An experimental assessment of the potential effects of human disturbance on Black Grouse *Tetrao tetrix* in the North Pennines, England

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In the United Kingdom, Black Grouse *Tetrao tetrix* have declined in range and abundance during the 20th century. In England at present, birds are largely found only on the margins of managed grouse moors in the north, where more than 80% of birds are confined to the North Pennines Area of Outstanding Natural Beauty. The Black Grouse is one of a group of species potentially at risk from increased human recreational disturbance owing to their threatened status and their use of habitats to which a statutory right of human recreational access has recently been granted. To assess the likely impact of increased disturbance to Black Grouse, 77 were caught and radiotagged between 2002 and 2004, and each was randomly assigned to one of three experimental disturbance categories: no disturbance (low), fortnightly disturbance (moderate) or twice weekly disturbance (high). Birds that were disturbed more regularly flushed at greater distances, especially in spring and winter when birds exposed to high disturbance flushed at 32% greater distances than those in moderate disturbance treatments. There were no differences in fecundity (clutch size, hatching success, breeding success) or survival between disturbance treatments. Winter survival was 78% and summer survival 92%. There was no age-related difference in survival. The disturbance regimes imposed had no discernible impact upon Black Grouse population dynamics. However, in the absence of appropriate data to indicate likely changes in patterns and levels of human recreation resulting from open access, we cannot be sure whether the levels we applied will be representative in the future. Should actual disturbance levels be higher than those we used in this study, we list visitor management options that may help reduce any conflict that arises.

In Britain, Black Grouse *Tetrao tetrix* were widespread during the latter half of the 19th century and, in addition to their current distribution in Scotland, northern England and North Wales, they occurred on low-lying heathland in southern England, from Norfolk through Hampshire and Dorset to Cornwall and throughout most of Wales (Gladstone 1924). By 1910 they were extinct in most southern counties of England (Sharrock 1976). The rate of decline and contraction of range in Britain has been greatly increased during the last 50 years, with an estimated 25 000 (95% confidence limits 13 800–36 700) displaying males in 1990 (Baines & Hudson 1995), but only 6500 (95% confidence limits 5000–8100) in 1996 (Hancock *et al.* 1999). However, the census methods used in these studies were not the same and hence the results are not strictly comparable, although they are at least strongly indicative of a severe decline. Factors associated with this decline include loss of appropriate moorland fringe habitat, either to agricultural intensification, overgrazing by Red Deer *Cervus elaphus* (Baines *et al.* 1994) or afforestation. Compounding factors include increased predation risk, in terms of both an increasing number of predators (Tapper 1992) and a simultaneous decline in protective cover (Baines 1996), and death from colliding with an increasing number of deer fences (Baines & Summers 1997, Baines & Andrew 2002).

The English population is restricted to the northern section of the Pennines, stretching from Wensleydale (North Yorkshire) to the Scottish border. A survey in 1998 found only 777 displaying males in England, a value close to the lower 95% confidence interval of 5000.
800 from the 1995/96 national survey (mean English estimate 1700 males) (Hancock et al. 1999). A repeat survey in 2002 recorded an increase in numbers to 895 males (Warren & Baines 2004).

The Black Grouse is one of a group of bird species that may be affected by increased human recreational disturbance following the implementation of the Countryside and Rights of Way (CRoW) Act (Liley 2001), which provides a statutory right of access to mountain, moorland, heaths, downland and common (Bathe 2007). This Act became law in England and Wales in 2000, with full implementation of the component of the Act dealing with access in May 2005. Our 2-year study aimed to quantify whether recreational disturbance is likely to impact on Black Grouse at the population level within the North Pennines Area of Outstanding Natural Beauty (AONB).

**METHODS**

**Study area**

The study encompassed an area of approximately 730 km$^2$ within the North Pennines AONB in northern England. The landscape and habitats are managed for Red Grouse *Lagopus lagopus scoticus* shooting and traditional hill sheep farming. Unenclosed heath and blanket bog dominate the upper slopes of the valley sides and cover 35% of the AONB area. The lower valley slopes consist of a mosaic of enclosed rough grazing pastures and allotments dominated by coarse grasses, sedges and rushes. Species-rich hay meadows and semi-improved pastures are located in the more fertile lower valley sides and floor.

The area comprises 40 privately owned separate units of heather moorland, at least 90% of which are used for grouse shooting (38% of the AONB area) and 1723 farm units, the latter employing just under 4000 people. The area has a high proportion of designated conservation sites, with 37% of the AONB declared as Sites of Special Scientific Interest. There are also two National Nature Reserves, five Special Areas of Conservation (SAC) under the EU Habitats Directive, with five more under consideration, and a Special Protection Area (SPA) under the EU Birds Directive. Although the North Pennines has a population of only about 12 000 people, it lies within an hour’s driving time of large conurbations. The area as a whole has in recent years become increasingly popular for tourism, now an important part of the local economy (Anon. 2004).

The North Pennines AONB holds approximately 80% of England’s remaining Black Grouse. Here, Black Grouse are found in the transition zone between heather moorland managed for Red Grouse shooting and rough grazing managed by hill farmers for sheep and cattle (Baines 1994). The majority of Black Grouse caught during this study were from the margins of four managed grouse moors: Raby Estate in Upper Teesdale, Rotherhope and Crossgill near Alston and Stanhope in Weardale (Fig. 1). Birds either

![Figure 1. Catch locations of sample Black Grouse radiotagged as part of this study.](image-url)
moved or dispersed from these four moors so that during the course of the project, marked individuals were studied on the edges of 15 different moors in three of the North Pennine Dales and the adjoining Eden Valley in Cumbria.

**Experimental design**

A total of 77 Black Grouse were radiotracked between December 2002 and August 2004. An existing sample of 22 birds was supplemented with a further 28 birds caught at night-time roosts in winters 2002/03 and 2003/04 (Table 1) using a high-powered lamp and a hand-held net. In addition, 26 juveniles aged approximately 8–10 weeks were caught, along with one adult female, in August 2003 in a large net dragged over a pointing dog that indicated the position of the brood. All birds were fitted with 17-g necklace radio-transmitters.

We applied a treatment of simulated recreational hiking to radiocollared Black Grouse by approaching individual birds until they were displaced. The rationale behind our disturbance treatment was that a small number of people targeting a specific sample of radiotagged animals could create an effect equal to a greater number of people hiking through an area (Phillips & Alldredge 2000). Accordingly, each bird was randomly allocated into one of three controlled disturbance treatments:

1. **High disturbance**: flushed twice a week ($n = 17$ females and seven males).
2. **Medium disturbance**: flushed fortnightly ($n = 24$ females and two males).
3. **Low disturbance**: triangulated monthly, but not flushed ($n = 17$ females and seven males). Triangulated birds had not moved on three consecutive days following the monthly visit, the bird was approached and either flushed or the corpse recovered.

All birds were likely to be subjected to other forms of human disturbance additional to those imposed by this experiment. Indices of these background sources were obtained by recording the number of people seen in the vicinity of our sample birds while we conducted our disturbance events. We recorded 29 human encounters (15 with gamekeepers, seven with farmers and seven with groups of walkers away from the main Pennine Way footpath) during 476 man-days of fieldwork. Even if all encounter observations resulted in a bird being disturbed, which is highly unlikely, this only approximated to a overall rate of 0.4 disturbances per week and this would certainly be lower if measured as disturbances per bird per week. This was five times less than our imposed high disturbance category and approximated to our medium category. However, our observations did not include most weekends or public holidays when human visitor use would probably have been higher. Visitor usage levels were very low when compared with the South Pennines and the Peak District where disturbance levels were very high and impacts on the Golden Plover *Pluvialis apricaria* were recorded (Yalden & Yalden 1988, Pearce-Higgins & Yalden 1997, Finney et al. 2005, Pearce-Higgins et al. 2007).

The study collected data to test the following hypotheses: (1) flushing distances increase with disturbance frequency, (2) home range sizes increase with disturbance frequency, (3) disturbance of prebreeding females lowers breeding success and (4) disturbance lowers survival rates.

A disturbance treatment was defined to have occurred when the sample individual or nearby Black Grouse were seen flying away and telemetry evidence supported the proximity of the individual and the subsequent fading signal in the same direction as the birds were flushed. Birds were generally flushed between 09:00 and 17:00 h, as this period corresponded to the likely hours of most recreational disturbance.

Owing to the large number of birds spread over a large geographical area, visits to birds were not strictly randomized, but varied in an uncontrollable manner according to daily variations in bird detection, distance from access and vantage points, access permission and availability of field assistance.

Disturbance treatments were carried out all year round, with the exception of females between

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**Table 1. Black Grouse caught and radiotracked as part of this study.**

<table>
<thead>
<tr>
<th></th>
<th>Adult male</th>
<th>Adult female</th>
<th>Juvenile male</th>
<th>Juvenile female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to December 2002</td>
<td>–</td>
<td>14</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>December–March 2003</td>
<td>2</td>
<td>10</td>
<td>–</td>
<td>6</td>
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<tr>
<td>August 2003</td>
<td>–</td>
<td>1</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>December–March 2004</td>
<td>–</td>
<td>5</td>
<td>1</td>
<td>4</td>
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mid-May and the end of August when they were either incubating clutches of eggs or had dependent broods. During this period, females were triangulated weekly, but were not disturbed for ethical reasons related to the species’ threatened status and because females tended to remain sitting on eggs, usually in tall cover, until virtually stroked, thereby restricting the likelihood of disturbance even under moderate levels of casual human recreation. Potential impacts of dogs on breeding females have already been mitigated within the Act, which stipulates that dogs should be restrained on short leads between 1 March and 31 July.

**Behavioural responses**

The straight-line distance between the observer and each of the radio-tagged study birds when flushed was recorded to the nearest 1 m using a Leica range finder. Flush locations were recorded and plotted onto maps. Home-range size was estimated for each bird. Eighteen females had winter home-ranges (October–March) separated from their breeding or summer ranges (April–September) by a mean of 1.2 km (range 0.2–5.2 km). For these birds, the winter and the breeding home-ranges were calculated separately and summed to give an overall home-range size. All remaining females and all males had continuous annual home-ranges within which both winter and summer ranges were overlapping. All estimates of home-range size excluded dispersal-type movements. A further index of home-range size, the distance a bird had moved between consecutive visits, was measured and compared between disturbance treatments.

The timing of autumn dispersal for each individual was taken as the last recorded presence within the natal home-range. The autumn dispersal distance was measured as the straight-line distance from the natal tagging location to the centre of the winter home-range. Similarly, spring dispersal was timed as the last recorded presence in the winter home-range, with spring dispersal measured as the straight-line distance from the centre of the winter home-range to either the nest-site for females or the lek attended for males. The overall natal dispersal distance, a combination of both autumn and spring dispersal, was measured as the straight-line distance from the natal tagging location to the nest-site for females or lek for males.

First-egg laying dates were back-calculated from the estimated date of hatching, assuming an incubation period of 26 days, an egg laid every day and incubation commencing on clutch completion (Cramp & Simmons 1980). Where the date of hatching was not precisely known, it was regarded as the mid-date between the last date when the female was still incubating and the visit date when it was found to have hatched.

**Demographic responses**

Females were flushed from their nests only once during incubation to record clutch size. Incubating females were then triangulated every week to assess hatching date and hatching success. In early August, all females that had successfully hatched chicks were flushed and the number of surviving juveniles counted with the aid of a pointing dog.

**Statistics**

Differences in response variables between birds within the three disturbance treatments were analysed using analysis of variance with disturbance treatment (low, medium, high), sex (male or female), age (adult or first-year) and season (spring, summer, autumn or winter) entered as factors. All first-order interactions involving these factors and disturbance treatments were also considered. In addition to the described analysis, which gives equal weighting to the three levels of disturbance, we also investigated whether disturbance had an effect, by comparing the mean of medium and high disturbance levels with the control, i.e. low disturbance, and whether the intensity of disturbance had an effect, i.e. comparing medium with high disturbance. This was done by subdividing the sum of squares for disturbance into the sum of squares corresponding to these two questions using orthogonal contrasts \(2^{-1} - 1\) and \(0^{-1} - 1\), respectively. However, this additional approach gave the same results as the standard analysis and only the results of the standard analysis are presented.

Flushing distances were log-transformed prior to analysis. As mean flushing distances were considered for the same bird in different seasons of the year, individual was included as a random effect within a mixed model. Estimates of home-range size increased in a linear manner in relation to the number of fixes, before levelling off at or above about 25 fixes. Accordingly, differences in home-range size were considered by entering the log-transformed number of locations upon which the home-range calculation was based as a covariate. Birds with ten or fewer locations were excluded to prevent inclusion of birds tracked in one season only.
The analysis of hatching success was undertaken using the Mayfield method to correct for biases due to differing observation periods (Mayfield 1975, Aebischer 1999).

Differences in the proportion of females with broods in August between disturbance treatment, year and female age were tested by a logistic regression with brood presence (1) and absence (0) as the dependent variable. The number of chicks reared per female was not normally distributed and was analysed using a Poisson error distribution and a logarithmic link function corrected for over-dispersion.

Survival rates were estimated by modelling individual survival histories (Lebreton et al. 1992) from 2 weeks after capture to either death, loss of radio signal or end of the study. The time of death was recorded as the mid-point between the last flushing/triangulation occasion and the date of corpse recovery. To avoid bias due to capture and handling, three birds which died within 2 weeks after capture were excluded. This method allowed for the inclusion of individuals tagged at differing times of the year. A bird’s survival history was modelled as a product of weekly survival rates for each week that the bird survived, or a weekly mortality rate if it died. The survival histories of birds captured as juveniles and followed for more than 1 year involved both first-year and adult survival rates. Juveniles were considered to become adults in September of the year following year and adult survival rates. Juveniles were considered to become adults in September of the year following capture. Models were fitted using the program SURVIV (White & Garrot 1990). Model selection was guided by ranking models according to Akaike’s information criterion (AIC) (Lebreton et al. 1992). Survival probabilities were calculated for two 6-month periods, winter (September–February) and summer (March–August) by raising weekly survival rates to the power of 26 (Warren & Baines 2002).

RESULTS

Behavioural responses

Flushing distances did not differ between either sex \(F_{1,100} = 0.05, P = 0.82\), age \(F_{1,100} = 0.02, P = 0.90\) or individual \(F_{46,100} = 1.40, P = 0.08\). Having controlled for the above variables, mean flushing distance differed between disturbance treatments and between seasons. Flushing distances were greatest in winter and spring with seasonal back-transformed means of 71 and 80 m, respectively, and lowest in summer and autumn with distances of 22 and 27 m, respectively \(F_{3,100} = 23.23, P < 0.001\). Birds flushed at 60% greater distances when exposed to high disturbance rates, at an average distance of 55 m, compared with 34 m at moderate disturbance rates \(F_{1,100} = 3.66, P = 0.05\). Birds that were flushed more frequently (logarithm of the total number of flushes) had greater mean flushing distances \(F_{1,100} = 3.96, P = 0.05\).

Geometric mean home-range size was positively related to the logarithm of the number of radiotracking fixes \(F_{1,61} = 48.20, P < 0.001\) when non-significant first-order interactions were excluded and main effects only were considered. After correcting for this, home-range size did not differ between sex \(F_{1,35} = 2.10, P = 0.16\), age \(F_{1,35} = 2.66, P = 0.11\) or disturbance treatment \(F_{2,35} = 0.44, P = 0.65\). The mean distance moved between successive flushes for each bird was used as an additional index of home-range size. Distance moved was not linked to any of the main terms, including the logarithm of the total number of flushes, or their interactions with disturbance, but within a minimal model involving the main terms only, it varied significantly between sexes. Males moved a mean of 0.73 km \((\pm 0.06\ se)\) \((n = 16\ birds)\), compared with 0.56 km \((\pm 0.03\ se)\) for females \((n = 56\ birds)\ (F_{1,66} = 4.72, P = 0.03)\.

Data on full dispersal distances were available for 15 juvenile females and 11 juvenile males. Females dispersed significantly further than males, with a mean geometric distance of 6.0 km (95% CL 3.8–9.4) for females compared with 0.6 km (95% CL 0.4–0.9) for males \(F_{1,42} = 1.49, P = 0.25\) or the interaction with sex \(F_{2,20} = 0.84, P = 0.45\).

First-egg laying dates were known for 53 clutches, 47 first clutches and six replacement clutches. Laying dates of first clutches did not differ between years \(F_{1,37} = 1.41, P = 0.24\), age of females \(F_{1,37} = 3.46, P = 0.07\) or disturbance treatments.

Demographic responses (Table 2)

Clutch size and hatching success

Clutch size was recorded from 47 first clutches, 25 in 2003 and 22 in 2004. Clutch size ranged from two eggs to 11 eggs, with an average of 8.5 eggs \((0.2\ se)\). Clutch size did not differ between disturbance treatment or year \(F_{1,42} = 1.31, P = 0.26\), but differed significantly between first-year breeders and older hens \(F_{1,42} = 21.39, P < 0.001\), with a mean clutch size of 7.3 eggs \((0.3\ se)\) in first breeding females compared with 9.1 eggs \((0.2\ se)\) in older females.
Of the 56 clutches considered across the two years, 33 successfully hatched chicks (59%). Of the successfully hatching clutches, an average of 8.1 eggs hatched, representing 95% egg hatchability. A similar value of hatching success of 47% was obtained using the Mayfield method to correct for bias due to differing observation periods. Hatching success did not differ between disturbance treatments ($D = 0.20$, $df = 2$, ns), or year, but differed between first breeders and older females ($\chi^2_1 = 4.86$, $P = 0.03$).

**Breeding success**

Brood size (excluding females with no chicks) was recorded from a total of 21 females. Brood size averaged 3.2 chicks ($\pm 0.4$ se) and ranged from one to seven. There was no effect of year ($F_{1,16} = 0.01$, $P = 0.91$), age of female ($F_{1,16} = 0.17$, $P = 0.69$) or disturbance treatment ($F_{2,16} = 0.11$, $P = 0.90$) on mean brood size.

Overall, 40% of 53 hens over the 2 years of the study had accompanying broods when surveyed in early August (46% in 2003 and 34% in 2004). A logistic regression model incorporating year, disturbance treatment and female age found that only age was significant in explaining differences in the proportion of females with broods, with 19 of 37 adult females rearing broods (51%) compared with only two of 16 first-year females (13%) ($\chi^2_1 = 5.11$, $P = 0.02$). There was no effect of disturbance treatment on the proportion of females with broods ($\chi^2_2 = 2.00$, $P = 0.16$).

Breeding success (chicks per hen) did not differ between years ($F_{1,50} = 0.61$, $P = 0.44$) or disturbance treatment ($F_{2,50} = 1.12$, $P = 0.29$). Adult females bred four-fold better than yearling females with 1.6 chicks per hen ($\pm 0.3$ se) ($n = 37$) compared with only 0.4 ($\pm 0.5$ se) for yearlings ($n = 16$) ($F_{1,50} = 7.09$, $P = 0.01$).

**Survival rates**

The statistical model with the lowest AIC was one with just two parameters, winter weekly survival and summer weekly survival rates. Relative to this reduced model, there was no effect of disturbance ($\chi^2_2 = 6.14$, $P = 0.18$) or of age ($\chi^2_2 = 4.46$, $P = 0.11$). Relative to a model with a constant survival rate, the seasonal difference was significant ($\chi^2_1 = 4.65$, $P = 0.031$). The average winter weekly survival rate was 0.9903 $\pm 0.0054$, equivalent to a survival rate over all winter of 78% ($\pm 11$% se); the summer weekly survival rate was 0.9966 $\pm 0.0044$, equivalent to 92% ($\pm 10$% se) over all summer.

**DISCUSSION**

**Behavioural responses**

Increased disturbance resulted in increased flushing distances, particularly in winter and spring. At this time of the year, birds feed predominantly on heather (Beeston et al. 2005) in what can be large winter flocks of both sexes (Baines et al. 2002) on
often small traditionally used allotment sites between the enclosed fields and the open moorland. Regular disturbance of these wintering flocks could theoretically impact upon survival rates, particularly if alternative foraging grounds are limited or of poorer quality, but in practice we found no evidence for this. Disturbance may locally limit the extent of habitat available to birds in the vicinity of frequently disturbed areas (e.g. Golden Plover; Finney et al. 2005, Capercaillie Tetrao urogallus; Summers et al. 2004b). In these cases, it would appear that birds were able to compensate for the impact of disturbance by moving to sites that are less disturbed or by perhaps increasing their food intake during foraging opportunities. This observation, however, relies upon birds having alternative sites to use and cannot fully consider the costs of moving to different sites or reduced foraging opportunities (Brenot & Menoni 1999). Alternatively, birds may not be displaced, but may decline in the long term due to reduced attractiveness of frequently disturbed areas to potential recruits (Meile 1981, Zeitler 2000).

**Demographic responses**

High levels of disturbance through the winter and early spring may potentially affect subsequent breeding success. We hypothesized that disturbance of females in the prebreeding period may result in smaller clutches through reducing maternal condition, with subsequent repercussions for overall breeding success. This study could not, however, detect any link between disturbance and either fecundity or survival. This inability to detect an effect is consistent with previous studies both on Black Grouse breeding success in relation to high levels of disturbance from winter skiing (Miquet 1988), and breeding success or shooting bags of Red Grouse and levels of public access on moors in northern England (Picozzi 1971, Hudson 1982).

Although not considered by our experiment, the effect of disturbing incubating females from nests probably differs between species and between areas in relation to differing densities of clutch predators. Whereas Picozzi (1975) found that increased nest disturbance was linked to higher nest predation rates by corvids, no differences in clutch predation rate were found when observers deliberately flushed either Northern Lapwing Vanellus vanellus (Galbraith 1987, Fletcher et al. 2005) or Ptarmigan Lagopus mutus from their clutches (Hannon et al. 1993). It is likely, however, that unrestrained dogs may have a significant impact upon breeding grouse. Any impact is likely to be highest when the grouse have chicks as dogs will detect incubating female Capercaillie only when within on average 2 m, but will detect a brood when within 39 m (Storaas et al. 1999). Similarly, uncontrolled dogs disturbed seven times more Red Grouse in August than dogs under strict control (Hudson 1982).

More frequent presence of humans may affect predation rates on clutches and small chicks by attracting more corvids to feed on discarded food scraps (Watson 1996, Storch & Leidenberger 2003). Corvid activity in Scottish pinewoods was negatively correlated with breeding success in woodland grouse and their impact could conceivably be high in areas where corvids are not routinely killed (Baines et al. 2004, Summers et al. 2004a). Given that almost 90% of Black Grouse in our North Pennines study area occurred on the margins of grouse moors, where gamekeepers are employed to kill predators of Red Grouse (Warren & Baines 2004), it is likely that crow numbers were strictly controlled, although interference with legal traps by the public may have reduced trapping efficiency.

**CONCLUSIONS AND RECOMMENDATIONS**

Within the constraints of the experiment, there was no clear evidence that increased human access into the North Pennine uplands will impact negatively upon Black Grouse. We are currently unaware of any substantive data that allow predictions of the effects of ‘open access’ on the public’s behaviour: whether numbers using the countryside will generally increase, whether the same number of people will distribute themselves more randomly, or whether people will largely restrict themselves to already existing footpaths. As we do not know what to expect, it is difficult to gauge whether our manipulated levels of disturbance will be representative in the future. However, we know that encounter rates of disturbance during the study period were more than four times lower than our imposed high disturbance category and broadly equivalent to our medium disturbance category. Furthermore, less than one-quarter of our human encounters were with walkers. Given that disturbance levels from gamekeepers and farmers are unlikely to increase in the future, there would need to be an overall 20-fold increase in parties of walkers to create an impact consistent with our category of high disturbance. Now, almost a year after the onset
of the statutory rights of access, there is consensus among a forum of gamekeepers, scientists and conservation bodies that no meaningful increase in human usage of the North Pennine moorlands has been detected based on collective anecdotal observations.

If actual disturbance levels in the future significantly exceed those used in this study, there may be conflict. Accordingly, under the precautionary principle we offer the following management advice to limit or prevent such circumstances arising: consider restrictions on access to wintering grounds where large numbers of birds regularly concentrate; extend existing restrictions requesting that dogs be kept on leads from April to the end of July through until August; extend these areas to encompass enclosed ground where Black Grouse breed; and provide viewing facilities for birdwatchers at leks.

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