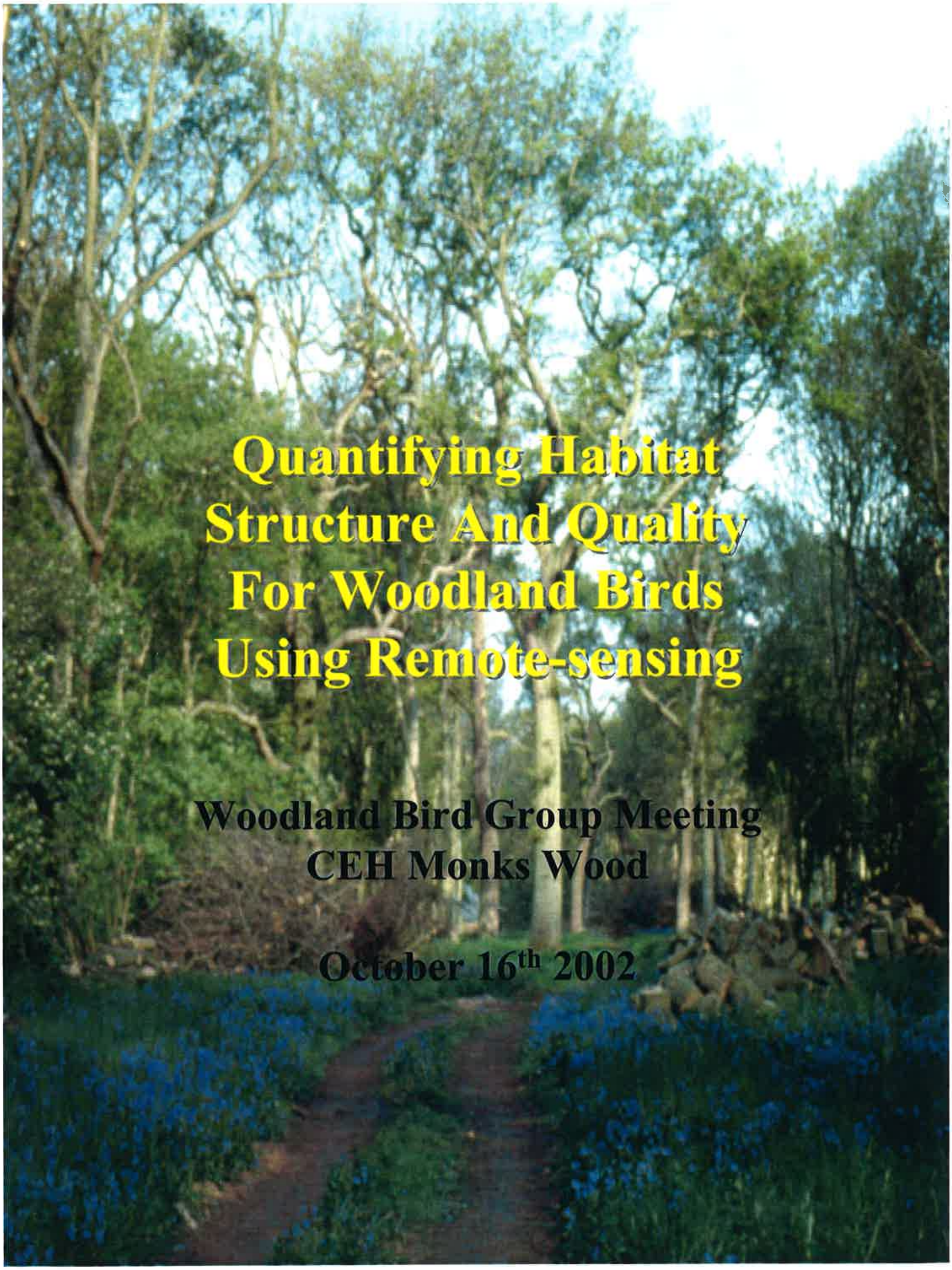


Quantifying Habitat Structure And Quality For Woodland Birds Using Remote-sensing

Woodland Bird Group Meeting
CEH Monks Wood

October 16th 2002

Quantifying Habitat Structure and Quality for Woodland Birds using Remote-Sensing

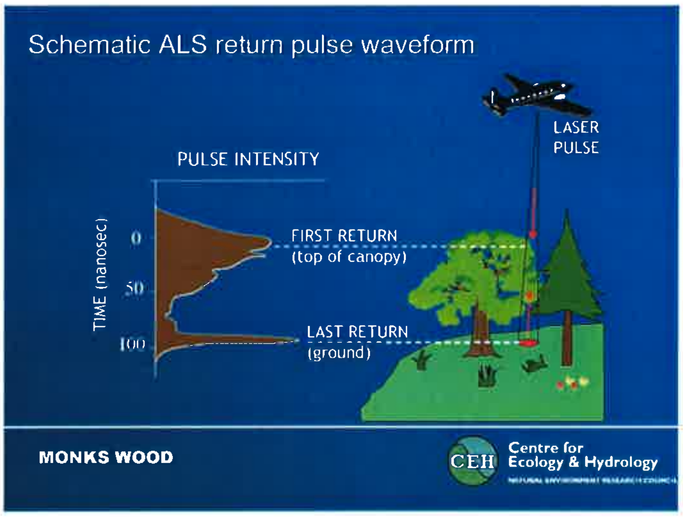
Background

The Wildlife Headline Indicator (H13) is one of 15 headline indicators of sustainable development and quality of life adopted by the UK Government (Anon 1999, www.sustainable-development.gov.uk) and is based on a number of population indices for wild birds. The headline indicators are updated as new figures become available with the aim of adjusting policies and instigating action to counteract unacceptable trends. The Wildlife Headline Indicator published in November 2001 showed a shallow decline for all bird species and declines of 20% and 40% for woodland and farmland birds respectively since 1970.

Over the last decade or so, a great deal of research effort has been concentrated on farmland birds (e.g. Aebischer *et al.* 2000, Boatman *et al.* 2002), whilst woodland and its birds have been largely neglected, relegated to a low priority conservation status in the shadow of the large and well documented declines in many farmland species (Fuller *et al.* 1995, www.bto.org/birdtrends/). However, as illustrated by the Indicator, a number of woodland species are in long-term decline and three new woodland species, Lesser-spotted Woodpecker, Willow Tit and Marsh Tit have been added to the most recently published Red List of Birds of Conservation Concern (Gregory *et al.* 2002) due to population declines over the last 25 years of 73%, 80% and 50% respectively. Other Red Listed woodland species include Song Thrush, Spotted Flycatcher and Bullfinch, and Amber Listed species include Dunnock, Willow Warbler and Wood Warbler.

Causes of declines in woodland birds are largely unknown and likely to be more complex than the situation concerning farmland birds. For example, some woodland species are stable or increasing and there is considerable geographic variation in the patterns of population changes for those in decline. Within the broad definition of "woodland", declining species occur across a range of ecological and habitat types and there is no obvious overall driver, such as agricultural intensification in the case of farmland birds, for the observed population changes. Possible causes include changes in management, woodland maturation and increased browsing pressure from deer (Fuller & Gill 2001). Differences and changes in woodland structure, and hence habitat quality, will affect bird species distributions, abundances and productivity on the scale of whole woods (and ultimately whole landscapes), but are difficult to quantify at this scale using field-based methods. In contrast, airborne remote-sensing combines high resolution data acquisition with a landscape-scale of operation, allowing variation and changes in habitat quality to be measured both within and between woods.

Remote sensing offers unique capabilities in providing digital information for modelling habitats and land surface morphology, and for deriving landscape metrics at a variety of spatial scales (Gulink *et al.* 2000). Airborne Laser Scanning (ALS) operates on a principle of LIght Detection And Ranging (LIDAR), using a pulse laser to measure the distance between the sensor and the Earth's surface (Flood & Gutelius 1997). Digital Surface Models (DSM) can be generated automatically from point-sample elevation data derived from ALS (Ackermann 1999, Wehr & Lohr 1999). A DSM contains information on the geomorphology of the Earth's surface and the morphology of features on its surface. The separation of these landscape elements from a DSM creates a Digital Terrain Model (DTM) and a Digital Canopy Height Model (DCHM). An operational method has been devised at CEH Monks Wood for de-coupling this information for a woodland area using dual-return ALS data acquired by an Optech ALTM scanner (Hill *et al.* 2002a, Hill & Gaveau, submitted). A DCHM not only supplies information on canopy height, but also canopy surface roughness. Additional research at CEH Monks Wood has demonstrated that the difference between the first and last return elevation provides information on canopy vertical density and can be used to model canopy gap fraction (Hill *et al.* 2002b).



ALS data can therefore supply a variety of 3-dimensional landscape metrics, but supplies little information on the landscape context (in terms of land-cover types or species composition). Surface reflectance data from airborne multi-spectral scanners, such as the Compact Airborne Spectrographic Imager (CASI) and the Airborne Thematic Mapper (ATM), have been widely demonstrated for thematic mapping (e.g. Thomson *et al.* 1998). Surface reflectance data from airborne multi-spectral scanners have the potential to provide important information on woodland type, canopy biomass and vigour.

Recent work at CEH Monks Wood has suggested that breeding success in tits can be influenced by canopy height (Hinsley *et al.* 2003) and by canopy vertical density and gap fraction (Hill *et al.* unpubl. data), suggesting that the characteristics of the tree canopy, as quantified using ALS, can be used as a measure of territory quality. Data on canopy height, vertical density and gap fraction have also been used to model Great Tit habitat quality in Monks Wood National Nature Reserve using Ecological Niche Factor Analysis (Baltzer *et al.* 2002). However, structural information alone cannot quantify habitat quality, other factors, such as plant species composition, area (total area and relative extent of different habitat types) and fragmentation/connectivity, are also important. The integration of multi-spectral and elevational data creates a synergy for mapping land-cover in a 3-dimensional context (Hill *et al.* 2002c). By integrating ALS and multi-spectral data for Monks Wood NNR, an experimental parcel-based thematic classification of woodland type, based on species composition and canopy structure, is being explored (Hill & Thomson, unpubl. data).

The Natural Environment Research Council's Airborne Remote Sensing Facility (NERC-ARSF)

Andrew K. Wilson

The UK's Natural Environment Research Council (NERC) Airborne Remote Sensing Facility (ARSF) exists to provide the UK environmental science community and other potential users with the means to obtain remotely sensed data in support of research and survey programmes. The ARSF provides the opportunity for training and promotes good practice in the use of remote sensing data, as well as promoting the awareness, application and technology of remote sensing among the wider scientific community. The application of such data, on a repetitive basis at almost any desired spatial and/or temporal frequency, is an increasingly cost effective means of monitoring the environment – terrestrial, freshwater, marine and atmospheric.

The ARSF is a unique service providing researchers with synoptic and analogue imagery of high spatial and spectral resolution. Radiometrically and geometrically corrected digital multi-spectral and hyperspectral data are produced from the AZ-16 Airborne Thematic Mapper (ATM) and the Compact Airborne Spectrographic Imager (CASI). A large format aerial survey camera is also deployed. The aircraft is capable of flying new imaging sensors and a recent collaboration with the University of Cambridge will make a terrain mapping Airborne Laser Scanning (ALS) system available from the 2003 flying season.

Figure 1: The NERC ARSF Dornier 228 Airborne Remote Sensing Platform, with CASI, AZ-16 ATM and RC-10 instruments.

The Airborne Remote Sensing Facility employs, through the Integrated Data System (IDS), a unique combination of GPS (Global Positioning Satellite) and INS (Inertial Navigations System) based attitude and positioning that can spatially reference image data to sub-metre accuracy, without the requirement for external ground control. The two images below show example Level 1b calibrated data (a), retaining the attitude motion distortions of the airborne platform, and the geo-corrected Level 3a image data (b) that is spatially referenced to the OS British National Grid, with all platform distortions removed.

(a) Level 1b

(b) Level 3a

Figure 2: (a) Radiometrically calibrated (Level 1b) data and, (b) the geo-corrected and spatially referenced (Level 3a) data.

Provision of spatially referenced (Level 3a) data allows integration of the remotely sensed multi-spectral images with 3-dimensional structural information, derived from Airborne Laser Scanning (ALS) systems, and with other spatially referenced point and vector information held in Geographical Information Systems (GISs).

Staff at CEH Monks Wood have been involved with the development and application of airborne remote sensing, since 1983, developing radiometric calibration procedures to derive quantitative information, procurement of new imaging sensors, and most recently, the development of the Integrated Data System (IDS) on behalf of the NERC-ARSF. The Section for Earth Observation also manages the processing line for all ARSF airborne data for the UK environmental science community, through a Service level Agreement with NERC. The ARS Facility is available to the UK academic community through annual peer-reviewed Announcements of Opportunity (AOs) and via Commissioned Research Projects.

The NERC-ARSF web page can be found at http://www.nerc.ac.uk/arsf/home.htm.

Modelling woodland canopy structure and pattern using airborne remote sensing data

Dr. Ross Hill

Airborne Laser Scanning (ALS) offers the ability to record the 3-dimensional structure of a forested landscape at a high spatial resolution by remote means. ALS technology operates on a principle of Light Detection And Ranging (LiDAR), using a laser range finder and a scanning mechanism to measure the elevation at points within a swath beneath the flight-path of an aircraft. A short-duration pulse of near infrared laser light is transmitted towards the ground by the aircraft-borne laser scanner. The timing and intensity of the return signal (following reflection from a feature on the Earth's surface) are recorded and used to derive a ranging measurement. By interpolating the elevation between the individual point-sample ranging measurements it is possible to derive a complete surface (Digital Surface Model – DSM) showing the upper canopy characteristics. A subsequent series of processes (adaptive morphological filtering, thin-plate spline interpolation, and data subtraction) is then performed to extract forest floor terrain and canopy height from the DSM as separate digital models (Figures 1 & 2).

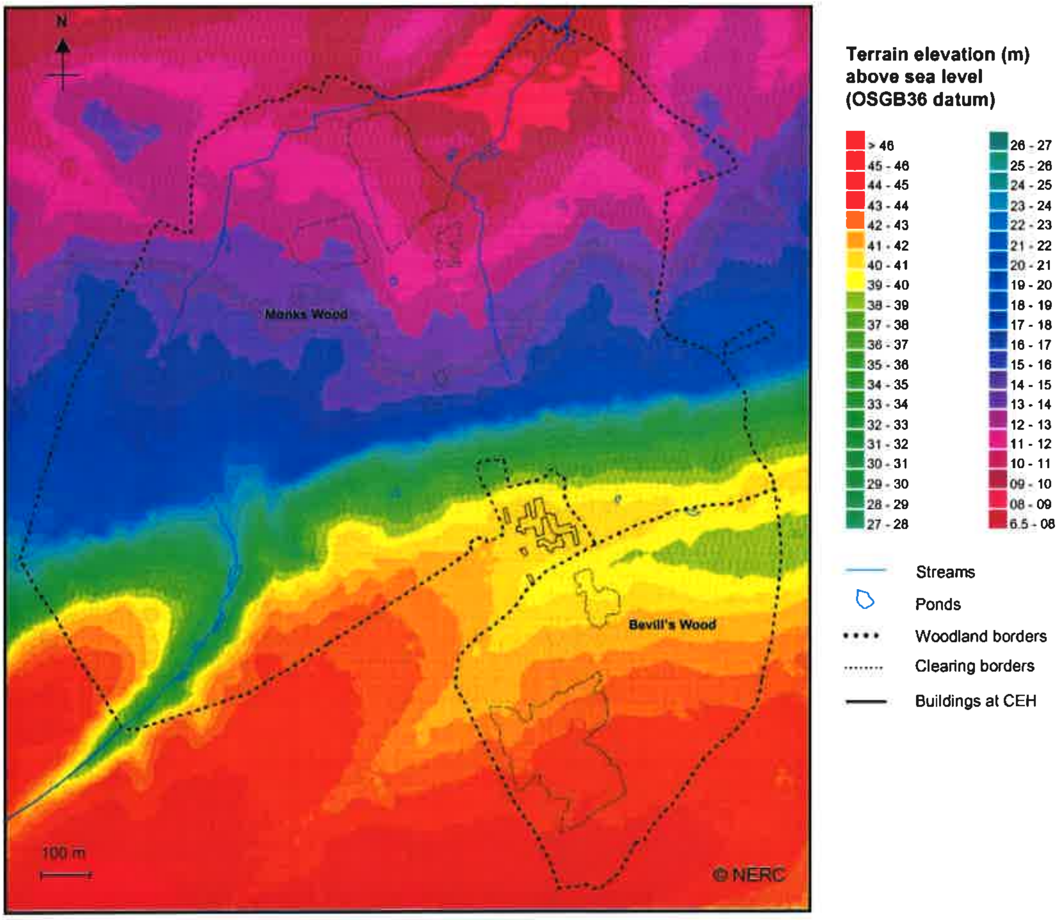


Figure 1: Digital Terrain Model of the woodland floor and surrounding area of Monks Wood N.N.R. (Reproduced by permission of NERC)

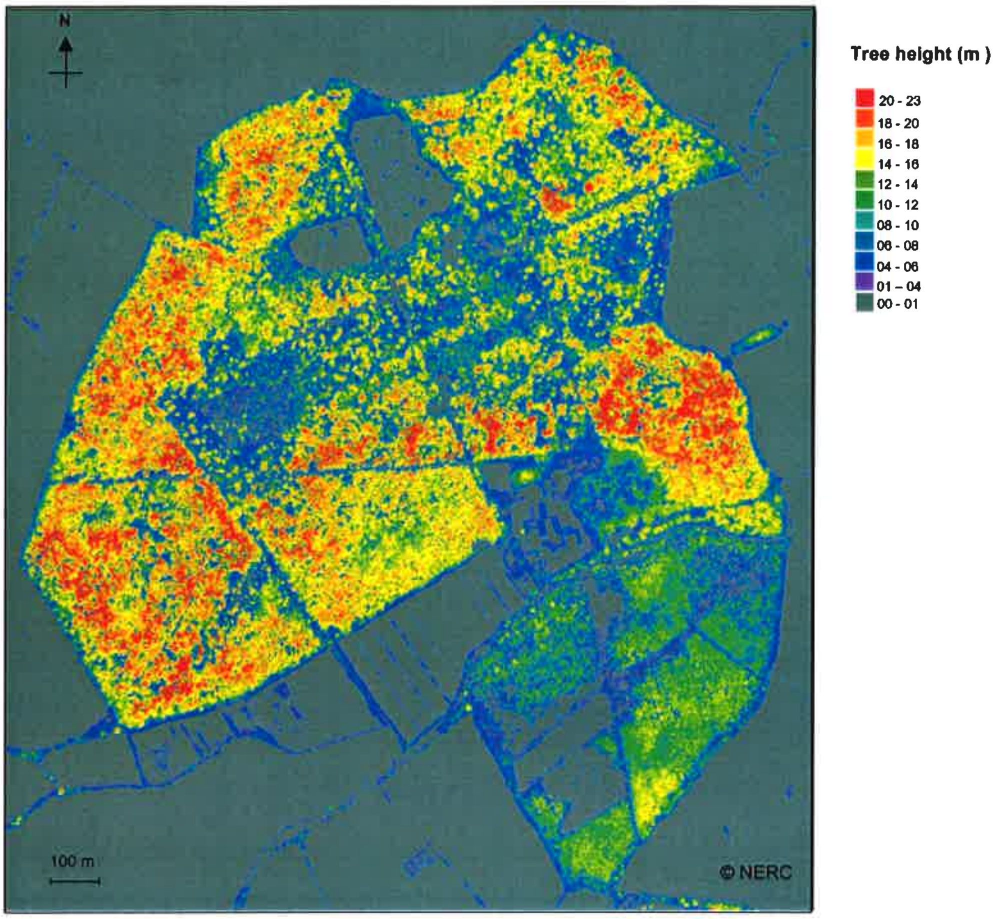


Figure 2: Digital Canopy Height Model of Monks Wood and neighbouring Bevill's Wood. (Reproduced by permission of NERC)

The above images are made up of rows and columns of pixels, each of which has a size on the ground of 1 m^2. The Digital Terrain Model (DTM) has a root mean square error of ± 0.5 m, whilst the Digital Canopy Height Model (DCHM) tends to underestimate the height of shrubs by approximately 1 m and trees by approximately 2 m. However, the canopy height underestimation can be corrected for by regression modelling.

The local spatial variation in the DCHM gives information on canopy surface roughness, whilst additional processing of the ALS data can supply information on canopy penetrability, potentially enabling canopy vertical density and gap fraction to be estimated. In addition, by integrating ALS data with multi-spectral data (e.g. from the CASI or ATM sensors) then it possible to place a woodland site into a wider landscape context (Figure 3). With such data it is possible to identify surrounding land-cover and potentially woodland species composition, and to identify landscape patterns and feature connectivity.

Figure 3: A 3-D visualisation of Monks Wood N.N.R. and surrounding landscape generated from integrated ALS and multi-spectral data. (Reproduced by permission of NERC).

An experimental parcel-based thematic classification of woodland type, based on species composition and canopy structure, has been developed for Monks Wood NNR and a first attempt has been made at relating this to habitat quality for a range of bird species (Figure 4).

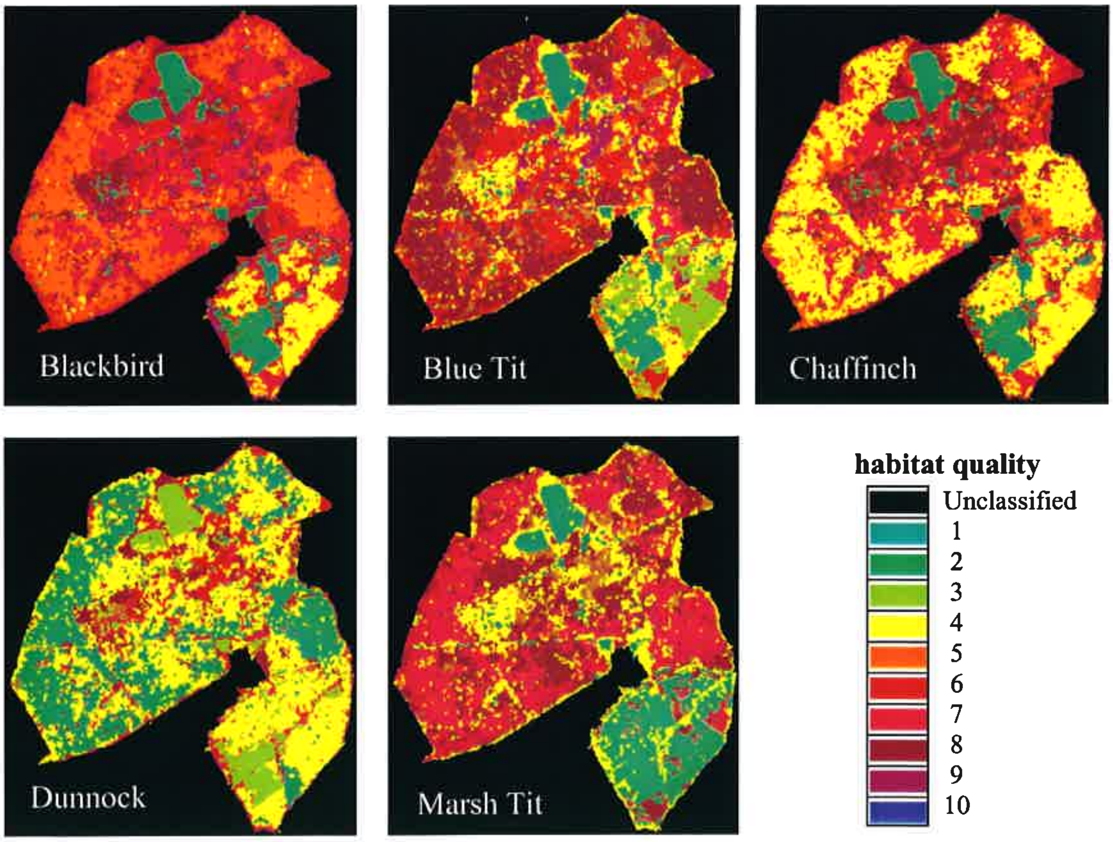


Figure 4: Predicted woodland habitat quality for a selection of British birds.

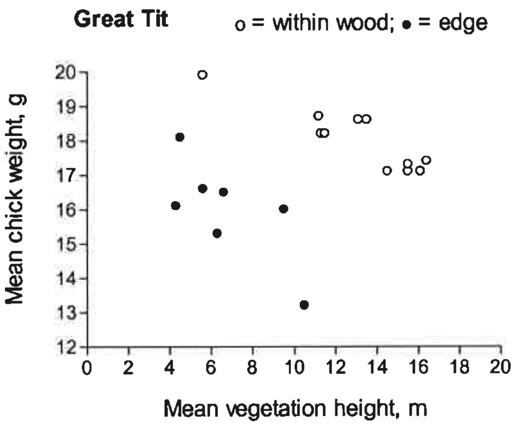
Tit breeding success and ALS woodland canopy height

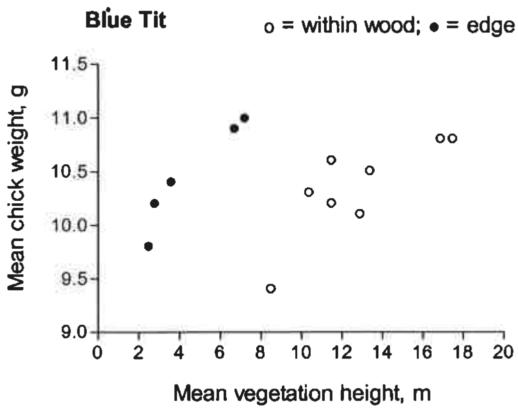
Dr. Shelley Hinsley & Mr. Paul Bellamy

Mean vegetation height was calculated from the ALS canopy height data for a sample area of 54 x 54 m centred on each of 22 nestboxes in the main body of Monks Wood NNR and for a further 14 boxes on the edges of the wood. The sample area was assumed to be representative of the birds' territory. The mean height for each sample area was derived from about 600 laser hits (*c.* one hit per 4.8 m^2), a sampling density unobtainable in the field. Mean chick weight was used as a measure of breeding success likely to reflect territory quality, combining the effects of food abundance with the adults' abilities to find it and to deliver it to the nest.

For Blue Tits, the relationships between chick weight and height were positive, but for Great Tits they were negative. Both species of tit feed their young chiefly on tree-dwelling lepidopteran larvae and thus positive relationships were expected, i.e. food resources and hence chick weights were expected to be greater where the tree canopy was well developed. However, the difference in the results was consistent with the birds' foraging behaviour. Blue Tits (9-11g) spend most time in the outer leaves and twigs whilst Great Tits (17-20 g) spend more time on the inner parts of trees and on the ground. Lower mean height may be associated with a more varied height profile which may favour Great Tits by providing a more robust vegetation structure and greater access to the ground. Great Tits also appeared to be more sensitive to habitat structure than Blue Tits; pairs using boxes in the body of the wood reared significantly heavier young than those using boxes on the edges (18.1 g versus 16.0 g, see below), but there was no difference for Blue Tits (10.5 g in both sets of boxes, see below).

However, these sample sizes are small and the results are for a single wood in one year, 2001. Bird performance in relation to habitat quality also varies temporally. In 2001, conditions for breeding were generally poor and it is under such difficult conditions that differences in habitat quality could be expected to have most effect and hence to be most detectable. Under good conditions, relationships between measures of quality and performance may be less apparent (Hinsley, unpubl. data).





Habitat quality mapping using remote sensing and Ecological Niche Factor Analysis

Dr. Heiko Balzter

The concept of habitat quality is fundamental to the study of ecology, but "quality" is frequently defined only in vague terms such as "good" or "poor". For woodland birds, the problem of quantifying quality is compounded by the three-dimensional complexity of the habitat, much of which is out of reach from the ground, and by the mobility of the birds themselves.
Hirzel et al. (2001) first presented the approach of Ecological Niche Factor Analysis (ENFA) to assess habitat quality. A number of spatial ecological input variables are transformed to a set of partial niche coefficients using pre-defined niche functions, which represent the value of the respective variable to the investigated species. A habitat quality index is calculated as the weighted average of the partial niche coefficients. Spatial and non-spatial variables (e.g. temporal climate data) can be combined (Figure 1). The performance of ENFA depends on the degree to which species occurrences are actually determined by their ecological niches, the relevance and accuracy of the ecogeographical variables and the realism of the niche functions and weights. The outcome of ENFA is a map of habitat suitability in the range from 0 to 1 (Figure 2).

Variables that are relevant to habitat suitability for certain species can be estimated from remote sensing. Different sensors can deliver specific variables. An example of an integrated habitat model based on ALS and Hyperspectral remote sensing images applied to Great Tits at Monks Wood NNR is presented. Input variables are (a) canopy height from ALS; (b) gap fraction map based on the canopy height model; (c) distance to woodland edge; (d) oak/ash frequency map from a claasification of HyMap hyperspectral data.

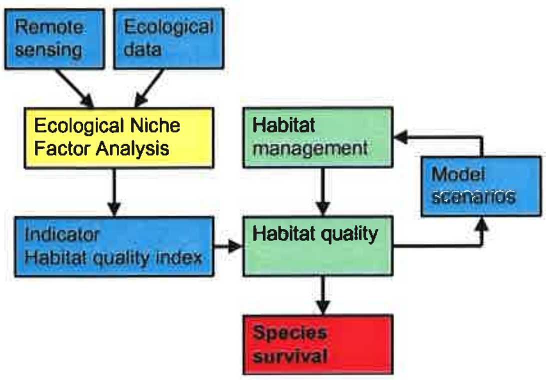


Figure 1: Conceptual approach of habitat quality mapping with remote sensing data and Ecological Niche Factor Analysis.

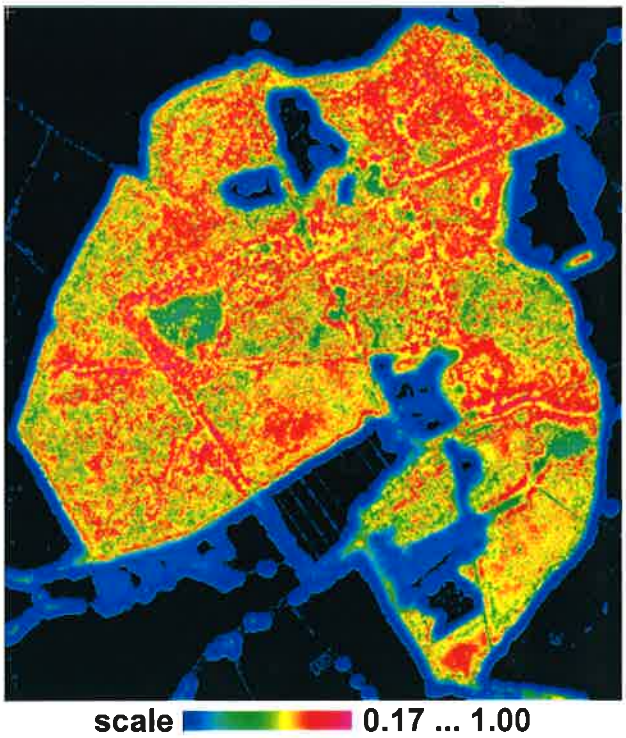


Figure 2: Habitat quality map of Monks Wood for Great Tits derived from an unweighted average of the four partial niche coefficients.

Putting woodlands into the wider landscape context

Dr. Geoff Smith

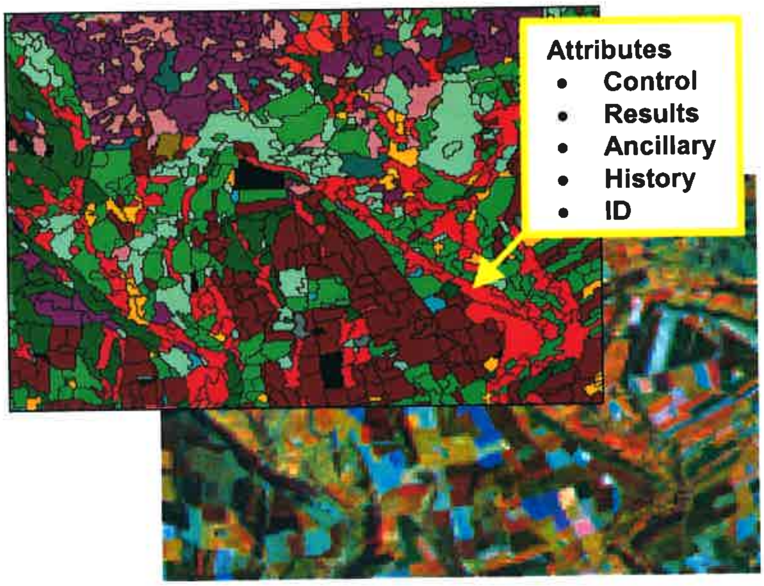
Woodlands do not exist in isolation, but as part of a much wider landscape. Woodland habitats are influenced by their adjacent habitats and land cover which could have important impacts on the development of the woodland over time and the species that it can support. It is essential therefore not only to categorise and assess a woodland on it's internal character, but also that of the landscape in which it sits. For instance, a woodland on the edge of an urban area will be under different pressures to one which is in a rural area. Also, whether the surrounding area is intensively managed (arable farming) or not (semi-natural land cover types) will be important.

Within Countryside Survey 2000 (CS2000: Haines-Young *et al.,* 2000), the parcel-based Land Cover Map 2000 (LCM2000: Fuller *et al.*, 2002) recorded the land cover of the United Kingdom in the form of vector land parcels, such as fields, woodland and lakes. LCM2000 was based on satellite images and identified 16 target classes, these were subdivided into 27 subclasses which could be aggregated to give the widespread Broad Habitats (Jackson, 2000). Subclasses were in turn divided giving 72 class variants, including 7 related to woodland. LCM2000 had a minimum mappable unit of 0.5 ha and target classes were mapped with an accuracy of approximately 90 %.

The Woodland Bird Survey Project and the interpretation of it's results could benefit extensively from the use of LCM2000 to place each woodland site into it's actual landscape context and thus assess the pressures on it. The distribution of land cover types around the woodland could be assessed as well as the distances to other woodland nearby. The satellite images that formed the LCM2000 contain further information within the land parcels which could be of use to assess woodland character. This work could also be extended to include the Land Cover Map of Great Britain, a pixel based map from 1990, in an attempt to assess how the landscape is changing around woodlands.

When considering the Survey results in the context of the original surveys of the 1970s and 1980s, it would be possible to explore the use of other remotely sensed data sources, such as archived aerial photographs, to compliment this information and help to explain differences.

LCM2000 showing full UK coverage.



The land parcel data structure (deciduous woodland in red), attribute groups and the source image data.

BIOPRESS

Linking pan-European land-cover change to pressures on biodiversity

Co-ordinator: Dr. France Gerard

A GMES project carried out by a consortium of 7 headed by (CEH Monks Wood) with the following partners:

- Centre for Geo-information - Alterra Green World Research (Alterra), The Netherlands.
- Centre for Ecological Research and Forestry Applications (CREAF), Spain.
- Geographical Information Management NV (G.I.M.), Belgium.
- Finnish Forest Research Institute (METLA), Finland.
- Institute of Landscape Ecology of Slovak Academy of Sciences (ILE SAS), Slovakia. & sub-contractor: GISAT – Czech Republic
- Forest Biometrics and Computer Sciences - Dresden University of Technology (TU Dresden), Germany.

The focus of BIOPRESS is to develop a standardised product that will link measures of historical (1950 to 2000) land-cover change to pressures on biodiversity. The product is aimed at the EU-user community concerned with the impact of land-cover/use changes on the environment and biodiversity. The proposed activities of the project are geared to the activities of the European Environment Agency (EEA) and European Topic Centres (ETC's) (Figure 1) and support the further development of Community Information Systems for nature, biodiversity and forests.

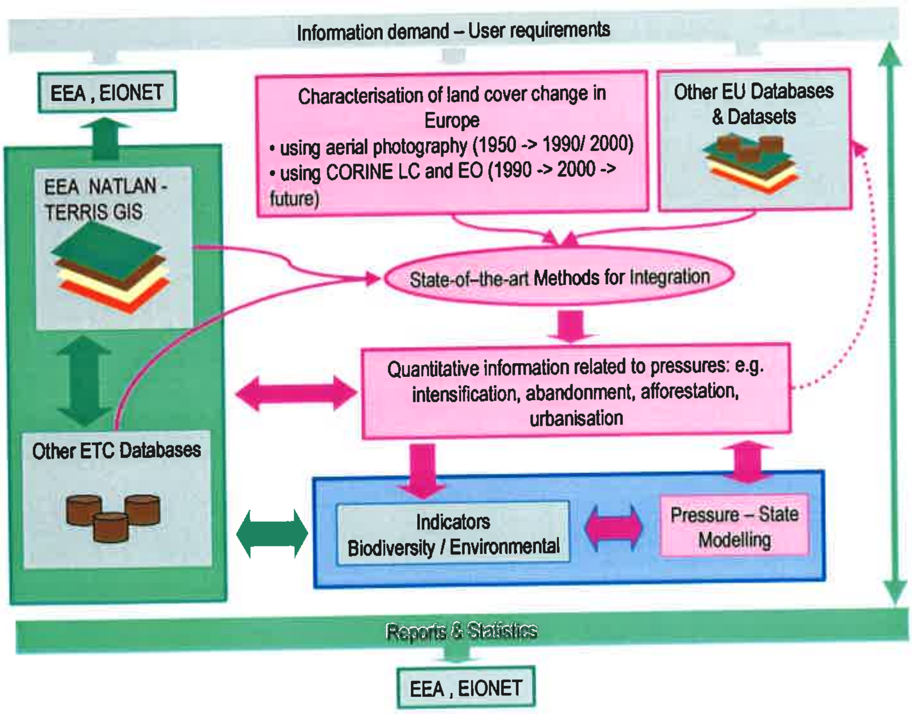


Figure 1: Relationships between the proposed work (in pink) and the activities and outputs of the EEA and its ETC's (in green and blue)

THE OBJECTIVES

The overall aim of the project is to develop a product that will allow measures of historical land-cover change (1950 to 2000) to be linked to pressures on biodiversity. The work consists of two closely linked but consecutive phases, I and II (Figure 2).

Phase I (months 1-18)

- The characterisation of land-cover change in and around a representative stratified sample of Natura2000 sites.
  - For a sample of ~200 Natura2000 sites land-cover change matrices will be produced by back dating CORINE land-cover 1990 (level 3) with aerial photos of the 1950s. By the end of 2003, a total of ~ 1500 aerial photos at a scale of 1:25000, distributed across Europe and the new candidate countries for EU membership, will be covered.
  - For a sample of ~50 Natura2000 sites land-cover change matrices will be produced from a more detailed interpretation and analysis of aerial photographs acquired in 1950, 1990 and 2000.
  - The land-cover change matrices from both exercises will be extrapolated using CORINE land-cover 1990.
- To report on the lessons learned and problems encountered during the production and extrapolation of the land-cover change matrices.

Phase II (months 19-36)

- To set up a GIS framework that will not only support the extrapolation of the change matrices but also facilitate the integration of pan-European spatial data sets building upon existing European led initiatives and concepts (e.g. EEA TERRIS database).
- To develop a pan-European land-cover change (1990-2000 and beyond) monitoring concept based on the integration of CORINE Land Cover, Earth observation and field data, and focusing on the area in and around the Natura2000 sites.
- To develop a spatially referenced product showing the main pressures on biodiversity (intensification, abandonment, afforestation, urbanisation) from the integration of data on land-cover change (1950 to 1990/2000) and other biological, environmental and socio-economic data. A state-of-the-art semi-quantitative pressure state-model called MIRABEL will convert the quantified pressures into assessments of biodiversity. The characteristics of the pressures product will be defined by the EU-user community and the pressure-state model operating on the product. This part of the project intends to add value to land-cover change product and will involve research that will examine specific problems related to data integration, land-cover change detection, pressure-state models and error propagation, with the aim of improving the tools used for monitoring the environment at a pan-European level.

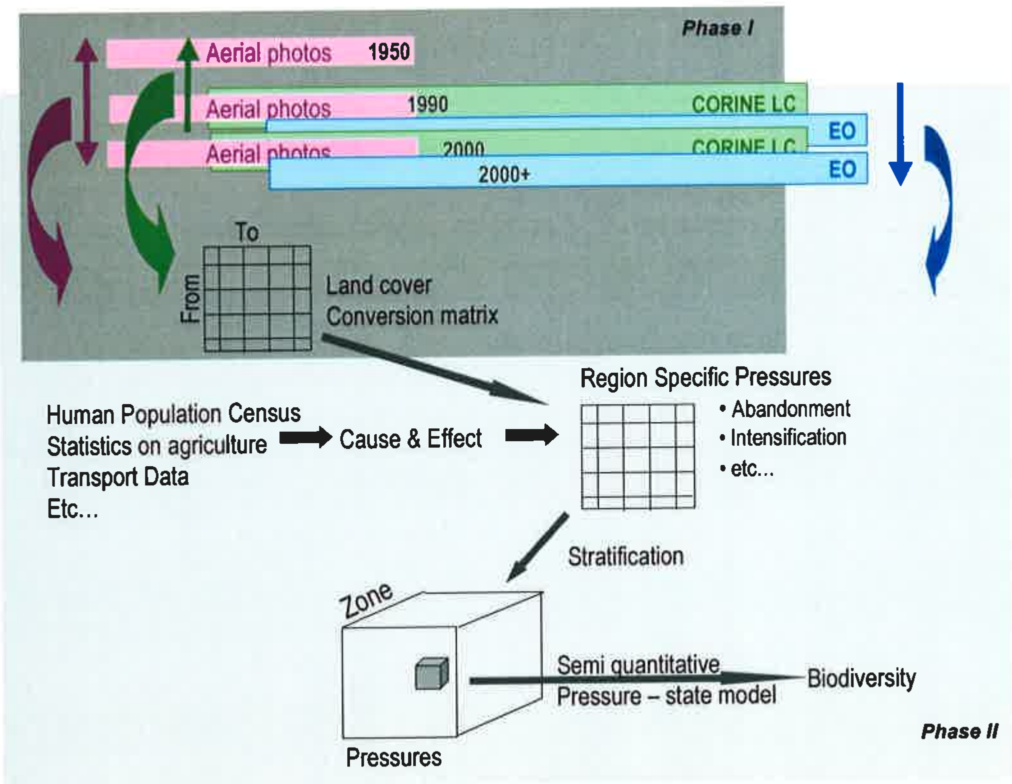


Figure 2: Schematic of the project's major work and research components. Phase I is shown as the dark shaded box, Phase II as the light shaded box.

Summary of bids to the NERC Airborne Remote-Sensing Facility (ARSF)

Funding under ARSF is for flights and data acquisition only; it does not include data processing time or collection of field-based data. Hence data pre-processing and analysis to generate value-added products incurs additional costs. Many of the methods developed at CEH are operational and could be transferred to data for other field sites. However, others are still experimental (e.g. integration of multi-spectral and structural data, and of remote-sensed and ecological spatial data) and some are quite novel (e.g. the use of winter data and its application to quantifying deer damage). Although a key strength of airborne remote-sensing is its ability to provide environmental information at a landscape-scale, and at a spatial resolution relevant to ecologists, collection of field data is still an integral part of the process, its extent dependant on the nature, and stage of development, of the analyses being undertaken.

A. Successful bid; flights deferred to 2003 due to delay in equipment availability.

Title:	Linking canopy structure to woodland bird distribution, breeding success and population size.
Authors:	Ross Hill and Shelley Hinsley.
Sites:	All in Cambridgeshire within a few kilometers of CEH Monks Wood. Monks Wood (157 ha), Wennington Wood (72 ha), Holland Wood (27 ha), Raveley Wood (6 ha), Lady's Wood (7 ha), Riddy Wood (8 ha), Grange Farm Wood (4 ha) and several small woods (*c.* 1 ha) in same general area. If conditions are unfavourable with respect to flight lines, Riddy and Grange Farm Woods may not be included.
Flight dates:	Summer 2003 and winter 2003/04 (although there is a good chance that the winter flights could be brought forward to 2002/03).
Sensors:	ALTM, CASI, ATM.
Bird data: (existing)	Breeding success of Great Tits and Blue Tits monitored since 1993 in all woods. Distribution and abundance of breeding birds estimated by territory mapping since 1990 in Raveley Wood, Lady's Wood, Riddy Wood, Grange Farm Wood, and the small woods. Distribution and abundance of breeding birds estimated for 6 x 500 m transects in Monks Wood for 3 years (2000 – 2002).
Aims:	1. To relate characteristics of canopy structure to bird species distributions and abundances. 2. To relate characteristics of canopy structure to breeding success in Great Tits and Blue Tits.

3. To assess the ability of remote-sensed data collected in winter to quantify characteristics of sub-canopy structure.

4. To investigate the utility of remote-sensed data in quantifying deer damage to woodland ground and shrub cover in relation to bird population structure and performance.

5. If work under (4) is successful, to set a baseline against which future changes in relation to deer grazing in Monks Wood can be assessed, using two exclosures (*c.* 8 and 14 ha) established in autumn 1999.

B. New bid; submitted October 2002.

Title:	Variation in woodland structure and habitat quality, and its effects on bird distribution, abundance and breeding performance.
Authors:	Shelley Hinsley, Andy Gosler, Rob Fuller and Ross Hill.
Sites:	1. Wytham Woods, Oxfordshire, 415 ha. 2. Sheephouse Wood, Buckinghamshire, 40 ha. 3. Bradfield Woods, Suffolk, 62 ha. 4. Brampton Wood, Cambridgeshire, 132 ha.
Flight dates:	Summer 2003 for all 4 sites. In addition, winter 2003/04 for Wytham.
Sensors:	ALTM, CASI, ATM
Bird data: (existing)	1. Wytham Woods have been a focus of world class bird research since 1947, including long-term population studies of Great Tits and Blue Tits, and territory mapping in a 7 ha census plot since 1972. 2. Sheephouse Wood. The bird population of the wood has been censused by territory mapping since 1984. 3. Bradfield Woods. Bird census work has been carried out in relation to vegetation structure since 1987. 4. Brampton Wood. Breeding success of Great Tits and Blue Tits has been recorded since 1993.
Aims:	1. To investigate the use of air-borne remote-sensing in quantifying habitat structure for a number of deciduous woodlands of various structures and tree/shrub species compositions.

2. To assess how remote-sensed data collected for deciduous woodland in winter (no leaf canopy) differ from those collected during the summer (full leaf canopy) and what can be gained from the combination of summer and winter data. Winter data should supply more information about low-level cover, such as brambles (evergreen), which is important for nesting/foraging birds and highly susceptible to deer damage.

3. To explore the utility of remote-sensed data in quantifying deer damage to woodland vegetation structure and to relate changes in structure due to deer grazing to bird species distributions, abundances and breeding success. Wytham has suffered extensive deer damage to the ground flora and shrub layer. Using a combination of summer and winter data we will investigate the structural characteristics of this level of damage. It might then be possible to use such characteristics as a signature of significant damage identifiable via airborne survey at a landscape-scale.

4. To combine habitat models derived from the remote-sensed data with existing information on bird species distributions, abundances and breeding success to explore relationships between woodland habitat structure and habitat quality for a number of woodland bird species.

Additional information – study sites

1. Wytham Woods, Oxfordshire. 415 ha. This is a mixed deciduous woodland of ancient abandoned Hazel coppice with Oak standards, natural regeneration of secondary woodland of mostly Ash and Sycamore and plantations of mostly Oak and Beech with areas of scrub, marsh, and semi-natural grass. It is an Environmental Change Network site. Between 1987 and 1989, the wood (*c.* 324 ha of woodland and 65 ha of agricultural land) was enclosed by a deer fence i.e. the deer (mostly Fallow) were fenced in and have caused large changes to the site by eating out the understory. Two large deer exclosures (*c.* 27 ha) were established in 2001.

2. Sheephouse Wood, Buckinghamshire. 40 ha. This is high forest Oak with some Ash and Field Maple. The wood is managed for timber using the contrasting techniques of clear felling and group felling and thus has a range of physical structures. Deer (mostly Muntjac) are present and damage is increasing. A 5 ha exclosure is present.

3. Bradfield Woods, Suffolk. 62 ha. This is a working coppice woodland of Alder, Ash, Silver Birch and Hazel coppice with Oak and Ash standards. It is an NNR. The woods are exceptional in that their history of coppicing can be documented as far back as 1252. As an actively worked site, the woods contain large areas of coppice at different stages of growth. Deer grazing (Roe, Muntjac and Fallow) is a problem and a number of experimental exclosures have been established to protect coppice regrowth and to study the impact of deer on the vegetation and birds.

4. Brampton Wood, Cambridgeshire. 132 ha. This is a mixed deciduous woodland of Field Maple, Ash, Oak, Silver Birch, Aspen, and abandoned Hazel coppice. There are also blocks of conifers (Spruce and Pine). It is a Wildlife Trust Nature Reserve. The wood was mostly clear-felled about 40 years ago and hence has relatively few old trees. A notable feature of Brampton is the extensive, dense growth of Blackthorn and other shrubs. Deer (mostly Muntjac) are present, but as yet have had a relatively low impact.

5. Monks Wood, Cambridgeshire. 157 ha. Monks Wood was declared as a National Nature Reserve in 1953. It is a mixed deciduous woodland dominated by Ash with Oak and Field Maple. Other tree species include Small-leaved Elm, Silver Birch and Aspen. The main shrub species are Hawthorn, Blackthorn and Hazel and the field layer is currently dominated by grasses and sedge due to deer grazing, mostly Muntjac. Formal coppicing was suspended in 1995 because of deer damage and in 1999 two compartments of about 8 ha and 14 ha were fenced to exclude deer. There are also ponds and several areas of open grassland maintained by periodic mowing and/or grazing.

6. Wennington Wood, Cambridgeshire. 72 ha. This is a mixed deciduous woodland dominated by Ash, with Oak and Field Maple. There is also an area of Small-leaved Elm and several young plantations of Oak. The main shrub species are Hawthorn, Blackthorn and Hazel. The wood is managed for hard wood timber production and pheasant rearing. Deer (mostly Muntjac, some Roe) are present, but numbers are controlled.

7. Holland Wood, Cambridgeshire. 27 ha. This is a mixed deciduous woodland of Ash/Oak with Field Maple and small numbers of a range of other tree species. The main shrub species are Hawthorn, Blackthorn and Hazel. The wood is managed for pheasant rearing and some areas of old Blackthorn scrub have been replaced with young trees. Deer (mostly Muntjac, some Roe) are present, but numbers are controlled.

8. Raveley Wood, Cambridgeshire. 6 ha. This is a mixed deciduous woodland dominated by Small-leaved Elm and Ash, with Oak and Field Maple. About half the wood lacks tree canopy (due in part to removal of dead Elm and coppicing of Ash) and these areas are dominated by thickets of Blackthorn, Hazel and Hawthorn. There is much standing and fallen dead wood, mostly Elm. The wood is leased by the Wildlife Trust as a nature reserve and supports a Rookery of about 60 nests. Deer (mostly Muntjac) are present in all these Cambridgeshire woods.

9. Lady's Wood, Cambridgeshire. 7 ha. This is a mixed deciduous woodland of Ash, Oak and Field Maple plus some Small-leaved Elm, but the tree canopy is relatively sparse in much of the wood, and the site is dominated by Blackthorn thickets. Other shrubs include Hawthorn and Hazel. The wood is leased by the Wildlife Trust as a nature reserve.

10. Riddy Wood, Cambridgeshire. 8 ha. This is a mixed deciduous woodland of Ash and Oak with Field Maple and an area of Small-leaved Elm containing much dead timber (standing and fallen). Another previously open area is now dominated by Hazel thickets and other shrubs, mainly Blackthorn and Hawthorn. The wood is managed for pheasant rearing.

11. Grange Farm Wood, Cambridgeshire. 4 ha. This is a mixed deciduous woodland of Ash, Oak and Field Maple and a large area of Small-leaved Elm with much dead timber (standing and fallen). About half the wood lacks tree canopy and these areas are dominated by Hazel coppice, Blackthorn thickets and Hawthorn. The wood is leased by the Wildlife Trust as a nature reserve.

12. Various small woods, Cambridgeshire, *c.* 1 ha. These are all deciduous Ash/Oak/Field Maple/Elm woods with an understory/open areas of Blackthorn/Hawthorn/Hazel, i.e remnant woodlands resembling the larger woods in the area. Some are used for pheasant rearing/release.

References

Ackermann, F. 1999. Airborne laser scanning – present status and future expectations. ISPRS Journal of Photogrammetry and Remote Sensing 54: 64-67.

Aebischer, N.J., Evans, A.D., Grice, P.V. & Vickery, J.A. (eds) 2000. Ecology and conservation of lowland farmland birds. Proceedings of the 1999 BOU Spring Conference, University of Southampton, March 1999.

Anon. 1999. Quality of life counts. Indicators for a strategy for sustainable development for the United Kingdom: a baseline assessment. DETR, UK.

Balzter, H., Hinsley, S., Bellamy, P., Gaveau, D., Gerard, F., Grant, J., Hill, R., Plummer, S. & Thomson, A. 2002. Habitat quality mapping using remote sensing and Ecological Niche Factor Analysis. ForestSAT, Operational tools in forestry using remote sensing technology. Edinburgh, August 2002.

Boatman, N.D., Carter, N., Evans, A.D., Grice, P.V., Stoate, C. & Wilson, J.D. (eds) 2002. Birds and agriculture. Proceedings of a meeting of the Association of Applied Biologists at Heriot-Watt University, Edinburgh, March 2002. Aspects of Applied Biology 67, Birds and Agriculture.

Flood, M. & Gutelius, B. 1997. Commercial implications of topographic terrain mapping using scanning airborne laser radar. Photogrammetric Engineering and Remote Sensing 63: 327-329 and 363-366.

Fuller, R.J., Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D., Baillie, S.R. & Carter, N. 1995. Population declines and range contractions among lowland farmland birds in Britain. Conservation Biology 9: 1425-1441.

Fuller, R.J. & Gill, R.M.A. (guest eds) 2001. Ecological impacts of deer in woodland. Forestry 74, Special issue.

Fuller, R.M., Smith, G.M., Sanderson, J.M., Hill, R.A., & Thomson, A.G. 2002. The UK Land Cover Map 2000: construction of a parcel-based vector map from satellite images. Cartographic Journal 39: 15-25.

Gates, D.M., Keegan, H.J., Schleter, J.C. & Weidner, V.R. 1965. Spectral properties of plants. Applied Optics 4: 11-20.

Gregory, R.D., Wilkinson, N.I., Noble, D.G., Robinson, J.A., Brown, A.F., Hughes, J., Procter, D.A., Gibbons, D.W. & Galbraith, C.A. 2002. The population status of birds in the United Kingdom, Channel Islands and Isle of Man: an analysis of conservation concern 2002-2007. British Birds 95: 410-450.

Gulinck, H., Dufourmont, H., Coppin, P., & Hermy, M. 2000. Landscape research, landscape policy and Earth observation. International Journal of Remote Sensing 21: 2541-2554.

Haines-Young, R.H., Barr , C.J., Black, H.I.J., Briggs, D.J., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D., Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C., & Watkins, J.W. 2000. Accounting for nature: assessing habitats in the UK Countryside. DETR, London.

Hirzel, A.H., Helfer, V. & Metral, F. 2001. Assessing habitat-suitability models with a virtual species. Ecological Modelling 145: 111-121.

Hill, R.A., Gaveau, D.L.A., & Spendlove, M. 2002a. Accuracy issues in the assessment of deciduous woodland canopy height by airborne laser scanning: a case study. ForestSAT, Operational tools in forestry using remote sensing technology. Edinburgh, August 2002.

Hill, R.A., Hinsley, S.A., & Gaveau, D.L.A 2002b. Mapping forest pattern and structure at a landscape scale using airborne laser scanning technology. In: Chamberlain, D. & Wilson, A. (eds) Avian Landscape Ecology. Proceedings of the 2002 Annual IALE(UK) Conference, pp. 60-67.

Hill, R.A., Smith, G.M., Fuller, R.M., & Veitch, N. 2002c. Landscape modelling using integrated airborne multi-spectral and elevation data. International Journal of Remote Sensing 23: 2327-2334.

Hill, R.A. & Gaveau, D.L.A. Submitted. Accuracy of canopy height estimates from airborne laser scanning: a case study of deciduous woodland. Canadian Journal of Remote Sensing.

Hinsley, S.A., Hill, R.A., Gaveau, D.L.A., & Bellamy, P.E. 2003. Quantifying woodland structure and habitat quality for birds using airborne laser scanning. Functional Ecology, in press.

Jackson, D.L. 2000. JNCC Report No. 307 Guidance on the interpretation of the Biodiversity Broad Habitat Classification (terrestrial and freshwater types): definitions and the relationships with other habitat classifications. Joint Nature Conservation Committee, Peterborough.

Thomson, A.G., Fuller, R.M. & Eastwood J.A. 1998. Supervised and unsupervised methods for classification of coasts and river corridors from airborne remote sensing. International Journal of Remote Sensing 19: 3423-3431.

Wehr, A. & Lohr, U. (guest eds) (1999) Theme issue on airborne laser scanning. ISPRS Journal of Photogrammetry and Remote Sensing 54: special issue.

Contact List

CEH Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire, PE28 2LS
Tel: 01487 772400
Fax: 01487 773467
www.ceh.ac.uk

Balzter, Heiko Tel: 01487 772471 e-mail: hbal@ceh.ac.uk
(Ecological Niche Factor Analysis)

Gerard, France Tel: 01487 772482 e-mail: ffg@ceh.ac.uk
(European perspective, BIOPRESS)

Hill, Ross Tel: 01487 772485 e-mail: rhill@ceh.ac.uk
(LIDAR/ALS, multi-spectral)

Hinsley, Shelley Tel: 01487 772554 e-mail: sahi@ceh.ac.uk
(Woodland birds - tit breeding performance)

Smith, Geoff Tel: 01487 772479 e-mail: gesm@ceh.ac.uk
(Landscape-level issues)

Wilson, Andrew Tel: 01487 772489 e-mail: akw@ceh.ac.uk
(NERC airborne remote-sensing facility)