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Winter sociality of hazel grouse *Bonasa bonasia* in relation to habitat in a temperate forest of South Korea

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Winter flock size, food abundance and habitat variables were determined for hazel grouse *Bonasa bonasia vicinitas* near the southern edge of the species' range in South Korea. Most of the hazel grouse formed sexually mixed flocks with a mean flock size of 4.21 ± 0.87 (SD) in winter. Understory coverage was higher at foraging sites than at random sites. Group size was inversely correlated with understory coverage, and hazel grouse foraging alone used sites with more cover than hazel grouse foraging in flocks in both mixed forest and coniferous plantations. Groups were larger in forests with less understory coverage, but larger groups were also found at sites with more food. The winter diet of hazel grouse was mainly buds and catkins of trees in the genera *Salix*, *Betula* and *Alnus*.

Key words: flock, habitat, hazel grouse, Korea, sociality, winter

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During the non-breeding season, birds show a wide range of social organisations, from solitary individuals that aggressively defend feeding territories to flocks that show no territorial boundaries (Pulliam & Millikan 1982). Social organisation of a species is in part an adaptation to prevailing environmental conditions and, in many aspects, can often be understood using only a limited set of environmental variables (Pravosudova, Grubb, Parker & Doherty 1999, King & Rappole 2000). These should reflect a response to ecological constraints, determined by relative costs and benefits to individuals of different forms of social organisation (Gosling & Petrie 1981, Powell 1985, Warkentin & Morton 2000).

The hazel grouse *Bonasa bonasia* is a Palaearctic species found in a wide variety of habitats from young successional to old-growth deciduous, mixed and coniferous forests (Bergmann, Klaus, Müller & Wiesner 1982, Swenson & Danielsen 1991, Swenson & Angelstam 1993, Rhim & Lee 2001). Hazel grouse show a wide range of social organisation types during the non-breeding season (Swenson, Andreev & Drovetskii 1995). In Europe, hazel grouse are almost always territorial, spending the winter as singles or pairs (Swenson et al. 1995). In most habitat types, they are reported to winter mostly in flocks (Bergmann et al. 1982, Potapov 1989), but as singles or pairs in evergreen coniferous and larch-birch forests (Swenson et al. 1995).

This pattern is especially complex in far east Asia. Hazel grouse have been reported to winter in flocks in the Amur Region of southeastern Russia (Babenko 1987), in northeastern China (Sun, Swenson & Fang 2000), on the island of Sakhalin (Mishin 1960), and in North Korea (Austin 1972). However, singles and pairs dominated in winter on the island of Hokkaido, Japan (Swenson & Fujimaki 1994, Fujimaki 1998), and both types of social organisation were found near Magadan

Table 1. Distribution of observations of three male and five female radio-marked hazel grouse in winter in relation to group size and habitat types.

Sex and group size	Habitat type Mixed forest	 Coniferous plantation	 Natural deciduous forest	Combined
Male; single	35	36	10	81
Male; pair	3	1	1	5
Male; group	63	32	8	113
Female; single	16	12	4	32
Female; pair	4	2	1	7
Female; group	47	39	10	96

in the Russian Far East (Swenson et al. 1995). The winter social organisation in South Korea has not been documented previously.

Swenson et al. (1995) proposed a conceptual model to explain the observed variation in winter social organisation. In this model, group size is correlated negatively with cover density because groups form in open habitats as a protection against predators. Food is also involved, and increasing food availability allows increasingly larger groups to form. Winter social organisation appears to depend on both cover density and food availability, and probably is a trade-off between resource selection and predator avoidance according to local conditions.

In this study, we document food abundance, dispersion and flock size of radio-marked hazel grouse in relation to forest type, understory coverage and food trees in a temperate forest in South Korea. The objective of our study was to assess differences between single hazel grouse and groups of hazel grouse in relation to habitat.

Methods

Our study area was in the experimental forest (37°48'0"N, 127°48'50"E) of the Gangwon Forest Development Institute at Chuncheon, Gangwon Province, South Korea. Our study area covered 170 ha and was located near the southern edge of the distribution range of hazel grouse (Rhim & Lee 2001). There were several types of forest, such as natural deciduous forest (60 ha), mixed forest (40 ha), coniferous plantation (38 ha), deciduous plantation (19 ha) and others (13 ha). The dominant tree species in the natural forests were Mongolian oak *Quercus mongolica*, Japanese elm *Ulmus davidiana*, Korean ash *Fraxinus rhynchophylla* and Japanese red pine *Pinus densiflora*. White birch *Betula platyphylla*, Japanese larch *Larix leptolepis* and Korean pine *Pinus koraiensis* were dominant in deciduous and coniferous plantation.

We recorded group size (i.e. number of grouse; a single grouse was a 'group' of one) during winter (1 December - 15 March) whenever grouse were encountered. When detecting a bird, we searched for other hazel grouse, marked or unmarked, in its vicinity and considered a bird as single when we encountered no other bird within 50 m (Rhim 2002). Whenever possible, the sex of the birds was determined from the colour of the chin patch. Hazel grouse were captured in December 1999 by luring or chasing them into nylon fishing nets and were radio-marked with 14-g necklace-type transmitters (Kenward 1987, Millspaugh & Marzluff 2001) that weighed 4% of the birds' weight. The radio-marked hazel grouse were located by triangulation 3-5 times per week during 1 December - 15 March in 1999-2000 and 2000-2001. The accuracy level of bearing was ± 10 m in this study.

We calculated home ranges as 95% minimum convex polygons (MCP; Samuel & Garton 1985, Todd 1992). The 95% home range is a conservative estimate which minimises the risk of including habitats that are never used.

We recorded habitat variables, including forest type, stand composition and structure within imaginary cir-

Table 2. Ranking matrix based on compositional analysis of the differences in habitat composition of mixed forest, coniferous plantation, natural deciduous forest, deciduous plantation and 'others' between the study area and the home range of eight radio-marked hazel grouse (A) and between habitat use and habitat availability within these home ranges (B). P-values are given in the upper right and the corresponding t-values are given in the lower left. Mixed forest is ranked highest and deciduous plantation lowest.

A)	Mixed forest	Coniferous plantation	Natural deciduous forest	Deciduous plantation	Others	Rank
Mixed forest		0.49	0.027	<0.001	<0.001	1
Coniferous plantation	0.49		0.18	<0.001	<0.001	2
Natural deciduous forest	2.29	1.27		<0.001	<0.001	3
Deciduous plantation	5.76	5.64	5.38		0.17	4
Others	7.21	6.23	6.57	1.26		
B)						
Mixed forest		0.028	<0.001	0.001		1
Coniferous plantation	2.34		<0.001	0.020		2
Natural deciduous forest	5.67	4.59		0.480		3
Deciduous plantation	3.64	2.91	0.72			4

Table 3. Understory (< 2 m) coverage index and tree density (expressed as number of trees ha^{-1} with DBH of > 6 cm) in mixed forests and coniferous plantations for radio-location points of eight radio-marked hazel grouse in relation to whether they occurred as singles or in groups of ≥3 birds. The results are given as mean ± SD and the P-values are results of Mann-Whitney U-tests.

	Mixed forest			Coniferous plantation		
	Singles	Groups (≥3)	P	Singles	Groups (≥3)	P
Understory coverage index	1.52 ± 0.45	0.81 ± 0.34	<0.001	1.34 ± 0.28	0.74 ± 0.31	0.005
Tree density	385 ± 64	427 ± 57	0.14	352 ± 43	340 ± 29	0.23
Sample size	185	208		142	187	

cles with a diameter of 5 m at each foraging point and at a random selection of 200 radio-location points of hazel grouse (see Tables 2 and 3). The relative amount of foliage coverage was estimated by understory (< 2 m) coverage class, e.g. foliage coverage of 0% was class 0, 1-33% class 1, 34-66% class 2, and 67-100% class 3. The understory coverage index was the mean of coverage class values for every circle. Also all trees with a diameter at breast height (DBH) of > 6 cm were recorded (Lee 1996, Rhim & Lee 2001).

Radio-marked hazel grouse suspected to be foraging were approached as unobtrusively as possible to determine the use of winter foods. Preferred plant species were those used significantly (P < 0.01) more than expected based on their availability, based on χ^2 goodness-of-fit test (Neu, Bayers & Peek 1974). Important species were those that comprised more than 10% of the diet (Swenson et al. 1995).

We tested relationships among group size, food availability and understory coverage using the Mann-Whitney U test, and habitat use was tested by compositional analysis (Aebischer, Robertson & Kenward 1993). The analysis was run in two steps: first by including all five habitat categories, then by including the forest categories only.

Results

We observed unmarked hazel grouse 191 times. Mean observed group size was 3.18 ± 0.33(SD), and mean group size excluding single birds was 4.21 ± 0.87 (N = 125). Group size varied from three to eight individuals; none consisted of two birds. Winter groups in the study area were not segregated sexually. Of 89 groups consisting of more than three birds for which we could determine the sex of at least two of the birds, 64 (72%) were mixed, i.e. containing both sexes. Of the single birds 47% were males (N = 29 birds), and 49% of birds in groups of ≥ 3 were males (N = 257 birds). There was no difference in sex ratio (Mann-Whitney U-test: U = 12.9, P > 0.1), and males constituted 48% (395 birds) of the total number of unmarked birds observed.

We radio-marked three male and five female hazel grouse. Most of the time, radio-marked hazel grouse were observed in groups (≥ 3 birds), but rarely in pairs (U = 57.4, P < 0.01). There was no difference in flock membership between radio-marked male and female hazel grouse (U = 5.6, P > 0.3; Table 1).

The habitat composition of home ranges differed significantly from that of the study area (Λ = 0.35, df = 4, P < 0.001). When comparing the composition of home ranges of hazel grouse with that of the study area, mixed forest and coniferous plantation ranked highest with no significant difference between them, followed by natural deciduous forest and deciduous plantation, which were ranked significantly lower than mixed forest (Table 2).

Within their home ranges, habitat use by wintering hazel grouse was non-random (Λ = 0.31, df = 3, P < 0.001). Mixed forest was used significantly more than coniferous plantation, which was used significantly more than both natural deciduous forest and deciduous plantation, relative to what could be expected from the habitat composition in home ranges (see Table 2).

Single radio-marked birds used denser understory coverage than groups in mixed forest (Mann-Whitney U-test: U = 82.7, P < 0.001) and coniferous plantation

Table 4. Understory (< 2 m) coverage index and tree density (expressed as number of tree ha^{-1} with a DBH of > 6 cm) in mixed forests and coniferous plantations for eight radio-marked hazel grouse in relation to whether the location points were used for foraging or were random. The results are given as mean ± SD, and the P-values are results of Mann-Whitney U-tests.

	Mixed forest			Coniferous plantation		
	Foraging	Random	P	Foraging	Random	P
Understory coverage	1.25 ± 0.41	0.82 ± 0.29	<0.01	1.08 ± 0.53	0.79 ± 0.31	<0.05
Tree density (N)	403 ± 59	395 ± 64	0.11	345 ± 34	351 ± 45	0.15
Sample size	193	200		129	200	

Table 5. Deciduous tree species used for winter foraging by eight radio-marked hazel grouse based on 247 foraging observations in the study area. 'Availability' is expressed as % of the species present, 'use' as share (in %) of the 247 foraging observations, 'selection' expresses the actual use compared to expected use and, based on χ^2 goodness-of-fit tests, + indicates a higher use than expected ($P < 0.05$), ÷ a lower use than expected ($P < 0.05$) and ns no significant difference ($P > 0.05$). In the column 'category', P indicates that the tree species is preferred, i.e. used more than should be expected, and I indicates that the species is important to the hazel grouse, i.e. contributes >10% of its diet.

Tree	Availability	Use	Selection	Category
Alnus sp.	18.9	47.6	+	P, I
Betula sp.	34.8	18.7	÷	I
Salix sp.	16.3	25.2	+	P, I
Populus sp.	21.5	7.3	÷	
Quercus sp.	5.2	0.7	ns	
Acer sp.	3.3	0.5	ns	

(U = 42.5, P = 0.005); however, there were no differences with regard to tree densities (Table 3).

The amount of understory coverage (U = 7.5, P > 0.05) and forest density (U = 5.3, P > 0.1) within 5 m of the tree used for foraging varied between mixed forest and coniferous plantation. However, the understory coverage index was higher at foraging sites of radio-marked hazel grouse than at random radio-location points in both mixed forest (U = 128.3, P < 0.01) and coniferous plantation (U = 85.7, P = 0.05). Differences in tree density between foraging and random radio-location points of radio-marked hazel grouse were not significant (Table 4).

Hazel grouse foraged on all the available deciduous tree species (Table 5). Based on 247 foraging observation of hazel grouse in the study area, alder *Alnus* sp. and willow *Salix* sp. were preferred, and birch *Betula* sp. were used less than expected. Oak *Quercus* sp. and maple *Acer* sp. were selected against and rarely used by hazel grouse. Major food trees at foraging sites of radio-marked hazel grouse were Korean willow *Salix koreensis*, *S. rorida*, Japanese alder *Alnus japonica*, Manchurian alder *A. hirsute* and costata birch *Betula costata* (Rhim & Lee 2000; see Table 5). Groups of radio-marked hazel grouse were located at points with greater amounts of preferred (U = 38.5, P = 0.005) and important (U = 29.5, P = 0.01) food tree species than were single grouse (Table 6). Occurrence of preferred (U = 24.8, P = 0.04), but not important (U = 5.3, P = 0.15), food tree species was significantly higher at group sites (see Table 6) than at the foraging sites of single grouse.

Table 6. Abundance (number of trees ha^{-1}) and occurrence (% of locations) of winter food trees at 247 radio locations of eight hazel grouse located either as singles or in groups of ≥ 3. The results are given as mean ± SD, and the P-values are results of Mann-Whitney U-tests.

	Singles	Groups	P
Abundance			
Preferred species	38 ± 19	96 ± 27	0.005
Important species	160 ± 61	291 ± 45	0.01
Occurrence			
Preferred species	18	32	0.04
Important species	65	69	0.15

Discussion

We found that hazel grouse formed sexually mixed flocks in winter on our study area in South Korea. The overall mean group size we recorded (3.2) was intermediate between the group size of 6.3 reported from deciduous riparian forests in the Russian Far East (Swenson et al. 1995) and the group sizes of 1.4-1.5 reported from European Russia, Japan and Sweden (Volkov 1986, Swenson & Fujimaki 1994). However, it was similar to the group size of 2.7 reported for larch-birch habitats in the Russian Far East (Swenson et al. 1995).

The social organisation shown by birds can be considered as a compromise between the costs of sharing a resource versus the benefits of being together (Pulliam & Millikan 1982). The primary and immediate benefit to the members of flocks probably is vigilance against predators. Several studies have shown that a single bird cannot detect predators as effectively as birds in groups and that lone birds forage more slowly than several, presumably because they must spend more time watching for predators (Metcalfe 1989, Pravosudova & Grubb 1999). By foraging together, in addition to increasing vigilance against predators, hazel grouse can forage faster than single birds and thus spend less time exposed to predators in open deciduous trees (Swenson 1993).

Swenson et al. (1995) proposed that the differences in winter social organisation among hazel grouse across their range could be related to differences in environmental variables in the habitat, specifically the availability of cover and food. We tested this hypothesis and found that, as predicted, group size was inversely correlated with understory coverage (see Table 3), and groups foraged at sites with more available food (see Table 6). Increased sociality can reduce vigilance time without increasing predation risk (Pravosudova & Grubb 1999), but predation risk must be substantial before such increased protection can have any value, and foraging time must be limited before the forager can benefit from reduced vigilance time (Ekman 1989). Winter is a period of relatively high mortality, and hazel grouse foraging in bare deciduous trees are probably vulnerable to attack by avian predators (Swenson 1993).

Thus, we agree with Swenson et al. (1995) and propose that reduced predation risk in less covered areas was the most important factor promoting flocking in winter by hazel grouse, and that groups needed foraging sites with more food than singles.

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