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# Factors affecting chick mortality of hazel grouse in a temperate forest, South Korea

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ABSTRACT

Between March 2006 and September 2013, hazel grouse *Bonasa bonasia* (35 hens and 157 chicks) were equipped with radio transmitters in a temperate forest, South Korea to document factors influencing chick mortality. We recorded habitat composition, mortality rates, and cause of death. Among 157 hazel grouse chicks, 75 survived and 58 were killed by predators. The mean spring–summer survival of chicks was 48% and mortality due to predation was 37%. According to the habitat composition analysis, natural deciduous forest was used by hazel grouse chicks significantly more often than the other forest types. The top-ranked model ($r^2 = 0.76$) for hazel grouse chick mortality included understory cover, forest type, distance from the nearest forest road, and overstory cover as the dominant variables for the mortality of hazel grouse chicks. This model had an Akaike weight of 0.72, which suggests strong model certainty. This study suggests that forest managers who want to protect of hazel grouse should aim for denser understory cover and higher portions of natural deciduous forest.



## 1. Introduction

A major question in avian ecology is how bird populations are regulated. Mortality, food resources, competition, social relationships, and climate change are major factors affecting population sizes (Tornberg et al., 2013). Habitat variables have been found to be important features for habitat selection by birds, and avian species management and conservation often focuses on the preservation of preferred habitat variables (Åberg et al., 2003; Patthey et al., 2012). Furthermore, increased predation pressure and deceased food are well known factors that often have been suggested to be potential causes of bird population declines (Kurki et al., 2000; Sirkiä et al., 2010).

Predation has been suggested to be a major cause of mortality for avian species (Korpimäki et al., 2004). Predation can affect populations through the killing of adult birds and lowering of reproductive success (Thirgood et al., 2000; Baines et al., 2004; Tornberg et al., 2012), and it influences many aspects of prey animals' lives, such as behavior, morphology, and life history (Hoverman et al., 2005; Ferrari et al., 2009). Predation is not evenly distributed through a prey population. It may vary through time, locality, social hierarchy, sex, or age groups (Newton, 1993; Valkama et al., 2005). Moreover, the breeding success and survival of grouse are strongly related to predation (Angelstam et al., 1984; Kauhala et al., 2000).

The hazel grouse *Bonasa bonasia* is declining in numbers or has gone extinct in many part of its range (Rhim, 2010). For the conservation of the species, more information on its breeding ecology, behavior, and habitat requirements is needed. Mortality is one of the forces that change the dynamics of local hazel grouse populations, but information on the causes of death of hazel grouse is limited (Johnsgard, 1983). Especially, little is known about the direct and indirect factors affecting chick mortality in hazel grouse. The survival of chicks may greatly influence breeding success (Baines et al., 2004; Lima, 2009). It is known that the recruitment rate in hazel grouse is mainly determined by chick mortality (Lindén, 1989). Therefore, information on hazel grouse chick mortality is very important for conservation and management.

This study focused on the chick mortality of hazel grouse in a temperate forest in South Korea from 2006 to 2013. This bird is of conservational interest, because of the dramatic decrease within its numbers in its range (Rhim 2012). The aim of this study was to document and define the factors affecting chick mortality in hazel grouse using habitat composition analysis and a mortality model.

## 2. Methods

This study was carried out during March 2006 to September 2013 in the experimental forest of Gangwon Forest Development

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Institute in Chuncheon, Gangwon province, South Korea (37°48′N, 127°48′E). The 3000 ha study area, including mixed forest (1000 ha), natural deciduous forest (800 ha), deciduous plantation (550 ha), coniferous plantations (450 ha), and other habitats (200 ha of rocky and bare areas), is located at the southern edge of the distribution of hazel grouse. The dominant tree species were Mongolian oak *Quercus mongolica* and Japanese red pine *Pinus densiflora*. Mongolian oak and Manchurian elm *Ulmus davidiana* were dominant in the mixed forest. Korean ash *Fraxinus rhynchophylla* was dominant in the natural deciduous forest. White birch *Betula platyphylla*, Japanese larch *Larix leptolepis*, and Korean pine *Pinus koraiensis* dominated the deciduous and coniferous plantations (Rhim and Son, 2009). The forest types differed in respect to habitat characteristics, such as age, tree height, tree density, and tree diameter at breast height (DBH) (Table 1).

Chicks and hens were captured within a few days of hatching in March and April of 2006–2013 by luring or chasing them into nylon fishing nets. Thirty-five hens were equipped with 14 g necklace-style radio transmitters (Kenward, 1987; Millspaugh and Marzluff, 2001; Rhim, 2012). We attached radio transmitters on 157 chicks in 32 broods. Because of the small size of chicks and their fast growth rate, we used different sizes of transmitters, and replaced them at intervals (Table 2). We fastened backpack transmitters to young chicks with instant glue to the feathers at the base of the neck (Wegge and Kastdalen, 2007). When the chicks were 5 weeks old, we replaced the backpacks with necklace-style radio transmitters.

We investigated the fate of the chicks by first locating their radio-tagged mothers. Individuals were located to within 20 m to minimize the disturbance by surveyors and predators, 10–15 times a week from March to September. When we approached to within 20 m of a brood, we usually received the signals from the chicks. Most dead chicks were found by this backtracking method. We determined the cause of death based on sign on the chicks and bite marks on the transmitter backpack (Wegge and Kastdalen, 2007). Sometimes we found only the transmitter package on the ground and field sign (tracks and excrement) of the predator.

We calculated the home range of hazel grouse chicks using the minimum convex polygon method (MCP; Samuel and Garton, 1985; Todd, 1992). The 95% home range is a conservative estimate that minimizes the risk of including habitats that are never used. Habitat selection was examined with compositional analysis (Aebischer et al., 1993; Rhim, 2006). The analysis was performed in two ways: by including all five habitat categories and by including forest categories only. The habitats used by the hazel grouse were classified into five categories: natural deciduous forest, coniferous plantations, mixed forest, deciduous plantations, and other (Rhim, 2013).

Habitat characteristics were measured at the point of each chick's death ($n = 153$; 58 marked and 95 unmarked) and random point ($n = 153$) of marked chick's location within a circle of 5.56 m in diameter (0.01 ha). Forest type, slope, altitude, distance from the nearest forest road, tree species, DBH of trees, lying deadwood, and foliage cover in each layer of vegetation were measured. The different vegetation layers included overstory (8–20 m), sub-overstory (2–8 m), mid-story (1–2 m), and understory (<1 m). The amount of foliage cover in each layer was rated as 0 (0% coverage), 1 (1–33%), 2 (34–66%), or 3 (67–100%). The coverage indices were the mean of all cover class values for each circle (Rhim, 2012).

**Table 2**
Technical data for radio transmitters used on hazel grouse chicks of different ages.

| | Chick age (weeks) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3–4 | 5–9 | 10–17 |
| Chick body weight (g) | 25–35 | 35–60 | 60–120 | 120–250 | 250–300 |
| Transmitter weight (g) | 1.0 | 1.4 | 2.7 | 5.5 | 10.6 |
| Percentage of bird weight | 2.9–4.0 | 2.3–4.0 | 2.3–4.5 | 2.2–4.6 | 3.5–4.6 |
| Battery life expectancy (days) | 7–9 | 7–12 | 15–22 | 45–55 | 60–100 |

Chick mortality models were used in the Program MARK (White and Burnham, 1999; Rotella et al., 2004; Rhim, 2013) to test hypotheses about the relationships between habitat variables and daily chick mortality. For every mode, MARK produces the Akaike Information Criterion corrected for a small sample size ($AIC_c$), allowing models to be ranked according to the amount of information loss. Throughout the analysis, an information-theoretic philosophy of model selection was employed with a focus on multi-model inference (Burnham and Anderson, 2002), including habitat variables (Table 3).

All possible models using the parameters we evaluated were assessed in order to identify the subsets of models that were worse than and better than the threshold model. Akaike weights ($\omega$) were determined for each variable present in at least one selected model. The average of parameter estimates (and confidence intervals) across the models where a given variable occurs (Burnham and Anderson, 2002; Rhim, 2012) was computed, along with a 95% confidence interval, which allowed for the assessment of the extent of the potential effects of covariates on daily chick mortality.

## 3. Results

During this 8-year study, 157 hazel grouse chicks were monitored to determine their spring-summer survival rate. Seventy-five chicks survived, 58 were killed by predation, 15 were unknown dead, and 9 missed. The mean spring-summer survival of chicks was 48% and mortality due to predation was 37%. The survival rate of hazel grouse chicks differed among years, associated with variations in mortality due to predation (Table 4).

The habitat composition within the 95% MCP home ranges differed significantly from that in the study area as a whole (Wilk's lambda = 0.01, $\chi^2 = 32.74$, $df = 4$, $P = 0.001$). Moreover, when the habitat category "other" was excluded from the analysis, habitat composition in the 95% MCP home ranges still differed significantly from that in the study area (Wilk's lambda = 0.01, $\chi^2 = 26.91$, $df = 3$, $P = 0.001$). In both analyses, natural deciduous forest was used by hazel grouse chicks significantly more often than the other forest types (Table 5).

The best model of hazel grouse chick mortality had an Akaike weight ($\omega$) of 0.72, which suggests strong model certainty

**Table 1**
Habitat characteristics of natural deciduous forest, mixed forest, deciduous plantation, and coniferous plantation of the study area in a temperate forest, Chuncheon, Gangwon Province, South Korea.

| | Mixed forest | Natural deciduous forest | Deciduous plantation | Coniferous plantation |
|---|---|---|---|---|
| Age (years) | 55–70 | 60–71 | 33 | 46 |
| Tree height (m) | 24.6 ± 8.1[a] | 25.6 ± 7.1 | 19.1 ± 5.9 | 20.1 ± 4.3 |
| Tree density (no./ha) | 201.6 ± 15.9 | 212.0 ± 12.6 | 188.3 ± 17.1 | 265.1 ± 29.3 |
| Tree DBH[b](cm) | 22.9 ± 4.2 | 21.6 ± 7.6 | 22.4 ± 4.2 | 26.7 ± 3.9 |

[a] Mean ± SD.
[b] DBH: diameter at breast height.