ENGLISH NATURE

Report Number
623

A literature review of urban effects on lowland heaths and their wildlife

English Nature Research Reports

working today
for nature tomorrow

English Nature Research Reports

Number 623

A literature review of urban effects on lowland heaths and their wildlife

J C Underhill-Day

RSPB, Syldata
Arne, Wareham
Dorset
BH20 5BJ

Telephone: 01929 550969
email: john.day.arne@rspb.org.uk

ISSN 0967-876X

Executive summary

Introduction

Heather clad lowland heath developed on light, freely draining, acid soils following prehistoric woodland clearance, and down the centuries, has been kept open by grazing, burning and cutting. As the economic value of these uses declined, considerable areas of heath were lost to agriculture, forestry, housing, roads, mineral working and other uses, and today, much of what is left is adjacent to built up areas, especially in Dorset.

These lowland heathland fragments can be found across much of southern England on suitable soils. Much of the research on heathlands over the last twenty years has concentrated on the Dorset heaths, which are now almost all SSSIs and mostly within the Dorset Heathland SPA. While this report reflects the bias in the literature towards work in Dorset, the results have wide applicability to urban heathlands that are accessed by the surrounding urban populations for amenity and recreation whether in Dorset or elsewhere. This urban public access places considerable pressures on the heaths, for example through disturbance, wild fires, trampling, predation by domestic pets, pollution and enrichment. A number of studies have examined urban effects on lowland heathlands and these, together with two case studies at Canford Heath SSSI in Dorset and two studies at Yateley Common SSSI in Hampshire, are included in this review.

Fragmentation

Urban pressures add to the problems of fragmentation and isolation of the Dorset heaths, the history and status of which has been well documented. There have been three surveys on the fragmentation and isolation of the heaths of Dorset during the last thirty years. From these, the recorded losses in heathland area between 1978-1987 were mainly due to agricultural conversion and urban development for houses industry and roads. Between 1987-1996, following the control of direct losses of heathland to development through planning controls, most losses have been from vegetation succession. The last survey, in 1996, restricted to heathland areas of over 4ha, found 7373 ha of heath in Dorset spread over 151 fragments.

Specific studies on the communities of large and small heathland fragments have generally shown an increase in plant and invertebrate species richness in the smaller, more isolated fragments, combined with fewer heathland indicator species and poorer characteristic heathland plant communities. As heathland is a species-poor habitat, increasing values for species richness on smaller heathland fragments suggests that the communities on these are less representative of heathland, and increasingly a consequence of edge effects. This is supported by finding similar invertebrate species richness on the edges of large fragments, compared to the species poor communities in the centres of large fragments. Spider species with poor powers of dispersal are confined to large fragments. There are a number of specialist heathland species and where these have been studied, negative effects of small size and isolation (fragmentation) have been found, including a lower probability of occurrence, lower abundances where they do occur and poorer colonisation/higher extinction rates.

Plant community succession is likely to be faster on smaller fragments due to edge colonisation, but these are also the fragments which are likely to have smaller populations and fewer and smaller suitable areas or potential areas for survival and colonisation of heathland specialists. Thus, these smaller populations (particularly of species associated with successional phases in the plant communities) are more at risk from extinction through chance events. Temporary fragmentation of heathland communities can be the caused by fires but the effects of this on species dynamics have not been studied.

Disturbance

Studies across a range of bird species have shown that effects from human disturbance can be both indirect and complex. Effects can include restriction of nest site choice, reduced breeding success, changes in population breeding density and composition of breeding communities, and lower foraging rates.

Several studies have shown that the distance to the disturbance source and the intensity of disturbance are important factors, although where disturbance levels are high, some species can become habituated to human presence. Reasons for lower reproductive success have included disturbance from; building and road development activity, off-road vehicle movements, general recreational use of paths and car parks, camping, walking and swimming. Mechanisms for reduced reproductive success have included, nest trampling, predation of eggs or chicks by dogs, flushing of adults leading to predation of eggs or young by natural predators, and young separated from parents. Effects have included poorer site fidelity, increased energy expenditure, changes in nest site choice, lower breeding densities, changes in community structure with increases in common species and negative effects on rarer species, failure of pairs to breed or abandonment of nest before or after egg laying or hatching, increased predation rates, reduced incubation or brooding times and lower feeding rates.

Recent studies of some heathland bird species have shown a number of effects attributed to disturbance. Breeding nightjars were recorded at lower densities and had poorer breeding success on urban, compared to rural heaths. They also had a greater risk of predation and lower nest success closer to paths. A study on woodlarks found high levels of predation on artificial nests and a greater density of corvids present on heathland sites with higher disturbance levels by people. Preliminary results from another study of woodlark territories showed lower densities on disturbed sites coupled with larger fledged young, suggesting a disturbance effect and a density dependent response. Woodlark nest density was reduced on sites with open, rather than closed access. One study also suggested that Dartford warbler densities were lower on urban heaths.

Fires

Concerns at the ecological effects of wild (ie uncontrolled) fires on English heathlands were first expressed following a series of large fires across the heathlands of the southern counties in 1976. The UK Government commissioned a study (Kirby & Tantrum 1999) following an adverse report on the condition of the Dorset heaths by The Council of Europe's Bern secretariat.

Kirby & Tantram concluded that fires occurred at higher densities on the fringes of larger conurbations and in sites within developed urban areas, where fire events present a serious risk to ecological integrity. They considered that the statistical data, in combination with visual assessment and their fire event density map, suggested that the incidence of fires on heaths in urbanised areas was higher than those in more rural locations, and that this was likely to be due to easier access to these heaths, as the data suggested that most fires were deliberately set. The evidence suggested that fire setting by children of school age may be a significant factor in the pattern.

Fire destroys heathland vegetation, which can then take many years to re-establish depending on substrates and the characteristics of the fire. In various studies it took between 4 and 20 years for heathland vegetation to recover, and in some cases the fire triggered a change from heathland to woodland on the better soils. In most studies, burnt areas go through a successional phase of grassland before dwarf ericaceous shrubs re-establish.

Invertebrate communities also develop successionally after a fire, with species of bare ground and predators increasing in numbers and abundance. Species living in litter, reliant on the humid microclimate which a heather canopy creates, or living in the heather canopy, are sparse or absent in the aftermath of a fire. Large fires can threaten populations of invertebrate species which are poor dispersers, and too-frequent, widespread fires can threaten the survival of some invertebrate communities of older heather or litter (which cannot colonise until 10 years or later after burning, as such fires perpetuate only continuous early successional communities. The re-burning of previously burnt areas as soon as the vegetation is tall enough to allow a fire to travel, is a feature of urban wild fires.

Unless islands of suitable habitat survive a fire, birds such as Dartford warbler are absent following a fire. Large fires remove both nesting cover and foraging habitat for insectivorous birds such as Dartford warbler and stonechat for a period of years, and regular re-burning will prolong this condition and could suppress populations indefinitely.

Once the vegetation has recovered, after six years in one study, Dartford warbler densities were higher than in adjacent un-burnt areas, presumably as the re-grown vegetation was more suitable both as foraging and nesting cover than it was before the fire.

Cats

There are about nine million cats in Britain. Surveys suggest there are about 320-330 cats per thousand households with some regional variation. There are wide differences in hunting behaviour with recorded annual catches per cat ranging from 0-95. In one study, 20% of prey was caught at dusk and dawn and 30% of prey was caught at night. Mean catches per cat p. a. ranged from 10 in Canberra, Australia to 37.5 for rural cats in Yorkshire. Using data from the most extensive UK studies suggested a mean figure of 29 prey items per cat p.a.

The proportion of mammals in total prey caught by cats ranged from 49% to 95%, birds from 5% to 30% and herpetofauna and fish from <1% to 9%. Combining the two largest UK studies suggests cats take about 73% mammals, 22% birds, 3% herpetofauna and fish and 2% invertebrates by number. Total prey brought home per annum per thousand households has been conservatively estimated as c. 9,300 items.

There is little information on the effects of cat predation on prey numbers, but some evidence that prey are generally unaffected at the population level, although numbers can be reduced locally. There is considerable evidence that cats visit heathlands in Dorset, but no data on their activities or effects on heathland animals and birds has been compiled.

A number of studies have investigated cat hunting ranges and found that males have larger ranges than females and both sexes range further at night than during the day. Hunting ranges of both sexes overlap, but there is some evidence that cats from different residences have little or no overlap.

The longest distance recorded for a cat travelling between two points is 1.5 km in one study, with a mean of 1107m for 16 males and 806 for 8 females in another study.

Evidence as to whether attaching bells to cats will reduce predation rates is contradictory, and may be more effective in reducing mammal predation than predation on birds or reptiles. Keeping cats in at night may also reduce mammal predation but may increase predation rates for some other groups. Similar variable effects have been noted from increasing feeding rates for cats.

No research results could be found on other ways (eg fencing) in which cat predation on heathland species might be mitigated.

Trampling

The ecological effects of human trampling include soil compaction, changes in soil hydrology and chemistry, changes to the soil invertebrate community (with an overall reduction in numbers of invertebrates), changes in plant communities (depending on the degree of wear), with bare ground and soil erosion an ultimate consequence of heavy use. The degree of change and damage depends on the soil type, slope, drainage and hydrology, scale, frequency and seasonality of wear and the composition of the initial vegetation. Coarse textured soils (such as heathland sands), with low levels of organic matter are particularly vulnerable to compaction from trampling, and are more vulnerable when wet than when dry.

Most studies have shown that heathland plant communities are more sensitive to trampling damage, and take longer to recover than grassland communities. Wet heathland communities seem more sensitive than those of dry heathland, but may recover more quickly depending on the conditions and season when the damage took place.

Dogs

Apart from disturbance to birds (dealt with separately), dogs can chase livestock, disturb wildlife in ponds and other water bodies and cause fouling and enrichment. From a number of heathland survey, an average of half (range 21-92%) of all visitors are accompanied by dogs, with a median of 1.5 dogs per walker. Between 40-100% of visitors let their dogs off the lead, and about 40% cleaned up if their dog defecated.

Dog fouling was a cause of enrichment due to inputs of nitrogen, phosphates and potassium which had a significant (although local), effect on heathland plant communities. The enrichment effects lasted three years on grassland in one study. Significantly higher levels of nitrogen and phosphorus were also found where horses had been ridden.

Other effects

There are few studies on urban noise, although it has been found in one study that some birds sing at higher frequencies and with a narrower frequency range in the presence of high levels of ambient noise. Relatively high background noise levels have been recorded at the nest of a nightjar. Noise may affect birds which have songs adapted to long distance transmission such as woodlark and nightjar. There are no published observations of the effects of urban light on heathland birds in the UK.

It seems probable that these urban effects can operate in combination. The removal of cover through fires allowing greater predation of reptiles by cats or the disturbance to nesting nightjars from dogs increasing the risk of predation are both examples of this. Fragmentation can result in low remnant populations of plants, birds, reptiles and invertebrates, with greater chances of extinction due to fires, trampling or other urban effects, and then lower chances of recolonisation due to smaller site size and greater distance to potential colonists. No studies have addressed the combination of individual urban effects on heathland wildlife although several studies mention the probability of such effects.

Further research

Whilst there is a considerable body of work on the effects of urban development near to heathland on its wildlife communities and species, further investigations are needed to establish the mechanisms by which these effects operate, particularly at the species level. A number of studies have looked at how people behave when visiting heaths, but little has been done on how this behaviour can be manipulated to minimise the impacts on the wildlife of people using heathlands as public open space for recreation and amenity.

Contents

1. Introduction

Lowland heath is a characteristic landscape largely dominated by heather or one of its close allies, generally developed on freely drained, acidic, sandy or gravelly soils under 250m above sea level (Gimingham 1992). The creation, and subsequent survival of heathland as a cultural landscape, has been inextricably bound up with its exploitation by humans for grazing domestic stock, minerals, fuel and other products. The use and abuse of heathland (mainly from studies in Dorset, UK) for access, recreation and associated activities in the urban environment in recent years, forms the subject of this review.

Up until 1992, there were many losses of heathland in the UK through planning consents for development, but in that year the publication of Circular DOE 1/92, *Planning controls over Sites of Special Scientific Interest* effectively halted development on SSSI heathland. This guidance was strengthened by the publication of PPG 9 on nature conservation in 1994, and by the designation of most of the larger heaths in southern England as SPAs or SACs.

A major concern since that time has been the effects of the proximity of urban development on heathlands, and there have been considerable efforts to restrict intensification of urban development, particularly housing, close to heaths.

This report reviews the literature on, or having relevance to, the direct and indirect effects of urbanisation and the use of heaths by people and their pets. The effects of roads have not been included as these have been comprehensively reviewed elsewhere (eg Markham 1996, Spellerberg 2002, Erritzoe 2002)

2. Urban effects on lowland heathlands

2.1 The scope of urban effects

Attention was drawn to the indirect effects of urban development on heathlands in 1989 in a report entitled *Lowland heathland – a habitat under threat*, published by the RSPB. Following representations on the continuing threats to heaths in Dorset to the Standing Committee on the Conservation of European Wildlife and Natural Habitats (The Berne Convention), an on-the-spot appraisal was carried out (de Molenaar 1998). A summary of effects was also described in a review article by Haskins (2000). More recently, a report on the ecological impacts of specific recreational activities has been commissioned by English Nature (Liley and others 2003), and a further report on incidents on urban heaths has been prepared under the Urban Heaths Project supported by the LIFE programme of the European Union (DERC 2004). The urban heaths covered by the Urban Heaths Project are shown in Figure 1.

De Molenaar (1998) and Haskins (2000) gave a comprehensive list of the main urban effects on lowland heaths (Table 1), while information from DERC (2004) summarises the wide range of urban pressures (Table 2).

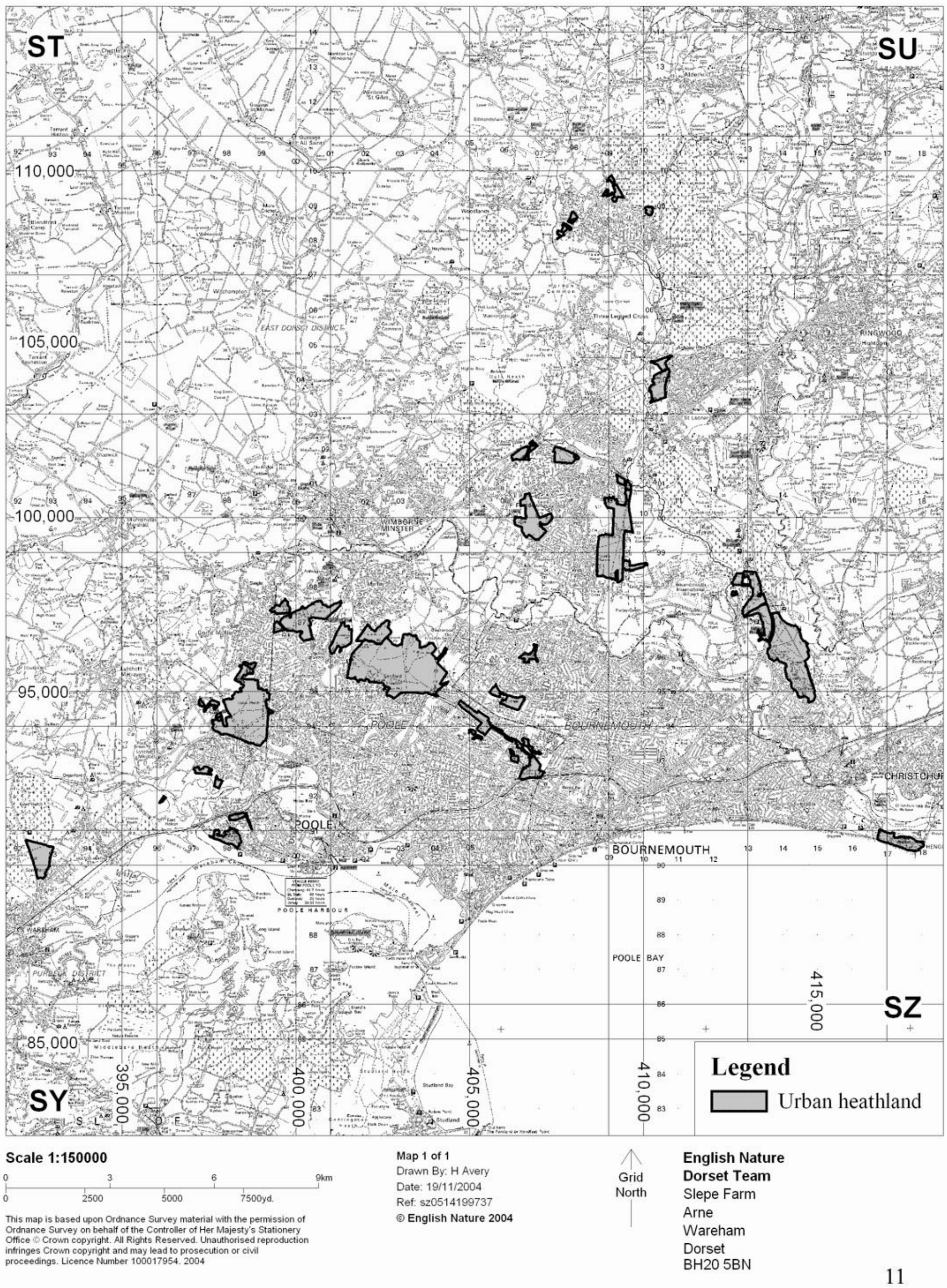

Figure 1. Component sites covered by the Urban Heaths LIFE Project

Table 1. The main urban effects on lowland heaths in Dorset (from de Molenaar 1998, Haskins 2000, or as referenced in the table)

Reduction in area	Mid 18C *c*36,000 ha to 1996 7373 ha (Webb and others 2000).
Fragmentation of heaths	768 fragments, 88% < 10ha (Webb & Haskins 1980).
Supporting habitats	Less semi-natural habitat adjoining heaths.
Predation	Cat/rat predation on ground nesting birds and reptiles.
Disruption to hydrology	Diversion of pre-existing natural water sources away from heathland catchments. Rapid run-off onto heaths from urban areas.
Pollution	Changes in pH of water supplies to heathland. Enrichment and pollutants from urban run-off. Pollutants from overflows, spills, accidents
Sand and gravel working with landfill after-use	Mineral working destroying habitat and disrupting hydrology. Polluted water can leak from landfill.
Enrichment	Dog excrement causes vegetation change along sides of paths. Rubbish dumping by roads and from gardens.
Roads	Increased fire risk from car thrown cigarettes. Pollution/enrichment causing vegetation change from vehicles in transport corridor. Roads forming barriers to species mobility. Road kills increasing mortality rates. Noise and light pollution from traffic.
Service infrastructures both over and under heathland	Disturbance during construction and maintenance. Leakage from underground pipes and sewers. Changes to heathland hydrology. Poles providing bird predator look-out posts.
Disturbance	Changes in breeding bird and animal distributions. Reduction in breeding success of birds/animals.
Trampling	Changes to vegetation. Creation of bare areas and subsequent soil erosion. Damage to bare ground reptile and invertebrate. habitats and populations. Increases in path and track networks. Damage to archaeological features.
Fire	Increased frequency of fires with majority in spring and summer. Long term vegetation changes. Increased mortality of heathland animals/birds.
	Fragmentation/reduction of habitat on heaths.
Vandalism	Damage to signs and fences.
Public hostility to conservation management	Opposition to management eg tree felling, fencing and grazing.
Management costs	Greatly increased management costs on urban heaths.

Table 2. Incidents reported from 33 Dorset urban heaths in 2003 (DERC 2004)

Incident type	Number	%
Fires	243	46.9
Motorcycles	105	20.3
Fly tipping	38	7.3
Cyclists (away from paths)	35	6.7
Vandalism	25	4.8
Den construction	15	2.9
Ramp building (for motorbike/cycles)	8	1.5
Fishing	6	1.1
Horse riders (away from bridleways)	4	0.8
Swimming	4	0.8
Theft	4	0.8
4X4 vehicles	3	0.6
Barbecue	3	0.6
Camping	3	0.6
Collecting from wild	3	0.6
Indecent exposure	3	0.6
Loose farm animals	3	0.6
Beach buggies	2	0.4
Abandoned vehicle	2	0.4
Trampling	2	0.4
Assault	1	0.2
Fireworks	1	0.2
Dog fouling	1	0.2
Fallen tree	1	0.2
Gun shots	1	0.2
Herbicide use	1	0.2
Illegal grazing	1	0.2
Total	518	

The figures for these incidents should be treated with caution. Some incidents are more visible than others, for example, a fire is far more likely to be seen and reported than an unauthorised fisherman at a remote water. Some activities, eg dog fouling, trampling and loose animals were likely to have been under-recorded. Despite these shortcomings, this report probably provides a comprehensive list of the types of activity that take place on urban heaths. One further activity, sand surfing was recorded on a heath outside the study area. In addition Liley and others (2003), record that organised orienteering and cycling can take place on heathland sites.

Of the 243 fires reported by the Dorset fire service or wardening staff, 220 (90%) were described as ‘malicious’ (ie started deliberately and maliciously), and of the remaining 23, one was started deliberately for management purposes, and the remainder were started accidentally. No reported fires were from natural causes (eg lightning).

2.2 Case studies of urban effects

2.2.1 Canford Heath Dorset

The urban effects on one heathland site in Dorset, Canford Heath (Figure 2), was compiled for the ten years 1991-2000 by Munns (2001), and is summarised in Table 3.

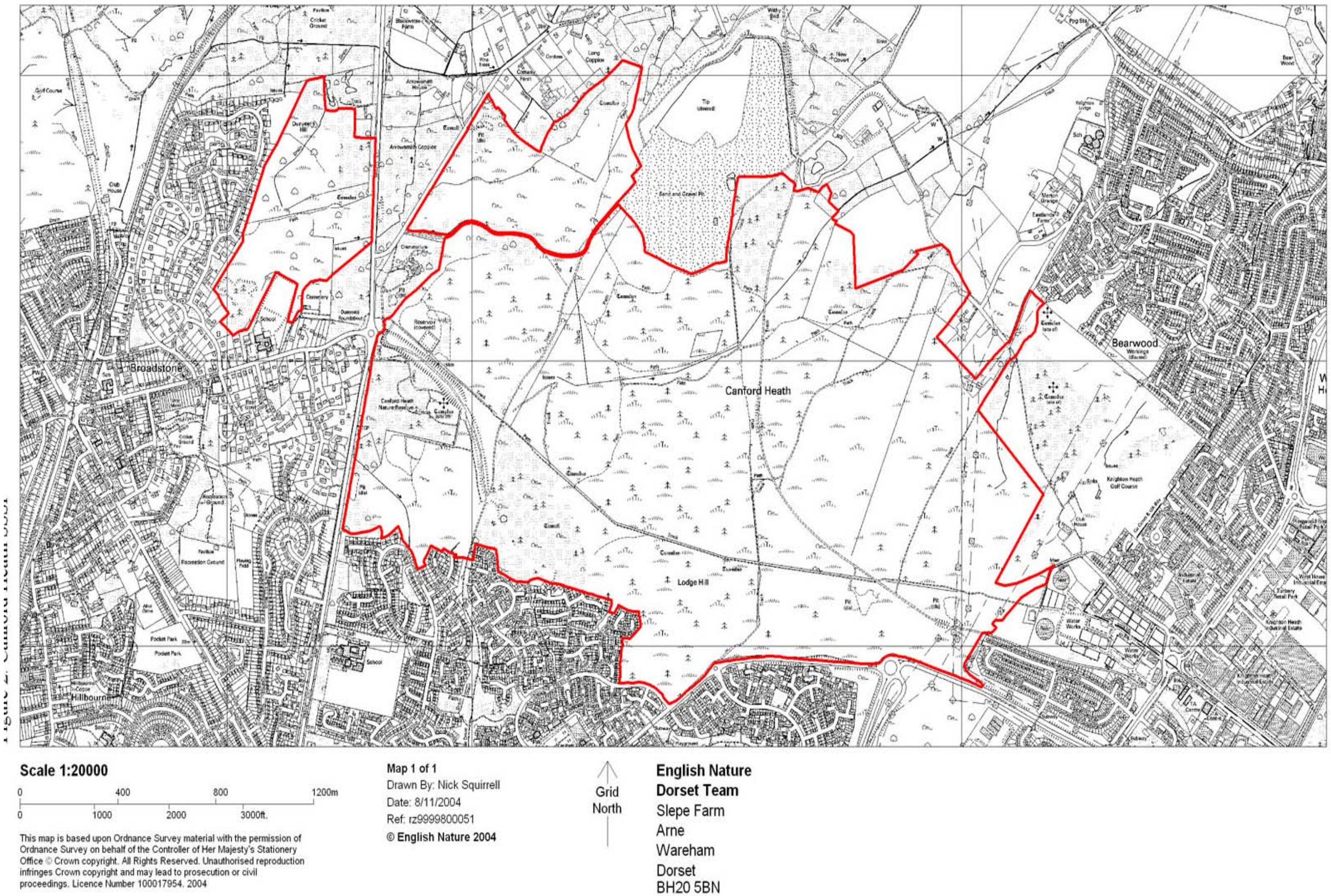

Figure 2. Canford Heath SSSI. Component SSSI of the Dorset Heaths cSAC, Dorset Heathlands SPA, Dorset Heathlands Ramsar

Table 3. Incidents recorded on Canford heath during 1991-2000 (Munns 2001)

Year	Fires		Dumping		Illegal access*		Police called	Other** vandalism	Total
	No.	(ha)	Litter	Car	M.bike	Evidence			
1991	15	2.7	16	27	34	39	19	4	154
1992	9	1.2	24	16	19	33	9	8	118
1993	24	1.8	20	18	47	27	16	24	176
1994	32	2.3	15	21	41	41	17	4	171
1995	61	27.1	19	17	23	41	3	10	174
1996	36	55.7	10	18	34	42	15	20	175
1997	22	12.5	16	17	54	34	14	14	171
1998	27	1.2	22	21	63	40	31	20	224
1999	27	1.1	22	33	59	67	40	17	265
2000	37	0.8	30	26	102	108	70	18	391
Total	290	106.4	194	214	476	472	234	139	2019

*Evidence of illegal access included broken or forced gates and fences, and tyre tracks.
**Other incidents recorded under vandalism included similar events to those recorded in Table 2, with, in addition, deliberate introductions of plants and fish into heathland communities and ponds respectively, pollution from sewers running under the heath and kite flying during the bird breeding season.

The apparent trend upwards in the latter half of the period might have been partly due to better recording. The areas affected by fires has also been more carefully recorded in recent years.

2.2.2 The Thames Basin Heaths and Yately Common, Hampshire

A study was commissioned by English Nature in 1996 of harmful activities, based on a site inspection, at Yateley Common SSSI (Figure 3). A subsequent report detailed these on maps, each accompanied by explanatory text (Hall 1996). In 2004 this study was repeated (Liley 2004), commissioned by English Nature and RSPB, and the site was re-examined and the results compared with the earlier survey.

From these two surveys the following points can be made:

- A number of urban effects, such as the dumping of garden refuse and the distribution of non-native garden plants, were strongly linked to the proximity of back gardens abutting the heathland. (Over 40 non-native plant species were recorded.) There was less dumping of garden rubbish where the houses faced the heath than when they backed onto it. The incidence of garden rubbish dumping changed little between the two surveys.
- Fly tipping took place mostly near the SSSI boundary, less often near housing in 2004 than 1996, and in both surveys generally away from car parks.
- There were fewer fires recorded in 2004 than 1996, and the size of fires in the later survey (size was not recorded in 1996) was generally small with only two fires covering more than 1ha. The difference in number of fires between the two surveys could have been weather related. Fires were typically close to the SSSI boundary but were not apparently linked to the proximity of housing or car parks. The number of large fires is now probably less than formerly due to an increase in firebreaks and quicker reporting as more people carry mobile phones.

Figure 3 Castle Bottom to Yately and Hawley Commons SSSI.

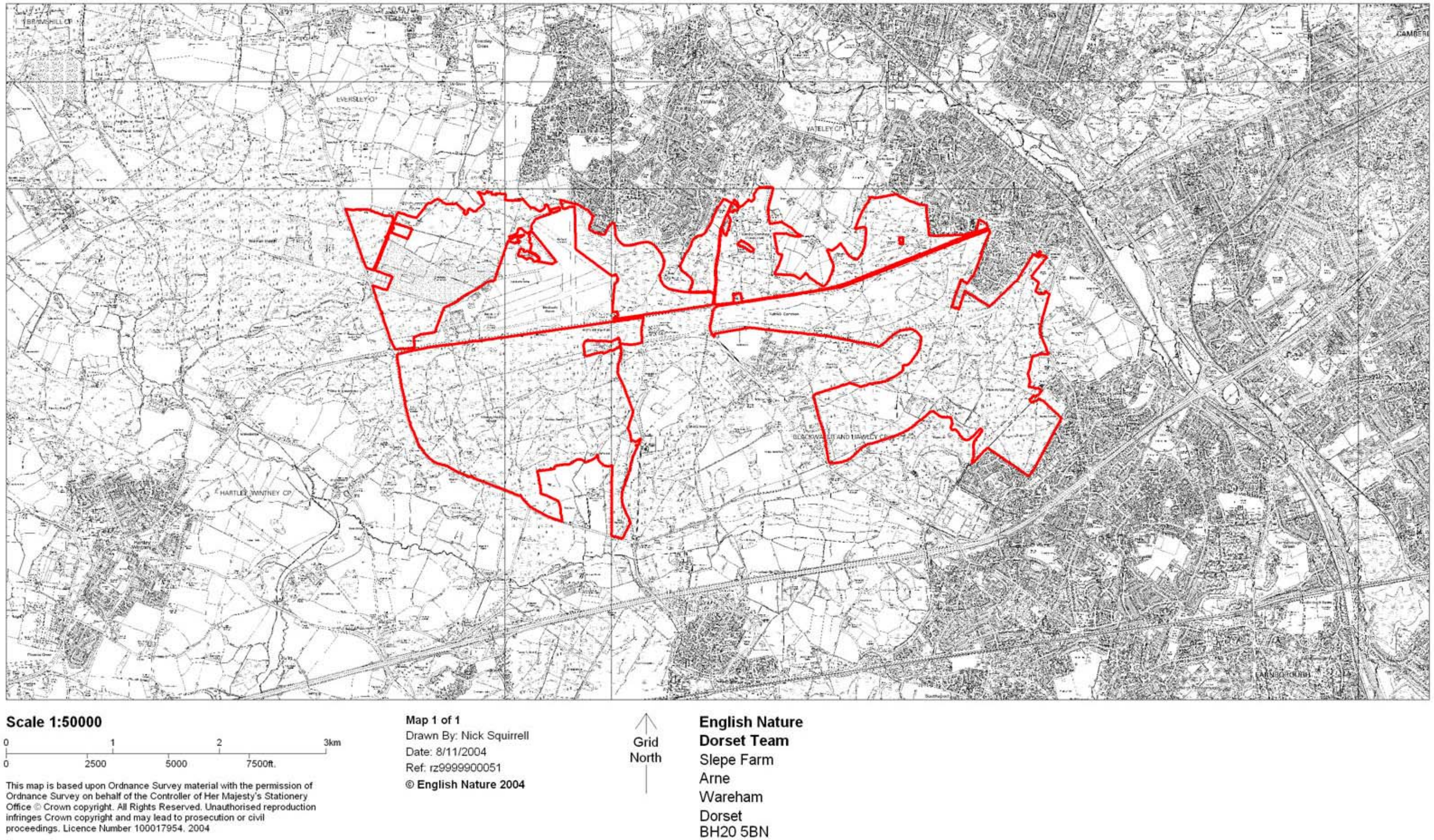

Figure 3. Castle Bottom to Yately and Hawley Commons SSSI. Component SSSI of Thames Basin Heath pSPA

- Other effects, included dumped materials, miscellaneous damage, burnt out cars, construction of camps or dens, graffiti and extensions of car parking or gardens onto the heath.
- Some recreational activities such as kart racing and open air markets had an effect, but this seems to have been confined to the immediately adjoining area. The effects from a caravan site within the heathland appear to have been more widespread.
- There seems to have been an increase in motor-cycle and cycle damage and possibly less garden dumping and fly-tipping in 2004 than in 1996. Generally, however, the occurrence of human impacts seems to have changed little between the two surveys.
- There are some effects which were recorded in 1996 as acting in combination, for example:
    1. A wildfire which burnt domestic property hedges and fences abutting the heath led to demands for a fire break. This was provided, causing direct loss of SSSI heathland, dumping of garden rubbish and more fires on the heathland side of the firebreak.
    2. An inaccessible part of the heath had a system of firebreaks installed following the burning of extensive areas. The new firebreaks opened up this core area of undisturbed heathland to walkers, joggers and mountain bikers.
    3. The route of a gas pipe installation became a new path and horse riding route.
    4. A mown firebreak became a track, with signs of vehicular use including wheel rutting and localised erosion.
- Other effects included extension of gardens onto the SSSI, sewage pollution, pollution from surface water from car parks and roads, damage from mountain bikes and horse riders away from established paths.

This report will now review more detailed studies on the ecological effects of urbanisation.

3. Fragmentation

3.1 Biological effects of fragmentation and isolation

Moore (1962) considered the effects of isolation due to reduction and fragmentation of the heathland habitat in Dorset, based on the distribution of eight typical heathland animal species including insects, birds and reptiles, of which four were confined to heathland and four were found on heathland and surrounding habitat. He found that the four heathland specialists were absent from the most isolated heaths, even though the habitat appeared suitable, and concluded that, within the study area, isolation was already starting to affect the distribution of these species.

Using 12 of the 13 heaths examined by Moore (1962), his study of eight animal indicator species was replicated using data collected between 1980-1993 (Webb & Rose 1994). This later study found that:

- Nine of the twelve heathlands used in the study declined in area between 1962-1993.

- The number of indicator species present had declined overall, with higher losses of both stenotypic and general heathland species on small (<100ha) sites than large (>100ha) sites.
- Although there was no correlation in 1962, in 1991 the number of indicator species correlated significantly with site area.
- Generally, it is the least mobile species that are lost first.
- On one heathland of 31 ha which had seven of the eight indicator species in 1962, fragmentation of the heath into three small parcels by 1993 had led to the loss of all seven species.
- Although it was difficult to separate the effects of area and isolation, it was considered likely that isolation in combination with changes in heathland quality were responsible for the decline in species number.

A number of studies of total areas and fragmentation of the Dorset heaths have been summarised in Webb (1990) and Rose and others (2000) and are shown in Table 4. A fuller description of the history of heathland decline and fragmentation in Dorset is given in Appendix 1.

Table 4. Total areas and fragmentation of Dorset heaths 1978-1996. (From Webb 1990 and Rose and others 2000)

	1978	1987	1996
Area of heathland (ha)	7,913	7,925	7,373
Number of fragments >4ha	137	142	151
Mean area of fragments >4ha	57.2	55.4	48.6
Mean distance to nearest heath (Km)	0.25	0.23	0.21

The table shows an increase in the number of fragments > 4ha over 20 years, with mean fragment size getting smaller, but fragments becoming slightly less isolated over the period. Direct comparisons with the earlier estimates of Moore (1962) and Rippey (1973) are difficult due to differences in methodology. The Table shows a loss of overall heathland area and an increase in the number of fragments, together with a decrease in mean fragment size over the period. Isolation as measured by mean distance to nearest heath also decreased because fragmentation of continuous heath results in several smaller, closely adjacent heaths.

3.1.1 Plant and vegetation studies

Webb and Hopkins (1984) reported that in a study of 22 samples in the Poole Basin, Dorset, the diversity of plant species at the sampling points was negatively correlated with both the areas of the sampled heaths and the area of heathland within 2km of the sampling point. Sampling points at the edges of large heaths had more species than those at the centre, and the combined cover of heather *Calluna vulgaris,* cross-leaved heath *Erica tetralix* and bell heather *Erica cinerea* increased with greater site size and decreasing isolation. These findings indicate that the dominance of typical heathland species is lower on the smaller heaths due either to increased rates of succession or to invasion of non-heathland species from the edges, and that large heathlands retain a typical (and species impoverished) plant community away from their edges. On the smaller heaths and the edges of larger ones, typical heathland plant communities are more likely to be invaded by non-heathland species.

Webb and Vermaat (1990) carried out a further study of the vegetation of 141 fragments of Dorset heathland from diversity indices using vegetation sub-types as groups and their cover values as abundances. They found that small fragments had high values of point richness and large fragments had lower values. They attributed the richness of vegetational groups on small fragments to succession to scrub and woody species. They obtained significant values for dry and wet heath and peatland. Tests indicated that the dominance of heathland vegetational types increased as fragment size increased.

3.1.2 Invertebrate studies

A study by Webb & Hopkins (1984) found that the species richness of beetle (Coleoptera) communities at fixed representative points at the centres of heathlands on large heathlands, was negatively correlated with both the area of the heathland sites they sampled and with the area of other heathland within 2km of the sampling point. Thus the beetle fauna was richer on small sites than large, and where there was less heathland close by. They also found that the Coleoptera fauna on the edge of large sites was richer than in the centre and comparable to the richness on small sites. There were no similar significant correlations for the richness of the spider faunas, but species richness in the bug (Heteropteran) community was also negatively correlated with the area of heathland within 2km. In other words, there were more bug species when the surrounding land was not heathland, but spider richness was not affected by the character of the surrounding land. In a further study of the spider data (Hopkins & Webb 1984), it was found that those species with the poorest powers of dispersal were confined to the larger heathlands and were absent or poorly represented on the smaller heathlands.

These differences in invertebrate species richness and characteristics can probably be attributed to the combined effects of isolation and succession. The invertebrate faunas of small isolated patches of heathland can be more influenced by species straying from the edge than can those of larger patches (edge effects) and succession may be more rapid on smaller patches due to the differing nature of the surroundings (Webb & Hopkins 1984). Edge effects will also vary according to the habitat along the edge so that there may be a greater number and diversity of woodland spiders penetrating heathland than grassland spiders (Webb 1985). All the spider species occurring on the small heathlands also occurred on the large ones (Hopkins & Webb 1984). The overall abundance of heathland invertebrates was greatest on the larger heaths, suggesting that the habitat was different in structure or quality to the smaller heaths (Webb 1989)

An analysis of the data on vegetation types collected for the Dorset heathland surveys in 1978, 1987 and 1996 (see Table 4), together with data at the same spatial scale (200m x 200m patches), and collected using similar methods, on the distribution of silver-studded blue butterflies *Plebejus argus* was reported by Rose (2002). He found that the butterfly distribution was associated with building phase humid and wet heath and peatland and mature humid heath, ie with the earlier and mid-successional phases of damp and wet heath and mire. Areas of suitable habitat varied between surveys, with 38% of the patches being classified as something other than heathland at some time during the survey period (1978-1996) and 43% of the patches being classified as of poor quality for the butterflies. This left only 19% of the patches containing high quality butterfly habitat at some time during the survey period. Few patches maintained high quality habitat between survey dates. This suggests that many butterfly populations are surviving in low quality habitat that may become unsuitable. It is therefore important that suitable alternative habitat is available within 600m, the maximum dispersal range for this species. However, the more fragmented the vegetation type is, the less likely there will be suitable habitat for colonisation within the dispersal distance and the more likely the risk of extinction.

In an earlier paper, Bullock & Webb (1995) found that in a sample of heaths surveyed in 1960 and 1987, a number of specialist heathland animals had higher extinction rates on smaller and more isolated heaths, and that between these dates, colonisation was more generally seen in heaths of medium size and isolation. The distribution of several such species (eg small red damselfly *Ceriagrion tenellum*, bog bush cricket *Merioptera brachyptera*, silver studded blue and nightjar *Caprimulgus europaeus*) was negatively correlated to an index of size/isolation, thus, the more isolated, smaller heaths were less likely to hold such species. They also found that larger and/or less isolated heathland patches hold more heathland animal species, and that small (4ha or less) heathland patches are more likely to be occupied by both specialist and generalist heathland species if they are near to other patches of heathland.

Surfaced roads and railways are significantly greater barriers to arthropod movements compared to grassy field tracks (Mader 1984) and (Mader and others 1990), who found that paved and gravel tracks and railway lines reduced the rate of arthropod crossings, whereas grassy field tracks had no significant effect.

3.1.3 Reptile studies

The main cause of decline in the UK sand lizard *Lacerta agilis* population has been the destruction and fragmentation of their heathland habitat. Since they have poor colonisation ability, fragmentation makes them more vulnerable locally to fire, collection and predation by cats (Presst and others 1974). The decline of the smooth snake *Coronella austriaca* is due to factors which are broadly similar to those affecting the heathland populations of sand lizard, and although greater mobility and longevity of the smooth snake may make it less susceptible to fragmentation (English Nature 1983), fragmentation has, nevertheless been a major factor in its decline (Spellerberg & Phelps 1977). As smooth snakes have low reproductive rates, their ability to colonise new areas (or re-colonise former sites) is probably limited (Goddard 1981).

3.1.4 Bird studies

The habitat requirements of Dartford warblers have been studied in Dorset using maps of breeding territories from 1974, 1984 and 1994, linked to maps of heathland vegetation and adjacent land use from 1978, 1987 and 1996 (van den Berg and others 2001). Using a fragmentation index, which described both the size and isolation of the heathland patches, van den Berg and others found that a lower proportion of smaller and/or more isolated heathland patches had Dartford warbler territories than larger, less isolated sites, in all years. This consistent effect showed that the proximity of a heathland square to other heathland squares was a major factor in determining Dartford warbler habitat preference. Van den Berg and others suggested that this negative effect of fragmentation on the probability of a patch being occupied by Dartford Warblers could have been due to greater anthropogenic disturbance, the avoidance of heath edges, or scarce food supplies on smaller sites.

In their study of the effects of urban development on heathland birds, Liley & Clarke (2002) found a linear relation ship between nightjar, woodlark and Dartford warbler numbers and patch size. Although the area of heathland was a good predictor of Dartford warbler numbers, it was not a good predictor of woodlark numbers due to the specialist habitat requirements of this species.

4. Disturbance effects

4.1 Disturbance effects from people and dogs

In a review of papers examining the effects of human disturbance on avian breeding, Hockin and others (1992) found that 36 of 40 studies reported breeding success to be reduced by disturbance. From 28 studies, where investigator disturbance was reported, mean reproductive success was reduced by about 40%. The main reasons for the reduction in breeding success as a result of disturbance were reported as being nest abandonment and increased predation of eggs or young

Studies on the effects of path use on birds in the USA have shown that; birds were flushed at a greater distance by people who have left paths than those who have stayed on them, and were less likely to nest near paths in open habitat such as grassland than in closed habitat like forest. Nest predation was greater near paths, with more nests near paths being attacked by bird predators than away from paths, but with mammals appearing to avoid nests near paths (Miller & Knight 1998, Miller & Hobbs 2000, Miller and others 2001).

Boorman & Fuller (1977) found some evidence that people avoid walking on areas dominated by *Calluna*. It has been shown for a variety of species, that birds will become habituated to human presence where visiting levels are high (Lord and others 2001, Ikuta & Blumstein 2003).

Both the distance to the disturbance source and its intensity appear to affect birds with nest success negatively correlated with distance to disturbance, and higher numbers of people or levels of recreation, resulting in increased nest failure (van den Zande and others 1984, Beale & Monahan 2004).

Apart from the direct effects of human disturbance on breeding success, disturbance has also been shown to reduce site fidelity in subsequent years (Blackmor and others 2004). Other reported effects include: increasing energy expenditure and lowering foraging times, not only by delaying arrival at feeding areas and causing earlier departure, but also by reducing the time spent feeding in foraging areas due to an increase in vigilance (Yalden & Yalden 1990, Burger 1994, Regel & Pulz 1997, Fernández-Juncic & Tellería 2000)

A number of studies have shown that birds are warier of dogs and people with dogs than people alone, with birds flushing more readily, more frequently and at greater distances, and staying longer off the nest when disturbed (Yalden & Yalden 1990, Lafferty 2001, Lord and others 2001, Miller and others 2001). However, the use of flushing distances should be treated with caution (Gill and others 2001.)

In a review of disturbance studies, Hill and others (1997) noted that larger birds, those higher up the food chain and those which feed in flocks in the open tend to be more vulnerable to disturbance, than small birds living in structurally more complex or 'closed' habitat such as a woodland.

On lowland heathlands, the proximity of urban development leads to greater access by people, dogs and vehicles (Atlantic Consultants 1998, Norrington 1998), and some of the effects on birds noted above might be expected to occur. However, little work has been done on the direct effects of disturbance on heathland birds, although recent studies (reported below) suggest that urbanisation is impacting on bird numbers and behaviour.

The following sections focus on likely disturbance effects to three of the main heathland breeding species, nightjar, woodlark, and Dartford warbler.

4.1.1 Nightjars

Twenty-five years ago, Berry (1979) in Suffolk, considered that human disturbance might be a problem for nightjars, noting that, "leisure activities on the heaths in the breeding season may be damaging". Berry's views were mirrored in Surrey, where it was suggested that the increased use of heathland for leisure purposes could be a contributory factor in the decline of the species in the county (Sage 1981).

Recent research in Dorset seems to confirm that nightjars are affected by the proximity of people. Liley and Clarke (2002, 2003) carried out an analysis of nightjar breeding densities on the Dorset heaths and related this to levels of urban development and woodland surrounding each study site.

They found a strong negative correlation between nightjar density and measures of urban development (area of housing and numbers of houses). In other words, sites with a higher proportion of surrounding development, or more houses within 500m of the heathland boundary, had lower densities of nightjars. Nightjar density was positively correlated with the percentage cover of woodland within 500m of site boundaries, in other words, there was a higher density of nightjars on sites surrounded by more woodland, which is one of the preferred foraging habitats for this species (Alexander & Cresswell 1990).

'The results clearly demonstrate that the number of nightjars present on a heathland site is linked to the measure of urban development around the periphery of the site, with sites surrounded by a high amount of development supporting fewer nightjars' (Liley & Clarke 2002). The measure of urban development has been used here as a surrogate measure for the level of human activity on the site and changes in land use and habitats surrounding the site, which could include disturbance from humans, light pollution, increased predation levels and habitat change through, for example, more fires.

These results are not conclusive evidence of a link between levels of disturbance by people (which could include pets, vehicles and the incidence of fires) and nightjar densities, but it does suggest that there is some link between human activity on heathlands and lower densities of nightjars.

Liley & Clarke (2002) also found that there was no difference between nightjar territory centre locations and random points with respect to distance to roads or to site edge, but territory centres were significantly further away from the nearest built up area.

The link between nightjar density and available woodland within 500m (which Liley & Clarke (2003) considered to be an additional effect to urban area), is also interesting, as it implies that, although nightjars have been recorded foraging up to 7km (average 3.1 km) from their breeding sites (Alexander & Cresswell 1990), woodland close by could also be of particular importance.

A further study of nightjars was carried out by Murison (2002), with the aim of determining the impact of human disturbance (mostly from dog walkers) on nightjar breeding success. She found that there was a negative relationship between both the density of nightjar territories on sites, and the proportion of successful nests (those nests producing at least one fledged young) on sites, and the number of buildings within 500m of the site boundaries. In other words, on those sites with a higher proportion of their boundaries adjoining built up areas, nightjars were at lower densities and had poorer breeding success.

Of the 47 nightjar nests found by Murison (2002), 19 (40%) were successful and 28 (60%) failed, with 24 of these failing at the egg stage. Ninety-three percent of failed nests were predated with 17 presumed to have been predated by birds and nine by mammals.

Predated nests were found significantly closer to paths than non-predated nests, and nests were more likely to be predated if they were associated with greater length of paths within 50m, 100m, and 500m of the nest site. Greater length of high and medium use paths within 500m of nest sites had a significant negative effect on nest success, and distance to nearest path proved the best predictor of nest failure.

The results of this work indicated that:

- Breeding nightjars are at lower densities and have poorer breeding success at sites with higher levels of visiting compared to those with little or no public access.
- On disturbed sites the proximity of paths correlate strongly with nest failure up to 225m from the path edge.
- Predation of nightjar nests is higher where there are more paths in the vicinity and where the nest is closer to a path.
- There seems to be a strong link between increased site disturbance, by dog walkers, higher predator numbers on disturbed sites and high predation rates on nightjar nests.

Another study by Woodfield & Langston (in press) using nest cameras, recorded 12 flushing events of sitting nightjar, one of which was flushed twice by a dog. They calculated that on average, birds had a 12.2% chance of being flushed per day. Dogs have been recorded predating the eggs or chicks of ground nesting birds (Nol & Brooks 1982, Pienkowski 1984). Nightjars (which lay white eggs), suffer between 36-86% of nest losses at the egg stage (Murison 2002, Woodfield & Langston, in press) and will stay off the nest for between five and 15 minutes after flushing (Lack 1932). It has been found that corvid numbers are higher on sites visited by more people (Taylor 2002), and other predators have been recorded at higher densities in urban than rural environments (Liley & Clarke 2003) including magpies (Groom 1993), and foxes (Harris & Raynor 1986).

Taylor (2002) analysed the degree of disturbance and the presence of predators and found that as human activity increases, the presence and activity of corvids also increases, and that the risk of predation is higher on sites with higher corvid activity. The link between corvids and disturbance is much stronger early in the season, in late season it is no longer significant. Taylor considered that the link between human presence and greater number of corvids was not solely due to increased scavenging opportunities as litter was not common on the study sites and most disturbance was due to dog walkers. She suggested that corvids have greater opportunities to find food when sites are more heavily disturbed because the disturbance is associated with greater urban development around sites, which probably offers better scavenging opportunities.

4.1.2 Woodlarks

In their study of urban effects, Liley & Clarke (2001) reported no apparent effects of higher percentages of urban development surrounding heathland on woodlark territory densities, although these were lower on sites with open, rather than closed, access. Preliminary results from another study of woodlark territories in Dorset found lower nesting densities on disturbed sites, which, coupled with larger young, suggested a disturbance effect and a density dependent response (Mallord pers. comm.).

A further study on woodlarks by Taylor (2002) was based on putting out 1755 artificial woodlark nests with clay eggs. This type of study using artificial eggs is a recognised method for determining predation levels and (through the marks on the clay), identifying predators. The predation rate on the artificial nests was 69%. Of those predated nests where the predator could be identified, 53% were corvids and 26% foxes. Early in the season 60% of nests were predated, in the late part of the season this rose to 83% corresponding to the first and second nesting periods of woodlarks. Predated nests were associated with reduced vegetation cover, a greater proportion of bare areas around nests, shorter vegetation and areas with less gorse. Distance to path and habitat edge were not significantly different between predated and non predated nests.

4.1.3 Dartford warblers

Compared to the previous two species, little work has been done on Dartford warblers and disturbance. Liley & Clarke (2002) found no link between the percentage of urban development surrounding heathland, or open access versus closed access, and Dartford warbler breeding density. However, van den Berg and others (2001) found an effect on the 1994 occupation of patches by Dartford warblers with surrounding land uses showing a negative affect with increased urban development.

5. Fire

For hundreds of years controlled fires have been a normal part of the management of heathland, as an adjunct to grazing, providing younger, more nutritious heather for grazing animals. Whilst this practice is still a regular part of the winter management of the New Forest heaths, (Tubbs 1968, 1986), in Dorset it had died out by the time Moore (1962) carried out his study of the lowland heaths in Dorset. Moore noted that, 'probably the most important effect of the decline of rough grazing has been the virtual extinction of controlled burning which used to accompany it'.

At the same time, there have been concerns about the increasing incidence of wild fires (these are unmanaged fires), particularly during spring and summer, and with fires associated with urban heaths. Such fires are not targeted at particular stages in the heather cycle, nor are they distributed across heather areas or restricted to a pre-determined size, as in the case of controlled cyclic burns. In contrast, wild fires are unpredictable, of varying sizes, sometimes consuming entire heaths and limited in their size and distribution only by the combustibility of the vegetation and the weather conditions.

The first report to draw attention in Dorset to the problem of wild fires was produced after the hot summer of 1976, when some 670 ha of heathland was burnt on 20 sites in 32 separate incidents, of which 56% were in urban or suburban areas (DNT & RSPB 1977). In 1976, 200 ha of the 243 ha of Hartland Moor in Dorset was burnt in a single event (Nicholson pers. comm.). In 1989, the RSPB published a further report on urban effects on heathland, which drew attention to the particular problems posed by wild fires.

In 1959, it was estimated that some 8.1% of the Dorset heaths were burnt (Webb 1997). Surveys in 1978, 1987 and 1996, found that 945 ha (12.0% of the area of Dorset heath at that time), 382 ha (4.8%) and 85ha (1.2) had been burnt during the preceding two years of each survey respectively (Webb & Haskins 1980, Webb 1990, Rose and others 2000). These figures suggest a decline in burning (whether controlled or wild) over the twenty years covered by the surveys.

In Surrey Harrison (1976) noted that there were a large number of fire incidents on the amenity heathlands around Guildford, Haslemere and Chobham, with an all year round fire risk but the highest incidence in March/April and August/September.

5.1 Recent surveys of heathland fires

In 1998, following the ‘On-the-spot’ appraisal of the Dorset heathlands by The Council of Europe’s Bern secretariat, the Department of the Environment Transport and the Regions commission specific research into heathland fires in Dorset. This was published the following year (Kirby & Tantram 1999).

The report presented an analysis of 3333 separate fire incidents during 1990-1998.
Part of this analysis evaluated fire incidence in relation to built up areas, and this aspect of the report will be summarised here. (Issues concerning annual, seasonal and diurnal fire patterns and the areas of heathland burnt are considered in the accompanying report by Rose & Clarke 2004.)

Kirby & Tantram (1999) noted that most fires were in the east of the county with significant concentrations around the fringes of the Bournemouth/Poole conurbation. Many of the mapped fire incidents were co-incident, so an analysis was conducted on geographical density, which confirmed the high incidence of fires on the northern fringes of the conurbation, and an examination of the profiles of fire locations also showed the highest number of fires clustered predominantly around the urban fringes.

This relationship was more formally investigated by Kirby and Tantrum by plotting fire incidence against the density of surrounding built up areas on heathland SSSIs. More fires occurred on SSSIs with more densely developed areas within 500m of their boundaries although this effect could have been over-estimated as the reporting of fires on urban heaths may be higher than on rural heaths. Kirby & Tantrum considered that there was a possible threshold operating such that fires were more likely to occur on sites with more than 15% of their surrounding 500m area developed than on sites where development was below this level.

Kirby & Tantram also ranked the 26 SSSIs with the highest number of fires 1992-1998, of which 70% were located in or adjacent to urban areas including the top nine. Apart from Canford Heath SSSI where the maximum number of fires recorded was 97 per month and 12 per day, the maximum for the other sites ranged from 3-32 per month and 2-6 per day. The ten SSSI sites with the greatest density of fires (fires/ha) during the recorded period, were located in or adjacent to highly developed urban areas (with the possible exception of Verwood Heaths SSSI). Canford Heath, Upton Heath, Ham Common, Corfe and Barrow Hills and Ferndown Common SSSIs all suffered in excess of 100 separately recorded fires during 190-1998.

Kirby & Tantram also looked at the causes of fires, based on 217 questionnaire returns from heathland owners and managers, the fire and police services and Dorset Environmental records Centre. They found 61% of these fires were caused by arson, 18% from camp fires, 8% from management fires getting out of control, 7% from the spread of bonfires and the remainder from spreading refuse and vehicle fires. Two respondents reported that there was a widespread belief amongst the public and nature conservation professionals that most fires, if not all, were deliberate, and that children were often believed to be responsible.

The effects of fire on wildlife are dependant on their extent and frequency of fires on any particular site, and for individual fires, on the date and the fire temperature, the time this is sustained at any point (ground surface intensity), and the type of habitat burnt. Temperatures are a function of the amount and structure of the material which is burnt, its moisture content and inflammable properties, together with the ambient humidity and wind strength at the time of the burn (Whittacker 1961, Kenworthy 1963, Hely & Forgeard 1990, Allchin and others 1996). High temperatures for sustained periods at the soil surface kill mature heather plants, (which at lower temperatures survive to resprout), and where the fire is hot enough to burn down into the soil , seedbanks can also be damaged (Hobbs & Gimingham 1987). Very hot, slow moving fires on organic soils can burn down into the peat and on these areas it can take many years for a heathland vegetation to become re-established, and during this time the soil can be at risk from erosion (Tallis 1973, Anderson 1986, Maltby and others 1990, Legg and others 1992).

5.1.1 Impacts of fire on heathland vegetation

In Dorset, a long term study of heathland vegetation recovery after a single fire on Hartland Moor by Bullock & Webb (1995), found that after 11 years, neither the extent nor the composition of the principal heathland vegetation types had been affected. The proportions of dry, humid and wet heath, peatland and bare ground were unaffected by the burn in the long term, but there was an increase in bracken and birch scrub and a decrease in gorse scrub on burnt, compared to un-burnt areas. Scrub cover had increased by 5% on adjoining dry heath which was un-burnt. In the short term, grasses dominated the dry and humid heath, which returned to heather dominance after ten years.

In another long-term study of heathland in the Quantocks, bracken was more likely to have replaced dwarf shrub if the ground was un-burnt between 1938 and 1987, than if it was burnt at least once during that period (Nimes 1995).

In Brittany, vegetation re-establishment after fire depended on topography and amount of combustible material, and took from 2-4 years to reach 90% cover. Grasses dominated for a number of years with burnt areas returning to heath after about 20 years, or, on more fertile substrate to birch woodland. Grass or moss cover developing after fire delayed or inhibited restoration of heathland (Clement & Touffet 1990, Gloaguen 1990).

5.1.2 Impacts of fire on heathland invertebrates

Most studies recognise a succession of heathland invertebrates after fire and during the recovery of heathland vegetation. Few soil and litter dwelling invertebrates are killed by fire unless temperatures exceed 45° (Webb & Thomas 1994). Some studies have shown a decline in species richness of some groups after fire, including bugs (Hemiptera and Homoptera) (Morris 1975), herbiverous beetles (Bulan & Barrett 1971), moths (Lepidoptera) (Haysom & Coulson 1998) and soil mites (Webb & Thomas 1994), while others have shown increases (Merrett 1976), including, ants (Webb 1997) and grasshoppers (Warren and others 1987). Generally, communities of predatory and scavenging species such as ground beetles, ants and hunting spiders increase in richness and numbers after a burn (Gardner & Usher 1981. Usher & Smart 1988). Overall, the highest densities of invertebrates are found in pioneer or old heather. This includes litter living species, web spinning spiders and herbivores (Merrett 1976, Barclay-Estrup 1974),

Invertebrate species with restricted niches eg species of old heather growth, are more susceptible to uncontrolled burning of large areas (Bell and others 2001), and for such species it is important that some unburnt refuges are left and that periods between burns are sufficient to allow re-colonisation to take place (Harpur and others 2000).

5.1.3 Impacts of fire on heathland reptiles

A heathland fire will kill most reptiles within the burnt area and the few that survive are then vulnerable to predators on the open ground, so in most cases, recolonisation will come from adjacent unburnt areas, and can take from 5-25 years (English Nature 1983).

The severe fires in 1976 reduced the old heather stands favoured by sand lizards and smooth snakes (Harrison 1983). Such fires can reduce or remove food and cover and result in serious habitat degradation for lizards (Corbett 1994). Smooth snake populations were found to be generally denser on sites with heather stands over 20 years old across their range in Southern England, and many years may be required before a predominantly mature heather habitat recovers from fire (Braithwaite and others 1989, Braithwaite 1995).

5.1.4 Impacts of fire on heathland birds

The widespread summer fires in Dorset showed how serious a threat these can be in a hot summer as some 20% of all the Dartford warbler breeding sites in Dorset were destroyed in a single season (Bibby 1977). Although some marked adult Dartford warblers survived on one site which sustained a large fire, none of these marked birds could be found breeding on this, or any other site the following summer (Bibby 1979). Adult Dartford warbler are site faithful and stay on the same territory throughout their lives (Bibby 1977) and it seems possible that, with their territories destroyed, these adults perished.

There have been few studies of heathland bird populations after fires. In Spain, it was found that Dartford warblers could persist in small islands of vegetation in burnt areas, although where such features were not present, Dartford warblers were absent. Dartford warbler populations took six years to reach the same densities as those in nearby un-burnt areas, but after that time densities were higher than in un-burnt areas (Herrando and others 2001).

Fire can provide a short term flush of insect carcasses, but after this, food can be greatly reduced for insectivorous vertebrates, and such shortages can last for some time and could affect insectivorous birds (Daubenmire 1968, Warren and others 1987).

6. The effects of cats on heathland wildlife

6.1 Cat numbers in the UK

The latest estimates of the number of cats in Britain suggest that there are some 8 million domestic cats and over 800,000 feral cats, with a total population of about 9 million (Turner & Bateson 2000, Harris and others 1995, Woods and others 2003). This is some 20 times the pre-breeding population of weasels and stoats and 38 times the pre-breeding population of foxes (Harris and others 1995).

A recent analysis of the figures produced by the Target Group Index, an annual survey of about 25,000 adults across Britain, investigated the pattern of cat ownership by households (Saul 2000). This found that 23% of households own at least one cat as a pet, with 13% of households having one cat and 10% of households, two or more cats, with an associated error of ±1%. In a study of the prey of domestic cats, Woods and others (2003) obtained figures for 396 households owning cats, where 75% of households owned one cat, 16% two cats, 5% three cats and 2% four cats. Five, six, seven and eight cats were owned by one, two, one and one households respectively. The results of the Target Group Index and the work of Woods and others (2003), suggests a figure of 320-330 cats per 1000 households. However, patterns of cat ownership vary between regions (eg in the South-West of England 30% of households own at least one cat, while in the West Midlands the figure is 10%). Such patterns also vary with age of owners (older people are less likely to own a cat), with income (as incomes increase, so does cat ownership) and with working status (working housewives are more likely to own a cat than non-working or retired housewives). Thus, detailed estimates of likely cat ownership in a particular place would need to consider location and characteristics of the resident human population, if known.

6.2 Cat hunting behaviour

There are wide differences in the hunting behaviour of domestic cats, with some individuals catching many prey animals and others catching none (Churcher & Lawton 1987, Barratt 1998). Panaman (1981) found clear differences in the proportion of time spent hunting and in the hunting efficiency of individual cats. Barratt (1998) found that there were no significant differences in total amounts of prey caught per year between male and female cats, between purebred and crossbred cats or between cats neutered as kittens or adults. (Most cats in Barratt's study were neutered, so he was unable to test for differences between neutered and un-neutered cats). However, older cats of both sexes which had not been neutered brought home less prey than younger cats (Churcher & Lawton 1987, Barratt 1998), with predatory activity declining after year four (Howes 2002). The sex of the cat did not significantly affect the numbers of mammals, birds or herpetofauna brought home by cats. Cats in poor condition and older cats brought home fewer birds and herpetofauna, but not fewer mammals than younger or fitter cats (Woods and others 2003).

Based on 24 hour observations of three domestic cats during 8,500 daylight and 7,300 crepuscular/nocturnal hours of observation, George (1971) found that they spent 14-18 hours hunting per day in spring, 13-17 hours in summer, 10-15 hours in autumn and 8-12 hours in winter. About half the prey his cats brought back to the house and garden were caught during the day, with 20% caught at dusk or dawn and 30% caught at night.

In a study of Cornish female farm cats, based on 15 daytime and eight 24 hour observation periods, Panaman (1981) found that cats spent 14.8±10.9% of 24 hours hunting, with peaks between 10-14 hours of up to 25% and between 16-19 hours of up to 32% and a low of between 0-2% between 2-5 hours. A study in Canberra, Australia, found that predation rates on mammals were greatest between 1800-2400 hours, and on birds between 0600-1200 hours. Fifteen of sixteen reptiles were caught between 2400-0600 hours (Barratt 1997).

George (1971) recorded his cats catching up to three items in 24 hours on several occasions in Illinois, USA. Over the course of a year, in Canberra, Australia, Barratt (1998) recorded a mean of 10.2 ±2.7 s.e. and a maximum of 72 prey items caught per cat per annum. A study in Yorkshire recorded a mean annual prey capture rate of 29 items per cat, varying from 8 items for urban cats to 37.5 items for rural cats (Howes 2002). Another study in Bedfordshire, found that, on average, 14 prey items were brought home by individual cats per annum, six of the study cats brought home no prey at all, and one brought home 95 items in 12 months (Churcher & Lawton 1987).

6.3 Cat prey

Most studies of the prey of domestic cats have relied on cat owners recording prey brought home. This method was first used comprehensively by Churcher & Lawton in the UK (1987), who recorded a total of 1090 prey items brought home by approximately 70 cats over a one year period. A breakdown from this and the other studies described here is summarised in table 5. The most comprehensive study in the UK was carried out on behalf of the Mammal Society, using questionnaires returned from 618 households between 1 April and 31 August 1997. In this survey, a total of 14,370 prey items were brought home by 986 cats, (Woods and others 2003).

The figures presented in the Mammal Society survey do not cover the full year, but using the same methodology, Barratt (1997), working on a varying number of suburban cats in Canberra, Australia, recorded 1961 prey items brought back over 12 months. Of these 57.5% were brought back during the summer months of Sept-March. In Yorkshire, Howes (2002) recorded 50% of 5,321 vertebrate and invertebrate prey items brought home during Sept-March, based on a survey of 180 domestic urban/suburban and rural cats. In this study, 54% of prey was five small mammal species (wood mouse, bank vole, field vole, common shrew and pygmy shrew) and 16% were house sparrows.

Adding the mean number of prey per cat from Woods and others (2003) for April-August (14.57) and the mean number of prey per cat for Sept-Mar (14.78) from Howes (2002), gives an annual catch per cat of 28.94 prey items. This is within the range recorded by other studies (Paton 1991, Churcher & Lawton 1987, Barratt 1998), and compares with Howes (2002) figure for a full year of 29.6 prey items per cat p.a. Taking 320 as the estimated figure for number of cats per 1,000 households, and using the calculated figures above, the likely number of prey items taken by these would therefore be 9,261 per annum per 1,000 households.

This figure is conservative, not only because it uses the lowest calculated estimates for cat numbers and the proportion caught during the winter, but also because not all prey items caught by domestic cats are brought home. George (1971), who undertook the most comprehensive study of daily and seasonal activity during 15,800 hours of observations over six years, based his calculations on the assumption that only 50% of the prey caught by his cats was subsequently recorded by observers. This was because he believed that some were scavenged by other animals before they were found, eaten by the cats before they could be recorded or simply not found.

Table 5. Proportions of different prey types taken by domestic cats in six studies

Source	Mammals		Birds		Herps/fish		Invertebrates		Unidentified	
	Numbers	%	Numbers	%	Numbers	%	Numbers	%	Numbers	%
Liberg 1984, Sweden January 1974-March 1979	830	91.9	73	8.1	-	-	-	-	-	-
Churcher and others 1987, UK July 1981-July 1982	535	49.1	297	27.2	-	-	-	-	258	3.7
Carss 1995, Scotland December 1983-February 1985	195	94.7	11	5.3	-	-	-	-	-	-
June 1991-May 1993	174	76.3	53	23.2	1	0.4	-	-	-	-
Barratt 1997, Australia (May 1993-April 1994)	1,273	64.9	529	27.0	157	8.0	-	-	2	0.1
Howes, 2000, Scotland (12 months 1978-79)	3,600	69.2	1,586	30.5	19	0.4	116	2.2	-	-
Woods and others 2003, UK (1 April-31 August 1997)	9,852	68.6	3,391	23.6	1,355	9.4	305	2.1	191	1.3

Taking the proportions of different prey types for April-August from Woods and others (2003) and for Sept-March from Howes (2000), and applying these to the total annual catch estimated per thousand households, the estimated figures are given in Table 6.

Although these figures give a general indication of scale and proportions of prey types, they should be treated with caution. They are derived from just two studies in different parts of the UK and from a mixture of urban, suburban and rural cat populations. It has been found that town/urban cats take lower numbers of prey than rural cats (Howes 2000). The figures for winter did not include a category for unidentified prey items. Both study estimates were based on survey data gathered from members of the public, and it was not known how representative these samples were of cats generally, and whether, for example, there was a bias in the figures towards cats which were regular hunters and owners who were particularly concerned by their behaviour. The figures may not reflect the prey intake of feral cats.

Table 6. Total prey caught by cats per 1,000 households per annum (estimated from Woods and others 2003 and Howes 2002)

Taxon	Estimated numbers	Estimated percentages
Mammals	6,735	72.7
Birds	2,075	22.4
Herps and fish	251	2.7
Invertebrates	140	1.5
Unidentified	6	0.7
Total	9,261	

Liberg (1984) found that the prey spectrum of domestic and feral cats was similar, although feral cats tended to catch more rabbits, and when these were abundant, feral cats took about four times the weight of natural prey than domestic cats over the same period. The figure of 8.9% for cats which brought home no prey from Woods and others (2003) was similar to the detailed study by Churcher and Lawton (1987) of 8.6%. Despite these caveats, it is probable that the total figures are conservative, as cats may not bring home all the prey they kill (George 1971) and this is particularly likely to be the case for small items such as invertebrates.

In calculating the number of prey caught by cats per annum, it seems reasonable to assume a minimum average catch per cat of 29 prey items, with a maximum average catch of 58 prey items using George's (1971) observation that only 50% of caught prey is brought home.

6.4 Effects on populations of prey species

The effect of cat predation on local or scarce heathland species is not known. A number of general studies exist, suggesting that cat predation can have a significant impact on common and widespread species populations locally. Churcher & Lawton (1987) collected prey from all but one cat owner in a Bedfordshire village over the course of 12 months. They also estimated the total population and productivity of house sparrows in the village (one of the main prey species of the cats). They concluded that at least 30% of sparrow deaths were due to cat predation during the year of the study, but that the figure could be higher if it was assumed that only half the kills made by cats were found and reported.

In a study in a 4,500ha area of S. Sweden, Liberg (1984) estimated that, of the annual production of prey species, a combined population of domestic and feral cats predated some 18% of the field voles, 24% of the wood mice, 23% of hares and 4% of the rabbits in a normal winter rising to about 8% after a hard winter.

In Illinois, USA, George (1974) found that his cats brought in very little prey during December-February, and considered that this was due to a scarcity of prey rather than hunting failures by the cats, which continued to eat all the voles they did catch, and extended their hunting ranges by about 25%. He considered that this prey shortage in winter was at least partly due to the prior predation by the cats earlier in the year.

At a population level Mead (1982) could find no evidence of cats affecting the eighteen bird species most commonly reported as having been taken by cats through the UK ringing scheme. It was clear, however, that cat predation was a significant cause of death for most of the species examined, and accounted for 25% of all recoveries in six species.

However, all six species were widespread with populations ranging from 250,000 to 7,100,000 in the UK and the same considerations may not apply to a species with a small population found on a localised or specialist habitat such as Dartford warbler or sand lizard.

6.5 Cats and lowland heathland

There are no quantifiable records of lowland heathland birds being taken by domestic cats. Cats have been recorded taking some heathland species including linnet, yellowhammer, Dartford warbler and green woodpecker (Bibby 1979, Howes 2002, Woods and others 2003, Murison pers. comm). It is not recorded, however, whether all these were killed on heathland. There are also records of cats hunting in sand lizard colonies (Henshaw 1998), catching and killing dragonflies (Goddard 2003, Emary & Emary 2004) and bats (Liberg 1984, Woods and others 2003).

There is considerable evidence that cats visit lowland heathland. There are records of cats being seen on heathlands in Dorset at Arne (pers. obs.), Middlebere Heath (Liley pers comm.), and at Noon Hill, Dewlands Common North, Bourne Valley, Kinson Common, Canford Heath, Upton Heath, Talbot Heath, Upton Heath, Turbary Common, Ferndown Common, Parley Common, Bourne Bottom and Alder Hills by staff of the Urban Heaths Life Project in Dorset. A number of these cats were recorded as hunting but no prey was identified.

6.6 Cat hunting ranges and distances

A number of studies have examined the hunting ranges of cats and the distance cats will travel (Table 7). Most of these have relied on radio telemetry, but few of these have been undertaken in the UK, and none in areas on or adjoining heathland. From these, the smallest mean home range (a female), was recorded by Konecny (1987) on the Galapagos, and the largest (a male), by Jones and Coman (1982) in S-E Australia.

In all comparable cases, male hunting ranges are larger than female, and nocturnal ranges are larger than diurnal ones.

Table 7. Mean (±sd) hunting ranges of cats (ha) from minimum convex polygons with sample sizes in parentheses

Females		Males			Source
Nocturnal	Diurnal	Nocturnal	24 hour	Diurnal	
42±25 (2)					Corbett 1979 (Scotland)
	170±141 (2)			615±275 (4)	Jones & Coman 1982 (Aus)
	206±31 (3)			480±340 (4)	Liberg 1981, 1984 (Sweden)
112±21 (7)		228±100 (4)			Warner 1985 (Illinois, USA)
35±20 (2)		149±146 (4)			Konecny 1987 (Galapagos)
130±114 (2)		407±284 (2)			Konecny 1987 (Galapagos)
154±21 (9)	91±67 (12)	239±97 (4)		134±85 (7)	Langham and others 1991 (NZ)
			53 (1)		Carss 1995 (Scotland)
			90.2-294		Naidenko and others 2002 (Germ)

A study by Page and others (1991) was based on records of feral cats seen in 25mX25m units of a grid placed over a map of Avonmouth Docks (Table 8).

Table 8. Mean (±sd) hunting ranges of cats (ha) from 25mX25m units with minimum and maximum ranges and sample sizes in parenthesis over 24 hour periods.

Female				Male				Source
Mean ± sd	(n)	min	max	Mean±sd	(n)	min	max	
10.3±2.6	(5)	2.6	17.6	15.0±4.7	(13)	0.9	56.1	Page and others 1991 (Avon)

A number of studies report that the hunting ranges of cats overlaps both within and between sexes, i.e. they use parts of the same geographical areas (Panaman 1981, Turner & Mertens 1986, Page and others 1991, Naidenko & Hupe 2002.

Barratt (1995) found that home ranges of cats living at the same residence (including a colony of farm cats), overlapped extensively, but there was little or no overlap between the home ranges of cats from different residences. Page and others (1991) noted a positive correlation between the size of home ranges and the weight of male cats. Thus, larger cats had bigger home ranges than smaller cats. He also found that cats were more active at night with peak activity between 1700 hours and 2100 hours around sunset.

No studies could be found which specifically examined the distances which cats travelled from their home base, although a number of studies gave observed distances (without confidence limits), and two casual observations have also been included (Table 5).

Table 9. Distances travelled by cats in a straight line between two points.

Location	Distance	Source
Cornwall farm cats	80-400m from home	Panaman 1981
Avonmouth Docks, Avon	Mean max. linear distance between	Page and others 1991
Feral cats	two points for two males 1107±589m,	
	n=16, for one female 806±334m, n=8	
N. Scotland, domestic cat	Distance moved from suburb edge by two males, 900m, 760m, and one female 810m, all at night	Barratt 1995
Arne, Dorset, UK	1000m from home during day	Day. Pers. Obs. 2001
Middlebere, Dorset, UK	560m from nearest house during day	Liley Pers Comm 2001

6.7 Mitigation of cat predation effects

A number of measures have been suggested to mitigate the effects of cats on wildlife within some of the wider studies considered here.

A study over eight weeks on 21 cats wearing bells for four weeks and no bells for four weeks found that on average 2.9 prey items were delivered home by the belled cats, and 5.5 by the un-belled cats (Ruxton and others 2002). Barratt (1998) found that the wearing of bells did not reduce the amount of prey caught per cat per annum or the amount of birds caught per cat per annum. Woods and others (2003) found that wearing a bell significantly reduced the number of mammals caught but not birds or herpetofauna.

Woods and others (2003) also found that if cats were kept in at night this significantly reduced the number of mammals brought home, and significantly increased the number of herpetofauna brought home, but there was no effect for birds. Barratt (1998) found that there was a positive relationship between total predation and nights outside, and that the number of nights outside helped to explain the number of mammals caught but not the number of birds or reptiles.

The number of feeding times per day did not influence the amount of prey caught per cat per year, and the number of birds and reptiles caught by cats was not related to the number of nights per fortnight spent outside (Barratt 1998). The mean number of birds and herpetofauna brought home per cat was significantly lower, and the number of bird species significantly greater, in households that provided food for birds (Woods and others 2003).

No scientific studies could be found in the literature on the efficacy of other proposed cat deterrents such as special collars, ultra sound, hard surface treatments or planting schemes, nor on the effectiveness of cat barriers such as walls, fences or water filled features. A number of these have been proposed in mitigation of proposed urban developments (eg Ecological Planning & Research 2001).

7. Trampling effects on heathland

7.1 Trampling studies

Direct effects of trampling can lead to damage to plant parts from breakage and abrasion, with indirect effects from soil compaction, changes in soil hydrology, pH and soil chemistry (Van der Maarel, 1971, Liddle 1975, Liddle & Greig-Smith, 1975, Dunn 1984).

A study by Weaver and Dale (1978) on grassland and dwarf shrub communities in Montana, USA, showed that on level ground, horses were most destructive, followed by motorcycles, but that motorcycles were more destructive on sloping ground, and could also be more destructive than horses on level ground if driven at more than 20Km h^{-1}. Hikers had less effect on vegetation than either horses or motorcycles on both level and sloping ground. Both soil erosion and compaction was greatest under horses, but on dwarf shrub sites, there was no difference in the level of damage to vegetation cover between horses and motorcycles. Appearance of bare ground was more rapid in dwarf shrub communities than in grass communities. Different effects were due to the relative weights, movements and downward pressures of the subjects studied. Horse trampling can damage populations of Hymenoptera and Diptera associated with bare ground on southern heaths (Miles 2003)

In a comparison of trampling damage to lowland grasslands and heathland in Southern England, Harrison (1981) also found that after 2000 summer passes, all plots recovered to at least 50% live cover in a few weeks of autumn growth except *Calluna* heathland which did not recover. The *Calluna* heathland plots showed a more delayed response than grassland to winter trampling, and did not recover. Harrison concluded that the vulnerability to trampling was related to soil structure and drainage in winter and to plant biology in the summer. Nutrient poor, coarse textured inorganic soils are affected more than fertile organic soils. Some vegetation types, notably those of bogs, and those with a high frequency of lichens and mosses are intolerant of high trampling intensities (Anderson & Radford 1992, Winning 1994).

Studies of experimental trampling of heathland in summer after periods of dry and wet weather, and in winter, in Brittany, France, have shown that dry heathland (DH), dominated by bristle bent grass *Agrostis curtisii,* bell heather *Erica cinerea* and gorse *Ulex europeaus* was more resistant to trampling than mesophilous heathland (MH) dominated by Dorset heath *Erica ciliaris,* bristle bent and gorse. Within heathland types, MH was more resistant to trampling in summer in wet conditions than dry, but there was no similar effect on DH, although it was significantly more resistant in winter than summer. There were also differences in the responses of individual plant species. These differences in trampling tolerance seemed to reflect different soil and hydrological conditions which place other ecological stresses on plant species (Gallet & Rozé 2001).

When the same plots were re-examined after one year, there was little difference between the two types of heathland on the summer trampled plots which both showed moderate levels of recovery, although both seemed to have greater resilience to trampling which took place under dry, rather than wet, conditions. Individual species also showed different rates of recovery (Gallet & Rozé 2002).

Finally, Gallet & Rozé (in press) looked at differences in experimental trampling depending on whether this occurred intensively in one event (on a single day), or over time on a number of occasions, but with the same total number of passes for paired treatments. Only limited differences could be found after 15 and 75 days following the trampling, but it appeared that there was less damage from the single event than from the cumulative damage from repeated trampling.

The results of these studies by Gallet and Rozé suggest that:

- dry heaths are more resistant to trampling damage than wet heaths;
- dry heaths are more resistant in winter than summer;
- damage to wet heath is greater in dry conditions than wet, but recovery is quicker when damage is caused in dry conditions;
- recovery from winter trampling is greater on wet heath than dry;
- gorse is more resilient to winter than summer trampling, as is Dorset heath;
- bell heather is most resilient to summer trampling in dry conditions;
- there is less damage from trampling after a single event than from repeated trampling where the total number of passes was the same in both treatments.

Another study has looked at long-term recovery of a number of vehicle track-ways on Dartmoor following cessation of use (Charman & Pollard 1995). This found that grassland tracks recovered after a maximum of 18 years once the use had ceased, that mixed grass and heath took from four to a maximum of 24 years to recover and that moorland/blanket bog vegetation took in excess of 24 years to recover, or might never recover without some form of intervention.

8. Other urban issues

8.1 Dogs: non-disturbance effects

The earlier section on disturbance effects included those caused by dogs on heathland birds and direct predation of eggs or young. This section reviews other effects of dogs on heathlands.

A number of visitor studies have collected data on the use of heathlands and other semi-natural habitat by dogs. In surveys where 100 observations or more were reported, the mean percentage of visitors who were accompanied by one or more dogs was 54.0% within the range 21-92% (UPE 1996, Turner 2000, EM 2003, RSPB 2003, MORI 2004).

In one study of the visitors to the New Forest, a greater proportion of residents visited to walk their dogs (42%) than day visitors (20%) or holiday makers (14%) (UPE 1996). Similarly, in a number of studies the ratio of dogs to dog walkers also varied from 1.2-1.6 (median 1.5) (Stride 2001, RSPB 2003, EM 2003, MORI 2004).

In three studies, the proportion of dogs off the lead was observed as 43.5%, 95% and 100% (Bull 1998, RSPB 2003, MORI 2004). In only one study, at Burnham Beeches was an estimate made of the proportion of dogs which defecated during their visit (26%), with 42% of owners cleaning up afterwards (EM 2003). In studies by Stride (2001) at Sandford and Winfrith heaths, all respondents said they did not clean up.

In the study at Burnham Beeches, an attitude survey of both dog owners and non-dog owners to dogs, found that over 70% of all respondents found dog fighting, fouling, livestock worrying and chasing/disturbing wildlife to unacceptable behaviour by dogs. The same survey found that 67% of respondent felt that dogs were generally kept under control, but this was contradicted by the same respondent sample, of whom only 6% felt all dogs were kept under effective control, and 21% felt that only a minority of dog owners have effective control of their dogs (EM 2003). A survey at Bourley and Long Valley Heath in Hampshire, found that 14% of the dogs not on leads were not under control (MORI 2004).

A survey by Bull (1996) on National Trust land recognised a number of effects of dogs, including disturbance of livestock, disturbance to birds (dealt with elsewhere in this report), disturbance to ponds and other water bodies and dog fouling.

Dogs will chase and can worry farm animals, particularly sheep, and dog chasing can result in deaths from injury through falls, entanglement or car accidents. There can be similar effects on deer. Conservation grazing schemes can be affected due to graziers not being prepared to enter a scheme, only being prepared to graze at quiet times of year or because stock concentrate their grazing away from the main sources of disturbance.

Dogs jumping into ponds can cause physical damage to banks and structures, disturb wildlife and possibly cause contamination if the dog has been treated for ecto-parasites (Bull 1998).

The most noticeable effect of dogs visiting heathland is the effect of fouling. A study in public recreation grounds found that there was a strong linear relationship between defecation density from dogs and soil phosphorus, and that in one area, there were high residual phosphorus levels three years after dogs had been banned (Bonner & Agnew 1983). Another study at Headley Heath in Surrey found that soil compaction and dog fouling declined with distance from path, that the effects were greatest on a major path and that the distribution of soil phosphate and to a lesser extent ammonium nitrogen followed the same pattern as canine faeces. Dog fouling (and trampling by humans) was associated with a shift away from heather *Calluna vulgaris* towards wavy hair grass *Deschampsia flexuosa*. On nutrient poor systems, such as heathland the inputs of nitrogen, phosphates and potassium from dog faeces can exert a significant fertilising effect (Shaw and others 1995).

8.2 Nutrients from horses

Little information could be found on the effect of horse faeces on heathland ecosystems. A study by Liddle & Chitty (1981) compared the vegetation and soil nutrients (from horse defecation) of horse tracks and adjoining areas on Calluna heather and bracken dominated sites. They found that vegetation was absent from the tracks probably due to horse trampling and water shortages caused by compaction and run-off. At track edges, heather and bracken were replaced by purple moor grass *Molinea caerulea*. At the heather dominated site there was significantly more phosphorus and at the bracken dominated site more nitrogen than in control areas 10m from the tracks, probably as a result of horse dung deposited on the paths.

8.3 Urban light and noise

There is little literature on these issues, and most research concerns aircraft or traffic noise, neither of which is covered by this review.

A study of the effects of noise from two landfill sites at heathland locations was undertaken for the Environment Agency in Dorset (Marks 2003). The study established noise contours and found that nightjars nested successfully within the 45dB L_{Aeq} contour but not the 50dB L_{Aeq} contour. (These parameters represent a continuous background noise level of between 45 and 50 decibels) However, as these contours fell within a short distance of the site, this finding could have been the result of other factors such as predation. Specific measurements taken at two successful nest sites established that these were experiencing moderate background noise levels during the day of between 70dB and 80 dB.

A recent study also showed that urban great tits *Parus major* can sing with a higher minimum frequency at noisy locations, presumably to counteract the predominantly low frequency noise (Slabbekoorn & Peet 2003). Hunter & Krebs (1979) found that great tits sang with a lower maximum frequency, narrower frequency range and fewer notes per phrase in some habitats rather than others. They suggested that this was, at least in part, related to differences in the acoustic qualities and territory sizes in different habitats. Both nightjars and woodlarks seem to have songs adapted to long distance transmission, and urban background noise may affect them in different ways to Dartford warblers or stonechats whose songs have a more limited transmission (Cramp 1992).

Most of the literature on the effects of artificial light is concerned with the disorientation of birds and insects, or with observations of artificial light assisting feeding by birds (Hill 1990). No published records could be found of nightjars using artificial lights for feeding in the UK, although there is a record of Asiatic nightjars C*aprimulgus asiaticus* feeding by the light of a mercury vapour lamp in India, and another species *Caprimulgus affinis* feeding by the light of artificial light in Indonesia (Bharos 1990, Harvey 1976).

No published studies could be found on other urban effects including, tipping, introduction of alien species, hydrological effects, installation of services , pollution or changes in pH.

9. Future research

The studies by Hall (1996) and Liley (2004) on Yateley Common SSSI suggest that whilst the impacts of different types of activity associated with nearby urban settlements may be changing, the overall effect of people on the heathland SSSI has not diminished over the last nine years.

In surveys carried out on the attitudes of people to heathlands in Surrey, Dorset and Cornwall (Atlantic consultants 1996, 1998), it was found that the public valued heathlands primarily for their wildlife (and attractiveness and natural beauty in Cornwall) and as public open space. The 1998 study also found that there had been slight changes in visiting patterns in Surrey and Cornwall but a significant increase in the number of daily visits to heathland in Dorset between the two surveys.

The same study showed that most people visited the heath to walk (with or without a dog), with other activities including horse riding, cycling, running, bird watching, studying wildlife and natural history, and for pleasure and relaxation. There were no major changes in the proportion of respondents giving these activities as reasons for visiting heathland between the two surveys.

These impact and visitor studies suggested that the level of visiting and the types of activity undertaken on heathland changed little between years.

Considerable research has been undertaken in recent years into biological aspects of heathland ecology and management, and some studies, including research into disturbance issues and heathland birds are ongoing. Further work is needed on the mechanisms of disturbance and its effects, into the behaviour of cats on heathland and on the impact of urban noise and light on heathland species.

There has been considerable investigation of the effects of people and their pets on the urban heaths but little is known about the behaviour of people on heaths, apart from some visitor studies, most of which have been based on questionnaires at specific sites. Further studies to objectively investigate people’s behaviour and to determine, via experimental investigation how this might be manipulated to minimise their impacts on heathlands would be useful.

10. Acknowledgments

I would like to thank the staff at the Dorset Environmental Records Centre and English Nature for their encouragement and assistance. I am particularly grateful to Phil Sterling for helping to set the background and parameters for the review and to Ian Dawson and Lynn Giddings from the RSPB library and Nick Squirrell from English Nature for their help in locating references. Durwyn Liley kindly suggested improvements to the section on disturbance effects. The review has been improved in numerous ways by the careful editing and helpful suggestions of Richard Archer.

11. References

ALEXANDER, I., & CRESSWELL, B. 1990. Foraging by nightjars *Caprimulgus europaeus* away from nesting areas. *Ibis,* 132, 568-574.

ALLCHIN, E.A., & PUTWAIN, P.D. 1996. Burning heathland for management, fire temperature and vegetative regeneration. *Aspects of Applied Biology*, 44, 407-412.

ANDERSON, P. 1986. *Accidental moorland fires in the Peak District: A study of their incidence and ecological implications*. Bakewell: Peak Park Planning Board.

ANDERSON, P., & RADFORD, E. 1992. A review of the effects of recreation on woodland soils, vegetation and fauna. *English Nature Research Reports,* No. 27.

ATLANTIC CONSULTANTS. 1996. *Attitude survey of the value of heathlands*. A report to English Nature.

ATLANTIC CONSULTANTS. 1998. *Repeat attitude survey of value of heathlands*. A report to English Nature.

BARCLAY-ESTRUP, P. 1971. The description and interpretation of cyclical processes in a heath community. III. Microclimate in relation to the *Calluna* Cycle. *Journal of Ecology*, 59, 143-166.

BARRATT, D. G. 1995. Prey habits and movement patterns of house cats in Canberra, Australia. *Executuve summary of MSc. Thesis.* University of Canberra.

BARRATT, D.G. 1997. Predation by house cats *Felix catus* (L.) in Canberra, Australia. I. Prey composition and preference. *Wildlife Research,* 24, 263-277.

BARRATT, D.G. 1998. Predation by house cats *Felix catus* (L.) in Canberra, Australia. II. Factors affecting the amount of prey caught and estimates of the impact on wildlife. *Wildlife Research,* 25, 475-487.

BEALE, C.M., & MONAGHAN, P. 2004. Human disturbance: people as predation-free predators? *Journal of Applied Ecology,* 41, 335-343.

BELL, J.R., WHEATER, C.P., & CULLEN, W.R. 2001. The implications of grassland and heathland management for the conservation of spider communities: A review. *Journal of the Zoological Society of London*, 255, 377-387.

BERRY, R. 1979. Nightjar habitats and breeding in East Anglia. *British Birds,* 72, 207-218.

BHAROS, A.M.K. 1990. Feeding by common nightjar *Caprimulgus asiaticus* and Indian roller *Coracius benghalensis* in the light of mercury vapour lamps. *Bombay Journal of Natural History*, 89, 124.

BIBBY, C.J. 1977. *Ecology of the Dartford warbler* Sylvia undata *(Boddaert) in relation to its conservation in Britain*. PhD Thesis. Council for National Academic Awards.

BIBBY, C.J. 1979. Mortality and movements of Dartford warblers in England. *British Birds*, 72, 18-22.

BLACKMER, A.L., ACKERMAN, J.T., & NEVITT, G.A. 2004. Effects of investigator disturbance on hatching success and nest-site fidelity in a long-lived seabird, Leach's storm petrel. *Biological Conservation,* 116, 141-148.

BONNER, & AGNEW, A. 1983. Soil phosphorus as an indicator of canine faecal pollution in urban recreation areas. *Environmental Pollution series B*, 6, 145-156.

BOORMAN, L.A., & FULLER, R.M. 1977. Studies on the impact of paths on the dune vegetation at Winterton, Norfolk, England. *Biological Conservation*, 12, 203-216.

BRAITHWAITE, A.C. and others. 1989. The distribution in England of the smooth snake *Coronella austriaca* Laurenti. *Herpetological Journal*, 1, 370-376.

BRAITHWAITE, A.C. 1995. *Pilot study for smooth snake* Coronella austriaca *species recovery programme. English Nature Research Reports,* No. 138.

BULAN, C.A., & BARRETT, G.W. 1971. The effects of two acute stresses on the arthropod component of an experimental grassland ecosystem. *Ecology*, 52, 597-605.

BULL, S.E. 1998. *The impact of dogs on National Trust properties*. Unpublished report. Cirencester: National Trust.

BULLOCK, J.M., & WEBB, N.R. 1995. A landscape approach to heathland restoration. In: K.M. Urbanska & Grodzińska, eds. *Restoration ecology in Europe*. Zurich: Geobotanical Institute SFIT.

BULLOCK, J.M., & WEBB, N.R. 1995. Responses to severe fires in heathland mosaics in southern England. *Biological Conservation,* 73. 207-214.

BURGER, J. 1994. The effect of human disturbance on foraging behaviour and habitat use in piping plover *Charadrius melodus. Estuaries,* 17, 695-701.

CARSS, D.N. 1995. Prey brought home by two domestic cats *Felix catus* in northern Scotland. *Journal of the Zoological Society, London,* 237, 678-686.

CHALFOUN, A.D., THOMPSON, F.R., & RATNASWAMY, M.J. 2002. Nest predators and fragmentation: a review and meta-analysis. *Conservation Biology,* 16, 306-318.

CHAPMAN, S.B., CLARKE, R.T., & WEBB, N.R. 1989. The survey and assessment of heathland in Dorset, England, for conservation. *Biological Conservation,* 47, 137-152.

CHARMAN, D.J., &, POLLARD, A.J. 1995. Long term recovery after vehicle track abandonment on Dartmoor, SW England. *Journal of Environmental management*, 45, 73-85.

CHURCHER, P.B., & LAWTON, J.H. 1987. Predation by domestic cats in an English village. *Journal of the Zoological Society, London,* 212, 439-455.

CLEMENT, B., & TOUFFET, J. 1990. Plant strategies and secondary succession in Brittany heathlands after severe fire. *Journal of vegetation Science,* 1. 195-202.

CORBETT, K. 1994. Pilot study for UK sand lizard recovery programme. *English Nature Research reports,* No. 102.

CORBETT, L.K. 1979. *Feeding ecology and social organisation of wildcats* Felix sylvestris *and domestic cats.* Felix catus *in Scotland*. PhD. Thesis. University of Aberdeen.

CRAMP, S. 1992. *Handbook of the birds of Europe the Middle East and North Africa. Vols. IV-VI.* Oxford: Oxford University Press.

DAUBENMIRE, R. 1968. Ecology of fire in grasslands. *Advances in Ecological Research,* 5, 209-266.

DE MOLINAAR, H.J.G. 1998. *On-the-spot appraisal of the Dorset heathland, UK*. Report and recommendations to the standing committee on The Convention on the Conservation of European Wildlife and Natural Habitats. Strasbourg: Council of Europe.

DORSET ENVIRONMENTAL RECORD CENTRE. 2004. *Urban heaths LIFE project-incident reporting.* Dorchster: DERC.

DORSET NATURALIST'S TRUST & ROYAL SOCIETY FOR THE PROTECTION OF BIRDS. 1977. *Heath fires in Dorset in 1976.* Unpublished Report. Exeter: RSPB.

DUNN, B.A. 1984. *Recreation effects on forest soil and vegetation: research synopsis and selected bibliography.* Technical paper. Department of Forestry, Clemson University, S.C. USA.

ENGLAND MARKETING. 2003. *Burnham Beeches visitor survey*. Farnham: The Corporation of London..

ENGLISH NATURE. 1983. The ecology and conservation of amphibian and reptile species endangered in Britain.

EMARY, C., & EMARY, L. 2004. The domestic cat: a regular dragonfly predator? *Journal of the British Dragonfly Society*, 20, 22.

ECOLOGICAL PLANNING & RESEARCH. 2001. *Holton Heath comprehensive development and B3075 improvements: Integrated Ecologiocal Strategy*. Winchester: EPR.

ERRITZOE, J. 2002. Bird traffic casualties and road quality for breeding birds. A summary of existing papers with a bibliography. Available from: www.birdresearch.dk.

FAHRIG, L. 2003. Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology Evolution and Systematics*, 34, 487-515.

FERNÁNDEZ-JURICIC, E., & TELLERÍA, J.L. 2000. Effects of human disturbance on spatial and temporal feeding patterns of blackbird *Turdus merula* in urban parks in Madrid, Spain. *Bird Study*, 47, 13-21.

FITZPATRICK, S., & BOUCHEZ, B. 1998. Effects of recreational disturbance on the foraging behaviour of waders on a rocky beach. *Bird Study*, 45, 157-171.

GALLET, S., & ROZÉ, F. 2001. Resistance of Atlantic heathlands to trampling in Brittany, (France): influence of vegetation type, season and weather conditions. *Biological Conservation*, 97, 189-198.

GALLET, S., & ROZÉ, F. 2002. Long-tern effects of trampling on Atlantic heathland in Brittany (France): resilience and tolerance in relation to season and meteorological conditions. *Biological Conservation*, 103, 267-275.

GALLET, S., LEMAUVIEL, S., & ROZÉ, F. In press. *Responses of three heathland shrubs to single or repeated experimental trampling.*

GARDNER, S.M., & USHEr, M.B. 1989. Insect abundance on burned and cut upland *Calluna* heath. *The Entomologist*, 108, 147-157.

GEORGE, W.G. 1974. Domestic cats as predators and factors in shortages of raptor prey. *The Wilson Bulletin*, 86, 384-396.

GIBB, H., & HOCHULI, D.F. 2002. Habitat fragmentation in an urban environment: large and small fragments support different arthropod assemblages. *Biological Conservation,* 106, 91-100.

GIBBS, J.P., & STANTON, E.J. 2001. Habitat fragmentation and arthropod community change: carrion beetles, phoretic mites and flies. *Ecological Applications*, 11, 79-85.

GILL, J.A., NORRIS, K., & SUTHERLAND, W.J. 2001. Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation,* 97, 265-268.

GIMMINGHAM, C.H. 1992. The lowland heathland management handbook. *English Nature Science*, No 8.

GLOAGUEN, J.C. 1990. Post-burn succession on Brittany heathlands. *Journal of Vegetation Science*, 1. 147-152.

GODDARD, D. 2003. The domestic cat: a new dragonfly predator. *Journal of the British Dragonfly Society*, 19, 39.

GODDARD, P. 1981. *Ecology of the smooth snake* Coronella asutriaca *Laurenti in Britain*. PhD Thesis, University of Southampton.

GODEFROID, S., & KOEDAM, N. 2003. How important are large vs. small forest remnants for the conservation of the woodland flora in an urban context? *Global Ecology and Biogeography*, 12, 287-298.

HALL, C.R. 1996. *A report on the condition of Castle Bottom to Yateley Common SSSI to English Nature, Lyndhurst*. Unpublished.

HARPUR, M.G., and others. 2000. Effects of prescribed fire on prairie arthropods: an enclosed study. *Natural Areas Journal*, 20, 325-335.

HARVEY, W.G. 1976. *Caprimulgus affinis* as an urban species in Indonesia. *Bulletin of BOC,* 96, 4.

HARRIS, S., and others. 1995. *A review of British mammals: Population estimates and conservation status of British mammals other than Cetaceans*. Peterborough: JNCC.

HARRIS, S., & RAYNOR, J.M.V. 1986. Urban fox *Vulpes vulpes* population estimates and habitat requirements in several British cities*.* *Journal of Animal Ecology*, 55, 575-591.

HARRISON, C. 1976. Heathland management in Surrey, England. *Biological Conservation,* 10, 211-220.

HARRISON, C. 1981. Recovery of lowland grassland and heathland in Southern England from disturbance by seasonal trampling. *Biological Conservation*, 19, 119-130.

HASKINS, L.E. 1978. *The vegetational history of south-east Dorset*. PhD. Thesis. University of Southampton.

HASKINS, L.E. 2000. Heathlands in an urban setting-effects of urban development on heathlands of south-east Dorset. *British Wildlife*, 4, 229-237.

HAYSOM, K.A., & COULSON, J.C. 1998. The Lepidoptera fauna associated with *Calluna vulgaris*: effects of plant architecture on abundance and diversity. *Ecological Entomology*, 23, 377-385.

HEAL, O.W. 1980. Fauna of heathlands in the United Kingdom. *Bulletin of Ecology and Conservation*, 11, 413-420.

HELY, C., & FORGEARD, F. 1990. Heterogeneity of a high *Ulex europeaus* heath with respect to relation to fire propagation. *Canadian Journal of Botany,* 76, 804-817.

HENSHAW, R.E. 1998. *An investigation to determine if the domestic cat* Felix catus *is a predator of the Sefton Coast sand lizard* Lacerta agilis *L.* MSc. Dissertation. University of Liverpool.

HERRANDO, S., and others. 2001. Factors influencing post fire dynamics of Sardinian and Dartford warblers in Mediterranean shrublands. *Ornis Fennica*, 78, 168-174.

HILL, D. 1990. The impact of noise and artificial light on waterfowl behaviour: a review and synthesis of available literature. *BTO Research Report 61.* Thetford: British Trust for Ornithology.

HILL, D., and others. 1997. Bird disturbance: improving the quality and utility of disturbance research. *Journal of Applied Ecology*, 34, 275-288.

HOBBS, R.J., & GIMMINGHAM, C.H. 1987. Vegetation, fire and herbivore interactions in heathland. *Advances in Ecological Research*, 16, 87-193.

HOCKIN, D., and others. 1992. Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. *Journal of Environmental Management*, 36, 253-286.

HOPKINS, P. J., & WEBB, N.R. 1984 . The composition of the beetle and spider faunas on fragmented heathlands. *Journal of Applied Ecology*, 21, 935-946.

HOWES, C.A. 2000. Red in tooth and claw: 2. Studies on the natural history of the domestic cat *Felix catus* Lin. in Yorkshire. *Naturalist*, 127, 101-131.

HUNTER, M.L. JR., & KREBS, J.R. 1979. Geographical variation in the song of the great tit *Parus major* in relation to ecological factors. *Journal of Animal Ecology*, 48, 759-785.

IKUTA, L.A., & BLUMSTEIN, D.T. 2003. Do fences protect birds from human disturbance? *Biological Conservation,* 112, 447-452.

JONES, E., & COMAN, B.J. 1982. Ecology of the feral cat *Felix catus* (L.) in south-eastern Australia. III. Home ranges and population ecology in semi-arid north-west Victoria. *Australian Wildlife Research*, 9, 409-420.

KENWORTHY, J.B. 1963. Temperatures in heather burning. *Nature,* 200, 1226.

KIRBY, J.S., & TANTRAM, D.A.S. 1999. *Monitoring heathland fires in Dorset: Phase I.* Report to: Department of the Environment, Transport and the Regions: Wildlife and Countryside Directorate. Northampton: Terra Environmental Consultancy.

KONECNY, M.J. 1987. Home range and activity patterns of feral cats in the Galapagos islands. *Oikos*, 50, 17-23.

LACK, D.L. 1932. Some breeding habits of the European nightjar. *Ibis,* 74, 266-284.

LAFFERTY, K.D. 2001. Birds at a southern California beach: seasonality, habitat use and disturbance by human activity. *Biodiversity and Conservation*, 10, 1949-1962.

LAHTI, D.C. 2001. The 'edge effect of predation' hypothesis after twenty years. *Biological Conservation,* 99, 365-374.

LANGHAM, N., & PORTER, R. 1991. Feral cats on New Zealand farmland. *Wildlife Research*, 18, 741-760.

LEGG, C.J., MALTBY, E., & PROCTOR, M.C.F. 1992. The ecology of severe moorland fire on the North York Moors: Seed distribution and seed establishment of *Calluna vulgaris*. *Journal of Ecology*, 80, 737-752.

LIBERG, O. 1981. *Predation and social behaviour in a population of domestic cats. An evolutionary perspective.* PhD Dissertation. Sweden: University of Lund.

LIBERG, O. 1984. Food habits and prey impact by feral and house-based domestic cats in a rural area, S. Sweden. *Journal of Mammology*, 65, 424-432.

LIDDLE, M.J. 1975. A selective review of the ecological effects of human trampling on natural ecosystems. *Biological Conservation*, 7, 17-36.

LIDDLE, M.J. & CHITTY, L.D. 1981. The nutrient-budget of horse tracks on an English lowland heath. *Journal of Applied Ecology*, 18, 841-848.

LIDDLE, M. J. & GREIG-SMITH, P. 1975. A survey of tracks and paths in a sand dune system I. Soils. *Journal of Applied Ecology*, 12, 893-908.

LILEY, D. 2004. *Human impacts on the Castle Bottom to Yateley Common and Hawley Commons SSSI, Hampshire.* Report to RSPB and English Nature.

LILEY, D., & CLARKE, R.T. 2002. Urban development adjacent to heathland sites in Dorset the effect on the density and settlement patterns of Annex I bird species. *English Nature Research Reports,* No 463. Peterborough: English Nature.

LILEY, D., & CLARKE, R.T. 2003. The impact of urban development and human disturbance on the numbers of nightjar *Caprimulgus europaeaus* on heathlands in Dorset, England. *Biological Conservation,* 114, 219-230.

LILEY, D., LANDSTON, R., & WALKER, J. 2002. *Sustainable recreation management on lowland heathland Sites of Special Scientific Interest.* Report to English Nature. Wareham: RSPB.

LORD, A., and others. 2001. Effects of human approaches to nests of northern New Zealand dotterels. *Biological Conservation,* 98, 233-240.

MACARTHUR, R.H. & WILSON, E.O. 1967. *The theory of island biogeography*. Princeton, New Jersey: Princeton University Press.

MADER, H.J. 1984. Animal habitat isolation by roads and agricultural fields. *Biological conservation*, 29, 81-96.

MADER, H. J., SCHELL, C., & KORNACKER, P. 1990. Linear barriers to arthropod movements in the landscape. *Biological Conservation*, 54, 209-222.

MALTBY, E., LEGG, C.J., & PROCTOR, M.C.F. 1990. The ecology of severe moorland fire on the North York Moors: effects of the 1976 fires, and subsequent surface and vegetation development. *Journal of Ecology*, 78, 490-518.

MARKHAM, D. 1996. The significance of secondary roads and road transport on nature conservation. A report prepared for English Nature by Environmental Resources Management. *English Nature Research Report*s, No. 178.

MARKS, P. 2003. *Assessment of noise impacts on nightjar in Dorset*. Report to Environment Agency. Tewkesbury.

MEAD, C.J. 1982. Ringed birds killed by cats. *Mammal Rev.* 12, 183-186.

MERRETT, P. 1976. Changes in the ground-living spider fauna after heathland fires in Dorset. *Bulletin of the British Arachnological Society*, 3, 214-221.

MILES, S.R. 2003. *Heathland flies-UK Biodiversity Action Plan Project*. Fifth and final report. British Entomological and Natural History Society.

Miller, J.R., & Hobbs, N.T. 2000. Recreational trails, human activity and nest predation in lowland riparian areas. *Landscape and Urban Planning*, 50, 227-236.

MILLER, S.G., & KNIGHT, R.L. 1998. Influence of recreational trails on breeding bird communities. *Ecological Applications*, 8, 162-169.

MILLER, S.G., KNIGHT, R.L., & MILLER, C.K. 2001. Wildlife responses to pedestrians and dogs. *Wildlife Society Bulletin*, 29, 124-132.

MOORE, N.W. 1962. The heaths of Dorset and their conservation. *Journal of Ecology*, 50, 369-391.

MORI. 2004. Bourley and Long Valley Heath users survey. London: MORI Social Research Institute.

MORRIS, M.G. 1975. Preliminary observations on the effects of burning on the Hemiptera (Heteroptera and Auchenorrhyncha) of limestone grassland. *Biological Conservation*, 7, 311-319.

MUNNS, D. 2001. *Urbanisation effects on Canford heath 1991-2000.* Unpublished Report. Wareham: RSPB.

MURISON, G. 2002. The impact of human disturbance on the breeding success of nightjar *Caprimulgus europaeus* on heathlands in south Dorset, England. *English Nature Research Reports,* No. 483.

NAIDENKO, S.V., & HUPE, K. 2002. Seasonal changes in home range use in feral tomcats in Solling, Central Germany. *ЗООЛОГИЧЁСКИЙ ЖУРНАЛ*, 81, 1381-1370.

NATURE CONSERVANCY COUNCIL. 1983. The ecology and conservation of amphibian and reptile species endangered in Britain. Nature Conservancy Council.

NIMES, R.B. 1995. Bracken, heath and burning on the Quantock Hills, England. *In*: D.B.A. THOMSON, A.J. HESTER & M.B. USHER, eds. *Heaths and Moorlands: Cultural landscapes.* London: HMSO.

NOL, E., & BROOKS, R.J. 1982. Effect of predator exclosures on nesting success of killdeer. *Journal of Field Ornithology*, 53, 263-268.

NORRINGTON, E. 1998. *A study of the impact of a statutory approach to extending public access to open countryside on the lowland heath of the Purbeck District.* MA Dissertation. University of Birmingham.

PAGE, R., ROSS, J., & BENNETT, D. 1991. A study of the home ranges, movements and behaviour of the feral cat population at Avonmouth Docks. *Wildlife Research*, 19, 263-277.

PANAMAN, R. 1981. Behaviour and ecology of free ranging farm cats. *Journal of Comparative Ethology,* 56, 59-73.

PATON, D. 1991. Loss of wildlife to domestic cats. *In*: C. Potter, ed. *The impact of cats on native wildlife.* Canberra: ANPWS.

PIENKOWSKI, M. 1984. Breeding biology and population dynamics of ringed plovers *Charadrius hiaticula* in Britain and Greenland: nest predation as a possible factor limiting distribution and time of breeding. *Journal of the Zoological Society of London*, 202, 83-114.

PRESST, I., COOKE, A.S., & CORBETT, K.F. 1974. *British Amphibians and reptiles*. *In*: D.L. Hawkesworth, ed. *The Changing Flora and Fauna of Britain*. London: Academic Press.

REGEL, J., & PUTZ, K. Effect of human disturbance on body temperature and energy expenditure in penguins. *Polar Biology*, 18, 246-253.

RIPPEY, H.R.T. 1973. *The conservation of the Dorset heaths: A factual study*. MSc. Dissertation. London: University College.

ROSE, R.J., & CLARKE, R.T. 2004. *Urban Impacts on Dorset heathlands.* Centre for Ecology and Hydrology. Dorchester.

ROSE, R.J., and others. 2000. Changes on the heathlands in Dorset, England, between 1987 and 1996. *Biological Conservation,* 93, 117-125.

ROSE, R.J. 2002. Habitat fragmentation and landscape scale processes: examples from invertebrate ecology. *In*: J.C. UNDERHILL-DAY & D. LILEY, eds. *Proceedings of the Sixth National Heathland Conference*. Sandy: RSPB.

RSPB. 1989. *Lowland heath-A habitat under threat. A background paper with an emphasis on Dorset Heaths.* Sandy: RSPB.

RSPB. 2003. *A visitor survey at Woolmer Forest, Hampshire*. Unpublished

RUXTON, G.D., THOMAS, S., & WRIGHT, J.W. 2002. Bells reduce predation of wildlife by domestic cats *Felix catus*. *Journal of the Zoological Society, London*, 256, 81-83.

SAGE, J.A. 1981. Nightjars in Surrey 1981. *Surrey Bird Report*, 1981, 53-57.

SAUL, J. 2000. *Cat ownership amongst the general public*. Unpublished Report. Sandy: RSPB.

SHAW, P.J.A., LANKEY, K., & HOLLINGHAM, S.A. 1995. Impacts of trampling and dog fouling on vegetation and soil conditions on Headley Heath. *The London Naturalist,* 74, 77-82.

SLABBEKOORN, H., & PEET, M. 2003. Birds sing at a higher pitch in urban noise. Great tits hit the high notes to ensure that their mating calls are heard above the city's din. *Nature*, 424, 267.

SPELLERBERG, I.F., & PHELPS, T.E. 1977. Biology, general ecology and behaviour of the snake *Coronella austriaca*. *Biological Journal of the Linnean Society*, 9, 133-164.

SPELLERBERG, I.F. 2002. *Ecological effects of roads.* Science Publishers. United states of America.

STEPHENS, S.E., and others. 2004. Effects of habitat fragmentation on avian nesting success: a review of the evidence at multiple spatial scales. *Biological Conservation,* 115, 101-110.

STRIDE, A. 2001. Survey of heathland use: Winfrith and Sandford Heaths. *Unpublished Report*. Wareham: RSPB.

TALLIS, J.H. 1973. Studies on southern Pennine peats: Direct observations on peat erosion and peat hydrology at Featherbed Moss, Derbyshire. *Journal of Ecology, 61*, 1-22.

TAYLOR, E. 2002. *Predation risk in woodlark* Lullula arborea *habitat: the influence of recreational disturbance, predator abundance, nest site characteristics and temporal factors*. MSc. Dissertation. University of East Anglia.

TUBBS, C.R. 1968. *The New Forest: An ecological history.* Newton Abbott: David & Charles.

TUBBS, C.R. 1986. *The New Forest.* London: Collins.

TURNER, D.C., & BATESON, P. eds. 2000. *The domestic cat: The biology of its behaviour.* Cambridge: Cambridge University Press.

TURNER, C., & MERTENS, C. 1986. Home range size, overlap and exploitation in domestic farm cats. *Behaviour*, 99, 22-45.

TURNER, L. 2000. *Haldon visitor survey-2000*. Dissertation. Rxeter: Exeter University,

UNIVERSITY OF PORTSMOUTH ENTERPRISE LTD. 1996. *The New Forest sport and recreation study*. Portsmouth: University of Portsmouth.

USHER, M.B., & SMART, L.M. 1988. Recolonisation of burnt and cut heathlands in the North York Moors by Arachnids. *The Naturalist*, 113, 103-111.

VAN DEN BERG, J.L., and others. 2001. Territory selection by the Dartford warbler *Sylvia undata* in Dorset, England: the role of vegetation type, habitat fragmentation and population size. *Biological Conservation,* 101, 217-228.

VAN DER MAAREL, E. 1971. *Plant species diversity in relation to management. In*: E. DUFFEY & A. S. WATT., eds. *The scientific management of animal and plant communities.* Oxford: Blackwell Scientific Publications.

VAN DER ZANDE, A.N., and others. 1984. Impact of outdoor recreation on the density of a number of breeding bird species in woods adjacent to urban residential areas. *Biological Conservation,* 30, 1-39.

WARNER, R.E. 1985. Demography and movements of free-ranging domestic cats in rural Illinois. *Journal of Wildlife Management,* 49, 340-346.

WARREN, S.D., SCIFRES, C.J., & TEEL, P.D. 1987. Response of grassland arthropods to burning: A review. *Agriculture, Ecosystems and Environment,* 19, 105-130.

WEAVER, T., & DALE, D. 1978. Trampling effects of hikers, motorcycles and horses in meadows and forests. *Journal of Applied Ecology*, 15, 451-457.

WEBB, N.R. 1985. Habitat island or habitat mosaic? A case study of heathlands in southern England. *In*: W. ZIELONKOWSKI & H-J. MADER, eds. Inseloecology-Andwendung in der Planung des ländlichen Raums, Akademie für Naturschtz und Landschaftspflege, Laufen/Salzach, 62-69.

WEBB, N.R. 1989. Studies on the invertebrate fauna of fragmented heathland in Dorset, UK, and the implications for conservation. *Biological Conservation*, 47, 153-165.

WEBB, N.R. 1990. Changes on the heathlands of Dorset, England, between 1978 and 1987. *Biological Conservation,* 51, 273-286.

WEBB, N.R. 1997. The effects of fires on the dynamics of heathland communities in Southern England. *NNA Berichte,* 10, 134-141.

WEBB, N.R., & HASKINS, L.E. 1980. An ecological survey of heathlands in the Poole Basin, Dorset, England. *Biological Conservation,* 17, 281-296.

WEBB, N.R., & HOPKINS, P.J. 1984. Invertebrate diversity on fragmented *Calluna* heathland. *Journal of Applied Ecology*, 21, 921-933.

WEBB, N.R., & ROSE, R. 1994. Habitat fragmentation and heathland species. *English Nature Research Reports,* No. 95.

WEBB, N.R., & VERMAAT, A.H. 1990. Changes in vegetational diversity on remnant heathland fragments. *Biological Conservation,* 53, 253-264.

WEBB, N.R., & THOMAS, J.A. 1994. Conserving insect habitats in heathland biotopes: a question of scale. *In*: P.J. EDWARDS, R.M. MAY & N.R. WEBB, eds. *Large scale ecology and conservation biology.* Oxford: Blackwell Scientific Publications.

WHITTAKER, E. 1961. Temperature in heath fires. *Journal of Ecology*, 49 709-715.

WINNING, S.A. 1994. *A quantitative study of the effects of human trampling on woodland vegetation.* MSc. Dissertation. University College, London.

WOODS, M., MCDONALD, R.A., & HARRIS, S. 2003. Predation of wildlife by domestic cats *Felix catus* in Great Britain. *Mammal Review*, 33, 174-188.

YALDEN, P.E., & YALDEN, D.W. 1990. Recreational disturbance of breeding golden plovers *Pluvialis apricarius*. *Biological Conservation,* 51, 243-262.

Appendix 1 History of heathland decline and fragmentation in Dorset

An examination of the map of Dorset produced by Taylor in 1765, indicates that there were some 40,000 ha of heathland in the south of the county at that time, consisting of ten large blocks, seperated only by major rivers (Haskins 1978).

The first study of fragmentation on the English heathlands was reported by Moore (1962) and was based on a study of successive Ordnance Survey (OS) maps and field studies. From the 1811 maps, Moore estimated that some 30,000 ha of heathland could be found between Dorchester in Dorset and Southampton Water in Hampshire, and was practically continuous, interrupted only by the river valleys.

His map of heathland west of the River Avon in Dorset from 1811 shows five main blocks of heath, with 16 unconnected heathland areas in all. By the end of the nineteenth century the heaths were being converted to housing and other urban uses and, based on the second edition of the Ordnance Survey, Moore (1962) mapped 39 separate pieces of heath and noted that the growth of the Bournemouth conurbation had substantially destroyed Poole Heath and reduced the heathland area to some 23,000ha by 1896.

By 1934, continuing urbanisation and the planting of conifers had further reduced the heaths to an estimated 18,000ha and caused further fragmentation to about 70 sites. In his last map showing the heaths, now reduced to about 10,000ha, in 1960, Moore recognised 104 sites over 4 ha in size, and cited urbanisation, forestry, mineral working and reclamation for agriculture as the main reason for the further declines and fragmentation.

Rippey (1973) estimated a further decline in the area of the Dorset heaths to 6,100 ha spread over 120 fragments over 4ha in size and estimated that of the 1811 heathland area, 28% had been lost to agriculture, 23% to urban development, 20% to forestry, and the remainder to mineral working, amenity and other uses by 1973. He noted that in 1960 only 6% was used for grazing and over 8% had been burnt in the 12 months to May 1960

By 1978, 5,832 ha of heathland remained in the Poole Basin, some 14% of the area recorded by Isaac Taylor in 1759 (Webb & Haskins 1980). A later calculation suggested that this area would be calculated as 7,900 ha using the same criteria as Moore (1962) (Chapman and others 1989). Webb & Haskins (1980) calculated that the remaining heathland was spread over 768 fragments, if metalled roads and railways crossing larger heaths are recognised as divisions separating the heath into smaller fragments. They concluded that the area of 100 ha lost to urban development between 1978-1987 is an irreversible change, but 140 ha lost since then to mineral extraction agriculture and forestry could be reversed over time.

English Nature is the Government agency that champions the conservation of wildlife and geology throughout England.

This is one of a range of publications published by:
External Relations Team
English Nature
Northminster House
Peterborough PE1 1UA

www.english-nature.org.uk

Cover printed on Character Express, post consumer waste paper, ECF.

ISSN 0967-876X

Cover designed and printed by Status Design & Advertising, 2M, 5M, 5M.

Front cover photographs:
Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
Paul Glendell/English Nature 24,888

Awarded for excellence