Spring-season social organization of the Hazel Grouse (*Bonasa bonasia*) in relation to habitat type in temperate forests of South Korea

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Spring-season social organization of the Hazel Grouse (*Bonasa bonasia*) was assessed in relation to habitat type by radio tracking 16 males and 19 females between February (late winter) and June (spring), 2004–2006, in a 3,000-ha study area of temperate forest in South Korea. In spring (breeding season), the social unit was a pair. The average home-range size of males was significantly larger than that of females in both 100% and 95% minimum convex polygons. Also, the home ranges of paired and single individuals were significantly smaller than those of individuals in flocks. Regarding habitat selection, natural deciduous forest ranked highest, followed by mixed forest, coniferous plantation, deciduous plantation, and others. The understory coverage was higher in habitats used by paired birds than in habitats used by birds in flocks, but there were no significant differences in tree densities. To sum up, natural deciduous forest provides suitable breeding habitat for Hazel Grouse, provided that understory vegetation is well developed.

1. Introduction

Ecological variables limit the range of types of adaptive social organization, apparently determined by the relative costs and benefits of different forms of social organization to each individual. This implies that many aspects of animal social organization can be predicted on the basis of an understanding of a limited set of environmental variables (Swenson 1991). Social organization of a species is in part an adaptation to habitat conditions (Swenson *et al*. 1995, King & Rappole 2000). The social organization shown by birds can be considered a compromise between the costs of sharing resources versus the benefits of being together (Pulliam & Millikan 1982).

The diversity, abundance, and distribution of animal species in a given area are affected by the structural characteristics of the environment, such as habitat type, patch size, edge length, configuration, and disturbance or artificial landscape structure (Fritz *et al*. 2003, Said & Servanty 2005). The relationship between habitat and animal distribution may differ markedly among landscape components, for example, between natural and anthropogenic forest habitats, due to the relatively soft edges and low contrast in natural as compared with anthropogenic habitats (Mönkkönen & Reunanen 1999). Responses of animals to habitat heterogeneity are also influenced by the spatial and temporal scale of significant ecological processes, such as dispersal or foraging. Thus, habitat specificity and availability, and spatial context, will influence the relationship between habitat structure and a species' behavior (Fisher *et al*. 2005). Studying a habitat specialist enhances our ability to identify

habitat availability concurrently with population dispersion among habitat types, which will in turn increase our understanding of the influence of large-scale landscape structure on populations (Donner *et al*. 2008).

The Hazel Grouse (*Bonasa bonasia*) is a Palaearctic species that is distributed over northern and central Eurasia (Rhim & Lee 2001). This species is declining in numbers or has even gone extinct in many parts of its distributional range, primarily due to habitat disturbances by human activities. Forest management can therefore be considered important for the conservation and management of Hazel Grouse habitats. Forest managers and conservationists benefit greatly from an understanding of the behavior and habitat requirements of Hazel Grouse to maintain habitats and populations of this species (Bergman *et al*. 1996).

Spring-season social organization, the topic of the present study, may influence the breeding ecology of Hazel Grouse (Johnsgard 1983). Hence it is crucial to separate this aspect from variation in flocking behavior between seasons, most notably between winter and spring. South Korea lies at the southern limit of the distribution of Hazel Grouse (Storch 2000). In this region, breeding starts earlier than in more northern regions. For example, egg laying begins already in March in South Korea, and breeding takes place from March to June; this period thus represents a distinct spring season and not a temporal gradient from winter to summer in terms of Hazel Grouse behaviour (Rhim 2002). Hence, the results of the present study are probably not confounded by winter-season flocking behavior of the focal species. My aim here was to document the spring-season (March–June) social organization (here, grouping behavior) of Hazel Grouse in relation to habitat type in temperate forests of South Korea.

2. Material and methods

My study area was located in the experimental forest of Gangwon Forest Development Institute at Chuncheon, Gangwon Province, Korea (37°48' N, 127°48' E). This 3,000 ha study area is located near the southern edge of the distribution of Hazel Grouse. The area consists of several habitat types, most notably natural deciduous forest (800 ha),

mixed forest (1,000 ha), coniferous plantations (450 ha), deciduous plantations (550 ha), and rocky and bare habitats (200 ha). The dominant tree species in natural forests were Mongolian oak (*Quercus mongolica*), Manchurian elm (*Ulmus davidiana*) and Korean ash (*Fraxinus rhynchophylla*) in deciduous forests, and Mongolian oak and Japanese red pine (*Pinus densiflora*) in mixed forests. White birch (*Betula platyphylla*), Japanese larch (*Larix leptolepis*), and Korean pine (*Pinus koraiensis*) dominated the deciduous and coniferous plantations.

I recorded the group size of Hazel Grouse from late winter to spring for three spring seasons (1 February–30 June, 2004–2006) whenever the species was encountered. When detecting a single individual, I searched for others, marked or unmarked, in its vicinity and considered a bird single when I encountered no other birds within 50 m. Thirty-five adult Hazel Grouse, 16 males and 19 females, were captured between December 2003 and January 2006 by luring or chasing them into nylon fishing nets. These grouse were radio-tagged with 14-g necklace-type transmitters that weighed 4% of the birds' weight (Millspaugh & Marzluff 2001, Rhim 2006). Sex was determined based on plumage characteristics: for example, males have black chin patches. Adults were distinguished from juveniles by the presence of a distinctive band on the first primary (Bonczar & Swenson 1992). The radio-tagged individuals were located ten times per week by triangulation between February and June during 2004–2006. The accuracy of each location was 10 m (Rhim & Lee 2004). Individuals from the same group or pair overlapped spatially only rarely: hence, I consider each data point (per sampling period) independent.

Home ranges of Hazel Grouse were calculated according to the minimum convex polygon method (MCP; Samuel & Garton 1985) using 100% and 95% MCP. The 95% MCP is a consecutive estimate, which minimizes the risk of including areas that are never used by the individuals. I used compositional analysis to assess habitat selection (Aebischer *et al*. 1993). I determined the use and availability of habitat types within the home range of each individual and study area. The analysis was run in two phases. In the first phase, I included five major habitat categories (natural deciduous

Table 1. Habitat characteristics of natural deciduous forests (NDF), mixed forests (MF), deciduous planta-tions (DP), and coniferous plantations (CP) in the experimental temperate forests of Gangwon Forest De-velopment Institute at Chuncheon, Gangwon Province, South Korea (MANOVA; F and P values shown). Factors: age of dominant trees (Age; in years), height of canopy trees (Height; in m), tree density (Density; no. trees ha^{-1}), and diameter (DBH; in cm). Values show minimum and maximum (for Age) or mean±SD (for Height, Density and DBH).

Tree variable	NDF	MF	DP	CP	F	P
Age	57–67	52–67	30	43	–	–
Height	24.8±8.2	23.4±7.1	18.6±4.9	19.8±5.5	9.28	0.05
Density	217.3±12.6	204.5±23.5	194.1±18.6	259.2±30.9	13.75	0.01
DBH	19.8±8.5	22.1±6.3	21.5±3.1	25.4±3.2	10.91	0.05

forest, mixed forest, coniferous plantations, decid-uous plantations, and rocky and bare habitats; the latter is henceforth referred to as 'others'; Rhim 2006). In the second phase, I only considered fo-rest categories.

I recorded forest type, tree age, height of domi-nant canopy trees, tree density, tree diameter at breast height (DBH), and understory cover, within circles with a diameter of 5 m, at 800 randomly-se-lected radio-location points of Hazel Grouse. The relative amount of foliage cover was estimated by understory (<2 m) cover class, i.e., foliage cover-age 0% = class 0, 1–33% = 1, 34–66% = 2, and 67–100% = 3. The understory cover index was the mean of all cover class values for each circle. All trees with a DBH of >6 cm were recorded (Rhim & Lee 2001). Among the five habitat types, habitat conditions differed by tree age (30–67 years), tree height (MANOVA; $F = 9.28$, $P = 0.05$), tree den-sity ($F = 13.75$, $P = 0.01$), and tree DBH ($F = 10.91$, $P = 0.05$; Table 1).

3. Results

In the study area, Hazel Grouse were encountered almost exclusively in flocks until early March (Table 2). As temperatures started to rise in mid-February, males began to display and whistle. Dur-ing this period of improving weather conditions, pairs began to form, but if the weather turned cold, birds regrouped into flocks. With the rapid melting of snow in late February, I began to encounter rela-tively more single and paired birds. The frequency of encounters of single birds, pairs and flocks (≥3 individuals) in February differed significantly from that in March (Wilks' lambda = 0.03, χ^2 =

12.38, df = 3, $P = 0.001$). The frequency with which pairs were encountered increased consider-ably between March and April, and encounters with lone birds increased between these periods (Wilks' lambda = 0.05, $\chi^2 = 10.14$, df = 3, $P = 0.006$). Pair was the dominant social unit in April and May, coinciding with the breeding season. In June, the proportion of single males increased and that of paired birds decreased, compared with those in May (Wilks' lambda = 0.01, $\chi^2 = 18.27$, df = 3, $P = 0.001$; Table 2).

For the thirty-five radio-tagged adult Hazel Grouse, the median 100% MCP home range in spring (here, March–June) was 24.3 ha (range 18.9–32.5 ha) and the median 95% was 22.2 ha (range 17.4–29.4 ha). The home-range size varied considerably due to social organization and gender (Table 3). The home range sizes of males were sig-nificantly larger than those of females for both 100% and 95% MCP (non-parametric two-way ANOVA; for 100% MCP, $F = 9.48$, $P = 0.01$; for 95% MCP, $F = 7.21$, $P = 0.05$). For both 100% and

Table 2. Frequency of encounters of single birds, pairs and flocks (3 individuals) of Hazel Grouse during March and June, 2004–2006, in the experi-mental temperate forest of Gangwon Forest Devel-opment Institute at Chuncheon, Gangwon Provin-ce, South Korea.

Period	Lone males	Lone females	Pairs	Flocks
February	5	4	2	24
March	13	12	10	8
April	8	6	19	1
May	9	5	24	0
June	31	8	5	0

Table 3. Home range size (ha) for sixteen male and nineteen female Hazel Grouse which were single, in pairs, or in flocks (≥3 individuals) when radio-tracked during March and June, 2004–2006, in the experimental temperate forest of Gangwon Forest Development Institute at Chuncheon, Gangwon Province, South Korea, estimated by the minimum convex polygon method (MCP). *n*: number of birds. *N*: number of radio-locations. Values are numbers of observations or mean±SD where appropriate.

| Sex and type	n	100% MCP	N	95% MCP	N
Males, single	5	21.9±4.73	1,169	19.3±4.38	967
Males, paired	8	24.7±5.31	1,854	22.6±4.67	1,685
Males, flocked	3	32.5±7.62	821	29.4±7.18	706
Females, single	4	18.9±3.29	762	17.4±3.12	634
Females, paired	13	20.3±4.92	2,365	19.5±3.69	2,167
Females, flocked	2	27.5±5.63	517	25.2±4.82	462

Table 4. Ranking matrix based on compositional analysis of (a) the differences in habitat composition of natural deciduous forest (NDF), mixed forest (MF), coniferous plantation (CP), deciduous plantation (DP), and 'others' (O) between habitat type and the home range of radio-tagged Hazel Grouse, and (b) between habitat use and habitat availability within these territories without the category 'other' (O). P values are given in the upper right and the corresponding t values are given in the lower left. A higher rank indicates higher importance of a given habitat type for the Hazel Grouse.

(a)	NDF	MF	CP	DP	O	Rank
NDF		0.39	0.04	< 0.001	< 0.001	4
MF	0.39		0.17	< 0.001	< 0.001	3
CP	2.08	1.62		< 0.001	< 0.001	2
DP	5.79	5.21	5.68		0.20	1
O	8.24	6.95	7.63	1.26		0
(b)						
NDF		0.021	< 0.001	0.001		3
MF	2.27		< 0.01	0.005		2
CP	5.73	4.59		0.51		1
DP	3.54	2.99	0.71			0

Table 5. Understory (<2 m) cover index and tree density (expressed as the number of trees/ha with DBH >6 cm) in natural deciduous and mixed forests for radio-location points of thirty-five radio-tagged Hazel Grouse in relation to whether they occurred as single, paired or flocked (3 individuals) birds (MANOVA).

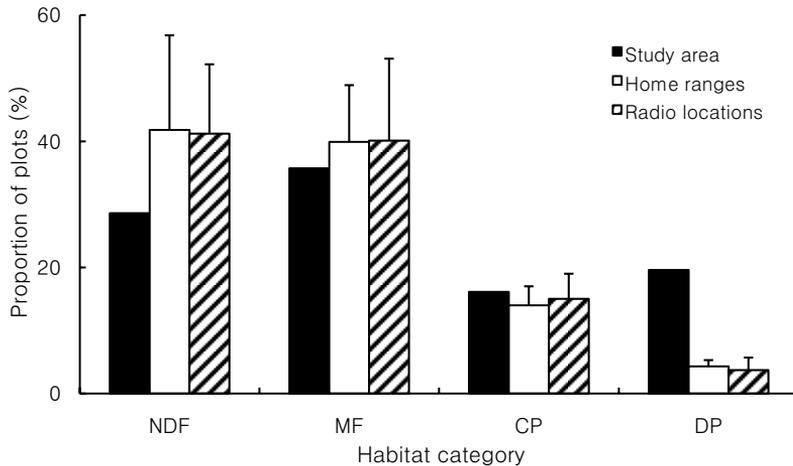| Habitat/Factor	Single	Paired	Flocked	F	P
Natural deciduous forest					
Understory cover	1.93 ± 0.47	2.35 ± 0.54	1.61 ± 0.42	17.29	0.005
Tree density	256.1 ± 27.5	204.9 ± 32.6	239.6 ± 20.4	2.53	0.17
Sample size	684	1,557	371		
Mixed forest					
Understory cover	2.13 ± 0.73	2.58 ± 0.54	1.57 ± 0.69	21.54	0.001
Tree density	202.5 ± 36.9	261.7 ± 28.1	233.1 ± 25.6	2.18	0.19
Sample size	425	1,029	243		

a)
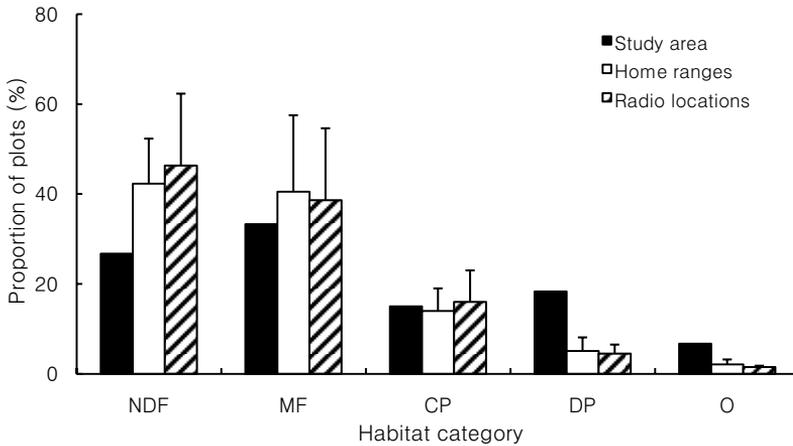
b)

Fig. 1. Habitat composition in the study area in a temperate forest of South Korea, based on the home ranges of thirty-five Hazel Grouse radio-tracked during March and June, 2004–2006, and of 800 randomly-selected radio locations of these birds. Mean SD are shown. NDF = natural deciduous forest, MF = mixed forest, CP = coniferous plantation, DP = deciduous plantation, O = other habitat types (see text). (a) Proportion of all habitat categories. (b) Proportion of habitat categories after excluding the category 'others'. For (a) and (b), Study area = habitat types over the entire 3,000 ha area; Home ranges = habitat types falling within the MCP estimated home ranges; and Radio locations = habitat types as represented by randomly-selected 800 radio-location points. See text for details.

95% MCP, the home range sizes of birds in flocks were significantly larger than those of single birds (for 100% MCP, $F = 18.71$, $P = 0.005$; for 95% MCP, $F = 16.91$, $P = 0.005$) and paired birds (for 100% MCP, $F = 10.43$, $P = 0.01$; for 95% MCP, $F = 11.28$, $P = 0.01$). There was a significant correlation between home-range size and the number of locations for 100% and 95% MCP (Spearman rank correlation; $r_s = 0.85$, $n = 35$, $P = 0.01$).

The habitat composition for the 800 randomly selected radio-location points of 95% MCP home ranges significantly varied among habitat type both when the habitat category 'others' was included (Wilk's lambda = 0.02, $\chi^2 = 24.27$, df = 4, $P = 0.001$) and excluded (Wilk's lambda = 0.04, $\chi^2 =$ 19.63, df = 3, $P = 0.005$. In the first analysis, natural deciduous forest significantly differed from all the other habitat categories (Table 4a, Fig. 1a). In the second analysis, i.e., when the category 'others' was excluded, natural deciduous forest was used significantly more frequently than was mixed forest, which was used significantly more often than both coniferous and deciduous plantations, relative to what could be expected from the habitat composition within the home ranges of the tagged individuals (Table 4b, Fig. 1b).

Radio-tagged single, paired and flocked birds differed significantly in their associations with characteristics of habitat structure in natural deciduous forests (MANOVA; $F = 17.29$, $P = 0.005$)

and in mixed forests ($F = 21.54$, $P = 0.001$). The understory cover indices was highest for paired birds, and was lowest for flocked birds in both natural and plantation forest types. However, there were no significant differences with regards to tree density (Table 5).

4. Discussion

In the present study, an important characteristic of the social organization of the Hazel Grouse was intra-sexual territorial behavior. Both male and female Hazel Grouse advertised spontaneously and responded aggressively to mimicked calls within their territories, and shared the same space (Swenson & Boag 1993, Rhim & Lee 2004). Thus, pair appeared the behaviorally dominant social unit of Hazel Grouse between March and June.

In February, i.e., before the period of copulation, 69% of all encounters concerned single individuals, and 31% concerned paired birds ($N = 13$; see Table 2). In March, when I also observed copulations, 56% of encounters concerned single and 44% concerned paired birds ($N = 45$). Moreover, in April, when females began laying, 27% of encountered individuals were single, and 73% were paired ($N = 52$). This ratio of proportions remained similar between April and May. In June, when females finished laying, 80% were again single and 20% were paired ($N = 49$; see also Drovetski 1997). After the egg hatching and before post-fledging dispersal of chicks, females care for their chicks alone (Fang & Sun 1997, Montadert & Leonard 2006).

Home ranges of single males and single females were smaller than those of paired birds, and they also often occupied sites with denser vegetation. Approaching predators can be detected by increasing the habitat openness, but also by increasing the number of conspecific observers: flocking Hazel Grouse can detect approaching predators more easily than single birds, although they are also be more readily detected by the predator, in open habitats. Swenson *et al*. (1995) concluded that Hazel Grouse prefer dense habitat to avoid predation, and indeed I too found that single birds were found in sites with denser understory more often than flocked birds.

The habitat composition in the studied spring-season home ranges of Hazel Grouse differed from what was available in the whole study area, suggesting that home ranges were not randomly located in the landscape (Rhim 2006). Natural deciduous forest ranked highest, followed by mixed forest, coniferous plantation, deciduous plantation, and others ranked lowest. This finding suggests a large-scale affinity for natural deciduous forest by the focal species in the breeding season.

In spring, when the understory vegetation undergoes rapid growth and development, natural deciduous forest provides particularly suitable habitat for the Hazel Grouse. Resource distribution is considered a major determinant of the variation in food and cover observed among grouse species (Storch 1997, Pearce-Higgins *et al*. 2007). The availability of understory vegetation for paired birds appears important for the selection of home range during the breeding season (Rhim 2002). A possible explanation for the preference of densely-vegetated areas is the avoidance of predators (Åberg *et al*. 2003) and the availability of well-sheltered nest sites (Thompson *et al*. 1987, Tirpak *et al*. 2006). Rhim and Lee (2001) found correlations between the density of Hazel Grouse and the cover of understory vegetation, and understory cover also influences Hazel Grouse in other geographic areas (Swenson 1991, 1993, Åberg *et al*. 2000). Indeed, I observed here that radio-tagged, paired birds occurred in areas with higher understory cover than did single or flocked birds.

Understanding habitat use, habitat choice and interactions between these aspects appears critical to improving our understanding of the ecology of Hazel Grouse (Kristan *et al*. 2007). The quality and amount of habitat at larger spatial scales, spatial constraints, estimation of survival rates, and variation in reproductive rates by habitat type would provide valuable insight into the influence of these habitat constraints on the dynamics of Hazel Grouse. My results indicate that the spring social organization of Hazel Grouse considerably varied in relation to habitat type. Hazel Grouse individuals were apparently especially sensitive to the type of forest characteristics. Thus, I recommend that the preferred habitats, i.e., natural deciduous and mixed forests, should be maintained and managed for conservation of Hazel Grouse population in Korea.

Kevään sosiaalinen organisaatio suhteessa ympäristötyyppiin pyyllä Etelä-Korean temperaattisissa metsissä

Kevätkauden sosiaalista organisaatiota tutkittiin pyyllä (*Bonasa bonasia*) suhteessa ympäristö-tyyppeihin helmikuusta (lopputalvi) kesäkuuhun (kevät) vuosina 2004–2006. Tutkimusalue oli 3 000 ha laajuinen, temperaattinen metsäalue Etelä-Koreassa. Työssä varustettiin 16 koiras- ja 19 naarasyksilöä radiolähettimin. Keväällä (pesimä-kaudella) pääasiallinen sosiaalinen yksikkö oli pari. Koiraiden elinpiiri oli merkitsevästi suurempi kuin naaraiden sekä 100 % että 95 % minimikonveksimonikulmiomenetelmillä arvioituna.

Elinpiiri oli myös pienempi yksinäisillä ja pariutuneilla kuin parvissa tavatuilla yksilöillä. Luontaisesti syntyneet lehtimetsät olivat suosi-tuinta ympäristöä pyylle; sen jälkeen tulivat seka-metsät, havu- ja lehtipuiden istutusmetsiköt ja lo-puksi muut ympäristöt. Aluskasvillisuuden peittä-vyys oli merkitsevästi korkeampi pariutuneiden suosimissa ympäristöissä kuin sellaisissa, joissa asusti yksinäisiä tai parveutuneita yksilöitä, mutta puuston tiheys ei vaikuttanut tähän. Tuloksien va-lossa luontaisesti syntyneet lehtimetsät tarjoavat soveliainta pesimäympäristöä pyylle edellyttäen, että kenttäkerroskasvillisuus on hyvin kehittynyt-tä.

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