Forestry Commission

Purple emperor butterfly

Research Note

The Environmental Change Network at Alice Holt Research Forest

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The Environmental Change Network (ECN) was established in 1992 to provide a framework for monitoring the effects of a range of environmental drivers on freshwater and terrestrial ecosystems. The Alice Holt ECN site represents the Forestry Commission's commitment to this long-term collaborative programme. This Research Note reviews data collected at the Alice Holt site over 14 years of operation from 1992–2006. Evidence of the impacts of climate change, pollution and their interaction with land management are explored. Monitoring of air quality has demonstrated a decline in the levels of some harmful pollutants and this is reflected in a reduction in soil acidity and resulting changes in plant communities. Meteorological data provide evidence that the climate is changing with significant trends in summer rainfall and winter cold days. Changes in moth populations have been linked to changes in climate while the decline in some butterfly species is identified as a possible consequence of reduction in open space. In contrast, this reduction has benefited several species of ground beetle, which prefer shady conditions. Bird surveys have enabled assessment and identification of possible causes of changes to the woodland bird populations, including those species subject to Biodiversity Action Plans. Similar trends are becoming apparent across the network, providing a robust early warning system for detecting changes in natural ecosystems as the effects of climate change set in.

Forest Research

Introduction

It is now accepted that the climate is warming, largely as a result of anthropogenic emissions of greenhouse gases into the atmosphere. Globally, temperatures have risen by 0.8 °C since the late 19th century and in England 8 of the 12 warmest years on record have occurred since 1995. The Intergovernmental Panel on Climate Change (IPCC, 2007) has concluded that the concentration of carbon dioxide in the atmosphere is likely to rise from the current of value of 383 parts per million (ppm) to between 550 and 700 ppm by the end of the century, leading to a 3–5 °C rise in global temperature. The magnitude and rate of these predicted changes are unprecedented since at least the last glacial period and highlight the need to understand their likely impacts on natural ecosystems. Monitoring the impacts of climate change is an important element of a strategy to forecast and adapt to the threats posed by global climate change. However, climate change is not the only environmental pressure; air pollution, habitat fragmentation and land management practices all affect the functioning of ecosystems. Identifying the cause and effect of individual drivers is a major challenge for environmental monitoring, as it requires that the effects of those drivers are distinguished from background variation.

The Environmental Change Network

The Environmental Change Network (ECN) is a multi-agency, long-term monitoring programme funded by a consortium of sponsoring government departments and agencies. The network (Figure 1) was established in 1992 to provide a long-term integrated monitoring platform that is more likely to detect change than several individual and unconnected components. Existing monitoring methodology was adopted by ECN where feasible, enabling inclusion of existing sites, surveys and networks. In addition, ECN methodology has been integrated into a number of new monitoring initiatives.

Alice Holt Forest is one of 12 terrestrial sites which operate to a uniform system of core measurement protocols. Atmospheric, soil and water chemistry data provide information on abiotic drivers. Indicator species, representing all trophic levels (herbivores, insectivores, decomposers, higher plants), provide information on biotic impacts. The indicator species/genera were selected as those most likely to show an early response to the effects of climate change. These biological indicators and the physical parameters outlined above are listed in Table 1.

Data collected at the ECN sites are available under licence for research purposes and for teaching in schools and universities. The ECN internet site is included in the National Grid for learning and, in 2000, ECN hosted a conference designed to promote the use of environmental data in teaching (www.ecn.ac.uk).

The Alice Holt ECN site

The Alice Holt Forest ECN site (latitude 0°50′W; longitude 51°10′N) occupies a gently sloping plateau on the Surrey–Hampshire border at an altitude of 70–125 m OD. The soils are heavy surface-water gleys derived from drift. Gault clay dominates the underlying geology, with some calcareous Upper Greensand material. The forest probably originated during the Atlantic period (*c.*7800–5700 BP) with pedunculate oak (*Quercus robur*) emerging as the dominant tree species. In 1812 the Crown enclosed the forest and undertook extensive replanting. In the late 19th century, because of poor growth, oaks planted on areas of leached gravel soils were cleared and replanted with coniferous species – primarily Scots pine, Norway spruce and Douglas fir. Ownership and management of the forest was transferred to the Forestry Commission in 1924. The forest is currently dominated by Corsican pine (*Pinus nigra* var. *maritima)* but 140 ha of old-growth oak woodland remain and it is in this area that both extensive and intensive long-term environmental monitoring are being carried out.

Figure 1 Map of Environmental Change Network sites in the UK.

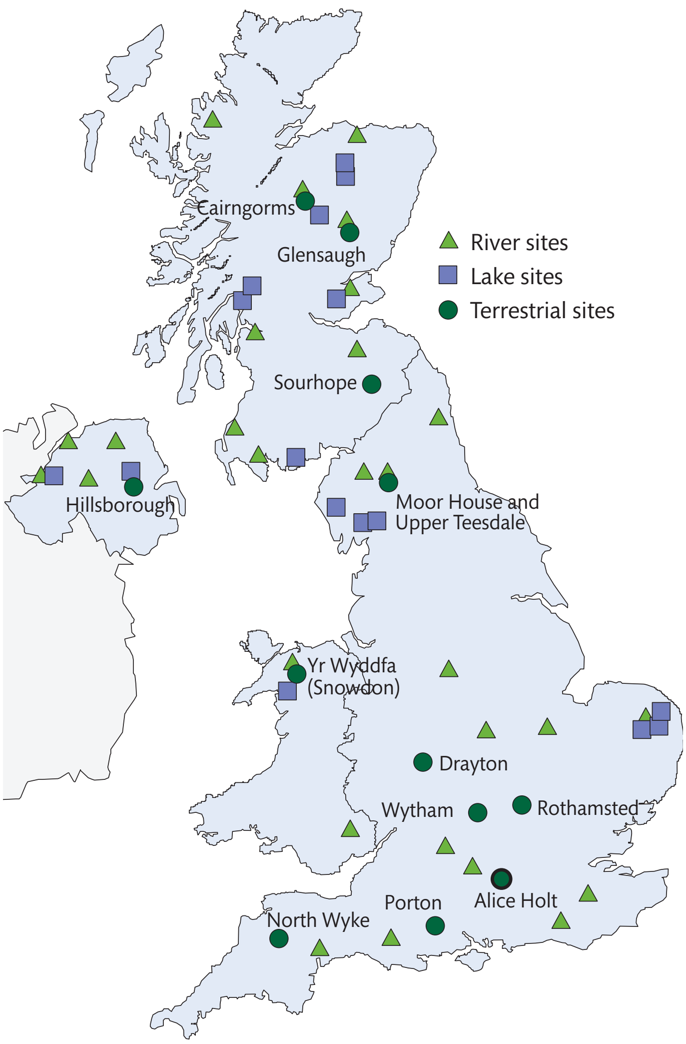


Table 1 Monitoring carried out by the ECN network at Alice Holt since 1994.

Parameter	Measurements	Survey method	Frequency	Surveys prior to 1994
Physical				
Meteorology	Temperature, rain, sun, wind, soil wetness	Manual and automatic	Daily	Since 1949
Precipitation chemistry	pH, conductivity, alkalinity, N, P, K, Ca, Mg, Na, Cl, Al, Fe, NO_3, SO_4, PO_4, TOC, Total N	Chemical analysis	Weekly	
Atmospheric chemistry	Ammonia Oxides of nitrogen Ozone Sulphur dioxide	Alpha sample, denuder tube Diffusion tubes Diffusion tubes Diffusion tubes	Monthly Fortnightly Monthly Monthly	
Soil survey	Soil series	Classification	At start	
Soil chemistry	Chemical and physical characteristics	Various	Every 5 and 20 years	
Soil solution chemistry	pH, conductivity, alkalinity, N, P, K, Ca, Mg, Na, Cl, Al, Fe, NO_3, SO_4, PO_4, TOC, Total N	Chemical analysis	Fortnightly	
Biological				
Vegetation	Canopy structure, vascular plants, seedlings NVC monitoring of vascular plants Mensuration Forest Health Survey	Plot and quadrat counts Plot and quadrat counts Heights and diameters	Every 9 years Every 3 years Every 3 years Annual	Since 1987
Invertebrates	Moths Butterflies Spittle bugs† Ground beetles	Rothamsted Insect Survey National Butterfly Monitoring Scheme Quadrat counts Pitfall traps	Daily Annually (Mar–Oct) Twice yearly (Jun, Aug) Annually (Apr–Oct)	Since 1966
Vertebrates	Birds Deer Bats Rabbits†	CBS and BBS Dung counts, infrared counts Activity Dung counts	Annually Twice yearly (Mar, Sep) Annually (Jun–Sep) Twice yearly (Mar, Sep)	

† Data collected at Alice Holt not represented in this Research Note.

Drivers of ecosystem function

Woodland management

The Forestry Commission is committed to sustainable forest management and this requires an understanding of the effects of management practice on woodland ecosystem function, associated biodiversity and the environment. Social and biodiversity objectives are now key priorities for woodland management, and in many cases these have replaced economics and timber production as the principal objectives. These changes in approach to management place different pressures on forests. Integrated monitoring provides the contextual detail that can help to explain the large variations found in biological data and help to interpret interactions between management and a range of environmental drivers, such as climate and atmospheric chemistry.

Recreation and education

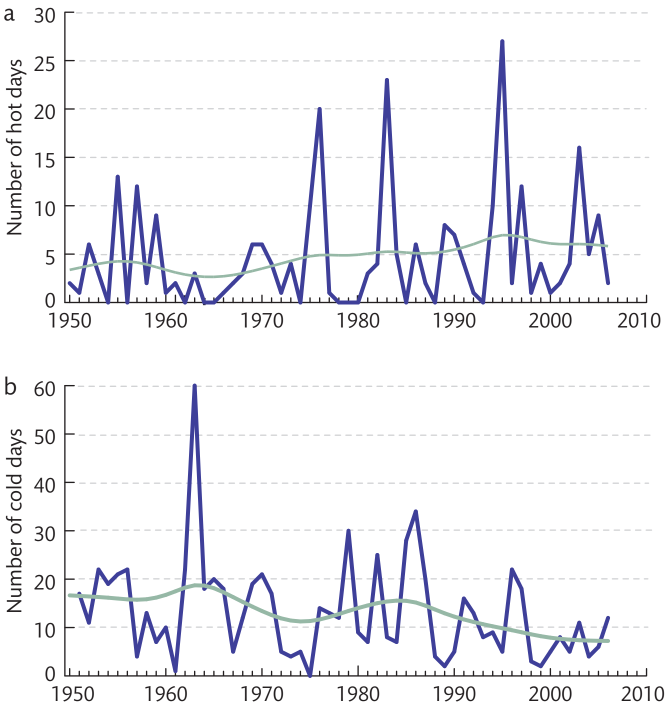
Well-managed forests can enhance quality of life; woodlands are now promoted for their contribution to a healthy lifestyle, and this requires additional infrastructure and increases visitor pressure. This trend is likely to continue in response to initiatives such as 'active woods', 'nature's health service' (O'Brien, 2005) and 'forest schools' (O'Brien, 2006). Sixteen hectares of Alice Holt Forest are devoted solely to recreational use and numerous new footpaths and cycle paths have been established in recent years. This has led to an increase in people using the forest from 197 000 visitors in 2001 to over 250 000 in 2006 – a trend that is likely to continue.

Climate

The climate at Alice Holt Forest is characteristic of southeast England, with the growing season typically extending from mid-March to November. Average annual (1994–2006) temperature is 10.1 °C with January normally the coldest month (4 °C) and July usually the hottest month (19 °C). Mean annual rainfall is 803 mm with November usually the wettest month (85 mm) and July the driest month (56 mm).

There is already evidence of a systematic change in seasonality of precipitation in Alice Holt Forest, with wetter winters and drier summers in recent years. The summers of 1995, 1996 and 2003 were some of the driest on record, while 2005 was the driest year since records began at Alice Holt in 1949. Average air temperatures are rising and the number of cold days (mean temperature <0 °C) in winter has decreased significantly (Figure 2a and b).

Figure 2 Trend in the number of (a) hot and (b) cold days at Alice Holt since 1947.



Climate change scenarios for the UK have been prepared by the Tyndall and Hadley Centres and published by the UK Climate Impacts Programme (the UKCIP02 scenarios: Hulme *et al.*, 2002). These scenarios indicate that by the 2080s average summer temperature in the southeast could be between 3 °C and 6 °C higher than the 1994–2006 average. Lower summer rainfall (up to 50% less) combined with higher temperatures will lead to more frequent and severe periods of drought. Cloud cover and relative humidity are predicted to decline.

Atmospheric chemistry

Nitrogen dioxide and ammonia

Power stations and transport are the main sources of nitrogen dioxide (NO_2) and natural sources such as fires, lightning and biological processes are minor in comparison. In rural areas, ammonia (NH_3) emissions from agriculture can dominate nitrogen deposition. Nitrogen is an essential nutrient for the growth of plants, but can have detrimental effects when they receive more than they need, making plants more susceptible to frost damage, disease and insect attack (NEGTAP, 2001). Nitrification of ammonia to nitrate in soil also contributes to soil acidification. More importantly for forest ecosystem function, vegetation community structure is affected by nitrogen availability (from both NO_2 and NH_3) and evidence is emerging of a change in ground vegetation towards more nitrogen demanding species (see section on vegetation, pages 6–7). Eutrophication (excess nitrogen deposition) is a particularly serious problem for nutrient poor communities such as heathland.

The 'critical load' approach is used to identify areas where exposure to a pollutant is higher than an ecosystem can withstand in the long term. For nitrogen, 98% of broadleaved woodland in the UK receives more than the threshold value. Annual average NO_2 concentrations at Alice Holt declined between 1994 and 2000, a trend shared by all ECN sites (Figure 3). However, levels have subsequently risen. Ammonia concentrations have been monitored at Alice Holt since 1996. Concentrations are highly variable with no clear temporal or spatial variation, and the mean concentration of 1.06 μg m^{-3} is well below the critical load of 8 μg m^{-3}, as an annual average (Figure 4).

Figure 3 Mean annual nitrogen dioxide concentration 1996–2006.

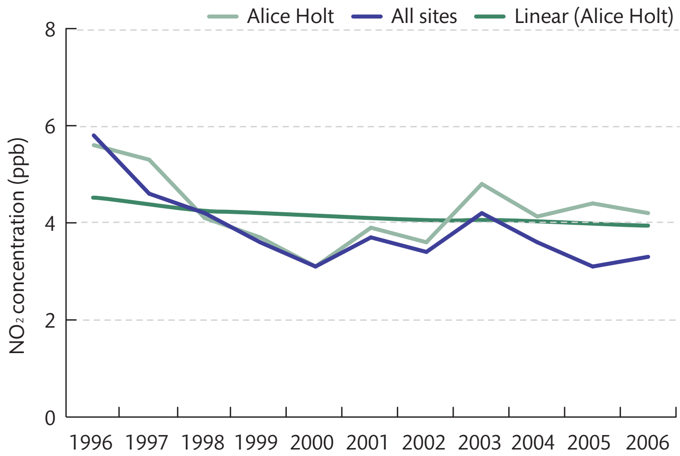
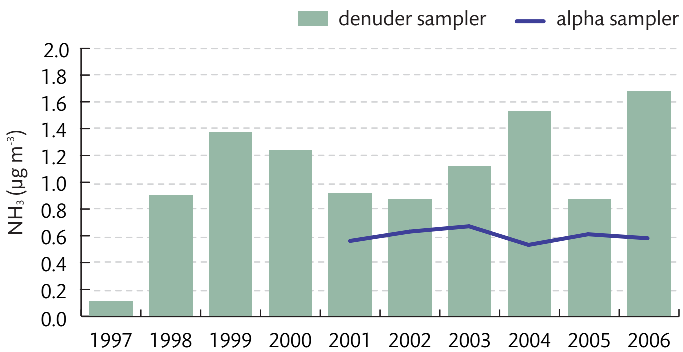


Figure 4 Mean annual ammonia concentrations 1997–2006.

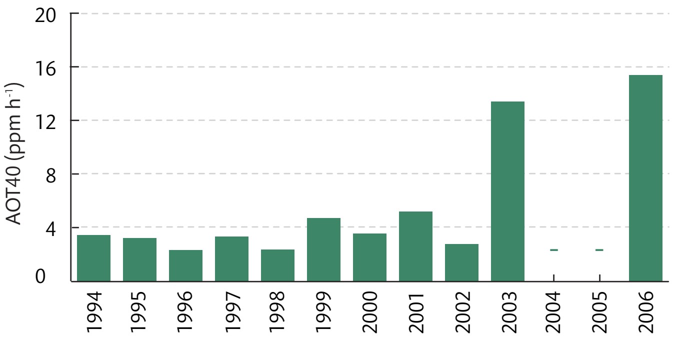


Ozone

Ozone (O_3) exists naturally in the stratosphere where it protects the earth from ultraviolet radiation. It also occurs naturally in the lower atmosphere at low concentrations. However, concentrations have increased since industrialisation as a result of a series of chemical reactions involving man-made volatile organic carbon compounds and nitrogen oxides, catalysed by sunlight. Peak ozone levels in the lower atmosphere have fallen in recent years, but background levels have been, and are predicted to continue, increasing as a result of the rise in emissions of the precursers to ozone formation. Unlike other pollutants, ozone concentration has a close relationship with climate variables. Polluted, slow-moving air of continental origin can lead to very high concentrations of ozone in the southeast of England.

High ozone concentrations affect the photosynthetic capability of plants by damaging the internal leaf structure leading to leaf tissue necrosis and early senescence. Accumulated O_3 exposure over a threshold of 40 ppb (AOT40) is calculated as the product of time and concentration (Figure 5). The critical level for forest trees has been set at 5 ppm h between April and September (Karlsson *et al.*, 2004), and this value is exceeded at the Alice Holt ECN site in some years. Predictions are for concentrations to continue to rise as a result of continuing precursor emissions, higher temperatures and reduced cloud cover (NEGTAP, 2001).

Figure 5 Ozone AOT40 values for each year at Alice Holt between 1994 and 2006; 2004 and 2005 values not available.



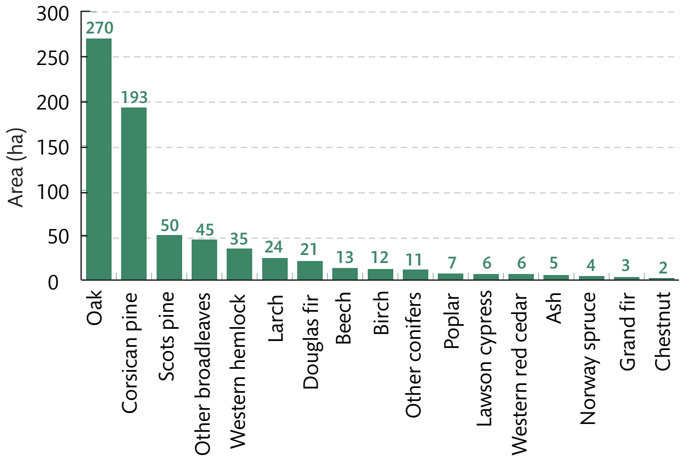
Sulphur dioxide

There has been a steady and marked decline in sulphur dioxide (SO_2) concentrations since the 1980s, initially achieved by emission controls on the power industry and continuing through the introduction of low-sulphur transport fuels. SO_2 levels measured at Alice Holt are usually close to the detection limits of the instrumentation and are not considered to be a threat.

Land use and land cover change

The Forestry Commission gave some woodlands in Britain special status in the late 1980s recognising that they were of special interest. These included Alice Holt Forest as well as the native broadleaved areas of the old inclosures of the Royal Forests. Ancient Semi-Natural Woodland (ASNW) is recognised as being of significant value for biodiversity. In Britain, around 300 000 ha of ASNWs still exist, although 44% are now planted with conifers, broadleaves or a mixture of the two (Pryor and Smith, 2002). *The UK Forestry Standard* (Forestry Commission, 2004) sets out the Government's commitment to the restoration of planted ancient woodland sites (PAWS). Within Alice Holt Forest there are 502 ha of PAWS consisting mainly of Corsican and Scots pine plantations (Figure 6). Of this, approximately 450 ha will be returned to native woodland over the next 100 years.

Figure 6 Tree species composition of Alice Holt Forest (2003).



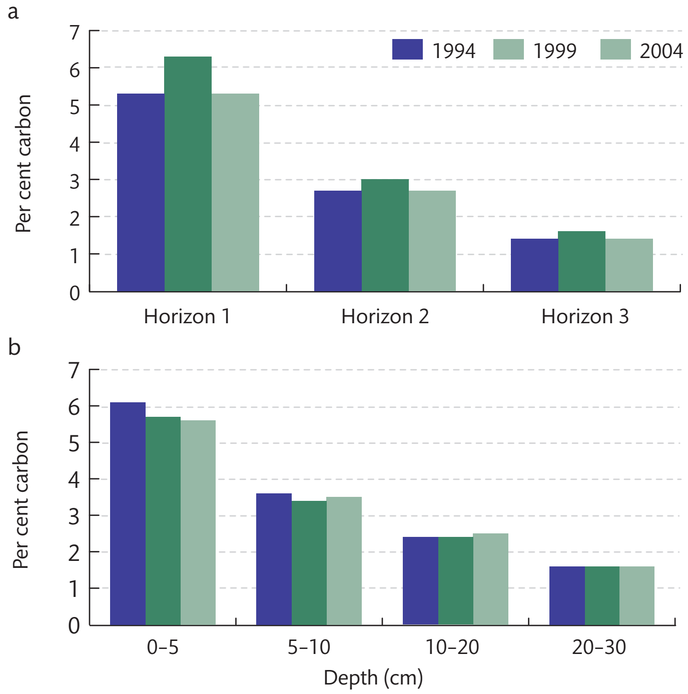
Indicators of ecosystem function

Soil chemistry

The accumulation or loss of soil organic carbon and nitrogen is dependent on complex climatic interactions. These can act directly on soil processes such as decomposition and chemical transformation, and indirectly by affecting productivity and the input of litter to the soil. Increased nitrate leaching from forest systems has been widely reported: signs of forest damage are linked to the input of atmospheric nitrogen. Nitrate is mobile in soil water and if present in excess of plant uptake can be leached out to surface waters, accompanied by aluminium on acidic soils. At Alice Holt there is no evidence of these processes occurring. Analysis of soil water chemistry has shown no significant changes over time. Nitrate and aluminium concentrations have remained within a constant range, with no evidence of increased leaching. Sulphate levels in the deep (50 cm) soil solution samples indicate a slight downward trend.

Soil properties at the ECN plots have been extensively assessed and characterised every five years (1994, 1999 and 2004). Soils have been sampled by both depth and horizon. Analysis suggests that the soil has become less acid as a result of the decrease in deposition of acidifying compounds, reflecting the success of emissions control measures for sulphur and nitrogen. This reduction is consistent with the findings of Kirby *et al.* (2005) for 103 woodland plots in Britain over a period of 30 years. While Bellamy *et al.* (2005) reported a loss of soil carbon from mineral soils under most land uses, including forestry, in England and Wales over the past 25 years, Alice Holt soil data show no change in carbon when analysed by horizon (Figure 7a) or depth (Figure 7b).

Figure 7 Average organic carbon by (a) horizon and (b) depth.



Field layer vegetation assessment

The structure and composition of the ground flora dictate the quality of the habitat for other trophic levels and are affected by a range of environmental drivers. Together they form a key component and indicator of ecological condition. The spatial distribution patterns of vegetation show a strong correlation with climate and the predicted increase in mean annual temperature of 2.0 °C to 4.5 °C could substantially change the composition of woodland ground flora. Climate and climate change can impact on both individual plants/populations and communities. Data collected within ECN can be used to identify these trends.

At Alice Holt, by classifying data obtained from the vascular plant surveys by the age of the canopy it is growing beneath (chronosequencing), an investigation into the effects of climate change on two major forest species Corsican pine (*Pinus nigra* var. *maritima*) and oak (*Quercus robur)* has been carried out. Using a system developed by Preston and Hill (1997), we have examined whether the balances of northern/southern species are changing in terms of continentality and temperature cline.

Corsican pine stands showed a slight but non-significant increase in continentality and temperature in mature trees with a tendency towards plants associated with wetter conditions. No changes in ground vegetation associated with oak stands were found. The lack of change is not surprising since understorey vegetation is well buffered by the canopy and climate effects would have to be prolonged or severe to register. Changes have, however, been observed at other ECN sites on less buffered systems. Woodland vegetation communities at upland sites, including some dominated by bracken, seem to show a decrease in southern components, while intensively managed grassland showed signs of an increase (Morecroft, 2004).

Reanalysing the Alice Holt data using British adjusted Ellenberg indicator values (Hill *et al.*, 1999) allows assessment of plant requirement with age according to their habitat and environmental requirements. Under this system each plant and bryophyte recorded is assigned a score for light, water, nitrogen and pH preference. Corsican pine showed the greatest change in age with significant differences detected for all indicators (Figure 8a–d). Oak showed significant differences in light, pH and nitrogen levels (Figure 8e, g and h), though light and nitrogen are in the opposite direction to those seen in the pine. No change was seen in water requirement for oak (Figure 8f). Both woodland types showed a significant increase in nitrogen levels with the age of the crop. This has implications for woodland vegetation surveys as nitrogen increase in ageing stands may be misinterpreted as being caused by nitrogen pollution.

Carbon balance

Forest carbon sequestration is dependent on factors such as tree species, stand density and age. Temperature, CO_2 levels, nutrient availability and thinning can all have a positive influence on tree growth. Change in carbon stocks in Alice Holt Forest have been modelled over time (model: BSORT) by using forest management records (Table 2).

Increases of 9500 tonnes of carbon per year, equivalent to one tonne per hectare per year, are in line with the national estimates even after the loss of 38 hectares due to forest restructuring.

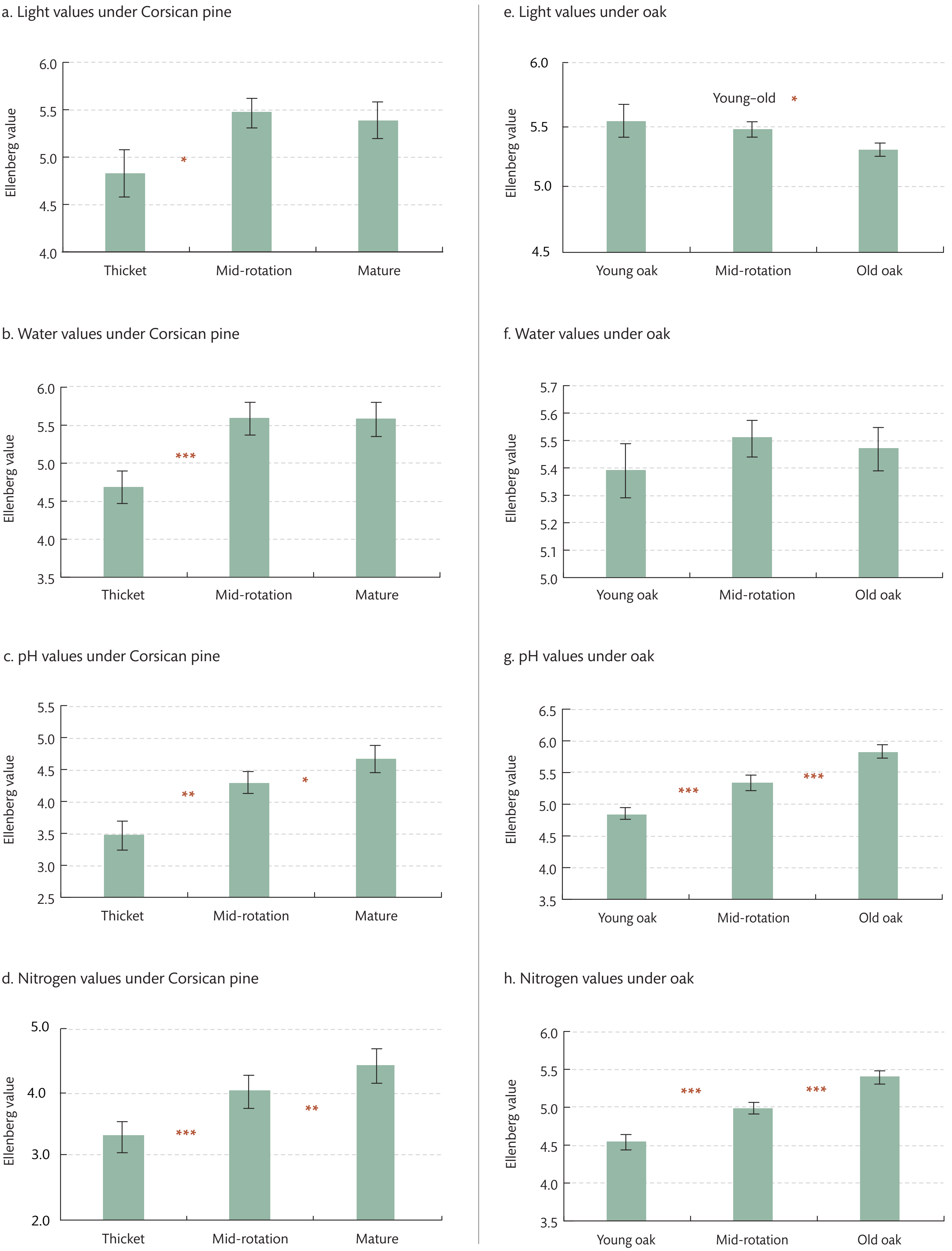
Table 2 Carbon stock change in Alice Holt Forest 1993–2002.

Above ground woody biomass	Area	Stem	Lop & top	Branch	Total	tC ha^{-1}	tC ha^{-1} yr^{-1}
Biomass 1993	765.5	52 148	1648	20 789	74 585	49	
Biomass 2002	727.6	61 045	1457	21 572	84 074	58	
Biomass change	-37.9	8 897	-190	783	9 490	9.1	1.0

Tree growth

The majority of tree species native to the UK are tolerant of a range of environmental conditions and are unlikely to disappear from southern England: their European distribution is testament to this. However, competition between species, their growth rates and distribution is likely to change as a result of climate

Figure 8 Ellenberg values on a chronosequence of Corsican pine (a–d) and oak (e–h); significance level is demonstrated by * ** ***.



change. Dendrochronological evidence from Alice Holt Forest highlights the impact of summer drought on diameter growth of Scots pine and oak (Figure 9), with summers such as those of 1976, 1984 and 1995 resulting in a decline in growth for 2–3 years. A longer chronology for oak (Figure 10) again shows a high level of inter-annual variation but also an apparent increase in growth rate since the late 1970s, which may be a result of rising levels of CO_2 in the atmosphere.

Figure 9 Dendrochronological record for Scots pine and oak.

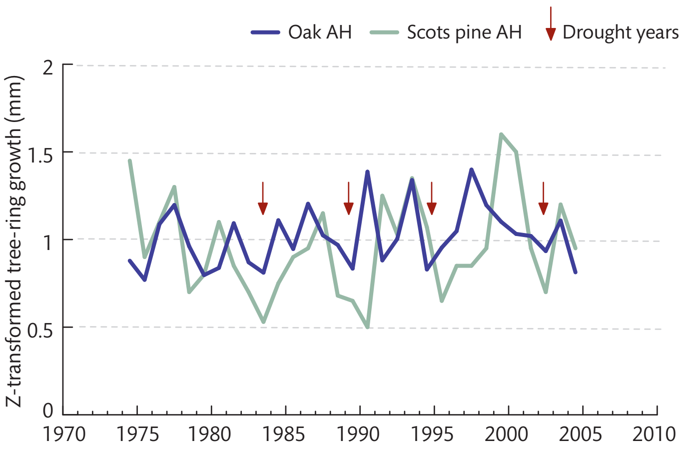
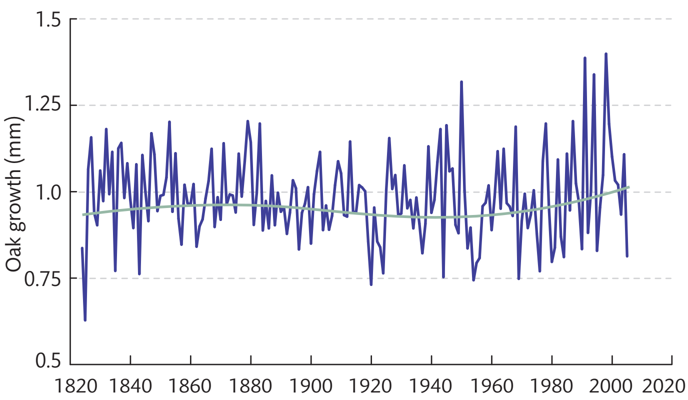


Figure 10 Oak chronology from Alice Holt Forest showing an increase in growth over the past two decades.



Invertebrates

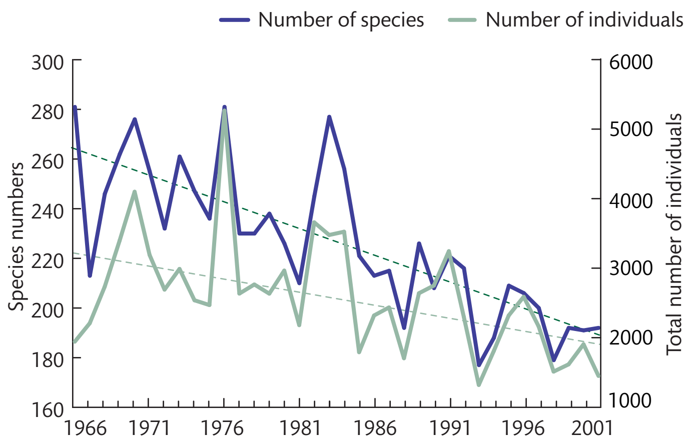
Some forest invertebrates damage trees and their impact is dependent on their abundance. Warmer temperatures could increase pest survival and the number of generations in a season, while drought stress would reduce the ability of plants to resist attack. Alternatively, higher temperatures may lead to more rapid plant development, leaving less time for pests to attack. Predictions about range expansions and migrant invasions are generally based on knowledge of the relationship between species biology and climatic variables, particularly temperature and precipitation (Turner *et al.*, 1987; Pollard, 1988). Tracking trends in local species demography provides an opportunity to relate community-wide changes to changes in environmental conditions, and to assess the relative impact of habitat disturbance and climate change.

Moths

As leaf flushing dates of trees and shrubs get earlier the moths that rely on these plants as a food source will need to modify their life cycle to survive. Records of moths and climate, collected over 36 years at the Alice Holt site, were summarised and used to examine trends in species abundance and numbers of species occurring in relation to climatic data (Pitts *et al.*, 2005).

The total number of moth species declined significantly during the period 1966–2001 with an average loss of about two species per year (Figure 11). Examining the relationship between climate and moth abundance showed that summer temperature has a significant positive effect and winter precipitation a negative effect. The results are in line with those of other studies which indicate a general 60% decline in national macrolepidoptera numbers since 1930 (Woiwod, 2003).

Figure 11 Variation in the total numbers of individuals and species of moths collected at Alice Holt, 1966–2001.



Trees in the UK are defoliated by several species of moth. Particular attention has been given to species which are known to favour broadleaved trees, in order to identify how the health and productivity of these trees might be affected in the future. Among the key species showing a negative trend were winter moth (*Operophtea brumata*) and mottled umber (*Erannis defoliaria*), both known to be responsible for episodes of broadleaved tree defoliation in the UK . The decline in abundance of these species suggests that there is likely to be a reduction in risk of defoliation in the future. The decline in moth numbers at Alice Holt and the reasons for extinction of resident species remain largely unknown. Research has shown that moths and oak trees use different temperature mechanisms to time life cycle events. This has led to a breakdown in the synchronisation of their life cycles with moths hatching up to three weeks before oak bud burst (Visser and Holleman, 2001). In isolation, climate change would be expected to benefit winter moth, but the loss of synchrony between flushing of oak and caterpillar emergence would have the opposite effect. Analysis of records from a nearby oak forest in Surrey shows that the flushing date of oak has advanced by two weeks since the 1950s (Sparks and Gill, 2002).

Butterflies

The trend towards warmer temperatures has favoured an increase in the number of butterfly species and an increase in population numbers. For example, the common blue (*Polyommatus icarus*) has shown an increased distribution across the UK in recent years. The large skipper (*Ochlodes sylvanus)* was predicted by the MONARCH (Modelling Natural Resource Response to Climate Change) project to be a species likely to expand its range into higher altitudes (Harrison *et al*., 2001). Although no evidence for this has yet been seen, ECN sites are well placed to identify this change if it occurs. Migrant species such as the painted lady (*Vanessa cardui*), red admiral (*Vanessa atalanta*) and clouded yellow (*Colias croceus*) may be expected to successfully overwinter as a result of climate warming. Analysis of the Alice Holt data set does not support this hypothesis. Apart from a 'freak' event in 1996, which saw large numbers of painted ladies and red admirals blown in from the continent, numbers have remained constant.

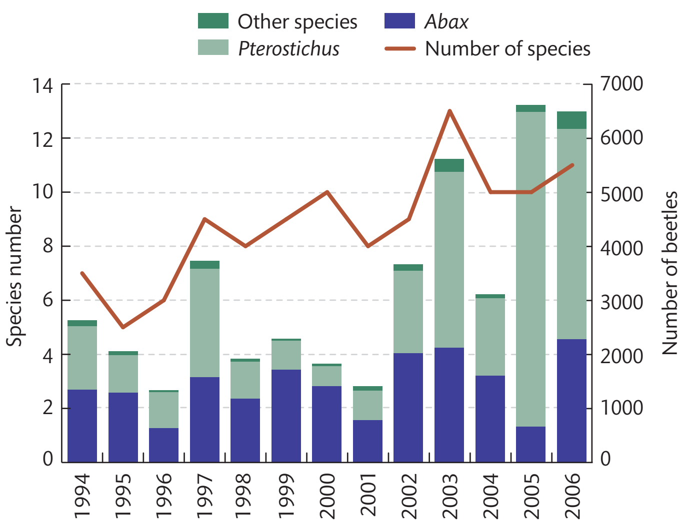
The first appearance of orange tips (*Anthochari*s *cardamines*) has been adopted as a UK government indicator of climate change (Defra, 2003). Analysis of first appearance and peak flight data should show an advance with warming temperatures. The data from the Alice Holt ECN site do not support these findings. The orange tip has shown a significant decline in numbers (p=0.05) over the survey period with peak flight times becoming later rather than earlier at the site. Five other species: comma (*Polygonia c-album*), small skipper (*Thymelicus sylvestris*), large skipper, purple hairstreak (*Neozephyrus quercus*) and white admiral (*Limenitis camilla*) also showed significant declines (p=0.05). This indicates that at the ECN site other factors are overriding the positive effects of temperature. Changing agricultural practices, habitat management and loss of habitat have been implicated as factors in the decline of moths and butterflies in the UK (Asher *et al*., 2001). At a broad scale, habitats in Alice Holt Forest have changed little over the past 40 years, but reduction in ride management and ageing of the crop has led to many rides becoming overgrown and has consequently reduced the number of open spaces available. Changes in land use in the area surrounding the forest may also be having an effect on butterfly populations.

Ground beetles

Ground beetles (*Carabidae)* are a predatory group and can respond to changes in distribution of their prey. At Alice Holt, 97% of beetles caught are of two species – *Abax parallelepipedus* and *Pterostichus madidus* (Figure 12). The latter is known to be sensitive to changes in temperature; Thiele (1977) demonstrated a morphological variation in colour of beetle legs over temperature clines.

Although very variable in number, most beetle populations at Alice Holt have remained stable over time (Figure 12). Three species, *Cychrus caraboides, Nebrai brevicollis* and *Notiophilus biguttatus* have increased significantly in numbers in the past ten years. *C. caraboides* and *N. brevicollis* prefer damp conditions with the latter often found under dead bark. *N. biguttatus* has no particular habitat preference. There are a number of factors which could be responsible for the rise in numbers, including an increase in food availability, decrease in predation or habitat change. The most likely reasons are the increase in litter accumulation (evident from the soil survey), dead wood associated with the natural stand ageing process and shade as the canopy ages and the hazel understorey develops.

Figure 12 Trend in beetle populations at Alice Holt 1994–2006.



Vertebrates

Birds

Bird populations are recognised as good indicators of the general environmental status of the countryside on account of their varied ecology and widespread distribution across the UK. The Woodland Bird Index for the UK, which relies on data from the Common Bird Survey (CBS) and Breeding Bird Survey (BBS), showed a 20% decrease in the population of woodland birds from 1970 to 2002. The main casualties were specialists such as the lesser-spotted woodpecker (*Dendrocopos minor*) and migrants such as the spotted flycatcher (*Muscicapa striata*) and willow warbler (*Phylloscopus trochilus*). Nationally, the more generalist woodland birds such as chaffinch (*Fringilla coelebs*) and robin (*Erithacus rubecula*) are maintaining stable populations. Species such as the wren (*Troglodytes troglodytes*) and long-tailed tit (*Aegithalos caudatus*) have increased in numbers, benefiting from the milder winters and warmer spring conditions leading to more successful reproduction. Migrant species such as the black cap (*Sylvia atricapilla*) and chiffchaff (*Phylloscopus collybita*) are doing well and many are now overwintering in our warmer climate.

The most bird-diverse woodlands in the UK tend to be the Ancient Woodland sites. Much of this woodland is identified in the UK Biodiversity Action Plan (BAP; GB Parliament, 1994). The BAP lists bird species according to three levels. Red list species are those showing a decline in population >50% in the past 25 years; amber species have suffered a 20–50% loss; and green list species are considered to be at no significant risk. The type of monitoring carried out at ECN sites is well placed to evaluate population dynamics and also to identify possible causal factors.

In general, woodland bird populations are increasing at Alice Holt (Figure 13). Of the 26 woodland bird species recorded between 1994 and 2006, five are red listed and seven are amber. Of the red list species, lesser-spotted woodpeckers have not been recorded since 1994 while marsh tits (*Poecile palustris*) and bullfinch (*Pyrrhula pyrrhula*) disappeared between 1998 and 1999 respectively. Spotted flycatchers have not been seen since 2001. Willow tits (*Poecile montanus*) were last seen in 2003. Song thrush (*Turdus philomelos*) showed a steady increase until 2000, and numbers have since stabilised across the forest. On the amber list, the cuckoo (*Cuculus canorus*), green wood-peckers (*Picus viridis*), willow warblers and woodcock (*Scolopax rusticola*) have all maintained small populations. Recent surveys across the country have shown a serious 56% decline in cuckoo numbers since 1977. The reasons are complex and include a shortage of hairy caterpillars, a major part of their diet (Glue, 2006). The goldcrest (*Regulus regulus*) and dunnock (*Prunella modularis*) have shown an increase in population size.

Changes in forest practice, including non-removal of deadwood, are likely to have had a positive effect on bird populations, while predation of eggs by grey squirrels and removal of the shrub layer due to grazing by deer have been shown to have a significant negative effect. Climatic factors also play a major role. Recent mild winters increase the survival chances of small birds, and have allowed previously migrant species to overwinter. Species susceptible to cold weather are benefiting from climate warming, although early nesting could increase mortality when late frosts occur. Milder winters and warmer springs may lead to an increase in food availability or a decline as pest emergence/egg hatching move out of synchronisation.

Deer

Browsing mammals such as deer and rabbits have a significant effect on their environment and deer numbers have been shown to have a dramatic effect on woodland structure. It is therefore important to know numbers in order to estimate any effect on vegetation caused by populations, rather than, or even as a result of, the effects of climate change. Monitoring of deer numbers has shown a significant decline in deer densities at the ECN site since 1995 (Table 3). Grazing by deer is known to have a significant effect on some bird species populations; overgrazing can reduce the amount of shrub layer and hence nesting sites. However, at Alice Holt, both seedling survival and shrub layer have increased since 1994 as deer densities have fallen (Figure 14a and b). This is reflected by the general increase in woodland bird populations observed as previously mentioned.

Figure 13 Bird population trends at Alice Holt between 1997 and 2006 (Common Bird Survey).

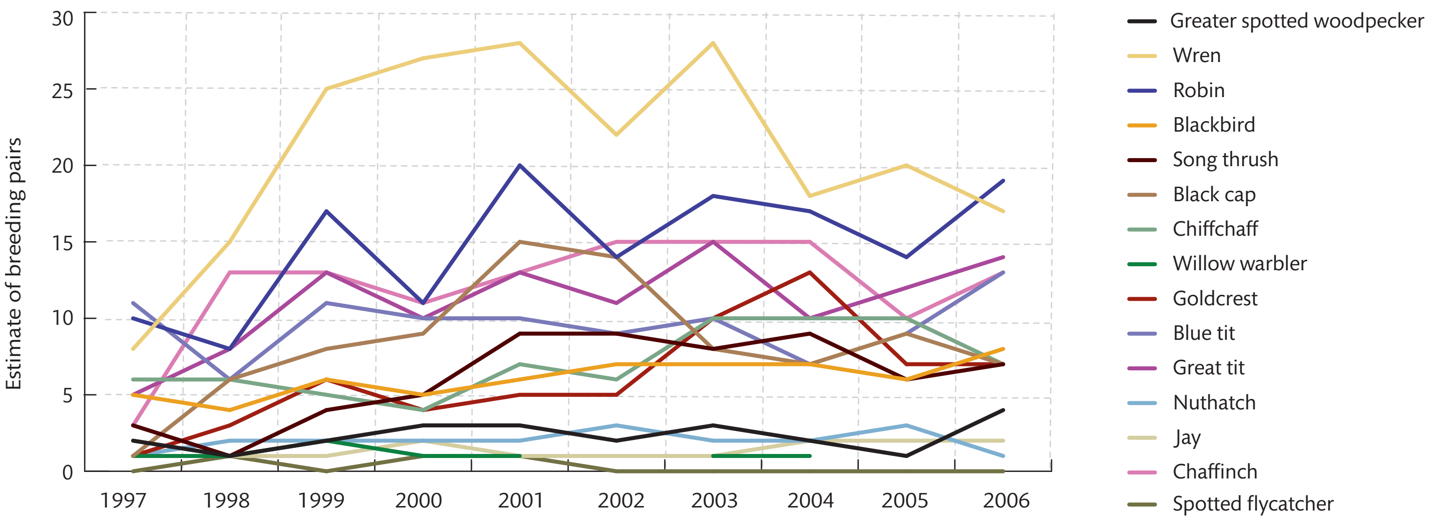
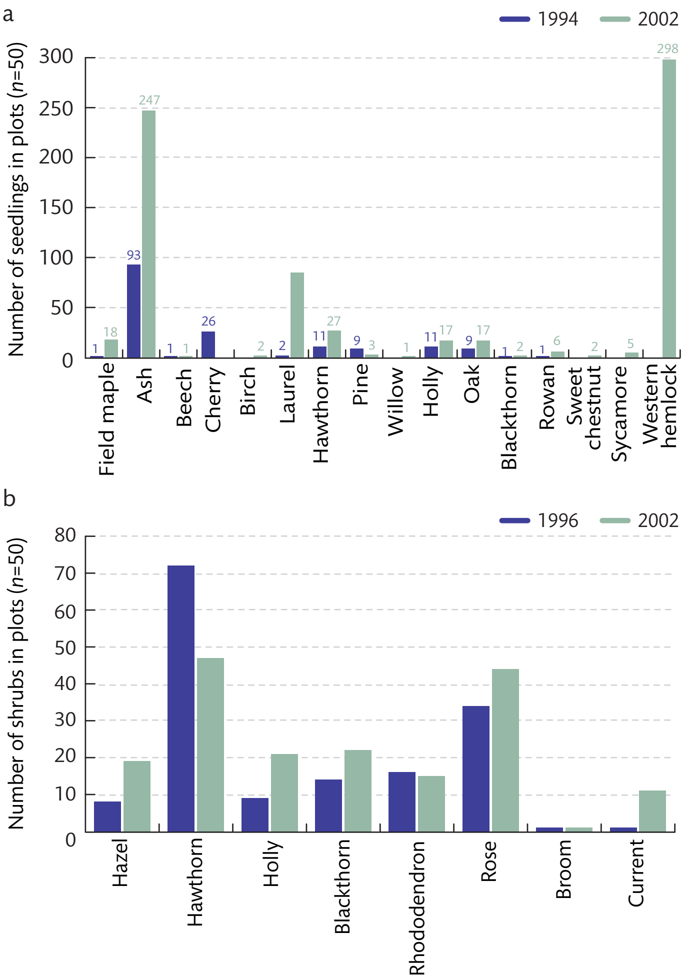


Table 3 Decline in deer densities in Alice Holt Forest.

Year	Density (deer per km^2)
1995	20.9
1998	16.4
2003	14.0

Figure 14 General increase in (a) seedling survival and (b) shrub layer since 1994 as deer densities have fallen.



Bats

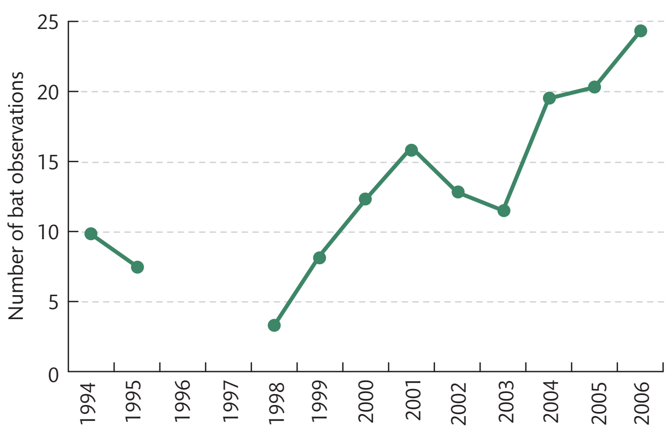
Bats are sensitive to alterations to their environment such as habitat loss, changes to commuting routes, roost destruction, pesticide poisoning and changes in climate. In examining the effects of environmental change, both large-scale change and small modifications to habitat will have a significant impact. Bats rely on trees as roosting sites, changing sites as temperature and humidity vary in order to maintain suitable environmental conditions. Geographical features such as rides and hedgerows are used to navigate between roost sites and feeding grounds. Warmer temperatures are expected to lead to a movement in the northern limits of some bat species, but this effect may be complicated by such factors as loss of roost sites, flight line features and feeding habitats.

In the UK bats hibernate throughout the winter to avoid food shortages, emerging in spring to feed and breed. Changes in the internal temperature of roost sites as the climate warms may force bats to abandon traditional hibernaculars and attempt to find new sites. Warmer winters and milder springs could lead to alterations in hibernation patterns. Pipistrelle bats take advantage of warm winter evenings (over 10 °C) to emerge and feed, leading to reduced risk of winter fatality. However, increased precipitation in spring may make it difficult for the newly emerged bats to find food and, because of their low reproductive rate, individual populations are highly vulnerable.

At the Alice Holt ECN site, the most common bat species is the common pipistrelle (*Pipistrellus pipistrellus*), considered to be the most widespread and abundant bat in Europe, including the UK (Stebbing and Griffiths, 1986). Other bats recorded at the site are the soprano pipistrelle (*Pipistrellus pygmaeus*), serotine (*Eptesicus serotinus*) and the noctule (*Nyctalus noctula*). The years since 1999 have been some of the warmest on record with higher summer temperatures and a decrease in cold days in winter. Analysis of the bat data shows a significant increase in activity measured by the number of observations made; this is associated with an increase in bat numbers at the site (Figure 15).

Although the overall habitat of Alice Holt Forest has not changed over the sampling period, localised activities have affected bat activity in specific areas. In 2000/2001, thinning was carried out in the compartments adjacent to the monitoring transect. A corresponding increase in bat activity in this area was recorded in the years following this work. It was noticeable, however, that despite the increase in activity, there was a decrease in feeding in this area in the year following the thinning. In 2003, forest operations in the area led to a corresponding drop in bat numbers immediately following this work, probably as a result of disturbance. By the following year, numbers had returned to previously observed levels.

Figure 15 Bat activity at Alice Holt between 1994 and 2006; no data recorded for 1996 and 1997.



Conclusions

The detection and monitoring of environmental change requires intensive monitoring of whole ecosystems. The ECN enables us to identify change within this context. Its use of common protocols provides links with other national, European and worldwide networks. The ECN site at Alice Holt provides ecological records to aid interpretation of interactions within the forest environment. It is relevant to sustainable forest management, the scientific community, forest managers and the wider public. It allows us to focus on the effects of both pollution and climate change and their interactions with biodiversity, soil and air quality; and it provides input to UK forestry policy. Initial findings of this short data set have proven the effectiveness of ECN. Some of the main causes and effects of change both to the forest structure and its associated biodiversity have been identified. ECN is proving itself to be an effective early warning system for environmental change effects and a comprehensive way of gaining information on the effect of management practices and land use changes.

References

ASHER, J., WARREN, M., FOX, R., HARDING, P., JEFFCOATE, G. and JEFFCOATE, S., EDS (2001). *The millennium atlas of butterflies in Britain and Ireland*. Oxford University Press, Oxford.

BELLAMY, P.H., LOVELAND, P.J., BRADLEY, R.I., LARK, R.M. and KIRK, G.J.D. (2005). Carbon losses from all soils across England and Wales 1978–2003. *Nature* **437**, 245–248.

DEFRA (2003). *Review of UK climate change indicators (revised 2004).* Contract EPG 1/1/158. Department for Environment, Food and Rural Affairs, London. www.ecn.ac.uk/iccuk

FORESTRY COMMISSION (2004). *The UK forestry standard: the government's approach to sustainable forestry*. Forestry Commission, Edinburgh.

GB PARLIAMENT (1994). *Biodiversity: the UK Action Plan*. Summary Report. HMSO, London.

GLUE, D.E. (2006). Cuckoos in crisis. *BTO News* **263**, 22–23.

HARRISON, P.A., BERRY, P.M. and DAWSON, T.P., EDS (2001). *Climate change and nature conservation in Britain and Ireland: modelling natural resources response to climate change (the MONARCH project).* UKCIP Technical Report, Oxford.

HILL, M.O., MOUNTFORD, J.O., ROY, D.B. and BUNCE, R.G.H. (1999). *Ellenberg's indicator values for British plants. ECOFACT volume 2, technical annex.* ITE Monkswood, Huntingdon. Department of the Environment, Transport and the Regions, London.

HULME, M., JENKINS, G., LU, X., TURNPENNY, J.R., MITCHELL, T.D., JONES, R.G., LOWE, J., MURPHY, J.M., HASSELL, D., BOORMAN, P., MCDONALD, R. and HILL, S. (2002). *Climate change scenarios for the United Kingdom: the UKCIP02 scientific report.* Tyndall Centre for Climate Change Research, UEA, Norwich.

IPCC (2007). *Climate change 2007: the physical science basis,* eds S Solomon, D Qin, M Manning, Z Chen, M Marquis, K B Averyt, M Tignor, and H L Miller. Contribution of Working Group 1 to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge.

KARLSSON, P.E., UDDLING, J., BRAUN, S., BROADMEADOW, M., ELVIRA, S., GIMENO, B.S., LE THIEC, D., OKSANEN, E., VANDERMEIREN, K., WILKINSON, M., CEULEMANS, R. and EMBERSON, L. (2004). Dose-response relationships for ozone impact on the biomass accumulation of young trees based on cumulative leaf ozone uptake. *Atmospheric Environment* **38**, 2283–2294.

KIRBY, K.J., SMART, S.M., BLACK, H.I.J., BUNCE, R.G.H., CORNEY, P.M. and SMITHERS, R.J. (2005). *Long term ecological change in British woodland (1971–2001)*. English Nature Research Reports 653. English Nature, Peterborough.

MORECROFT, M. (2004). Plotting change. Vegetation change at ECN sites from 1993– 2002. *ECN News* **16**, 6–7.

NEGTAP (2001). *Transboundary air pollution: acidification, eutrophication and ground level ozone in the UK.* Report of the National Group on Transboundary Air Pollution. Defra, London.

O'BRIEN, L. (2005). *Trees and woodlands: nature's health service*. Forest Research, Farnham.

O'BRIEN, L. (2006). *A marvellous opportunity for children to learn. A participatory evaluation of Forest School in England and Wales*. Forest Research, Farnham.

PITTS, A., BENHAM, S., STRAW, N.A. and MOFFAT, A.J. (2005). Evaluation of moth-trap data from Alice Holt Forest, Hampshire, 1966–2001: possible effects of changing climate on Macrolepidoptera. *Entomologist's Gazette* **56**, 237–247.

POLLARD, E. (1988). Temperature, rainfall and butterfly numbers. *Journal of Applied Ecology* **25**, 819–828.

PRESTON, C.D. and HILL, M.O. (1997). The geographical relationship of British and Irish vascular plants. *Botanical Journal of the Linnean Society* **124**, 1–120.

PRYOR, S.N. and SMITH, S. (2002). *The area and composition of plantations on ancient woodland sites*. The Woodland Trust, Grantham.

SPARKS, T. and GILL, R. (2002). Climate change and the seasonality of woodland flora and fauna. In: *Climate change: impacts on UK forests*, ed. M. Broadmeadow. Forestry Commission, Edinburgh, 69–82.

STEBBING, R.E. and GRIFFITHS, F. (1986). *Distribution and status of bats in Europe*. Institute of Terrestrial Ecology, Huntingdon.

THIELE, H.U. (1977). *Carabid beetles in their environments*. Springer-Verlag, Berlin.

VISSER, M.E. and HOLLEMAN, L.J.M. (2001). Warmer springs disrupt the synchrony of oak and winter moth phenology. *Proceedings of the Royal Society B* **268**, 289–294.

WOIWOD, I.P. (2003). Are common moths in trouble? *Butterfly Conservation News* **82**, 9–11.

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