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Research Paper

Effect of human disturbance on long-term habitat use and breeding success of the European Nightjar, *Caprimulgus europaeus*

Andrew Lowe [1], *Amy C. Rogers* [2] *and Kate L. Durrant* [2]
[1]Birklands Ringing Group, [2]The University of Nottingham

ABSTRACT. Land managers often respond to declining numbers of target species by creating additional areas of habitat. If these habitats are also subject to human disturbance, then their efforts may be wasted. The European Nightjar (*Caprimulgus europaeus*) is a ground-nesting bird that is listed as a species of European Conservation Concern. It appears to be susceptible to human disturbance during the breeding season. We examined habitat use and reproductive success over 10 years in a breeding population on 1335 ha of managed land in Nottinghamshire, England. The study site was divided into a heavily disturbed section and a less disturbed section of equal habitat availability, forming a natural long-term experiment. The site is open to the public, and visitor numbers approximately doubled during the study. We found that overall Nightjar density was significantly lower and there were significantly fewer breeding pairs in the heavily disturbed habitat compared with the less disturbed habitat. However, average breeding success per pair, in terms of eggs and fledglings produced, was not significantly different between the two sections across years. Our findings suggest that human recreational disturbance may drastically alter settlement patterns and nest site selection of arriving females in some migratory ground-nesting species and may reduce the utility of apparently suitable patches of remnant and created habitat. Land managers should bear this in mind when creating new areas of habitat that will also be accessible to the public. Our study also highlights the value of long-term population monitoring, which can detect trends that short-term studies may miss.

Effet des perturbations d'origine anthropique sur l'utilisation de l'habitat et le succès de reproduction à long terme de l'Engoulevent d'Europe, *Caprimulgus europaeus*

RÉSUMÉ. Afin de contrer le déclin d'espèces prioritaires, les gestionnaires de territoires ont souvent recours à la création de nouveaux habitats. Si ces milieux créés font l'objet de perturbations d'origine anthropique, les mesures de conservation entreprises par les gestionnaires peuvent alors être vouées à l'échec. L'Engoulevent d'Europe (*Caprimulgus europaeus*), un oiseau qui niche au sol, a été désigné « préoccupant » en Europe. On pense que cette espèce est sensible à la perturbation humaine au moment de la nidification. Nous avons examiné l'utilisation de l'habitat et le succès de reproduction d'une population nicheuse durant dix ans sur un territoire aménagé de 1335 ha dans le Nottinghamshire, en Angleterre. Le site d'étude présentait deux sections dans lesquelles la disponibilité de l'habitat était égale, l'une qui était fortement perturbée, l'autre moins perturbée, l'ensemble formant un contexte d'expérimentation naturelle à long terme. Ce site est ouvert au public et le nombre de visiteurs a pratiquement doublé au cours de l'étude. Nous avons trouvé que la densité d'engoulevents était significativement plus faible et qu'il y avait significativement moins de couples nicheurs dans les milieux fortement perturbés comparativement aux milieux moins perturbés. Toutefois, le succès de reproduction moyen par couple, en termes de nombre d'oeufs et de jeunes à l'envol produits, n'était pas significativement différent entre les deux sections du site d'étude au fil des ans. Nos résultats indiquent que les perturbations venant des activités récréatives humaines sont susceptibles de nuire sérieusement à l'établissement et à la sélection des sites de nidification par les femelles chez certaines espèces migratrices nichant au sol, et pourraient diminuer l'utilité d'îlots de milieux résiduels ou créés apparemment propices. Les gestionnaires devraient garder ce résultat en tête lorsqu'ils désirent créer de nouveaux secteurs d'habitat qui seront aussi accessibles au public. Enfin, notre étude souligne également l'importance des suivis de population à long terme, qui peuvent détecter des tendances que les études à court terme pourraient manquer.

Key Words: *ground nesting; heathland; population decline; recreational disturbance; Red List*

INTRODUCTION

The decline of many species has been directly or indirectly linked with the result of human activities (Reijnen et al. 1996, Brawn et al. 2001, Birdlife International 2004, Beebee and Griffiths 2005, Reed and Merenlender 2011). Often causes are obvious, such as anthropogenic destruction of habitat, but many human activities appear benign yet ultimately may cause population numbers to decline in an area over time. These forms of disturbance include human recreational use of otherwise protected areas, and represent a conflict for managers, who must balance the requirements of fauna and flora with consumer demand to use natural spaces (Drewitt 2007). It is widely believed that access to natural areas by the public should be increased, and that allowing access to conservation areas can increase the value placed on them by society, which can assist conservation efforts (Adams 1997). Limiting access can be expensive, time-consuming, and

Address of Correspondent: Kate L Durrant, The University of Nottingham, School of Life Sciences, University Park, Nottingham, Nottinghamshire, United Kingdom, NG7 2RD, kate.durrant@nottingham.ac.uk

unpopular. There is a growing need to quantify the effects of disturbance on the long-term population dynamics of species to enable managers to make informed decisions about how land is accessed. This becomes increasingly important when new areas of habitat are being created with the aim of increasing population numbers of target species. If the areas being created are also subject to human disturbance, it is possible that management efforts are being wasted.

Human disturbance can be defined as any human activity that disrupts an animal and forces it to trade off energy in avoiding disturbance with activities such as foraging, courtship, or incubation (Frid and Dill 2002). It is predicted that this trade-off could result in a negative impact on population size for some species (Hill et al. 1997). Human recreational disturbance can take many forms, including walking, especially dog walking, and use of off-road vehicles (e.g., mountain bikes, motor bikes). Numerous studies have shown that walkers can induce anti-predator behavioral responses in birds, including increased vigilance and earlier flight initiation (Blumstein and Daniel 2005, Wang et al. 2011). Previous studies have also demonstrated a negative effect of human disturbance, in the form of dog walking, on the diversity and abundance of bird species in an area (Banks and Bryant 2007). While it is acknowledged that studies demonstrating the consequences of disturbance on population size, rather than effects on behavior, are most useful for providing evidence of impacts on a species (Drewitt 2007), long-term studies of the effects of disturbance are currently lacking.

The European Nightjar (*Caprimulgus europaeus*, hereafter Nightjar) is a crepuscular, ground-nesting species found throughout the Western Palearctic (Hagemeijer and Blair 1997). In Britain, Nightjars are summer migrants, predominantly found nesting on lowland heath or open ground in conifer plantations in the south and east of the country (Gribble 1983, Morris et al. 1994). The Nightjar is listed in the Annex I EU Directive on the conservation of wild birds 79/409/EEC and is identified as a Species of European Conservation Concern 2 (BirdLife International 2004). It has an "unfavorable" declining population status in northwest and northern Europe (BirdLife International 2004). The Nightjar is a priority species within the UK Biodiversity Action Plan (HMSO 1998) and is on the Red List of species of conservation concern (Eaton 2009, BirdLife International 2012). Between 1972 and 1992, its breeding range decreased by more than 50% (Stattersfield and Capper 2000, Gregory et al. 2002). The historic causes of decline are considered to be loss of breeding habitat, primarily through a combination of loss of heathland and changes in availability of open-ground habitat within forest plantations, together with potential factors operating on overwintering grounds and migration stopover locations (Langston et al. 2007*b*). Recent evidence suggests that some UK Nightjar populations increased by at least 36% between 1992 and 2004 (Conway et al. 2007). However, this increase was not consistent across the UK and represents only a partial recovery against the background of a substantial historical decline. Within the Nottinghamshire region of the East Midlands, where our study site was located, a recent population decline of 10% has been reported (Conway et al. 2007).

Despite the fact that some Caprimulgids are globally threatened, their ecology remains poorly understood. Previous studies of the Nightjar have been largely confined to investigations of foraging behavior (Alexander and Cresswell 1990, Sierro et al. 2001), habitat use (Ravenscroft 1989, Wichmann 2004, Verstraeten et al. 2011), population monitoring, and population monitoring methods (Rebbeck et al. 2001, Jiguet and Williamson 2010). Several short-term studies, over one or two breeding seasons, have suggested that the recovery of Nightjar populations may be impeded by a reduction in breeding success due to increased human disturbance (Murison 2002, Liley and Clarke 2003, Langston et al. 2007*a*, *b*). For example, Murison (2002) found that increasing total path length surrounding Nightjar nests was correlated with lower nest success and that breeding success was reduced in heavily visited sites compared with sites with little or no public access. Langston et al. (2007*a*) found that Nightjar nest failure was greater near heavily used paths, and Liley and Clarke (2003) found that Nightjar density decreased with increasing density and proximity of urban development. However, there have been no long-term studies on the effect of human disturbance on Nightjar populations.

We investigated the factors that are influencing breeding success and population density in a population of Nightjars in Nottinghamshire, UK in order to determine what is contributing to the recent recorded decline of Nightjars in this area. We collected nesting data on the population over 10 years and compared nest location and nesting success with levels of human activity in a managed area of heathland that was also open to the public. We predicted that areas of the park that are subject to increased human traffic would show a reduction in total numbers of Nightjars, including the number of breeding pairs, and would show a higher rate of nest failure compared with areas of the park that are less frequently entered by the visiting public.

METHODS

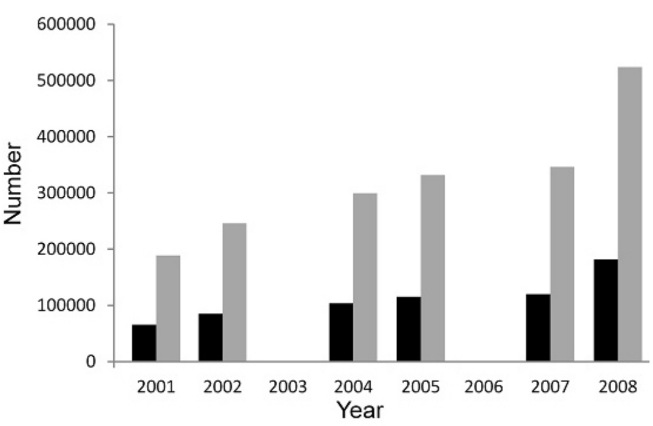
Study site

The study was conducted between 2001 and 2010 at Sherwood Pines Forest Park in Nottinghamshire, UK (Lat. = 53.15°, Long. = -1.08°). The study site comprised 1335 ha of woodland owned by the Forestry Commission (FC) and is a designated as a Site of Importance for Nature Conservation, a local nature conservation designation. The site consisted predominantly of a commercial pine plantation with a patchwork of deciduous trees, clear-fell, and fragmented lowland heath. Heathlands are a priority habitat in the UK Biodiversity Action Plan and were being actively created during the period of this study in accordance with the National Action Plan (http://jncc.defra.gov.uk/page-5155,). The FC conservation plan for this site aimed to create and maintain 100 ha of heather-dominated (*Calluna* spp.) heathland (FC, *personal communication*). Nightjars were found nesting predominantly in clear-fell and heathland habitats. Clear-fell areas developed into heathland as the study progressed, both types of habitat were occupied by Nightjars equally, and management practices for heath and clear-fell patches were consistent for both habitat types across the entire site; thus, we combined the two habitats for analyses. We lack detailed habitat data for each Nightjar territory in each year because these data were not recorded by fieldworkers at the time. However, we do not view this as a major flaw because the management practices were consistent across the entire site over the 10 years of the study, and the comparison between the disturbed and less disturbed areas was the key issue.

Recreational disturbance

Our estimation of human recreational disturbance was derived partially from FC data collected on public use of the site. A recent FC visitor survey found that 90% of visitors arrived by car, while the remainder arrived on foot or horseback, and indicated that between 2001 and 2008, the number of visitors to the site had doubled from 200,000 to approximately 400,000 per year (Fig. 1). Day visits made by people on foot or horseback were not counted in these attendance figures. Public access is allowed only during opening hours (0800 hours until dusk), and gates are locked at 2000 hours between April and September. Events held at the site included car rallies, sledge dog racing, and occasional nighttime outdoor concerts. Most visitors remained in the northern section of the park, close to the car park and amenities (a café and shops built between 1998 and 1999, and an adventure ropes course constructed in 2003). Additionally, 23 km of cycle routes had been recently created throughout the site. There is evidence from the FC to indicate that human disturbance is affecting wildlife distribution. The FC's Forest Design Plan 2009–2019 states that Fallow deer (*Dama dama*) were moving out of the park, with numbers decreasing in the North section due to human disturbance (FC, *unpublished data*). It is in the interests of the FC to survey and produce high quality public attendance and usage data because their governmental budget partly depends on the public use of the park; therefore, we assumed these figures to be reliable.

Fig. 1. Increase in human recreational traffic to Sherwood Pines Forest Park, Nottinghamshire, England between 2001 and 2008. Forestry Commission data showing yearly increase in cars (in black; numbers obtained from car park receipts) and visitors (in grey; numbers obtained from questionnaire data). No data were available for years 2003, 2006, and 2009–2010.



We divided the site into areas of perceived high and low human disturbance, creating two sections, North and South, divided by a roadway. This allowed us to compare a heavily used area containing amenities and 28.3 km of walking and cycling tracks (North) with a relatively undeveloped area containing no amenities and only 3.3 km of walking and cycling tracks (South). Based on FC GIS data, there were comparable amounts of heathland and clear-fell habitat in similarly sized patches between the North and South (see *Results*), which we considered to meet the criteria for typical breeding habitat for Nightjars (as described for the UK by Ravenscroft 1989, Liley and Clarke 2003, Langston et al. 2007*b*).

Nightjar monitoring

At this site, Nightjar males established breeding territories between late April and mid-May in patches of heath, unplanted clear-fell, and restocked conifer plantations. Females paired with established territorial males on arrival from migration 1–10 days later. Using tape-lures, we mist-netted adult birds within known territories, detected by exhaustive searches in areas of typical Nightjar habitat and identified by the presence of pairs or by males producing a distinctive "churring" call. The churring of a paired male can be discerned by experienced fieldworkers: it tends to be shorter, begins later in the evening, and is more often followed by a characteristic "dreerr-dreerrr-dreerrrdreerrrr" call at the end of the churr compared with that of unpaired males (Ferguson-Lees et al. 2011).

Nest searching commenced annually in late May and continued to August, with nests located by observing adult behavior (Langston et al. 2007*a*). Every suitable patch of habitat identified from FC maps was regularly watched during the breeding season. Potential patches of habitat were checked six or more times during the season (10–12 weeks in length), whether a Nightjar had been heard or not. We identified areas for nest searching by listening for churring males. These areas were then systematically searched for nests by observers who walked in lines approximately 2 m apart. In later years, as we became familiar with Nightjar nesting behavior, paired males were targeted by their distinctive calling behavior, and territories were searched in the same manner but over a smaller, more targeted area when a male was observed approaching the suspected nest area (Ferguson-Lees et al. 2011). We are certain that all Nightjars and their nests within a patch of habitat would have been located using these methods. Locations of nests were recorded using a GPS unit (Garmin etrex, USA). Females were very susceptible to disturbance between site arrival and clutch initiation. Observations suggest that half of all females desert if flushed before laying has commenced, or between clutch initiation and completion (A. Lowe, *personal observation*). For this reason, nest searching did not commence immediately after females arrived. Once found, nests were checked every 7–10 days. Clutch initiation dates for nests found during incubation were estimated using Integrated Population Monitoring Reporter software v. 2.4.7 (Cubitt 1997–2011). We used actual nest success or failure to fledge as an indication of breeding success rather than Mayfield's estimates of nest survival (Jehel et al. 2004). Mayfield's estimates assume monitoring does not influence nest survival, and there was a high chance of fieldworkers leading predators to nests if they were checked frequently, so they were checked infrequently. Mayfield's estimates also assume that failure occurs midway between the nest check intervals, which would have produced unrealistic and biased estimates of nest survival given the occasionally long nest check intervals.

Statistical methods

We constructed generalized linear models (GLMs) with a Poisson distribution from the data, with "year" and "section" (North or South) as the categorical predictor variables, including the interaction between them, to test for differences in the following response variables: number of breeding pairs, total number of nests, average number of nests per pair, average number of eggs per pair, average number of pulli per pair, and average number of fledglings per pair. We also performed an ANCOVA using the same variables, where "year" was treated as a covariate to explore trends over time. We constructed a binomial GLM to test for differences in the proportion of Nightjar males between the two sections across years. Other questions concerning differences between the sections within years, or when considering the 10-year time span as a whole, were analyzed using Chi-square tests or paired-sample *t* tests. All statistical tests were performed with PASW Statistics v. 18. All mean values are cited ± 1 S.E.

Ethical note

All volunteer nest finders were licensed by the British Trust for Ornithology's Nest Record Scheme, which provides training on approaching nests with minimal disturbance and without leaving obvious traces. Although disturbance effects caused by researchers can never be completely removed, we made every effort to minimize negative effects. There is evidence to suggest that appropriate researcher nest monitoring activities do not affect likely predation rates of nests (Stevens et al. 2008) and may in fact reduce predation rates and improve nesting success for certain ground-nesting species (Ibáñez-Álamo et al. 2011).

RESULTS

Available Nightjar habitat

Amounts of Nightjar suitable habitat area and type were similar between the North (N) and South (S) sections of the site. FC GIS data indicate that during the study period, there were 82.3 ha of Nightjar suitable habitat in the N and 77.5 ha in the S. In the N, this comprised 28.1 ha of heath in six patches and 54.2 ha of clear-fell in nine patches. This compares with 27.4 ha of heath in seven patches and 50.1 ha of clear-fell in seven patches across the S. Average patch area was not significantly different between the two sections (N mean patch area = 5.49 ± 1.10 ha, $n = 15$; S mean patch area = 5.54 ± 1.22 ha, $n = 14$; two-tailed *t* test, $t = -0.03$, DF = 27, $p = 0.98$).

Although there was some loss of suitable breeding habitat as pine plantations matured, the amount of heath and clear-fell increased; therefore, the total amount of suitable habitat remained relatively stable across the entire site (A. Lowe, *personal observation*; FC, *personal communication*).

Population estimates

Between 2001 and 2010, the annual breeding population was estimated at 13–20 nesting pairs. Average density of adult birds of either sex per hectare of suitable habitat over 10 years was significantly lower in the N (0.16 ± 0.01 birds/ha) than in the S (0.27 ±0.02 birds/ha) (two-tailed paired-sample *t* test, $t = -8.38$, DF = 9, $p < 0.001$). By the end of 2010, there was an overall decline of 38.3% in the total number of adults across the entire site (2001: 37 adults; 2010: 29 adults). This was primarily a consequence of a decrease in the number of adults in the N.

There were significantly fewer breeding birds in the N than the S overall (Table 1). There was a significant difference between numbers of breeding pairs and total numbers of nests between N and S (Table 1), and this can be seen in abundance remaining stable in the S but declining markedly in the N over time (Fig. 2a, 2b). The number of breeding pairs in the N had declined by 71% from seven in 2001 to two in 2010, whereas in the S, the number of pairs declined by only 10% across the course of the study (Fig. 2a). If "year" is treated as a covariate, there was a significant interaction between "year" and "section" (N or S) (Breeding pairs ANCOVA, "section*year," $F(1,16)= 4.742$, $p = 0.045$), indicating a decline in the number of breeding pairs of Nightjars in the N over time. This progressive loss of breeding pairs in the N is shown in Fig. 3, and a summary of population parameters is provided in Table 3. There was no significant difference in the number of unpaired males in the N versus the S across the 10 years (Table 2).

Fig. 2. Nightjar population trends between North and South sections of Sherwood Pines Forest Park, Nottinghamshire, England, 2001–2010: (a) numbers of breeding pairs; (b) numbers of unpaired males; (c) total numbers of fledglings (averaged per pair across multiple broods).

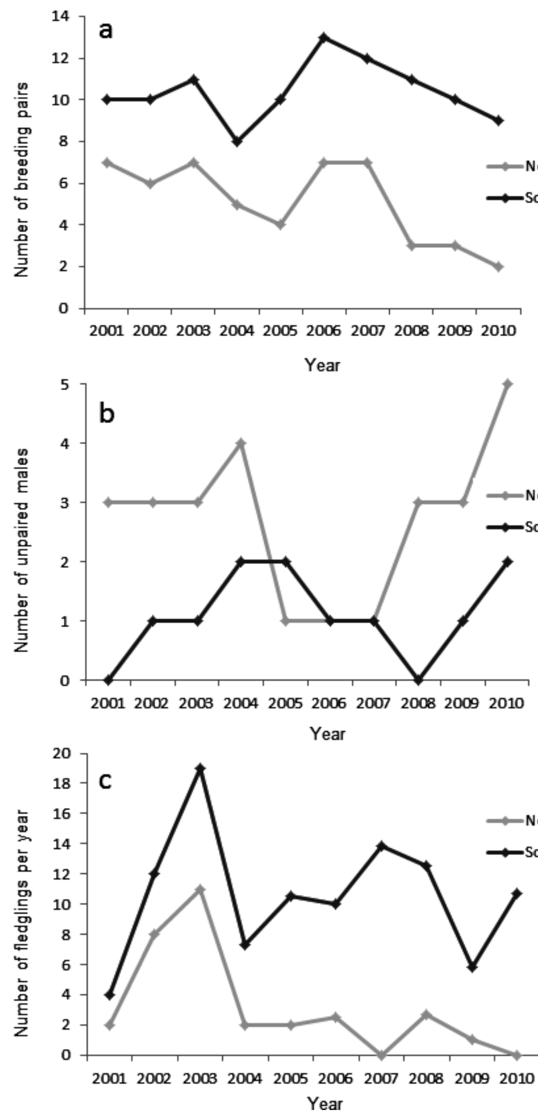


Fig. 3. Territory maps, 2001–2010. Maps show progressive loss over 10 years of Nightjar breeding pairs (black dots) and increase in numbers of unpaired males (grey dots) in the North section (stippled) compared with the South section (lined) of Sherwood Pines Forest Park, Nottinghamshire, England. Hatched lines represent disused railways; bold lines represent roadways.

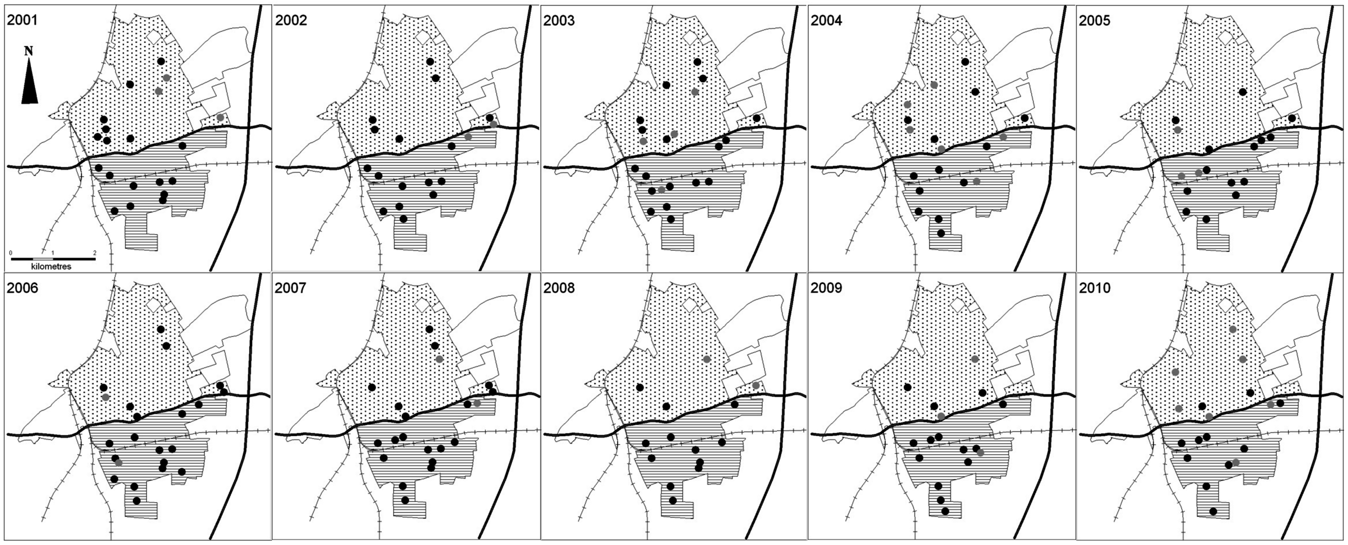


Table 1. Results from generalized linear models with Poisson distribution testing differences in variables from a population of Nightjars between two sections (North and South) across years (2001–2010, inclusive) showing a significant effect of section (North or South) on the number of breeding pairs present and total nests. Averages of breeding parameters include multiple broods within a year averaged for a single pair.

Dependent variable	Source	Wald Chi-square	DF	*P* value
Breeding pairs	Year	6.79	9	0.659
	Section	18.59	1	**<0.001**
	Section*Year	3.81	9	0.924
Total nests	Year	5.53	9	0.785
	Section	42.44	1	**<0.001**
	Section*Year	9.71	9	0.374
Average nests per pair	Year	8.49	9	0.485
	Section	0.69	1	0.793
	Section*Year	1.25	9	0.996
Average eggs per pair	Year	1.58	9	0.996
	Section	0.001	1	0.981
	Section*Year	0.40	9	1.000
Average pulli per pair	Year	7.76	9	0.558
	Section	0.35	1	0.555
	Section*Year	1.94	9	0.963
Average fledglings per pair	Year	14.08	9	0.120
	Section	0.39	1	0.535
	Section*Year	2.64	9	0.917

Breeding success

Between 2001 and 2010 we located and monitored 192 Nightjar nests (181 found at incubation stage, 11 found with nestlings). Significantly more nests were found in the S section (n = 147) compared with the N section (n = 45) across the 10 years, and this difference was reflected in the significant effect of "section" in the GLM (Table 1). This was also supported by the ANCOVA results (Total number of nests ANCOVA, "section," F (1,16) = 4.544, p = 0.049, "section*year," F (1,16) = 4.729, p = 0.045), indicating that there were more nests in the S than in the N, and that there were more nests in the S than in the N across the 10 years. However, there was no significant difference in the number of nests per pair under GLM or ANCOVA models (Table 1 presents GLM results; Table 3 presents population parameters). If enough time was left in the season, or a nest failed early on, we found Nightjars laid a second or third clutch of eggs. Fifty-three of 192 nests in this study were second or third nests. There was no difference between the average number of nesting attempts between the N and S sections of the park, and no significant effect of "year" interacting with "section" (Table 1). Pairs in each section were as likely to renest due to clutch failure as they were for successfully fledging young (Chi-square test, number of extra nests initiated due to clutch failure or success, X^2 = 0.45, DF = 1, p = 0.50).

Table 2. Results from a binomial generalized linear model texting differences in the proportion of males in a population of Nightjars between sections (North and South) across years (2001–2010, inclusive) showing no effect of year or section on the proportion of males present.

Dependent variable	Source	Wald Chi-square	DF	*P* value
Proportion of males	Year	0.042	9	0.838
	Section	0.052	1	0.820
	Section*Year	0.052	9	0.820

Across the whole site, 337 eggs were laid over 10 years and produced 211 pulli (62.6% hatching success). Of these, 187 fledged (88.6%); therefore, 55.5% of eggs laid produced fledged young. In the N, 73 eggs were laid, which hatched 43 pulli (54.4%). Of

Table 3. Summary demographics of a breeding population of Nightjars monitored between 2001 and 2010, inclusive.

Category	Section	Min.	Max.	Mean ± S.E.M.
Unpaired males	North	1	5	2.70 ± 0.42
	South	0	2	1.10 ± 0.23
Breeding pairs	North	2	7	5.10 ± 0.56
	South	8	13	10.40 ± 0.45
Number of nests	North	2	6	4.50 ± 0.48
	South	9	26	14.70 ± 1.73
Average nests per pair within a season	North	1	3	1.34 ± 0.11
	South	1	3	1.55 ± 0.07
Average fledglings per pair within a season	North	0	2	0.97 ± 0.15
	South	0	2	1.11 ± 0.08

these, 34 successfully fledged (79.1%); therefore, 46.6% of eggs produced fledged young. In the S, 264 eggs were laid, which hatched 168 pulli (63.6%). Of these, 153 successfully fledged (91.1%); therefore, 58.0% of eggs laid produced fledged young. Total nest failure was not significantly different across years in the N (48.8% failed) than in the S (38.8% failed) (Chi-square test: $\chi^2 = 1.46$, DF = 1, $p = 0.228$), and was significantly higher in the N within years only in 2007 (Chi-square test: $\chi^2 = 6.061$, DF = 1, $p = 0.014$).

Across years, nesting pairs had equal mean productivity per nest in the S compared with the N at all stages (data were averaged across multiple broods within a single season): clutch size (N mean = 1.76 ± 0.06; S mean = 1.80 ± 0.03; see GLM results in Table 1), number of pulli (N mean = 1.24 ± 0.15; S mean = 1.21 ± 0.08; see GLM results in Table 1), and number of fledglings (N mean = 0.97 ± 0.15; S mean = 1.11 ± 0.08; see GLM results in Table 1, Fig. 2c). The ANCOVA results for nesting productivity at all stages were also nonsignificant, indicating no difference between N and S or across years (results not shown).

DISCUSSION

Settlement patterns

During the 10 years of data collection, there was an appreciable change in settlement patterns displayed by the adult Nightjar population at Sherwood Pines Forest Park. At the start of the study, the distribution of adult Nightjars was similar across the North and the South sections of the park. However, despite similar amounts of suitable habitat remaining available in each section, by the end of the study total numbers and the density of Nightjars were significantly lower in the North section compared with the South section. This was primarily a consequence of a decline in the number of breeding pairs in the North of the park; the number of unpaired males did not show a significant change across years between sites. The major difference between these two sections is the amount of human recreational use experienced over time. There were higher levels of human activity in the North and no significant difference in the total area of suitable habitat available or management strategy across the site. We lacked detailed habitat data for each Nightjar territory in each year, so specific patterns of habitat use could not be analyzed; however, the broader patterns of settlement by Nightjars across the site over the years remain informative. It appears that breeding Nightjars have largely abandoned areas within the North section of the park, but it is unclear whether they have moved elsewhere, suffered excess mortality, or displaced birds in the South.

Our results suggest that the female Nightjar population showed a greater change in settlement patterns than the male population. While the number of unpaired males was not significantly different between the two sections over the course of the study, the number of breeding pairs significantly declined in the North yet remained relatively stable in the South. This could be an indication that females more actively avoid settling in heavily disturbed areas than do males, and it raises interesting issues related to altered settlement and nest site selection patterns for female birds returning from migration, when faced with human disturbance. Sex-specific differences in response to human disturbance have been found in other ground-nesting species. For example, female Burrowing Owls (*Athene cunicularia*) have a longer flight initiation distance than do males (Carrete and Tella 2010). One reason for the increased sensitivity of female birds may be a consequence of the negative effect of disturbance on nest site selection and nesting. Perceived predation threats that result from direct disturbance of roosting birds caused by visitors or dogs flushing birds accidentally could result in females abandoning otherwise suitable nest sites, and flushing of birds from active nests could result in an increased rate of nest predation (Langston et al. 2007*a*). There is a critical period during the first weeks of breeding territory establishment when disturbance of a bird is highly detrimental to breeding productivity. Disturbance effects may go unnoticed in the short term if the result is behavioral changes in female settlement that are not easily observed in the field, which cause females to avoid a territory that the male subsequently abandons; these subtle effects can be detected only via long-term population dynamics. These factors could reduce overall density of Nightjars despite the availability of suitable habitat, as we have observed over time in the North section of Sherwood Pines Forest Park.

Breeding success

There were significantly more nests located in the South than in the North of the study area during the course of the study. However, we found no significant difference in individual reproductive success of Nightjars nesting in the heavily disturbed North section of Sherwood Pines Forest Park compared with the South section. There was a nonsignificant tendency for birds in the North section to have fewer nests and a lower number of fledglings per pair; however, it appears that those few Nightjars that have remained in the North are breeding as successfully as those in the South. This contrasts with findings from previous, short-term studies on the effects of human disturbance on Nightjars in other areas of the UK. Murison (2002) indicated that Nightjar breeding success was lower on heavily disturbed sites than on sites used less frequently by the public. Langston et al. (2007*a*) found that failed Nightjar nests were located significantly closer to footpaths, closer to main points of access to heaths, and in areas with higher footpath density than were successful nests. It would be interesting to investigate reasons for these observed differences in individual reproductive success. Our results may indicate an uneven occupation of territories by individual Nightjars with different tolerances to human disturbance (Carrete and Tella 2010). There is a possibility that individual, personalitybased differences in disturbance response by Nightjars is enabling some birds to have a higher reproductive success in disturbed areas than predicted or that individual birds may be becoming habituated to the effects of disturbance. Alternatively, it may be that Nightjars in the North section of our study site were making the "best of a bad job," and were able to find safe nest sites despite more human disturbance because the Nightjar population was at a lower density. Studies of other ground-nesting birds have reported no effect of recreational disturbance on nest survival rates and have attributed this finding to the effects of density, suggesting that breeding output declines strongly with increasing population density (Mallord et al. 2007). Certainly, the average density of Nightjars recorded in the South section of our study site was three times higher than estimates of Nightjar density reported in other UK-based studies (0.10 ± 0.01 birds/ha of available habitat [Liley and Clarke 2003]; 0.008 ± 0.003 males/ha of available habitat in the Midlands [Conway et al. 2007]). This could suggest that population density is playing a role in the relative reproductive success observed across the two sites. Other studies have indicated that recreational disturbance may affect juvenile birds post-fledging, so that while nesting success may be unaffected, the juveniles may suffer excess mortality at times of peak disturbance, which would reduce population viability over time (Kerbiriou et al. 2009). We have limited survival data from marked Nightjars that fledged in our study site, but there are currently not enough to examine these effects given the cryptic nature and long-distance migratory habits of the species.

Management implications

Our observations suggest that increased recreational disturbance may result in a decrease in Nightjar population density over time, females may be particularly susceptible to the effects of disturbance, and individual reproductive success may not be impacted by disturbance, either because of different behavioral tolerance levels to disturbance or through confounding effects due to population density. These findings have several implications for land managers.

We would suggest that conservation managers create protective buffer zones around territories based on the response to disturbance of females rather than males. Manipulating access patterns by the public to heathland areas during critical nesting periods could reduce the effects of disturbance. Previous studies have suggested that the control of dogs and restriction of access to dog walkers would be particularly important considerations (Langston et al. 2007*a*). Currie and Elliot (1997) proposed safe forestry working distances around Nightjars of 50–250 m; however, Murison (2002) detected negative effects on density of Nightjars 500 m from heavily traversed pathways. It would be useful to quantify flight initiation distances of female Nightjars to determine what area would be required to minimize the impact of disturbance. A recent model that predicted consequences of disturbance on populations of ground-nesting birds suggests that the spatial distribution of visitors may have a greater negative impact than visitor numbers (Mallord et al. 2007). In the case of Sherwood Pines Forest Park, the most sensible option may therefore be to restrict or close access to the South section and leave the North open between May and July. This would obviously require education and enforcement. Creating an increased number of potential nest sites for female Nightjars may also help reduce the effects of recreational disturbance. This could involve clearing patches of heather away from the base of small birch trees (Burgess et al. 1990) in areas that receive lower levels of disturbance.

CONCLUSION

An important issue that has emerged from our work is the need for land managers to state clearly their intentions behind the creation of new habitats. If the intention is to provide habitat for threatened species such as the Nightjar and not just to increase total habitat area, then consideration should be given to the levels of disturbance that will occur in the new habitat. A habitat that fails to attract the target species has reduced conservation value. If disturbance effects are not considered, using total available habitat rather than suitable habitat actually in long-term occupation by a target species will give a false and artificially inflated impression of the overall area and quality of the habitat and the value of maintaining it.

The second important issue arising from our work is the value to conservationists of long-term field studies of population change. Effects of recreational disturbance on population dynamics and the subsequent impact on species recovery may be missed in one or two breeding seasons for any species, especially if the metric used is reproductive success, as we have shown. Longer term monitoring, although costly and difficult, appears vital to understand a species' response to disturbance on a broad scale.

Responses to this article can be read online at:
http://www.ace-eco.org/issues/responses.php/690

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