six of the selected woodlands in Scotland were greater than 10,000ha, and four (woodlands 1, 4, 3 & 5) of these were in north Strathclyde. Woodland 1 covers most of the Cowal peninsula. The 19 other woods in the region ranged from 200–10,000ha, half being between 1000 and 5000ha. Woodland 1, 7 and 62 had at least 7 different conifer species present in the woodland but half of the woodlands in the region had four or less conifer species present. All the woodlands were dominated by Sitka spruce, which made up at least 80% of all the conifer blocks. Just under half of the woodlands had 20% or less of the conifer crops at cone bearing age (30–60 year). Three woodlands attained the maximum score (five) representing 80–100% of conifers at cone bearing age. These were woodlands 62 (on Isle of Arran), 188 (Meal Mhor) and 190 (Ormaig).

Red squirrel populations were considered to be stable in all the woodlands appearing in the final ranking and ownership of all these were also secure.

Eleven of the woodlands scored the highest figure for defendability produced in the analysis (4.6). These woodlands are all in West Argyll and Knapdale, running from the head of Loch Fyne and down the peninsula. Woodland 142 (Ormsary Estate) had the lowest defendability score in the area (1.7). The four most southerly woodlands on Knapdale peninsula were greater than 50km from the nearest grey squirrel and all the woodland on Arran were also given this top score. Distance to nearest grey squirrel was less for the woodlands in the north and west of the region; only one woodland was within 1km of a grey squirrel record (woodland 1). The size of human population may be significant in this region with most woodlands estimated as having between 1000 and 10,000 people in the surrounding 5km buffer zone. This region had the highest large-seeded broadleaf component, which was particularly true for woodlands in Argyll, which were surrounded by Atlantic oakwoods with occasional upland ash woods. The proportion of large-seeded broadleaves in the 5km buffer zone ranged varied from 0–70%.

With the exception of four woodlands, clearfell was planned for over 80% or more of the woodland area. Clearfell was planned for up to 40% of the area of woodland 1 and up to 60% of woodlands 102 (Glen Loin), 111 (Ardgarten) and 142 (Ormsley estate). For the majority of woodlands, no development or land use change was planned. Some development of windfarms and some housing was planned for two woodlands and development was a possibility for two further woodlands. While a number of woodlands contained black grouse, no capercaillie were reported as it is outwith the current range of capercaillie, excluding Loch Lomond sites. Raptor species present included golden eagles, hen harriers, osprey, merlin and peregrines and three woodlands in Argyll reportedly contained wood ants.

### **Strathclyde South**

The majority of the woodlands were located at the southern part of this region along the border with Galloway. Others were scattered along the M74 corridor and a few were located to the north and to the west of Glasgow. The woodlands in this region appear to be some of the least suitable in Scotland. The highest ranking woodland only comes 85th (out of 127) and the lowest ranking woodland takes bottom place.

Grey squirrel presence has had an important impact on the selection of the woodlands in this region. A large woodland to the south of Glasgow and another to the east of Motherwell have been excluded from the analysis due to the presence of grey squirrels. Some of these woodlands, notably the ones near East Kilbride and near Maybole contain both red and grey squirrels. For most of the woodlands grey squirrels are within 20km.

The largest woodlands were in the south of the region. Woodland 184 (Glentool) and woodland 2 (Carsphairn Forest) were over 10,000ha in size. The majority of woodlands were much smaller than this being less than 2000ha. Conifer diversity in all the woodlands was low with the majority having three species or less and with all but one woodland consisting of 80% or more Sitka spruce plantation. Woodland 13 (Erriff) was the exception with 20–40% of the conifer area planted with species other than Sitka spruce.

For most of the woodlands, conifers at cone bearing age made up more than 40% of the conifer woodland area. Woodland 40 (Todlaw and Cumberhead), 85 (Crawfordjohn) and 120 (Highcain), 80–100% of the conifers were at cone bearing age. But at 37 (Glen App Estate) and 58 (Bidhouse) less than 20% of the conifers were in the 30–60 year age class.

In all woodlands the red squirrel populations were considered to be stable, although reliable information was sometimes hard to ascertain on this point. The presence of a recognised Red Squirrel Group would help to clarify such areas of uncertainty.

Defendability scores were between 1.6 and 3.8, which is in the middle of the range of scores achieved in this analysis. Despite the high human population of this region the woodlands included in the analysis received relatively low scores for human population size in the 5km buffer zone. For most woodlands, population size in the surrounding 5km buffer did not exceed 5000 people. The large-seeded broadleaf component in the surrounding buffer zones was considerably lower than that found in the north of the region. However, there were still reasonably high percentages noted in some of the Ayrshire woodlands.

Woodland ownership was secure and all were supportive of red squirrel conservation. There were no definite plans for development or landuse changes in any of the woodlands but for nearly half, the possibility of windfarm development was mentioned. The felling regime in the Strathclyde south region is dominated by the clearfell system. This was planned for 80–100% of the area of each of the woodlands. Four of the woodlands were reported as having black grouse on their boundaries and otters, badgers, osprey and brown hare were also present in individual woods.

### **Central, Fife & Tayside**

The distribution of the 25 selected woodlands in Central, Fife & Tayside region are shown in Figure 5.

The selected woodlands were concentrated along Loch Rannoch and Loch Tummel valleys, and from Loch Tay south down the A9 valley to Dunkeld. Other woodlands were selected in the south of the region from the Trossachs to the mouth of the Tay.

Three of the woodlands were in the top 10 ranked as most suitable for red squirrel conservation in Scotland. These were 22 (South Rannoch), 135 (Glen Head) and 156 (Glen Doll). A further 12 woodlands ranked in the top half of all the woodlands analysed. There were four woodlands that fell below the 100th position out of 127, the one with the lowest scores was woodland 126 (Meggernie Estate).

Grey squirrel distribution has affected the choice of woodlands in this area and many woodlands were excluded due to the presence of greys being highlighted during the project. The majority of woodlands containing grey squirrel in this region also contain red squirrel. Grey squirrels were in reasonably close proximity to the woodlands in Central, Fife & Tayside, and no woodland was more than 50km from a grey squirrel record. Over half of the woodlands had grey squirrels within 5km.

There were no very large woodlands in this region. All the woodlands in the selection were of 5000ha or less and three quarters were less than 200ha in size. Conifer species diversity in the woodlands in the region was relatively high with half of the woodlands having between five and nine species. The proportion of the conifer plantation made up of species other than Sitka spruce was variable depending on the woodland. One woodland (60, Atholl Estate) was planted with 20% or less Sitka spruce and five others (mostly in the southern part of the region) were dominated by Sitka spruce (80–100%). Half of the woodlands were composed of between 20%–60 % Sitka spruce. In most of the woodlands, age structure was favourable for red squirrel. In 10 of the 25 woods, 80%–100% of the conifers were at cone bearing age, but at three of the woodlands (19 Barracks, 150 Clunes and 126 Meggernie Estate) less than 20% of the conifers were at cone bearing age.

Red squirrels were thought to be declining in one woodland (150 Clunes) but the population was considered to be stable in the rest. Landowner attitude to red squirrel conservation was mostly supportive, one was less supportive and three were considered very supportive. Land ownership was also secure for all the woodlands in this region.

Defendability scores for the woodlands in this region ranged from 0.5–4.0 and most scored between two and three, which was in the middle of the range of defendability scores calculated for the woodlands in the analysis. The most defendable woodland was woodland 158 (Tentsmuir) and the least defendable was woodland 128 (Airlie Estate). Most of the woodlands were in the less populated parts of the region. Half of the woodlands were estimated as having 500 or fewer people in the surrounding 5km buffer zone. Two woodlands, however, were given the lowest score for human population indicating there were more than 10,000 people in the buffer zone. These were 32 (Carron valley) and 158 (Tentsmuir). In these three regions the large-seeded component of the broadleaves in the buffer never exceeded 40%, and ranged from 0%–40%. Oak was strongly represented along with hazel. The presence of beech increased markedly with proximity to the Grampian region. Clearfelling appeared to be the preferred harvesting regime over most of the area of the selected woodlands. There were some exceptions where alternative felling regimes, or long

Figure 5 Priority woodlands in Central, Fife & Tayside



term retention, were planned for 80% or more of the woodland area as in woodland 55 (Loch Voil side), 60 (Atholl Estate), 158 (Tentsmuir), 98 (Greenscares/Coirrie Odhar) and 150 (Clunes).

Threat from development or land use change appeared particularly low for the woodlands of this region. For only five out of 25 woodlands was there a possibility of development – either for recreational facilities or windfarm development. A number of species of conservation interest were reported, notably black grouse and capercaillie. Other species found in individual woods were ospreys, hen harriers, golden eagles, pearl bordered fritillaries and dragonflies.

## **4 DISCUSSION**

### **4.1 Discussion of the ranked woods in the 5 regions of Scotland**

#### **Squirrel distribution**

Red and grey squirrel distribution was a major factor influencing woodland selection. The differing levels of resolution for the presence of grey and red squirrels were of particular concern and influenced the type of analysis possible. Ideally distribution data for the two species should have been at the same high level of resolution enabling presence to be identified to individual woodlands. This would also allow level of presence at the landscape scale to be considered.

Where red squirrel presence was only recorded at the 10km<sup>2</sup> level, it was necessary to confirm presence of red squirrels in woodland through discussions with local staff or site visits. The presence of red squirrels was not confirmed in 37 of the original 192 woodlands. However improved knowledge of squirrel distribution has resulted and it is recommended that revised distribution maps are produced. (This was outside the scope of this study). Where active Red Squirrel Groups are present they should be encouraged to survey woodlands for the presence of red and grey squirrels and report back to the SSDB.

Woodlands excluded due to the absence of red squirrels were located in north-west Highland region and at the southern tip of Knapdale peninsular. This is at the fringe of the red squirrel's range in Scotland. Other woodlands where red squirrels were absent, but which were within the red squirrels distribution range, were mostly plantations that were too young to support a squirrel population (ie pre-coning age).

Woodlands containing grey squirrels occurred in a band running from the north of Galloway, through the central belt (including the Lothians) and up the East Coast to Aberdeen. Many of these woodlands also contained red squirrels and represent important points of grey squirrel incursion. Grey squirrel control targeted at these areas could significantly benefit red squirrels by stopping the further spread of the species.

The high resolution of the grey squirrel data, recorded to 10m, enabled distance to the nearest grey squirrel to be used in the analysis of 'magnitude of threat'. Woodlands that lie close to the main grey squirrel areas such as Rhinebuckkie and Maryfield Woods (wood 147) in Grampian, and Airlie Estate (wood 128) in Central, Fife and Tayside therefore had a reduced ranking.

Size and stability of the red squirrel population within the woodlands was one of the most difficult factors to assess as it relied on good information about the red squirrel populations in the different woodlands. This was rarely available and as the majority of woodlands were scored as 2 – 'Stable' it has not influenced the overall ranking.

#### **Woodland and tree species distribution in Scotland and priority woodland distribution**

Although 17% of the land cover in Scotland is woodland, this is not evenly distributed across all regions. Of the area covered by this study, the most densely wooded region is Strathclyde (approx. 25%) followed by Grampian (approx. 20%) then Central, Fife & Tayside and Highland (15%). Lothian is least wooded with 10% cover.

In the study area, the largest and least fragmented woodland blocks are in north Strathclyde, Moray, along the Great Glen and northwards in the eastern Highlands, and in Central and Tayside. Woodland cover is also high in Speyside, and in Grampian along the Dee and Don valleys where, although the woodlands are small, they tend to be well linked. South of the Highland boundary fault, woodlands are generally very small and isolated, with the exception of a few large blocks south of Glasgow and on the Dumfries and Galloway border.

Tree species distribution across Scotland is dictated by variations in geology and climate. South of the Highland boundary fault, the geology tends to produce richer soils and native woodlands would be dominated by oak and mixed broadleaves (NVC classes W11 and W18). These have largely been replaced by Sitka spruce except on the low-lying sandy soils in Fife, where pines are the preferred plantation conifer species. North of the Highland boundary fault the geology is poorer and the soils more acid and nutrient deficient. Here Scots pine and birch are the dominant native woodland species. The range of these species is restricted by climate to areas such as Grampian and central and Eastern Highlands. On the western side of the Highlands, the highly oceanic and windy climate is less suitable for Scots pine and it is replaced by birch and oak naturally, or Sitka spruce in plantations. Currently the woodland composition of Scotland is dominated by Sitka spruce, which covers 47% of the woodland area. Pines make up a quarter of woodland, with Scots pine covering 13%. Of the broadleaved species, birch covers 8% of the woodland area and mixed broadleaves 6%, with oak making up a quarter of this area.

In terms of considering the distribution of priority woodland related to woodland cover in Scotland, the woodlands that were selected as 'potential' priority woodlands in Phase 1 of the analysis fall mainly within the areas where there are large contiguous blocks of woodland. The distribution of the woodlands selected during the suitability analysis in Phase 2 is strongly influenced by tree species distribution, with the highest ranking woodlands occurring in the Scots pine-dominated areas and, in particular, where the woodland blocks are also large, eg Moray, Speyside and parts of Central region.

Having indicated some areas that contain the high-ranking woodlands (above), it should be noted that no one region is optimal for all the suitability factors assessed, and different regions have particular strengths and weaknesses. Strathclyde, for example, has some of the largest and most defendable woodlands but the woodlands lack species diversity, tending to be dominated by Sitka spruce. Grampian has woodlands with the greatest proportion of area planted with conifers other than Sitka spruce, a larger amount of woodlands where alternatives to clearfell were practised, and woodlands with the most appropriate age structure for red squirrels. However, the woodlands scored poorly for defendability.

Assessing the variable qualities of woodlands requires the use of a multi-factor analysis to allow woodlands to be compared. This method would also accommodate other factors that would help to refine the ranking process, eg the future management regime of woodlands. Any further analysis should be extended to cover all regions in Scotland, including woodlands identified as potential priority areas within Dumfries and Galloway and the Borders. The results from this study suggest that woodlands from each Region, perhaps with less from Strathclyde, would feature as all are represented in the top 25 sites.

### **Woodland ownership**

Differences of privately owned, Forestry Commission and jointly owned woodlands may reflect differences in management as well as in size. Privately owned woodlands were generally smaller than the FC

woodlands, and jointly owned woodlands tended to be larger than FC woodlands. Private woodlands also appeared to have a lower conifer species diversity compared to the FC and jointly owned woodlands in terms of numbers of species. However, where conifers other than Sitka spruce were planted, they often made up a larger proportion of the woodland. For example, of the 15 woodlands that had 80 to 100% of other conifers planted, 10 were in private ownership. However, it should be noted that the higher reported conifer diversity in FC woods compared to private woods may be an artefact of better data availability for FC woodlands provided through SCDB.

Woodland age structure suitability was scored by considering the proportion of trees of cone bearing age (30–60 years old), within 5 categories. There were more FC-owned woodlands (37%) in the top category of 80–100% of the crop aged between 30–60 years. For private and jointly owned woods, there tended to be a more equal number of woodlands in each of the score classes for this factor. There was a tendency for felling regime to differ with ownership, with less clearfell being practised in privately-owned and jointly-owned woodlands compared to FC woodlands.

Landowner support might be expected to differ with woodland ownership. However, in practice, it was difficult to create much resolution in the data for this factor. All FC woodlands were assumed to be supportive (score 2) and very few of the private woodland owners were strongly biased either way.

## **4.2 Woodland management policy influences on habitat**

### **Deforestation**

The identification of priority woodlands within regions for red squirrel conservation action will enable more informed debate in areas where conflicts may arise with regard to woodland management. In particular, issues of deforestation may arise where owners may not wish to re-stock following felling for economic or other reasons. This may include meeting biodiversity objectives under UKBAP or EU Conservation Directives. Current FC policy in Scotland is that deforestation should be an option in situations where 'new planting' proposals would be unlikely to be acceptable (for Environmental reasons). This approach is subject to Environmental Impact Assessment (IEA) where it is likely to have a significant effect on the environment. The Assessment would require the owner to outline the main alternatives to the deforestation proposal, such as including conversion of all or part of the site to semi-natural woodland and/or restoration to open ground habitat. Clearly deforestation in areas of red squirrel distribution would be detrimental to any local red squirrel population. If the EIA scoping identified red squirrels being affected by any proposal to deforest an area, the Environmental Statement would need to quantify the impact on the red squirrel population and any measures envisaged in order to avoid, reduce and, if possible, remedy the significant adverse effects.

### **Woodland defragmentation**

The Scottish Forestry Strategy encourages the development of Forest Habitat Networks. Criteria for a Forest Habitat Network are that they should retain ancient woods and improve their condition, create large woods and well wooded districts, locate new woodland next to existing woodland to minimise isolation, and improve 'matrix' quality (ie non-woodland) by restoring scrub and other semi-natural habitat.

The new Scottish Forestry Grant Scheme (SFGS) has been designed to target native woodland expansion and restoration where it will deliver environmental benefits to forest biodiversity. The SFGS will also provide financial support for work that restores native woodland on ancient woodland sites, consistent with the recommendations in Thompson *et al.* (2003), and to expand the area of native woodlands.

To contribute to Forest Habitat Networks, there must normally be either existing native woodland within 300m of the proposed new woodland, or areas of non-native forest within 300m of the proposed new woodland, which meet the criteria for conversion to native woodland.

The creation of Forest Habitat Networks will create linkages between woodland blocks which may be beneficial in areas of red squirrel distribution well away from grey squirrels, but may increase risk of incursion by greys in areas on the edges of grey squirrel distribution. For the Scottish Borders region Ray *et al.* (2003) suggested that the SFGS rules would, in particular, add to the upland oak woodland, upland birch woodland and wet woodland HAP expansion targets for this Region. Using the Biological and Environmental Evaluation Tool for Landscape Ecology (BEETLE) model they found that a 500m, rather than the original 300m, threshold would provide a more continuous linkage between core riparian woodland forming the main framework. However they noted that as red and grey squirrels have similar habitat preferences any Forest Habitat Network scenario should maintain a barrier between known red squirrel forest habitats and any native woodland expansion suitable for grey squirrel habitat expansion (eg upland oakwood). In the upper Ettrick catchment, for example, Craik forest is a red squirrel core area separated from the broadleaved grey squirrel networks lower in the valley. The BEETLE model could be used to check that broadleaved woodland expansion does not create a Forest Habitat Network that offers dispersal routes for grey squirrel into Craik forest.

A similar study is currently underway for West Lothians, and the results of this prioritisation study will be used to inform the modelling approach there.

### **Parapox virus issues**

Woodland de-fragmentation policies may have severe implications with regard to potential grey squirrel incursion and parapox virus disease transmission. Rushton *et al.* (2000) demonstrated that the disease probably played a role in the replacement of red by grey squirrels in the UK. Tompkins *et al.* (2003) have demonstrated that, even at low levels of infection in grey squirrels, parapox virus accelerates the process of replacement and has therefore been a crucial factor in the decline of red squirrels in the UK. As increased habitat connectivity has also been demonstrated to increase the risk of pathogen transmission (Hess, 1996 and Rodriguez & Torres-Sorando, 2001 cited in Tompkins *et al.*, 2003) they suggest that maintaining endangered species in a state of relative population fragmentation will limit opportunities for pathogen transmission, and may be desirable where infectious disease is deemed to be a major threat.

The first case of parapox virus was identified in the Borders area of Scotland at Bonchester Bridge (south of Jedburgh and N of Warkhope) in August 2001. Particular consideration should be given to the suitability of developing Forest Habitat Networks in this area as increasing woodland connectivity would most likely increase the risk of grey squirrel incursion and parapox virus transmission.

## **4.3 Regional analysis**

### **Highland**

In Highland, there is extensive knowledge of the distribution of red squirrel through the Highland Red Squirrel Group. This provided an excellent opportunity to verify red squirrel presence in selected woodlands and suggest further woodlands. Sixteen woodlands in Highland were excluded due to lack of red squirrel presence, suggesting that either the coarse nature of the red squirrel data did not allow the squirrel inhabited woods to be accurately identified or that the range of the red squirrel in Highlands is diminishing. With the exception of Glen Etive (66, 141) and Ben Alder (64) estates, all the other excluded woodlands appear to be on the extreme northerly and westerly limits of the red squirrel range, which suggests their range is contracting.

Unlike the remainder of Scotland, Highland is in the highly favourable position of being outwith grey squirrel distribution, and this is reflected in the fact that six out of the top 10 ranked woodlands for Scotland occurred in the Highlands. Highland woods were distributed reasonably well amongst the 127 recommended woodlands, with high quality suggested by the dominance of upper ranking woodlands (22 in the top 60 ranking woodlands).

The 33 woodlands selected in Highland can be divided into two categories: production conifer woodlands and Caledonian pine forests of Speyside and, to a certain extent, Glen Moriston. Production conifer forests generally had a higher proportion of Sitka spruce. In such forests there is a move away from single storey monocultures into species-diverse and age-diverse stands, particularly with the increased use of Continuous Cover Forestry. Such diversification will be of benefit to the red squirrels, particularly on the northern and western edges of their distribution where maintaining large stands of Sitka spruce with simple age structures may be detrimental. However, there is still extensive clearfell planned for a number of woods in the Highland, more so on the western side of the country where the wind climate and thinner soils dictate management choices.

The vast majority of the woodlands in Highland were well defended, and all were at least 50km from the nearest grey squirrel record. Ignoring the sightings at the top of Loch Etive, the nearest grey squirrel was either at Pitlochry or to the south of Huntly. Although not impossible, it appears unlikely that greys would cross over the Drummochter pass and so the main routes for grey squirrel incursion appear to be through to Huntly and then down the riparian corridor of the Spey into Highland around the top of the Cairngorm massif. Should greys reach Nairn, they may follow the river Nairn into Inverness and then down the Great Glen from there. Should greys reach Oban, then there is a danger they may spread north, but the dominant conifer composition of the woodlands in that area, combined with the Ben Nevis range, make this an unlikely route.

Focus therefore needs to be turned to the defendability of the woodlands along the Spey valley and around Inverness, as these are the most vulnerable to encroaching greys. All 7 woodlands along the Spey valley have the same defendability score of 3.4, the tenth best defendability score for the whole country. Woodland 81 (Cawdor estate), 44 (Castle Stuart and Culloden) and 11 (Daviot) to the north-east and surrounding Inverness have defendability scores of only 2.1, indicating that should greys reach the surroundings of these woods, colonisation would be far more rapid than for the Speyside woodlands. This threat is less severe when the composition of the broadleaved woodland in the buffer zone surrounding the

woodlands is considered. The data, where available, indicated that the presence of large-seeded broadleaves was fairly limited throughout the entire region. In many cases birch formed the principal component of the deciduous woodlands which, in conjunction with the significant distances from the grey squirrels, adds to the overall defendability of the region. Small areas of oak can be found in the region, for example, along the Great Glen and increasingly towards Sunart and Morvern, but their distribution is currently very patchy. The move towards development of forest habitat networks is perhaps a cause for concern as this may allow greater dispersion of grey squirrels were they to get into Highland. However, any expansion of broadleaved woodland in this region is likely to be dominated by birch. Inverness may become a significant source of grey squirrels in Highland as it expands and more suburban habitat for grey squirrels is created.

Black grouse and capercaillie were found to be present in a number of the Highland woods, with active management for capercaillie in various woodlands in Speyside. Such an approach will provide inherent benefits for red squirrel conservation through habitat creation and retention of pinewood stands. No woodlands were being managed for black grouse but if active management were to take place, notably the felling of trees to create open ground habitats, this could pose a potential conflict with red squirrel conservation. Such a conflict could also occur if habitat creation for pearl bordered fritillaries was to occur. However, the only issue to be raised is that, increasingly, woodlands are being managed on a habitat-based as opposed to a species-based approach. The focus is towards allowing trees to develop into full maturity and then old age, and it should be noted that this may lead to a possible reduction in cone production. Although a number of raptor species were reported, anecdotal evidence suggests that, while they are known to occasionally take red squirrels, they do not pose a significant threat to the red squirrel population.

It can be argued that the distance to the nearest grey squirrel population in Highland is such that to focus upon coniferous woodlands ignores the fact that reds are known to inhabit deciduous woodlands in Highland. However, in order to take a consistent and strategic countrywide approach, it has been necessary in this instance to exclude deciduous woodlands that contain greater than 5% large-seeded broadleaves as deciduous woodlands in more southerly locations are now the prime habitat of grey squirrels.

Although this is only a preliminary analysis, the results indicate the viability of the Highland red squirrel population and an expansion of this study should also be considered to take into account habitation of smaller deciduous woodland in the region. Such a review could also be used to incorporate woodlands which may have been rejected due to the presence of greater than 5% broadleaves. The woodland between Foyers and Inverfarigaig being a notable example of this. Also worthy of inclusion in a further review are Glen Urquart woodlands, Fort Augustus, Port Clair and Alt Saigh, all of which support healthy red squirrel populations and, with the exception of Glen Urquart woodlands, contain less than 5% large-seeded broadleaves.

## **Grampian**

The Grampian Red Squirrel Group's recent survey of red and grey squirrel distribution, conducted in 2000, provided a comprehensive picture of the squirrel distribution in the region with data to supplement the original selection. This region had the highest number of favourable woods from the study, with 36 woodlands selected in Grampian. However, unlike Highland region, there are greys present which appear to be spreading steadily north and westwards out of Aberdeen, the main source for grey squirrels in the region. This is confirmed by the exclusion of two of the woodlands along the Dee due to the presence of greys.

With rankings ranging from 1st to 126th, the woodlands of Grampian varied significantly in quality for red squirrels. However, it is interesting to note that 19 out of the top 60 woodlands occurred in Grampian and, of those, 15 were found north of the river Don. This reflects two different situations, the proximity of greys in southern Grampian and the favourable species composition of woodlands in Northern Grampian. In northern Grampian, Scots, Lodgepole or Corsican pine formed a significantly larger proportion of the forest cover than woodlands further south, where Sitka spruce was the main species. Pines tend to cone for longer periods than other conifers so the presence of significant areas of pine ensures a greater stability of food supply in these woods.

These woodlands also scored favourably on the high levels of CCF management practices in some of the woodlands, particularly the woodlands along the northern coast, which have a high value for both biodiversity and recreation. The age structure of these north Grampian woodlands was also favourable, with many of them having at least 60% of their trees within cone bearing age.

However, these results may give a distorted view of the southern Grampian woodlands. These woodlands still provide core habitat for red squirrels, particularly amongst the pinewoods of Glen Tanar and Balmoral and, increasingly, amongst the commercial conifer plantations as restructuring takes place. With effective management this situation can continue, but the proximity of grey squirrels is a cause for concern. Perhaps immediate focus should be paid to these woodlands, particularly those surrounding Aberdeen rather than those in the north as it is these woodlands which are currently in danger of colonisation by grey squirrels. Two such woodlands are Blackhall and Kirkhill, both of which have had isolated grey squirrels reported, but which require active control measures to prevent further colonisation of the woods.

Compared to Highland, none of the woodlands have particularly high defendability scores, the maximum being 2.8, which raises further concern about the threat of encroaching grey squirrels. Another point is that, for all the woodlands, only six different defendability scores were generated compared to nine different scores in north Strathclyde and 12 different scores in Highland, illustrating the uniformity of the landcover. Physical barriers to grey squirrel incursion are lacking in Grampian, specifically the lack of significant mountain ranges particularly in northern Grampian. There are no mountains exceeding 500m in height north of Banchory and east of Huntly.

A study of the topography of Grampian would suggest that while grey incursion will almost inevitably increase further into Deeside, they are unlikely to be able to pass over the Cairngorms into Speyside. Of perhaps greater concern is the spread of greys along the River Don and through the relatively low lying land to the north and into the coniferous woodlands of northern Grampian. Both the Dee and, especially, the Don need to be targeted for monitoring and control of greys.

The presence of considerable areas of large-seeded broadleaf forest in Grampian is another factor that limits the general defendability of the region. The data, where available, seems to suggest that the presence of beech, often in conjunction with sycamore, increases towards the northern coasts. At present, these woodlands remain relatively isolated from one another by open hill, or areas of farmland, with connectivity in the landscape found mainly along the riparian corridors. With this in mind, any moves for increased connectivity of woodlands should be regarded with caution if this is going to facilitate the movement of grey squirrels. The area surrounding Aberdeen and towards Banchory is well populated, but from Huntly northwards there are also several major centres of population, with suburban gardens providing further

attractive habitats for greys. However, these centres of population are reasonably widely distributed and are often separated by relatively open areas of hill ground, which would present some form of barrier to grey migration.

While black grouse and capercaillie were present, capercaillie was far more widely reported than black grouse, but no active management was reported for the species. However, there are a number of European LIFE schemes for Capercaillie distributed throughout Grampian, and these will indirectly benefit red squirrel conservation through habitat enhancement and preservation. With no known development planned for any of the woodlands, and ownership secure throughout, the main threat to the red squirrel population therefore is the migration of the grey squirrel into their territories. Immediate grey squirrel control is required on Deeside and Donside and monitoring is needed on the woodlands to the north and east of Huntly to prevent greys reaching the riparian corridor of the Spey valley.

### **Strathclyde North**

There was no recognised Red Squirrel Group in the north of Strathclyde region but a meeting was arranged with SNH staff, the local ranger service, LBAP officers, FWAG and Forestry Commission rangers. 11 woodlands were excluded from the original 192 due to the lack of red squirrels. With three of the woodlands being on the Kintyre peninsula, this would suggest that the squirrel population is dwindling in this area. However, the population in woodland 7 (Carradale) is reported to be healthy and, once again, the absence of sightings may be solely due to a lack of recording. With the nearest grey squirrel well over 50km away, it may also be possible that the red squirrels are inhabiting the deciduous woodland on the peninsula and would only move into the coniferous areas as a result of pressure from grey incursion. Two woodlands were excluded due to the presence of greys: 183 on the side of Loch Lomond and 104 located to the north of Helensburgh. These two records represent the western edge of the grey squirrel distribution.

The highest ranked woodland was number 7 (Carradale), ranked at 23rd and the lowest ranked wood was 172 (Arkanglass estate), ranked 125th. Despite their size, woodlands 1 (Cawal peninsula), 3 (Inverliever), 4 (Minard Forest) and 5 (Eredine) ranked no higher than 29th with woodland number 5 ranked 75th. This suggests that other factors limited their score. One of these is the overwhelming dominance of Sitka spruce, which comprised at least 80% of the cover in every woodland in north Strathclyde. Another limiting factor is the lack of conifer diversity and, hence, the lack of a variable and stable food source for red squirrels.

A point worth consideration is the lack of trees of cone-bearing age. However, as many of the Forestry Commission woodlands are currently at polestage development, a significant increase in the proportion of cone bearing trees is likely to occur in the future. The same is true to a lesser extent for the private woodlands in the area. Due to the soil and prevailing weather conditions, clearfell is the most widely used felling regime in the area, which leads to disruption and loss of habitat.

While a number of factors assessed for the north Strathclyde woodlands were seen as detrimental to red squirrel conservation, one of the key factors in their favour is the woodlands' defendability. With many of the woodlands surrounded by water on at least one side, the avenues for grey incursion are limited. This is particularly true of Arran, where the introduced population of red squirrels appears to be very well protected. However, these woodlands had lower defendability scores than some of the woods on the mainland and a possible explanation for this is that if greys actually reach the island, the habitat conditions there are more conducive to woodland colonisation than on some of the woods on the mainland.

One of the key factors which favours North Strathclyde and Argyll, in particular, for red squirrel conservation is the wide distribution of Atlantic oakwoods, which provide a valuable alternative habitat to the conifer woodlands. Indeed, the FC distribution data indicates that the majority of red squirrel sightings are found in these broadleaved linear strips between the loch sides and the upland conifer plantations. However, these oakwoods would also provide excellent habitat for grey squirrels were they to enter the region. Greys would rapidly colonise the oakwoods, thus marginalising the reds to the commercial plantations which, currently, do not present particularly favourable red squirrel habitat in terms of species composition. At present the distribution of the Atlantic oakwoods is non-contiguous and this presents a barrier to grey movement in the region. Therefore, any moves to link woodlands through forest habitat network development must be viewed with caution. The nearest grey squirrel is known to be at Arrochar, at the top of the Cowal Peninsula but expansion into the rest of the region appears limited by the relatively high ground between the heads of Loch Long and Loch Fyne. Should greys reach Loch Fyne side, the sizeable areas of Atlantic oakwood, if linked by woodland expansion, would provide an excellent corridor for the migration of greys down Loch Fyne and onto the Kintyre peninsula. Such an occurrence could be extremely detrimental to the red squirrel population as their opportunities for expanding their territories northwards are limited by the narrow link to the remainder of Argyll between Lochgilphead and Crinan.

The biodiversity potential of this area is considerably higher than that of South Strathclyde due, mainly, to its relative isolation and comparatively low numbers of humans, particularly in the western parts of the region. There are healthy black grouse populations reported from both FC and private woodlands, but no mention was made of active management for the species. Several raptor species are present, but none were regarded as a threat to red squirrels, while pine martens were widely reported but, again, were not regarded as a potential predator of the reds. The overall lack of major development is of benefit both to red squirrels and other wildlife species.

There are three factors that need to be addressed in order for red squirrel populations to remain viable in this area. Firstly the management of the existing woods, with a move made towards increased CCF and conifer diversity both in terms of age and species. Secondly the need for vigilance at the key points where greys could enter the region, particularly at the top of the Cowal and Kintyre peninsulas. Finally, while the presence of extensive areas of Atlantic oakwood is of benefit to the biodiversity of the region, caution should be exercised in Forest Habitat Network planning.

### **Strathclyde South**

The Ayrshire Red Squirrel Group was a valuable source of information on woodlands to the south of Ayr, but considerable difficulty was found in obtaining information on the woodlands in north Ayrshire and Lanarkshire, with no recognised Red Squirrel Group present. For FC and private woodlands, the level of information provided on age, species composition and felling was reasonably comprehensive, but knowledge about the presence of red and grey squirrels within the woodlands was at times very vague. Two woodlands had to be excluded due to the lack of reliable data on their squirrel presence, while the removal of woodlands as far south as Maybole, due to the presence of greys, indicates the extensive expansion of grey squirrels into the region.

With no woodland in this area ranked higher than 85th, it is clear that there are a number of factors which were poorly scored for these woodlands. The diversity of conifers was often low and the overall cover dominated by Sitka spruce. The Forestry Commission woodlands, which supported up to seven or eight

different conifer species in Grampian and Highland, were only planted with a maximum of five different species in Strathclyde south, and these were often only in small pockets of less than 1.5% of the plantation area. The prominence of Sitka spruce is a reflection of the climatic and edaphic conditions. In addition, in the area of the Lowther Hills and the Southern Uplands, the low human population density and the marginal economic viability of the land for hill farming has allowed un-diversified, commercial forestry to dominate. Although many woodlands scored highly on age structure, the prevalence of Sitka spruce and widely used clearfell practices means that conditions are considered far from suitable for the remaining red squirrel populations.

A more immediate threat is the southerly movement of grey squirrels out of the central belt. Greys are reported from as far south as Douglas in Lanarkshire, and in Ayrshire they are as far south as Girvan. With greys also widespread throughout the Scottish Borders and reported sightings around Dumfries, immediate action is required to prevent them spreading throughout the lowlands of Scotland. With only two of these woodlands having defendability scores over three, the surroundings of all the woodlands appear highly permeable to grey immigration. Detailed information regarding the large-seeded broadleaf component in this area was difficult to find, but the few statistics available suggest that it could be as high as 70% around woodland 40, and significantly lower than this in the more exposed parts of Lanarkshire and south Ayrshire. Oak appears to be the most common species, but sycamore and beech were also known to be present.

To compound the problem, a large number of windfarm proposals are being put forward for areas in Lanarkshire in particular. There were few species of conservation interest reported, with only black grouse and otters reported from more than one woodland. While this presents few conflicts of interest, the general lack of biodiversity may discourage efforts to develop CCF practice on suitable sites. This lack of biodiversity may also be a function of infrequent monitoring of the sites, and the presence of a dedicated Red Squirrel Group for the region may provide clearer information not only on squirrel distribution but other notable species of interest.

While the situation in south Strathclyde may not initially appear to be favourable, it should be noted that in this survey of virtually all of Scotland, a number of woods in the region were represented and therefore with regard to funding it should not be dismissed. It can be argued that, with stringent controls of greys, and diversification of the forest structure particularly in terms of species composition, viable refuges for red squirrels can be maintained but the need for swift action is more pressing than in regions further north.

## **Fife & Tayside**

There was no formal Red Squirrel Group covering this area. As a result coverage of this region was felt to be patchy with perhaps many more potential woodlands yet to be identified. Only a few contacts with a specific interest in woodland management for red squirrel conservation were located. In Perthshire, meetings were held with the Ranger from Atholl Estate. Help and information on private woodlands was provided by the local FC woodland Officer in Perth, and data for Forestry Commission woodlands by local Forest Enterprise Rangers. Meetings were also held in Angus and Fife with local FWAG, LBAP, SNH and Council Ranger staff. Even within the last week of the contract, potential woodlands were being suggested (eg Torlum owned by Drummond Estate), usually by private woodland owners that had only recently been traced and who wished to contribute. There is a large potential for more consultation in this region.

Central, Fife & Tayside contain some of the most suitable woodlands for red squirrel conservation in Scotland. The woodlands provided good habitat in terms of woodland composition and age structure. There

was a high diversity of species in the conifer plantations and, in some cases, a dominance of conifers species other than Sitka spruce. Scots pine and Lodgepole pine formed an important component in woodland 185 (Tentsmuir) and the woodlands along Loch Rannoch, Tummel and Tay. Birch usually made-up the broadleaved element within the woodlands.

Woodlands that appeared to be less suitable in this analysis may be very important locally for red squirrel conservation. For example, wood 32 (Carron Valley) appeared in 96th place in our analysis but is listed as potential protection site in the Scottish Lowlands Forest District Red Squirrel Strategy (SLFDRSS) (Stewart, 2003) reflecting the regional importance of this woodland.

There were significant pressures from grey squirrels in this region as no woodland was further than 50km from a current grey squirrel sighting. The analysis suggested that most woodland had average defendability. The woodlands in the selection occurred within well-wooded landscapes, and the presence of a large proportion of woodland surrounding the sites, as opposed to open moorland or water, will have reduced the score. Despite this relatively high connectivity between woodlands, the low proportion of large-seeded broadleaves present (less than 40%) would help to offset this effect. Defendability scores incorporate a measure of woodland size, smaller woodlands being less defendable. In this region woodlands were relatively small compared to the rest of Scotland.

Also working in favour of suitable sites for red squirrel conservation in this region was favourable woodland owner support for conservation, security of woodland ownership and lack of development threat.

Two other species of conservation interest were important in this region; capercaillie and black grouse. There should be little conflict between management for red squirrel and capercaillie, but there is possibly a problem with black grouse management especially if there was any significant deforestation to create black grouse habitat. Grey squirrels were present within much of the region and, as a result, many woodlands that were identified in the analysis had to be excluded, notably Blairadam and Devilla in Fife. Several others are shown on Figure 1. In nearly all cases, red squirrels were also present and there is evidence that the two species are capable of co-habiting in this region (Bryce *et al*, 2002). Sites that have been excluded in this analysis may still represent key sites for local conservation, and the two woodlands in Fife, above, are listed in the SLFDRSS as potential refuge sites for red squirrel (Stewart, 2003).

Despite problems in finding the correct contacts in Central, Fife & Tayside, no woodlands had to be removed from the analysis due to lack of available data. For the woodlands that are included in the final 127, a comprehensive dataset was collected.

## **5 CONCLUSIONS AND RECOMMENDATIONS**

The aim of this study was to identify priority woodlands for red squirrel conservation in accordance with the UK Strategy for Red Squirrel Conservation. The results indicate that there were initially 127 woodlands worthy of consideration, widely distributed amongst the 5 geographical regions considered. The use of a ranking process has allowed comparative analysis between regions and, despite some problems with data collection and analysis, the results have been generated with reasonable confidence.

The results show that there is a marked geographical split between the conservation value to red squirrels of woodlands to the north and south of the Central Belt, which has implications for the allocation of resources. The threat from encroaching grey squirrels is particularly severe in south Scotland, with expanding grey squirrel populations moving south from the Central Belt and north from northern England into the Scottish Borders and Dumfries & Galloway. While there are arguments for focussing the finite resources available towards woodlands north of the Central Belt, equally valid arguments can be put forward for targeting those woodlands under immediate threat elsewhere. With no suitable woodlands found in the Lothians, and those in Lanarkshire and south Ayrshire of low suitability and defendability, it could be argued that southern Scotland requires immediate action in order to protect the area against the further spread of grey squirrels.

In north Strathclyde, Central, Fife and Tayside, Highland and Grampian, there are a number of encouraging factors to focus upon. In north Strathclyde, the highly fragmented nature of the landmass has given woodlands strong defendability. In Grampian, the woods particularly in the north are composed of suitable species, and the management of the woods is complementary to red squirrel conservation. In the Highlands, the main supporting factor is the large distances to the nearest grey squirrel coupled with highly mountainous terrain which act as a strong natural barrier to grey incursion. In northern Tayside and Central region, there is often a combination of habitat suitability, defendability and management, which counteracts the relative proximity of the grey squirrels.

While the ranking process has demonstrated that there is no dominance by one region, the study as a whole has indicated that there are a number of key locations that need to be targeted. The first of these are the Dee and Don valleys. The movement of grey squirrels particularly northwards along the Don must be limited before they reach the Spey valley, as this could lead to migration of greys down into the prime Caledonian pinewood habitats of Speyside. The second area is the woodlands surrounding Inverness, as this is the possible entry route for greys into the Great Glen to the south, and into Ross and Cromarty to the north. The third area is the upland regions between the head of Loch Long and Loch Awe, which acts as a bottleneck for species migration. Should greys pass through these areas into the Cowal and Argyll peninsula, this will surround the red squirrel population. This is an important issue for the development of Forest Habitat Networks which risks increasing the connectivity of woodlands and facilitating the distribution of grey squirrels and parapox virus disease into these otherwise defensible areas.

This study has also shown that a number of factors require consideration when determining the suitability of woodland for red squirrel conservation. While large areas of woodland may be considered inherently better, if the species composition of these woodlands is poor then they will not be suitable for sustaining a healthy red squirrel population.

One very encouraging aspect to arise from the study was the overall level of support shown by landowners for red squirrel conservation, suggesting that measures to benefit red squirrel conservation may be readily embraced.

The key recommendations from this study are:

- 1 Extend consultation over the choice of priority woodlands to areas where Red Squirrel Groups are not currently in operation, eg Central, Fife & Tayside;
- 2 Include woodlands which were omitted from Highlands in the analysis;
- 3 Fully analyse the future composition of the 127 woodlands from Long Term Management Plans in terms of age structure and species composition;
- 4 Further monitor the 127 woodlands selected to ascertain viability of the existing red squirrel populations;
- 5 In Grampian, target grey squirrel control on Deeside and Donside, with concurrent monitoring of woodlands to the north and east of Huntly to prevent greys reaching the riparian corridor of the Spey Valley;
- 6 In North Strathclyde, target grey squirrel control at the top of the Cowal and Kintyre peninsulas to prevent the spread of grey squirrels into the Atlantic oakwoods;
- 7 Make the findings from this report available for consideration in plans for Forest Habitat Networks;
- 8 Influence the design and targeting of incentives for diversification of forest in the key red squirrel priority areas;
- 9 Revise current red and grey squirrel distribution maps in the light of information received during this study;
- 10 Promote squirrel presence monitoring to improve population distribution and 'level of presence' information;
- 11 Re-select and analyse the woodlands in Highland to include large-seeded broadleaved woodlands of less than 200ha;
- 12 Extend analysis to cover the priority woodlands selected in Dumfries & Galloway and Borders to provide a Scotland-wide ranking.

## 6 REFERENCES

- Anon (1995).** *National Inventory of Woodlands and Trees: Scotland Inventory Report 31*, Forestry Commission, Edinburgh.
- ArcView 8.3 (2003).** *ESRI Redlands*, California
- Bryce, J., Johnson, P. J. & Macdonald, D.W. (2002).** *Can niche use in red and grey squirrels offer clues for their apparent coexistence?* *Journal of Applied Ecology* 39(6): 875–887.
- Gurnell, J. & Pepper, H. (1993).** *A critical look at conserving the British Red Squirrel (Sciurus vulgaris).* *Mammal Review* 23(3/4): 127–137
- Harris, S., Morris, P., Wray, S. & Yalden, D. (1995).** *A review of British Mammals: population estimates and conservation status of British Mammals other than cetaceans.* JNCC, Peterborough.
- Hess, G (1996).** *Disease in metapopulation models: implications for conservation.* *Ecology* 77: 1617–1632.
- Humphrey, J., Ray, D., Watts, K., Brown, C., Poulson, L., Griffiths, M. & Broome, A. (2003).** *Balancing upland and woodland strategic priorities.* Report to Scottish Natural Heritage.
- Mayle, B., Griffiths, M. & Clare J. (2002).** *The identification of priority areas for red squirrel management in Scotland using the National Inventory of Woodlands and Trees.* Unpublished report to the Scottish Squirrel Forum.
- Middleton, A. D. (1931).** *The grey squirrel.* Sidgewick and Jackson Ltd., London.
- Pepper, H., Bryce, J. & Cartmel, S. (2001).** *Squirrel Management 2. Co-existence of red squirrels and grey squirrels.* In *Forest Research Annual Report and Accounts 1999–2000.* HMSO London.
- Poulson, L., Broome, A., Griffiths, M. & Mayle, B. (2003).** *Identification of priority woodland for red squirrel conservation.* Phase 1 contract report to SNH.
- Ray, D., Watts, K., Griffiths, M., Brown, C., & Sing, L. (2003).** *Native Woodland Habitat Networks in the Scottish Borders.* Report to Scottish Natural Heritage, Forestry Commission Scotland and Scottish Borders Council.
- Reynolds J. & Bentley, S. (2001).** *Selecting refuge sites for red squirrel conservation.* Unpublished paper to the England Squirrel Forum.
- Rodriguez, D. J. & Torres-Sorando, L. (2001).** *Models of infectious diseases in spatially heterogenous environments.* *Bulletin of Mathematical Biology* 63: 547–571.
- Rushton, S. P., Lurz, P. W. W., Gurnell, J. & Fuller, R. (2000).** *Modelling the spatial dynamics of parapox virus disease in red and grey squirrels: a possible cause of the decline in the red squirrel in the UK?* *Journal of Applied Ecology* 37: 997–1012.
- Stewart, E. (2003).** *Scottish Lowlands Forest District Red Squirrel Strategy.* Forest Enterprise internal report.
- Thompson, R. N., Humphrey, J. W., Harmer, R. & Ferris, R. (2003).** *Restoration of Native Woodlands on Ancient Woodland Sites.* Practice Guide, Forestry Commission, Edinburgh.
- Tompkins, D. M., White, A. R. & Boots, M. (2003).** *Ecological replacement of native red squirrels by invasive greys driven by disease.* *Ecology Letters* 6: 189–196.

## APPENDIX 1 – Scoring sheet for red squirrel reserves proposed by Reynolds & Bentley (2001)

### Magnitude of Threat

#### Red squirrel presence/absence

		Rating
Only red squirrels present	<input type="checkbox"/>	Excellent
Only red squirrels present but greys are expected to appear soon	<input type="checkbox"/>	Very good
Red squirrel population and very few grey squirrels present	<input type="checkbox"/>	Good
Red squirrel population and many grey squirrels present	<input type="checkbox"/>	OK
Reds recently disappeared and no greys are present	<input type="checkbox"/>	Poor
Only grey squirrels present	<input type="checkbox"/>	Very Poor
Is it uncertain if any of the above apply*	<input type="checkbox"/>	Find Out

\*Implement visual or hair tube surveys or transect monitoring in woodland, as described in *Practical techniques for surveying and monitoring squirrels*. Forestry Commission Practice Note 11, September 2001

### Extent and Suitability of Habitat

#### Woodland Type and Size\*

Coniferous woodlands: 2000+ha or a large woodland on an island	<input type="checkbox"/>	Excellent
Coniferous woodlands: >200–2000ha or a medium sized woodland on an island	<input type="checkbox"/>	Very Good
Mixed woodlands: containing 2000+ha contiguous conifer or a small woodland on an island	<input type="checkbox"/>	Good
Mixed woodlands: containing 200–2000ha contiguous conifer block	<input type="checkbox"/>	OK
All other woodlands	<input type="checkbox"/>	Poor

\*Specifics about size, tree species and age structure will be required for precise planning – considered after the list has been drawn up.

#### Suitability of the Habitat (Do not apply this criterion to island populations)

No mature large-seeded deciduous trees	<input type="checkbox"/>	Excellent
<5% mature large-seeded deciduous trees	<input type="checkbox"/>	Very Good
>5% mature large-seeded deciduous trees	<input type="checkbox"/>	Poor

**Site Defendability**

**Landscape defendability (Do not apply this criterion to island populations)**

Expected to be a highly effective barrier		Excellent
Expected to be a reasonably effective barrier		Good
Expected to only be a slight barrier		OK
Expected not to act as an effective barrier		Very Poor

**Buffer size - Woodland perimeter (km)**

15+		Very Poor
13-15		Poor
8-12		Good
5-8		Excellent

**Site Management**

**Management potential of forest and buffer Forest Buffer**

Highly suited			Excellent
Good potential, a few compromises			Good
Some scope. Conservation value may arise, but not as a major consideration.			OK
Unsuitable and/or Many conflicts with red squirrel conservation			Poor

**Reserve Confirmation, Phase II**

**Socio-economic/other considerations**

**Landowner/manager support**

Majority of land managed by very supportive owners/managers		Excellent
Majority of land managed by supportive owners/managers		Very Good
Majority of land managed by ambivalent owners/managers		Poor
Majority of landowners/managers unsupportive or don't know		Very Poor

## **APPENDIX 2 – Questionnaire for the regional contacts, woodland owners and agents**

### **1 Location of woodlands**

- a) Do the woodlands shown exist and occur where they are indicated?

### **2 Squirrel presence**

- a) Are reds present in the woodland?
- b) Are greys present in the woodland?
- c) Would you say that the red squirrel population in the woodland blocks we have identified is increasing, stable or declining?
- d) If the population is declining, do you know why?
- e) Are there red squirrels in nearby woods (up to 5km) which haven't been included in our survey?
- f) Are there greys in the nearby woods (up to 5km) which haven't been included in our survey?

### **3 Woodland type and size (this information can be gained from long term management plans if available – please let us know if they exist)**

- a) What is the species composition of the woodland blocks?
- b) What is the proportion of broadleaves that are large-seeded?
- c) Specifically, is there a presence of large-seeded broadleaves in the woodland? (Oak, hazel, beech, sycamore and chestnut).
- d) What is the age structure of the woodland block?

### **4 Habitat suitability in surrounding 5km wide buffer zone**

- a) What is the proportion of broadleaves that are large-seeded?
- b) Specifically, is there a presence of large-seeded broadleaves in the woodland? (Oak, hazel, beech, sycamore and chestnut).

### **5 Landscape defendability**

- a) Where is the nearest grey squirrel that you know of?
- b) Could you put an estimate on the size of the human population in the surrounding area? (surrounding area is within 5km of the site).
- c) Are there many hedgerows, suburban areas with trees that would encourage grey incursion?

### **6 Site ownership**

- a) Do you know who the agent/owner is for the woodland?
- b) Is the woodland owned by more than one private owner?
- c) How much of the woodland is owned by each owner?
- d) Is landowner support forthcoming for red squirrel conservation in the private woodland blocks?
- e) Are they all supportive of red squirrel conservation and if not which ones are opposed to it?
- f) Is the ownership of the woodland secure?

**7 Management (some of this information can be gained from long term management plans if available – please let us know if they exist)**

- a) What is the felling regime for the woods?
- b) Have the needs of red squirrels been considered in the felling regime?
- c) Is there going to be continuous cover forestry as opposed to clearfell?
- d) Are there any other species of conservation interest that are present in or being managed for in the woodland eg butterflies and black grouse
- e) Are there any other socio economic factors that would limit the conservation potential of the woodland block eg mining, road construction, urbanisation or housing development?

**8 Additional woodlands**

- a) Can you identify any woodlands that have not been identified so far which contain reds but not greys based on your local knowledge? For these woodlands to be included in the analysis the above information will have to be available for each.

## **APPENDIX 3 – Protocol for assessing presence of red squirrels in woodlands**

### **Transect methodology**

*Aim:* The aim of this project is to establish whether red squirrels occur within the selected woodlands. Presence is determined by actually seeing red squirrels whilst walking along a preset transect, or by identifying squirrel chewed cones whilst walking the transect.

*Identification of squirrels:* Red squirrels often display marked variation in coat colour, with some displaying distinct areas of grey or even black fur. However, as the survey is only going to be conducted in areas where it is known that grey squirrels are absent, the problems of misidentification of reds and greys should be minimal. As the reds frequently live high up in the canopy, only fleeting glimpses may be possible. Photographs of red and grey squirrels will be provided for guidance. Animals seen which are considered to be grey squirrels should be reported to Woodland Ecology Branch (date, time, specific location in the wood) as soon as possible.

*Identification of red squirrel chewed cones:* The presence of red squirrels can be more clearly ascertained from the presence of feeding remains beneath the trees. In coniferous areas, cone cores can be found scattered beneath trees (with the removed scales), but can also be found in concentrated piles (eg around a tree stump) where specific feeding takes place. There is some evidence that red squirrels gnaw off most of the scales on the cone, but leave some strands behind giving it a messy appearance. Mice and birds also strip cones. Mice leave a more regular 'tidier' cone core. Birds often leaves ragged edges all over the cone – and generally do not remove the scales.



*Pine cones stripped by red squirrels*

Squirrels will also feed on hazelnuts if available. Nuts which have been opened by squirrels can be identified clearly from those opened by mice and voles from differences in size in the tooth marks (see Collins Guide to Animal Tracks and Signs by Bang and Dahlstrom, 1974, Harper Collins, London).

*Method:* The surveyor will walk along a transect of at least 2km. This transect should pass where possible through mature seed bearing conifers, the habitat where red squirrels are most likely to occur, and seed bearing broadleaf areas if present. Sections of the transect passing through areas of immature conifer or broadleaved areas, or open ground, should be discounted. The transect should be continued at the resumption of mature conifer/broadleaf woodland.

The minimum woodland size is 200ha. For a wood of between 200 and 300ha, a total transect length of 2km should be used. An additional 1km should be searched for each additional 100ha of woodland block, eg for 300–400ha woods a total length of 3km should be used, 400–500ha, 4km transect etc.

In order to cover as wide an area as possible, the 2km transect should be subdivided into sections which cross at right angles to one another. Transects should not be located along racks or rides, but between the rows of trees, as this will maximise the likelihood of finding stripped cones or hearing squirrels in the canopy as the surveyor walks through the forest. The length of these sub sections of transect will depend on the presence of the unsuitable habitats as described earlier and the size and shape of the woods, but ideally these sections should be at least 500m long.

When walking the transect, the surveyor should take about 5 minutes to walk each 100m, checking the ground for chewed cones, listening for signs of squirrel activity (sound of cone scales dropping from canopy) and watching the canopy for signs of squirrels. The survey should start approximately 2hrs after dawn as red squirrels are at their most active 2–4hrs after sunrise in summer. If there is heavy rain, strong winds or very low temperatures then the survey should be rescheduled, as squirrel activity is likely to be very low.

*Results:* Record all squirrels observed, location in wood and what kind of habitat they were in. Report back any possible sightings of grey squirrels to Woodland Ecology Branch immediately. Note down the number and species of chewed cones observed, and location in the wood (subcompt).

Once signs (squirrel observed, chewed cones/nuts found) indicate that squirrels are present in the wood, the survey should stop. For extremely large woodland blocks (1000+ha) it may be necessary to confirm the presence of squirrels in each of the main sub-areas.

**APPENDIX 4 – List of 127 woodlands ranked by priority for red squirrel conservation**

Rank	Woodland no.	Woodland name	Grid Ref.	Region	Final score
1	6	Ordiequish/Whiteash/Ben Agin	NJ336499	G	43.05
2	8	Rothiemurcus	NH859053	H	42.40
3	39	Inveroykel estate/Rossal wood	NC487031	H	42.19
4	174	Glen Morrison	NH343141	H	41.52
5	156	Glen Doll	NO270762	C,F&T	40.33
6	43	Culrain	NH560941	H	40.19
7	22	South Rannoch	NN592549	C,F&T	40.18
8	21	Garrygualaich	NN204994	H	39.52
9	163	Tom an Uird	NJ097302	H	39.40
10	135	Glen Head	NO273633	C,F&T	39.39
11	154	Frenich	NN817581	C,F&T	39.18
12	24	Culbin Forest	NH961606	G	39.05
13	56	Seafield (Cullen)	NJ479645	G	39.05
14	107	Fourpenny Plantation	NH795927	H	38.94
15	177	Strathgarve	NH393617	H	38.88
16	61	Clunes	NN232915	H	38.52
17	26	Abernethy	NH999166	H	38.40
18	14	Black Isle	NH652583	H	38.05
19	46	Fe and Glenlivet	NJ240290	G	38.05
20	109	Loch Moy	NH781346	H	38.05
21	149	Darnaway/Altyre/Newtyle	NJ023509	G	38.05
22	50	Glengarry	NN093996	H	37.52
23	7	Carradale	NR749444	S	37.46
24	164	Grant-on-Spey and surroundings	NJ036303	H	37.40
25	62	Gortonallister	NS014331	S	37.32
26	153	Faskally	NN932552	C,F&T	37.18
27	77	Seafield (Cullen)	NJ528592	G	37.05
28	136	Sillyearn	NJ512529	G	37.05
29	1	Cowal Peninsula	NS061860	S	36.88
30	75	Cushnie	NJ499096	G	36.81
31	170	Balmoral to Inver	NO225927	G	36.81
32	151	Errochty aand Allean	NN800618	C,F&T	36.18
33	155	Craigvinean	NN983453	C,F&T	36.18
34	11	Daviot	NH682370	H	36.05
35	17	Glennochty/Bunzeach	NJ351123	G	35.80
36	167	Birse Forest to Glen Tanner	NO567935	G	35.80
44	57	Aultmore	NN437174	G	36.05
37	55	Loch Voil side	NN437174	C	35.60
38	4	Minard Forest	NJ568329	S	35.46

**Appendix 4 – (continued)**

Rank	Woodland no.	Woodland name	Grid Ref.	Region	Final score
39	47	Gartly Moor	NN757463	G	35.37
40	67	Drummond Hill	NN570595	C,F&T	35.18
41	152	North shore of Rannoch	NO125573	C,F&T	35.18
42	110	Dallrulizian	NJ287535	C,F&T	35.08
43	45	Teindland	NJ472586	G	35.05
45	78	Wester Buthill (Roseisle) and Fe	NJ112661	G	35.05
46	138	Seafield (Cullen)	NJ530630	G	35.05
47	143	Tarryblake	NJ521494	G	35.05
48	51	Aultmore	NM828628	G	35.05
49	179	Strontian	NO058613	H	35.00
50	63	Kindrogan	NH813970	C,F&T	34.96
51	113	Loch Fleet woods and Littleferry NNR	NO411986	H	34.83
52	169	Muir of Dinnet to Cambus of May	NN050637	G	34.80
53	181	Onich	NR764642	H	34.52
54	187	Torinturk	NR834729	S	34.46
55	188	Meall Mhor	NH918165	S	34.46
56	165	Boat of Garten (Triangle between A95, Spey and railway)	NH902174	H	34.40
57	166	Inverlaidnan, Kinveachy and Craigellachie plus Corner wood between A938, A95 and A9	NN009531	H	34.40
58	36	South Ballachulish (Glen Duror block)	NO039074	H	34.29
59	34	Glen Devon	NH647903	C,F&T	34.20
60	176	Spinningdale	NN438524	H	34.19
61	19	Barracks	NN834677	C,F&T	34.18
62	60	Atholl Estate	NH776471	C,F&T	34.18
63	44	Castle Stuart and Culloden	NJ426582	H	34.05
64	144	Mayen	NJ566494	G	34.05
65	158	Tentsmuir	NO480250	F	34.01
66	180	Acharacle & Sunart	NM732644	H	34.00
67	133	Bridgend	NJ434033	G	33.80
68	168	Pannanich	NO390961	G	33.80
69	190	Ormaig	NM813017	S	33.46
70	18	Glenashdale	NS007257	S	33.32
71	80	Merkland Wood	NS012395	S	33.32
72	106	Glen Sherrup	NN960033	C,F&T	33.20
73	69	Balloch Woods	NJ475483	G	33.05
74	88	Glenlivet Estate	NJ206209	G	33.05
75	25	Glen Dye	NO644877	G	32.80
76	142	Ormsary Estate	NR771717	S	32.67
77	35	Novar Estate and Fe	NH541778	H	32.54

**Appendix 4 – (continued)**

<b>Rank</b>	<b>Woodland no.</b>	<b>Woodland name</b>	<b>Grid Ref.</b>	<b>Region</b>	<b>Final score</b>
78	3	Inverliever	NM908152	S	32.46
79	5	Eredine	NN015069	S	32.46
80	189	Knapdale & Inverneil	NR794871	S	32.46
81	42	Clashindarroch/Bin	NJ491432	G	32.05
82	53	Innes, Pitgaveny (Lossiemouth) and Fe	NJ303663	G	32.05
83	81	Cawdor Estate	NH796562	H	32.05
84	184	Glentool	NX349921	SS	31.96
85	102	Glen Loin	NN304076	S	31.88
86	93	Dunrobin and Uppat woods	NC870038	H	31.83
87	171	Glen Shira	NN152141	S	31.46
88	186	Corraruie	NR872662	S	31.46
89	86	Carron Valley North	NS696854	C, F&T	31.02
90	2	Carsphairn Forest	NS527086	SS	30.96
91	112	Haddo House Estate	NJ882348	G	30.84
92	185	Skipness	NR896611	S	30.46
93	54	Craigmore	NJ028227	H	30.40
94	98	Greenscares/Coirrie Odhar	NN825132	C,F&T	30.28
95	129	Boreland	NN700433	C,F&T	30.18
96	32	Carron valley	NS690833	C	30.02
97	120	Highcairn	NS668115	SS	29.88
98	111	Ardgarten	NN217021	S	29.88
99	89	Learney Estate	NJ635049	G	29.80
100	148	FE and Dunecht	NJ713010	G	29.80
101	91	Garbole	NH750247	H	29.72
102	114	Todlaw/Mount Blairy	NJ689527	G	29.70
103	13	Erriff	NT001156	SS	29.62
104	128	Airlie Estate	NO403620	C,F&T	29.54
105	70	Glen Loy	NN121827	H	29.52
106	76	Clauchan	NR943299	S	29.32
107	37	Glen App Estate	NX084748	SS	29.32
108	16	Tulloch/Currou	NN372797	H	29.06
109	115	Strathconon estate	NH246540	H	28.88
110	97	Tillypronie	NJ410068	G	28.80
111	145	Durriss and Fetteresso	NO753881	G	28.80
112	147	Rhinebucckie and Maryfield Woods	NO707940	G	28.80
113	101	Watermeetings	NS948103	S	28.62
114	191	Three Bridges	NN093142	S	28.46
115	92	Bolfracks Estate	NN807456	C,F&T	28.18
116	150	Clunes	NN780668	C,F&T	28.18

**Appendix 4 – (continued)**

<b>Rank</b>	<b>Woodland no.</b>	<b>Woodland name</b>	<b>Grid Ref.</b>	<b>Region</b>	<b>Final score</b>
117	40	Todlaw and Cumberhead	NS775338	SS	27.84
118	58	Bidhouse	NS989137	SS	27.62
119	99	Abriachan	NH551368	H	27.05
120	126	Meggernie Estate	NN585455	C,F&T	27.04
121	125	Watermeetings	NS967085	SS	26.62
122	96	Sliabh Fada	NR915260	S	26.32
123	48	Whitehaugh	NJ560227	G	26.27
124	85	Crawfordjohn	NS896222	SS	26.09
125	172	Arkanglass Estate	NN188014	S	25.88
126	122	Kildrummy Estate/Clova	NJ449175	G	25.80
127	119	Gryfe Forest	NS280709	SS	25.76

## APPENDIX 5 – Tables showing woodland rankings per region

### Highland

Rank	Woodland no.	Woodland name	Grid Ref.	Final score
2	8	Rothiemurcus	NH859053	42.40
3	39	Inveroykel Estate/Rossal wood	NC487031	42.19
4	174	Glen Morrison	NH343141	41.52
6	43	Culrain	NH560941	40.19
8	21	Garrygualaich	NN204994	39.52
9	163	Tom an Uird	NJ097302	39.40
14	107	Fourpenny plantation	NH795927	38.94
15	177	Strathgarve	NH393617	38.88
16	61	Clunes	NN232915	38.52
17	26	Abernethy	NH999166	38.40
18	14	Black Isle	NH652583	38.05
20	109	Loch Moy	NH781346	38.05
22	50	Glengarry	NN093996	37.52
24	164	Grant-on-Spey and surroundings	NJ036303	37.40
34	11	Daviot	NH682370	36.05
49	179	Strontian	NO058613	35.00
51	113	Loch Fleet woods and Littleferry NNR	NO411986	34.83
53	181	Onich	NR764642	34.52
56	165	Boat of Garten (Triangle between A95, Spey and railway)	NH902174	34.40
57	166	Inverlaidnan, Kinveachy and Craigellachie plus Corner wood between A938, A95 and A9	NN009531	34.40
58	36	South Ballachulish (Glen Duror block)	NO039074	34.29
60	176	Spinningdale	NN438524	34.19
63	44	Castle Stuart and Culloden	NJ426582	34.05
66	180	Acharacle & Sunart	NM732644	34.00
77	35	Novar Estate and Fe	NH541778	32.54
83	81	Cawdor Estate	NH796562	32.05
86	93	Dunrobin and Uppat woods	NC870038	31.83
93	54	Craigmore	NJ028227	30.40
101	91	Garbole	NH750247	29.72
105	70	Glen Loy	NN121827	29.52
108	16	Corrour	NN372797	29.06
109	115	Strathconon Estate	NH246540	28.88
119	99	Abriachan	NH551368	27.05

Appendix 5 – (continued)

**Grampian**

Rank	Woodland no.	Woodland name	Grid Ref.	Final score
1	6	Ordiequish/Whiteash/Ben Agin	NJ336499	43.05
12	24	Culbin Forest	NH961606	39.05
13	56	Seafield (Cullen)	NJ479645	39.05
19	46	Fe and Glenlivet	NJ240290	38.05
21	149	Darnaway/Altyre/Newtyle	NJ023509	38.05
27	77	Seafield (Cullen)	NJ528592	37.05
28	136	Sillyearn	NJ512529	37.05
30	75	Cushnie	NJ499096	36.80
31	170	Balmoral to Inver	NO225927	36.80
35	17	Glenochty/Bunzeach	NJ351123	35.80
36	167	Birse Forest to Glen Tanner	NO567935	35.80
44	57	Aultmore	NN437174	36.05
39	47	Gartly Moor	NN757463	35.37
43	45	Teindland	NJ472586	35.05
45	78	Wester Buthill (Roseisle) and Fe	NJ112661	35.05
46	138	Seafield (Cullen)	NJ530630	35.05
47	143	Tarryblake	NJ521494	35.05
48	51	Aultmore	NM828628	35.05
52	169	Muir of Dinnet to Cambus of May	NN050637	34.80
64	144	Mayen	NJ566494	34.05
67	133	Bridgend	NJ434033	33.80
68	168	Pannanich	NO390961	33.80
73	69	Balloch Woods	NJ475483	33.05
74	88	Glenlivet Estate	NJ206209	33.05
75	25	Glen Dye	NO644877	32.80
81	42	Clashindarroch/Bin	NJ491432	32.05
82	53	Innes, Pitgaveny (Lossiemouth) and Fe	NJ303663	32.05
91	112	Haddo House Estate	NJ882348	30.84
99	89	Learney Estate	NJ635049	29.80
100	148	FE and Dunecht	NJ713010	29.80
102	114	Todlaw/Mount Blairy	NJ689527	29.70
110	97	Tillypronie	NJ410068	28.80
111	145	Durris and Fetteresso	NO753881	28.80
112	147	Rhinebuckkie and Maryfield Woods	NO707940	28.80
123	48	Whitehaugh	NJ560227	26.27
126	122	Kildrummy Estate/Clova	NJ449175	25.80

**Appendix 5 – (continued)**

**Strathclyde North**

<b>Rank</b>	<b>Woodland no.</b>	<b>Woodland name</b>	<b>Grid Ref.</b>	<b>Final score</b>
23	7	Carradale	NR749444	37.46
25	62	Gortonallister	NS014331	37.32
29	1	Cowal Peninsula	NS061860	36.88
38	4	Minard Forest	NJ568329	35.46
54	187	Torinturk	NR834729	34.46
55	188	Meall Mhor	NH918165	34.46
69	190	Ormaig	NM813017	33.46
70	18	Glenashdale	NS007257	33.32
71	80	Merkland Wood	NS012395	33.32
76	142	Ormsary Estate	NR771717	32.67
78	3	Inverliever	NM908152	32.46
79	5	Eredine	NN015069	32.46
80	189	Knapdale & Inverneil	NR794871	32.46
85	102	Glen Loin	NN304076	31.88
87	171	Glen Shira	NN152141	31.46
88	186	Corraruie	NR872662	31.46
92	185	Skipness	NR896611	30.46
98	111	Ardgarten	NN217021	29.88
106	76	Clauchan	NR943299	29.32
113	101	Watermeetings	NS948103	28.62
114	191	Three Bridges	NN093142	28.46
122	96	Sliabh Fada	NR915260	26.32
125	172	Arkanglass Estate	NN188014	25.88

**Strathclyde South**

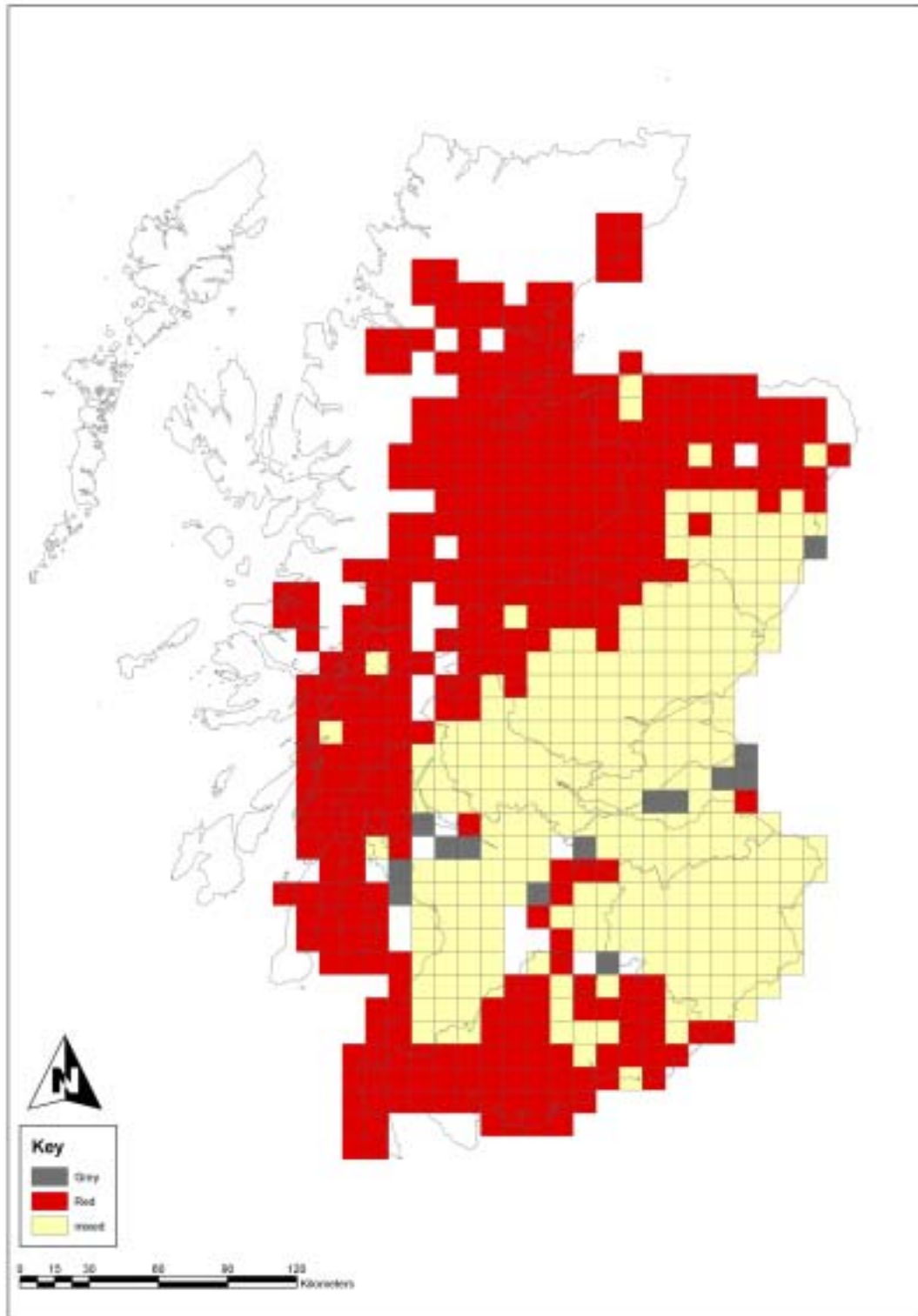
<b>Rank</b>	<b>Woodland no.</b>	<b>Woodland name</b>	<b>Grid Ref.</b>	<b>Final score</b>
84	184	Glentool	NX349921	31.96
90	2	Carsphairn Forest	NS527086	30.96
97	120	Highcairn	NS668115	29.88
103	13	Erriff	NT001156	29.62
107	37	Glen App Estate	NX084748	29.32
117	40	Todlaw and Cumberhead	NS775338	27.84
118	58	Bidhouse	NS989137	27.62
121	125	Watermeetings	NS967085	26.62
124	85	Crawfordjohn	NS896222	26.09
127	119	Gryfe Forest	NS280709	25.76

Appendix 5 – (continued)

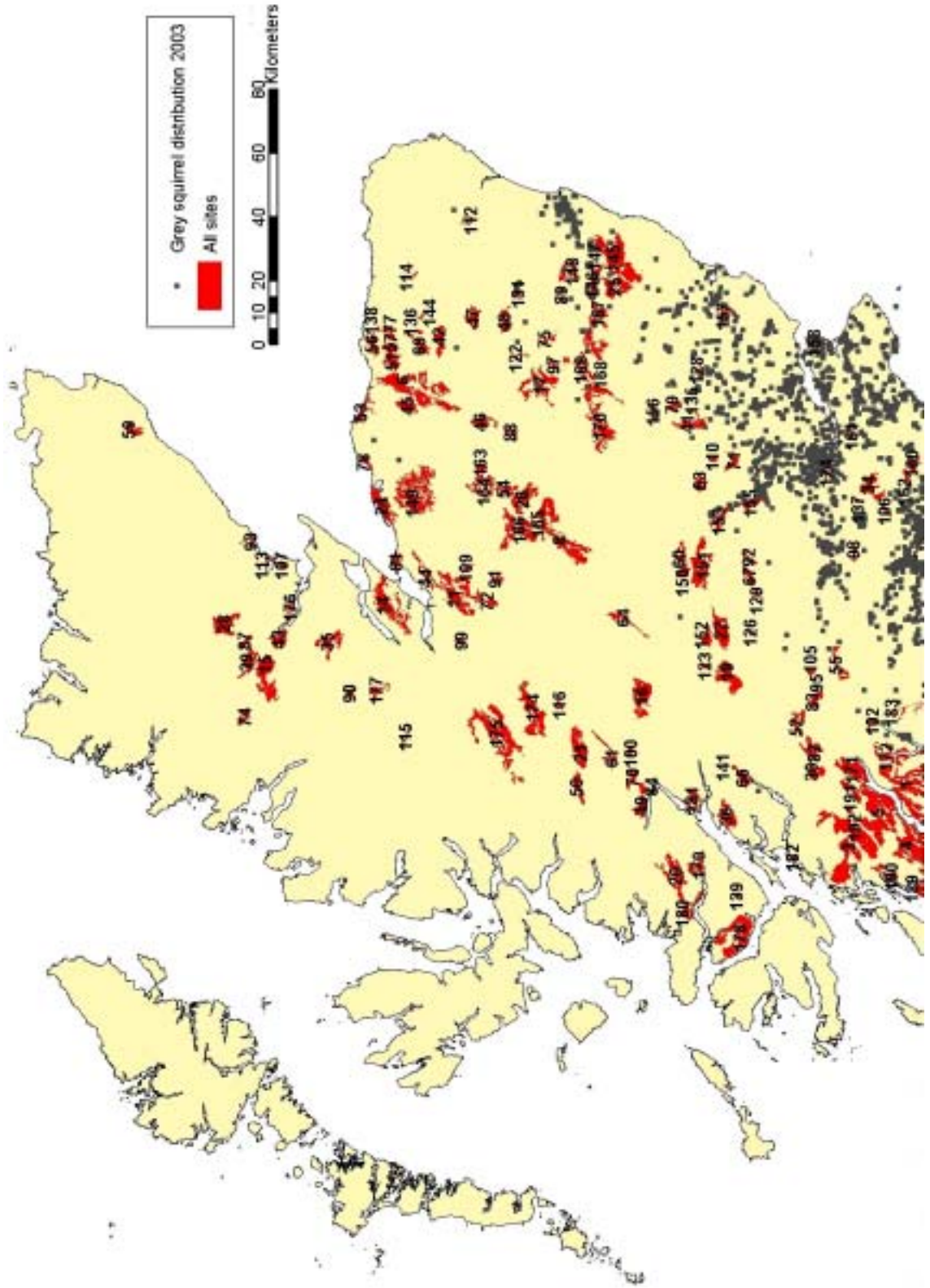
**Central, Fife & Tayside**

Rank	Woodland no.	Woodland name	Grid Ref.	Final score
5	156	Glen Doll	NO270762	40.33
7	22	South Rannoch	NN592549	40.18
10	135	Glen Head	NO273633	39.36
11	154	Frenich	NN817581	39.18
26	153	Faskally	NN932552	37.18
32	151	Errochty aand Allean	NN800618	36.18
33	155	Craigvinean	NN983453	36.18
37	55	Loch Voil side	NN437174	35.60
40	67	Drummond Hill	NN570595	35.18
41	152	North shore of Rannoch	NO125573	35.18
42	110	Dallrulizian	NJ287535	35.08
50	63	Kindrogan	NH813970	34.96
59	34	Glen Devon	NH647903	34.20
61	19	Barracks	NN834677	34.18
62	60	Atholl Estate	NH776471	34.18
65	158	Tentsmuir	NO480250	34.01
72	106	Glen Sherrup	NN960033	33.20
89	86	Carron Valley North	NS696854	31.02
94	98	Greenscares/Coirrie Odhar	NN825132	30.28
95	129	Boreland	NN700433	30.18
96	32	Carron valley	NS690833	30.02
104	128	Airlie Estate	NO403620	29.54
115	92	Bolfracks estate	NN807456	28.18
116	150	Clunes	NN780668	28.18
120	126	Meggernie Estate	NN585455	27.04

## APPENDIX 6 – Red and grey squirrel distribution at the 10km<sup>2</sup> scale for Scotland



**APPENDIX 7 – Location of the 192 priority woods in North Scotland and grey squirrel distribution from the Scottish Squirrel Database (SSDB) updated with grey squirrel records gathered during the contract**



**APPENDIX 7** *(continued)* – Location of the 192 priority woods in South Scotland and grey squirrel distribution from the Scottish Squirrel Database (SSDB) updated with grey squirrel records gathered during the contract

