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What effects do walkers and dogs have on the distribution and productivity of breeding European Nightjar *Caprimulgus europaeus*?

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Several successive studies of European Nightjars *Caprimulgus europaeus* (hereafter, Nightjar) on the Dorset heaths demonstrated negative effects of the proximity of urban development and associated disturbance from access on foot by people and dogs. Surrogate measures of human density and settlement, including the amount of developed land around each heathland patch and the number of houses, were significantly and negatively related to the density of Nightjars (using data from the 1992 national survey) on heathland patches, regardless of patch size. These findings prompted targeted field studies, the subject of this paper, which investigated the mechanisms and effects of recreational disturbance on breeding Nightjars. Fieldwork in 2002 focused on a suite of heathland sites representing a range of access from sites closed to the public to heaths heavily used for recreation, notably by dog walkers. Studies in 2003 concentrated on the heavily used heaths. Nests which failed were significantly closer to paths, tended to be closer to the main points of access to heaths, in areas with higher footpath density, notably of high levels of use, and in more sparsely vegetated locations. The proximate cause of nest failure was most frequently egg predation. Nest cameras, deployed in 2003 in an attempt to identify the predators of eggs or chicks, recorded just one instance of predation, that of an egg by a Carrion Crow *Corvus corone*, and two instances of the incubating bird being flushed by a dog, once from an egg and once from a chick, neither event preventing fledging. Flushing rate of Nightjars from the nest was associated with the height of vegetation around the nest and the extent of nest cover. The studies indicate that access disturbance interacts with environmental conditions for breeding birds. Birds flush more readily from eggs, which are highly visible when exposed, especially in areas with sparse nest cover, leaving them vulnerable to predation. Although Nightjar flushing rates were observed to be low in 2003, just one event leading to predation is enough to end that nesting attempt. Management measures are recommended to minimize the effects of walkers and their dogs on Nightjars.

The Countryside and Rights of Way Act, 2000 (the CRoW Act) introduces a statutory right of access, on foot, to mountain, moor, heath and down, and Registered Common Land. The last category comprises a range of habitats, including inland and coastal wetlands. These access provisions came into force in October 2005.

Lowland heath is a priority habitat under the EU 'Habitats' Directive (*Directive on the conservation of natural habitats and of wild fauna and flora* 92/43/EEC). The European Nightjar *Caprimulgus europaeus* has been identified as a Species of European Conservation Concern [Annex 1 of the EU 'Birds' Directive

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(*Directive on the conservation of wild birds* 79/409/EEC)], and has an unfavourable conservation status in Europe where its global population is concentrated (BirdLife International 2004). It is a priority species of the UK Biodiversity Action Plan (HMSO 1998) and a red-listed bird of conservation concern (Gregory *et al.* 2002).

The Nightjar is a key breeding species on lowland heath. It lays its eggs on bare ground in small clearings; there is no attempt to make a nest or even a scrape (Cresswell 1996). The nest relies on crypsis of the incubating adult and of the chicks. Nightjars are crepuscular and nocturnal, being most active at dusk and dawn (Cramp 1985). Their breeding success is poor on the smaller urban heaths, postulated to be at least partly due to disturbance (Berry 1979, Haskins 2000). Thus, it was one of the species given high priority within a research programme established to investigate whether access-related disturbance poses a constraint on the breeding productivity of several bird species of conservation concern, and hence has the potential to limit their population size (Liley 2001).

Dorset held 12.8% of the national Nightjar population at the time of the 1992 census (Morris *et al.* 1994). This Dorset population was distributed across 7373 ha of heath, split into 151 different fragments (Rose *et al.* 2000), some of which occur close to or within the large urban centres of Bournemouth and Poole. Liley and Clarke (2003) used measures of percentage cover of urban development within fixed distances from 36 heathland sites in Dorset and the density of residential and non-residential property to explore whether the amount of development surrounding a heathland site could predict the number of Nightjars present on that site. They found a significant negative relationship between the density of Nightjars present on a heath and development, irrespective of heath size. They were also able to demonstrate that the relationship shown could not be explained by a loss in off-site foraging habitat, but the mechanism or cause of the effect was unclear. They suggested that human disturbance, as a result of the higher human populations living around urban heaths, might be the cause. Their results prompted field studies to investigate the effects of disturbance on Nightjar nest success, as described below.

METHODS

Study area

Studies were undertaken on heaths in Dorset in 2002 and 2003 (Fig. 1). In 2002 fieldwork was undertaken on ten heaths, encompassing a range of access from no public access (Arne and Holton) to open access, from 29 May to 31 August, coinciding with the peak breeding season for Nightjars (Berry 1979, Berry & Bibby 1981). In 2003 studies focused on four of the most heavily used heaths that held breeding Nightjars to investigate the mechanisms for access-related disturbance. Fieldwork was undertaken from 13 May to 21 August.

Territory mapping and nest location

Standard territory-mapping procedures were followed to register 'churring' male Nightjars (Morris *et al.* 1994). Each area identified as having a territory was then systematically walked over in daytime to locate nests. Cues for nest locations were also derived from observed behaviour of adult birds during evening territory-mapping visits. Some cold searching for nests was also carried out in areas of suitable habitat. Nest locations were plotted on aerial photographs using MapInfo© (Version 6 for Windows, MapInfo 2000).

Nest monitoring

Nests were visited every 4–5 days to monitor progress and were relocated using a combination of a Global Positioning System (GPS) and distinctive landscape features noted when first located. Prematurely empty nests found on revisits were considered to be predated, including absence of chicks from the nest or its vicinity. The characteristics of any failed nests (e.g. remains of eggs or eggshell fragments) were recorded and any remains checked to aid the identification of predators. However, reliance on nest remains to determine nest loss is problematic, especially if whole eggs disappear, and so nest cameras were introduced.

In 2003 a sample of nests was monitored using VHS time-lapse video photography (Appendix) to record Nightjar behaviour, notably time spent on and off the nest, during day and night and at different stages of the breeding season, as well as recording any disturbance events, flushing of the sitting bird and causes of nest failure. Once the camera was in place, a procedure taking approximately 5 min at the nest clearing, it was not necessary to approach the nest closely again until removal of the equipment. Checks and changes of battery and video, although required daily, could be done remotely without obvious disturbance to the nest. One image was taken

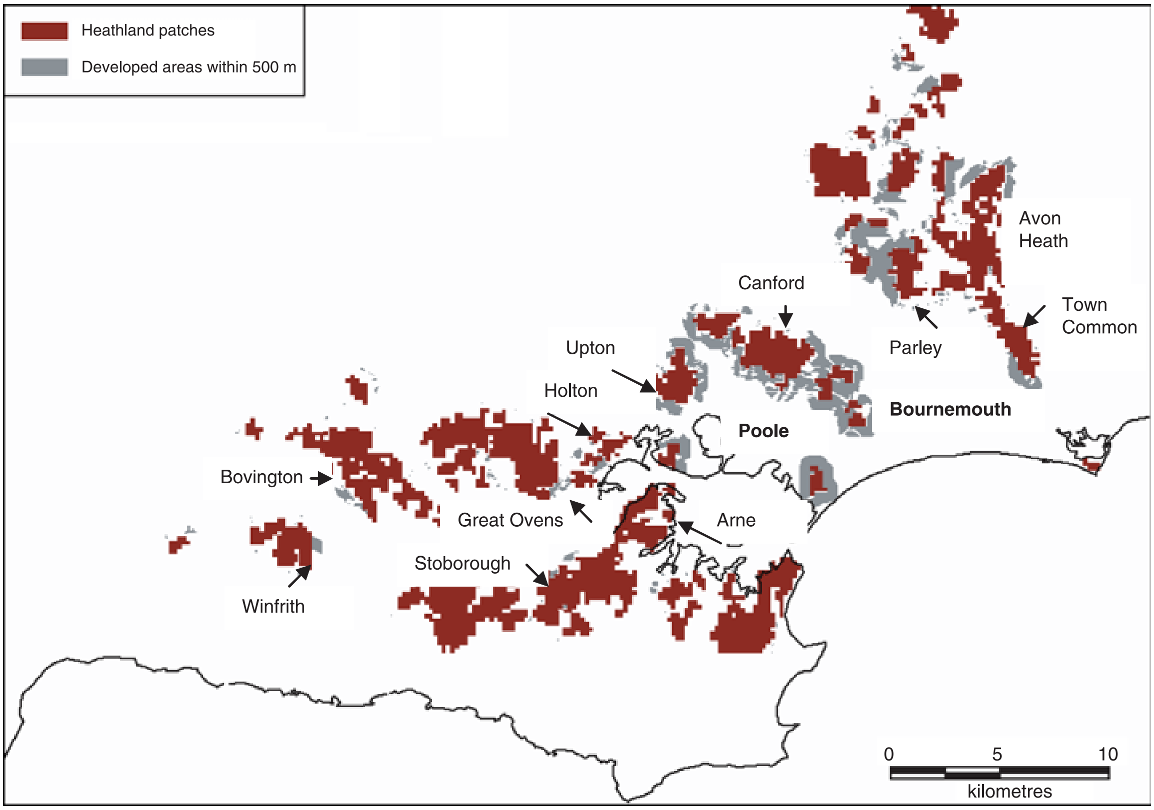

Figure 1. Dorset heathland study sites in 2002 and 2003.

every 0.2 s, allowing 24 h of recording on a 3-h video tape. Nest cameras were removed if the nest failed, equipment failed or once chicks were over 1 week old as they spend less time in the nest clearing, and so in view of the camera, thereafter.

Disturbance measurements

Disturbance characteristics

Using MapInfo, the distance from Nightjar nests and from random points to the nearest path, the nearest path in each of low-, medium- and high-use categories, the nearest access point and the nearest road were measured. In 2002, footpath usage was ranked using site managers' knowledge. In 2003 path use was categorized on the basis of direct observations of usage (see People transects, below). The total lengths of footpaths and of each use category of footpath, within 50-, 100- and 500-m radii of each nest clearing were also calculated.

People transects

In 2003 transects were established to record temporal and spatial levels of access, patterns of use and types of user at each of the four study sites, requiring 1 h to complete each survey and taking a route that maximized visibility of other paths in the study area. Study areas did not necessarily cover the entire heathland fragment, owing to differences in site size, but were selected to cover areas where there was greatest overlap between breeding Nightjars and paths used by visitors. Surveys were repeated to yield information for the period 07:00–18:00 h at each site, dispersed throughout the season so that each site had a comparable number of transects completed in early, mid and late summer, on weekdays and weekend days. During surveys all people and dogs were recorded individually just once, irrespective of the number of encounters, providing snapshots of site use for each of the main hours of usage.

Paths on sites for which people transects were undertaken in 2003 were plotted on aerial photographs using MapInfo and each footpath section categorized as high, medium, low or zero use on the basis of the average number of people (including walkers, cyclists, joggers, horse riders) and dogs per metre per hour.

Nest habitat

Vegetation measurements were taken from each nest-site at the end of the breeding season to avoid further disturbance to breeding adults or nests. Vegetation height was the average of two measurements taken along each side of the nest clearing (north, south, east and west) using the sward stick method (Sutherland 2000, Sutherland *et al.* 2004). Nest cover (horizontal vegetation density) was estimated using an adaptation of the Secchi disc method (Sutherland 1996). A red card (30 cm^2) was placed in the centre of the nest clearing and the percentage of the card obscured from view, at a distance of 3 m (the average approach distance noted to elicit flushing from eggs), was averaged for each compass bearing around the nest. The averaged total gave an approximate percentage of nest cover at each nest.

Relationships between nest success/failure and nest habitat characteristics were investigated using Principal Components Analysis (PCA), followed by Mann–Whitney tests as the data were non-normal in distribution. Binary logistic regression was used to build and test a predictive model of nest predation based on nest vegetation and disturbance characteristics that were significantly different for successful and failed nests. Minitab statistical software was used for analyses.

Nest survival analysis

Daily nest survival rates, separately for eggs and for chicks, were estimated following Mayfield (Mayfield 1975, Aebischer 1999). For the 2002 data, the average incubation period was taken to be 19 days and fledging to occur 18 days after hatching. For the 2003 data, the average incubation period was taken to be 20 days and fledging to occur 17 days after hatching (Cramp 1985). Differences in values used for incubation and fledging stem from different interpretations of the literature by the separate studies.

RESULTS

In 2002 46 nests were found, 38 with eggs, seven with chicks and one well-grown brood. In 2003 29 nests were found, 19 with eggs, eight with chicks and two with immature birds close to fledging.

Breeding success and causes of mortality

In 2002 39% of nests (18/46) were successful, with 29 young reared. The average number of young reared per nest was 0.63 (n = 46) and per successful nest (n = 18) was 1.61 young. Of the 28 failed nests, 26 were predated (93%), one was abandoned and one was trampled by a horse. Most losses were at the egg stage, although three were predated at the chick stage.

By contrast, in 2003 66% of nests (19/29) were successful, producing 32 young, with a higher proportion of successful nests on those sites studied in both 2002 and 2003 (Fig. 2). The average number of young reared per nest was 1.10, and the average per successful nest (n = 19) was 1.68 young. The ten nests which failed did so at the egg stage; eight were

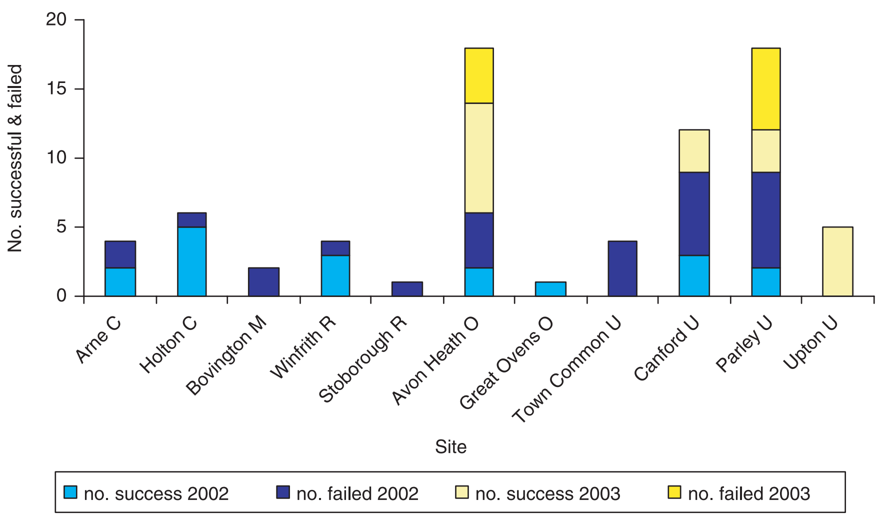

Figure 2. Comparison of successful and failed Nightjar nests at sites studied in 2002 and/or 2003.

predated and two abandoned. Five of the successful nests fledged just one chick, losses in these cases being due to starvation (one), probable predation (one disappeared), egg trampling by cattle (one), avian egg predation (one) and unknown cause (one found dead in nest).

Failed nests were characterized by much shorter surrounding vegetation and significantly lower overall vegetation cover than for successful nests [successful nests 70% cover (n = 17), unsuccessful nests 7.5% cover (n = 26), Mann–Whitney W = 427.0, P < 0.001]. Unfortunately, no vegetation height or cover data were collected at two sites (Great Ovens and Bovington with, respectively, one successful and two unsuccessful nests found).

Disturbance

In 2002 failed nests were found significantly closer to paths than successful nests [median distance from nearest path 45 m for unsuccessful nests (n = 26) vs. 150 m for successful nests (n = 18), Mann–Whitney test: W = 457.0, P = 0.002] across all sites (except Bovington for which no data on paths were collected). Furthermore, nests surrounded by a greater total path length in any of the three distance bands were associated with higher losses (mainly predation) (Table 1). The 2003 data also showed negative trends with nest proximity to any paths, high-use paths and access points, total footpath length within 50-, 100- and 500-m distance bands around the nest, but none was statistically significant (Woodfield & Langston 2004).

All the nest disturbance characteristics and the nest cover variable from the PCA showed a good fit to the logistic regression model (Table 2). A nest's proximity to paths was a significant predictor of nest success (Goodman–Kruskal measure of association, *Gamma* = 0.72) (Murison 2002).

People transects in 2003 showed some clear patterns of path use, with higher passage along paths close to main access points on to the heaths (Fig. 3). However, no significant differences in levels of path usage and nest failure were detected. The main users of heathland sites were dog walkers and, although the pattern showed some variation across sites,

Table 1. Differences in nest-site characteristics for successful and failed nests of Nightjars in 2002.

Variable	Median value for successful nests (n = 18)	Median value for unsuccessful nests (n = 28)	Mann–Whitney U-test (W)	P
Total length of all paths within 50 m of nest	0.0 m	203.1 m	757.0	0.009
Total length of all paths within 100 m of nest	0.0 m	1317.6 m	753.0	0.028
Total length of all paths within 500 m of nest	2638.9 m	6482.2 m	753.0	0.031

Table 2. Results of the univariate binary logistic regression tests (n = 46 nests) to determine which variables were significantly related to nest success/failure and subsequently which variables were significant predictors of nest failure. Significant results are highlighted in bold type (P < 0.05) (after Murison 2002).

				Log-likelihood test		Pearson goodness of fit test		Goodman–Kruskal measure of association
Variable	Coefficient	z	P	G	P	χ^2	P	*Gamma*
PC2	0.034	2.75	0.0006	10.19	**0.001**	40.86	0.48	0.52
Distance to nearest path	**0.016**	**2.59**	**0.01**	**15.12**	**< 0.0001**	16.44	0.56	**0.72**
Total length of paths within 50 m	−0.00072	1.48	0.14	2.41	0.1	21.02	0.46	
Total length of paths within 100 m	**−0.00083**	**2.24**	**0.025**	**7.61**	**0.006**	23.18	0.51	0.51
Total length of paths within 500 m	**−0.00025**	**2.39**	**0.017**	**6.41**	**0.011**	27.44	0.44	0.50
Total length of high-use paths within 500 m	**−0.00043**	**2.25**	**0.024**	**5.85**	**0.016**	17.57	0.42	0.49

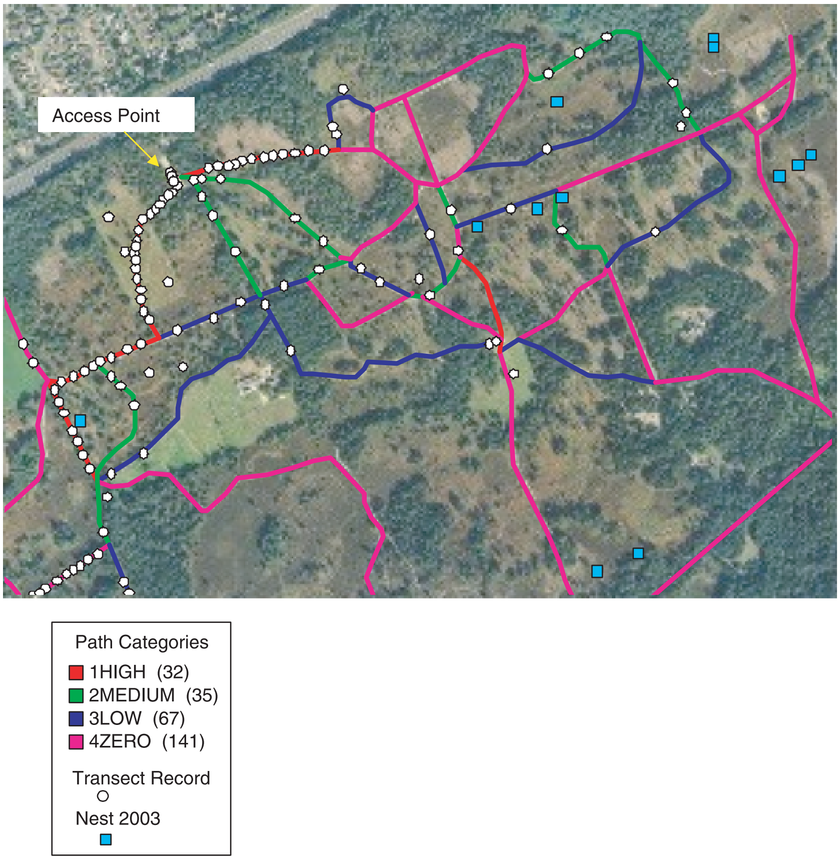

Figure 3. Example map of study area showing footpath use categories, overlaid with transect records, and showing Nightjar nest locations in 2003. NB: each transect record is a single observation and may be of one individual or a group.

visitor numbers tended to peak in the early morning and late afternoon/early evening, with a smaller peak in the middle of the day (Woodfield & Langston 2004). Avon Heath, a country park close to the Bournemouth/Poole conurbation and a popular location for day excursions, had considerably higher numbers of visitors (Fig. 4). In the majority of cases, both people and dogs stayed on the main footpaths, although very few dogs were on leads and it was clear that just one dog running into the heather could disturb large areas.

Nest monitoring

Video data were collected from eight nests, totalling 1942 recording hours. Of the 12 flushing events that were recorded on camera, all during daylight, one led to predation of eggs by a Carrion Crow *Corvus corone* (Fig. 5a). In this instance the cause of flushing was not caught on camera, but the Crow was in the nest within 20 s of the incubating Nightjar leaving the nest. The Crow was easily able to remove the eggs

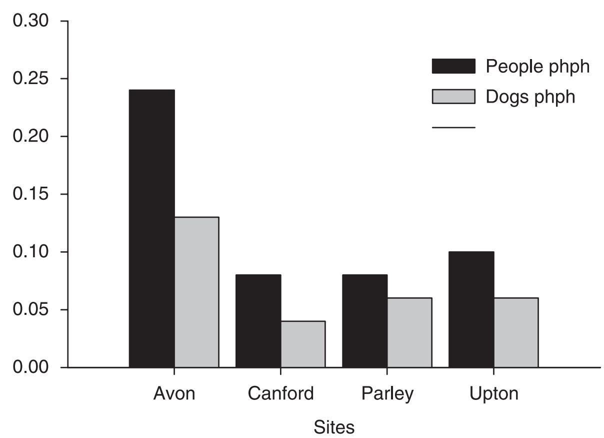

Figure 4. Visitors to heathland sites in 2003. Average number of people and dogs per hectare per hour (phph), from the 'people' transects.

whole, so left no evidence. Camera failure meant that a second predation event was missed. Only two of the flushing events had identifiable causes, both at

Figure 5. Images from the nest video cameras showing (a) predation of eggs by Carrion Crow *Corvus corone* and (b) dog (Springer Spaniel) investigating a Nightjar egg in the nest, after flushing the incubating bird.

the same nest, located within 5 m of a footpath. A Springer Spaniel dog, on both occasions, entered the nest and sniffed at the contents (Fig. 5b) before running away, visiting the nest at the egg stage and at the chick stage. Nonetheless, this nest was successful. Flushing of the sitting bird was preceded by a characteristic vigilance posture in the Nightjar, with neck extended and head tilted upwards and slightly to one side. Attempted, but unsuccessful, egg predation by Wood Mouse *Apodemus sylvaticus* was recorded on two successive nights whilst the incubating bird was away foraging. The video footage confirmed that an incubating bird leaves the nest voluntarily only during the period after dusk and before dawn to forage.

DISCUSSION

The studies in 2002 and 2003 were separate studies with rather different aims and objectives. The 2002 study focused on establishing whether there was field-based evidence for disturbance, in particular surrogates of disturbance (nest proximity to footpaths etc.), influencing nest outcomes for Nightjars on heathlands across a range of access provision. The 2003 study investigated the likely mechanisms for disturbance-influenced nesting success and so concentrated on a small sample of more heavily visited and mainly urban heathlands where the potential for people and dogs to come into contact with breeding Nightjars was maximized. There were differences in nesting success in the two years, with a greater proportion of successful nests in 2003.

Good weather conditions in 2003 may have masked any impact of access disturbance on breeding success, raising the possibility that, whilst access disturbance is a factor in Nightjar breeding success, it may be of greater significance in years when breeding conditions are less favourable for other reasons. There is likely to be a synergistic influence of habitat structure (nest failure was associated with low vegetation and sparse cover), weather conditions and disturbance on Nightjar breeding success, such that exposed nests are more vulnerable to predation or chilling and desertion in cold and or wet weather, when the bird is flushed as a result of access-related disturbance. Certainly, one known incidence of nest abandonment occurred at the egg stage when a sitting bird was flushed during cold and increasingly wet weather. These abandoned nest contents were not subsequently predated.

The study did not find a threshold level of disturbance for the observed effects on breeding Nightjars, nor do we attempt to place the effect of disturbance in a population context. We simply show that in one year of study, failed nests were significantly closer to footpaths and were surrounded by a greater length of footpath, with similar but not statistically significant results observed in 2003. The lack of a significant effect in 2003 may be due to a lack of statistical power due to small sample size (Woodfield & Langston 2004). Mallord *et al.* (in press) found that recreational disturbance has significantly influenced the distribution of breeding Woodlarks *Lullula arborea* on the Dorset heaths and has the potential to constrain population size if existing numbers of visitors to heathland were to be evenly distributed across all heathlands. Further work on Nightjars would be necessary to clarify whether disturbance is limiting population size on the Dorset heaths, or could do so under likely future access scenarios.

Nightjars have a low flushing frequency, albeit greater in taller vegetation. This apparently counterintuitive response presumably arises because the bird cannot see the source of disturbance. Taller vegetation is still associated with successful nests. Nests with good vegetative cover are scarcely visible in the absence of the sitting bird. The probable mechanism for nest failure is that flushing of the sitting bird leaves the nest open to predation, especially where there is sparse cover and particularly at the egg stage because Nightjar eggs contrast markedly with the substrate, whereas both the incubating adult bird and the chicks are cryptic. Furthermore, once the chicks are approximately 1 week old, they often move out of the nest clearing into the surrounding vegetation where they may be better protected (they are clearly also seeking shade from the sun on hot days).

The observed low frequency of flushing, the occurrence of all flushing events in daylight, and nest camera evidence of Nightjars being flushed by dogs and predation by Carrion Crow all lend weight to the suggested principal mechanism: flushing of birds in daylight leads to predation, notably of eggs, by diurnal predators. Predation was the key cause of nest failure for Nightjars, but there was difficulty in attributing the cause of predation as evidence was often equivocal or lacking. Nightjars do not build a nest but use a heathland clearing which, at least in the predominantly dry conditions in 2003, provided little opportunity for visible disruption or prints that might help to identify a predator. In 2002 Murison (2002) attributed over 60% of Nightjar nest predation to corvids on the basis of nest remains. A previous study, using plasticine eggs, also indicated that corvids were the main predators of Woodlark nests on heathland (E. Taylor pers. comm.). Taylor also found that corvid abundance was positively correlated with counts of people on heathland sites in Dorset. The nest cameras were used to identify nest predators in 2003 but contributed little information in a season when there were fewer nest failures.

Most dogs were off lead but remained on paths. However, a few dogs, especially of certain breeds, and particularly when there were several together, or when encouraged by their handlers, ranged widely into the heathland vegetation. This ranging behaviour was prevalent in areas of short heather, but gorse was a deterrent to such behaviour. Habitat penetrability for access will influence patterns of access and could be used as a management tool, especially at path margins. There have been records of predation of eggs and chicks of Killdeer *Charadrius vociferus* (Nol & Brooks 1982) and Great Ringed Plover *Charadrius hiaticulus* (Pienkowski 1984a, 1984b, Liley 1999) by dogs. Birds also tend to flush more readily in response to dogs than people (Yalden & Yalden 1990, Lord *et al.* 2001), and stay away from the nest longer when disturbed by a dog (Taylor *et al.* 2007). This highlights a management issue for reconciling the recreational needs of people and their dogs with the conservation requirements of specialist heathland birds such as Nightjars.

The access provisions of the CRoW Act 2000 replace often long-standing informal, *de facto* access and so may introduce a change in access arrangements. Responsible access necessitates the provision of information for visitors to heathland to help them to understand their rights and responsibilities and, in some cases, change their behaviour. There is a need for proactive measures as well as passive measures of path closures and redirecting paths away from sensitive areas. The provision of information and implementation of management measures are feasible for heathlands that have staff on site but problematic on those sites without such resources. There is a need to develop a better understanding of the communication methods that deliver the desired outcomes of responsible access, public ownership and support for conservation and the long-term conservation of heathlands and their wildlife. There is provision in the CRoW Act 2000 for restrictions and statutory restrictions to be introduced but these should be a last resort for deployment in intractable situations. The Act requires that dogs should be kept on a short fixed lead, of not more than 2 m in length, when on open access land during the breeding season for wild birds, generally 1 March to 31 July. Our conclusions underpin the need for this provision. However, positive management options could include the provision of dedicated areas for games and off-lead dog exercising away from sensitive parts of heathland sites. Positioning car parks and access points away from areas used by breeding Nightjars would be beneficial. The provision of alternative green space is especially necessary in the light of proposals for thousands of new homes around heathlands in southern England.

Research on corvid species associated with heathland would be useful to understand better their behaviour, and in particular their foraging behaviour. Recent advances in nest camera technology offer greater utility and flexibility, and further studies would benefit from the ability to observe images of the area around the nest clearing, as well as close views of the nest clearing itself, to improve the chances of recording the causes of Nightjar flushing events. The addition of a small microphone could enhance the interpretation of information from the nest cameras.

CONCLUSIONS

Nightjar breeding success can be influenced by disturbance. There was a significant relationship between nest failure and disturbance attributes, nest failure being more likely in nests closer to paths, and with higher total path length within 50, 100 and 500 m of the nest clearing. Failed nests also had poorer cover, being surrounded by short vegetation. Predation of eggs was the major cause of nest failure. The most likely mechanism for nest failure is that the incubating Nightjar is flushed from the nest during daylight, leaving eggs in particular exposed and vulnerable to predation by diurnal avian predators, notably corvids. Nightjars display a very low frequency of flushing, only recorded in daylight, but it requires only one untimely flushing event for nest failure to occur through predation. Flushing agents included dogs. Recommendations are made for management measures to minimize the effects of walkers and their dogs.

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APPENDIX

Maplin PH86T miniature monochrome camera with a lens of *f*3.6 mm, surrounded by an array of six infrared light-emitting diodes of type TSU5400. These illuminated the nest and surrounding area at night using a wavelength of 950 nm that produced no visible glow. A timer controlled the timing of illumination. The camera lens was staked to look across the nest from about 50 cm. The Sanyo TLS-4024P time-lapse video recorder, timer and a Yuasa cyclic sealed lead acid 12-V 38-Ah battery were housed in a waterproof case about 25 m from the nest. All equipment was camouflaged, painted to mimic heathland vegetation and concealed in surrounding vegetation.