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Evaluating Biodiversity in Fragmented Landscapes: Applications of Landscape Ecology Tools

INFORMATION NOTE

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SUMMARY

This Information Note presents examples of how the tools being developed within Biological and Environmental Evaluation Tools for Landscape Ecology (BEETLE) can be used to aid the Forestry Commission and other land management agencies, at strategic and operational levels, to:

- **target biodiversity conservation action through direct management, grant schemes and other incentives;**
- **evaluate the impact of planned landscape change on biodiversity, incorporating various environmental, economic and social objectives, in order to develop multi-use sustainable landscapes.**

Six examples are used to illustrate a range of applications of the landscape ecology tools to help improve understanding of their potential.

INTRODUCTION

This Information Note expands on the basic principles of biodiversity evaluation in fragmented landscapes introduced in Forestry Commission Information Note 73 (Watts *et al.* 2005b*)* and demonstrates how these principles can be applied to forest management and landscape issues. Six examples have been chosen to illustrate the particular issues being addressed (targeting and evaluating), the approach taken (structural and functional), their spatial scale (from forest to country) and the types of spatial data and species data used.

BACKGROUND

Forest biodiversity and fragmentation

Forests and woodlands support a large proportion of the UK's biological diversity, providing a patchwork of wildlife-rich habitats and the potential building blocks for ecologically sustainable landscapes. However, forest cover in the UK has been considerably reduced and fragmented over past centuries. The remaining woods are often small and isolated from one another, and this is especially true for native, ancient and semi-natural woods, which have the highest biodiversity value. Such fragmentation threatens forest biodiversity because of the reductions in habitat area and increases in patch isolation. These impacts can be exacerbated by the intensification of surrounding land use management, leading to an increase in the ecological isolation of individual woods. Climate change may further compound these effects.

Drivers for action

The need to conserve woodland biodiversity and combat habitat fragmentation is therefore a key element of the forestry strategies for the England, Scotland and Wales (Forestry Commission, 1999; 2000; 2001) and the UK Biodiversity Action Plan (UKBAP). The UKBAP states:

> *' One of the principal threats identified in many of the species conservation action plans is that posed by habitat fragmentation. A key conservation aim for many species is, therefore, to create conditions that allow particularly fragmented habitats to expand or, in the case of animal species, to retain or create wildlife corridors allowing natural migration, escape from danger and inter-breeding.'*
>
> UK Biodiversity Steering Group, 1995.

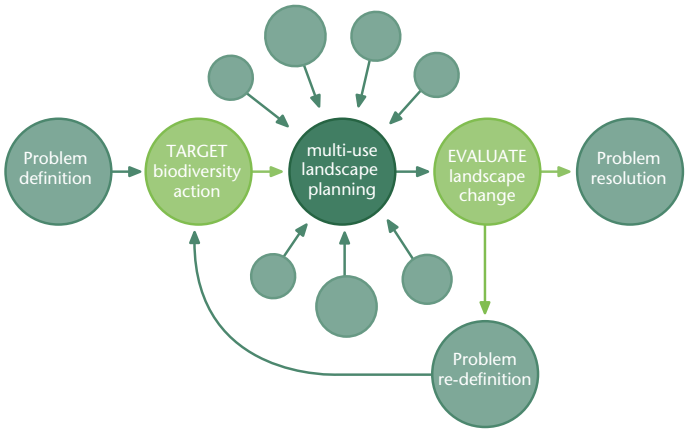
Each forestry strategy stresses the need to adopt a wider landscape-scale approach to effectively conserve biodiversity and combat fragmentation. Such an approach would also promote the integration of biodiversity goals with other environmental, economic and social objectives.

TARGETING AND EVALUATING ACTION

To assist planning and policy making at the strategic level, and guide management at an operational level, there is a need to proactively target biodiversity conservation action and to reactively evaluate planned landscape change (Figure 1). The targeting element aims to ensure that appropriate action is applied in the most effective areas, and to influence the development of multi-use landscape plans. The evaluation of planned landscape change, often entailing a balance or compromise between various objectives, will ensure biodiversity needs are represented.

Figure 1

The process of using targeting and evaluation to reduce the problem of habitat fragmentation in multi-use landscape planning.



Analysis of landscape structure and function

Proposed landscape change will affect both the structure and function of the landscape, and the need to understand each of these will depend on the particular issue being addressed.

Landscape structure refers to the spatial arrangement and organisation of distinct landscape elements. An approach based on landscape metrics[1] may be appropriate where the aim of the planned action is to change landscape structure. For instance, the ancient and native woodland policy for England *Keepers of time* (Forestry Commission, 2005a) aims to promote woodland creation which improves links with ancient woodland. Therefore, the success of this policy aim could be evaluated by assessing change to the total area of woodland, the number of individual woodlands, their size distribution and the amount of core habitat.

Landscape function is concerned with the interactions between the structural elements, through ecological processes and the flow of energy. The ancient and native woodland policy also has an aim related to landscape function:

> *'The landscape context of woodland should be improved ... create new native woodland to extend, link or complement existing woodland and other habitats ... work towards creating landscapes that are "ecologically functional".'*

In terms of biodiversity, landscape function is often related to the movement and viability of particular species within these structures. Therefore, evaluation of the latter policy aim may require a more complex functional approach utilising focal species, estimates of functional connectivity and the identification of habitat networks.

The concepts of structure and function are explained further in Information Note 73, which also outlines the development of BEETLE evaluation tools. These tools are intended to range from those that produce metrics, or indicators, of landscape structure to more complex tools that measure landscape function. This Note provides six examples of the use of these tools.

EXAMPLE APPLICATIONS

This section illustrates the application of the structural and functional approaches to targeting and evaluating biodiversity conservation action, as summarised in Table 1. The examples, which comprise three targeting and three evaluation studies, vary in terms of the particular issues being addressed, the approach taken and the spatial scale of evaluation. They range from large country and regional analyses, related to strategic planning, down to operational forest plans to assist management; a range of spatial and species data are used. Each example may still be regarded as a 'landscape-scale application', as we consider landscape as an entity with its scale determined by the issue being addressed (Quine *et al.*, 2006). The extent may therefore vary from a forest (several square kilometres), through to a catchment or region (tens to hundreds of square kilometres) or to a whole country (hundreds to thousands of square kilometres).

[1]Landscape metrics, or landscape indices, are quantifiable descriptions of landscape structure or pattern.

Table 1

Summary of the examples of structural and functional approaches to the targeting and evaluation of biodiversity conservation action at the landscape scale.

No.	Spatial scale	Location	Issue	Approach	Spatial data	Species data
1	Country (21 000 km²)	Wales	**Target** and prioritise strategic conservation action within habitat networks	**Function** – Networks for ancient and broadleaved woodland	Medium quality – Phase 1 habitat survey data	Four generic focal species – two ancient and two broadleaved
2	Region (24 000 km²)	South West England	**Target** and prioritise conservation action to aid implementation of ancient woodland policy	**Function** – Networks for ASNW, PAWS and RSNW	Low–medium quality – LCM, NBN habitat inventories, NIWT, AWI	Six generic focal species – two ASNW, two PAWS, two RSNW
3	County (430 km²)	West Lothian Scotland	**Target** areas for woodland conservation within the peri-urban environment	**Function** – Networks for ancient and broadleaved woodland	Medium quality – Phase 1 survey data	Generic focal species – ancient specialists and broadleaved generalists – overlaid with actual species
4	Region (32 000 km²)	Scottish Highlands	**Evaluate** impact of Locational Premium scheme for woodland planting in habitat networks	**Structure/function** – Metrics/indicators of core woodland within pine and broadleaved woodland networks	Medium quality – NIWT, SSNWI, LCS88, LCM – with local knowledge used to qualify woodland habitat	Generic focal species – pinewood and broadleaved woodland specialists
5	Island (380 km²)	Isle of Wight South England	**Evaluate** effectiveness of alternative woodland expansion schemes	**Structure** – Metrics/indicators for woodland habitats	Relative change between different grant schemes	Non-species approach
6	Forest (55 km²)	Clocaenog North Wales	**Evaluate** impact of forest design plan on biodiversity	**Structure** – Metrics/indicators for focal species and networks	High-quality data – FC sub-compartment (30 years, five-year time-steps)	Three specific focal species – empirical data and expert opinion

Note: ASNW – Ancient Semi-Natural Woodland; PAWS – Plantations on Ancient Woodland Sites; RSNW – Recent Semi-Natural Woodland; LCM – Land Cover Map 2000; NBN – National Biodiversity Network; NIWT – National Inventory of Woodland and Trees; AWI – Ancient Woodland Inventory; SSNWI – Scottish Semi-Natural Woodland Inventory; LCS88 – Land Cover Scotland 1988; FC – Forestry Commission.

Example 1
Wales – targeting action within a country

The Countryside Council for Wales, Forestry Commission and Forest Research are working together to develop a woodland habitat network for Wales (Forestry Commission, 2001; Watts *et al.*, 2005a). This network strategy is intended to identify key areas and prioritise actions aimed at:

- **protecting** and **managing** areas of existing high quality habitat, e.g. Ancient Semi-Natural Woodland (ASNW);
- **restoring** and **improving** sites with high restoration potential, e.g. Plantations on Ancient Woodland Sites (PAWS);
- **improving** and **managing** other recent broadleaved woodland, e.g. through direct management and woodland grant schemes;
- **improving the landscape matrix** by reducing land use intensity and increasing matrix permeability, e.g. through direct management and agri-environment schemes;
- **creating/re-creating** new woodland and associated semi-natural habitat, e.g. through direct management and appropriate grant schemes.

Generic focal species were developed to represent ancient and broadleaved woodland, which are habitats of conservation importance within Wales. As there was a need to identify the interactions between woodland and other semi-natural habitats, a functional approach assessing landscape permeability was used to define connectivity between woodland patches. Focal species with high habitat area requirements and low dispersal ability were developed to represent woodland species with a high sensitivity to fragmentation and thereby define core networks for ancient and broadleaved woodland. Focal species less sensitive to fragmentation, with medium habitat area requirements and medium dispersal ability, were used to define focal networks (Figure 2). The shared understanding is that conservation actions, as described above, will be targeted within and around these core and focal networks (Figure 3).

Figure 2

The 10 largest ancient woodland focal networks within Wales.

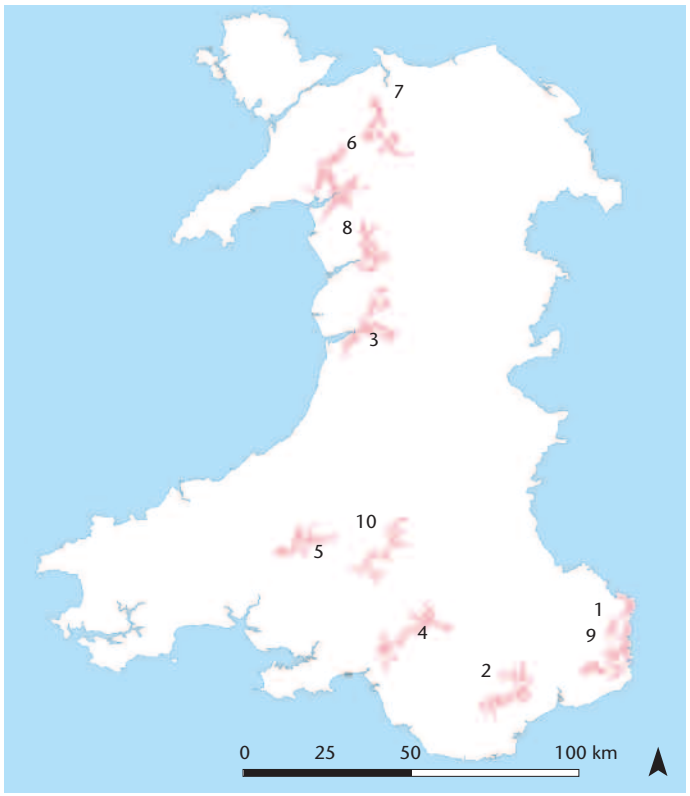
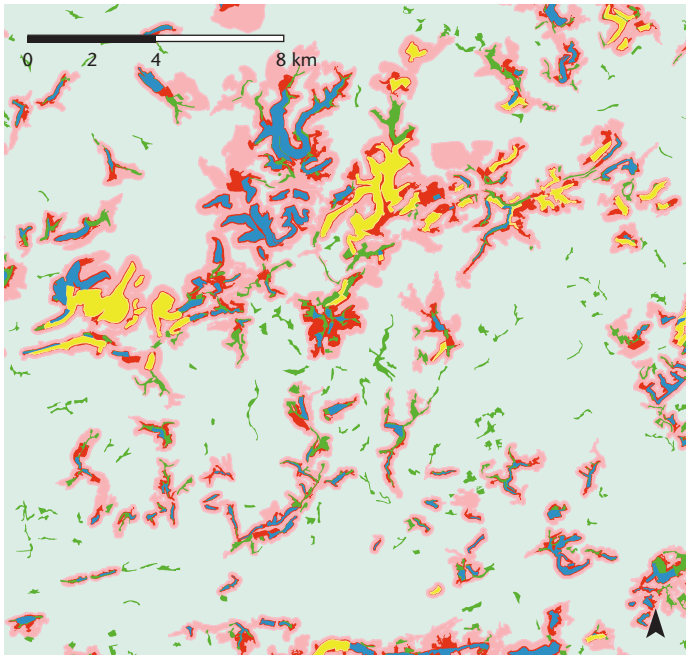


Figure 3

ASNW, PAWS and broadleaved woodland within ancient woodland focal network number 5, as identified in Figure 2. These core and focal networks can help target and prioritise actions to conserve woodland biodiversity and combat habitat fragmentation.



Example 2
South West England: targeting action within a region

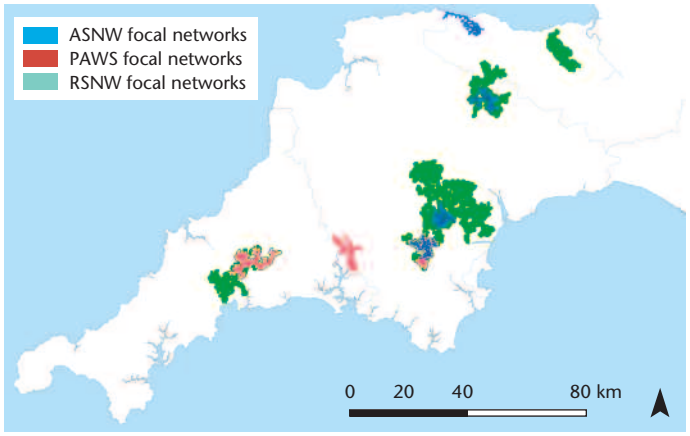
A similar approach has been developed with the South West England Conservancy of the Forestry Commission to help implement the new ancient and native woodland policy *Keepers of time* (Forestry Commission, 2005a). The policy aims to ensure that '*ancient woodlands, veteran trees and other native woodlands are adequately protected, sustainably managed in a wider landscape context*' (p. 9).

By considering woodlands as an integral part of the wider landscape, the policy aims to create opportunities to expand networks of woodland and other semi-natural habitats into ecologically functional landscapes. With this emphasis on 'functional landscapes' there is a clear need to use a functional connectivity approach.

Focal species were developed to represent the different woodland elements within the policy (i.e. ASNW, PAWS and RSNW) and identify core and focal networks (Figure 4) for each, in order to help target and prioritise the management actions.

Figure 4

Illustration of some of the major ASNW (blue), PAWS (pink) and recent semi-natural woodland (RSNW) (green) focal networks within the southern part of the South West Conservancy of the Forestry Commission.



Example 3
West Lothian: targeting action within a county

The county of West Lothian, to the west of Edinburgh and covering an area of 42 700 ha, has a moderate woodland cover (14% of the land area). A small percentage (0.7%) is of ancient origin, with a high biodiversity value, as demonstrated by the presence of a significant number of ancient woodland indicator plants such as moschatel (*Adoxa moschatellina*) and giant bellflower (*Campanula latifolia*).

The county is within commuting distance of new business centres to the west of Edinburgh. Therefore, Scottish Natural Heritage and the Local Biodiversity Action Plan Woodland Group were keen to assess opportunities for combining woodland with housing development in designated areas. Their aim was to safeguard and expand the considerable biodiversity value of the ancient remnant woodlands by extending the peri-urban forest habitat network and linking with other woodland patches throughout the county.

This ambition is consistent with the *Woods in and around towns* (WIAT) policy of Forestry Commission (Forestry Commission, 2005b). WIAT promotes the need to develop woodlands close to communities and improve access to woodland for recreation, health and well-being. This initiative should help stimulate economic activity and investment in local communities, while benefiting the environment and ecology.

Forests for Scotland: the Scottish forestry strategy (Forestry Commission, 2000) also recognises the need for forest habitat networks to reduce fragmentation of woodland, and to protect and increase woodland biodiversity. Habitat networks may assist the survival of woodland species during climate change by maintaining and extending functional connectivity throughout the landscape.

The West Lothian study linked these two policy objectives (Ray *et al.*, 2004). Woodland specialist focal species were used to assess the linkages of the remnant ancient semi-natural woodland of highest biodiversity value. The protection and buffered expansion of these areas was identified as a priority in the forest habitat network plans, and opportunities for combining this woodland expansion with development plans were explored. Broadleaved woodland generalists identified potential locations to develop woodland linkages within existing development plans and other land uses. Known distributions of species of conservation concern were compared with the identified networks for ancient specialist and broadleaved generalist focal species to support communication and provide preliminary validation.

The approach demonstrated that, at a broad-scale level of planning, it is not always necessary to consider requirements of individual species. Indeed, we rarely have sufficient data on species and their landscape–process interaction. This approach concentrated on broad landscape processes, and only after the analysis was it necessary to demonstrate the relationship between the real species and the generic focal species model outputs.

Example 4
Scottish Highlands: evaluating potential change via the Locational Premium scheme

In 2006 a new Locational Premium scheme, linked to the Scottish Forestry Grant Scheme, was announced. It provides additional financial support for woodland expansion in the Scottish Highlands. One strand of the scheme is concerned with linking existing pine and broadleaved woodland within forest habitat networks. Underpinning the scheme is an analysis of the existing broadleaved and pine woodland habitat networks in the Scottish Highlands, which uses focal species and functional connectivity (Moseley *et al.*, 2007). This first stage in the analysis produced maps for prospective grant applicants showing the areas in which new habitat will functionally connect existing habitat of the same type. The next stage, in which applications are assessed, requires individual applicants with candidate schemes to attend a surgery with a woodland officer, at which the expansion options are explored. At the surgery the applicant provides the scheme plan, including its location and spatial configuration. This is digitised into a specially designed Geographical Information System (GIS) assessment tool, which measures the area of proposed woodland and the core woodland area (after removing a 50-metre strip around the margins as this buffer will be subject to woodland edge effects). Metrics are produced to assess the change, in terms of functionally connected core habitat, that the proposed scheme would provide. Finally, the woodland officer discusses the amount of Locational Premium payable, based on an index of the changed network metrics.

This is the first time in Britain that landscape ecology tools have been incorporated within a forestry grant scheme to target native woodland (or any woodland) expansion.

Example 5
Isle of Wight: evaluating grant-aided woodland defragmentation

The England forestry strategy: a new focus for England's woodlands (Forestry Commission, 1999) declares that '*a priority will be to work towards reversing this fragmentation*' (p. 23), and talks about promoting the need to '*target grants…to reverse the fragmentation of existing native woodlands*' (p.26). Expansion has been encouraged through a number of financial incentives, from small-scale measures that encourage any contribution to increase woodland cover, to grant schemes that have set out to restore connectivity to existing

woodlands. This study on the Isle of Wight assessed the relative success of two contrasting grant aid schemes – Woodland Grant Scheme (WGS) and Joining and Increasing Grant Scheme for Ancient Woodland (JIGSAW) – in improving the structural connectivity of woodland habitats. WGS is a broad-based scheme with little spatial targeting, whereas JIGSAW is a proactive, spatially targeted scheme that offers a premium for woodlands that expand, buffer or join existing woodland habitats (Figure 5). Both grant schemes have contributed approximately 200 ha of additional woodland habitat between 1998 and 2005.

As both grant schemes were focused on landscape structure, their relative impact was assessed using a selected number of indicators, based on landscape metrics, which had clear and appropriate assumptions. For instance, the number of individual woodland patches was examined (Figure 6a). This metric showed a considerable increase for WGS woodlands but decreased for JIGSAW woodlands. This indicates that JIGSAW built on and linked existing woodlands, whereas WGS created numerous new, isolated woodlands. WGS also reduced the mean woodland size (Figure 6b), while JIGSAW led to an increase.

The study confirms the merit of spatially targeted woodland expansion to combat fragmentation, in terms of structural connectivity.

Figure 5

Spatial distribution of non-targeted WGS woodland and spatially targeted JIGSAW woodland in relation to existing broadleaved woodland in the east of the Isle of Wight.

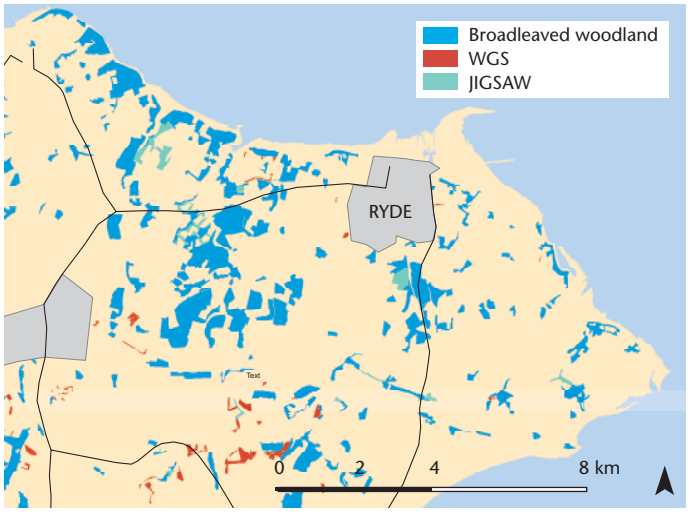
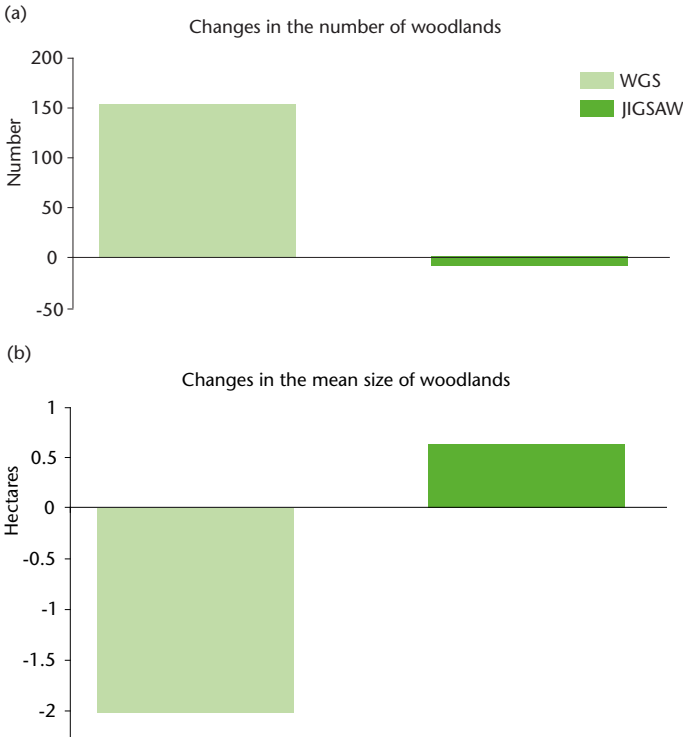


Figure 6

The impact of new woodland created by non-targeted WGS and spatially targeted JIGSAW grant schemes (1998–2005) on (a) number of woodlands and (b) mean woodland size.



Example 6
Clocaenog: evaluating a future forest design plan

Modern forest design planning must take account of multiple environmental, economic and social uses. To understand the impact of planning scenarios on forest biodiversity (a key environmental objective) there is a need to examine potential changes over time to the spatial distribution of important habitats such as open and mature forest (Figure 7). Important elements of UK biodiversity can be associated with open and forest edge habitats (e.g. small pearl-bordered fritillary, black grouse) and mature conifer habitat (e.g. red squirrel).

Within Clocaenog Forest, a 5500 ha conifer plantation in North Wales, we are beginning to examine the planned changes in open and mature conifer habitats and their potential impacts on key species. Forest managers are planning new patterns and types of forest to meet current objectives and balance future ones, for example through the development of continuous cover silviculture and an increase in open space. The detailed land cover data, coupled with new GIS techniques to model future forests, are providing an opportunity to explore the sequential impact of these planned changes at fine spatial (Figure 8) and temporal (Figure 9) resolutions.

Figure 7

Clocaenog Forest in North Wales, illustrating a mixture of open and mature conifer habitat.

Figure 8

Planned spatial distribution of open and mature habitat in Clocaenog Forest, North Wales, in 2020.

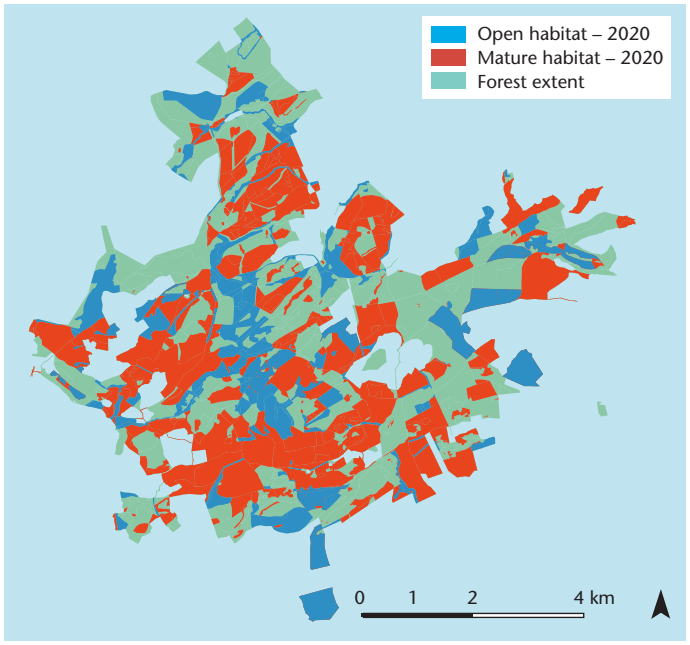
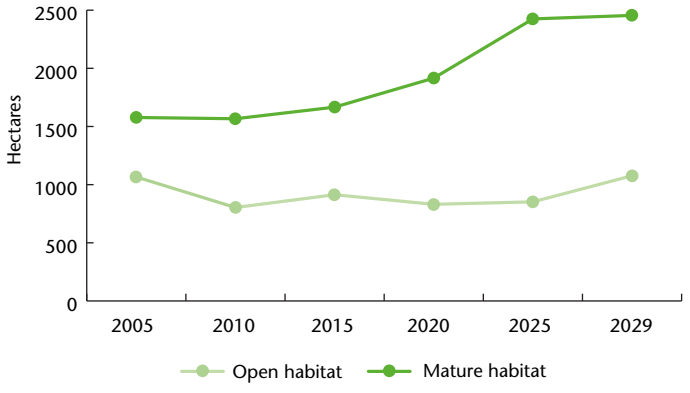


Figure 9

Planned temporal changes, at five-year intervals, in the area of open and mature habitat in Clocaenog Forest during the period 2005–2029.



These impacts can be examined in relation to changes in broad habitats, through structural approaches, or to specific target or focal species through more complex functional approaches. Biodiversity impacts can then be combined with other environmental, economic and social objectives to ensure a balance is achieved and a multi-use sustainable forest is developed.

CONCLUSIONS

These six examples illustrate how the principles introduced in Information Note 73, and developed within BEETLE, can be used to guide and support both strategic policy and operational management. The techniques can be used proactively to target biodiversity conservation action and reactively to evaluate landscape change, and can be applied at a variety of scales, from a single forest to a whole country. As shown, the choice of a simple structural approach or a more complex functional one will depend upon the issue being addressed.

The application of these approaches is heavily reliant on the availability of spatial and species data. High-quality data are available only for a limited number of forests and protected sites (e.g. Clocaenog Forest), and more often data are of moderate quality (e.g. field survey data for Wales and West Lothian), or are low-resolution but spatially extensive remotely sensed data (e.g. South West England). Spatial data are commonly historical, and may have limited value in terms of assessing *current* habitat quality or management. There is also very limited information on the dispersal and landscape permeability function for most species.

Although there are limitations in data quality and precision, the basic methodology is considered to reflect the general processes operating at the landscape scale. The various BEETLE tools can provide useful support for policy makers and forest and land managers making decisions on a broad scale.

BEETLE is designed to be an adaptive evaluation tool that will be refined by on-going monitoring and research. Further validation of the model will be achieved from the continued improvement of both spatial and species data and a number of fundamental studies to examine/update the underlying principles. Substantive proof of biodiversity gains can only be obtained from further detailed studies and monitoring.

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REFERENCES AND USEFUL SOURCES OF INFORMATION

FORESTRY COMMISSION (1999).
England forestry strategy: a new focus for England's woodlands.
Forestry Commission, Cambridge.

FORESTRY COMMISSION (2000).
Forests for Scotland: the Scottish forestry strategy.
Scottish Executive, Edinburgh.

FORESTRY COMMISSION (2001).
Woodlands for Wales: the National Assembly for Wales strategy for trees and woodlands.
Forestry Commission, Aberystwyth.

FORESTRY COMMISSION (2005a).
Keepers of time: a statement of policy for England's ancient and native woodland.
Forestry Commission, Cambridge, 10–11.

FORESTRY COMMISSION (2005b).
Woods in and around towns (WIAT). Policy document.
Forestry Commission Scotland, Edinburgh.

MOSELEY, D.G., RAY, D. and WATTS, K. (2007).
Improving forest habitat networks with new woodland planting schemes. *Forestry and British Timber*.
January 2007, 14–18.

QUINE, C., WATTS, K., RAY, D. and HUMPHREY, J. (2006).
Landscape ecology: emerging approaches for planning and management of forests and woodlands with Britain. In:
Forest Research Annual Report and Accounts 2004–2005.
The Stationery Office, Edinburgh, 52–59.

RAY, D., HOPE, J. and WATTS, K. (2004).
Development of a Forest Habitat Network Strategy in West Lothian. Scottish Natural Heritage Commissioned Report No. 049 (ROAME No. F03LJ15).
Scottish Natural Heritage, Edinburgh.

UK BIODIVERSITY STEERING GROUP (1995).
Biodiversity: the UK Steering Group Report – Vol. II: Action Plans (Annexes F and G).
HMSO, London, 79.

WATTS, K., GRIFFITHS, M., QUINE, C., RAY, D. and HUMPHREY, J.W. (2005a).
Towards a woodland habitat network for Wales.
Contract Science Report No. 686.
Countryside Council for Wales, Bangor.

WATTS, K., HUMPHREY, J.W., GRIFFITHS, M., QUINE, C. and RAY, D. (2005b).
Evaluating biodiversity in fragmented landscapes: principles.
Forestry Commission Information Note 73.
Forestry Commission, Edinburgh.

This Information Note is the second in a series on biodiversity evaluation in fragmented landscapes; the previous Information Note 073 explored the principles. Future Notes will explore the use of focal species, additional applications, and issues on further refinement and development. Further information is also available at www.forestresearch.gov.uk/landscapeecology.

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