

Are temperature loggers useful for studying nest disturbance in Rock ptarmigan *Lagopus mutus*?

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Abstract - The incubation rhythms of three Rock ptarmigan hens were monitored during spring 1999, 2001 and 2002 in the eastern French Pyrenees, by placing programmable temperature data-loggers in the nests. We tried to classify incubation recesses into two groups, normal vs. atypical, in order to detect disturbance events. Incubation patterns varied noticeably between the three hens, but we could not find a clear relationship between incubation patterns and disturbance levels, defined as distance from nests to hiking paths. The only incubation parameter apparently related to nesting disturbance was the mean number of recesses per day. The highest values of two other incubation parameters (mean length of recess and mean time off the nest per day) occurred in the hen incubating the largest clutch, suggesting the possibility of an effect of energy requirements on incubation rhythm. Body condition before incubation could also have affected incubation patterns, but we did not measure it. Even if individual differences in clutch size and body condition might have explained most of the individual variation in incubation rhythm, we suggest that disturbance was perhaps an additional factor. Because the distinction between normal and atypical recesses is subjective, the number of the latter will represent at best a rough index to the level of nesting disturbance. Given that modifications in incubation rhythm related to disturbance might reduce egg or chick viability, any evaluation of the effect of nest disturbance on breeding success should include a measure of final reproductive output (i.e. ratio of number of young reared to number of adults).

Introduction

Incubation is a critical period for birds because they lose body heat to warm the eggs, while simultaneously meeting their own energetic requirements (Drent 1975). The energetic cost of incubation to Rock ptarmigan *Lagopus mutus* hens is particularly high because males do not incubate in this species and environmental conditions are severe on the breeding range. This energetic cost is illustrated by the loss in body mass of incubating hens, reaching up to 30% for Rock ptarmigan (Steen and Unander 1985) and Willow ptarmigan *Lagopus lagopus* (Erikstad 1986). Disturbance during nesting may further increase energetic costs and compromise success of nests or chick survival. In recent reviews addressing disturbance in birds, most studies reported a significant negative effect on breeding success (Hockin *et al.* 1992, Götmark 1992). Effects of disturbance have often been investigated by recording reproductive parameters or escape behaviour of a species according to

different levels of nest disturbance defined in advance by the researchers (Cotter and Gratto 1992, Ingold *et al.* 1996). Unfortunately, apart from researcher-induced disturbance, the real level of disturbance of nests is rarely known. However, a quantitative estimate of disturbance would be useful, for instance in comparing the nest success rates in two areas with different intensities of human activity (e.g. disturbed by tourism vs. undisturbed, or grazed vs. ungrazed). In our study, we wished to determine if the monitoring of nest temperature during incubation could be used to detect disturbance events. This method has been employed to study the incubation rhythms of several grouse species such as Willow ptarmigan (Erikstad 1986), White-tailed ptarmigan *Lagopus leucurus* (Wiebe and Martin 1997), Capercaillie *Tetrao urogallus* and Black grouse *Tetrao tetrix* (Storaas and Wegge 1997). Our study was carried out on three nests of Rock ptarmigan, a species exhibiting low breeding success over the last ten years in France (Ellison and Léonard 1996). Although post-hatching

weather conditions are thought to be the main factor determining this low breeding success in the Pyrenees (Brenot 2000), no data are available on the potential adverse effects of disturbance on nesting. However, managers of wild lands are becoming concerned about such effects on ptarmigan populations, because recreational activities are increasing in alpine habitats.

Methods

Study area

The study was conducted in June and July of 1999, 2001 and 2002 on the Canigou massif (42°31' N, 2°29' E), which represents the eastern limit of the distribution of Rock ptarmigan in the French Pyrenees. The breeding habitat of the species is located on steep slopes, between altitudes ranging from 2,200 m to 2,700 m a.s.l. The area is characterized by the predominance of gneiss screes mixed with sparse alpine vegetation (*Rhododendron ferrugineum*, *Vaccinium uliginosum*, *Dryas octopetala*, *Saxifraga* sp.). At 2,150 m, mean annual temperature is 4.6°C and mean annual precipitation is 1,458 mm.

Cattle grazing occurs in the study area from June to October, but grazing pressure is very low. The study area is also a renowned tourist site, and each year about 25,000 people climb to the peak of the Canigou.

Nest characteristics

The nests of three radio-tagged hens of Rock ptarmigan (hereafter H1, H2 and H3) were monitored, one during spring 1999, the other two during spring 2001 or 2002. Each of these hens had been marked the previous year, i.e. 27/09/98 for H1, 14/09/00 for H2 and 06/07/01 for H3. The hens were adult birds – older than 12 months – by the time of nesting. The nests were located by flushing the hens toward the end of laying.

The H1 nest numbered 4 eggs when first located on 14/06/99, and 5 eggs at the time of the second visit on 17/06. It was situated on a NE-facing slope at 2,360 m altitude, and 250 m from a heavily frequented hiking path. The H2 nest included 5 eggs when first visited on 11/06/01, and 7 on 13/06. It was located at the top of a steep NE-oriented gully, at 2,590 m, and 200 m from a heavily used hiking path. The H3 nest included 3 eggs when first visited on 18/06/02, and 5 on 20/06. It was situated on a NW-facing slope at 2,330 m, and only 6 m from the same hiking path as H2.

Incubation monitoring

The monitoring of incubation rhythms was carried out using temperature data-loggers (model: “Stowaway”; PROSENSOR - Thermométrie industrielle – 57865

Amanvillers - France). Each logger cost 145 euros and could be used during several nesting seasons. The logger is a disk 3 cm in diameter and 1.5 cm thick, i.e. less than the size of a Rock ptarmigan egg (44 mm x 31 mm : Cramp and Simmons 1980). Loggers were placed in the nest bowls, in the same position as the eggs. However, to prevent the hen from removing the logger from the nest, the logger was firmly fixed to the ground. The fastening system allowed a certain mobility of the logger in the midst of the eggs so that the temperature of the logger remained consistent with that of the eggs. This logger also enabled us, via an infra red optical reader, to program the date of the first recording and also the interval between two temperature recordings. We chose a 3-min interval, like Wiebe and Martin (1997) for their study of the incubation rhythm of White-tailed ptarmigan.

For H1, the logger was placed on the second day of incubation (17/06/99) and for H2 one day before the start of incubation (13/06/01). These second visits resulted in a further disturbance only for hen H1, H2 being off the nest. For H3, the logger was placed at the time of first visit (18/06/02). In spring 2002, an infra red optical system placed beside the hiking path, 30 m from H3 nest, allowed us to count the number of times a hiker passed during the incubation period.

Data Analysis

Data was recovered as ASCII files, including for each recording: date, hour and temperature to the nearest 0.01°C. For each day, we first plotted the graph of daily temperatures, and then identified on each graph the different recesses of the hens, indicated by a sharp drop in temperature (Fig. 1). For each recess, we noted the initial time, the duration of the recess and the drop in temperature (Fig. 1). We also tried to identify “atypical” recesses such as those occurring

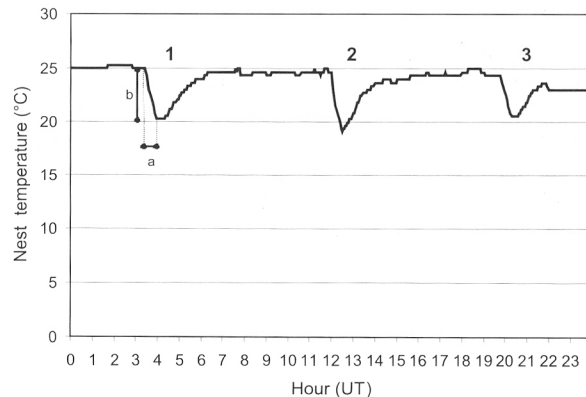


Figure 1. Graph of the daily temperatures recorded in a Rock ptarmigan nest (hen n° 2 - 17/06/01). (1, 2, 3: recess number; a: recess length; b: temperature fall).

during the night or immediately after a “normal” recess, or those that were abnormally long or brief (Fig. 2). Unusually large temperature drops were also examined to determine if they could be used to distinguish normal recesses from atypical ones.

For each hen, we calculated the following incubation parameters: incubation constancy (% time spent on the nest), mean number of recesses per day, mean length of recesses (min) and mean time off the nest per day (min).

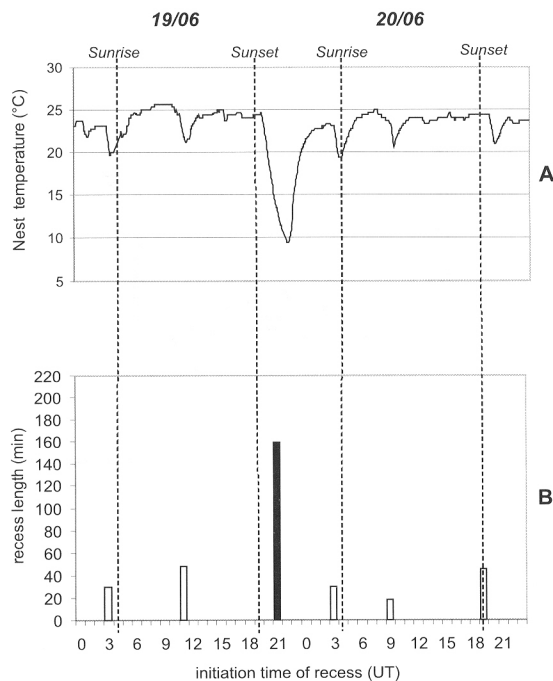


Figure 2. A: nest temperatures of hen n° 2 recorded on two consecutive days (19-20/06/01). B: classification of incubation recesses according to initiation time and length of recess. White bars indicate normal recesses and the dark bar an atypical recess that occurred at night and was abnormally long.

Results

Fate of clutches

The presence of the logger in the nest bowl did not influence the general pattern of incubation or the fate of clutches. H1 successfully hatched her clutch after 21-22 days of incubation (15-16/06 - 07/07). The clutch included 4 hatched eggs and one infertile egg. H2 successfully hatched her clutch after 23 days of incubation (14/06 - 07/07). Six eggs hatched, but we could not determine the fate of the seventh egg. The five eggs of H3 hatched after 22 days of incubation (21/06 - 13/07).

Incubation rhythms

On 17/06/99, we flushed H1 off her nest to install the temperature logger. She came back 40 min later to continue incubating. We monitored her incubation rhythm over a period of 21 days, during which time we noted a total of 50 recesses. We did not find any “atypical” recesses among the 50 recorded for H1. However, three recesses resulted in abnormal temperature drops, -10.8° , -21.3° and -12° respectively. These drops were much larger than the average drop of -4.8° ($n = 50$). Initiation times of these recesses were normal, but they were relatively brief, 12, 18 and 9 min respectively, suggesting that the hen voluntarily shortened these recesses. Because during incubation Rock ptarmigan hens do not cover their eggs when leaving the nest (Watson 1972), ambient temperature may strongly affect egg temperature. For instance, we noted that the greatest temperature drop recorded here (-21.3°) coincided with a storm that occurred during the hen’s recess. Hence, we had no objective reason to believe that these temperature drops were caused by disturbance.

H2 started incubating one day after laying the last egg of the clutch. We recorded 66 recesses over the 23 days of monitoring. Out of these 66 recesses, 3 were considered to be “atypical”. One of them occurred during the night and the other two lasted 132 and 159 min respectively, a duration much greater than the mean length (Table 1, Fig. 3A). The temperature drops observed during these two recesses were -12.5° , -15.2° , while the temperature drop of the 66 recesses averaged -3.6° . We could not determine any cause for these three recesses. Because the nest was not predated, we think that the hen may have been disturbed by wild ungulates, such as Chamois *Rupicapra pyrenaica*, grazing and/or resting close to the nest.

On 18/06/02, we flushed H3 off the nest to install the temperature logger. She came back 29 h later to lay the fourth egg of the clutch. The fifth and last egg was laid on 20/06, 20 h after the fourth one. The incubation rhythm of H3 was characterised by the large number of recesses and their relative shortness (Table 1; Fig. 3A). Over the 22 days of monitoring H3, we recorded 86 recesses of which 7 were considered as to be “atypical”. Each of these 7 recesses lasted only 6 to 12 min and occurred soon after a “normal” recess. On several days with a high level of tourist frequentation, we noted up to six recesses per day, suggesting a possible effect of hiker disturbance on incubation rhythm. Like for H1, we recorded two recesses during storms, accompanied by large drops in temperature, -10.1° and -13.1° respectively.

When the monitoring data for the three hens were pooled, and first and last days of monitoring excluded (i.e. 60 days of monitoring), the general pattern of

Table 1. Incubation parameters (mean values and range) of three Rock ptarmigan hens, determined by monitoring nest temperatures.

Incubation parameters	Hen n° 1 (5 eggs, 250 m) ^a	Hen n° 2 (7 eggs, 200 m) ^a	Hen n° 3 (5 eggs, 6 m) ^a
Incubation constancy ^b	95.6 %	93.2 %	95 %
Number of recesses / day ^b	2.5 (2 - 3) (n = 19)	3 (1 - 5) (n = 21)	3.9 (3 - 6) (n = 20)
Length of recess (min)	26 (9 - 48) (n = 50)	33 (15 - 159) (n = 66)	19 (6 - 90) (n = 86)
Time off the nest / day ^b (min)	64 (39 - 93) (n = 19)	98 (27 - 237) (n = 21)	72 (48 - 99) (n = 20)

^a (clutch size and distance of nest from hiking path)

^b first and last day of monitoring excluded

recess initiation times was : one recess before sunrise every day (60/60), one to five recesses during the day on 98% of the days (59/60) and one recess after sunset on 48% of the days (29/60) (Fig. 3B).

Inter-hens differences and nesting disturbance

The frequency distribution of length of recesses, grouped by 10-min intervals (Fig. 3A), differed among hens ($\chi^2 = 74.87$, $df = 12$, $P < 0.001$) (6 classes for intervals of 10-60 min plus 1 class for 60-150 min). Likewise, distribution of initiation times of recesses (Fig. 3B) differed ($\chi^2 = 9.299$, $df = 2$, $P = 0.01$) (2 classes, recess initiated 7-18 h or outside this period).

H3 made more short recesses (< 20 min) than either H1 ($\chi^2 = 35.07$, $df = 6$, $P < 0.001$) or H2 ($\chi^2 = 60.45$, $df = 6$, $P < 0.001$). But frequency distribution of recess lengths did not differ between H1 and H2 ($\chi^2 = 8.22$, $df = 6$, $P = 0.22$) (Fig. 3A). H3 showed a higher frequency of recesses between 7 h and 18 h than either H1 ($\chi^2 = 3.798$, $df = 1$, $P = 0.051$) or H2 ($\chi^2 = 7.288$, $df = 1$, $P = 0.007$), whereas H1 and H2 had similar frequencies in this time period ($\chi^2 = 0.095$, $df = 1$, $P = 0.76$) (Fig. 3B).

The hen located furthest from a hiking path (H1) showed the lowest values for the mean number of recesses per day and the mean daily time spent off the nest but such a relationship with distance did not persist when considering H2 and H3 (Table 1). Only the greater number of recesses per day of H3 may be viewed as a possible effect of human disturbance. Indeed, the nest of H3 was situated very close to a hiking path where 900 "hiker passages" were recorded during the 22 days of incubation. Both mean length of recess and mean daily time spent off the nest were higher for H2 than for H1 and H3. Even if the two longest recesses noted for H2 were associated with disturbance events, this factor could not

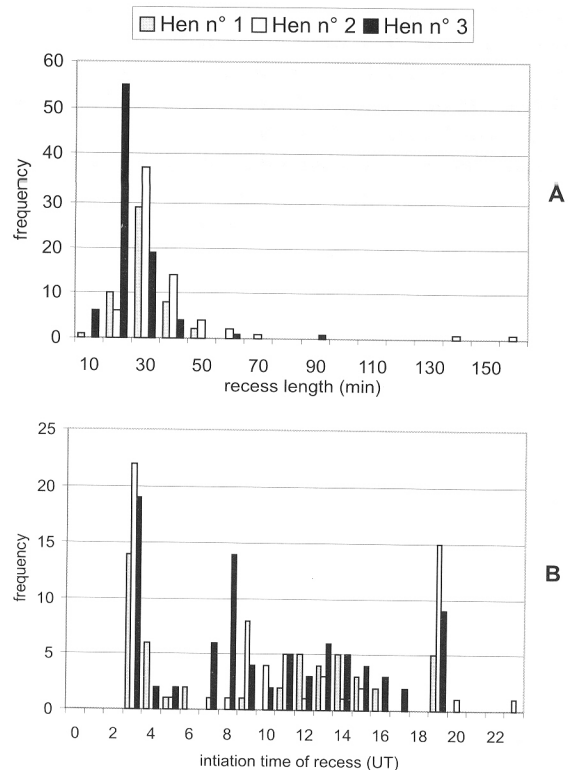


Figure 3. Comparison of the length (A) and initiation time (B) of incubation recesses among three hens of Rock ptarmigan.

explain all these differences. Because clutch size of H2 was 40% larger than the two other clutches, the lower nest attentiveness of H2 may be explained by a greater energetic demand for incubation, which required the hen to spend more time off the nest for feeding.

Discussion

Investigator disturbance caused by placement of temperature loggers in nests did not influence fate of clutches. Previous studies have already shown that ptarmigan species are rather tolerant to investigator disturbance (Cotter and Gratto 1995, Hannon *et al.* 1993, Wiebe and Martin 1997). However in their intensive study of Rock ptarmigan breeding biology, Steen and Unander (1985) noted that human interference may have contributed to a high level of nest predation (56%). Because ptarmigan hens show a high attachment to their nests, nesting disturbance will seldom result in nest abandonment, but rather in less visible effects such as modification of incubating behaviour or physiology of nesting birds. Heart rate

changes are useful indicators of nesting birds' reactions to events in their environment because often their behaviour does not appear to vary in response to a threat until the point at which they flee (Nimon *et al.* 1995, Nimon *et al.* 1996). For instance, the experiment of Ingold *et al.* (1996) clearly showed that the passage of hikers close to the nest may modify cardiac rhythms of incubating Rock ptarmigan hens, and hence most likely their energy requirements. In the same experiment, hens who had been previously flushed off their nest, returned to incubate only after the source of disturbance had moved away.

The incubation periods found in our study, 21-23 days, concur with those recorded in other Rock ptarmigan populations (Couturier 1964, Watson 1972, Steen and Unander 1985). Nevertheless, the three clutches monitored in the present study provided new data on the incubation rhythm of the species. Watson (1972) reported 3-4 recesses of 25-45 min in Scotland, whereas in Iceland Gardarsson (*in litt.*) noted 4-6 recesses of 7-25 min totalling about 90 min/day. Although the number of recesses that we recorded per day was rather similar to that in Scotland and Iceland, we found greater variation in both recess length and total time off the nest per day (Table 1). We also noted considerable difference in incubation behaviour among the three hens. Such inter-individual variability has also been observed in other ptarmigan species, such as Willow ptarmigan (Erikstad 1986) and White-tailed ptarmigan (Wiebe and Martin 1997).

The interesting question is to determine to what extent disturbance contributed to inter-hen differences in incubation rhythm. Although there is strong evidence that the greater number of recesses per day of H3 was related to the frequent passage of hikers, the discrimination between normal and atypical recesses remained more subjective. Hence, the number of "atypical" recesses identified during the incubation period will represent at best a rough index to the level of nesting disturbance. Furthermore, even if atypical recesses were actually related to disturbance events, we could not determine the specific cause of disturbance. As suggested for H2, the source of disturbance was not necessarily related to humans. Indeed, wild ungulates as well as sheep flocks (Miquet and Deana 2002) may also disturb incubating ptarmigan hens.

Other studies of incubation rhythm in ptarmigan species make no reference to disturbance to account for inter-hen differences (Erikstad 1986, Wiebe and Martin 1997). Instead, differences in incubation patterns are explained by body condition of hens, measured before incubation. We did not measure body condition and so cannot evaluate its influence. Nevertheless we believe that both nesting disturbance and body condition should be taken into account when

comparing incubation constancy of nesting birds, especially where human activities occur in the breeding habitat. Grazing activities, hiking or other recreational sports are very widespread in the Rock ptarmigan habitat throughout the Alps and the Pyrenees. In such circumstances, low incubation constancy may be caused by a combination of poor body condition before incubation, disturbance at nests and perhaps large clutch size.

Despite a noticeable difference in the incubation rhythms of the three hens, each of them successfully hatched their clutch. However, this result does not exclude the possibility that frequent or prolonged absences from the nest might lead to abnormal egg temperatures. Temperature stress on eggs may affect either embryonic viability (Westemeier *et al.* 1998) or chick viability (see Erikstad 1986). Furthermore, leaving the nest in a hurry may result in knocking one or two eggs out of the nest, increasing the possibility of egg losses (Watson 1972). Therefore an evaluation of the effects of disturbance on breeding success should also include a comparison of the reproductive output (i.e. young / adult ratio) between the disturbed vs. undisturbed nesting hens. If a significant difference in reproductive output is found between the two groups of hens, and body condition just before incubation is the same, then the comparison of incubation parameters might reveal the period and the extent of nest disturbance.

Direct observation of incubating hens may be used to identify disturbance events during incubation (Miquet and Deana 2002), but in addition to being time-consuming this method provided only daytime data. Bernard-Laurent and Laurent (1991) monitored hens carrying radio-tags equipped with a movement-sensitive device to record incubation rhythm of *Alectoris* partridges. However the technique required a receiver for each nesting hen and frequent manual tuning of the incoming signal. Like temperature loggers this technique did not allow one to distinguish "normal" and "atypical" recesses. Other recent techniques, such as video monitoring (King *et al.* 2001) or measuring heart rate of incubating birds (Nimon *et al.* 1996) would probably provide a more accurate assessment of nesting disturbance, but such studies (especially video) could be more expensive. A recently developed system based on an artificial pressure-sensitive egg (Bottitta *et al.* 2002) has the advantage of being able to detect briefer recesses (less than 5 min) than the loggers but requires more equipment (transmitter in nest, receiver, control panel to download data, 12 volt battery to power the system). Nevertheless it might be more cost effective than loggers for following many nests simultaneously within a small area, for example in colonial nesting birds.

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Résumé - Les rythmes d'incubation de trois poules de Lagopède alpin ont été suivis en 1999, 2001 et 2002 dans les Pyrénées Orientales françaises, en plaçant des enregistreurs de températures dans les nids. Les sorties du nid ont été réparties en deux groupes, normales vs. anormales, dans le but d'estimer l'importance des dérangements durant l'incubation. Les profils d'incubation ont varié sensiblement entre les trois poules, mais nous n'avons pas trouvé de relation claire entre les profils d'incubation et l'intensité du dérangement, définie comme la distance séparant les nids des chemins de randonnée les plus proches. Le seul paramètre d'incubation apparemment influencé par le dérangement a été le nombre moyen journalier de sorties du nid. Les plus fortes valeurs de deux autres paramètres (durée moyenne des sorties et temps moyen journalier passé hors du nid) ont été observées chez la poule couvant la plus grande ponte, suggérant un effet possible des besoins énergétiques sur le rythme d'incubation. La condition physique des poules avant incubation pourrait également avoir joué un rôle, mais ce facteur n'a pas été mesuré. Même si les différences de taille de ponte et de condition physique entre les poules pourraient expliquer l'essentiel des différences des rythmes d'incubation, nous suggérons que le dérangement a été peut-être un facteur additionnel. Comme la distinction entre les sorties normales et anormales reste le plus souvent subjective, le nombre de sorties anormales représentera au mieux un indice grossier du niveau de dérangement des nids. Etant donné que les modifications des rythmes d'incubation, liées au dérangement, pourraient réduire la viabilité des œufs ou des poussins, toute évaluation des effets de ces dérangements sur le succès de la reproduction devrait inclure une mesure du résultat final de la reproduction, comme le rapport du nombre de jeunes sur le nombre d'adultes.

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