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Activity budgets and microhabitat use in the Siberian Jay *Perisoreus infaustus* in managed and unmanaged forest

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In this paper, we compare activity budgets and microhabitat use of Siberian Jays *Perisoreus infaustus* in spruce-dominated (pristine) forest and pine-dominated (managed) forest in northern Sweden. Besides tree species composition, the forest types differed in the abundance of dead standing trees, lichen and moss cover, and visibility. Three broods in each forest type were monitored for behavioural activity, use of tree species and vertical dimension (ground vs. tree) after fledging (from late May to late July 1998). We found significant difference in behavioural activity among the forest types. For adult jays the two dominating behavioural categories were food search and sitting, whereas for juveniles sitting and resting were the most common activities. Adult Siberian Jays allocated relatively more time for food search in the spruce-dominated forest; juveniles spent relatively more time sitting and less time resting in spruce-dominated forest. Adult jays used tree species proportional to availability for food search in both forest types. Birch was used more than expected by abundance for sitting by adult jays in spruce-dominated forest, whereas spruce was used disproportionately for sitting in pine-dominated forest. Spruce-dominated forest may provide more diverse feeding opportunities than pine-dominated forest, and reduced visibility in spruce-dominated forest may offer better concealment from avian predators. The strong preference for spruce in pine-dominated forest suggest that spruce is an important cover component in Siberian Jay territories.

1. Introduction

Forest structure is an important determinant of habitat suitability for foliage-gleaning birds. For example, natural old spruce-dominated *Picea abies* forests have higher abundance of invertebrates than younger managed forest stands (Pettersson *et al.* 1995). Furthermore, most forest trees show the highest species richness of invertebrates at late growth stages (e.g. Bernes 1994). Abundance of old trees can thus affect the wellbeing of many forest-gleaning birds, residents in particular (e.g. Virkkala 1988). The height structure also affects conditions for food acquisition in foliage-gleaning birds; a multi-layered stand can provide more niches for food search than a single-layered stand. The realisable niche space may also be affected by the height structure. For example, birds experiencing elevated predation risk in open-canopied, even-sized forest stands might avoid feeding in exposed

places, such as on the ground or in open-canopied trees. Birds may also respond by altered behaviour, such as time allocated to feeding or vigilance.

In Fennoscandia much recent interest has been devoted to analysing effects of large-scale habitat alteration on forest birds, particularly the role of forest fragmentation (e.g. Helle & Järvinen 1986, Väisänen *et al.* 1986, Edenius & Elmberg 1996, Kouki & Väänänen 2000). However, habitat changes take place on different spatial scales (e.g. Virkkala 1991, Jokimäki & Huhta 1996, Elmberg & Edenius 1999). In northern Sweden forest management has led to extensive replacement of spruce-dominated forest with Scots pine-dominated *Pinus sylvestris* stands. Moreover, the silvicultural paradigm has been managing for even-aged single species stands, so as to allocate growth to targeted "production" stems (Esseen *et al.* 1997). As a consequence, the share of very old and multi-layered stands has been drastically reduced (Axelsson & Östlund 2001). The extent to which this has affected habitat suitability for forest-dwelling birds has not been thoroughly explored. Analysing behaviour and habitat use in different types of forest can give insight into forest birds' adaptations to forest structure changes.

The Siberian Jay *Perisoreus infaustus* is a resident of northern boreal coniferous forest. Few studies have addressed behavioural adjustments to habitat structure among foliage-gleaning birds such as the jay. Virkkala (1988) studied the foraging niche of Siberian Jay near the coniferous forest margin in northern Finland, and Sklepkovych (1997) addressed nest site selection in Siberian Jay in relation to vegetation characteristics and landscape structure. However, to our knowledge no studies have explicitly analysed the behaviour of fledged jays in forest with different internal structure, viz. spruce-dominated forest and pine-dominated forest. We studied activity budgets and microhabitat use of Siberian Jays in these contrasting forest types, addressing whether jays allocate time budgets similarly, and whether there was differentiation in microhabitat use between the forest types.

Table 1. Analysis of visibility in spruce-dominated and pine-dominated forest determined by scoring vegetation cover at five 0.5-m height intervals from the ground. Estimates based on means of three readings on a vegetation profile board taken at 30-m distance. ANOVA.

Source	SS	df	MS	F	P
Forest type	20.93	1	20.93	14.20	< 0.001
Height	8.02	4	2.01	1.36	0.254
Forest type × height	0.35	4	0.09	0.06	0.994
Error	132.62	90	1.47		

2. Material and Methods

2.1. Study area

The study took place in northern Sweden (66°30′N, 21°45′E) within the limits of the transition between northern boreal and middle boreal zones (*sensu* Ahti et al. 1968). We selected a Norway spruce-dominated (i.e. more than 50% by basal area) forest landscape containing old-growth forest (> 120 years), i.e. a pristine forest characterised by a multi-layered internal structure, high abundance of standing and lying dead wood, and old trees. Scots pine-dominated forest was selected in a managed forest landscape ≈ 50 km from the pristine forest landscape. This area was intensively managed, with 67% of the forestland converted to plantations (less than 60 years) and 21% older than 100 years. The old forest compartments originate from natural regeneration but are devoid of very large trees due to selective dimension felling in the past.

These pine-dominated forests therefore tend to have a simplified vertical structure with little under-growth. Visibility was estimated by the cover density board technique (Nudds 1977). A 2.5-m high and 0.3-m broad vegetation profile board marked alternately black and white at 0.5-m intervals was located in the ground at 10 randomly selected sites in each forest type. Vegetation cover was scored (1–5) for each height interval (strata) in 20% increment classes, where 1 = 0–20%, 2 = 21–40%, and so on. Readings were taken at 10, 20 and 30-m distance intervals in three directions. There was no significant difference in visibility at the 10 and 20-m distances, but at 30-m distance spruce-dominated forest scored higher in vegetation cover than pine-dominated forest (mean 3.2 and 2.3, respectively; SE 0.17 and 0.17, respectively) (Table 1).

2.2. Siberian Jay field data

Siberian Jays were attracted to feeding stations baited with tallow in March 1998. Jays were captured by mist netting, and aged and sexed primarily by shape and wear of tail feathers and wing length measurements, respectively (Svensson 1992). Five birds in spruce-dominated forest and four in pine-dominated forest determined as adult females were radio tagged for monitoring breeding. Seven breeding attempts of the radio tagged females were registered in April 1998, three in spruce-dominated forest and four in pine-dominated forest. In late May nestlings were found in all three nests in spruce-dominated forest (4, 4 and 3 in each nest), whereas in pine-dominated forest one nest was deserted and one nest inaccessible for control, resulting in two nests with young (4 and 3 in each nest). In early June the female of the unchecked nest in pine-dominated forest was found killed, and no signs of fledged juveniles were recorded later. During the field control in May 1998 all nestlings were ringed and one nestling from each brood was radio tagged following Rappole and Tipton (1991), i.e. the transmitter was mounted with a two-loop harness around the thighs with the transmitter placed over the synsacrum. The radio tagged females facilitated relocation of adult birds until mid June when the transmitter was lost with the moult of the rectrices.

2.3. Behaviour and habitat-use sampling protocol

Behavioural observations of jays were carried out from May, after fledging, to late July 1998. In addition to the two territories made available by the radio tagged juveniles in pine-dominated forest, we secured data from adults in a third territory by locating one additional successfully breeding female in June.

In all, jays from six territories (three per forest type) were observed by "instantaneous sampling". With this method a focal animal is observed and its behaviour recorded at constant intervals (Martin & Bateson 1986). The sampling interval selected for our study was 20 s. Observations began when a bird came into sight and ended when it was out of sight for five signals (100 s). Average observation time was 5.5 minutes (adults) and 12.8 minutes (juveniles) per sample (i.e. each uninterrupted observation period) (Table 2). To cover as many activity periods as possible, observations were made alternately from 7.00–15.00 h or 12.00–20.00 h. Adults and juveniles were registered separately. Starting with the first observation, temperature and cloud cover were noted hourly.

We classified behaviour into 15 categories (Table 3), and recorded whether these activities took place in trees or on the ground (i.e. height strata). Among tree species we distinguished between Norway spruce, Scots pine and Birch *Betula* spp.

For each sample the position of the focal bird was marked in the field. Every 10-minutes a new position was added until the sampling was terminated (see above). In all we collected a total of 57 spatially non-overlapping positions visited by the jays (32 in spruce-dominated and 25 in pine-dominated forest). From August to September 1998 the positions were revisited and measurements of basal area ($m^2 ha^{-1}$) of tree trunks (> 1.3 m; spruce, pine, birch, standing dead trees) were taken with a relascope. The following vegetation parameters were recorded within a 10-m^2 circular plot:

Table 2. Siberian Jay behaviour sampling data. Table contains total observation time for all observed behavioural categories.

	Spruce-dominated forest		Pine-dominated forest	
	Adults	Juveniles	Adults	Juveniles
Number of linked observations	50	64	57	52
Total observation time (min)	237	1009	351	508
Mean observation time (min)	4.7	15.8	6.2	9.8

cover (%) of lichens, mosses and dwarf-shrubs (Bilberry *Vaccinium myrtillus*, Cranberry *V. vitis-idaea*, *V. uliginosum*, Heather *Calluna vulgaris*, *Rubus chamaemorus* and *Empetrum hermaphroditum*), and number of tree seedlings (height < 20 cm; spruce, pine, birch).

2.4. Statistical analysis

We analysed differences in activity budgets (behavioural categories) by fitting log-linear models to the data. Log-linear models are powerful for analysing interactions in multi-dimensional frequency tables (Heisey 1985). We used the territory as the observation unit. Because it was not always possible to separate individual adults in the field, we pooled observations of adults within each territory in these analayses. We first analysed whether behavioural categories differed between forest types for adult and juvenile jays. We only included behavioural categories containing at least five observations (over all territories). We then proceeded by analysing differences in microhabitat use (within tree species and height strata) for common behavioural categories. All analyses were carried out in the SYSTAT statistical software (version 8.0; SPSS Inc. 1998).

3. Results

Sites used by Siberian Jays in spruce-dominated and pine-dominated forest differed with respect to basal area of pines, spruce and dead standing trees, coverage of lichens and mosses, and density of tree seedlings (Table 4).

For adults five behavioural categories qualified for analysis (i.e. had more than 5 observations), namely pair bonding, feather care, feeding, food search and sitting. Five qualifying categories were also found for juveniles; these were the same as for adults except for pair bonding, which was replaced with resting. Significant differences in these behavioural categories were found for adults and juveniles (Table 5), which allowed us to proceed with analysing individual behavioural categories. For juveniles we secured data from only four territories. Time outs were frequent, and significant differences were found among territories but not between forest types. For adults food search and sitting were the most dominant behavioural activities (Table 6). We found significant differences between forest types in use of tree species for both activities (Table 5). In contrast, we found no difference for sitting on the ground or in trees (Table 5). Different tree species were used in proportion to abundance for food search by adult jays in both forest types (Table 7). While

Table 3. Behavioural categories used do differentiate activity by adult and fledged juvenile Siberian Jays with reference to the focal bird.

Category	Definition
Sitting	Perched in a tree or on the ground
Food search	Searching for food in a tree or on the ground without flying
Feeding	Holding of food with the bill and swallowing
Food begging	By juveniles
Feeding juveniles	An adult is feeding a juvenile
Pair bonding	Adults showing wing shaking together with sounds and short flying passages
Resting	Resting with head under plumage
Feather care	Preening
Stretching	Stretching of leg and/or wing often of one body side, normally connected with body shaking afterwards
Body shaking	An individual ruffles its feathers, then shakes the whole body
Attacking another jay	Chasing, normally connected with excitement-calls
Fleeing from another jay	An individual is chased by another jay and flees
Attacking an alien individual	A non-group individual is chased
Fleeing from an non-group individual	A jay is chased by an individual and flees
Calls	An individual is giving calls together with one of the above behaviour patterns

birch was more used in relation to abundance of sitting jays in spruce-dominated forest, the opposite was true in pine-dominated forest. Spruce was less used than expected in spruce-dominated forest, whereas it was used disproportionally to abundance in pine-dominated forest (Table 7).

Table 4. Vegetation characteristics at jay sites in spruce-dominated and pine-dominated forest (N = 25 and 32, respectively). Differences in means tested by Student's T-test.

	Spruce-dominated forest		Pine-dominated forest		
Variable	Mean	SD	Mean	SD	P
Basal area, ha^{-1}					
Pine	0.1	0.3	7.8	6.9	< 0.001
Spruce	11.3	2.4	3.4	5.3	< 0.001
Birch	2.8	1.2	2.8	2.6	NS
Standing dead trees	2.1	1.4	0.2	0.4	< 0.001
Ground cover %					
Lichens	16	17	4	8	0.001
Mosses	48	30	68	24	0.008
Dwarf-shrubs	46	26	55	28	NS
Tree seedlings[1]; number ha^{-1}	80	119	159	159	0.001

[1]Test performed on log-transformed data

Table 5. Log-linear analysis of different behavioural categories and microhabitat use among adult and juvenile Siberian Jay in spruce-dominated and pine-dominated forest. Models were tested hierarchically, i.e. if a lower-order effect was removed, so were the higher-order effects that included it. The full model was forest type × territory × the term. Figures in brackets are degrees of freedom of the model without the term. Included are results of all models fitting the data (P > 0.05).

Jay category	Term	Significance of removal of term from model		
		χ^2	df	P
Adults	Behavioural categories	36.27	4 (12)	< 0.001
Juveniles	Behavioural categories	295.79	4 (8)[1]	< 0.001
Adults	Tree species (sitting)	129.34	1 (3)	< 0.001
Adults	Tree species (food search)	29.40	1 (3)	< 0.001
Adults	On ground or in tree (sitting)	0.23	1 (3)	0.630

[1]Analysis performed on data from 4 territories

Table 6. Distribution of observations (in percent) in different behavioural categories for adult and juvenile Siberian Jays in different forest types.

Category	Forest type	Pair bonding	Feather care	Feeding	Food search	Sitting	Resting	Observation instances
Adults	Spruce-dominated	0	2.3	1.0	13.5	83.2		399
	Pine-dominated	4.5	5.6	1.5	7.8	80.6		715
Juveniles	Spruce-dominated		3.4	1.6	2.0	76.5	16.5	1331
	Pine-dominated		5.1	3.6	3.3	59.8	28.2	2193

For juveniles sitting and resting were the most common behavioural categories. Sitting was a relatively more common activity in spruce-dominated forest than in pine-dominated forest, whereas the opposite was true for resting (Table 6). None of the single behavioural category models aiming at analysing differences in use of tree species and height strata fitted the data ($P < 0.05$), thus precluding further analysis.

4. Discussion

The Siberian Jay is an opportunistic forager with a versatile diet (Blomgren 1964, Cramp *et al.* 1994). This makes it difficult to unambiguously determine the type and amount of food taken relative to availability. We observed Siberian Jays feeding on a variety of food items both on the ground and in trees during the study, but could not discern any readily apparent differences in diet selection between spruce-dominated and pine-dominated forest. Furthermore, we found no difference in cover of dwarf-shrubs at jay activity sites that could indicate differences in type and amount of ground feeding substrate

Adult Siberian Jays tended to be more actively food searching in spruce-dominated forest than in pine-dominated forest. It may be advantageous for jays to allocate much time for food searching during summer in order to secure food resources for winter; hoarding starts already in July (Blomgren 1964). Winter conditions are unpredictable in northern boreal forests; for example access to stored food occasionally may be restricted by heavy snow accumulation in trees (personal observations). Under such uncertain conditions a broad niche use during food gathering may be an optimal strategy (Levins 1968). Virkkala (1988) observed that Siberian Jay rarely used birch for food search in his study area. We observed no difference in food search in birch among forest types, but admittedly our sample size was small. However, we found a relatively more frequent use of birch of sitting adults in spruce-dominated forest than in pine-dominated forest. Birch provides ample food for foliage-gleaning birds in summer, as witnessed by the intensive use by migratory evertebrate feeders such as the Bramling *Fringilla montifringilla* and Willow Warbler *Phylloscopus trochilus*. Siberian Jay probably is too heavy to utilise invertebrates confined to birch leaves, but may use the branches either as feeding substrate or for scanning. The lower visibility in spruce-dominated forest may provide better concealment from avian predators, such as the Goshawk *Ac-*

Table 7. Use of different tree species for food search and sitting by adult Siberian Jays in spruce-dominated and pine-dominated forest. Observed instances of the different behavioural categories and expected instances derived from tree species composition at jay sites in the different forest types (Table 4). df = 2.

	Spruce-dominated forest		Pine-dominated forest	
	Observed	Expected	Observed	Expected
Food search				
Pine	1	0	23	30
Spruce	24	25	23	13
Birch	6	6	7	10
	$\chi^2 = 1.02$ $P = 0.600$		$\chi^2 = 4.23$ $P = 0.120$	
Sitting				
Pine	0	3	155	226
Spruce	144	176	212	97
Birch	78	43	36	80
	$\chi^2 = 16.0$ $P < 0.001$		$\chi^2 = 72.7$ $P < 0.001$	

cipiter gentilis, hence allowing jays to exploit a broader niche space, including birch. Spruce was used disproportionally to abundance in pine-dominated forest of sitting adult Siberian Jay. This result is in line with an anti-predatory strategy: a "sit-and-hide" strategy may reduce predation risk and the relatively denser foliage of spruce trees provides better cover than pine or birch. Differences in inter-specific competition may be another reason for the observed differences in activity and tree use among adults, but we have no data to test this. However, the Jay *Garrulus glandarius*, a potential competitor, was seen only in the pine-dominated forest. In conclusion, our results indicate plasticity in activity patterns and use of tree species in Siberian Jay, typical of the family Corvidae (Coombs 1978). This adaptability may help to explain the species prevalence in diverse types of forest.

Much new information has been gathered on the Siberian Jay recently (e.g. Lillandt 1993, Sklepkovych 1997, Ekman *et al.* 1999, 2000, 2001). This study adds some pieces of information to this knowledge. Ekman and co-workers (2001) found a positive relation between reproductive success in Siberian Jay and density of spruce trees, and vice versa for density of tall pines. Our results support the idea that spruce is a vital component in Siberian Jay territories: spruce was used disproportionally to abundance of sitting adult jays in pine-dominated forest. The proximate factors for this difference in microhabitat use may be related to food acquisition, predation risk and inter-specific competition. In light of our results, we suggest that retaining or restoring the spruce component may be a means to increase habitat suitability for Siberian Jay in managed forest. Further studies are needed to find out critical spruce densities in managed forest.

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Sammanfattning: **Aktivitetsbudget och nischutnyttjande hos lavskrika i brukad och obrukad skog**

Vi undersökte aktivitetsbudget och utnyttjande av olika trädslag hos lavskrika, en stationär skogslevande art, i grandominerad naturskog och talldominerad brukad skog i Norrbottens län, norra Sverige. Vidare undersökte vi eventuella skillnader i nyttjande av marken respektive träd. Tre kullar i vardera skogstypen följdes med hjälp av telemetri från det att ungarna lämnat boet i slutet av maj, till slutet av juli 1998. De vanligaste beteendena hos vuxna fåglar var födosök och sittande, medan sittande och vilande dominerade bland ungfåglar. Relativt mer tid ägnades av gamla fåglar åt födosök i grandominerad skog än i talldominerad skog. Ungfåglar å sin sida tillbringade mer tid sittande än vilande i grandominerad skog. Gamla fåglar födosökte i olika trädslag i relation till förekomst i båda skogstyperna. Gran utnyttjades mer i förhållande till förekomst bland gamla skrikor i talldominerad skog, medan björk utnyttjades relativt oftare i grandominerad skog.

Grandominerad skog erbjuder fler möjligheter till födosök än talldominerad skog, t ex genom att grenverket hos gran sträcker sig ända ned till marken. Vidare erbjuds bättre skydd för predation, genom att grenverket minskar insyn nära marken. Våra resultat visar att gran spelar en viktig roll i lavskrikans hemområde. Bibehållande och återskapande av en skiktad beståndsstruktur, med inslag av gran i botten, kan vara sätt att bevara och öka skogens värde som habitat för lavskrikan. Våra resultat visar på en hög plasticitet i beteendet hos lavskrika. Denna anpassningsförmåga är förmodligen en viktig bakomliggande förklaring till varför lavskrikan förekommer också i intensivt brukade skogar.

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