Forestry Commission Scotland
Forest Research

Improving the ecological content of Forest Plans

A Case Study from Glen Affric
MAY 2008

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1. CONTEXT FOR THE FOREST PLAN AREA

Introduction

Glen Affric forms part of the Upper Beauly Catchment Forest Design Plan (FDP) area and contains the largest area of Caledonian forest owned by the Forestry Commission as well as a range of other habitats of conservation importance. There has been a long history of successful collaboration between Forestry Commission Scotland (FCS), Forest Research (FR) and others in linking research to practice in Glen Affric. The challenge of this project was to convey a long-term vision of the desired forest structure and habitat dynamics for the next 150–200 years as the forest is managed less intensively and reverts to more natural dynamics. This vision would be supported by an evaluation of options and the creation of a plan that best meets objectives for the next 20-30 years. Finally, a specific approved programme of work for the next 10 years would be prepared to build into business planning and funding strategies.

The project was a partnership between Fort Augustus Forest District, Forest Research Ecology Division and FESMB (Environment, Planning & Landscape Architect Managers), with input from other bodies such as SNH and Trees for Life. A range of GIS supported tools has been used to improve the ecological content and function this FDP in predominately native woodland settings. These are:

- The Biological and Environmental Evaluation Tools for Landscape Ecology (BEETLE) which provides a landscape scale approach to habitat management
- The Ecological Site Classification Decision Support System (ESC-DSS) to help guide forest managers and planners to select species ecologically suited to sites
- The ForestGALES computer based decision support tool which enables forest managers to estimate the probability of wind damage

It was agreed between FR and FCS that there was a need for better incorporation of these modelling approaches into the design planning process within the Upper Beauly Catchment. The use of these models can help with the spatial delivery of the management objectives but also improve the objectivity, transparency and accountability of the decision making process in relation to habitat factors at the landscape scale. The work in Glen Affric could also act as an exemplar for other FDPs

Currently, predictive modelling is limited by the availability of good data on forest structure and composition. The FE SCDB holds valuable information on planted stands, but semi-natural woodland needs to be characterised in a way that is meaningful in terms of habitat requirements for key species, but is relevant also to the types of data that can be held within the database (Forestry Commission, 2005).

The current forest plan covers 17,245 Ha in the heart of the north central Highlands and encompasses Glen Cannich to the north, the western part of Strathglass, Cougie and Guisachan to the south and Glen Affric at the centre. It extends some 18 miles from the Village of Cannich in the northeast to Alltbeithe in the southwest. It thus covers a range of climatic conditions with rainfall varying from 1600 mm in the east to 2800 mm in the west as well as an altitudinal range from 100 m above sea level in the east to over 1000 m in the west.

1.1 Location

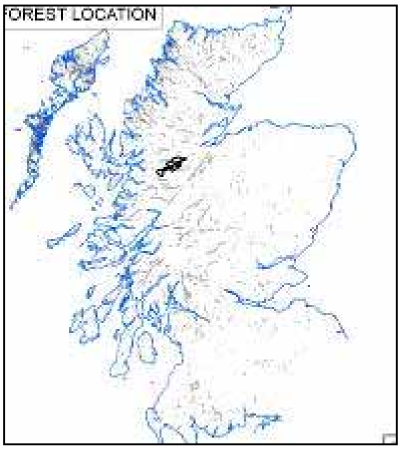
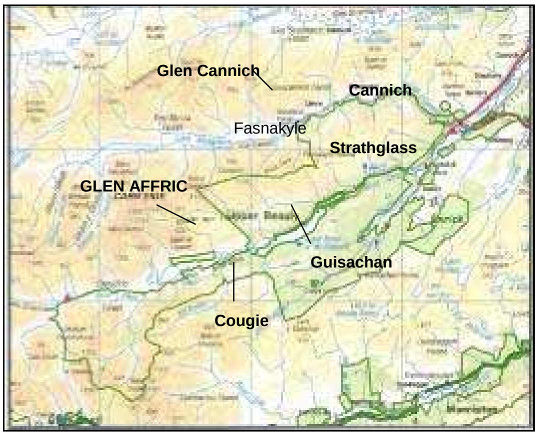


Figure 1.1 Location

Figure 1.2 Looking west from Dog Falls

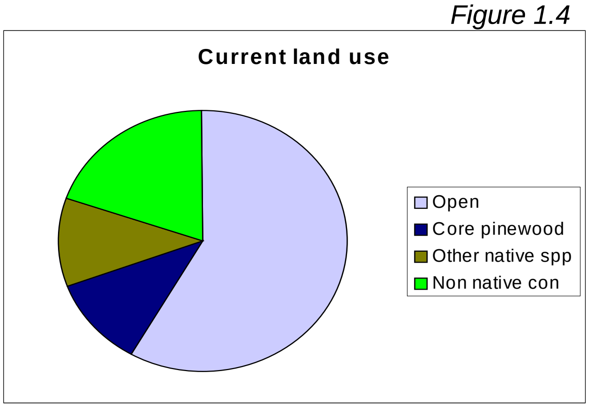
Figure 1.3 topography



1.2 Description

The Forestry Commission acquired Guisachan in 1935, the main part of the Glen Affric pinewoods and Fasnakyle in 1951 and Cougie in 1964. The Affric Pinewoods were declared a Pine reserve in 1960 and enclosures established to protect regeneration. This area is the fourth largest area of genuinely native pinewood in Scotland[1].

Figure 1.4

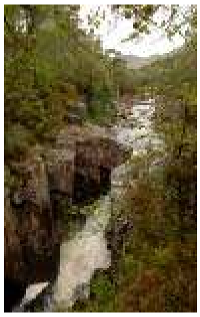
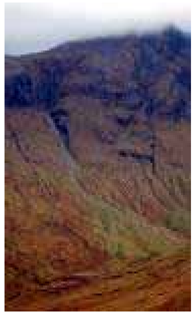


[1] From the Caledonian pinewood inventory

Over half the area is currently open ground and is mostly heath. Of the woodland area, just over half consists of native species with the native Caledonian pinewood and other native species, mostly in Scots pine plantation equally represented. The remaining half of the woodland area consists of non-native conifers including the notable stands of Douglas fir at Guisachan.

The character of the area with its mosaic of pine, birch, water and heath against the backdrop of mountains sweeping up from remote deep glens establish the area as one of Scotland's iconic landscapes. It is a key destination for visitors, conservation volunteers, students and a venue for outdoor activities and adventure sports supporting the local economy.



1.3 National and International importance

The national and international importance of its landscapes and the range of habitats and species that the area supports is recognised and protected by a number of overlapping designations, each with features requiring protection under EU or UK law. These are reflected in the requirements of the UK Forestry Standard and UK Woodland Assurance Scheme (UKWAS). Designations can apply to the site, the habitats found on that site or species which use those habitats.

1.3.3 European importance

SAC: Special Area of Conservation
These sites are designated under the European "Habitats Directive". The Strathglass Complex SAC covers 23,596Ha and contains a range of montane and woodland habitats and species which are considered rare or threatened within a European context. FCS is responsible for the management of 14% of this SAC, the woodland and a small part of the montane comprising 20% of the forest plan area.

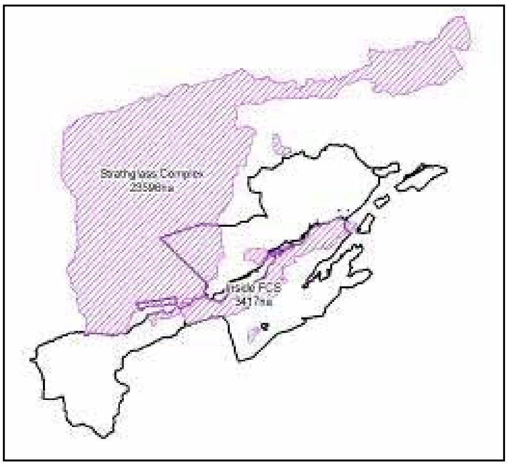


Figure 1.5 Strathglass complex SAC

Qualifying features are listed as:-

- Caledonian forest
- Bog woodland
- Acidic scree
- Tall herb communities
- Dry heath
- Wet heath with cross-leaved heath
- Alpine and sub alpine heath
- Montane willow scrub
- Clear water lochs with aquatic vegetation and poor to moderate nutrient levels.
- Otter

SPA: Special Protection Area
SPAs are designated under the European Habitats Directive for bird species considered rare or vulnerable within Europe and listed in Annex 1 of the Birds Directive. Loch Affric has recently been identified as a potential Special Protection Area for divers. While the Loch itself is under different ownership, FCS is responsible for the management of part of the loch shore.

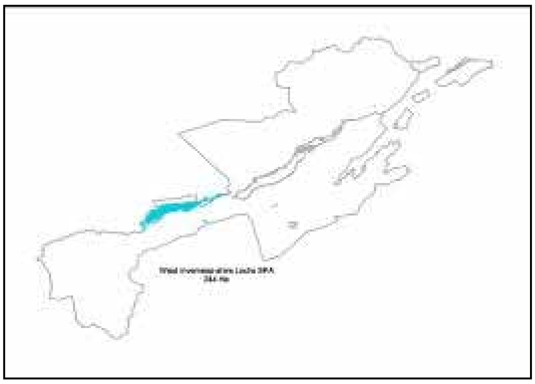


Figure 1.6 West Inverness-shire Lochs SPA

Habitats Directive: Annex 1 Habitat and Species
In addition to the areas above which are part of the Natura 2000 site network under the "Habitats Directive", a number of habitat types (see SAC above) and species are listed as being of European interest. The UK is committed to achieving "favourable conservation status" for some of these Annex 1 habitats, not just those within SACs. The number and distribution of these Annex 1 habitats need to be established by survey. At the start of the project, the distribution of these habitats and species apart from some high profile examples such as Capercaillie (below) had not been established.

Woodland Grouse
Capercaillie is both a European priority Annex 1 species under the European Habitats and Species Directives and a UKBAP priority species. The eastern part of the project area is identified as a core area for this species in Scotland. Glen Affric is an important site for black grouse, which is a UKBAP priority species. The restoration of the pinewoods is creating young regenerating pinewood and open space, which black grouse can currently utilise. Glen Affric is adjacent to one of the two Black Grouse Trial Management Projects in Scotland, which is a partnership project with RSPB, SNH and FCS. It is also adjacent to the RSPB Reserve at Corrimony, which is being managed for black grouse.

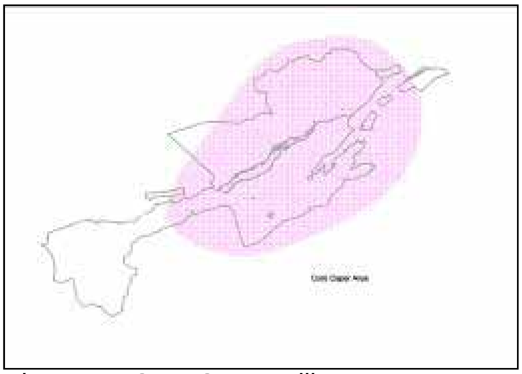


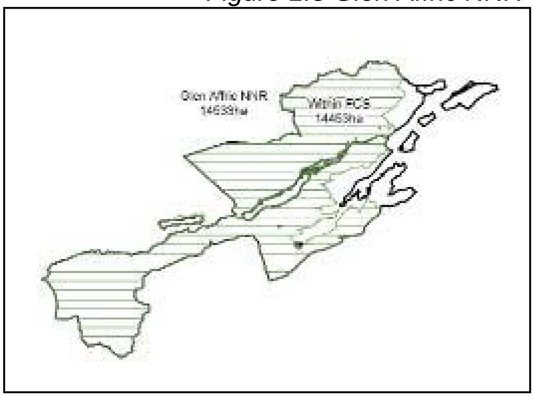
Figure 1.7 Core Capercaille Area

1.3.4 National importance

NNR: National Nature Reserve
NNRs are areas of National importance including the best examples of particular habitat types. The majority (84%) of the forest plan area was declared an NNR in 2000 on the basis of its scientific interest, SSSI, Natura and NSA status. Attributes are identified as:-

- Nationally important component of Caledonian Pinewood.
- Managed primarily for conservation.
- Management demonstrates best practice
- Security of tenure.

Figure 1.8 Glen Affric NNR



SSSIs: Sites of Special Scientific Interest.
Glen Affric and Affric-Cannich Hills SSSIs are components of the Strathglass complex SAC. FCS manages 18% of these nationally important sites which form 20% of the plan area (same areas as SAC above)

Glen Affric SSSI is representative of the central pinewoods of Scotland. Most of this area is managed by FCS and notified features include:-

- Native Pinewood including flowering plants such as one-flowered wintergreen and twinflower.
- Breeding bird assemblage including diver, golden eagle Peregrine, merlin, hen harrier, Scottish crossbill, crested tit, capercaillie and black grouse.
- Dragonfly assemblage including the rare Brilliant Emerald.
- Lichen assemblage including 14 rare species

Affric- Cannich Hills SSSI is a large upland site containing some of the highest mountains north of the Great Glen with a rich diversity of habitats and species. A small part of this site is managed by FCS. Notified features include:-

- Montane acid grassland
- Montane willow

- Montane heath
- Dry and wet heath
- Blanket bog
- Tall montane herb communities
- Scree
- Nutrient poor lochs.

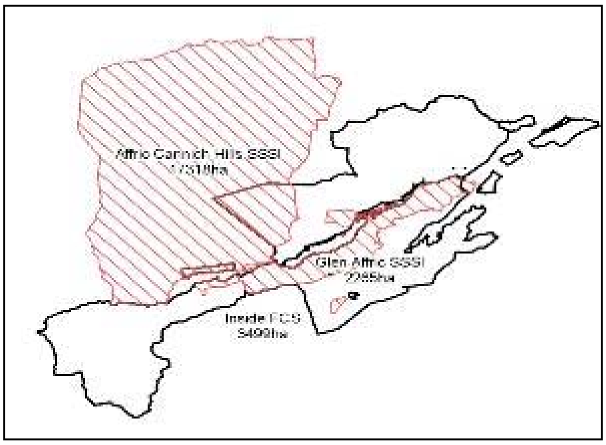


Figure 1.9 Glen Affric and Affric – Cannich hills SSSIs

UKBAP: UK Biodiversity Action Plan
Set priorities for conservation action to protect and enhance habitats and species, generally those listed as Annex 1 under the "Habitats Directive" within UK context, through making these the subject of UKBAP Habitat Action Plans (HAP) or Species Action Plans (SAP). In addition, the Country Biodiversity List identifies species considered to be of principle importance for biodiversity in Scotland.

NSA: National Scenic Area.
These areas, which are judged to be nationally important, are designated sites representing the best examples of Scotland's landscapes. FCs manages just under half of the NSA and 50% of the plan area falls within the NSA. The citation describes the area as displaying a fine variety of scenery. *"It is flanked by the highest mountains in the north west highlands, shapely conical peaks above a long glaciated valley. The slopes of the hills are clothed in forest, one of the most beautiful remnants of native Caledonian pine forest, with a leavening of birches. It maintains a sense of wilderness and has a grandeur and classic beauty"*

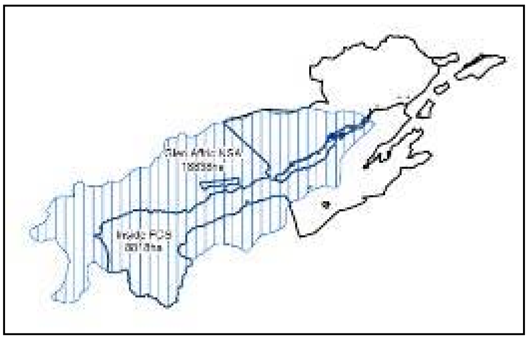


Figure 1.10 Glen Affric NSA

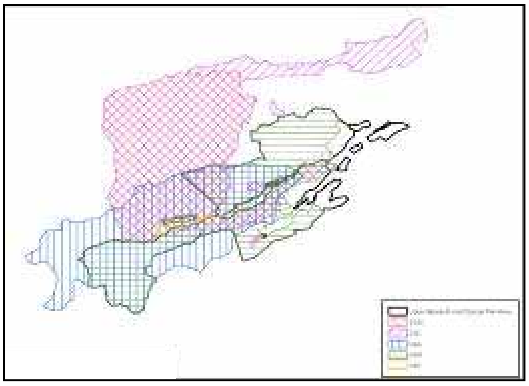


Figure 1.11 All statutory designations

Ancient Woodland sites
In addition to these statutory designations, the area has a long woodland history with about half the present woodland (20% of the plan area) on an Ancient Woodland site. About 75% of this area comprises site native species and the remaining 25% (900 Ha) contains an element of non-native species (Plantation on Ancient Woodland Sites PAWS)[2]. Under the Scottish Forestry Strategy, FCS is committed to maintaining and enhancing ancient woodland features and restoring, *"….at an ecologically appropriate pace, sites with a significant biodiversity legacy or at key locations in native woodland networks."* See also UKWAS 6.3.2

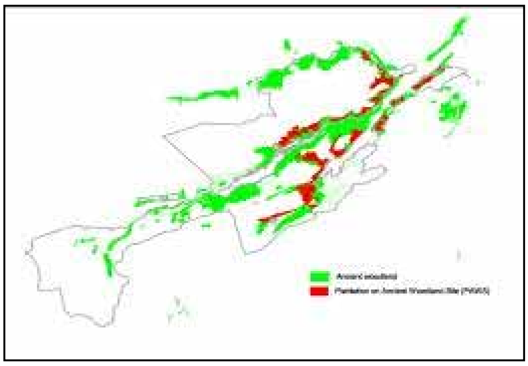


Figure 1.12 Ancient Woodland Sites

1.4 Species

Largely because of the status of the area and the interest shown in its flora and fauna from both scientific researchers and amateur naturalists, there have been a large number of studies carried out and lengthy species records gathered from a wide variety of sources. Some of these are a result of structured survey work, others derived from individual sightings. These were compiled for the NNR management plan and in 2003-4 a total of 1310 species had been recorded. This has subsequently risen to 1818.

[2] This is an approximation using the UKWAS second edition definition of PAWS as Ancient Woodland Site where native tree cover has been replaced by species not native to the site. The practice Guide on the *Restoration of Native Woodland on Ancient Woodland Sites* uses a different definition of PAWS.

These break down into:

Group	No of spp recorded
Bird Species	117
Bryophytes	168
Fungi	224
Lichens	222
Vascular plants	272
Butterflies and dragonflies	30
Moths	101
Other invertebrates	140
Freshwater fish	2
Mammals	28
Reptiles and amphibians	6
Total	1310

2. CURRENT FOREST PLAN

The current plan was approved in 2004 and is thus due for a review in 2008/9. During its preparation, much emphasis was placed on achieving a consensus with stakeholders. This resulted in a Community Concordat between FCS and Strathglass Community Development Group who are signatories to the Forest Plan along with FCS and SNH. A Management Group for the National Nature Reserve comprising FCS, SNH and the Community Development group was formed to undertake regular liaison.

Within the NNR the overriding objective is the "Primacy of nature" and the plan aims to show how this could be achieved while embracing other important objectives such as encouraging tourism. It recognises that the nature of the landscape, as a mosaic of birch, pine, water, hilltop and open space is something to be carefully conserved and it does not advocate the wide scale expansion of woodland.

Because of the complexity of designated sites and the desirability of avoiding several different plans covering the same area, the Forest Plan also embraces the required Habitat Action Plans, SSSI, SAC and NNR Management Plans.

Some aspects of the plan preparation were hampered by lack of baseline environmental data including soils and NVC (which affect the ability to run ESC), ground vegetation condition survey and identification of Annex 1 (SAC qualifying features) on the ground. This meant that many of the actions identified were not spatially explicit. At the same time, there was an abundance of information on individual species records (1.4 above) but not always a clear approach on how this data could be used with the Forest Plan.

The written objectives can be summarised as:-

Community
- Embrace, value and accommodate the input and participation of stakeholders, particularly the local community and work together in the spirit of partnership by undertaking regular liaison.

Biodiversity
- Ensure the primacy of nature by increasing biodiversity, maintaining favourable habitat condition and enhancing the pinewood habitat by encouraging natural regeneration.
- Non-native trees are to be removed and pine plantations thinned to make them appear more natural and achieve healthy woodland mosaic with a diverse range of structure.
- Fell non-native trees where native woodland remnants are at threat and where there is no prospect of harvesting being economic in the long term

Recreation, Education and Interpretation

- Promote and respect the recreational and educational values of the area for the benefit of the local and wider community.
- Encourage national awareness of Native pinewoods and National Nature reserve purpose.
- Encourage research into Pinewood Ecology.
- Encourage access through network of trails and access features and promote interpretation.

Landscape

- Ensure new woodland areas fit with landscape, maintaining an aesthetically pleasing landscape
- Assess impacts of non-native conifer removal and other operations

Timber production

- Minimise the use of the clear-fell silvicultural systems.
- Carry out the harvesting of timber where this supports the achievement of the other aims using techniques with minimal impact.
- Encourage the development of local economic opportunities from timber operations.

Gaps in the process leading to the current design plan included:-

- How best to use the mass of biodiversity information and studies and relate this to the requirements of biodiversity legislation.
- How to incorporate the environmental tools, models and advice being developed by Forest Research into the Forest Plan process.
- How to improve the cover of baseline data in a cost-effective way.

There was therefore interest in answering the question-If this work was carried out, how would it change the conclusions of the plan?

3.0 OBJECTI

3 OBJECTIVES OF THE STUDY

The objectives of the study were:-

- To look at how the ecological content of Forest Plans for important biodiversity sites could be improved.
- To assess to what extent Forest Research information tools, analytical models (BEETLE, ESC, FOREST GALES) & advice could help to achieve this and how these might be integrated into the Forest Plan process.
- To assess what happens when models are used in combination.
- To develop a process to help Forest District teams to deal with large amounts of data and a large, complex area.
- To allow Forest Research to understand how managers might use the models & advice.

The study used a real area to test the data that are needed to run the models, examine how the outputs could be synthesised into the forest plan process and identify if they might change the conclusions of the plan when this is revised.

The case study is not a revision of the Forest Plan. The conclusions of the case study may help to inform the next revision of the Forest Plan and fill some of the gaps identified, but as normal this will involve a full consultative process.

The study was an exploratory process; the team didn't set out to provide all the answers! The site chosen was one of the most complex areas possible. The process is ongoing with further work on developing both the models and the forest plan process.

4. ECOLOGICAL PRINCIPLES OF CONSERVATION MANAGEMENT

4.1 Introduction

It has been proposed that should be no specific historical point of reference for ecological restoration in the uplands (Tipping et al. 1999), but rather we should aspire towards the development of ecologically functioning landscapes. In these, key ecological processes across the range of representative habitats, communities and species at all scales from regional (e.g. the Beauly catchment) to local (e.g. stand of veteran trees or montane scrub) should be restored to favourable condition (Poiani et al. 2000). This would allow for the development of increased connectivity across the landscape from lowlands to uplands to reverse the effects of fragmentation.

Investigations into historical and ecological records have shown that the extent, structure, distribution and composition of upland woodlands and open habitats in Scotland have evolved as a result of both anthropogenic and environmental influences. Many of upland woods have historically had a range of types and structure because they have long been managed alongside extensive pastoral land-use over hundreds of years. The species composition of open habitat communities is likely to have changed over time and will continue to do so as a result of these influences.

The development of ecological functionality will require a range of different management options to deliver the necessary mosaics of habitats and woodland structures.

The recent increase in number of large-scale ecological restoration projects in Scotland in recent time reflects the increased awareness of the importance of landscape ecology, and a move away from site-based conservation strategies. Recognition that the structural diversity of upland woods is linked to the long historical management (e.g. shieling wood pastures), and that the associated natural and cultural heritage is a product of this ancient land-use system, should provide some pointers for future management of the uplands. This approach to ecological restoration allows a range of different woodland structure types to be incorporated in recognition of the historical origins of the landscape. There are biodiversity benefits in this approach with an increase in niches as a result of the diversity in structure types. In restoration projects there should be an emphasis on the protection and enhancement of keystone structures (e.g. veteran trees) and habitats (e.g. ecotones transition zones between different vegetation types) these are where their influence on ecosystem function is greater than expected from to their size or extent),. These have the potential to provide both ecological connectivity and continuity, and to act as focal points or nodes for landscape restoration. Maintaining these keystone structures should be seen as a measure of success in landscape restoration.

4.2 Understanding the ecology of a site

From understanding what is present within a site it is possible to generate a landcover of a site/landscape that reflects its ecology at 4 different scales.

4.2.1 Landscape context of a site

We need to be aware of how the habitats and species that are present on a site relate to the wider landscape context and to the national context and how different sites and land-uses relate to each other within a landscape.

In this case, it is the whole of the Strathglass catchment (Figure 4.1) of which the upper Beauly forms part from the extensive montane uplands to low lying farmland around the Beauly Firth. It is interesting to note that every woodland HAP type found in Scotland is represented to some degree in the Strathglass catchment.

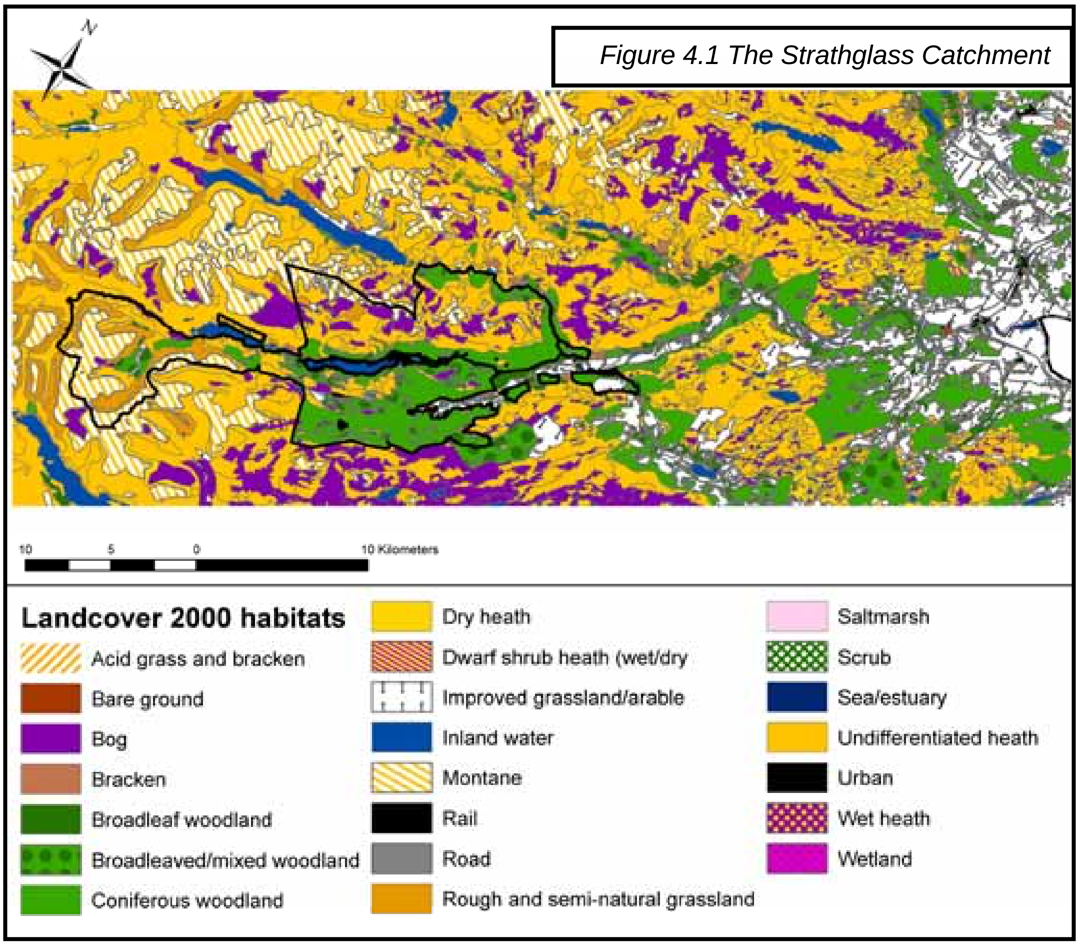
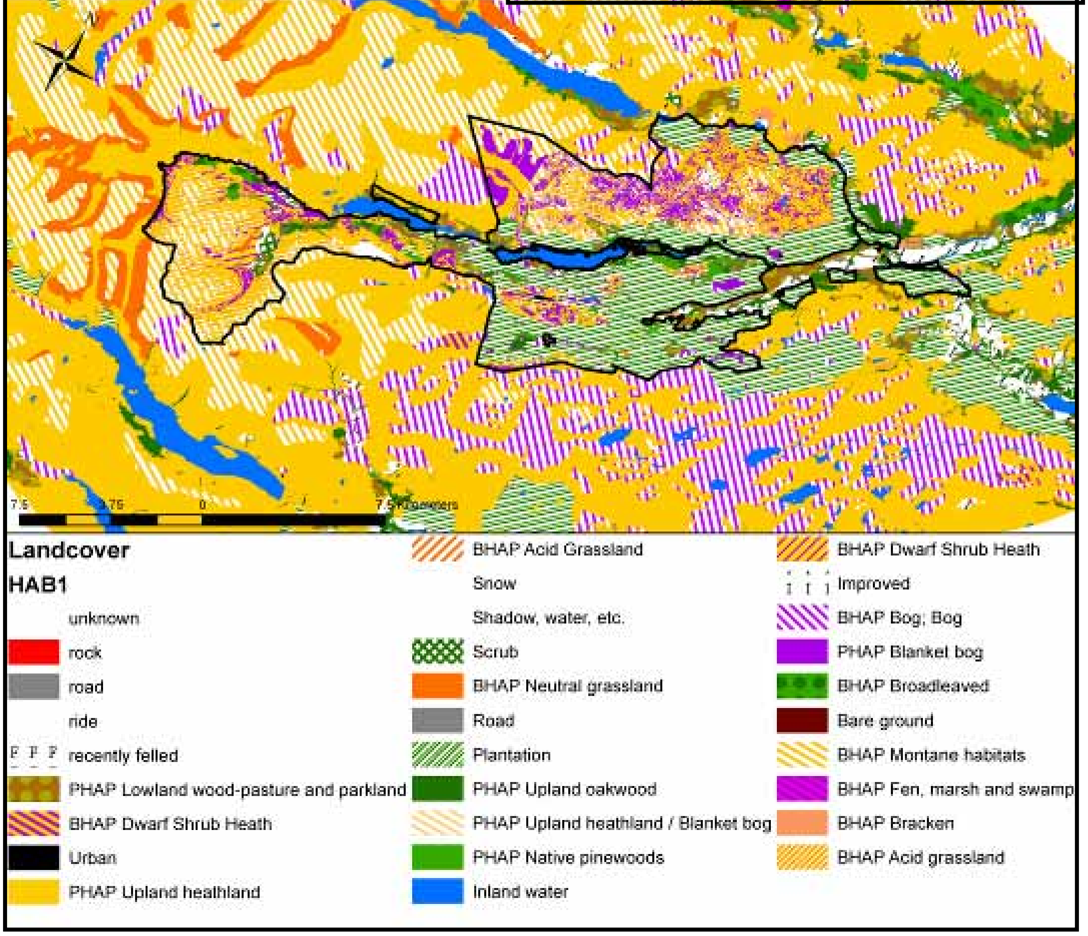


Figure 4.1 The Strathglass Catchment

<u>4.2.2 Site ecology</u>

This needs to be based on an understanding of the habitats and species that are found on a site and the dynamic relationship between them. This will also need to take into account to any designations that may be applied and should be underpinned with an understanding of the soils and climate that have shaped the ecology of a site. In this case study the whole of the design plan area is regarded as the site. This is likely to be a larger area than most sites for which design plans are undertaken, and the Upper Beauly Catchment (Figure 4.2) could for other purposes be regarded as having a landscape scale.

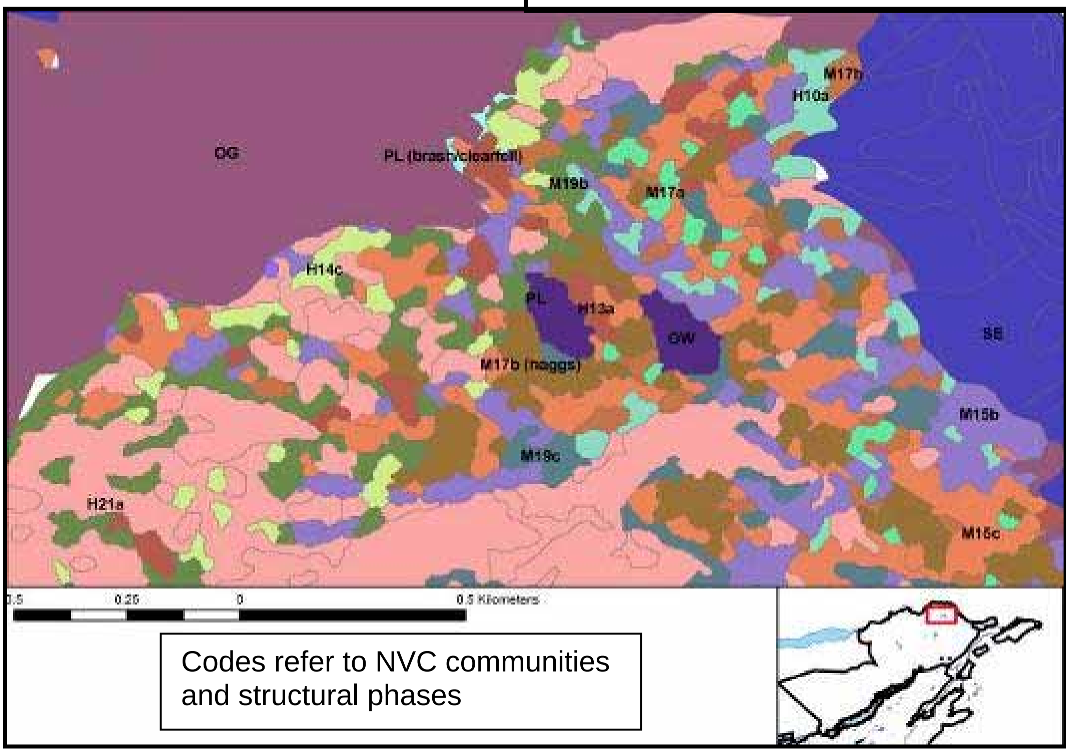
Figure 4.2 The Upper Beauly catchment



4.2.3 Stand and community ecology

We need to be aware of how different stands or plant communities relate to each other within habitats. This includes the woodland structural phases (section 5.4.2) or the vegetation communities for example the relation ship between the montane heath and grass heath communities as shown in figure 4.3.

Figure 4.3 Detail of Cannich

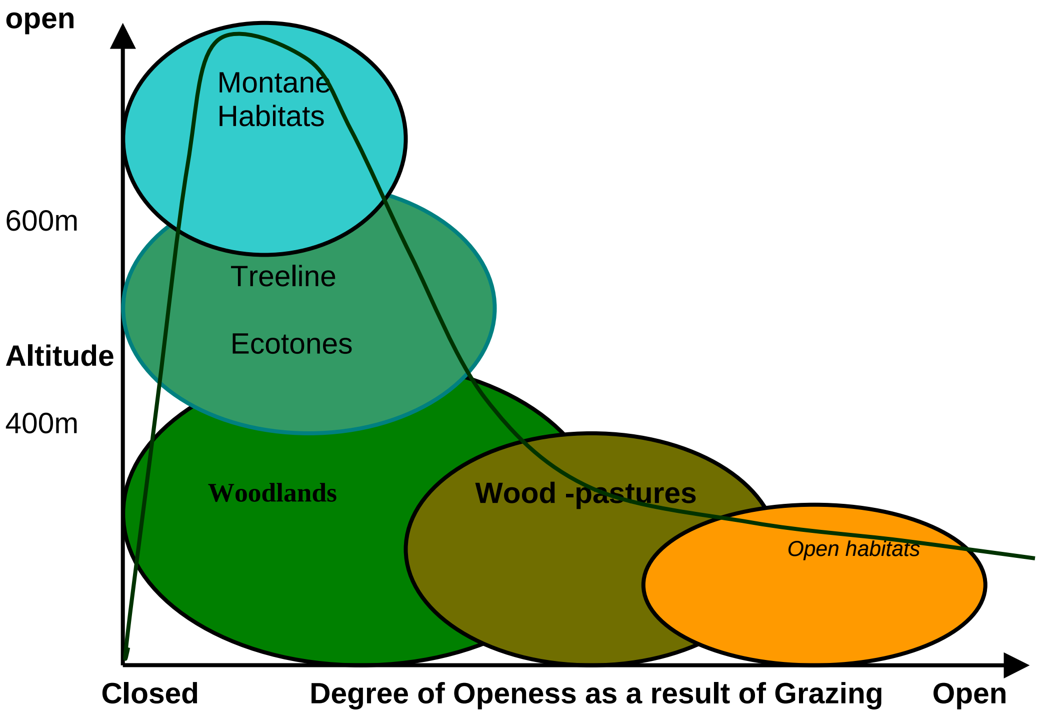


4.2.4 Ecotones and successional changes

The ecology of a site is not static and ecological processes are continual drivers of change. While policy sometimes focuses on patches of priority habitats that are islands within the landscape, the ecological reality is that there are few definitive lines on maps or set areas of habitat. Conservation objectives should aim to initiate site specific management which allows for spatial and temporal change and the development of the transitional zones between habitats. This may result in different outcomes from that originally planned but which maybe more ecologically suitable for the site.

Ecotones are the transition zones between different vegetation types. They contribute to increased habitat diversity by providing habitats different from and intermediate between the types on either side. They are often species-rich because they support many of the species from both vegetation types and may also support specialist species unique to edge habitats. This is often a result of the sub optimal condition for different vegetation types that allow the specialist niches for less competitive species. Ecotones between forest and open habitats can be particularly valuable for heat- and light-demanding species, including many invertebrates.

Figure 4.4 Ecotones between habitat types



4.3 Setting Ecological objectives

These should be set at the appropriate scale based on an understanding of the ecology of a site.

Landscape context
We need an overall vision at the regional landscape scale of how the site or individual forest fits within the wider landscape. In the Strathglass catchment this could be ensuring that the forest contributes to connectivity between all the different woodland types that are represented within the catchment.

Site or forest level
This will be driven by the understanding of the forest and is the scale at which forest plan level objectives can be achieved by applying management. In terms of the woodland component, this could be by ensuring that all site suitable woodland types are represented and that the balance of structural phases (see section 5.2.2) of these types function as habitat networks (see Section 7.1)

Stand or coupe and community level
Detailed management prescriptions can be applied at this level to achieve community or stand level objectives. This could involve selective thinning of stands to accelerate the forest ecological succession or the planting of montane scrub in suitable vegetation types.

These three levels (landscape: forest: stand) do not work in isolation from each other; for example, for good ecological condition at the landscape scale would require a balance of stands of the different woodland structural phases within the forest area across the landscape. These objectives must, however be seen in the context of the dynamic systems that are constantly changing as a result of both natural and man-made influences. It is important to be aware of the ecotones and successional changes that may occur and these may result in different outcomes from those planned and that these may actually be more ecologically suitable for the site at a particular point in time.

4.4 Ecosystem Function

The overall aim is to achieve and enhance ecosystem function that provides structural and compositional diversity and can support extensive biodiversity at the landscape scale. This implies a focus on ecological process rather than solely the needs of those rare and endangered species that are afforded legislative protection. The premise is that if we have an ecological functioning landscape then there will be the ecological opportunities for viable populations of these species to exist. The development of ecological functionality may best be achieved the habitat networks. These networks are "*Systems of landscape elements that are designed and managed in a way that restores ecological functions and conserves and enhances biodiversity*" (Council of Europe, 1998). The identification of areas that are considered to be ecologically connected can be used to target, justify conservation effort to reverse the effects of fragmentation. www.forestresearch.gov.uk/habitatnetworks

4.5 Management Prioritisation

In order to achieve the objective of enhancing ecosystem function the aim should be for:-

- A balance of stands of the different woodland structural phases within sites across the landscape.
- The range of woodland types for site types that are functionally connected within habitat networks across the landscape.
- The maintenance of the full range of priority open habitats and their successional ecotones between them in favourable ecological condition.
- Integrated networks for range of habitats and focal species that reflect local landscapes can be used to prioritise conservation effort.

This should be undertaken following the prioritisation outlined below:

1. Protect & manage high quality habitat
2. Restore & improve sites with restoration potential
3. Improve & manage other sites
4. Improve landscape matrix - reduce land use intensity
5. Create/recreate semi-natural habitat

4.6 Indicators of ecological function

In order to monitor the achievement of ecological function there needs to be simple measures that can assess this at the different scales (landscape, forest and Stand). These are outlined below:

Wooded Habitats
Structural diversity
This can be measured by of the balance of the woodland structural phases that are functionally connected within habitat networks across the landscape. Isolated woodlands and limited habitat networks should be in favourable condition (JNCC Common Standards Monitoring) for structure. This can be assessed in a GIS using the BEETLE model to define the habitat networks and remote structure survey from aerial photography interpretation.

Compositional diversity
This can be measured by the range of woodland types appropriate to those site types in the site that are functionally connected within habitat networks across the landscape. Isolated woodlands and limited habitat networks should be in favourable condition (JNCC CSM) for composition. This can be assessed in a GIS using the BEETLE and ESC models combined with the results from the NWSS.

Open Habitats
The maintenance of open habitats, which tend to undergo succession, in favourable condition will need management involving grazing, burning or some form of cutting to prevent succession. An alternative approach is to allow succession in some patches but to maintain the habitat resource by restoring or creating new habitat patches elsewhere. This would not result in an overall loss in any of the habitats at the landscape scale but a change in their distribution.

Species diversity
The maintenance and enhancement of species diversity can be realised more effectively through the ecological function than by single species approaches to conservation. So it is not the amount of habitat for a designated species that is important but rather the quality of the full range of habitats and the zonations and succession between their mosaics. The relationship between biodiversity and ecosystem function (the degree to which an ecosystem is working effectively) has been of interest to ecologists for some time (Shultze et al., 1993). Various indicators for assessing ecosystem function have been proposed such as: indicator species, keystone species, species richness, diversity indices, functional species and functional diversity. There is continuing discussion about the effectiveness of such indicators and the most appropriate method of assessment of ecosystem function but the consensus would appear to fall in favour of the use of what are termed ‘functional species groups’ (Davic, 2003; Patchley, 2002).

Functional species groups are groupings of species with similar ecological niche requirements. This allows for species of different taxonomic groupings to be allocated to the same functional group as they have evolved to fulfil similar functional roles within an ecosystem. Key woodland niches (KWN) that represent a range of microhabitats within an ecosystem are identified with species groups representing their functionality. The assumption is that the KWN are functioning if the representative species of that niche are present. These species should have known, similar evolutionary and ecological traits (i.e. are in intraspecific competition with each other) and are grouped to form a functional species group.

4.7 Ecological principles and the Forest Plan

Incorporation of ecological principles into a Forest Plan should take account of:-

- The historical context of a site or stand
- External drivers of change (wind, fire etc)
- The potential of any given site to ecologically support the habitats proposed
- The ecological connectivity between habitats across the landscape and within the site through the development of habitat networks

This will require a wide range of ecological data and other information that relates to the site. These data will also need organising and analysed so that the important relevant information and the data that is required to run ecological models is readily available.

Summary
In order to include elements of biodiversity into a forest plan there is necessity to have some understanding of the ecology of the site not just the designations that have been applied to it. It is suggested that the aim for any site is the development of ecologically functioning landscapes. In these, key ecological processes across the range of representative habitats, communities and species at all scales from regional (e.g. the Beauly catchment) to local (e.g. stand of veteran trees or montane scrub) should be restored to favourable condition. As a result habitats and species with designations are more likely to be in favourable condition. The development of ecological functionality will require a range of different management options to deliver the necessary mosaics of habitats and woodland structures.

5. Understanding the place: Landscape character and structure

5.1 The process of understanding the landscape character *(the physical, human influenced and aesthetic attributes of the landscape)* helps to assess the potential impact of change and ensure that proposals maintain or enhance scenic quality and make an overall positive contribution to the visual environment. The landscape character also underlies the value of the area as a recreation resource, identifying its diverse nature and distinctiveness as well as some of the reasons why it is of particular scenic value.

The objective within the case study area went beyond this and aimed to identify areas of broadly similar characteristics that would allow this large, diverse and complex area to be broken down into recognisable and manageable landscape units. The scale of resolution is appropriate to a concept plan and extends outwith the plan area to take account of interaction with adjoining areas. This helped to contextualise the modelling processes with ground knowledge and contributed to discussion of opportunities, constraints and multipurpose objectives. It also helps to communicate findings in a way that can be recognised and understood by a wide range of people.

5.2 The Landscape Character Assessment (LCA) for Inverness District[3] formed a useful starting point for identifying the principle landscape units. However, because the scale of resolution of this assessment, it did not include enough detail to be useful in a more in depth application to the case study area. The process used here was similar to that used in the LCA studies and was systematic in that it is based on a range of physical and descriptive criteria drawn from available sources, in particular OS 1:25,000 maps and 1:50,000 digital terrain models, air photos, sub-compartment data as well as field survey and photographs. [4]
The main criteria are identified below

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[3] John Richards (for SNH) 1999 Landscape Character Assessment for Inverness District.
[4] Methodology and descriptors were based on Landscape Character Assessment; Guidance for England and Scotland, SNH 2002. These descriptors are appropriate to the Upper Beauly area but not necessarily to other forest plan areas.

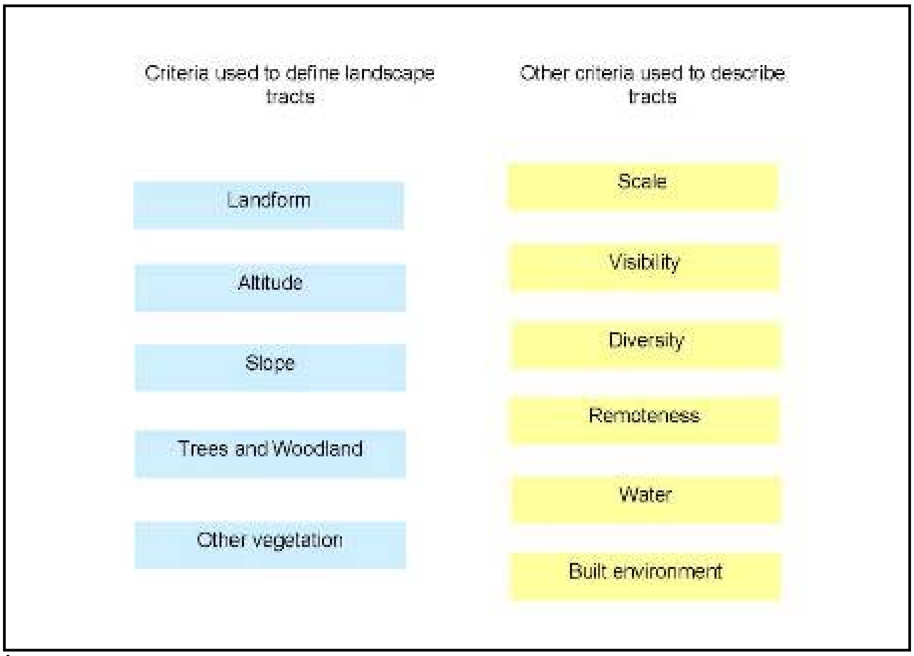
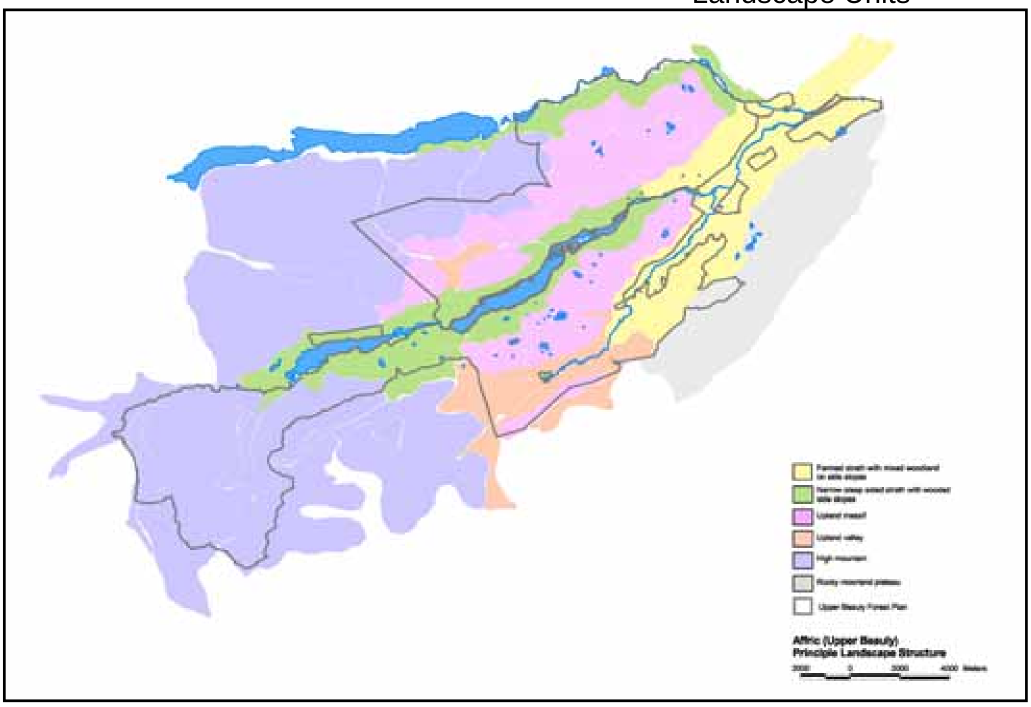


Figure 5.1

The boundaries of the units were established using judgements based on field observation over a period of 4 days between July and November 2007, an understanding of the landscape and drew on the listed criteria. Digital terrain modeling was used for the identification of slope. The tracts were modified throughout the case study as further information became available.

Figure 5.2 Principle Landscape Units



A defining characteristic of the study area is the range of landscapes from northeast to southwest. Six **principle landscape units** were identified:-

5.3 Farmed strath with wooded slopes

To the south and east is the relatively low lying and fertile **Farmed strath with wooded slopes.** – This is a valley with flood plain and moderate to steep wooded lower side slopes, mostly below 200 metres and gentler upper valley slopes. There is a high proportion of broadleaves on the lower valley slopes with plantation conifers on the upper slopes and within FCS woodland. It is a managed, settled landscape of fields, estate houses and small woods and contains the villages of Cannich and Tomich as well as policy woodland and parkland around the former Guisachan house. Local views are important.

This is bounded to the south by **Rocky moorland plateau**. This is a relatively low (< 500m) area of moorland, bog, plantation, and rough pasture. Because it is above eye level from most significant viewpoints, it is of low visibility. Only a small part is within FCS management.

5.4 Rocky moorland plateau

Extending west and north are **Narrow wooded glens** - rugged, locally steep, complex, with semi-natural pinewoods and plantation, small lochs and reservoirs, mostly above 150m rising to 400m. This area contains the core Glen Affric pinewoods as well as the younger pinewoods of Glen Cannich to the north. The area is relatively remote with minor roads, sporting lodges, rough pasture and woodland. The combination of water, woodland and mountain views make this area a focus of recreation interest.

5.5 Narrow wooded glen

Between and to the south of these glens are 2 areas of **Upland massif**. These comprise rolling, irregular or rounded summits and plateau between 250 and 650m with plantation, open moorland, rock and bog. The areas are remote and much of the area is visible only in the distance.

5.6 Upland massif

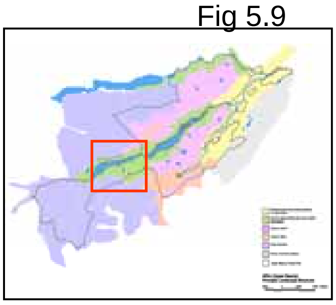
Within and adjacent to the upland massif are **Upland valleys**. Lying between 250 - 400m, these areas are higher and more exposed than wooded glens plantation, relatively remote with bog, plantation and pinewood.

5.7 Upland valley

5.8 High mountain

To the west lies an area of High **mountain**, rugged, sweeping steep sided mountains rising to 1000m penetrated by glaciated valleys. It comprises open deer range with moorland, rock, scree, and bog and scattered broadleaves in gulleys. It is "Wild" in character and summit ridges are a mecca for hill walkers and mountaineers.

Fig 5.9



Within each of these larger landscape units, there is considerable variability in terrain and vegetation. To create a framework that could be used for analysis and as a start point for future management, these broad units were broken down into some 50 landscape types varying in extent from 20Ha to over 1000Ha. Not all of these are unique and areas of similar characteristics are found in more than one part of the study area as shown in the example from the south side of Loch Affric below.

Gentle to intermediate slopes between 200 and 350m. Rough complex terrain with rocky heather knolls, peaty hollows and dubh lochans. Pine woodland with varied structure and open glades.

As above but more open with widely spaced, mature pine.

As above, some previously felled plantation with patches of young birch and pine.

Rounded or irregular steep sided and rocky slopes and mountain summits rising from 400 - 1000m. Open heath with scattered broadleaves in clefts and gulleys.

Fig 5.10

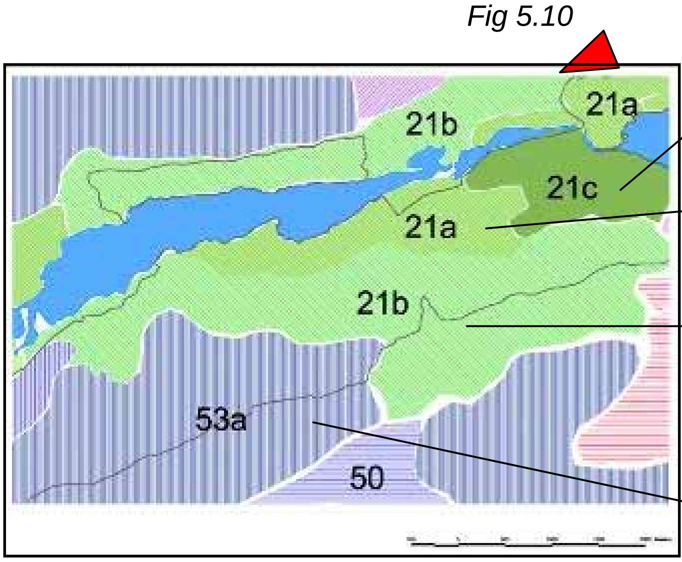


Fig 5.11 Looking west from point shown on map above

Fig 5.12 Digital terrain image from same viewpoint showing landscape

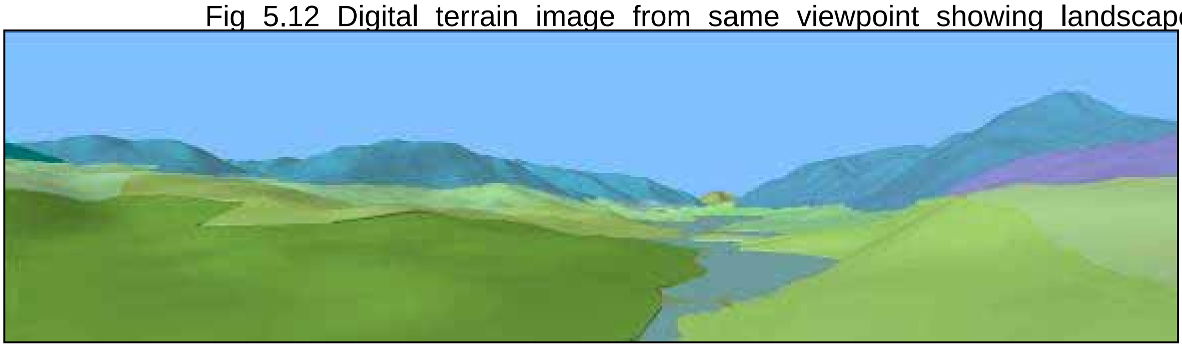
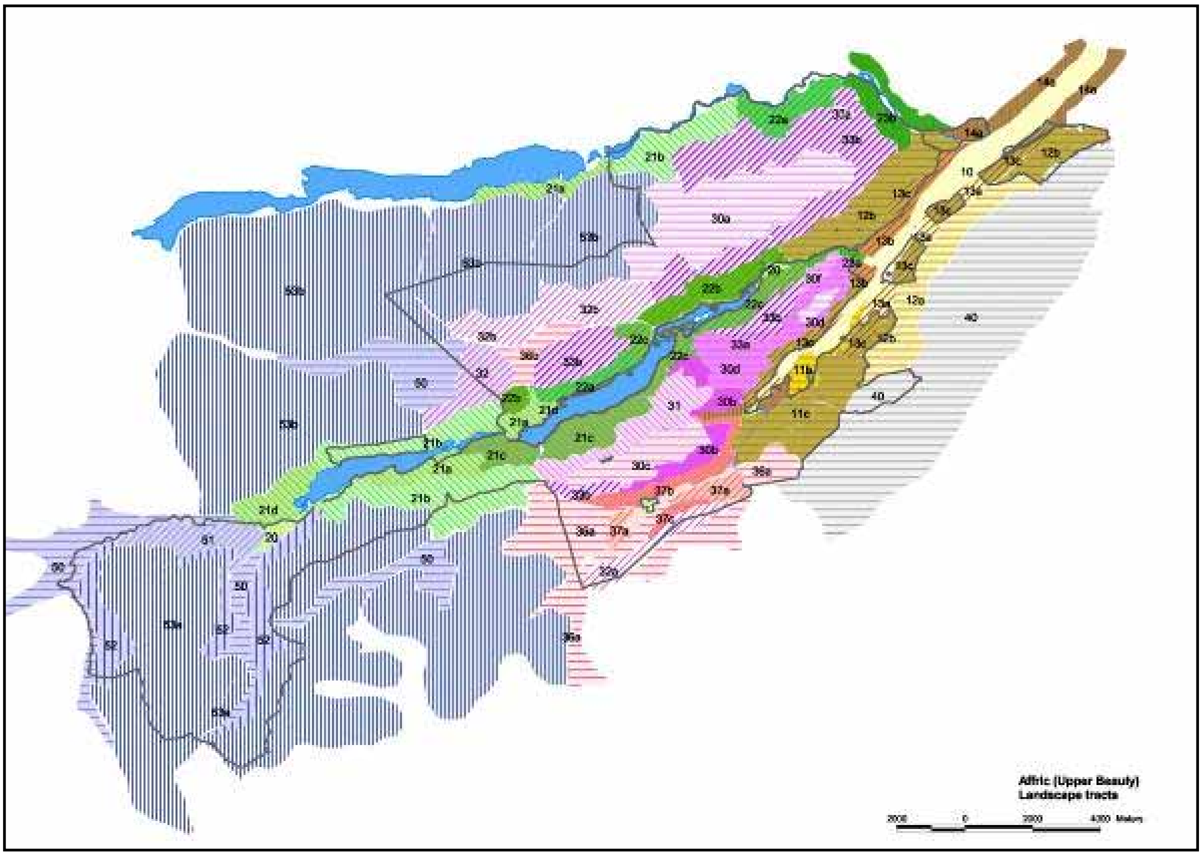


Fig 5.13 Landscape types



6 DATA INTERPRETATION AND ANALYSIS

6.1 Introduction

Forest Design plans often require the assembly of a wide range of data and the organising ecological data for a site is a complex one, especially on such an extensive and diverse area as the Upper Beauly Catchment. At this scale there is a wide range of habitats in complex mosaics that supports a wider and more complex range of communities of species (guilds). There is also a seemingly equally complex set of policy drivers, ways of recording and reporting on these habitats and species. It is therefore vitally important to identify what data are needed and why, as this will inform the format of the data and information that is required. A structured approach is needed for the design planning process (Figure 6.1).

Figure 6.1 Data acquisition and interpretation for Forest planning process.

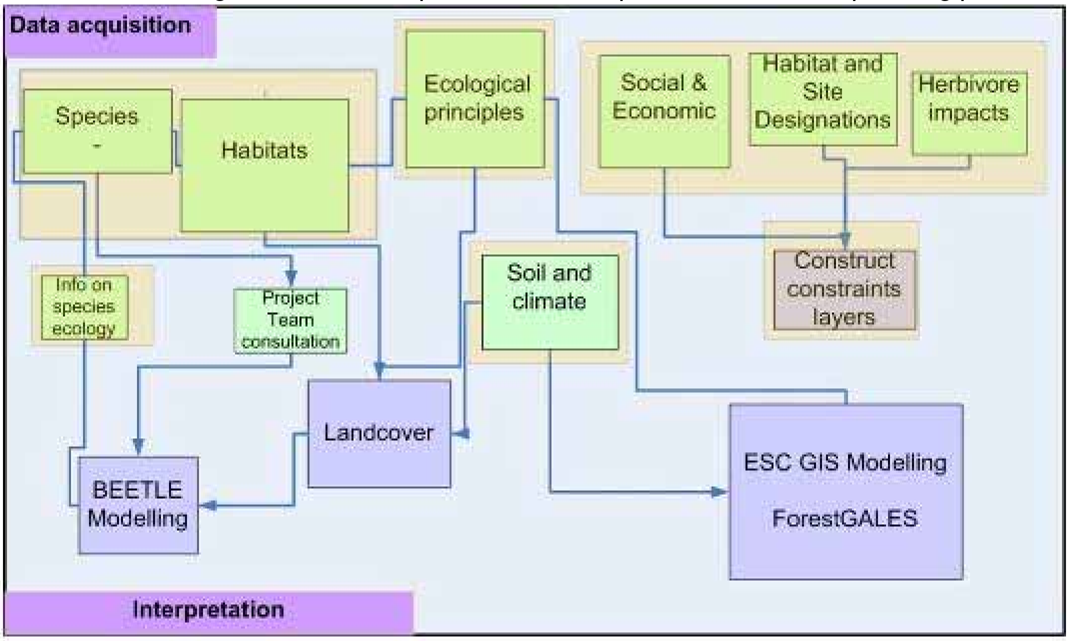


Figure 6.1 shows how the available data and information have been organised to meet the requirements for running the models used to inform this case study. Not all the information is required for the modelling process; these are used to construct other information layers that will affect the decision making process. This chapter sets out how the data were collated and organised within the structure shown above and the range of designations that have been applied to habitats and species.

6.2 Soils and Climate

6.2.1 Landscape scale assessment for soils

The estimation of soil characteristics for an area ideally begins with an initial assessment of geology, topography & climate influences. These factors are fundamental to the formation of soils and are interdependent as geological characteristics influence the topography and soil parent material. Topography in turn influences the climatic conditions, drainage and soil depth.

Analysis of the slope, geology and soil data from the relevant National Soil survey (Soil Survey of Scotland) allows an understanding of the general soil character ranges, drainage potential and vegetation communities. This can then lead to some assumptions on the potential for site moisture, nutrient and rooting parameters. This in turn can be allows some idea of species suitability at a landscape scale. Climatic data used are taken the UKCIP (UK Climate Impacts Programme).

Although all of the above is essentially a desk exercise, site visits can be necessary to ground truth any assumptions made.

6.2.2 Detailed soil surveys

To fully assess the site for detailed planting operations, a more detailed soil survey is required which involves the examination of local topography and climate at a sub hectare level and then sampling the local soil variations found in each unique location.

This detailed soil survey usually gives an exact description and is labelled using both a soil type and several suffixes to represent the various phases. Analysis of the vegetation and soil data allows assessment of soil moisture, nutrient and rooting, which gives a high confidence in species suitability choices.

This type of work is ideally done before felling as restocking sites tend to promote a temporary lush vegetation species mix due to the sudden availability of nutrients and light.

6.2.3 Affric survey methodology

The Initial plan was to sample at 1km grid intervals and uses these data to assist in the formation of a soil model. After initial survey was underway, it became obvious that the complexity of the terrain was not being sampled sufficiently and the 1km interval was therefore too wide a sampling interval.

To obtain a representative sample of the site variations, the original point sample survey was augmented with sample pits dug along the route. These were targeted at areas of distinct zones of vegetation on the aerial photography.

Outputs ranged from several hundred ha per day in the open uplands to as little as 50 ha per day in the undulating terrain of the old growth pinewood. The overall average for the 16,000 ha was approximately 340 ha per day. The costs averaged out at around £1 per hectare.

6.2.4 Map Quality

The finished result was felt to be a representative map of the likely soils in any given area. The high quality of aerial photography allowed the vegetation types to be accurately plotted, but due to similar vegetation covering different soil types, the mapped soil types may represent several related types and phases. As a result the soil map created was given a precision of +/- 10 hectare.

This fell somewhere between a landscape scale site assessment and a traditional soil survey (precision +/- 0.5 hectare).

6.3 Habitats and Species

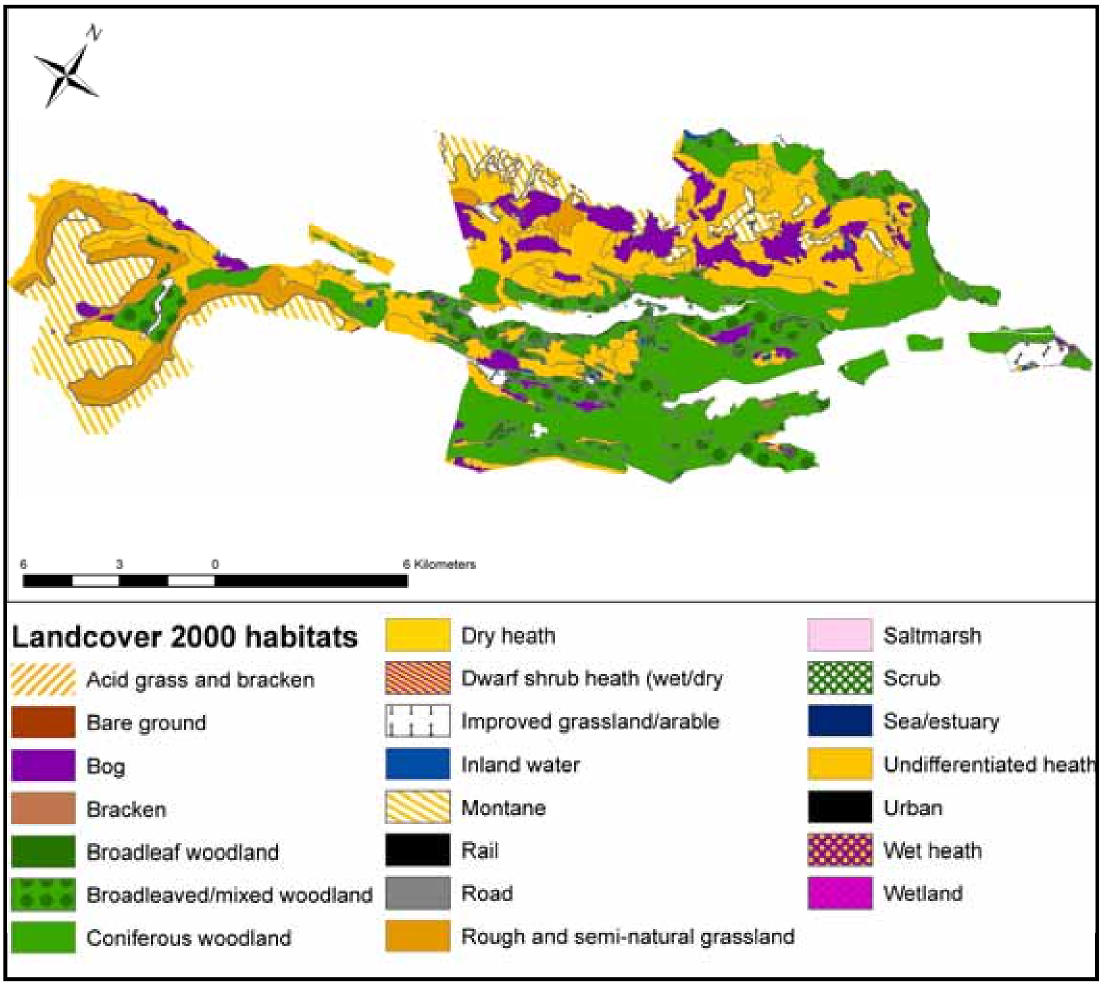
6.3.1 Survey and Landcover types

There are a range of survey methodologies and existing datasets that can be used to identify habitats and plant communities. These range from broad brush remotely sensed datasets to detailed field surveys of vegetation types. These have been designed to capture specific data, so again it is important to know and understand what data is required to make any management decisions before commissioning any survey. The purpose is to understand the ecological relationships between existing and potential habitats (and plant communities or woodland structure types where appropriate). This will then inform the forest manager of any habitats with designations that are present on the site that constitute a responsibility (either corporate or legal) to protect and enhance. Surveys can also be used to inform management of the existence of these habitats and where there might be possibilities for expansion. An example might be where there are suitable habitat/plant communities for the creation of new areas of montane scrub or treeline woodland ecotones. A description of the different habitat Landcover types and surveys is given in this section.

Land Cover Map 2000

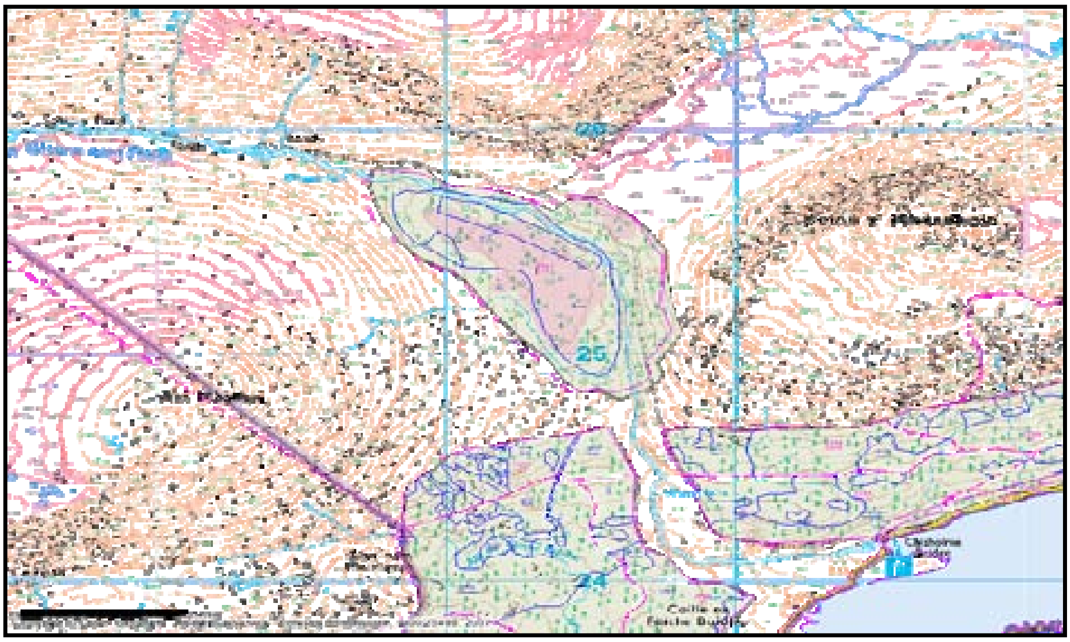
Land Cover Map 2000 is a broad-brush classification which fits the entire land area of the UK into 27 landcover classes. These classes do not directly relate with UKBAP or Habitats Directive habitats. The maps can be translated to show UKBAP broad habitats but are too broad-brush for planning practical habitat management. They can help to indicate areas where more detailed survey data are needed. FR has this dataset and should in due course have the updated version, LCM 2007 late in 2008.

Figure 6.2 Land Cover Map 2000



FC Scotland map browser is useful for identifying designated sites and the Macaulay Institute's peatland layer is available on the browser; this can be used to identify areas of peatland and upland moorland habitats (Figure 6.3). When combined with the sub-compartment layer it can highlight areas suitable for more detailed investigation of the potential for restoring open or sparsely wooded bog habitats. The air photo imagery available on the browser adds to its usefulness.

Figure 6.3 FC Scotland map browser showing Macaulay peatland layer and sub-compartment layer



NCC Phase 1 habitat survey

This survey protocol intended for environmental audit purposes and designed so that it can mostly be accomplished from the edge of a site or a vantage point outside it using binoculars. Mapping is at the 1:10,000 scale and target notes are used to indicate patches smaller than 0.25 ha of important habitats. It uses a land cover classification into major classes (Box1), two further levels of sub-division within these, and a further level of sub-division according to the dominant species: e.g. ‘class E - mire’ and narrowing down to more specific types, e.g. ‘E1.6.1 Blanket bog’. For many areas, the best existing land cover data available will be a Phase 1 habitat survey. Some UKBAP priority habitats and EU Habitats Directive Annex 1 habitats correspond directly to a single Phase 1 class while others are contained within broader classes or overlap more than one class.

Box 1 ***NCC Phase 1 habitat survey***

Major Classes

A. Woodland and scrub
B. Grassland and marsh
C. Tall herb and fern
D. Heathland
E. Mire
F. Swamp, marginal and inundation
G. Open water
H. Coastland
I. Rock exposure and waste
J. Miscellaneous

Examples

D3 Lichen/bryophyte heath
Includes Racomitrium heath
D4 Montane heath/dwarf herb
Includes snow bed vegetation

FE Scotland HAP surveys

FES has been managing a programme of HAP surveys covering open habitat sub-compartments on Scotland's national forest estate. These are field surveys of largely open areas, recording the open and native woodland habitat types present, both UKBAP HAP types and also non-HAP types. Large sub-compartments are remapped into smaller relatively uniform areas (Figure 6.4). At the last report 19% of the open habitat survey programme had been completed.

Figure 6.4 extract from the HAP survey for Strathgarve.

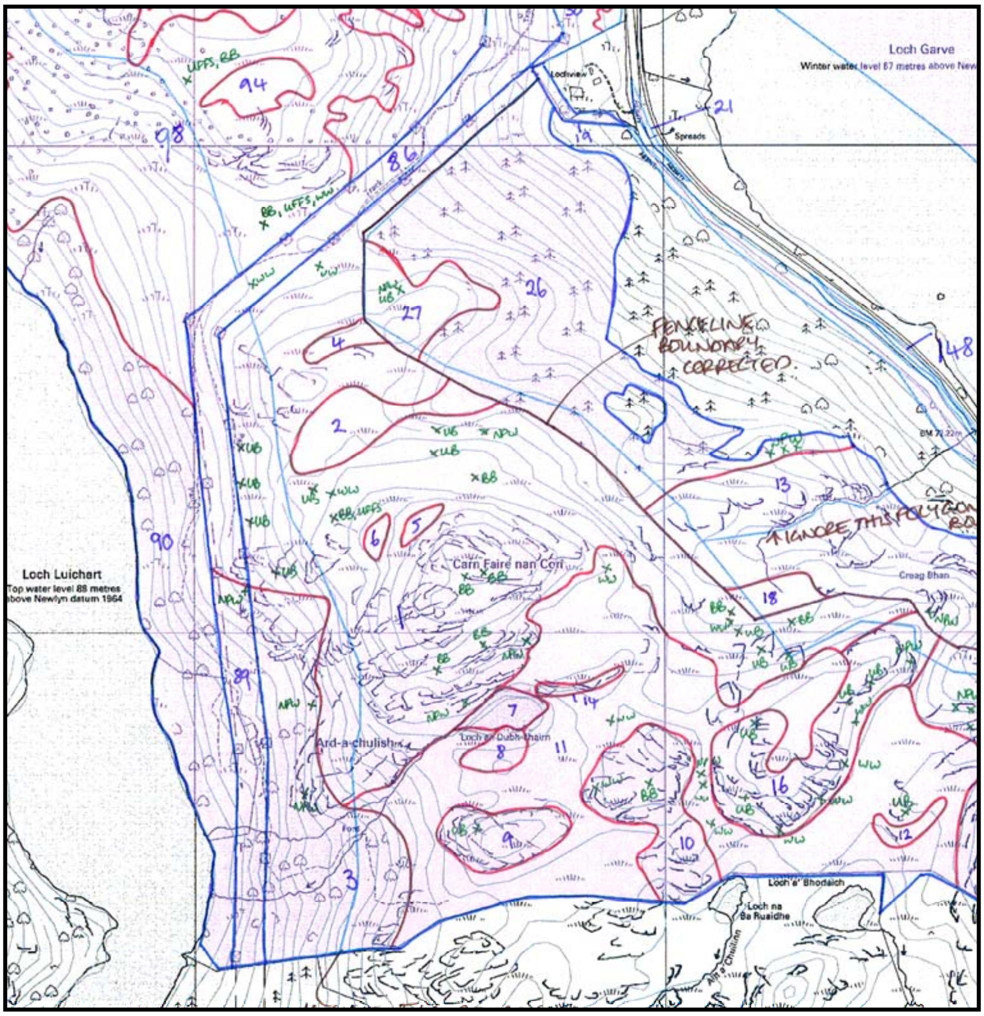


Table 6.1 shows how the new sub-compartment layout is mapped and the percentage area of each component habitats is recorded for each sub-compartment.

Table 6.1 Details of priority habitats database

Sub-comp	Habitat 1		Habitat 2		Habitat 3		Habitat 4	
	Type	%	Type	%	Type	%	Type	%
1	UHE	89	UB	5	IR - NON	5	BB	1
2	BB	90	UHE	5	WW	5	AG - NON	0
3	UB	80	UHE	20	BR - NON	0	NPW	0
4	BB	100						
5	BB	100						
6	BB	100						
7	SOWC	100						
8	UHE	90	IR - NON	10	BB	0		
9	UHE	90	IR - NON	10	BB	0	UB	0

UHE - upland heathland
UB - upland birchwood
AG-NON – acid grassland
WW – Wet Woods
IR-NON - non-HAP inland rock
BB - blanket bog
SOWC - Standing open water
BR NON non-HAP Bracken

National Vegetation Classification

The national vegetation classification gives an account of the vegetation types found across GB, describing over 250 plant communities with summaries of vascular plants, bryophytes and lichens and the range of variation within them. It acknowledges that plant communities are not static and identifies current points on a continuum of vegetation types. It is often used as a mapping tool where homogenous stands of the same vegetation type occur. It can be fairly subjective especially in complex vegetation mosaics where the presence or absence of a few species can place an area in different vegetation types. Figure 6.6 gives an indication of this complexity. It is however the basis of identifying some Annex 1 and Priority HAP types, which would not be, identified from other survey techniques.

In most cases it is possible to bulk up the NVC data to identify HAP types (figure 6.5), there are notable exceptions such as W11 and W17 oak/birchwood which depending on the dominant canopy species canopy can be either Upland oakwoods or Upland-birchwoods Figure 6.6 illustrates the complexity of the plant communities found and also the limitation of using the NVC classification as a mapping tool.

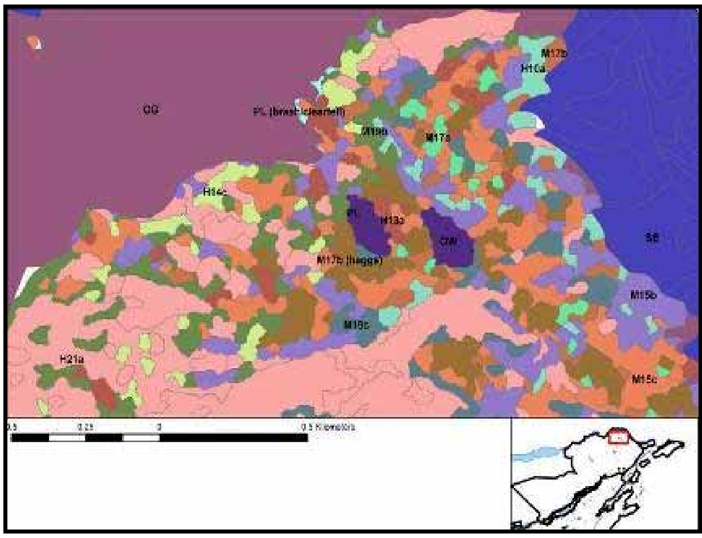


Figure 6.5 NVC data converted into HAP types

The NVC data has been used to produce a map (figure 6.7) of bearberry heaths and cloudberry snow beds (Pink areas) which are the areas best suited for developing natural treelines. The green areas are the Racomitrium moss heaths which are a priority HAP type and also the most site suitable restoring areas of scattered montane scrub. These areas could not have been identified from the more broad-brush land cover maps.

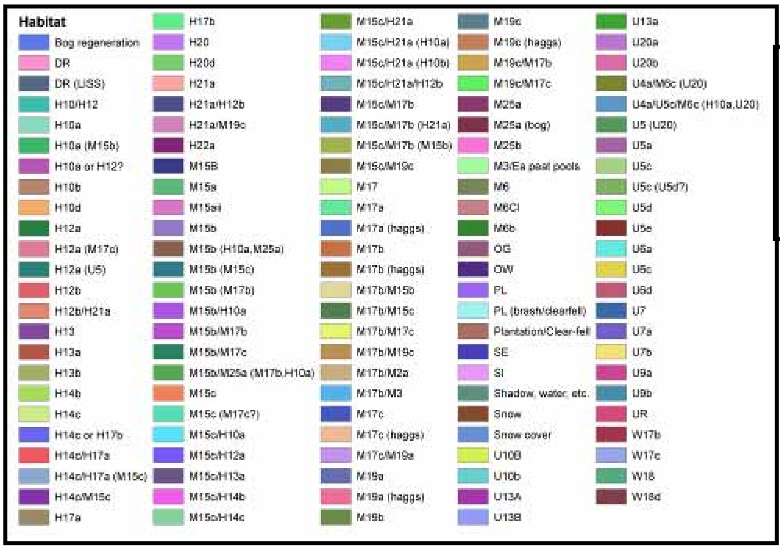
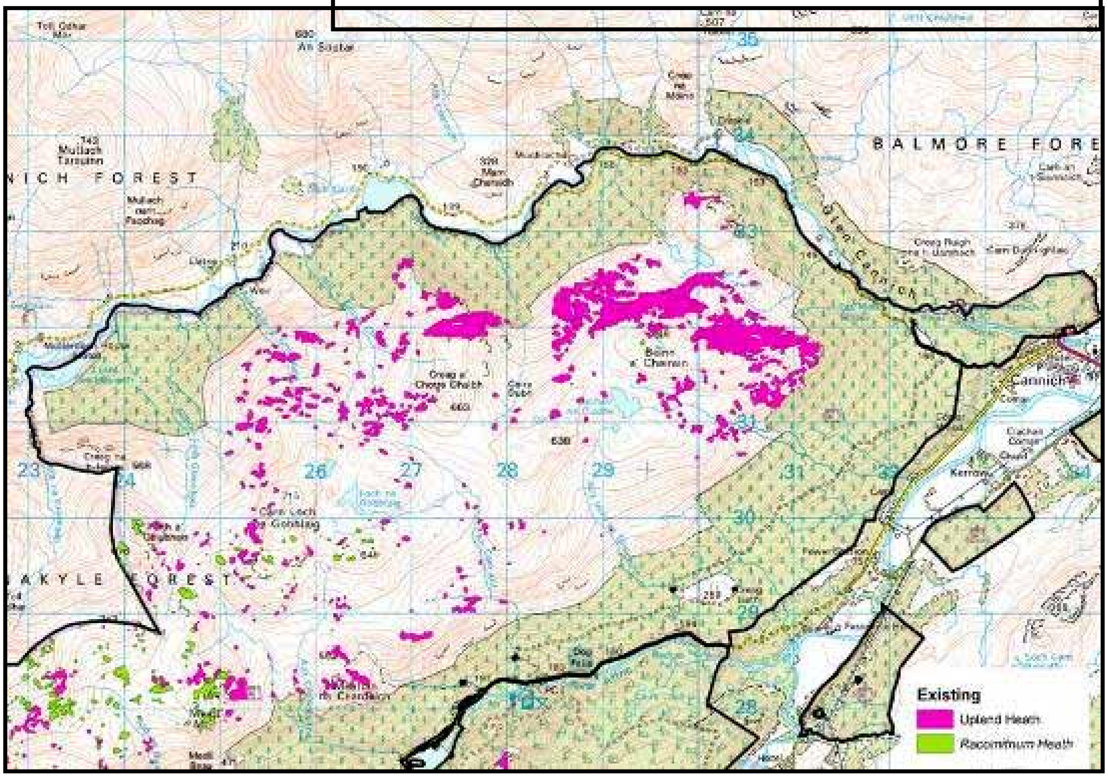


Figure 6.6 Extract from Glen Affric NVC survey key showing complex mosaics.

Figure 6.7 Using NVC data to identify priority HAP types



NVC maps can be immensely useful but they have limitations and may not always be required. It can be expensive to survey large areas, and problematic if they show polygons with large numbers of mosaics that do not relate to distinct habitats.

Upper Beauly Open Habitats Survey

One of the major problems in trying to create a holistic design plan for the Upper Beauly catchment was the lack of data for the complex mosaics of open habitats present. It was known from existing surveys of designated sites that there was a wide range of habitats present, including some of the best examples of designated habitats in Scotland. It was proposed that a survey should be undertaken to digitally map the open habitats with the primary objective of identifying the HAP type that were present. This data would also be used to map the connectivity of the open habitat networks present (see section 6X). It was decided for practical reasons to employ a remote sensing technique using the most up to date aerial photographs in combination with field survey validation. This survey initially mapped non-wooded areas to NVC community level, which were subsequently bulked up to give Annex 1 and BAP priority habitat types. This was a semi-automated process where a computer programme allocated pixels from the aerial photographs to the NVC type based on their reflective properties. The programme was 'trained' by the field validation, where the reflective properties of surveyed vegetation types were used to inform the program. This was then further modified based on topographical information and expert surveyor knowledge to generate the landcover. While this methodology will not be as good as a full summer field season ground survey, the latter was not practical due to both financial and time constraints. A detailed survey to a high standard of this area is likely to be twice the cost of the aerial photography interpretation method used The Upper Beauly catchment has an extremely complex mosaic of vegetation communities and indeed during the field work related to this project, a probable new pinewood ground vegetation type was identified. Indicative costs by area are unlikely to be applicable here for a quality output. A quality assurance exercise was carried out visiting polygons created from the survey to validate the habitats types.

No single data source

Note that this process of obtaining information for habitat conservation is very complicated because the various pieces of legislation use different classifications, and yet more classifications within the various established survey protocols. The best approach seems to be to use the more readily available land cover maps to highlight areas needing more detailed NVC mapping where appropriate e.g. to identify specific HAP types such as differentiating between fen and swamp habitats.

NVC mapping may become cheaper due to developments in the interpretation of remote sensing data. FR is trialling the use of E-cognition software for interpreting remote sensing data. This involves obtaining information from satellite and aircraft mounted sensors and cameras that can use infra-red and LIDAR sensors to obtain habitat information. There should soon be costings for mapping open habitats and forest structure by this method.

6.4 Species

There is no infallible method of finding out what priority species are present in or make use of an area. Existing records can be useful but recording intensity varies with geographical area and taxonomic group so the records will, at best, provide partial coverage of the priority species in each area. The National Biodiversity Network (NBN) Gateway website (http://www.searchnbn.net/) provides access to an enormous range of species records and is the best place to start looking. However many records only have a 1km spatial resolution which is not that useful for identifying that habitats they have been recorded in It holds records contributed by many professional and amateur naturalists and nature organisations and is searchable by geographical area. Data from surveys of individual priority species are particularly useful. Users can register to obtain access to restricted records not available to the general public. Species lists are appended to the Forest Design Plan, and there are also lists on the Trees for Life web site (http://www.treesforlife.org.uk/). Various surveys have been carried funded jointly by FE and TFL (e.g. Ewing, 2004; 2005).

Table 6.2. All recorded species related to their habitats in Upper Beauly catchment.

Habitat	Amphibian	Bird	Bryophyte	Fungi	Invertebrate	Lichen	Mammal	Reptile	Vascular plant	Total Species
Bog		1	1	1	5				16	24
Bracken					2					2
Broadleaf					6				47	53
Grassland		2			1		6		71	80
Heath		1			6			3	10	20
Montane					5	1	1		39	46
Open Broadleaf					1					1
Open SP					3					3
Open Wood					2		2			4
Pinewood							1		13	14
Rock					1					1
Scots Pine		1		15	20				8	44
unknown					604					604
Water		1			6		2			9
Wetland	4								88	92
Widespread		104					8			112
Woodland		3	154	224	145	176	7			709
Total Species	4	113	155	240	807	177	27	3	292	1818

6.5 Preparation of Data

The main focus of the analysis was to link species requirements to habitats and any designations for those present within the case study area. This process should help inform management through ecological modelling. The habitats and structure types are collated to generate a land cover which covers both wooded and open habitats. Understanding the detailed ecology of species present and how they use the range of habitats within a landscape can give us a better understanding of the conservation measures necessary given the interaction between habitats and species. This allows for the selection of 'focal species' which can be used to represent species and habitat of high conservation value (i.e. those with designations) within the BEETLE model. This tool allows forest managers the ability to address a landscape scale approach to habitat and species management. This landscape approach will allow for the protection of the designated species and habitat present by improving the quality and connectivity of the habitats that species require.

6.5.1 Landcover

One of the important tasks was the development of a landcover that could be used to assess the permeability of the catchment area for selected focal species (see section 5.6.2) to be used in the BEETLE modelling of potential connectivity (see section 7.4). This has been constructed from the datasets set out in table 6.3, Ordnance Survey (OS) Strategic road and rail data, and OS 50m DEM. Landcover datasets were assembled in 10 metre resolution raster grids. It should be noted that other sources of landcover can be adapted for use in BEETLE modelling.

Table 6.3 Datasets used to construct the landcover data, ranked in hierarchical order.

Rank	Resource name
1	FR Structure survey
2	FE Sub-compartment database
3	Ancient woodland inventory
4	NVC designated sites
5	FE NVC open habitat landcover
6	OS 1st edition landcover
7	Land Cover Scotland 1988 (LCS88)
8	Land Cover Map 2000 (LCM2000)

As discussed earlier there is no consistent terminology used to describe and record habitats, their designations and how species use them. There will always have to be some interpretation of the terminologies used. Tables 6.4 and 6.5 are an attempt to relate the different terminologies for open and woodland habitats respectively. This could be regarded as a habitat brigading exercise (compare with 6.7.3).

Table 6.4 Open habitats

BAP Habitats	**Habitats related to species from Brigading exercise**	**Key macro and micro habitats ****
Blanket bog*	Bog	Wet heath/bog
Bracken	Bracken	n/a
Acid Grassland Rush pastures	Grassland	n/a
Upland heathland* Mountain heaths and willow scrub*	Heath	Dry heath
Mountain heaths and willow scrub*	Montane	Montane scrub Racomitrium heaths
Inland rock outcrop and scree habitats*	Rock	n/a
Unknown	unknown	unknown
Open water	Water	Water
Upland flushes, fens and swamps*	Wetland	Wetland

* denotes priority habitat
** Preliminary analysis including earlier work by Hope et al (2006); Humphrey et al. (2005) and Bell (2003), has helped to define some of the key macro and micro habitat types within the study area.

Table 6.5 Wooded Habitats

BAP Habitats	Habitats related to species from brigading exercise	Structural phase	Key macro and micro habitats *
All woodland HAP types	Woodland	All phases	All woodland habitats
All broadleaved woodland HAP types	Broadleaf woodland	All phases	Broadleaved woodland
Caledonian pinewood*	Scots Pine	All phases	All woodland habitats
Wood pasture and parkland*	Open Broadleaf	Old growth)	Old, open canopy Broadleaved woodland with fresh or well rotted deadwood
Wood pasture and parkland*	Open Scots pine	Old growth	Old, open canopy pinewood with fresh or well rotted deadwood
Wood pasture and parkland*	Open Woodland	Old growth	Old, open canopy woodland with fresh or well rotted deadwood
All woodland HAP types	Woodland Scots Pine Broadleaf woodland	Stand Initiation	Young regenerating woodland
All woodland HAP types	Woodland Scots Pine Broadleaf woodland	Stem Exclusion	Developing woodland**
All woodland HAP types	Woodland Scots Pine Broadleaf woodland	Understorey Reinitiation	Mature woodland with regeneration**
All woodland HAP types	Open Woodland Open Scots pine Open Broadleaf	Old Growth	Old, open canopy pinewood with fresh or well rotted deadwood

* Preliminary analysis including earlier work by Hope et al (2006); Humphrey et al. (2005) and Bell (2003), has helped to define some of the key macro and micro habitat types within the study area.
**Not identified as key habitat.

<u>6.5.2 Focal Species</u>

Focal species represent the ecological requirements of a range of species within a particular habitat. The focal species approach is useful in evaluating the impacts of forest management on biodiversity. It circumvents the need to measure impacts on all species which would be completely impractical. A number of studies have used focal species modelling as a way of helping to inform guidelines for habitat creation, restoration and configuration at the landscape scale (e.g. Freudenberger and Brooker, 2004; Humphrey et al., 2007). Usually focal species are selected because they have wider appeal or are of conservation importance in their own right (Fleishman et al., 2000).

Focal Species

A focal species can be simply defined as 'the species being focused on to examine a particular issue'. A more detailed definition evaluates landscapes in relation to the requirements of all the species present (Lambeck, 1997), focusing on the key issues of habitat requirements and dispersal capability to identify species with the strictest requirements.

There are different processes involved in focal species selection depending on the objectives of a site and these are outlined in figure 6.8 below. The objectives for a site can be focused on the conservation of existing known biodiversity or the development ecological potential, though these are in no way mutually exclusive. The selection of focal species would be different between the management of a large nature reserve with many designated species and the restoration of degraded rush pastures with conifer plantation.

Regardless of overall focus there are alternative approaches to characterising the focal species. Key parameters can be by 'expert decision' or by the 'species brigading' exercise (See section 5.7.3) both of which contain an element of subjectivity and expert opinion The process involved in both of these approaches are set out in figure 6.9. There is also the choice between the use of actual focal species or generic focal species.

Figure 6.8 Focal species flow chart

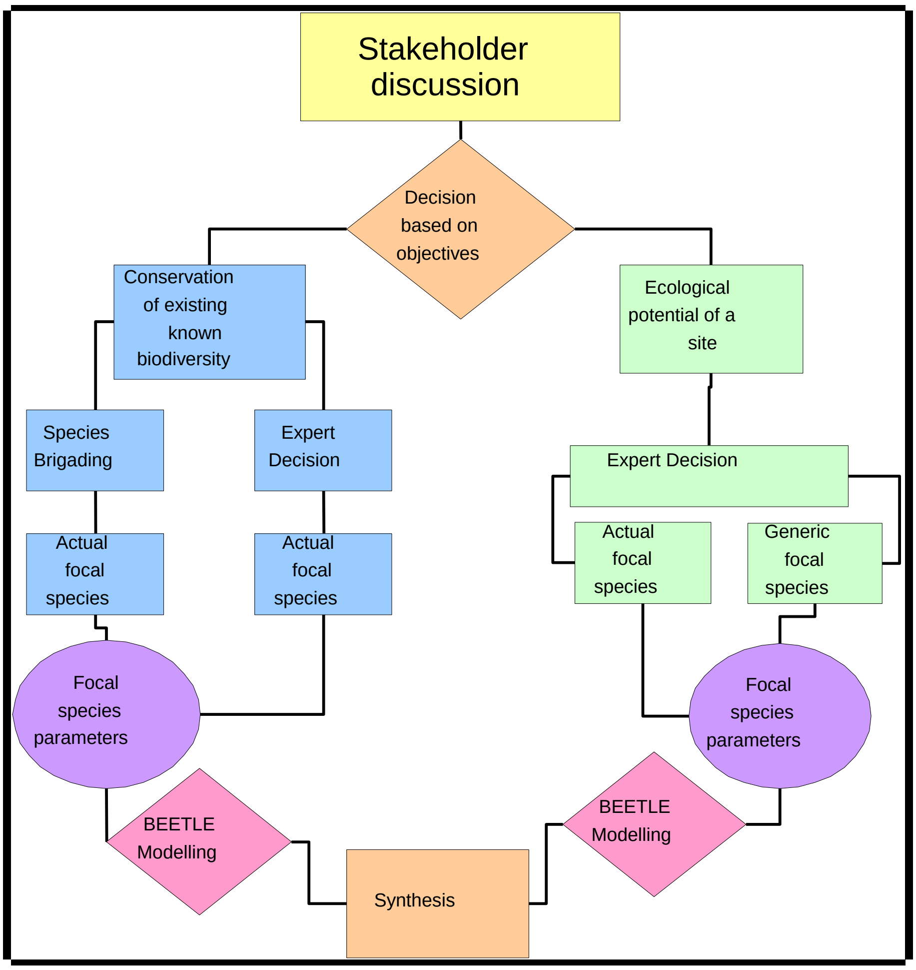


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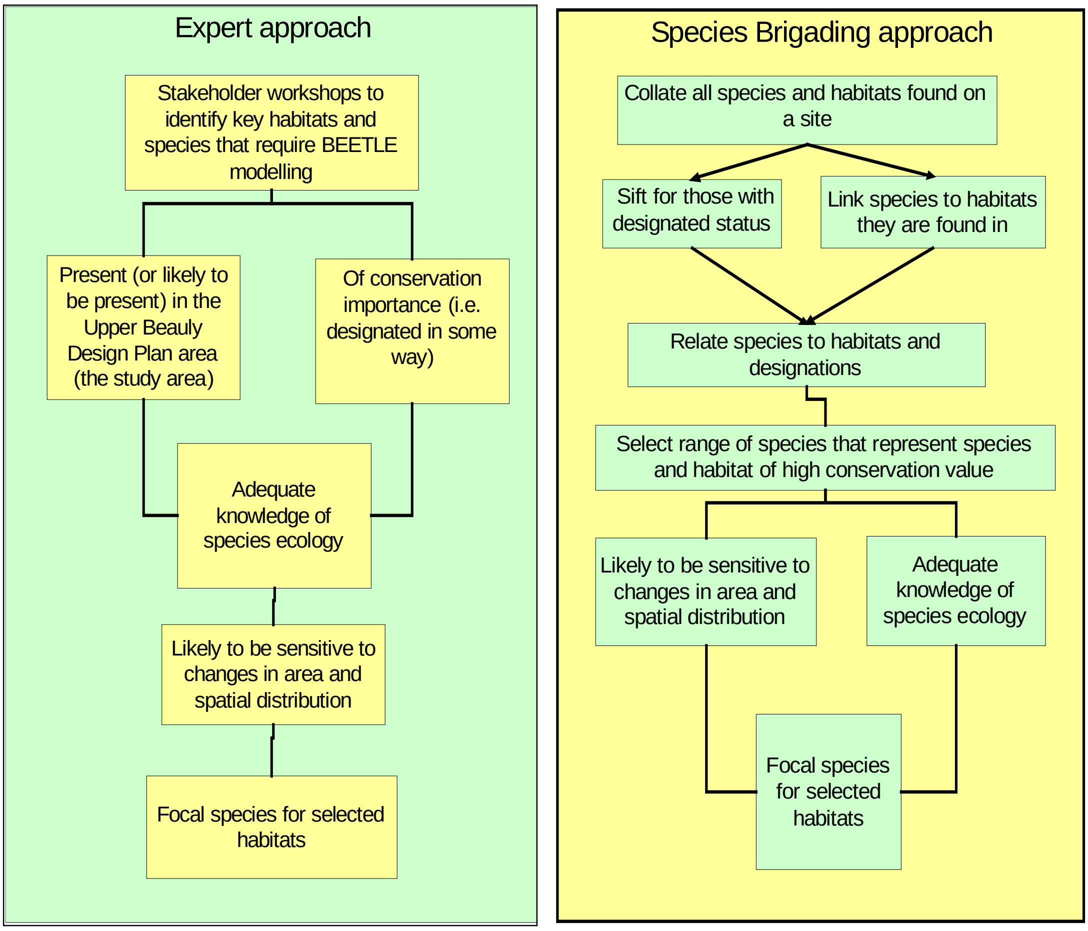
Figure 6.9 Focal species selection



There is a degree of subjectivity in both approaches to the choice of focal species. The identification of key habitats and species by stakeholders is always going to be dependent on the composition of the stakeholder group. There is also some subjectivity in allocating species to habitat and some species will use more than one. The species brigading is a more structured justification of focal species selection. The brigading exercise identifies species with designations that have been recorded on a site, for which there is an obligation to be conserved. It is dependent however on what survey work has been undertaken. This in itself can be subjective and may lead to management decision making being based on survey work on specialist groups of species. An example of this could be the lack of recorded old open Scots pine species with only 4 recorded of which 3 have designations compared to 75 grassland species of which 3 have designations. This could lead to conclusion that grasslands are of a higher priority that the old open pine woodland. A closer inspection of the data and an understanding of ecology at other sites may suggest a different conclusion. Abernethy Forest another pinewood site has over 40 species with designations in open Scots pine and the 3 designated at Affric are all HAP species. The 3 grassland designated species have been allocated to grassland but also use a wide range of open upland habitats.

Generic Focal Species is a conceptual or virtual species, whose profile consists of a set of ecological requirements reflecting likely needs of real species where species data are unavailable. GFS are selected to represent particular species, groups of species, habitats, important landscape features or specific policy objectives.

Criteria for selection of Focal Species

Presence within the study area

Species lists are appended to the Forest Design Plan, and there are also lists on the Trees for Life web site (http://www.treesforlife.org.uk/). Various surveys have been carried out and funded jointly by FE and TFL (e.g. Ewing, 2004; 2005). Species were only selected as a focal species if they are known to occur in the study area, or have been recorded there in the past. This process is undertaken in detail through the species brigading exercise (section 5.7.3)

Adequate knowledge of species ecology

The ecology of some of the species groups recorded in the study area is well known (e.g. hoverflies) whereas others have been little studied (e.g. beetles, lichens). Species were only selected where ecological information was reasonable and there was expert knowledge and literature available for consultation. Values for habitat requirements and dispersal distances are required to undertake the BEETLE modelling.

Sensitivity to changes in area and spatial distribution of different types of habitats

Figure 6.10 illustrates how habitat fragmentation has differential impacts on a species' persistence in the landscape, depending on its dispersal ability and habitat area requirements. Species with moderate area requirements and moderate dispersal abilities tend to be more sensitive to fragmentation, and hence to population decline and extinction (towards the left of the diagram). Equally these are the species that may respond positively to measures to increase connectivity (Fig 6.11). Species with very poor dispersal abilities (bottom left) are unlikely to respond very quickly, if at all, to reversal of fragmentation and require action that focuses on securing long term survival of existing habitat patches (Fig 6.11).

In this case study, species were selected that would be sensitive to changes in the amount and spatial distribution of the key habitat types listed above, and likely to respond relatively quickly (e.g. 50 years) to measures to improve habitat connectivity.

Figure 6.10 – Example of relative sensitivity of species to fragmentation

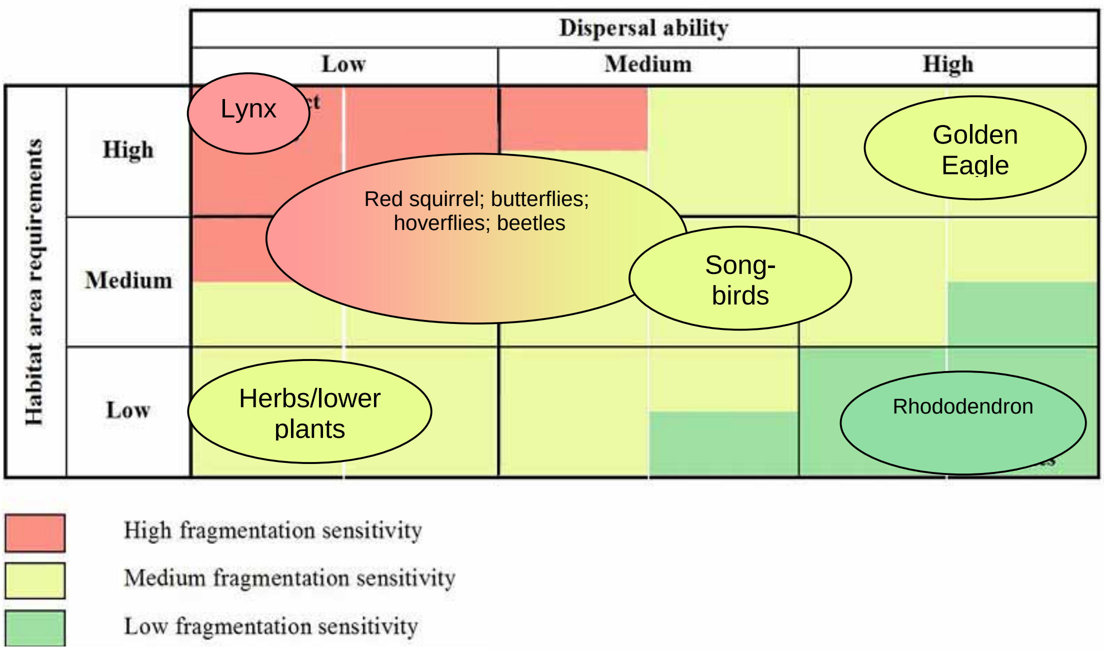
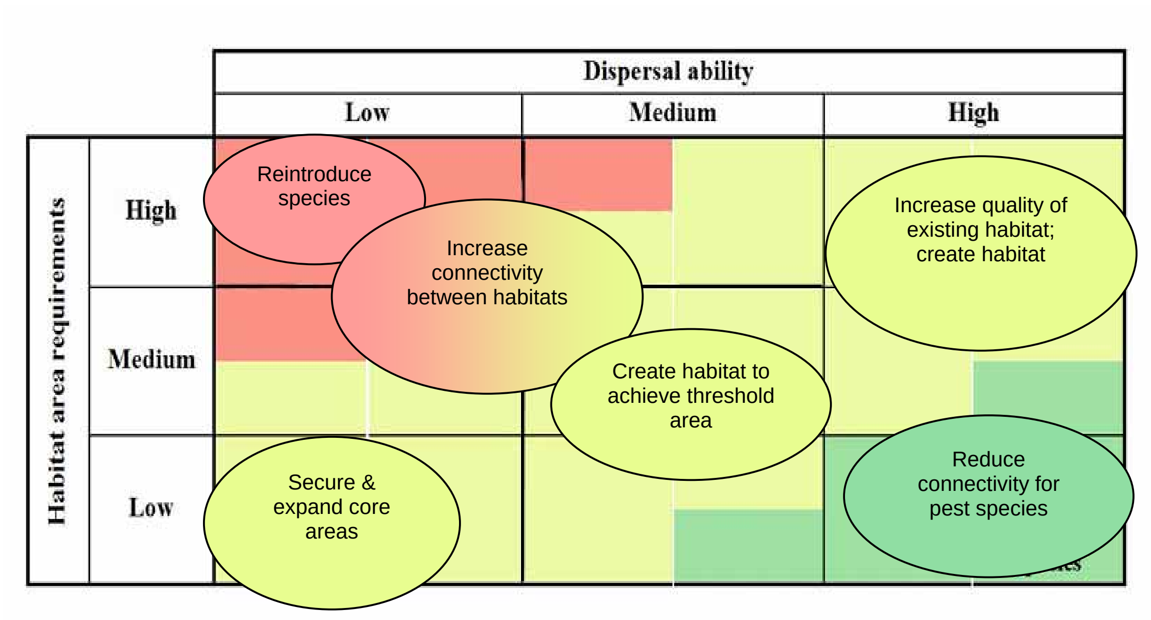


Figure 6.11 -Management actions based on focal species ecology



Conservation Importance
Species were also selected on the basis of the following designations (i.e. if they had one or more of the designations)

- **UK BAP Species,**
- **W & CA Schedule 8 species,**
- **EC Habitats and Species Directive Annex1 species;**
- **IUCN RDB species**
- **SNH priority species**

<u>6.5.3 Species Brigading</u>

The species brigading exercise section was intended to relate those species recorded in Glen Affric to any relevant designation they have and to their habitats.

The species can be ‘brigaded’ by habitat type and their conservation status. This allows the Forest manager to understand any legal or corporate obligations that they may have for the protection of species or habitats with in the forest plan area. This can then be used as part of the decision making process for focal species selection.

The first step in this process was to collate all datasets using available records in Glen Affric, including related web sites and existing studies. A parallel process collated all databases of designated species to determine which species have any form of designation. These databases were then formatted to allow interrogation, enabling marshalling of the species, habitat and designation data in relation to one another (Tables 6.6 and 6.7)

Table 6.6 All species recorded in Upper Beauly catchment by habitat type

Habitat	Amphibian	Bird	Bryophyte	Fungi	Invertebrate	Lichen	Mammal	Reptile	Vascular plant	Total Species
Bog		1	1	1	5		1		16	25
Bracken					2					2
Broadleaf					6				47	53
Grassland		2			1		1		71	75
Heath		1			6				10	17
Montane					5	1			39	45
Open Broadleaf					1					1
Open Scots pine					4					4
Open Woodland					2					2
Pinewood									13	13
Rock					1					1
Scots Pine		1		15	20		1		8	45
Water	4	1			6		1			12
Woodland		3	154	224	145	176	3			705
(to be updated)		104			604		16	3	88	815
Total Species	4	113	155	240	807	177	23	3	292	1814

Table 6.7 All species with BAP, Red listed, Nationally rare or Nationally scarce designation in Upper Beauly catchment by taxonomic group and habitat

Habitat	Amphibian	Bird	Bryophyte	Fungi	Invertebrate	Lichen	Mammal	Vascular plant	Total Status
Bog		1	1	1	3		1	2	9
Bracken					1				1
Broadleaf					6				6
Grassland	1	1					1		3
Heath					3				3
Montane					3	1			4
Open Scots pine					3				3
Open Woodland					3				3
Rock								2	2
Scots pine				15	16		1	8	40
Water		1			4		1		6
Woodland		5		3	16	27	3		54
Total Species	1	8	1	19	59	28	7	13	137

The habitats chosen were grouped by the available autecology and does not necessarily fit with BAP habitat types as not all habitats represented in Glen Affric have known species with any designation. This requires there to be some interpretation of the habitat information. Further details on the ecology of selected species that were representative of the habitats found in the Upper Beauly catchment were researched using a range of different methods.

- HaRRPS (see Box 1)
- NBN Gateway
- Web Searches (including Trees For Life Website)
- Literature search

Whilst the brigading exercise is useful in understanding the relationship between habitats and species, it is a time consuming process. Further development of HaRRPS to automate the interrogation of databases would be of great use to forest planners and managers and this could integrated into the conservation extension used by forest design planners.

Tools: HaRPPS – a habitats and species information source

HaRPPS (Habitats and Rare, Priority and Protected Species)

A decision support tool and information resource for forest biodiversity management, set up as an internet application with wide accessibility. It provides basic ecological and forest management information on species and provides predictions of species that might be affected under different woodland habitat and management scenarios, at given locations. HaRPPS also provides FC recommended guidance for the management of rare and threatened species and habitats. See the Forest Research website for details (www.forestresearch.gov.uk).

6.6.4 . Focal species descriptions

Details of the focal species selected are given in Table 6.8 and briefly summarised here (the difference in detail reflect the amount of autecologcal information available)

Great Crested Newts: *Triturus cristatus* breed in deep persistent nutrient-rich ponds and still water bodies that are large enough to contain prey for their larvae but do not contain predatory fish which eat the larvae (Bowles et al., 2006; Skei et al., 2006). Great Crested Newt populations have declined, due in part to loss of ponds to development, agricultural change and agrochemicals, but also to the 'degradation, loss and fragmentation' of terrestrial habitats (Anon, 1995). Great Crested Newts have been the subject of sufficient research to be able to set realistic dispersal distances (e.g. Arntzen and Wallis, 1991; Kupfer and Kneitz, 2000).Although not currently within the NNR, it is thought that Great Crested Newts are in the Design Plan area.

Long horn Beetles*: Cerambicidae:* These are an indicator of connectivity of old growth areas and are large slender beetles with long legs and long antennae. Active during the day, fly in sunshine often to flowers for pollen. Females lay eggs on or in tree where larvae will feed. Larvae pupate in tree; adult gnaws its way out through oval flight hole (Olsen et al., 2001). Dispersal is thought to be reasonably restricted.

Hoverflies*:* Syrphidae: an excellent set of indicator species covering a wide range of different habitat types. Species ecology is also well known (Speight, 2000). Unfortunately, only two pinewood species have been recorded in the study area. Further work is required to identify species of non-woodland habitats from the Design Plan.

Pearl-bordered fritillary (*Boloria euphrosyne*) is a mosaic species requiring open woodland with plentiful glades. In Scotland, typical sites are found on sunny, dry and sheltered south facing edges/clearings comprising patches of lightly grazed/ungrazed mosaics of bracken *Pteridium* *aquilinum*, grass and woodland herbs which lack significant natural tree regeneration (Kirkland, 2002). The eggs are frequently laid amongst the food plants (dog violet *Viola riviniana*) in flattened bracken litter. Where bracken dies and becomes brown it readily absorbs heat, creating an artificially warm microclimate for the larvae to develop in. Their habitat is characterised in spring by violets growing through shallow (<15cm) bracken. A suitable mosaic is 1/3 grass (tend to be acidiophilic grasses with woodland herbs mixed in) to 2/3 bracken on neutral to slightly acidic soils (soils which are too acidic will not support violets). The species is very sedentary and colonial. Adults (upwards of hundreds of individuals) form discrete (100 m^2) colonies around food plants (Barbour and Kirkland, 2000). Dispersal from colonies to other colonies can occasionally be up to 4.5 km on bracken hillsides, and 2 km between woodland clearings and open woodland habitats although colonies are essentially 'closed'. The majority of individuals will not move more than 0.75 km in their lifetime, even if their colony is much larger than this. In Scotland, breeding habitats are smaller and widely scattered than in southern Britain, resulting in a loose population structure, found at lower densities over a larger area (Barbour and Kirkland, 2000). Areas of dense woodland, farmland and moorland are barriers to dispersal. Pearl-bordered fritillaries tend to fly at around 50 cm above the ground. They do not normally fly under closed canopy and very rarely fly over mature stands of trees. They tend to like canopy openings or early successional habitats up to two years after felling. Colonies in rotational coppice and young conifer plantations tend to become extinct after a few years once woody growth has shaded out the field layer. Colonies will not survive in mature conifer plantations unless extensive thinning is done to create sufficient light at ground layer for field layer development. The species will not breed in densely shaded conditions (Hofmann and Marktanner, 1995).

Wood ants: The ecology of three ant species associated with native pinewood (Table 1) are relatively well known. Management actions for their conservation have been outlined in Hughes and Broome (2007) and Ratcliffe (1998). The three species represent different niches in the pinewood system (Table 1). *Formica exsecta* has been recorded from Affric in the past, but there are no recent records, it is possible that the species has been overlooked and reintroductions could be considered. The current inclusion is useful in that it picks up connectivity of very open scattered shrubby areas.

Large heath (*Coenonymphya tullia*). The large heath butterfly inhabits lowland raised bogs, upland blanket bogs and acid grasslands all of which are sources of hare's tail cottongrass *Eriophorum vaginatum*, the food source for the larvae. It is typically found on sites where the peat is greater than 50 cm depth, with the water table, at or just below, the surface. In Scotland it is typically found on upland blanket bogs, on flat or sloping ground with poor surface drainage in oceanic climates with heavy rainfall. Sites are often a mosaic of *Sphagnum* spp. mixed with *E. vaginatum* and cross leaved heath *Erica tetralix*, which is the main food source for the adults. The species requires grass tussocks for breeding and hence is not tolerant of heavy grazing. Colonies can survive for many years as isolated populations but the species has a poor colonising ability. Most adults move less than 100 m and the maximum recorded distance is 450 m between recaptures. There is unlikely to be any interchange of adult populations unless the colonies are very close together. Small populations are known to survive on areas as small as 1 hectare for many years. Colonies can number up to 15,000 individuals although the majority are much smaller. Positive site attributes include: presence of overlapping nectar plant and host plant areas; existence of some surface water; sheltered valley location (lee side of a hill or trees on periphery of the site); light grazing ($\leq$ 2 animals ha^{-1}); low intensity patch burning of the site. In a survey of 117 sites in Northumberland, habitat occupation occurred between 140 and 410m, but the species has also been found up to a height of 750m (Hofmann and Marktanner, 1995); (Thomson, 1980).

If the site is afforested and in particular is completely encompassed by afforestation then this is detrimental to the butterfly. The butterfly will usually continue to occupy the site until the habitat is virtually closed over with young trees. Even in particularly wet areas where the conifers fail, these tend to be surrounded by trees, which although providing shelter, reduce light and water availability and increase the isolation between habitat patches. The smaller the patch size the more prone it is to desiccation. The larger the patch size and the closer these are to occupied sites the more likely is the incidence of patches being occupied. Patch size relates to the area occupied by *E.*

vaginatum and *Erica tetralix*. Afforestation and woodland expansion also represent barriers to dispersal.

Table 6.8 – details of focal species selected for Glen Affric

Species	Status	Surrogate/indicator	Habitat Description	Dispersal
LONGHORN BEETLES				
Timberman *Acanthocinus adilis*	Nb	Connectivity of open old pinewood with fresh deadwood	Dead pine in mature, open pine woodland	500 m^2
Judolia sexmaculata	Na	Connectivity of open, old pinewood with fresh deadwood	Open woodland. In decaying roots of large pines, including rootplates.	500m ^{2}
Leptura sanguinolenta	RDB 3	Connectivity of open, old pinewood with fresh deadwood	Dead pine in mature, open pine woodland. Adult requires herbaceous flowers, particularly Apiaceae (Umbellifers)	500 m^2
Pogonocherus fascicularis	Nb	Connectivity of open, old pinewood with fresh deadwood	Recently dead pine branches in open pine woodland.	500 m^2
Rhagium[1]*inquisitor*	Nb	Connectivity of open, old pinewood with fresh deadwood	Recently dead pine (stumps and logs) in mature, open pine woodland (also birch and oak). Larvae feed within the bark on phloem and cambium. Prefers thick corky bark	500 m^2
NEWTS				
Smooth and Great Crested newts	UK BAP SNH	connectivity of ponds/waterbodies and wetland	Ponds and non-acid wetlands; moist grassland during the adult phase	1 km
HOVERFLIES				
Callicera rufa	UKBAP	Connectivity of, old pinewood with well rotted deadwood	Larvae feed in rotten pine stumps, water filled holes; likes moist woodland	1 km
Cheilosia longula		Connectivity of old pinewood with well rotted deadwood	Larvae feed on fungal fruiting bodies	1 km
WOOD ANTS				
Formica exsecta	UKBAP	Connectivity of scattered woodland with open veg	beyond woodland edge, very open scattered trees/shrubs – sun exposed; minimum patch 5 ha	2 km
F. lugubris	RDB Nt	Connectivity of pinewood glades/rides	in woodland edge zone SP and Bi woodland; needs access to larger trees; minimum patch 5ha;	2 km
F.aquilonia	UKBAP RDB Nt	Connectivity of mixed age denser pinewood	within woodland; rides/glades in plantations; min patch 5 ha	100 m
BUTTERFLIES				
Pearl-bordered fritillary	UKBAP SNH	indicator of connectivity of Broadleaved glades and edge habitats	Larvae – mosaics of bracken/grassland with violets – scattered woodland only	2 km
Large heath		Indicator of connectivity of wet heath/blanket mire	Larvae – feed on Eriophorum in wet heaths/mire. Adults use Erica tetralix	450m

[1]Galleries/holes provide nests for Osmia *uncinata* Gerstaecher - **RDB2.** Boreo-alpine old pine *Pinus* forest species; nest in borings in trunk and stumps of pine, especially those of the longhorn beetle *Rhagium inquisitor.* Surveys in 1999 & 2001 have confirmed nests in beetle galleries (Rhagium inquisitor) within thick corky bark of old Scots pine trees. Already known was the

importance of Lotus corniculatus as only pollen source in UK. These two requirements have highlighted the importance of suitable sites with juxtaposed pinewood with old trees & successional or disturbed habitats with Lotus. Such sites were best where winter grazing maintained a short turf, but where summer grazing was minimal.

[2]The more species with similar species requirements and dispersal distances helps to reinforce and validate the parameters used in the BEETLE modeling.

Key of codes for table 5.14:
N = nationally notable and have been recorded in 16-100 ten kilometer squares in UK,
Na = nationally notable and have been recorded in 16-30 ten kilometre squares in UK;
Nb = nationally notable and have been recorded in 31-100 ten kilometer squares in UK;
Ns = Nationally scarce;
Nr = nationally rare;
E = endangered; **T** = threatened; **C** = critical; **V** = vulnerable; **U** = undetermined; **S** = Scarce; **Nt** = near threatened; **DD** = data defficient; **UIR** = uncommon increasing reage; **RR** = restricted range
RDB = red data book listed; **RDB 3**= rare, **RDB K** = insufficiently known
BAP = listed in UK Steering Group responce to Biodiversity, the UK Action Plan, as priority species
Sch. 8 = Schedules of the Wildlife & Countryside Act 1981

Summary

Understanding what is present, in terms of habitats and species, on a site is vital in setting conservation objectives. This helps us understand the ecological process that do have, or have the potential to happen of a site. It also allows a site to put in the context of the ecological landscape within which it is situated, and inform detailed management prescriptions. The historic context of a site, with changes in land use over many hundreds of years have shaped and influenced the present ecology. This information can be marshalled to inform ecological modelling, which will help planners make structured decisions about long-term site management.

6.6 Management Prescriptions for Native Woodlands based on Structural Phases.

6.6.1 Introduction.

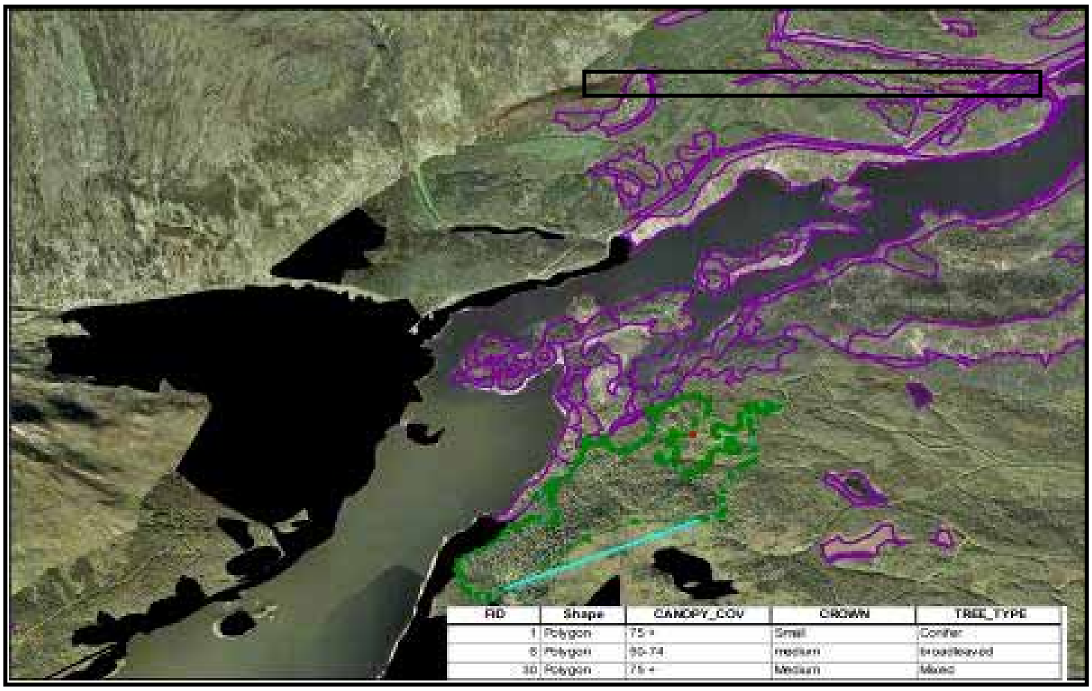
The appropriate level and type of management intervention suggested here for the native woodlands, is based on the relationship between the growth and dynamics or stage of development of the stand and its structural phase. Woodlands naturally develop in complexity through a series of structural phases typically termed ‘growth’, ‘stand succession’ or ‘stand dynamics’, which are driven by disturbance events such as fire, windthrow and individual tree growth and mortality. These phases are normally identified by assessing the spatial arrangement of seedlings, saplings, trees and deadwood in a stand using standard forest mensuration techniques. The allocation of a woodland stand into a phase has been most recently developed by Oliver and Larson (1996), and has been adopted by Forest Research as an appropriate methodology of allocating stands into a developmental stage depending upon their structural characteristics (Figures 6.12, 6.13 and Table 6.9).

6.6.2 Stand Structure Survey

Aerial photographs of the native woodlands in Glen Affric were used to create polygons of similarity of canopy structure based upon a combined score from three variables:

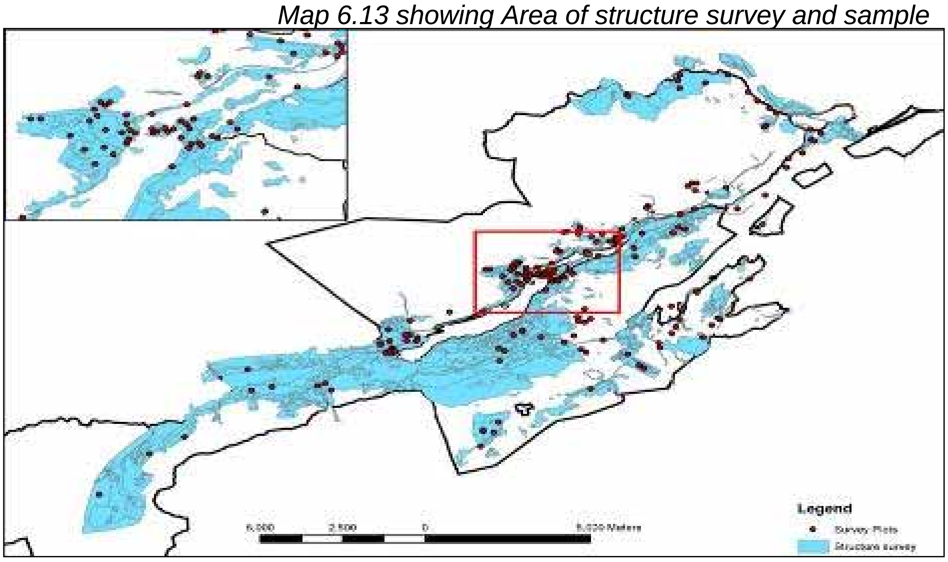
1) Canopy Cover (four percentage classes);
2) Crown Size (small, medium, large), and
3) Species (Conifer dominated, Broadleaved dominated or Mixed).

Figure 6.12 the polygonisation of structure survey



One hundred and seventy circular sample plots of 12.6 m radius were located in a sub-sample of the most abundant canopy structure polygons.

Map 6.13 showing Area of structure survey and sample



Structural Phases

An understanding of the Structural Phases for a stand and the balance of Phases within a particular area, provides information on the current stage of development, and the likely direction of change. Once the likely natural development is understood this provides the context to consider how the stand will develop over time as a result of various management operations. Management prescriptions, i.e. silviculture, can then be provided that will help move the stand or woodland towards a specific goal, e.g. the creation of habitats, enhancement of biodiversity or provision of a commercial crop. For example; thinning mimics the process of individual tree mortality in a stand, resulting in an opening of the canopy allowing individual trees to develop in size. Depending on the stage in which it is applied, thinning also increases light availability in the understorey, and increases cone development on the retained trees. Non-Intervention can be seen as a deliberate management prescription, one that allows the development of the stand to progress.

6.6.3 Development of Management Prescriptions

It is proposed that the Performance Standard is the expected succession of movement of stand structure through the four main phases of stand dynamics (Stand Initiation, Stem Exclusion, Understorey Reinitiation, and Old-Growth). Deviation from Performance Standard is measured by comparing the current phase allocation in the woodland against the modified Oliver and Larson stand dynamics diagram (Figure 6.14). Any deviation from this standard is likely to be an indication that natural stand dynamics are not operating, and that something is ‘wrong’ with the system. The two main deviations from the standard are the development of a Delayed Reinitiation phase, or the development of a Non-Wooded Habitat on a site that should naturally the wooded.

A combination of current standing basal area and quantity of large and very large diameter trees (those above 50 cm DBH, and those above 80 cm DBH), and the state of the vegetation into which any regeneration is expected to develop, are also needed to help identify the extent of the deviation. Dry heathland habitats are more likely to regenerate with both pine and birch spontaneously compared with vegetation habitats that are wet, or dominated by grass sward. Sites that have high levels of continued browse damage or damage to seedlings to other agents will also take longer to develop towards the performance standard than sites that have no damage, or low levels of damage that are acceptable.

Table 6.9 Stand successional phase and the phase description used for the Glen Affric data. (Seedlings are < 1.3 m height; saplings are > 1.3 m height but < 7 cm BDH; trees are > 7 cm DBH).

Successional Phase name (* those described by Oliver & Larson)	Phase Description
Non Wooded Habitat	No trees and no regeneration, but has the potential to be a woodland habitat. Can contain deadwood indicating past woodland status. Identified by; *a lack of seedlings, saplings or trees, but soils suitable for native woodland communities.*
*Stand Initiation	The initial stage in the development of a stand in an area, this is the recruitment period (either natural or artificial) which can last for many years. Identified by; *No overstorey trees but dense seedling and/or sapling recruitment.*
*Stem Exclusion	Once recruitment is complete and canopy closure has started, inter-tree competition begins. No further recruitment is then possible. Individual tree mortality becomes common allowing the development of neighbouring trees through canopy expansion to fill gaps. Identified by; *Plots with high tree density (> 1,000 ha^{-1}) and low mean dbh; basal area > 25 m^2 ha^{-1}; no seedling or sapling regeneration.*
*Understorey Reinitiation	Mortality of individuals no longer stimulates canopy expansion of neighbouring trees, but the canopy openings created by tree deaths allows light to penetrate to the forest floor developing both vegetation and seedling growth. Identified by; *Plots with medium - low tree density and medium - high mean dbh; basal area < 25 m^2 ha^{-1}; seedling and/or sapling regeneration present.*
*Old Growth	Continued mortality of overstorey creates increasing canopy openness, and growth of seedlings into saplings and small trees from the UR phase creates a variable stand structure. Components of all size classes usually present, with many large and very large DBH trees. Mortality of large trees leads to increased standing deadwood category. Identified by; *Variable tree density, mean dbh medium - high with many trees > 80 cm dbh. Standard deviation of dbh high. Sapling and/or seedling regeneration present. Deadwood present in standing and fallen categories.*
Delayed Reinitiation	Has the structural characteristic of UR or OG but seedling and sapling recruitment missing due to limiting factor(s) (e.g. high deer pressure, competitive vegetation sward etc). Usually has an open canopy structure with strong development of below canopy vegetation. Identified by; *Variable tree density and mean dbh. No seedling or sapling regeneration despite the basal area being suitable for recruitment (< 25 m^2 ha^{-1}).*

6.6.4 The Management Prescriptions

Stand Initiation (SI)

1. Management Objectives

1.1. *Continued recruitment* of suitable densities of seedlings to feed into the later stages of stand development (i.e. Stem Exclusion).

2. Management Prescriptions

2.1. *Provide Protection;* from animal browsing or from injury by other damaging agents, including from major fires. Protection can be given through suitable culling of deer populations, or provided by fencing the area at risk.

2.2. *Enhance Recruitment*; the creation of suitable conditions to encourage seedling recruitment at appropriate densities and encourage early seedling survival and growth. These conditions can be created through the use of a range of disturbance mechanisms. The intensity of disturbance would depend on the distance to a seed source and the site and soil type into which the seedlings are being recruited. Areas close to seed sources (e.g. < 50 m for Scots pine) on site types suitable for rapid regeneration (e.g. Dry heathland) will require less intervention than sites at greater distances from seed sources and/or on site or soil types that are unsuitable for high-density recruitment.

Stem Exclusion (SE)

1. Management Objectives

1.1. To allow stands to *develop at a natural pace*; with an accumulation of small diameter standing deadwood and high stand density – this provides high cover (shelter) beneath the canopy and favours the development of shade tolerant vegetation species. Use non-intervention prescriptions

1.2. Develop a later phase faster; especially where the stand is Native or Non-Native PAWS, to allow the development of the next phase type (Understorey Reinitiation) at a rate faster than in non-thin stands. Encourage the recruitment of natural regeneration of appropriate species for the soils. In the case of non-native non-PAWS sites this will involve conversion to broadleaved tree species. Use thinning prescriptions

2. Management Prescriptions

2.1. *Non-intervention;* to allow natural size differentiation. No thinning of the stand, which will allow the stand to mature at its own rate depending on the growth and mortality of the trees on site (self thinning). This will develop stand structure towards the Understorey Reinitiation phase. This prescription will create high densities of small diameter trees, which are at greater risk from snow damage and windthrow on high DAMS sites.

2.2. *Standard MTT thinning*; to allow the stand to deliver a commercial crop of timber where appropriate. Thinning will still move the phase towards Understorey Reinitiation, through the development of larger diameter trees and more open canopy conditions.

2.3. *Variable Density Thinning*; a combination of thinning treatments, including heavy interventions and non-thin, in intimate mixture to gradually lower the basal area over an appropriate period of time. Maximum removal of 20% of stand basal area in each intervention. Minimum interval between interventions four years to a maximum interval between interventions of 15 years. Open the canopy to stimulate the development of larger diameter trees.

2.4. *Crown Thin plus interventions*; to develop seed bearing native trees (100 – 150 ha^{-1}) where present for future natural regeneration. Coupled with suitable site disturbance and underplanting of native broadleaved tree species this will speed the process of seedling recruitment and move the stand towards the Understorey Reinitiation phase more rapidly than natural dynamics would.

Understorey Reinitiation (UR)

1. Management Objectives.

1.1. Maintain or develop structural diversity and volume of deadwood. Ensure continued recruitment of seedlings and saplings and their development into trees.

2. Management Prescriptions

2.1. *Non intervention* in areas where structural diversity is high (i.e. they have a high standard deviation for mean DBH) and/or regeneration, seedlings and saplings, present at a suitable density.

2.2. *Crown thin* mature trees where structural diversity is low (i.e. they have low standard deviation from mean DBH) and light levels are insufficient to enable sustained seedling growth. This is a form of LISS management. Basal area can be used to determine target stand densities.

2.3. Enhance tree mortality: Kill standing trees from a range of DBH classes to generate additional deadwood over a range of volumes and conditions where deadwood accumulation is low

Delayed Reinitiation (DR)

1. Management Objectives

1.1 To remove the limiting factor (the deviation from performance standard) to stimulate the recruitment of natural regeneration within this (Delayed Reinitiation) phase. Interventions depend upon the degree of Deviation from Performance Standard. Increasing intervention is required where there is decreased ability of the site to respond naturally or favourably to the management interventions designed for it.

1. Management Prescriptions

2.1. Non-intervention management; where the probability of future spontaneous natural regeneration is high.

2.2. Thinning plus disturbance; where the overstorey is: a). Broadleaved, b). Very mature or overmature and beginning to break up; but there is a lack of natural regeneration recruitment or c). There is heavy damage to any seedlings which is preventing them from developing into saplings and trees; then more interventionist type management prescriptions are required. These more interventionist prescriptions would include Locally Intensive Site Disturbance (LISD), protection through animal exclusion i.e. fencing, and assisted regeneration (cultivation, planting and application of fertiliser).

Old-growth (OG)

1. Management Objectives

1.1 Maintain or develop structural diversity and volume of deadwood. Ensure continued recruitment of seedlings and saplings and their development into trees. Increase the abundance of under-represented native species present in other native pinewoods.

2. Management Prescriptions

2.1 Non intervention; in areas where structural diversity is high (have a high standard deviation for mean DBH) and/or regeneration, seedlings and saplings are all present at a suitable density. Natural stand dynamics should ensure self-sustainable stand development. Natural disturbances at a range of spatial and temporal scales will drive the dynamic process (see Figure 1).

2.2 Selective thinning; thinning of mature trees where structural diversity is low (low standard deviation from mean DBH) and light levels are too high to allow recruitment of regeneration. This will increase seeding levels on retained trees and develop the appropriate light climate beneath the stand.

2.3 Enhance tree mortality; deliberate killing of standing trees from a range of DBH classes to generate additional deadwood over a range of volumes and conditions where deadwood accumulation is low (refer to publication by Andy Amphlet, Abernethy for details of the expected volume of deadwood in natural pinewoods).

Non Wooded Habitats (NWH).

1. Management Objectives

1.1 To develop the Stand Initiation phase of tree recruitment on NWH's adjacent to existing seed sources. The levels of intervention required by management are dictated by the period within which the recruitment of saplings or small trees is expected. Table 2 indicates the likely management prescriptions for various situations.

2. Management Prescriptions

2.1 Non-intervention management. Allow the area to regenerate naturally, if the site is less than 50 m from pine seed source, or less than 80 m from a birch seed source, the opportunity of regeneration is high, particularly where the vegetation is non-competitive to regeneration (e.g. dry heathland) or the area has been subject to some form of disturbance that has generated suitable seedbed conditions for germination and growth.

2.2 Locally Intensive Site Disturbance and Protection. If the site is less than 50 m from pine seed source, or less than 80 m from birch seed source, and the opportunity for spontaneous regeneration is low. Particularly in wet soils, dense Calluna heathland, or a grass sward. The type of locally intensive site disturbance that can be applied here will vary depending on the speed at which regeneration is required to be recruited. In situations where rapid recruitment and growth of seedlings is required then more intensive disturbance that creates suitable conditions for seedling growth is recommended. Lower level disturbance intensities are appropriate where the speed of recruitment needs to be less.

2.3 Assisted regeneration. If the site is greater than 50 m from a pine seed source, or 80 m from a birch seed source, then the probability of spontaneous natural regeneration is very low, and if it occurs the density of seedling recruitment will be low and the development of an open wooded habitat would be expected. Where sites are expected to contain a tree habitat, but there is no seed source to help the development of the stand initiation phase, then cultivation, planting, and the application of fertiliser to create a new stand is warranted.

Table 6.10 The management prescriptions appropriate for a Non Wooded Habitat (NWH), where the objectives of sapling (> 1.3 m height; <7 cm DBH) or tree recruitment (> 10 cm DBH) are wanted within a target period of time.

Target Period to Achieve Objective: (years)	**Objective for the Non Wooded Habitats.**	
	Recruitment of Saplings (early SE) (> 1.3 m height; <7 cm DBH)	**Recruitment of Trees (late SE) (> 10 cm DBH)**
10–15	Locally Intensive Site Disturbance and Protection.	Not possible.
16–30	Spontaneous, protected natural recruitment on the best sites (Non-intervention). Locally Intensive Site Disturbance and Protection required on poor sites.	Not possible unless planted.
31–50	Spontaneous, protected natural recruitment on most sites (Non-intervention) or on unprotected sites with moderate browsing rates.	Locally Intensive Site Disturbance and Protection on good sites, assisted regeneration on poorer sites.
51–80	Spontaneous natural recruitment on most sites with moderate browsing rates (Non-intervention) or beneath a well developed tree canopy (e.g. >25 m^2 ha^{-1}).	Spontaneous natural recruitment on suitable site types (Non-intervention).
>80	Spontaneous natural recruitment on most sites with very high levels of damage, and on very poor site types (Non-intervention).	Spontaneous natural recruitment on most site types (Non-intervention).

6.6.5 Analysis of Glen Affric Phase Distribution

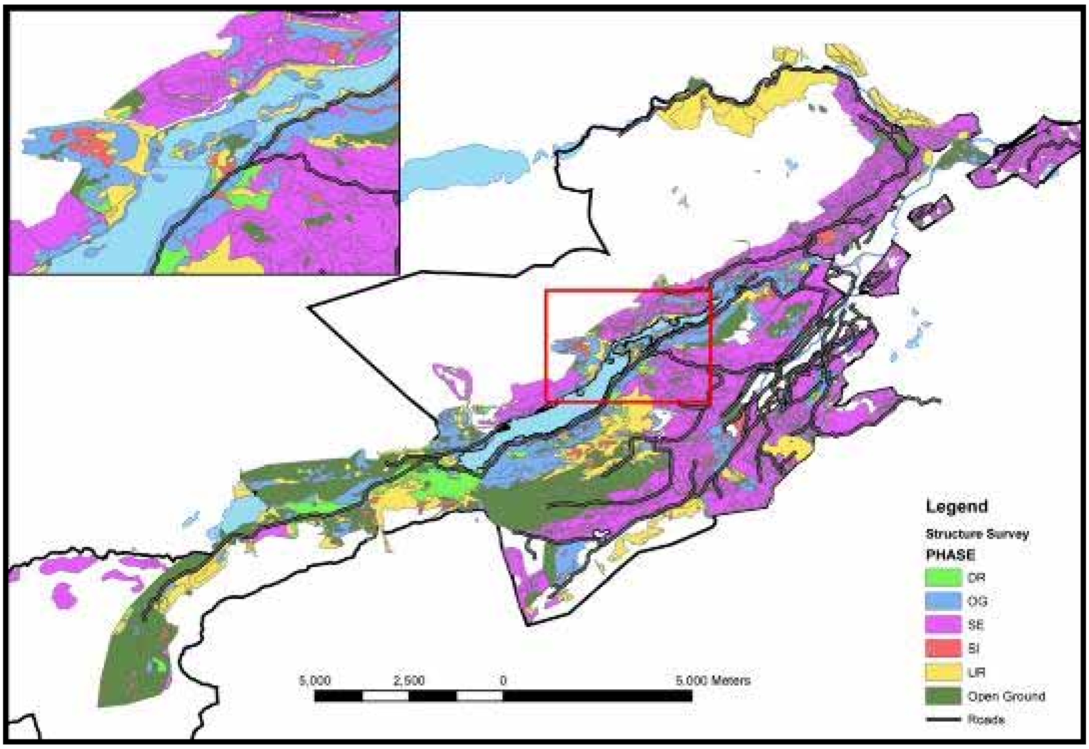
A comparison was made between the relative abundance of each of the Woodland Phases in Glen Affric from the Structure Survey and the allocation of Phase type to the polygons, with the distribution expected in hypothetical self-sustainable woodlands subject to a disturbance (fire) return period of 150 years. The composition recorded in Abernethy Scots pinewood is included for comparison. (Table 6.11).

The proportion of woodland in the Delayed Reinitiation phase in Glen Affric has been combined with the Understorey Reinitiation phase area, the assumption we have made is that past surveys have not had this class to record, and will have recorded it as UR. Our survey and its analysis would suggest that the limitations to the DR phase will be reduced through appropriate future management and will begin to develop natural regeneration through the adoption of Management Prescriptions for DR

Table 6.11 The proportion of stands in each of four growth phases as calculated using a fire frequency model[1] (Mason et al*. 2004), interpretation of the plot data from the Glen Affric Stand Structure Survey[2] and forecast distribution in 50 years in management prescriptions are followed. (UR is a combination of UR plus DR).*

Approximate mean stand Age (years)	Oliver & Larson Growth Phase	Proportion of stand			
		1 in 150 year fire return period[1]	Glen Affric[2]		
			Structure Plot data	Polygon distribution	[3]Forecast in 50 years
0 – 20	Stand Initiation	12%	6.4%	2.5%	3%
20 – 80	Stem Exclusion	29%	4.2%	57.2%	34%
80 – 150	Understorey Reinitiation	22%	50.6%	23.7%	23%
> 150	Old Growth	37%	38.8%	16.6%	40%

Map 6.14 showing current structural phases



This indicates an overabundance of stands in the Stem Exclusion phase (mainly native and non-native PAWS), and an under abundance of those in the Stand Initiation phase. The former (SE) will be managed according the four management prescriptions described in detail on page 5. The allocation of management prescriptions to the range of PAWS sites in Glen Affric is suggested as follows:

SE PAWS Sites	Management Prescription	Brief Description
Native SE sites	2.1;	*Non-intervention*
Native PAWS	2.1;	Non-intervention
Native non PAWS	2.2;	*Standard MTT thinning*
Non native PAWS	2.3;	*Variable Density Thinning*
Non Native non PAWS	2.4;	*Crown Thin plus interventions*

The explicit objective is to increase the proportion of area developing into the UR phase over the next 50 years by increasing thinning in appropriate stands and increasing the rate of development of stands into more natural structures.

7.0 ECOLOGICAL MODELLING

The role of ecological modelling in a Forest Plan (FP) is to identify the ecological potential of a site to help guide management decision-making. The management aim in Glen Affric is to promote natural processes and foster the return to more natural woodland. The challenge is to convey a long-term vision of the desired forest structure for the next 150 – 200 years and to identify silvicultural options that achieve these aims, while maintaining biodiversity and landscape values. This requires an evaluation of options and the creation of a plan for the next 20 - 30 years.

A suite of GIS supported models has been applied and integrated into the standard forest planning process to assess the impacts of alternative management interventions on this forest of high conservation and landscape value. These tools can provide forest managers with the ability to implement a landscape scale approach to habitat management, select species ecologically suited to sites, and estimate the probability of wind damage. The use of these Decision Support Systems will help the spatial delivery of the management objectives at the landscape scale and also improve the objectivity and transparency of the decision making process. They also enable the exploration of the consequences of a range of approaches over a period of several decades.

The following GIS supported tools have been developed to improve the ecological content and function of FPs. These are:

The Biological and Environmental Evaluation Tools for Landscape Ecology (**BEETLE**): provides a landscape scale approach to habitat management

The Ecological Site Classification Decision Support System (**ESC-DSS**): helps guide forest managers and planners to select species ecologically suited to sites

The **ForestGALES** computer based decision support tool: enables forest managers to estimate the probability of wind damage and the risk of alternative management options.

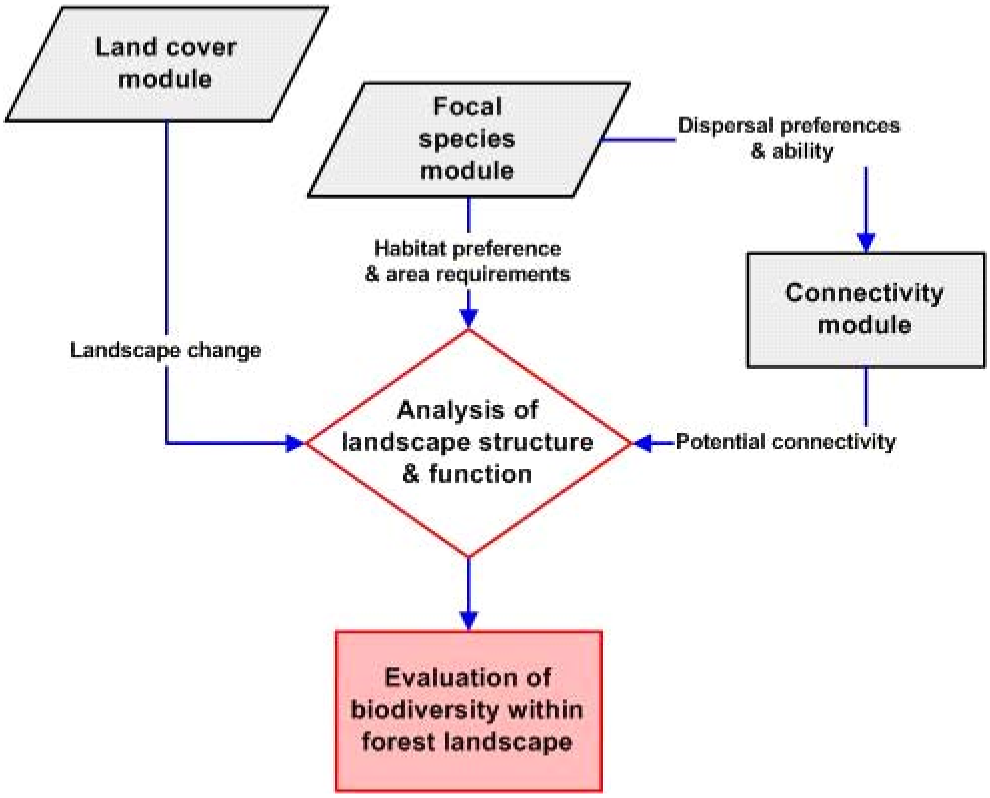
The ecological modelling does not provide definitive solutions to conservation management priorities; rather it helps to target land-use decisions that have been, or need to be made, by providing a **structure** and sound **justification** for the decision making process

7.1 Description of BEETLE modelling process

The approach is based on a GIS-based model from the ‘BEETLE’ suite of tools developed by Forest Research (see www.forestresearch.gov.uk/habitatnetworks). The model considers how areas of habitat are spatially arranged within the whole landscape, and how species can utilise and disperse between patches of habitat. Part of this model is a focal species tool that utilises habitat requirements and dispersal characteristics to identify functional habitat networks for a given species. The BEETLE accumulated cost distance tool (ACDT) was used to analyse the selected habitat networks within the Upper Beauly Catchment. This approach negates the need to carry out a vast number of individual species analyses, which is particularly important as data regarding species habitat requirements and dispersal through the landscape is lacking.

Various iterations of the BEETLE modelling approach have been described by Humphrey *et al*. (2004a, b), Watts *et al*. (2004) and Humphrey *et al.* (2005). BEETLE is implemented through a set of modules that represent and process data, as illustrated in Figure 7.1. There are two input data elements: a **land cover module** (see section 6.5.1) and a **focal species module** (see section 6.5.2)**.** The model's outputs is controlled by variation in the parameters of these modules. The **connectivity module** models the interaction between land cover and focal species. This module produces areas identified as habitat, and indicates the probability of movement across the landscape. This analysis allows an assessment of landscape structure and function to identify habitat patches within functional networks.

Figure 7.1 BEETLE components.



One of the key aspects of the BEETLE approach is the calculation of connectivity. Connectivity is a functional attribute of the landscape related to an ecological process, as opposed to connectedness, which is based on physical distance. Connectivity is modelled on the dispersal ability of a focal species and the ease of movement through the surrounding landscape. It is becoming accepted that the surrounding matrix (landcover) has a significant impact on connectivity for many woodland species. Semi-natural and extensive habitats are considered to be more conducive, or permeable, to species movement: whereas, intensive land uses are predicted to be less permeable, thereby reducing connectivity and increasing ecological isolation. The ease of movement, or permeability, through different land cover types is expressed in terms of 'ecological cost' (Watts et al., 2004).

The outputs of the BEETLE modelling in Glen Affric show habitat networks for the following habitats. These have been based on the focal species as described in section 6.5.2.

- **Wood pasture** (Figure 7.2)
- **Caledonian Pinewoods** (Figure 7.3)
- **Upland birch and oakwoods** (Figure 7.4)
- **Heathland** (Figure 7.5)
- **Wetland** (Figure 7.6)
- **Rides** (Figure 7.7)
- **Rides and wetland** (Figure 7.8)

Figure 7.2 Wood pasture networks

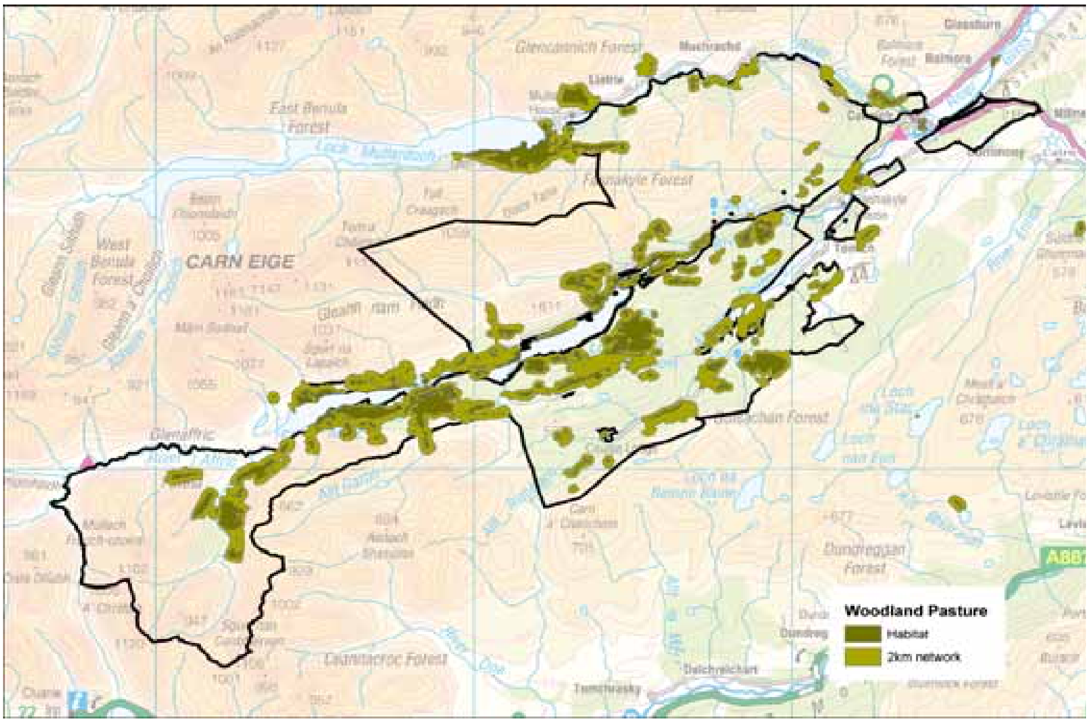


Figure 7.3 Caledonian pinewood networks

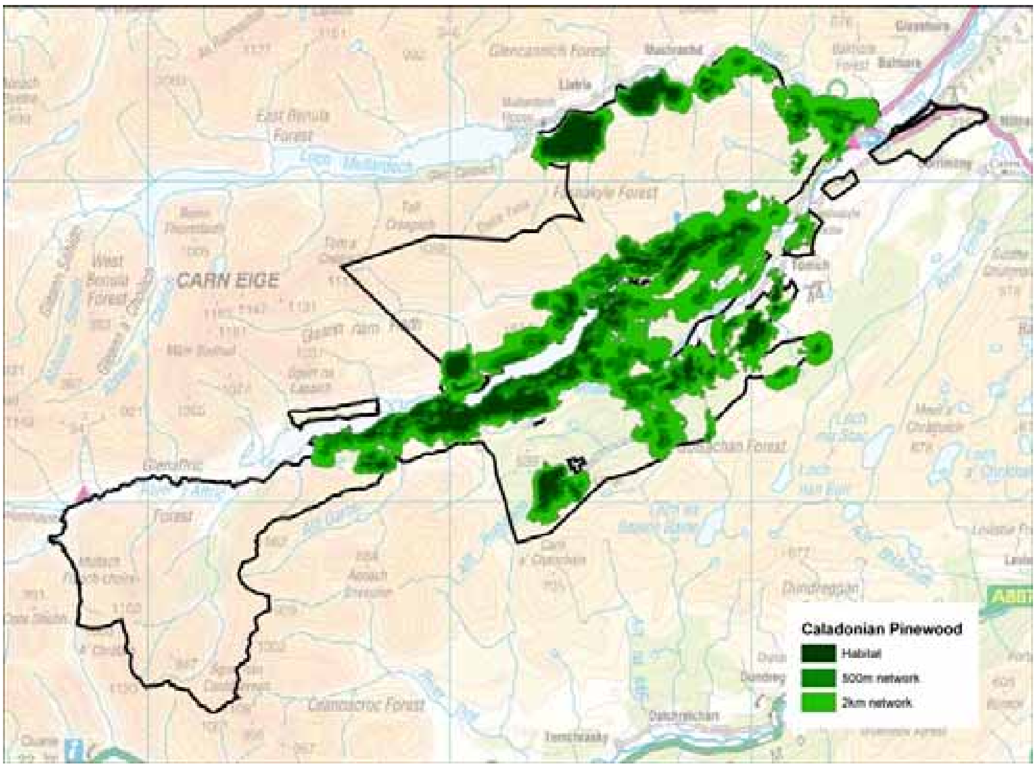
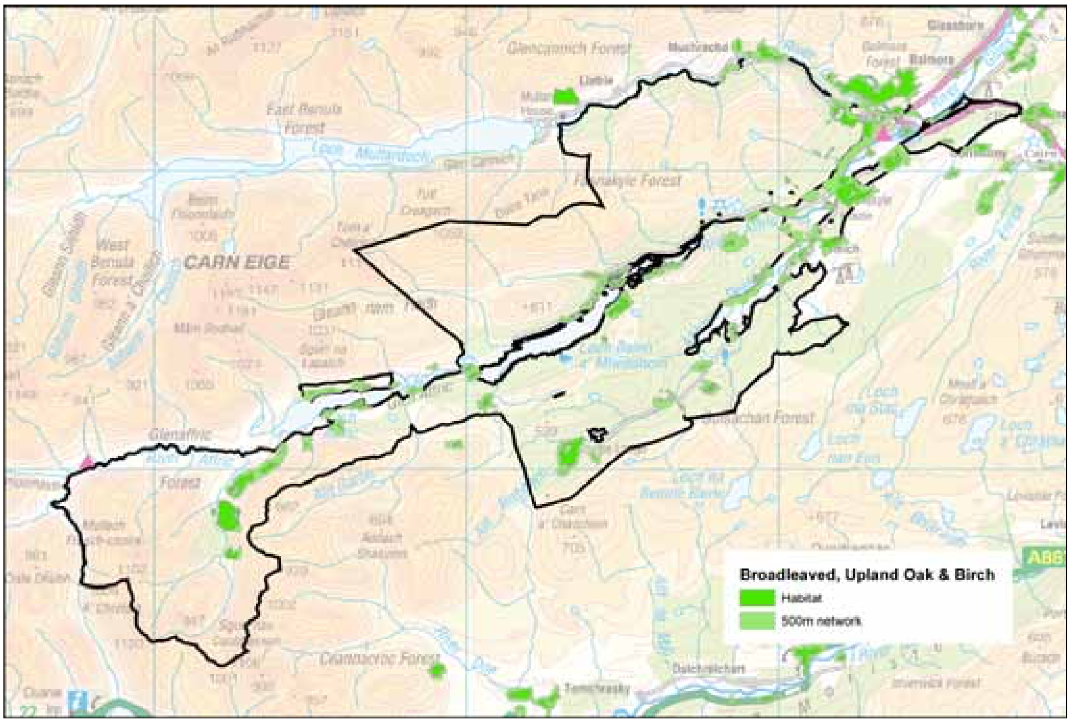


Figure 7.4 Upland birch and oakwoods



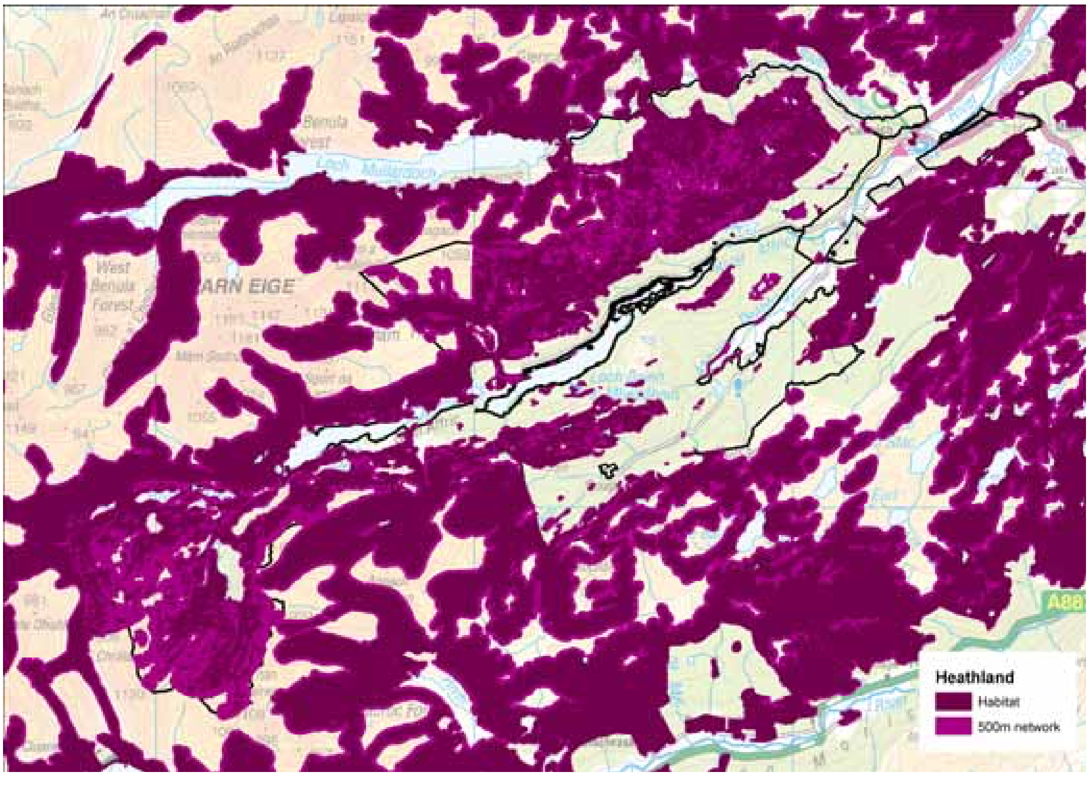


Figure 7.5 Heathland habitat networks

Figure 7.6 Wetland Habitat Networks

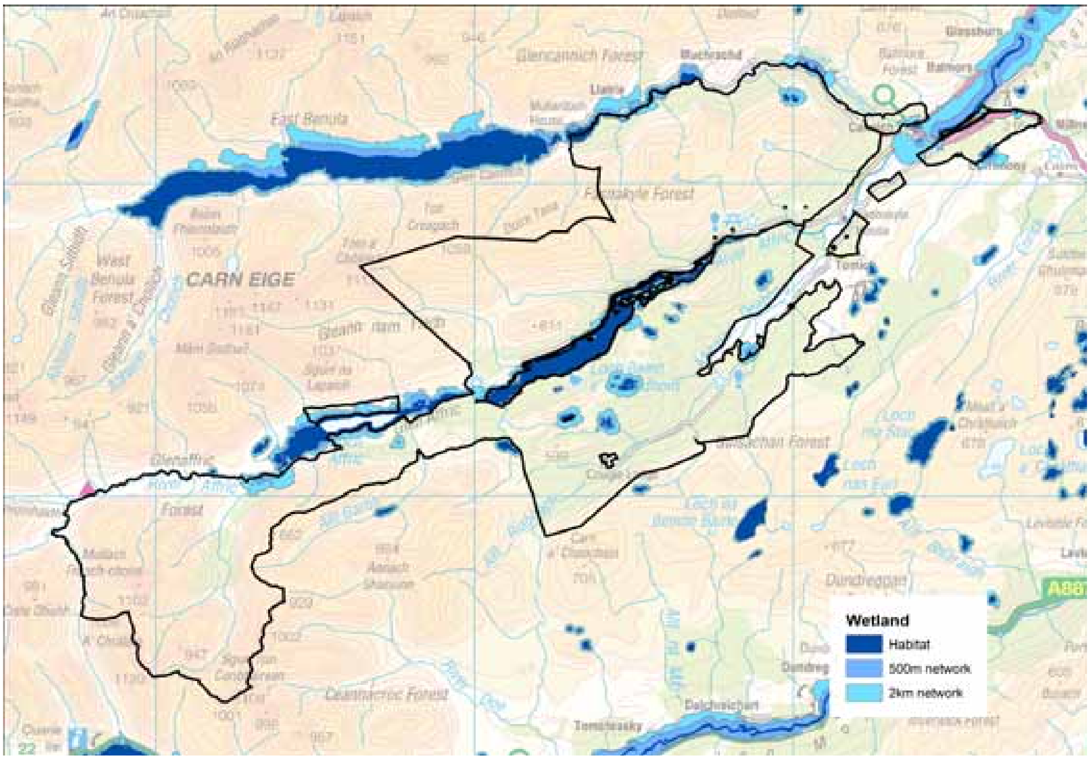


Figure 7.7 Ride habitat networks

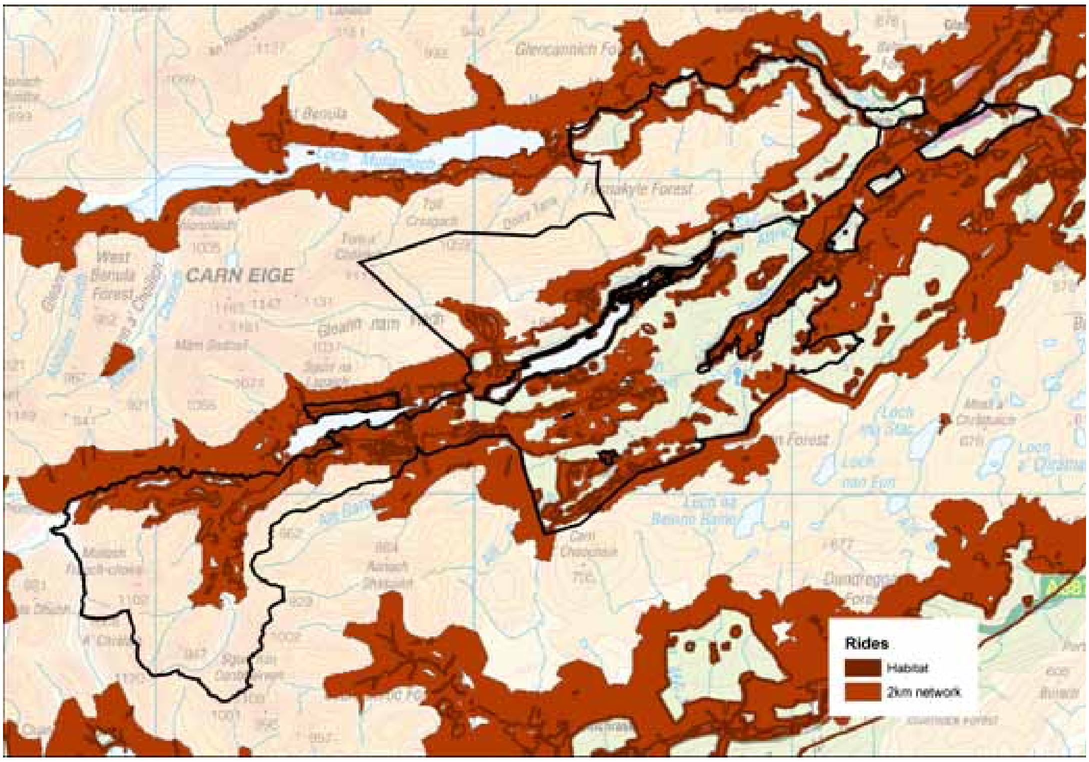
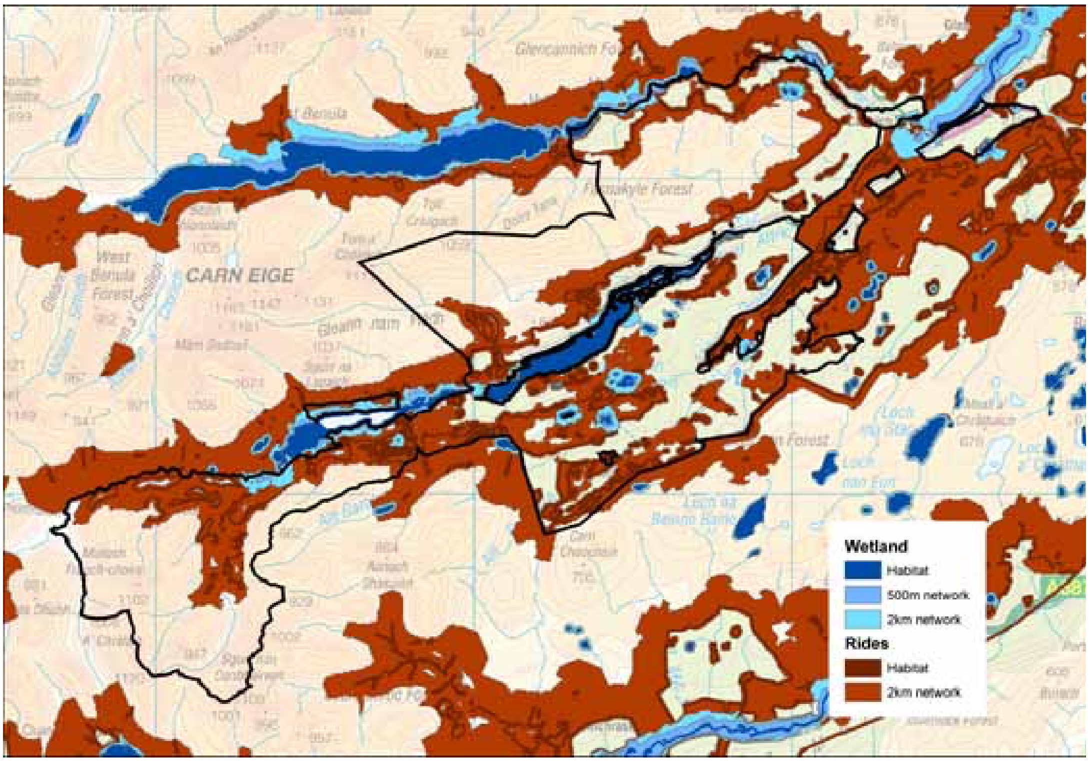


Figure 7.8 Ride and wetland Habitat Networks



The different habitat networks can be used to inform management of the different habitats or designated species. For example the ride and wetland networks (Figure 7.8) could be used to inform the management of the designated dragonfly assemblages that require the wetlands for their reproductive and juvenile stages and the rides for adult stages. Not all habitats are going to require networks for example volcanic outcrops are not readily recreated. The different network can be related to each other to ensure that management for one habitat type does not interrupt the connectivity of other habitat types.

7.2 Description of ESC-DSS modelling process

Introduction

The professional ability of the forester to 'read' the site conditions and select well-suited tree species is of fundamental importance. Ecological Site Classification (ESC) has been developed to draw on site-related knowledge of site suitability for a range of species, in a decision support system, to help the forest manager in the development of Forest Plans.

7.2.1 Method

The method uses six factors as criteria for testing site suitability: four climatic factors (accumulated temperature - AT, moisture deficit - MD, windiness and continentally) and two soil quality factors (soil moisture regime - SMR and soil nutrient regime -SNR) (Pyatt et al., 2001). ESC-DSS (Ray, 2001) calculates the climatic indices from the grid reference and elevation of the site. Soil quality is estimated from a combination of soil type and associated measurements, and an analysis of the field layer plant indicator species occurring. The ESC suitability models assess which factor is likely to limit suitability and growth on any particular site by calculating a suitability score from response functions (Ray, 2001). The method assumes that any number of suitable or very suitable factors cannot compensate for an unsuitable factor. The approach also offers a sensitivity analysis to assess the effect of varying one or more factors on the results.

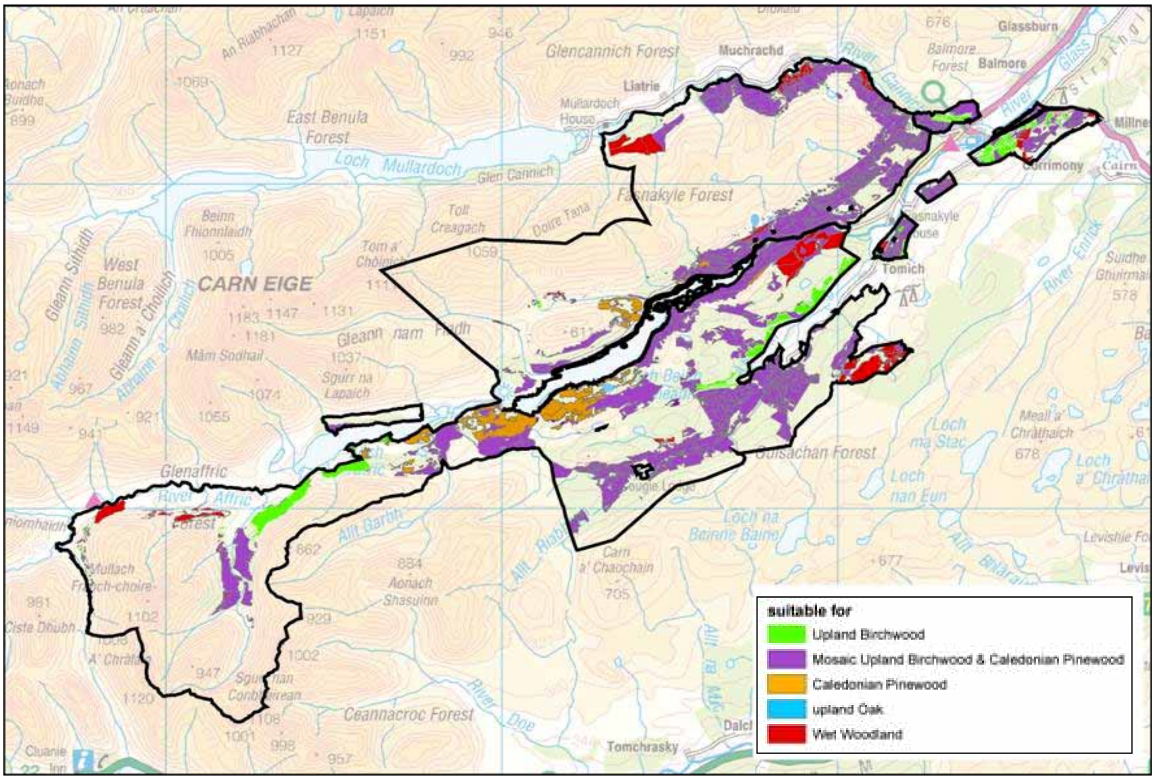
7.2.2 Using ESC at different scales

ESC was designed to be used at the stand scale. ESC-DSS (Ray, 2001) allows the user to input basic site information and obtain results for a single location; more detailed information can refine the predictions. The ESC-GIS model derives climate factors from a digital elevation model, and calculates default values of soil quality (SMR and SNR) from digital soil maps, or vegetation community maps that have been validated by field survey. Ideally, a soil map surveyed at a scale of 1:10 000 should be used to provide soil quality for an ESC analysis at the forest landscape scale. However, soil or vegetation information surveyed at a scale of 1:25 000 would provide reasonable soil quality information for a regional ESC analysis (Ray *et al*., in press) (see below).

It is therefore possible to use ESC analyses at three different scales. At the regional scale of forest planning, the Indicative Forestry Strategy scenarios (Quine *et al*, 2002), or the effects of climate change on tree species suitability can be explored. Forest scale analyses (Figure 7.9) will be useful for more general forest planning, such as the production of design plan scenarios and site yield assessments. At the stand scale (Figure 7.10) the forester would check species or woodland community suitability from surveyed information prior to management operations within a coupe. To illustrate these uses, ESC case studies are presented in the following three sections.

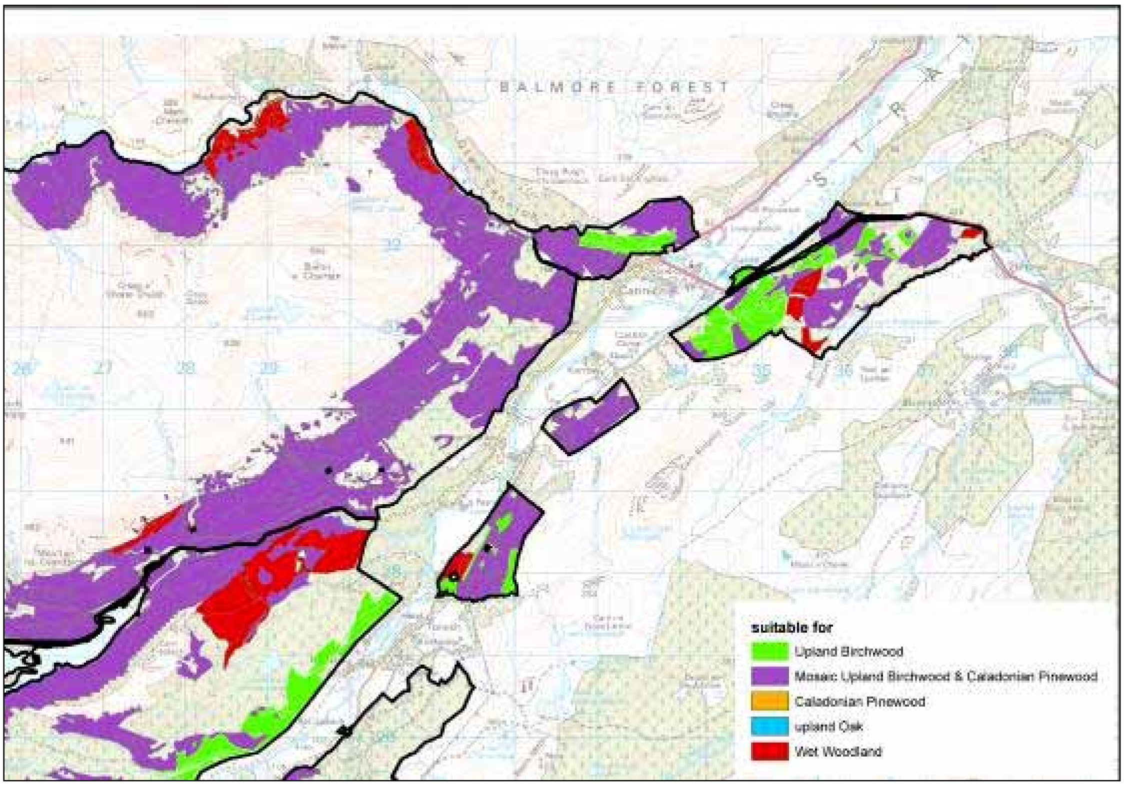
Note that the maps only show areas of suitability for the woodland communities, not areas which are suitable for the growth of individual tree species. The area in which Scots pine can grow is much larger but the range of community associates may not be able to develop in these areas, hence the gaps.

Figure 7.9 ESC analysis at Forest level Upper Beauly Catchment



Areas of priority open habitats have not had their potential woodland communities shown, as these should not be converted to woodland. In Upper Beauly catchment, the pine and birch are so intimately mixed it is not possible to differentiate between.

Fig 7.10



7.2.3 Conclusions and future developments

ESC can provide decision support for forest planning at a range of scales using ESC-DSS or ESC-GIS. The examples have illustrated the application of the ESC methodology, to species or native woodland suitability at the stand scale (ESC-DSS), the development of forest design plans (ESC-GIS), and the assessment of the strategic futures of forestry at a national or regional scale in a changed climate. At each level of use, and despite the different types of data being used, ESC uses a common terminology that is consistent between the users. This brings transparency to the forest planning process, also enabling users to assess and make sense of the variation that occurs when moving from one scale of application to another.

7.3 ForestGALES modelling process

Wind risk assessment of stands in Glen Affric was carried out using ForestGALES

7.3.1 Introduction

ForestGALES (Gardiner et al. 2004) is the most reliable method available in Britain for assessing wind risk to forest stands. It was developed to replace the 'windthrow hazard classification' that was found to have substantial deficiencies that led to poor management of wind risk and premature felling of stands. ForestGALES may be run for individual conifer stands or for multiple stands in batch mode, and can give outputs of either the current risk, or of the changing risk as a stand grows. Risk is expressed as the 'Return Time' of the critical wind speed calculated to overturn an average tree in the stand. The return time of a wind speed is how often that wind speed would be expected to occur in that location and is calculated for a site using windiness scores called "DAMS" (Detailed Aspect Method of Scoring) that have been mapped for Britain. For example, if ForestGALES predicts that a stand with particular tree and soil characteristics would require a wind speed of 20 ms^{-1} to be windthrown, this wind speed would have a return time of more than 200 years in a sheltered part of the country (DAMS 10), but a return time of only 5 years in a more exposed part of the country (DAMS 16).

7.3.2 Application of ForestGALES for Glen Affric

ForestGALES is more commonly run in single stand mode and the Glen Affric case study provided an opportunity to test the multiple stand 'batch mode' function with a complex landscape scale forest area. As the Glen Affric area contains a mixture of uniform conifer plantations (various species) and "natural" native Scots pine woodland, different approaches were required to estimating current and future wind risk (using ForestGALES), due to the differences in available data. Conifer plantations were run using sub-compartment data and standard ForestGALES batch mode. There were insufficient data in the SCDB to run ForestGALES for the more complex native Scots pine woodland, so these were tested by applying appropriate default values to ForestGALES. These areas will be rerun through ForestGALES using data from a remote-sensing (LiDAR) survey of the area conducted in 2007

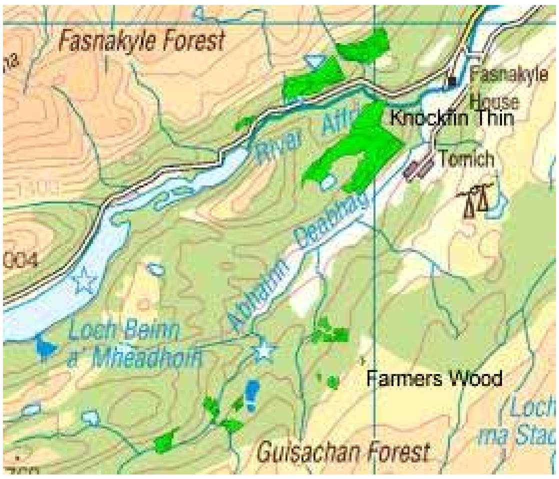


Figure 7.11 Glen Affric proposed LISS areas.

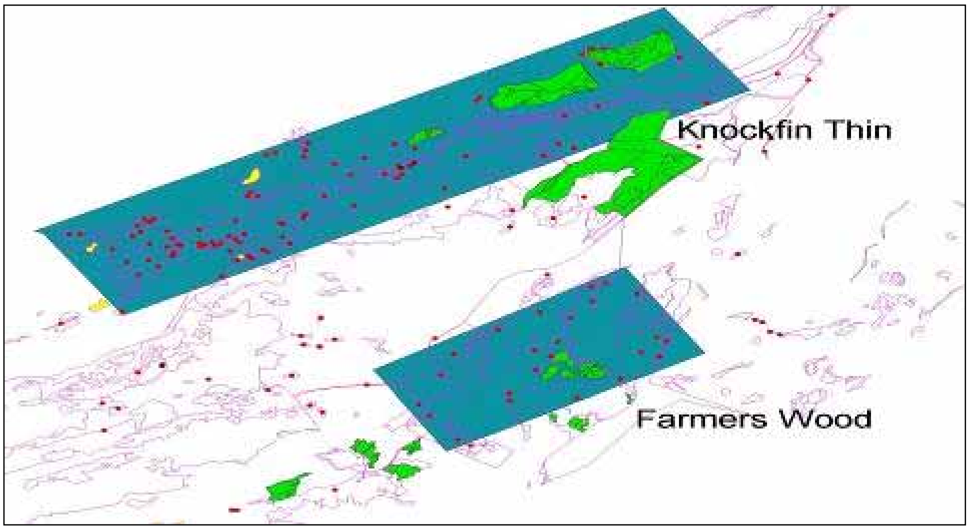
7.3.3 Methods

Uniform stands

Phase 1. ForestGALES was initially run for all proposed LISS areas at Knockfin and Farmers Wood (Figure 7.11) in Glen Affric, using default soil types

The uniform stands had available sub-compartment data describing stand species, age, location, and yield class. Soil data was not available for most of the Glen Affric area when this task was attempted, but default soil values were effective in highlighting sub-compartments with the highest risk (Figure 7.13).

Figure 7.12. Map of Glen Affric showing LiDAR survey areas in blue, in relation to ground survey sample points in red, and proposed LISS areas in green.



Phase 2. ForestGALES was then run for all conifer stands in Glen Affric to produce a current risk GIS layer. New soil survey work in 2007 allowed ForestGALES to be run using either the correct or the best estimate of soil type for each stand.

"Natural" stands

Phase 3 – to be conducted during 2008. To improve the ForestGALES risk calculations for the more complex "natural" Scots pine stands in Glen Affric, more detailed stand structure data are required. This will be provided using a combination of airborne LiDAR remote sensing, and the 2007 ground survey sample plots (Figure 4). Airborne LiDAR surveys were conducted in summer 2007 by Environment Agency of the sample areas marked blue on the map. Data analysis and generation of input values are underway by FR Biometrics.

Defaults used to run ForestGALES (Phase 1 and 2)

Starting with all components of the sub-compartment data-base for the Glen Affric area, it was first necessary to delete rows where there were no data as ForestGALES can not cope with missing data (1414 rows removed). Where a species or spacing could not be run through ForestGALES because there is no appropriate yield model for it in the FC Yield Tables, the closest yield class and/or spacing was substituted. Where there was more than one soil code for a component, the first soil code from the list was used, as this was assumed to be the dominant soil for a stand. Where there was no recorded soil for a stand, or where it was listed as 'VC' , a default soil (value 7, surface-water gley) was used. The mean DAMS value was used for all stands, but this could be repeated using Min or Max DAMS. Where there was no mean DAMS value (mostly stands planted 2002 onwards), ForestGALES was run separately in single stand mode to calculate a DAMS value for the grid reference. Where old Scots pine stands were listed in the sub-compartment database as Yield Class 0 (apparently to remove them from the production forecast), the data were 'corrected' to have a default Yield Class 4 (the lowest that yield tables are available for).

ForestGALES currently only works for conifer species, however to provide an output for all stands, Beech and Birch were run as SS YC 6, but these may be removed from the output if preferred. Where spacing was missing in the database, especially P2002 onwards, a default spacing value of 2.0 m was used. All stands were run assuming No Thin (NT), except EL, WH and NF where this was not an option in the FC Yield tables, and 'Intermediate thinning with no delay' (IZ) was used instead. In the current version of ForestGALES, the maximum return time for damaging wind output is 200 years, even though it would often be much greater. As this doesn't help understand risk to trees that are approaching or greater than 200 years old (native SP stands), we assumed a default minimum Risk status 1 for all mature SP stands.

ForestGALES Wind Damage Risk Status
The risk status classes used for Glen Affric were:

Risk status 6 currently <10 year return period for damaging wind
Risk status 5 currently 20-10 year return period for damaging wind
Risk status 4 currently 33-20 year return period for damaging wind
Risk status 3 stand will reach Risk status 4 in <10 years
Risk status 2 stand will reach Risk status 4 in >10, <20 years
Risk status 1 stand will reach Risk status 4 in >20 years

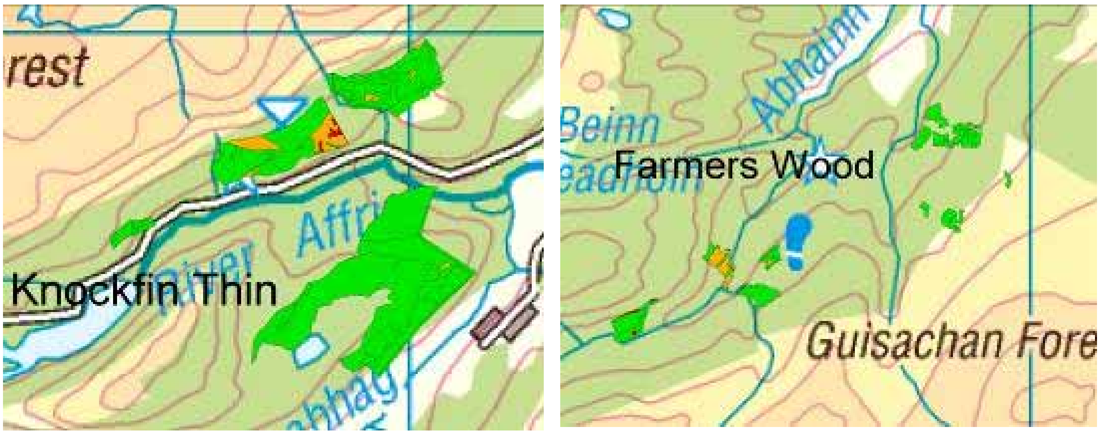
Risk status 6, 5 and 4 were direct outputs from ForestGALES, while 3, 2, and 1 were calculated from the outputs to show increasing risk to vulnerable, but not currently high risk, stands over time. However, with this system, all except Risk status 1 represents an appreciable wind risk that should be taken into account in design planning and management of the stands.

7.3.4 Results and discussion

Outputs from Phase 1 - LISS conversion areas

Risk maps were produced of proposed LISS (currently ‘uniform’) stands in Glen Affric (Figures 3 and 4). Orange indicates stands that are predicted to reach ForestGALES risk status 5 within 25 years, and red indicates stands that are already at risk status 5 or above. Risk status 5 indicates a return time of damaging wind speed of less than 20 years. Areas marked red would be particularly vulnerable, and should be considered for harvesting (if still standing), and areas marked orange would not be recommended for thinning for conversion to continuous cover. Overall, most of the proposed LISS areas are suitable for conversion, but the small areas that are indicated as being high risk should be treated differently, and possibly clear-felled for replanting with lower risk slow growing species. It should be remembered that wind risk to any stand will increase if it is exposed by removing an upwind stand or green edge, and ForestGALES should be rerun for stands where such operations are proposed.

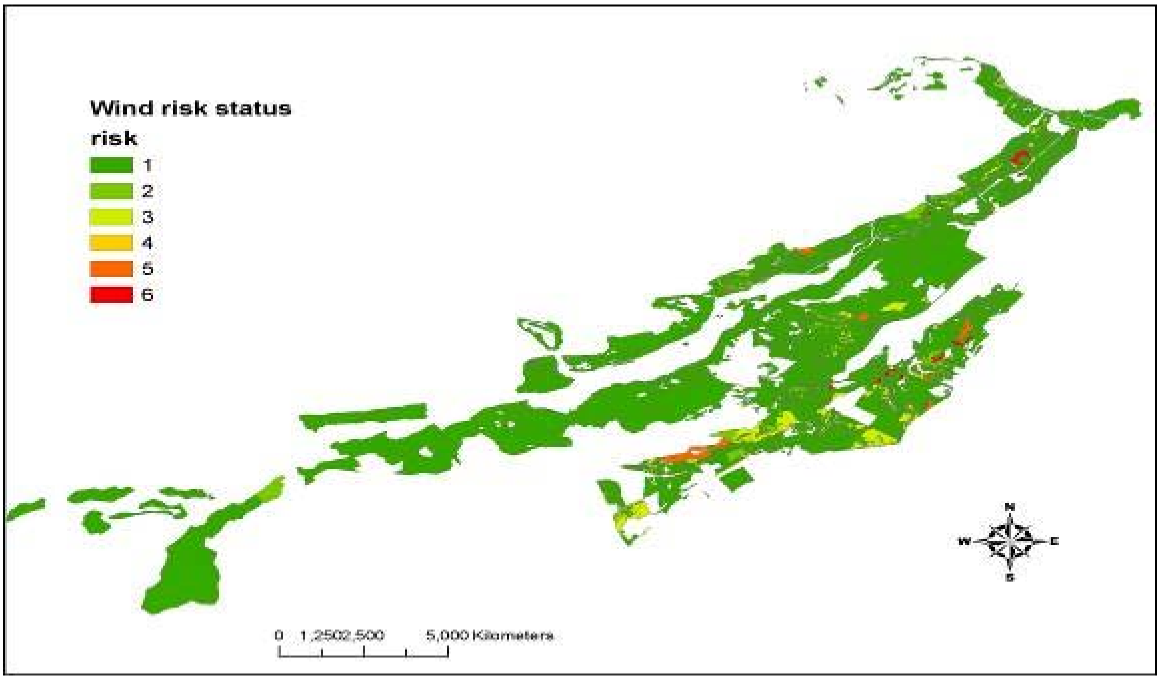
Figure 7.13. Wind risk map of Farmers wood and Knockfin LISS areas.



Outputs from Phase 2- ForestGALES wind risk assessment of all stands

Overall, wind risk to current stands appears low across most of Glen Affric with stands at higher risk mostly concentrated in plantations towards the South of the area (Figure 7.14). It is recommended that areas marked red (Wind risk status 6) should be considered for clearfelling in the near future. Stands with risk status 2 to 5 also have appreciable wind risk, and care should be taken in management of these stands as the risk would be increased considerably by operations such as thinning, felling adjacent stands, or removal of the existing green edge. The native Scots pine stands have low risk on the map, but data from the sub-compartment database were insufficient to allow a reliable analysis of risk using ForestGALES. A low-risk assessment appears to be reasonable for such stands, but this assumption will be checked during 2008 by re-running ForestGALES for these areas using data from the LiDAR remote sensing survey.

Figure 7.14 Current wind risk in all Glen Affric stands from ForestGALES

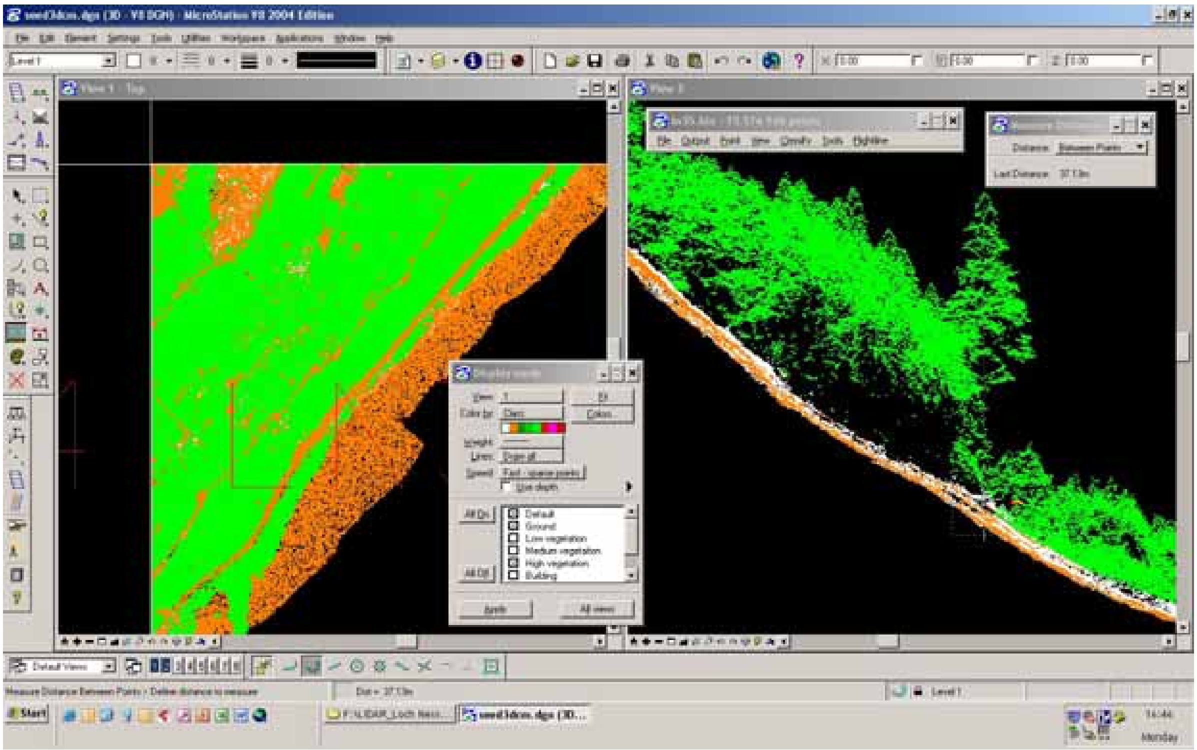


Phase 3 – ForestGALES / LiDAR assessment of wind risk in 'natural' stands

The LiDAR survey was part funded by the EC Interreg North Sea Region – 'Stormrisk' project and the areas were flown in summer 2007. The data was initially processed by Environment Agency and made available by end 2007. An example image showing Glen Affric LiDAR data interpretation is shown in Figure 7.15. Algorithms to provide stand data required for ForestGALES from LiDAR data (stand density, species, height and DBH distributions) have been developed by Juan Suarez (FR Biometrics) and will be verified using Glen Affric 2007 ground survey data. Data will be extrapolated to the remaining stands not covered by the LiDAR survey, using relationships between LiDAR data and the field survey data.

A complete GIS wind risk map will be produced to give current risk, and predicted years to wind risk status 5, in both uniform and 'natural' stands. An extreme event scenario will be tested and mapped to show projected damage following a 'catastrophic' storm with windspeeds >45 ms^{-1}. These results will be provided in a separate report to be complete by August 2008.

Figure 7.15 Example of LiDAR data for Glen Affric.



Summary of advantages and disadvantages of different modelling and analytical tools			
Source	**Advantages**	**Disadvantages**	**Applications**
BEETLE	Interactive and can be used to appraise proposals. Quick to run	Requires some expert interpretation Uses "Spatial analyst" for which there are limited licences and therefore not currently available directly to FDs.	DSS identifying connectivity and fragmentation of habitat, current and future.
Regional Forest Habitat networks	Will be available for whole of Scotland shortly through GIS and FCS map browser (Currently available for Highland)	Data currently available to FDs is not interactive and therefore of limited value in appraisal of proposals.	Identifying current regional context.
ESC GIS	Based on a comprehensive range of site and environmental factors.	Data "hungry" - requires survey of a range of soil related factors. Requires some expert interpretation when used at forest plan level.	DSS for assessing site quality and potential.
FOREST GALES	Available to run in Arcview	Mainly applicable to plantation forests	Identifies "at risk" stands at sub cmpt level.

These ecological models allow planners to target habitat restoration based on ecological principles that reflect ecosystem function:

- within functionally connect networks
- on Ecologically Suitable sites
- by balancing conservation conflict and priorities
- accounting for wind risk factors

Ecological models do not provide definitive solutions, but can be used to help target land-use decisions that have been, or need to be, made by providing a structure and sound justification for decisions. This allow for conservation strategies based on habitat function rather than species protection. With the understanding that designated species will be protected and indeed enhanced through this ecological function. It will allow for structured and supported decision making that should be quicker for forest planners. In time these should become key tools for landscape assessment and design planning, allowing planners to feel confident with the decisions they are make. Planners will be able to feel confident that they have the framework to ensure that the correct management can be put in place. This will mean that the range of habitats that the range of designated species require will be moving towards favourable condition. This will of course require monitoring and adaptation of management to ensure this

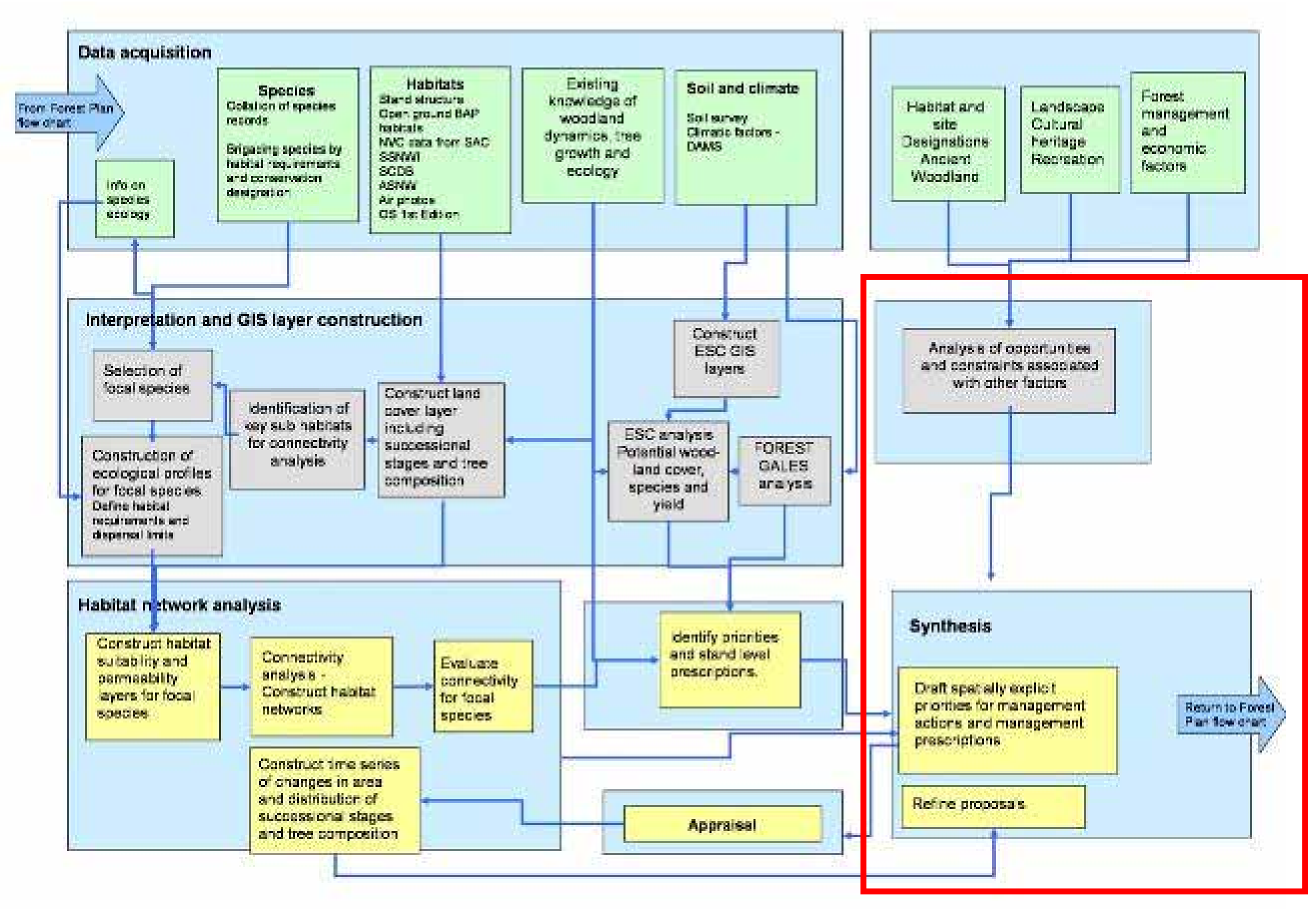
As with any modelling there are limitations and no model will ever be wholly accurate, but these tools can aid the decision making process by providing better ecological information for the forest planning process than is currently available.

Limitations:

- Accuracy of data
- Boundaries of model: what they can and cannot do
- Operator competence: the ability to use and ask the right questions of the models

There is the demand for these models to become a button on desktop computers immediately but technically this is some way off. A way to address this requirement would be for regional modellers to undertake analysis for planners and provide advice. This would allow forest planners to become familiar with the outputs of the models and be ready to use them efficiently when they become available as a desktop tool

8.0 APPLYING OUTCOMES TO THE FOREST PLAN



8.1 General outcomes

8.1.1 Analysis of opportunities and constraints

At the synthesis stage, the identification of future management options relied on subjective expert assessment by the whole team of a range of other key information such as physical characteristics, landscape, recreation and forest management considerations as well as model outputs. These discussions were recorded for future reference gives an example) Key factors were identified for all the landscape units within the Case study area *(Fig 8.1)* and 5 examples demonstrating a range of circumstances were selected to show how the modelling process might influence future decisions.

Fig 8.1 Key factors in analysis

	Habitats and species						Landscape, cultural heritage and recreation				Forest management and economic considerations					
	NNR	European designated sites (SAC)	Other protected habitats and species	Connectivity fragmentation	Plantations on Ancient Woodland site	Potential native woodland area and type (ESC)	Landscape value – Designated sites	Landscape views	Archaeology Cultural historic heritage	Recreation	Restricted operational access	Stability of current stands	Deer impacts	Productivity – timber potential	Market considerations	Access: permissions, wayleaves, leases
Farmed strath with mixed woodland.																
Karrow*				✓	✓	✓		✓	(✓)					✓	✓	
Fasnakyle* (Woodland)	(✓)			✓	✓	✓		(✓)						✓	✓	✓
Guisachan	(✓)				✓				✓	✓				✓	✓	
Knockfin valley slopes				✓	✓	✓		✓						✓	✓	✓
Narrow steep-sided wooded glen.																
Loch Beinn a Mheadhoin (South)	✓	✓		✓			✓	✓		✓	✓					✓
Loch Beinn a Mheadhoin (North)	✓	(✓)		✓	✓		✓	✓		(✓)	✓					✓
Loch Affric*	✓	✓		✓			✓	✓		✓	✓		✓			✓
Glen Cannich	✓			✓	✓						✓					✓
Upland massif																
Fasnakyle* (Hill ground)	✓		✓			✓	(✓)				✓					✓
Fasnakyle (Hill ground – outwith fence.	✓	✓	✓				✓				✓		✓			✓
Cougie – Meall-Dubh Moorland.	✓	(✓)	✓	✓		✓	(✓)				✓					
Knockfin	(✓)															✓
Beinn a Mheadhoin	✓			✓		✓				(✓)	✓					
Upland valley																
Cougie*	✓	(✓)		✓	(✓)	✓				(✓)	✓	✓				
High Mountain																
Far west	✓		✓	✓		✓	✓	✓	✓	✓	✓		✓			✓

* Example discussed below ✓ Key factor in the area (✓) Applicable to part of the area

8.1.2 Priorities for connectivity and species choice

Models are *Decision Support Systems*, they help to analyse complex information over a large area in an objective and systematic way but are reliant on the data and rules applied. They identify options and priorities, but do not provide answers.

For example, over the case study area as a whole, the current habitat connectivity for Caledonian Pinewood specialists based on the BEETLE model can be use to highlight significant opportunities to improve connectivity between the current pinewood habitat for these species (shown as dark green in Fig 8.2) in Glen Cannich and Cougie with the main pinewood reserve in Glen Affric.

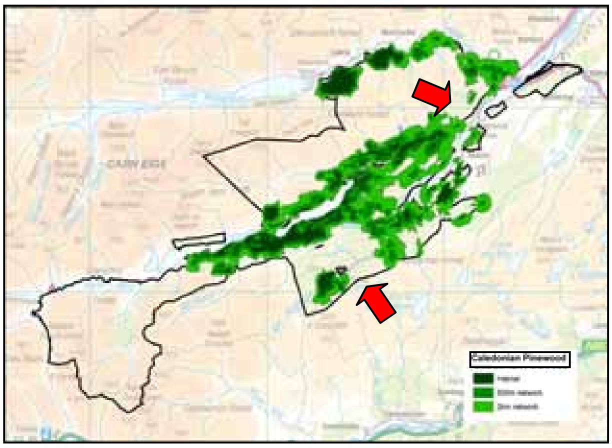


Fig 8.2 Current Caledonian Pine network

Glen Affric is intermediate between the oceanic pinewoods of the west coast and the more continental drier east coast. Native woodland habitat suitability based on the ESC model (Figure 8.3) suggests that typical Caledonian Pinewood habitat (W18 woodland type) would be relatively restricted in extent, occurring mainly on the southern shores of Loch Affric and Loch Benevean. More extensive are complexes of site types which would be more likely to support a mosaic of Caledonian pine and Upland birch woods with birch grading into oak – birch woodland (W17 or W11) on south facing slopes and those having a higher proportion of brown earth and towards the west. It is likely that the birch component is currently under-represented. At higher elevations and on wetter gleyed and peaty sites and areas with a high water table within riparian areas, birch woodlands are likely to fall into the wet woodland category (W4).

On other wet peaty, exposed or higher elevation sites, the forest would tend to thin out and be transitional to open moorland.

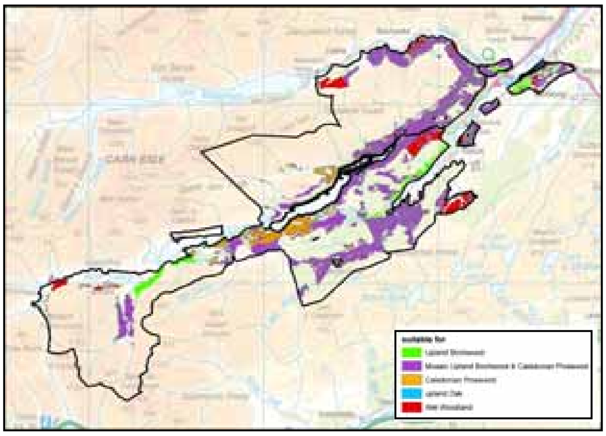


Fig 8.3 Native woodland habitat suitability

8.2 Kerrow

Key factors in this area were identified as:-

- **Connectivity - BEETLE**
- **Suitability - ESC GIS**
- **Landscape views**
- **Plantations on Ancient woodland Sites**
- **Production**
- **Adjacent land management**

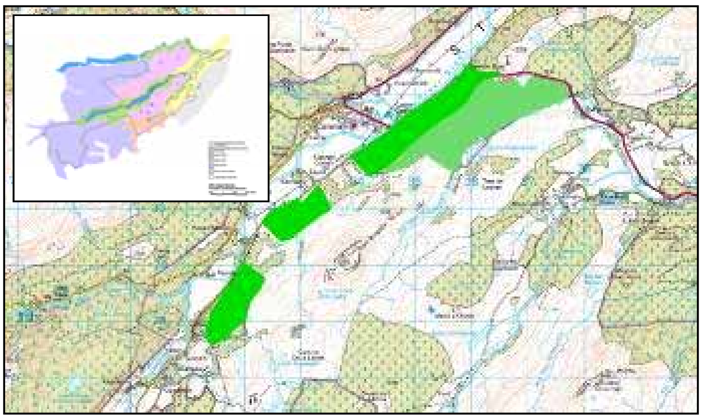


Fig 8.4 Kerrow location

Fig 8.5 Kerrow from Fasnakyle Power Station

8.2.1 Description

These three separate woodland blocks lie on the north west facing valley slopes of the "Farmed strath" within the lower elevation eastern part of the case study area (Figure 8.4 & 8.5). On the intermediate gradients of the lower valley, soils are a complex of brown earths, podsols with peaty gleys and surface water gleys following riparian areas and on concave slopes. On the more gentle gradients of the upper slopes, soils are a complex of gleys, podsols rock and peat.

Fig 8.6 Kerrow: current species

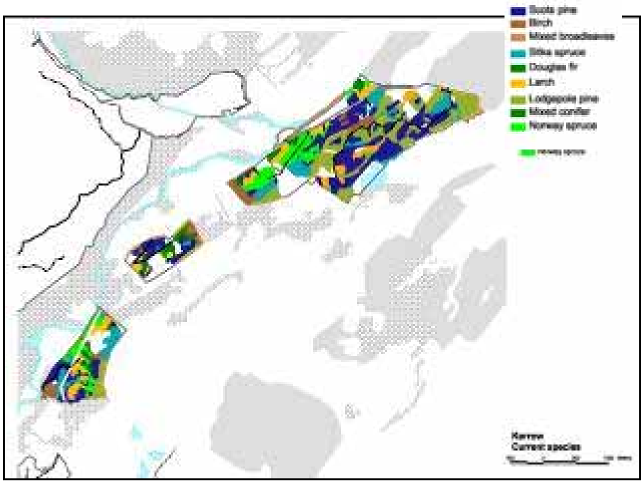
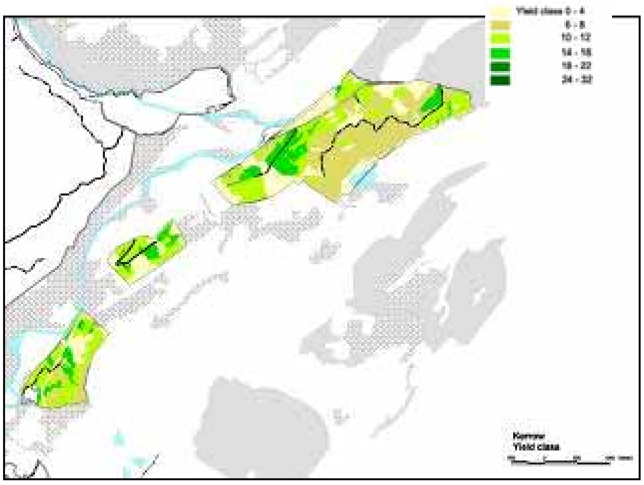


Fig 8.7 Kerrow: yield class



FCS woodlands lie on the lower and upper valley slopes and comprise mixed conifer woodland (Figure 8.6) planted during 1950s with yield classes for SS and DF on the lower slopes in the range of 10 – 16 (Figure 8.7). They are significant in terms of timber production but not the highest yielding trees in the study area. The upper slopes are younger (mid 1980s) and on poorer ground. Wind risk was not an important issue in this area. The woods are easily accessed although the public road is narrow, particularly beyond the Cannich junction.

There are no designations affecting this area but most of the lower slopes have been identified as an Ancient Woodland site (Figure 8.8) and outwith the FCS boundary, landuse in this area comprises scattered woods of birch and rough pasture of grass and bracken. The flood plain is farmed with fields, rough grazing and riparian woodland.

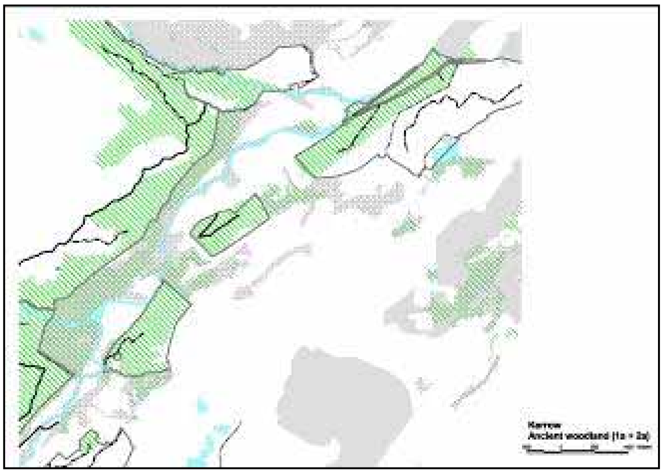


Fig 8.8 Kerrow: Ancient Woodland sites

On the upper slopes, outwith the FCS boundary, land use is a mosaic of open moorland, conifer plantation, scattered trees, rough grazing and bog. This is a key area for Black Grouse and includes significant young native woodland. (RSPB Corriemony).

The area is a settled, managed, landscape, relatively close to the communities of Cannich and Tomich and potentially highly visible to both residents and visitors to the area travelling on the minor roads. Current boundaries to these conifer plantations are geometric and this is re-inforced by frames of larch firebreaks. They are therefore somewhat discordant with their surroundings and create an element of disunity in the landscape. The southernmost woodland contains remains of an early township.

<u>8.2.2 Priorities from connectivity and species modelling</u>

Fig 8.9 Regional broadleaved network

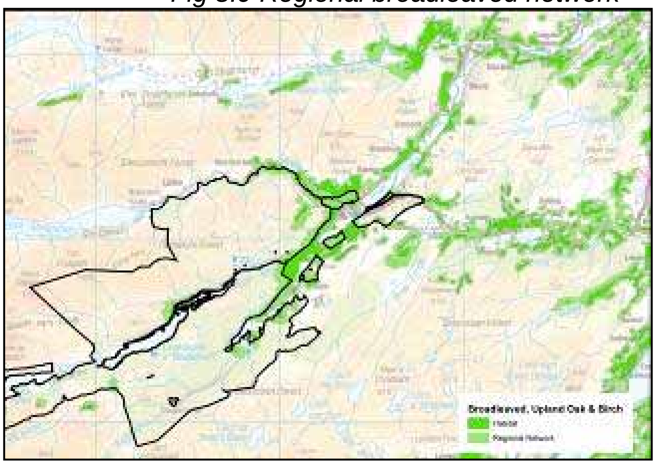
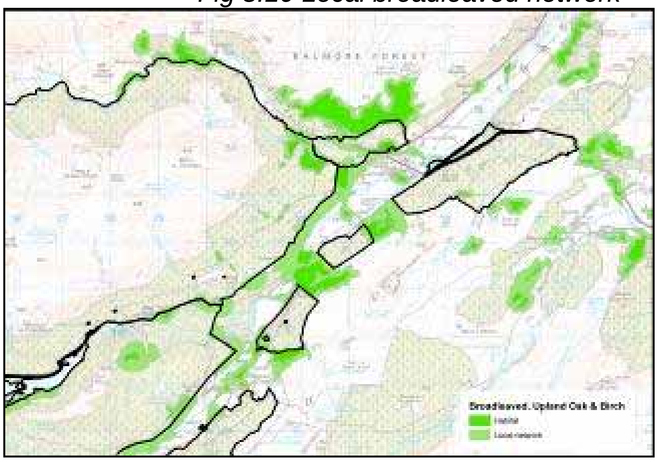


Fig 8.10 Local broadleaved network



The regional habitat network for Upland oak and birch (with 500m dispersal distance for focal species figure 8.9) show potential links along the lower slopes of Strathglass extending from Beauly at the seaward end to beyond Tomich. The local network analysis (with 500m dispersal distance for focal species figure 8.10) shows how the current conifer plantations interrupt this connectivity on the south side of the strath.

Analysis of native woodland suitability based on the ESC model suggests that much of the site would support a mosaic of Upland birch and Caledonian pine or Upland birch woodland communities (Fig 8.11 below). It is worth noting that the potential distribution of tree species alone (Fig 8.12) is wider than that of the full woodland communities as defined by a wider assemblage of species. Running ESC for tree species alone will not therefore give the potential distribution of Upland birch or Caledonian Pine HAP types.

Fig 8.11 Native Woodland habitat suitability

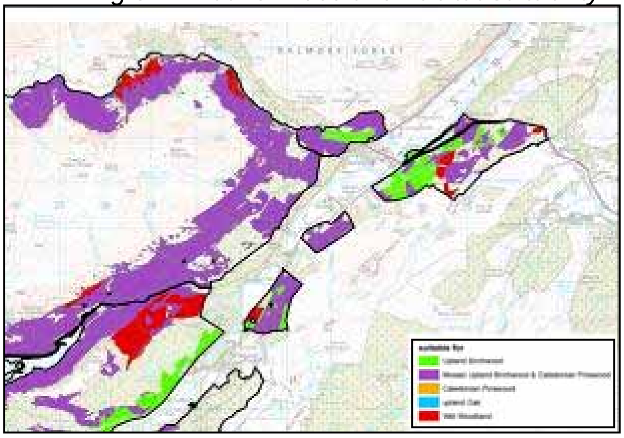
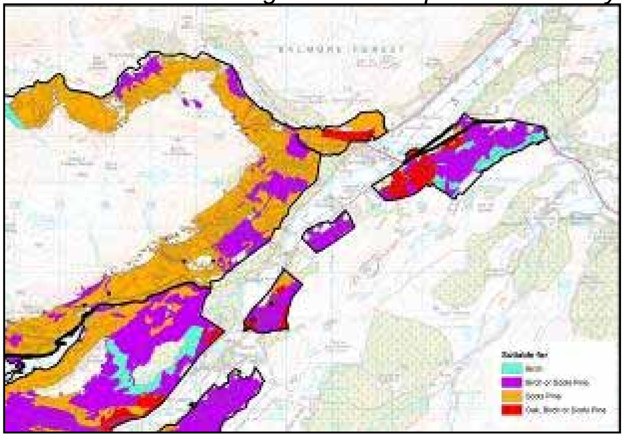


Fig 8.12 Tree Species suitability



8.2.3 Draft management proposals and appraisal

The **current plan** (Fig 8.13) proposes clear felling in small to medium sized phased coupes and restock with a mixture on plantation conifers and broadleaves. There has been some previous clear felling which only partially addresses the visual problems inherent in the shape of the woodlands.

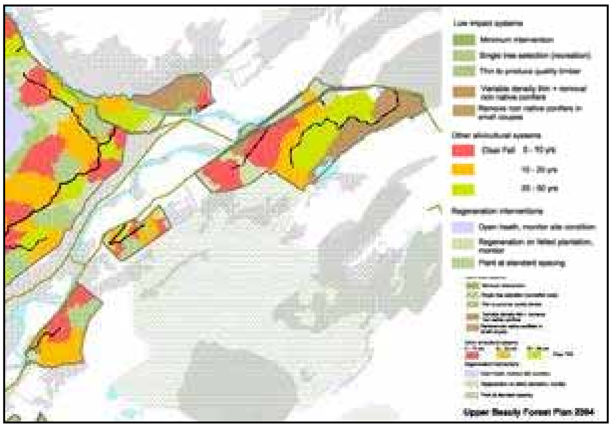


Fig 8.13 Current management proposals

The combination of the potential for improving the connectivity of the broadleaved habitat network both at a regional and local level and the presence of extensive PAWS sites, led us to recommend that priority shown be given to the conversion of the lower slopes of these woodlands to broadleaved woodland (birch – oak - pine) within a 50 yr time frame.

While a gradual conversion to broadleaved woodland by variable density thinning would be preferred, this would need to be weighed against current market commitments and the opportunity to achieve positive impact on the landscape by improving visual unity. Revision of the felling regime to include simpler larger coupes which would help to improve the short-term economics with some preparatory crown thinning around existing native woodland remnants to strengthen these groups might be considered as an alternative here, given the extensive low impact systems elsewhere in the plan area. The absence of key species from within the W17 community suggests supplementing birch regeneration by planting groups of oak would be desirable.

In the longer term, the upper slopes would support a mosaic of pine birch, open bog and heath. This area does not directly contribute to a habitat network although parts of the area are suited to a mosaic of Caledonian Pine and Birch woodland linking to the adjacent Corrimony RSPB reserve and recently established woodland within this area. This would extend the area of suitable habitat for black grouse.

Appraisal of the impact of these suggested management proposals would have on the habitat network for broadleaved specialists at year 50 show of improving connectivity not just on the south side but also strengthening links to the north side of the Strath. Further expansion of the broadleaved habitat network is achieved by converting the lower slopes of Knockfin (lower left in Fig 8.15) to Upland Oak. It should be noted however, that this outcome is partly dependent on the maintenance of the current broadleaved elements outwith FCS ownership. The implications of this being removed or allowed to decline are shown in figures 8.14- 8.16.

Fig 8.14 Draft Future species and habitats at 50 yrs

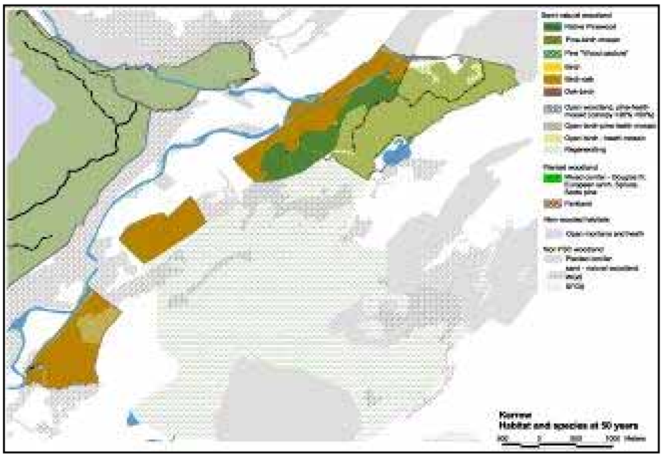


Fig 8.15 Broadleaved network at 50 years

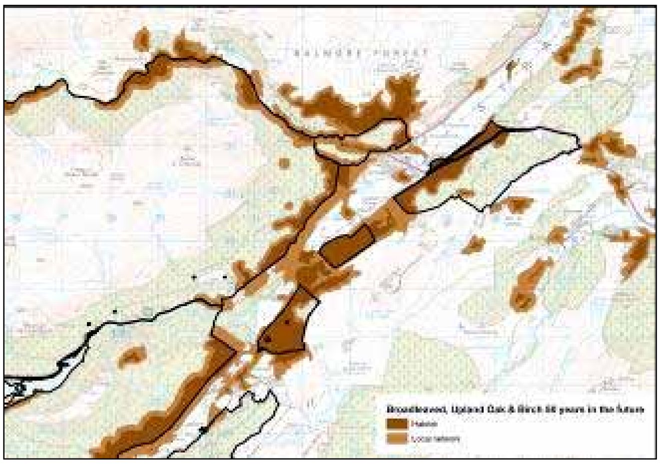


Fig 8.16 Broadleaved network at 50 years, non FCS woodland removed

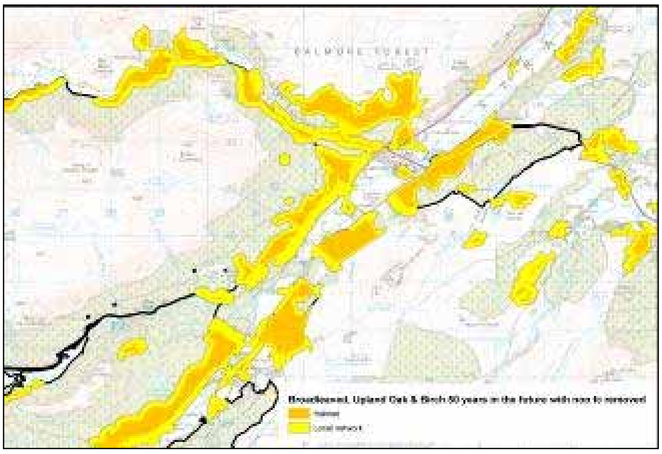


Fig 8.17 Habitat networks at yr 50

	Number of habitats of networks identified	Total area of habitat or networks (ha)	Mean area of habitat or networks (ha)	Area of largest habitat or network (ha)
Future habitat	160	678.38	4.24	106.53
Worst case	**159**	**622.62**	**3.92**	**106.53**
Future network	25	1820.57	72.82	1267.90
Worst case	**28**	**1720.54**	**61.45**	**560.38**

Fig 8.17 shows details of the metrics if non-FCS woodland is removed and the effects on connectivity after 50 years. The worst case shows that there is a reduction in the number and area of networks following the loss of this woodland habitat

8.3 Cougie

Key factors in this area were identified as:

- **Designated sites - SAC**
- **Connectivity - BEETLE**
- **Suitability - ESC GIS**
- **Wind Risk FOREST GALES**
- **PAWS**
- **Accessibility**

Fig 8.18 Cougie location

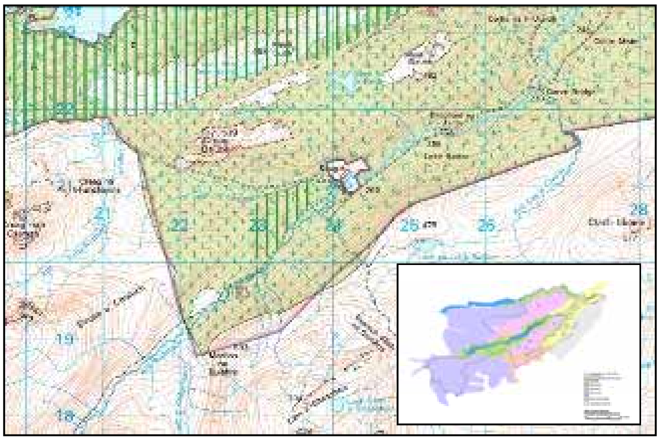
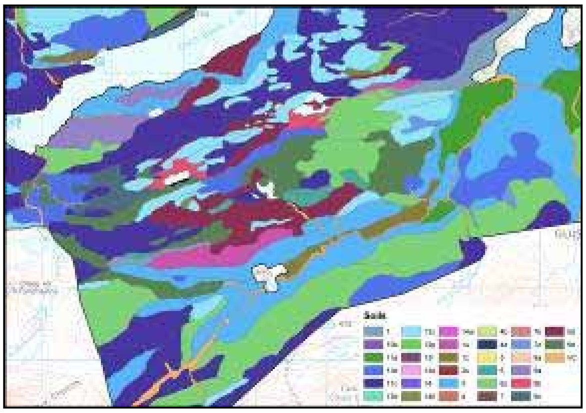


Fig 8.19 Cougie looking north

Fig 8.20 Cougie soils



For and explanation of soil types see Kennedy, 2002.

8.3.1 Description

The area lies to the south of the case study area within the “Upland valley”. It is higher and more exposed than the previous area, lying above 250m and comprises gentle to intermediate gradients on north-east and north-west facing slopes and steeper south east facing slopes. Podsols and podsolic brown earth are found on lower and south east facing slopes. The remainder of the area is characterised by peaty podsolic gleys and bog (Figures 8.18-8.20).

The forest comprises an area of Native Pinewood (SAC), to the south and east an extensive area of cleared plantation with scattered groups of native pine on wet heath. To the north and west, plantation of mixed conifers, predominately spruce and lodgepole pine were planted in the mid to late 1960s, figure 8.21.

The higher and more exposed stands of lodgepole pine are at some risk of wind blow in the next 20yrs (Figure 8.22). Lower slopes are identified as an Ancient Woodland site, figure 8.23. Red squirrels are known to be present in the plantation area. Accessibility is the principle problem for forest operations in the northern part of the area. Only part of the area is accessible from the current road network and locally, steep slopes restrict machine access, figure 8.24. The area is remote and apart from the Pony trekking enterprise at Cougie farm and a few cyclists or walkers, attracts relatively few visitors. It lies on the edge of the National Scenic Area which focuses on the mountainous area to the west.

Fig 8.21 Cougie Species

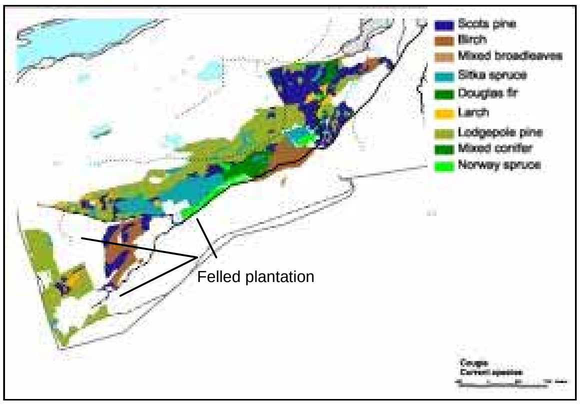


Fig 8.22 Cougie DAMS

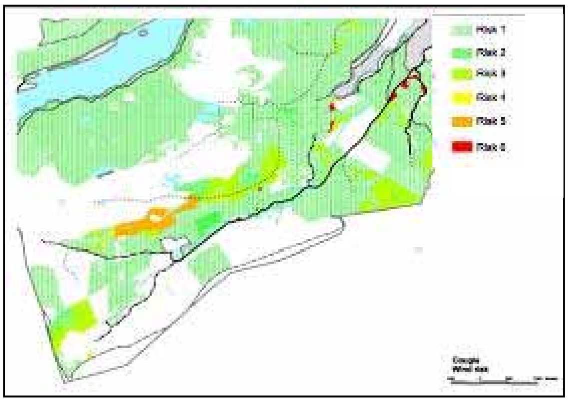


Fig 8.23 Cougie Ancient woodland sites

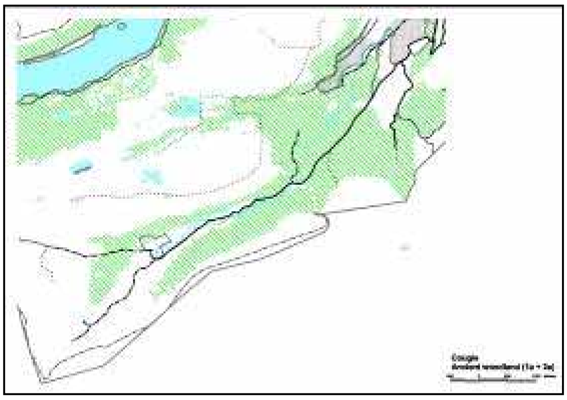
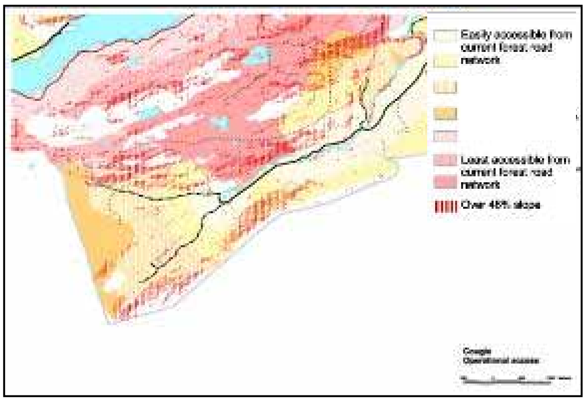


Fig 8.24 Cougie Accessibility



8.3.2 Priorities from connectivity and species modelling

The local habitat network for Caledonian Pinewood (Figure 8.25) demonstrates that although the Cougie pinewood SAC is in favourable condition,[1] it is isolated from the core Affric Native Pinewood by the current extent of plantation conifers.

Analysis of native woodland suitability based on the ESC model (Figure 8.26) suggests that the south facing and lower slopes would support a mosaic of Upland birch and Caledonian pine communities. It also suggests that other areas, although containing groups of remnant pine and part of the area is an ancient woodland site, would be less likely in the long term to support the full range of species associated with the Caledonian Pinewood or Upland birch communities. From a closer examination of the input data, it appears that this may be a result of the wetter gleyed and peaty soils and the degree of exposure.

Fig 8.25 Current Caledonian pine habitat

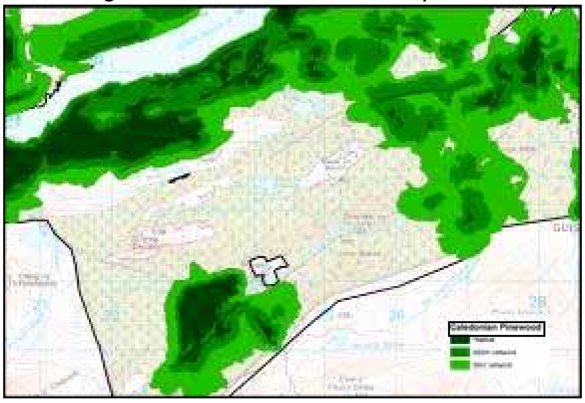
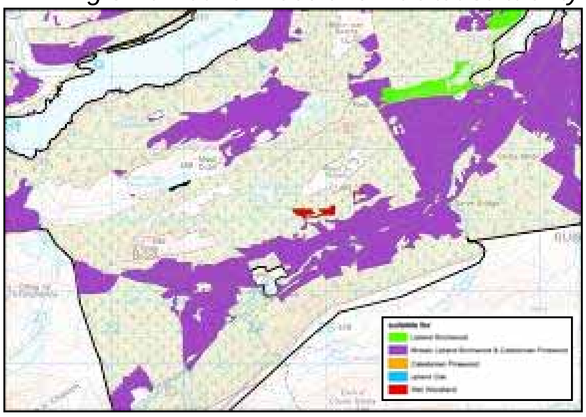


Fig 8.26 Native Woodland Habitat suitability



8.3.3 Draft management proposals and appraisal

Management actions have focussed on the clearance of lodgepole pine and Sitka spruce in the south and west of this area. Most of these plantation conifers have now been cleared apart from areas shown in Fig 8.21 above. Part of area included PAWS assessed as having a high potential for restoration by the Forest District[2]. It was also the most accessible part of the site and the economics of restoration were therefore favourable. The work was part funded under an MFST scheme and targeted enhancement of Ancient Woodland remnants.

Applying the BEETLE model to target restoration on sites that contribute to habitat networks suggests that the first priority in ecological terms would be to convert the south east facing slopes

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[1] Assessment by SNH

[2] Priorities assessed using methodology described in Practice guide "Restoration of Native Woodland on Ancient Woodland Sites"

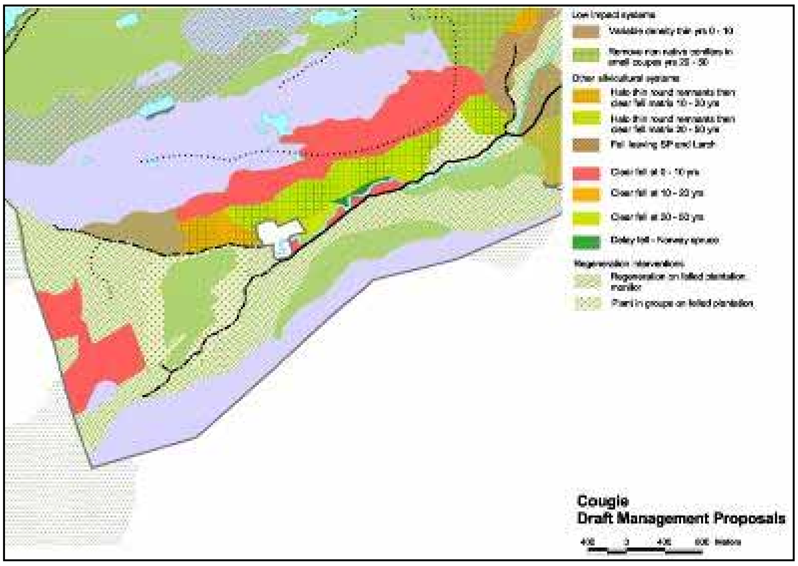
to pine-birch woodland (Figure 8.27). This would improve connectivity by linking the SAC pinewood to the core Affric woodland as well as restoring ancient woodland sites. This is the most difficult part of the area to access and the most practical solution would be to clear fell the remaining non-native conifers as a one off operation in large simple coupes. This is not ideal in terms of restoration of the PAWS sites, but there appear to be relatively few woodland remnants left in this area (The Forest District assessment indicates it to be of low restoration potential). Some preparatory thinning around existing pine and native woodland remnants on PAWS sites could be carried out. We also suggest that stable groups of larch and Norway spruce on the lower slopes should be left at the time of felling as these would assist the objectives of early establishment of a woodland corridor and help to maintain red squirrel populations. Access requires further on-site investigation that was outwith the scope of this study.

Removal of the remaining areas of Sitka-lodgepole plantation are outwith PAWS sites and not key for habitat restoration but are at risk of wind damage and are incongruous in this remote landscape. Felling should proceed early, as the opportunity arises. Within a buffer zone around the area of the SAC, it would be consistent with the ecological objectives of maintaining and enhancing high quality habitats to remove of all exotics and promote regeneration with groups of low density planting on suitable sites. Elsewhere within the peripheral parts of the area which do not contribute directly to native woodland connectivity, no short term actions are required and the area should be allowed to regenerate naturally on a longer time scale (+ 50yrs). Some regeneration of exotics could be tolerated here.

While not described in detail in this study report, the area of open heath to the north contains a number of priority open ground habitats and is mostly unsuited to the development of the key woodland communities except for scattered birch (wet woodland). The maintenance of linkage to open ground to the west is important in maintaining open habitat networks.

Appraisal of the impact that these suggested management proposals would have on the connectivity of native woodland in this area is shown in figure 8.28.

Fig 8.27 Draft management proposals



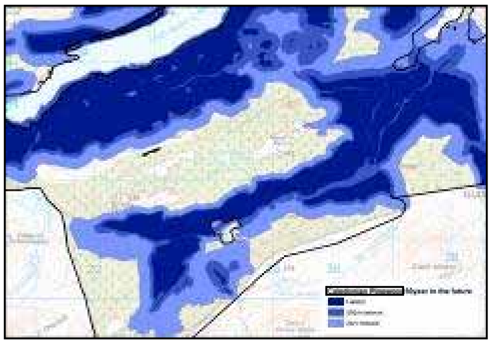


Fig 8.28 Native Pinewood habitat network at 50 yrs

8.4 Fasnakyle Woodland

Key factors in this area were identified as:

- **Connectivity - BEETLE**
- **Suitability - ESC GIS**
- **PAWS**
- **Economic Considerations**

8.4.1 Description

Fig 8.29 Fasnakyle woodland location

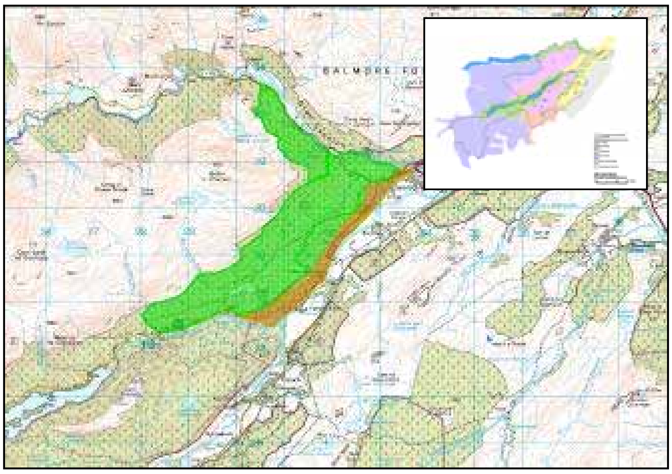
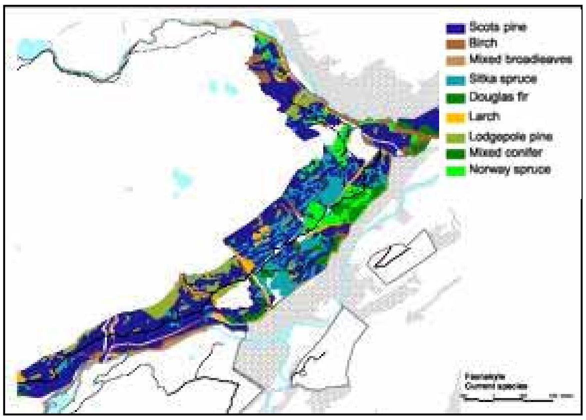


Fig 8.30 Fasnakyle from A 831 above Cannich

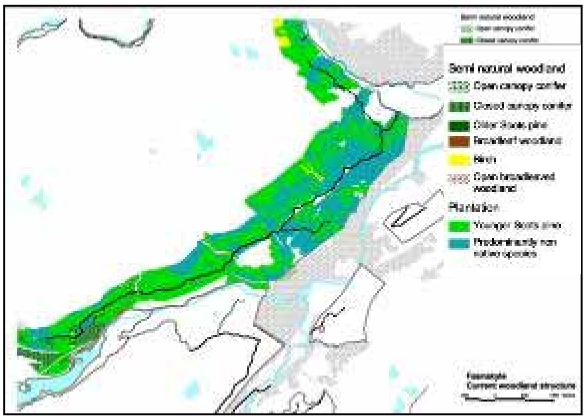
This area lies on the upper slopes of the "farmed strath" between 200 and 350m (Figure 8.29 &8.30). The gradients are gentle to moderate and soil types range from rankers, podsols, peaty podsols and podsolic brown earth to peaty podsolic gleys and peat in hollows. The woodland comprises mixed conifer plantation with scots and lodgepole pine mainly on the upper slopes and Sitka spruce, Douglas fir, Norway spruce and larch (mainly in fire breaks) on the mid and lower slopes (Figure 8.31). The woodland was planted between 1953 and 1956 and is currently at an ecologically relatively young "stem exclusion" structural phase (Figure 8.32). Yield classes are generally 10 – 12, locally 14 – 16 (Figure 8.33) and access within the forest is relatively good although the public road is narrow.

Fig 8.31 Current species



There is a substantial area of birch woodland on the lower valley slopes outwith the FCS boundary and the lower part of the plantation and eastern part of the upper slopes are identified as an ancient woodland site with the remainder unwooded. The 1st Edition OS map shows the area as broadleaved woodland and open ground with ancient woodland sites (Figure 8.34).

Fig 8.32 Current woodland structure



The area is a settled, managed landscape, relatively close to the community of Cannich and there is evidence of a (medieval/post medieval) township between the 2 burns north west of the current cemetery.[3] For the most part the woodland is not highly visible from the valley although it is seen on the approach to Cannich from Drumnadrochit. The junction between the FCS conifer plantation and adjacent broadleaves is hard and unsympathetic to the landscape and some of the larch firebreaks are prominent. It has no formal recreation facilities and relatively few visitors.

[3] http://jura.rcahms.gov.uk/HLA/Map Within the study area, only the lower section of Strathglass is currently covered by the Historic Landscape Assessment survey.

Fig 8.33 Yield class

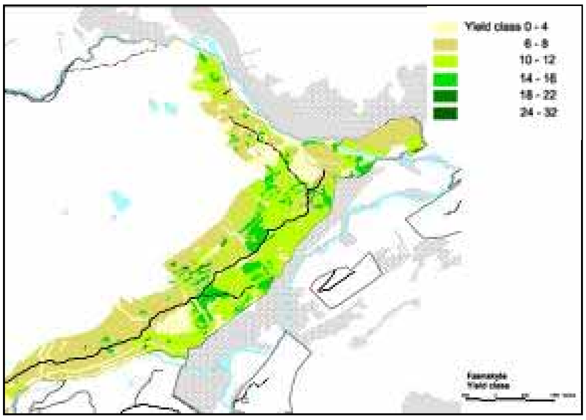
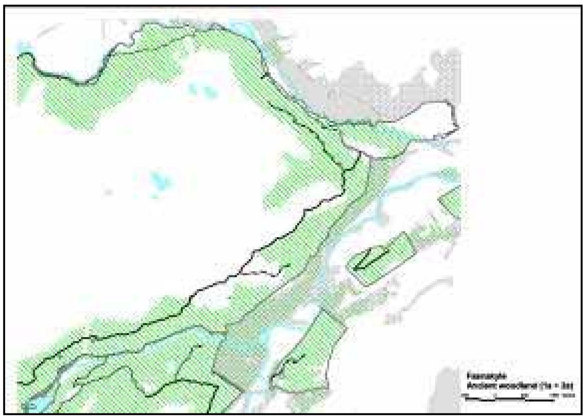


Fig 8.34 Ancient woodland sites



<u>8.4.2 Priorities from connectivity and species modelling</u>

The local habitat network for Caledonian Pinewood illustrates the current lack of connectivity between the pinewood of Glen Cannich and the Affric Pinewoods (bottom left Fig 8.35). This is largely a result of both the plantation conifers present and the structural stage of the woodland which is relatively young in ecological terms and largely unthinned with few of the characteristics of the pinewood community.

Analysis of native woodland suitability based on the ESC model suggests that most of the upper slopes would be suitable for Caledonian pine – Upland birch woodland communities (Figure 8.36). Interpretation of the ESC model needs to take account of the relatively coarse precision level of the input data (soils +/-10Ha) and avoid literal interpretation of boundaries.

Fig 8.35 Current Native Pinewood Habitat Network

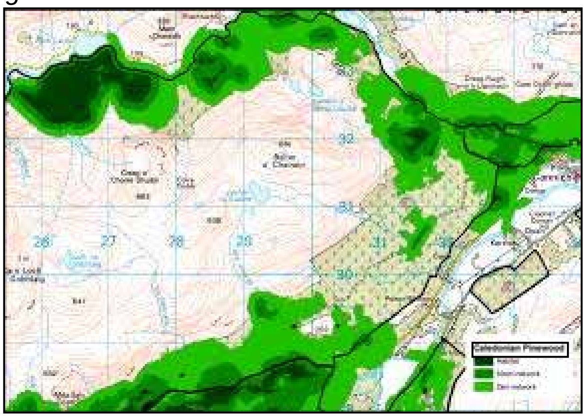
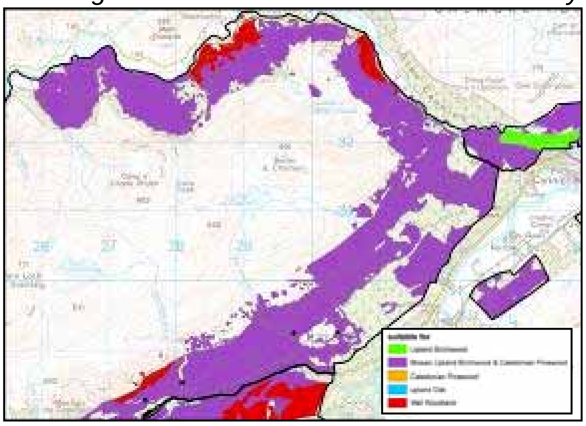


Fig 8.36 Native Woodland habitat suitability



<u>8.4.3 Draft management proposals and appraisal</u>

Current management proposals are based on clear fell coupes designed to diversify the age structure of the woodland over a period of some 40 years. Restocking is with mixed conifers.

The analysis indicates that retention and management of the Scots pine on the upper slopes and replacement of the poorer yielding non-native conifers (mainly lodgepole pine and some Sitka spruce) with younger generation of pine and birch would help to achieve earlier connectivity of the pinewood habitats. (Fig 8.39 below). Thinning of the pine matrix would additionally help to advance the woodland beyond the current structural phase and mean that these areas could continue to be managed to yield timber. If felling and thinning took place within the existing coupe structure, this would help to spread the output of timber over a longer time period and achieve a smaller scale pattern of stand types (Figures 8.37 & 8.38).

Some felling and restocking with Sitka spruce has already taken place on the middle and lower slopes. Because these areas are relatively productive and accessible, the mid slopes which are less suited to Caledonian pine - Upland birch communities could be restocked with mixed conifers for the next rotation and continue to yield commercial timber. This defers the restoration of some of the PAWS until the next rotation. However, connectivity for broadleaved woodland on the lower slopes is already good although not under FCS management. Partial restoration is suggested at this stage by extending the birch –oak woodland on the lower margin to secure this resource and achieve better visual interlock between the FCS woods and the adjacent broadleaved woods

With the increased emphasis on LISS, it is likely that the amount of clear fell in the revised plan would have been reduced and this is not a significant change resultant on application of the BEETLE model alone. It does however demonstrate that ecological objectives can be achieved relatively cost effectively and the analysis strengthens the case and provides a sound rational for proposals.

Fig 8.37 Draft Management proposals

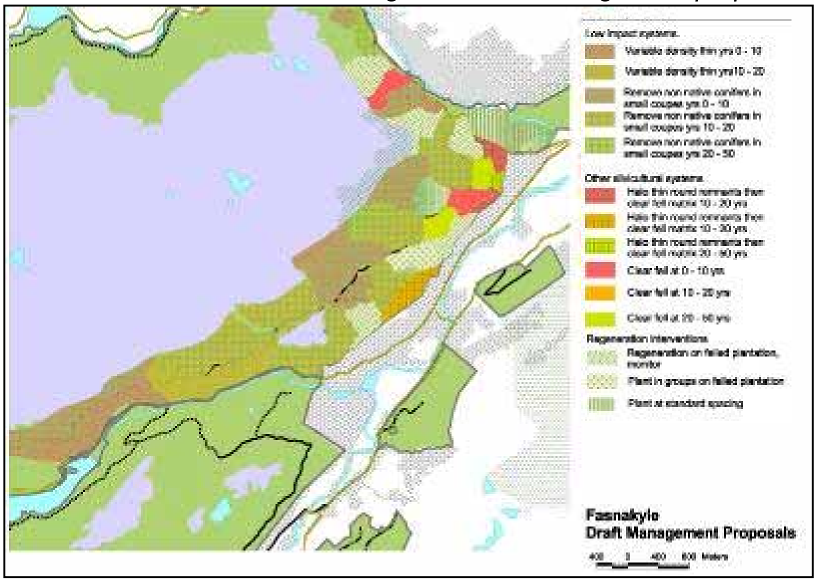


Fig 8.39 Native Pinewood habitat network at 50 yrs

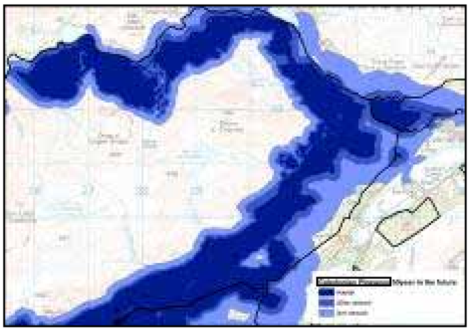
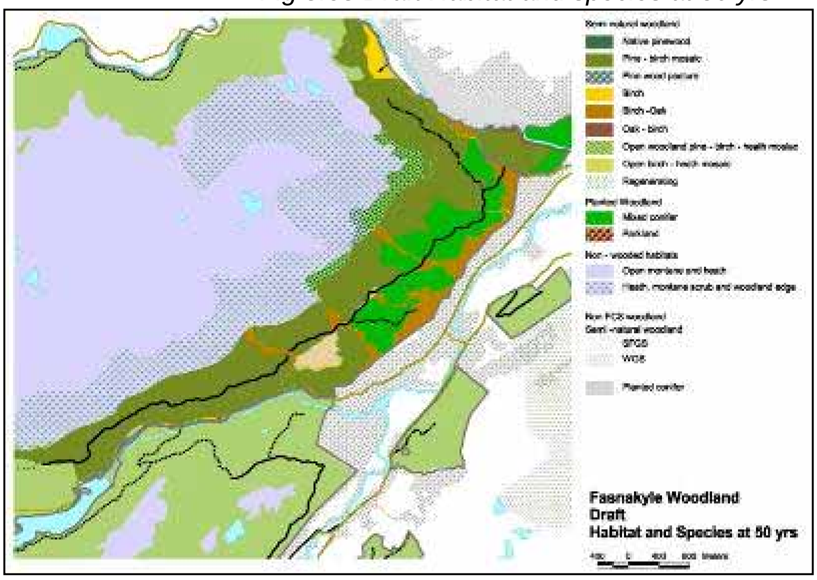


Fig 8.38 Draft Habitat and species at 50 yrs



	Number of habitats of networks identified	Total area of habitat or networks (ha)	Mean area of habitat or networks (ha)	Area of largest habitat or network (ha)
Current hab	81	146.26	1.81	95.03
Future hab	67	898.54	13.41	688.77
Current 500network	14	509.49	36.39	166.30
Future 500m network	2	1287.25	643.63	1275.88
Current 2km network	5	1416.18	283.24	470.90
Future 2km network	2	1949.41	974.71	1947.99

8.5 Fasnakyle hill ground

Key factors in this area were identified as:

- **Protected habitats**
- **Designated sites - NNR (part SAC)**
- **Other Habitats and Species**
- **Suitability - ESC GIS**
- **Deer Impacts**

Fig 8.40 Fasnakyle Hill ground location

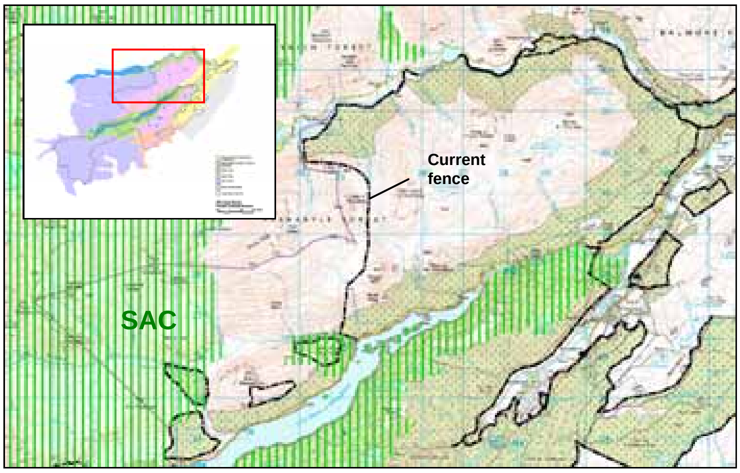


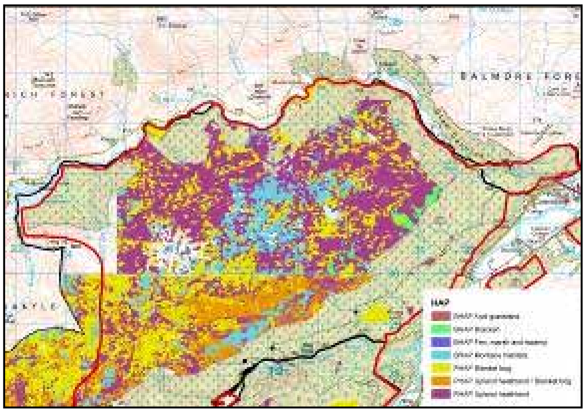
Fig 8.41 Fasnakyle Hill from Glen Cannich

<u>8.5.1 Description</u>

This area of open hill ground lies at the eastern end of the "Upland massif" and comprises intermediate to locally steep slopes and rounded rocky summits between 350 and 700m and areas of gently rolling upland plateau generally above 550m. The western end grades into "High mountain" with the highest summit rising to 1000m (Figures 8.40 and 8.41).

Slopes and summits are characterised by rock and scree, peaty podsolic gleys, with podsols on the lower slopes, while the gently sloping ground has developed a complex of blanket bog, peat hags and dubh lochans.

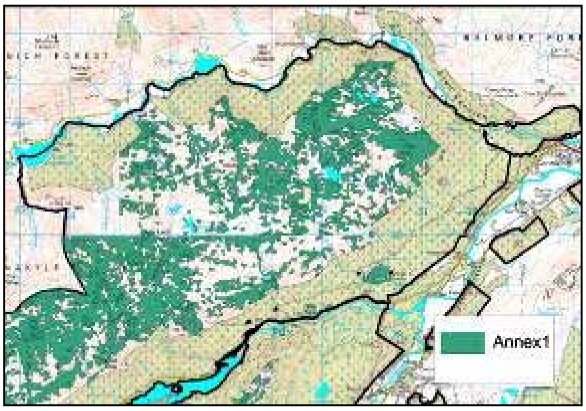
Fig 8.42 Open ground PHAP communities



Vegetation comprises a mosaic of dry heath and alpine or boreal heath on steeper or rocky slopes with some bracken on drier south facing slopes and local patches of *Molinia* and *Nardus* grassland and extensive areas of wet heath and blanket bog

Most of these vegetation types fall within one of the UK Biodiversity Action Plan Priority Habitat (PHAP) (Figure 8.42) communities and much of the area comprises Annex 1 habitat types protected under EU Habitats Directive (Figure 8.43). The west corner of the area falls within the much larger Strathglass complex SAC which is indicated as in “unfavourable” condition by site condition monitoring carried out by SNH.

Fig 8.43 Annex 1 habitat types



The area is large in scale, simple and much is of relatively low visibility except in middle distance views from the approach to Cannich. The higher western end is within the NSA and apart from this area which forms the eastern end of the north Affric ridge walk, there is little recreation activity and few known sites of archaeological interest. The area is above the latitudinal limit for commercial forest and was previously let as hill grazing. The eastern part is within the deer fence and deer numbers, managed concurrently with sporting tenants, are estimated at 6/100 Ha. Outwith the fenced enclosure, deer numbers are higher at 10/100Ha. The immediately adjacent owner to the north has an interest in conservation management while other estates further to the west are primarily sporting estates.

8.5.2 Priorities from species modelling and site types

While currently open ground, the survey of vegetation, site types and existing regeneration, indicate that part of the area could support tree and shrub communities with potential to establish a more complete and representative altitudinal range of habitats. Fig 8.44 this is derived from NVC survey and shows areas that are site suitable for treeline ecotones and montane scrub and fig 8.45 shows in more detail where there is potential for these habitats from existing vegetation types

The area falls into 3 main zones *(Fig 8.44): -*

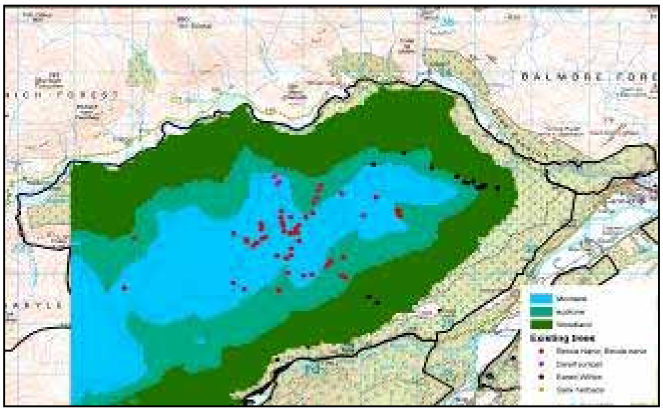


Fig 8.44 Potential woodland edge and montane scrub

Woodland: There is some local potential for extending Caledonian Pine and Upland birch woodland (W17/W18 and W4) mainly within the green zone and regeneration is already fairly well established on lower south facing slopes.

Ecotone communities: Patches of *Calluna vulgaris-Arctostaphylos* heath *Calluna vulgaris-Vaccinium myrtillus-Sphagnum* heath and *Vaccinium myrtillus-Rubus chamaemorus* heath within the Upland heath and Montane areas between 400 and 600m indicate potential to support a woodland edge or ecotone habitat of stunted pine and juniper.

Montane scrub: The presence of moss heath (*Calluna –Racomitrium* heath and *Carex – Racomitrium*) within the Montane habitat *that* indicate suitability for Montane scrub species such as *Betula nana* and *Salix spp*. These patches are most extensively represented in the west of the area, within the SAC but outwith the deer fence.

Fig 8.45 NVC communities associated with montane scrub and woodland edge within deer fence

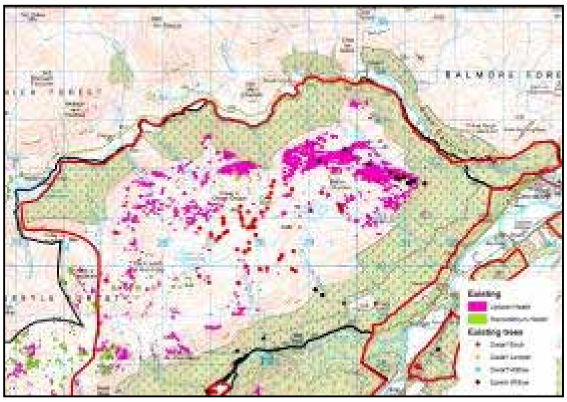
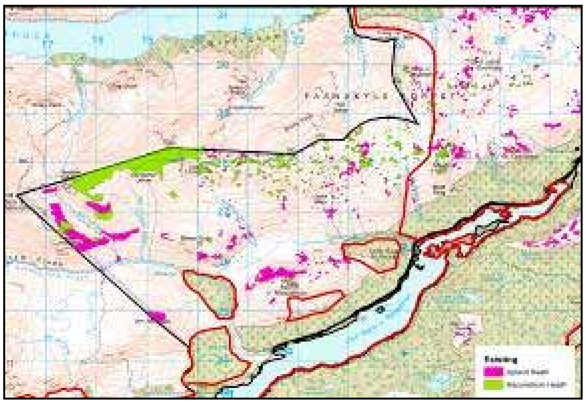


Fig 8.46 NVC communities associated with montane scrub and woodland edge out with deer fence



(It should be remembered that the NVC survey is based solely on the presence of plant species regardless of physical characteristics such as altitude, soil type, land use or location. Consequently distributions will be influenced by past and current grazing pressure and the potential distributions of these vegetation types may be different from those seen at present Figure 8.45 and 8.46)).

<u>8.5.3 Draft management proposals.</u>

There are no specific proposals in the current plan for this area of open hill ground other than to maintain deer populations at their current low level.

Habitat and species survey and analysis indicate potential for some low density planting (suggested density of approx 100/Ha within scattered groups) on selected sites to establish a more representative range of woody species within the montane and woodland edge "ecotone" zones. At this density, planting would have no negative impact on open ground habitats. The priority is to establish these shrub species within the existing ring fence. Establishment outwith this fence would be more difficult to achieve and any extension of the current fence line to the west would need to take into account interests of neighbouring estates, deer management interests and hill walkers but might be a longer term objective.

8.6. Loch Affric

Key factors in this area were identified as:

- **Designations -NNR SAC NSA**
- **Protected habitats and species**
- **Connectivity - BEETLE**
- **Suitability - ESC GIS**
- **Historic context**
- **Landscape**
- **Visitors**
- **Deer Impacts**

Fig 8.47 Loch Affric location

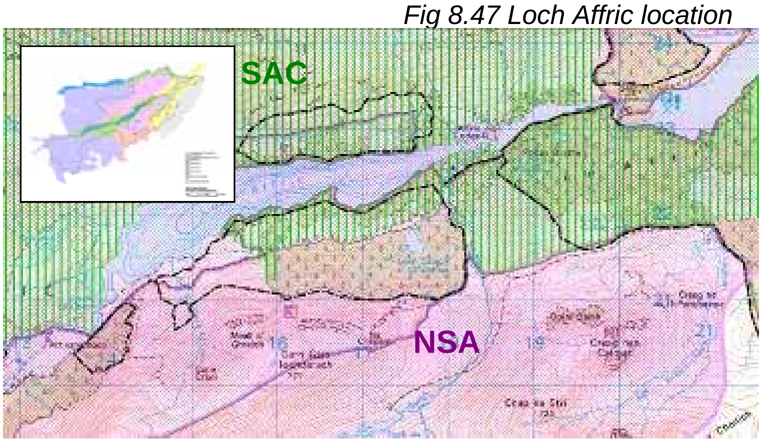


Fig 8.48 Looking north-west over Loch Affric.

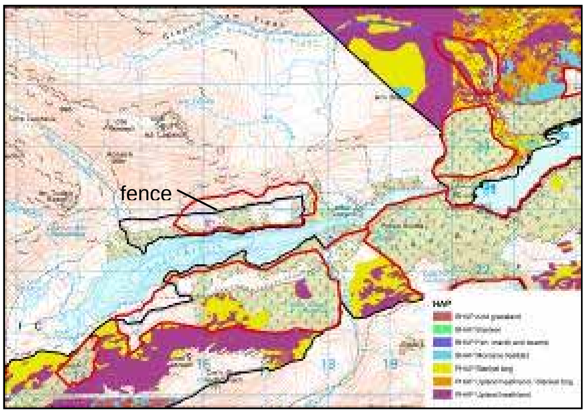
Fig 8.49 Affric lodge and woodland to the south.

8.6.1 Description

At the western end of the "Narrow wooded glens", this area comprises gentle to intermediate slopes and undulating terrain between 200 and 350m with rocky knolls, peaty hollows and dubh lochans rising more steeply to the south. Soil types are a mixture of podsols, rankers and bog. (Figures 8.47-8.49)

The Caledonian Pinewood is fairly dense at the eastern end with a varied structure and open glades but becomes more open towards the west with patches of widely spaced veteran pine and young trees in a mosaic of heather, wet heath, *Molina* and bog. This open ground includes patches of UK Biodiversity Action Plan Priority Habitat Blanket bog and Upland Heath (Figure 8.50). The area to the south includes felled plantation sites with recent regeneration, mainly of birch. Associated species include Black grouse in the open woodland and Capercaillie in the denser woodland.

Fig 8.50 Open ground PHAP communities



The present day pattern of woodland is at least partly a product of land management history and historical records show a number of shieling huts and farmsteads in the general area. This is particularly the case west of Athnamulloch at the west end of the loch where some of the better drained slopes are associated with relatively fertile brown earth soils. The current track on the south side of the loch follows the route of an old drove road. In addition to these early agricultural features, Affric lodge *(left above)* was the shooting lodge for Guisachan House. These features would be associated with grazing on the better in-bye land and summer pasturage on outlying areas, suggesting a wood pasture origin to some of the open structure pinewood. The 1st Edition OS map shows a mosaic of closed and open woodland approximating to those areas identified as Ancient Woodland (Figure 8.51). Part of the area is within a separate regeneration enclosure, outwith the main Strathglass deer fence, with a downfall to the south of Affric Lodge serving as an important wintering ground. *(See Fig 8.46 above)*.

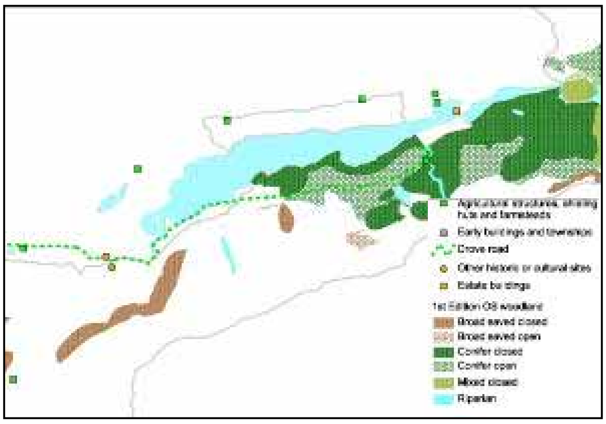


Fig 8.51Historic land use

The area lies at the core of the National Scenic Area and encompasses the elements of water, “natural” woodland and mountain views and remoteness that defines much of the scenic quality associated with Glen Affric. These qualities make this area a focus for visitors and the walk round Loch Affric starting from the river Affric car park is publicised in a number of guidebooks with other long distance routes to the west coast via the Youth Hostel at Alltbeithe. It is also a focus for forest based tourist businesses e.g. photography and wildlife tours and one of the start points for the high level ridge walks in the mountains to the west and north.

At an early stage of the project, modelling of recreation networks using BEETLE was considered but not progressed as the rough terrain largely restricts patterns of use to existing routes (Figure 8.52).

Fig 8.52 Patterns of recreation use

8.6.2 Priorities from connectivity and species modelling

Analysis of native woodland suitability based on the ESC model indicates that some of the open heath not falling within a UK Biodiversity Action Plan Priority Habitat would be suitable for Caledonian pine-birch although from the mid point of the loch westwards, site conditions are more suited to Upland birch or birch –oak on the more fertile soils.

The local habitat network for Caledonian Pinewood (Fig 8.53) shows the current stands of pine to be reasonably well connected to the main Affric pinewood and expansion of the current pinewood area to further improve connectivity is not a priority.

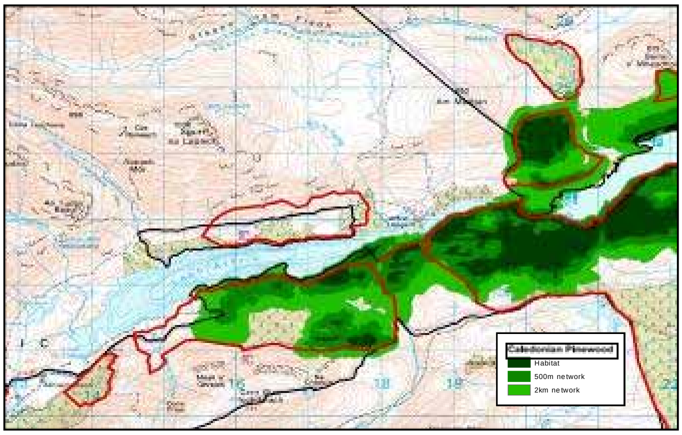


Fig 8.53 Current Caledonian Pinewood Habitat network

The veteran trees, key features of these upland wood pastures are old, often many hundreds of years old, and therefore dating from a pre-clearance landscape, when a very different land management system was in place to our contemporary one. It is clear that many of these veterans regenerated in open grazed woodlands, and consequently are now seen as indicators of this older pastoral landscape, with their own distinct associated biodiversity, quite different to that of closed canopy woodland. They are also important biophysical structures in the landscape, functioning at both the local and landscape scale. As loci of woodland ecological processes in an otherwise open grazed landscape, they provide connectivity for woodland species, and are hosts for their own unique suite of specialist species. At the local scale veteran trees provide shelter and a potential food source for livestock, as well as influencing local ecological, hydrological and nutrient cycles. They can be described as keystone features in that they have a disproportionate effect on the ecosystem relative to their individual area occupied, biomass and collective density

8.6.3 Draft management proposals and appraisal

Current management proposals are based on the regeneration of Caledonian Pinewood within the enclosures following the removal of plantation conifers in. In the long term however, dense regeneration, especially on drier sites, would be detrimental to the specific habitat value of the pine woodpasture and open ground PHAP sites as well as to the landscape and recreation value of the relatively open character of the landscape by obscuring views. Management to maintain the character of the area would require periods of regeneration (as at present) followed by periods of grazing after the required density of trees was achieved. The regeneration phase might last 10 -20 years and there may be no need for a subsequent pulse of regeneration for 100 years

9 COMPARISONS WITH CURRENT PLAN

The process undertaken did not suggest radical changes of direction to the overall concept or vision. However, it provided a clearer rationale for decisions and an alternative, ecologically based prioritisation for management programmes. It added detail and give a spatial dimension to some of the more general aims of the plan and producing a more robust and justifiable outcome. It also helped to fill some of the gaps in the baseline survey.

The application of ecological principles places priority on consolidation and improving the habitat quality through restoration and improving connectivity before expansion of woodland area. The incorporation of habitat network theory into the forest plan process provides a framework for consideration at a range of different geographical scales e.g. the landscape scale including the consolidation of downstream networks for the whole of Strathglass from Beauly to Tomich and as well as at a local areas e.g. Cougie.

Qualitative statistical comparisons with the current plan are difficult because of the general nature of many of the proposals that this contained.

Consideration of connectivity helped to identify clear ecological priorities for removal of non-native conifers, native woodland restoration and regeneration. The suggested revisions to the management proposals as a result of the process therefore includes some redistribution and re-programming of felling and assisted regeneration in response to the priorities identified by the habitat network analysis (BEETLE) and to a lesser extent the application of FOREST GALES.

Analysis of current stand structure created a base line for comparing the current forest structure with the theoretical ideal and that are likely in 50 years time following interventions *(fig 9.1).* It provided a goal and rationale for these interventions. The 50 yr forecast shows how proposed management would move the current distribution toward this optimum. It is likely that this evaluation underestimates the proportion of the Stand Initiation phase at year 50, as it doesn’t include areas currently regenerating or those within LISS stands where regeneration will take place as a result of thinning and felling. It also helped to identify a time scale for management appropriate to the natural cycle for semi natural woodland.

Fig 8.54 Development of structure stages at 50 yrs

Approximate mean stand age	Oliver and Larson growth phase	Proportion of stand		
		1 in 150 yr fire return period	Glen Affric Current	Glen Affric Forecast in 50 yrs
0 – 20 yrs	Stand initiation	**12%**	**2.5%**	**3%**
20 – 80yrs	Stem exclusion	**29%**	**57.2%**	**34%**
80 – 150yrs	Understorey re-initiation	**22%**	**23.7%**	**23%**
>150yrs	Old growth	**27%**	**16.6%**	**40%**

The areas at Guisachan identified for LISS management for production of high quality timber and as a recreation setting are similar to that in the current plan and at Fasnakyle, it is demonstrated that continued timber production need not compromise ecological objectives. Other areas where active management should be part of maintaining ecological diversity e.g. wood pasture and maintenance of priority open ground habitats are also identified.

The process encourages consideration of the contribution of all habitat types and highlighted the specific opportunities for establishing a more complete and representative altitudinal range of woodland edge or ecotone and montane species as at Fasnakyle hill.

Analysis of native woodland suitability based on the ESC model helped to identify the priority sites for woodland habitat restoration and, where enrichment planting is required, the range of species appropriate for these areas. It also identified potential sites for woodland types that are currently absent e.g. Upland Oak.

The linkage of species to habitat was designed to help steer the emphasis from individual species management and the conflicts and shortcomings inherent in this approach to a more holistic habitat management.

10 DISCUSSION AND CONCLUSIONS

This section reviews progress on the project, combining views of the project team and those emerging at a meeting on 21st February 2008 of forest planners and other interested stakeholders.

Objective: To develop a process that allows Forest District teams to deal with large amounts of data for a large complex area.

We felt that this objective was partly achieved but raised a number of general issues.

A major gain was the fact that data was obtained to fill gaps identified in the current Forest Plan. This allowed the application of the ESC model, the drafting of proposals in more detail and gave a spatial dimension to some of the more general aims of the plan, helping to produce a more robust outcome.

The data collection was more expensive and took longer to collect than originally anticipated, delaying the completion of the project by some 3 months. (It could have been delayed by 2 years if we had used the standard procedures and would have required a much larger budget.) This highlights the need for a clear prioritised shopping list at the outset and the benefits of talking to the specialist advisors at this stage to make sure that everyone has a clear understanding of what is really required and what the survey can deliver. All data benefited from expert interpretation particularly where there were different survey origins with different resolutions. It is worth noting that there are current developments in remote sensing which might in the future reduce the costs of data collection.

The large extent of the case study site meant that data collection was at quite a course scale yet gave useful results. The same resolution may be less useful on a smaller site where more detailed and specific site accurate outputs would be more appropriate.

The broad-brush soil survey was approximately 20 times cheaper than a full soil survey. However, the case study area is characterised by complex small-scale terrain that was much finer grained than the sampling density and mapping units used. This resulted in most of the area being described by complexes. This gave useful results at a broad scale, but the accuracy of the model outputs were limited by the resolution of the input data and operational decisions at a coupe level would require a more detailed survey. The methodology might be suited to fairly simple terrain and it should be possible to identify forests that could be targeted for this type of survey, thus improving the cost effectiveness of survey resources.

NVC survey was identified as desirable in the forest plan for certain habitat types, notable montane habitats. However, this represents a 200% additional cost over BAP survey if ground-truthing is included. This should only be required in special locations, which could be identified from a broad brush survey. As with soils data, much of the area is characterised by mosaics with up to 9 habitat levels and the translation from NVC to BAP types is not straightforward**.** This highlights the importance of good ecological advice in the planning process

The brigading of the species recorded by habitat and status was a complex task. It does, however, link species and habitats to any designations allowing a forest planner or manager to understand their responsibility for biodiversity. Further linking this brigading exercise to ecological principles of ecosystem function and habitat networks allows for a move away from site and species based conservation strategies. Incorporating these principles into the forest plan should allow more natural ecosystem dynamics and ultimately for the manager to feel confident that their biodiversity responsibilities are being fulfilled.

Understanding, organisation and recording of the data ideally requires the use of consistent definitions across FC activities. The study highlighted a number of areas where the use of different terminology in Practice guides, OGBs, UKWAS and GIS Forester can be confusing with no clear translation from one to another.

- The Practice Guide “The restoration of Native Woodland on Ancient Woodland Sites” identifies PAWS as “Planted woodlands of any species on Ancient Woodland sites” whereas UKWAS defines this as “where native tree cover has been felled and replaced by planting of tree species not native to the site”. Choice of definition makes a significant difference to the area identified in this case study with extensive pine plantation on pine sites and on some sites a mixture of planted and regenerated pine or site native trees planted in naturalistic patterns.

- The structure survey identified a number of stand characteristics for semi-natural woodland that do not fit easily into current SCDB recording rules. The structure classes looks at stand structure in a different way, and it is important that foresters start to think of both structural composition and stage. The timescales for each structural stage were generally much longer than those normally applied in plans to plantation areas.

- Forester GIS has been designed principally around managing timber producing forests and running the production forecast for these. As a result, description and prescription categories for LISS are not always structured in a way that helps native woodland management. The interventions recommended by Forest Research specialist staff did not fit easily into UKWAS or

Forester GIS categories. Because we looked at interventions that advanced structural stages, LISS operations such as group selection would need to be allocated a "fell year" or intervention time and this is not the case at present within Forester. The use of non-standard descriptors for LISS systems should be accepted more readily (although some cross referencing to existing nomenclature) for a more flexible approach to native woodland silviculture.

- We found that defining future habitat and species by single BAP Priority habitats alone could, in many cases, be inadequate to achieve objectives. The priority habitats are often found in intimate mosaics with each other within a sub-compartment notably upland birch and Caledonian pinewoods HAP types. It could be possible to allocate to one HAP type but acknowledge that there are components within the sub compartment that relate to another HAP type. The possible danger here is that future habitat management is driven by what is in the SCDB and not by the natural processes that are functioning on the ground.

- There is a fairly straightforward translation between ESC, where outputs are in the form of NVC woodland type or tree species, and Priority habitats. Ongoing developments of ESC should further simplify this in the future. There are the complications with Upland oakwoods and Upland Birchwoods. This is where good ecological advice, which is available both from FR and FES staff, should assist forest planners.

- There is a similar complexity in relating descriptions of woodland structure to other habitat descriptions where these have been derived for different purposes

- The storage and retrieval of large amounts of data generated by the case study is likely to be difficult in existing systems.

Objective: To develop a process for integrating Forest Research ecological model outputs & advice into the Forest Plan process

Again, we felt that this objective was partly achieved but raised a number of issues.

The models used are <u>Decision Support Systems</u> – they help to analysis a lot of complex information over a large area in a transparent and systematic way, reliant on the rules applied and the data sets available. They identify options and the implications of different choices <u>but do not provide answers</u>. At the synthesis stage, management decisions were a result of discussion within the team taking into account the range of other key information. This reflects the existing Forest Plan process rather than developing a "new" process as such and, because the models introduced new factors to be considered along with others, they do not necessarily save time at this stage.

We found the BEETLE model was valuable as an appraisal tool in identifying the potential impacts of changes in woodland type on habitat networks e.g. change from conifer plantation to upland oakwoods. It was also possible to demonstrate that the proposed changes in forest structure would lead to a better balance of stand types from the work undertaken on stand dynamics. The network approach allowed the impact of proposals on priority habitats and species to be investigated to ensure management for woodland habitats did not impede on designated habitats or their associated habitat network.

The BEETLE model, as well as helping to identify opportunities and priorities, enabled us to quickly appraise draft proposals to assess if they would be likely to achieve the objectives of improving habitat connectivity. It is important to consider all relevant habitat networks during the planning process, not just those for woodland specialists and there will be occasions when habitat networks e.g. for open heath or woodland overlap. Similarly, the priority for connectivity suggested by the model may appear, at times, to be in conflict with other priorities, for example, PAWS restoration. These are management decisions that might be based on habitat status and presence of priority habitats and species or designations and the impact of changes on these features. Again, the models will not provide answers. Decisions based on the models therefore remain to some extent subjective, but the outputs help to identify potential conflicts and set out the implications of these decisions in a transparent way.

While front line planning staff will see value in the ability to model a range of scenarios to appraise their ecological content, we don't think the BEETLE and ESC models, in their current form, are particularly user-friendly for non-specialist staff and the results can be difficult to explain. For example, the difference between woodlands that are considered to be habitat and those that are "not habitat" is a difficult concept for general staff to understand. Those using the outputs need a good understanding of ecological sciences and of the limitations of the model to avoid interpreting results out of context and non-specialist staff would require guidance to explain the significance of these outputs to stakeholders. There is a need to be aware of how changing some basic assumptions e.g. about landcover, the type of woodland that will develop or about the dispersal ability and habitat requirements of the focal species used can affect results.

At a technical level, BEETLE uses GIS "Spatial Analyst" and licences for this are currently limited by cost within FC. We don't therefore advocate this tool as a desktop application for all forest planners in the near future. In addition, BEETLE remains a specialist tool and no decision has been made to develop it as a desktop application.

ESC GIS is designed to assimilate of a lot of complex environmental data in a consistent way over a large area and thus saved time in searching through technical papers and bulletins and "manually" processing this information. It allowed us to identify potential future woodland habitat and species at a broad scale, particularly the potential for woodland HAP types, e.g. Upland Oak currently absent, or present only in isolated stands. As above, output requires some expert interpretation without which it could give spurious results. Its wider use at a forest plan level is hindered by lack of data. At the scale of resolution used in this case study, it needs to be clearly understood that map outputs are indicative only and not interpreted too literally.

FOREST GALES was principally designed to apply to uniform plantation areas as described by the SCDB (e.g. yield class) and takes little account of the characteristics of native woodland. While it did help to inform priorities for management of the plantation woodland within the plan, we saw no real advantage in the further development of this model for semi-natural woodland areas as we judged windblow to be a natural intervention in these areas.

Objective: To allow Forest Research to understand how managers might use the models & advice.

We felt that this objective was partly achieved but also raised a number of issues and we were aware that the objectives of FES and FR were not always necessarily the same. Certainly research staff were more aware, via the project, of the complexities of the forest planning task in relation to UKWAS and other requirements. The principle difference was that the case study did not set out to incorporate the consultation process and therefore the conclusions in section 8 (Applying the outcomes to the forest plan) can only identify options for further discussion at the time of plan revision. However, because the process was transparent, it should make this later process easier.

Forest District staff welcomed the resources available for processing data and running and explaining the models in this case study.

Objective: To improve the ecological content of the Forest Plan

We felt that the case study did achieve this overall objective.

Improving the ecological content of a forest plan will require a greater understanding of ecological function. The process of district and research staff working together through this project resulted in this greater understanding. Access to specialist staff as well as the application of analytical models played an important part in achieving this. If applied to the real plan, the result would be more refined proposals with better prioritisation and a clearer justification for decisions. The working relationship also allowed research staff to better understand the working of the district and this should allow for the development of applications which are well suited to needs of the district. In return, the district developed a better understanding of the potential of the research models, even if these were not directly available to them. This working relationship and the participatory process involved in taking pioneering piece of work forward is in many ways as important as improving the ecological content of the forest plan.

Final comments

Discussion of the case study with the stakeholder group identified four general issues pertinent to improving the ecological content of forest plans generally.

Data
A greater appreciation of the challenge of marshalling the appropriate data both to run the models and to take informed decisions (with or without the model output). Collection of new data is costly, can delay planning, should be targeted, and requires specification of classification scheme and of future storage (including metadata).

Models
There was a greater appreciation of the potential of the suite of models and a better understanding of how they can aid (and not take) decisions. Some of the models appear complex to FD staff, and some have yet to be developed and subsequently implemented. There is a substantial step between developing tools that can be run by experts, and developing equivalent tools to be run by many staff. The latter requires collaboration between FR and those parts of FC that develop corporate GIS. Discussions are ongoing to improve the process by which such developments are prioritised.

Integration
There was a greater appreciation of the complexity of decision-making that integrates multiple objectives, and a greater understanding of the element of subjectivity inherent in this. The case study showed that integration could be developed by team effort but that challenges remained in explaining the decisions made. There also remained a challenge of how to generalise such a process, and possibly reduce the amount of time invested in such team work.

Learning
Each participant in the team work had learnt from the experience – insights included the difference between ecological and plan timescales; the breadth of habitats to be considered; that incorporation of ecological thinking does not prevent management; and that the application of new models does provide a robust and auditable process for decision-making.

Next steps
There was interest in pursuing:

1. Continued input of ecological knowledge when the real forest plan for the area was undertaken.
2. Continued method development – how best to integrate multiple objectives.
3. Increased availability of ecological knowledge, either by producing operational versions of the models, or considering some form of regionally-based model expertise, or FR service.
4. A test of the process in another case study area where ecological issues were not predominant (as in Glen Affric), but were part of the mix of objectives (e.g. a more typical upland forest).

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