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Influence of large snow depths on Black Woodpecker *Dryocopus martius* foraging behavior

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Large snow depths are assumed to constrain the Black Woodpecker's (*Dryocopus martius*) ability to feed on carpenter ants (*Camponotus herculeanus*) in stumps and logging debris following clearcutting. To document foraging behavior in a snow-rich area, we radio-marked three Black Woodpeckers in Nordmarka, southcentral Norway, and compared the results with data from a nearby snow-poor area at Varaldskogen (Rolstad et al. 1998). At snow depths below ca. 1 m, birds were feeding on carpenter ants in stumps and dead downed wood. At snow depths above 1 m birds increasingly fed on carpenter ants in the base of trunks of infested living trees, and on bark beetles (*Ips typographus*) and beetle larvae in dead standing trees. Home ranges at Nordmarka were markedly larger (mean = 449 ha, SD = 71, n = 3) than at Varaldskogen (mean = 226 ha, SD = 109, n = 23). One female at Nordmarka, killed by a pine marten (*Martes martes*), had lost 20% of body mass due to starvation. The results indicate that winter food limits Black Woodpecker populations in snow-rich managed forests, and we suggest that arboreal feeding on bark beetles renders the birds more vulnerable to goshawk (*Accipiter gentilis*) predation.

1. Introduction

The Black Woodpecker (*Dryocopus martius*) is the largest resident bird of Palearctic boreal forests, which is obligate insectivore during winter. During the last century it has expanded its range and increased in number in central and western Europe, explained by an increase in the amount of coniferous forest (Mikusinski 1995). In contrast, northeastern Europe, and northern Finland in particular, seem to have experienced a population decline despite a slight increase in total forested area and growing stock of conifers (Dementiev et al. 1951, Järvinen et al. 1977, Ahlén & Tjernberg 1992). In northern regions carpenter ants (*Camponotus* spp.) constitute the staple winter food (Pynnönen 1939, 1943, Mikusinski 1997), which the birds excavate from colonies in dead wood and infested trees. In southcentral Scandinavia the clearcutting practice of modern forestry seems to benefit the Black Woodpecker by creating large amounts of stumps colonized by ants (Rolstad et al. 1998). However, this applied to a snow-poor area. Although the black woodpecker is known to dig deep holes in the snow to access subnival ant colonies (Pynnönen 1943), at some critical snow depth stumps and downed woods are expected to become inaccessible. In managed forests vertical structures like snags and rotten trees are being harvested in salvage silvicultural operations. It can therefore be hypothesized that changes in the internal forest structure, combined with severe snow conditions, constrain the winter diet of Black Woodpeckers in northern regions (Mikusinski 1997, Rolstad et al. 1998). The hypothesis is supported in a Finnish bird census documenting an inverse relationship between snow depth in February and abundance of Black Woodpecker the following breeding season (Saari & Mikusinski 1996). Likewise, a positive correlation between mean winter temperatures and a winter index of Black Woodpecker numbers in a Swedish bird census conforms to this explanation (Nilsson et al. 1992).

In this paper we present data on three radio-marked Black Woodpeckers from a snow-rich area, Nordmarka in Norway, which supports the hypothesis that this woodpecker's ability to find food in managed forests is limited by large snow depths. Combined with previous data from the Varaldskogen study area, the findings point at a critical snow depth of ca. 1 m, above which ground feeding becomes prohibited.

2. Study areas, material and methods

Three Black Woodpeckers, one male and two females, were captured in roosting holes and radio-monitored during January–April of 1994 (Table 1). All resided within a 5 000-ha forested tract, centrally located at 300–400 m a.s.l. within the Normarka area, 25 km north of Oslo in south-central Norway (60°06´N, 10°45´E, Fig. 1). Nordmarka is in the middle boreal zone (Ahti et al. 1968), and the forest is dominated by Norway spruce (*Picea abies*), with Scots pines (*Pinus sylvestris*) scattered at bogs and on poor sites with exposed rocks. Birch (*Betula pubescens*), rowan (*Sorbus aucuparia*), and alder (*Alnus incana*) occur regularly along wetlands, rivers and lakes. Aspen (*Populus tremula*) is rare, but occurs as single trees, or in small patches, presumably on sites that previously have been burned or disturbed. Snow covers the ground from mid-November to mid-May, with maximum snow depths of 1–2 m occurring in February–March. The climate is humid with yearly precipitation averag-

Table 1. Recorded data on home range and foraging behavior of three radio-marked black woodpeckers in Nordmarka, a snow-rich forest area in southcentral Norway, during January–April 1994.

Bird	Period of monitoring	Body weight (g)	Home range size (ha)	No. of telemetry-locations	No. of feeding observations				Comments
					Dead trees	Stumps and logs	Live trees	Sum	
Male #1	22/2–20/4	348	368	14	3	0	6	9	Killed by goshawk
Female #1	25/1–5/3	315	483	21	9	1	4	14	Lost radio-contact
Female #2	18/1–19/2	310	497	19	5	9	0	14	Killed by pine marten after longer period of starvation. Had empty stomach and weighted 250 g at death.

ing 1 200 mm.

The Nordmarka data is compared with that of Varaldskogen (Rolstad et al. 1998), a 10 000-ha study area in the middle boreal zone (60°10´N, 12°30´E), 100 km east of Nordmarka (Fig.1). Varaldskogen has a more continental climate, and snow depth rarely exceeds 1 m. Here we use data from 23 birds (15 males and 8 females) with ≥ 20 radio-fixes during December–March 1990–1995.

A detailed description of the study area and dataset from Varaldskogen is reported in Rolstad and Rolstad (1995) and Rolstad et al. (1998).

The woodpeckers were fitted with a 7-g (1.8–2.6% of body mass) radio transmitter (Biotrack, Wareham, UK) attached to the back with a nylon harness enclosed in silicon rubber. Expected battery lifetime was 8 months, and average detecting distance of radio-signals was 5 km. Field monitoring and assessment of home ranges followed the procedure of the Varaldskogen study (Rolstad et al. 1998). The proportional use of different feeding substrates was obtained by approaching the birds at close distance. In most cases the birds were not flushed, and the feeding sites were later revisited to ascertain feeding substrate and source of prey items. Feeding sites were easily detected by fresh signs of wooden debris and prey remains in the snow. Snow depth, averaged to the nearest 10 cm, was measured at level ground at 5 sites in open habitat, adjacent to the bird plots. The age of forest stands was extracted from forest plan documents of the forest owner, cross-checked in the field by counting twig wreaths and annual rings sampled with an increment borer.

3. Results and discussion

At Nordmarka snow depth increased from 100 cm in mid-January to 150 cm in late-February and March. At Varaldskogen snow depth did not exceed 70 cm. We observed two main prey groups, carpenter ant (*Camponotus herculeanus*) and bark beetle (*Ips thypographus*). Other prey groups were occasionally recorded in negligible proportions (e.g. Cerambycid larvae at Varaldskogen). Carpenter ants occurred in stumps, dead downed woods, and basal trunks of living spruce trees. Bark beetles were recorded between the bark and wood of dead spruce trees that had been killed the

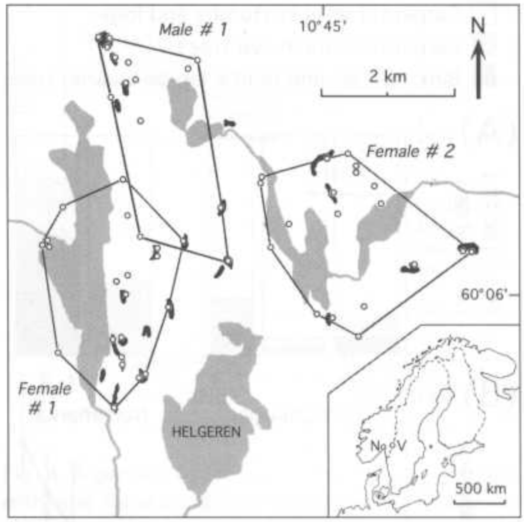

Fig. 1. Map of home ranges and habitats of three Black Woodpeckers monitored by radio-telemetry in Nordmarka, southcentral Scandinavia, January–April 1994. Black areas show forest stands with trees killed by bark beetles. Grey shadings denote water-systems. Inset map shows the locations of the Nordmarka (N) and Varaldskogen (V) study areas. Confer Table 1 for statistics.

previous spring and summer. Bark beetles occurred in two life-history stages; as immature beetles and as larvae that remained arboreal in winter.

We recorded three types of feeding techniques that were closely linked to type of prey and habitat (Fig. 2). First, up to snow depths of 120 cm, birds mainly excavated carpenter ants from colonies in stumps and downed woods, after removing snow with lateral movements of their bill. Birds often excavated stumps beneath branches of dense young spruce trees that were less covered with snow. These substrates were remains from loggings, and young spruce plantations (15–40 years) were the most frequented habitats. Second, as snow accumulated, birds sought out large-stemmed, living spruce trees where they excavated carpenter ants from colonies within the basis of the trunks. Birds often spent the whole day getting access to these large colonies, and once opened, they revisited these sites at later events. Most of these trees were in old forest stands. Third, at snow depths 130–150 cm, birds bark-scaled recently dead spruce trees killed by bark beetles. These

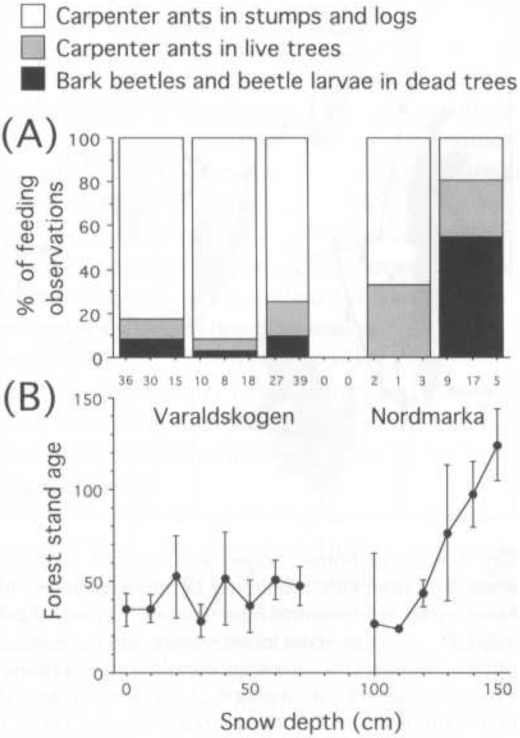

Fig. 2. (A) Percent of Black Woodpecker feeding observations categorized according to foraging substrate, prey type and snow depth. (B) Black Woodpecker feeding observations in relation to snow depth and forest stand age. Bars denote 95% confidence intervals. Study areas and sample sizes are indicated between the graphs. Varaldskogen 1990–1995 (Rolstad et al. 1998), and Nordmarka 1994, southcentral Scandinavia.

trees occurred in patches of 5–20 trees, and most were located at the clearcut-edge of old forest stands. Often birds completely stripped the trees from bark before leaving the sites.

At Nordmarka, home ranges were 368, 483 and 497 ha large (mean = 449 ha, SD = 71), and their outer boundaries seemed to be determined by the spatial distribution of patches of bark beetle-killed trees (Fig. 1, Table 1). These patches constituted < 2% of the total area, whereas the woodpeckers were observed feeding there 46% of the recorded cases. Compared to winter home ranges at Varaldskogen (mean 226 ha, SD = 109, n = 23), the Nordmarka home ranges appeared larger (Mann-Whitney U-test: $U = 66$, $Z = 2.53$, $P = 0.012$) (Fig. 3). When the datasets were combined, a large part of the variation in home range size (54%) was explained by the area proportion of feeding habitat in the landscape ($r = 0.74$, $P < 0.001$, $n = 26$). Home range size increased 4–5 fold when the area proportion of feeding habitat decreased from 60 to 2% (Fig. 3).

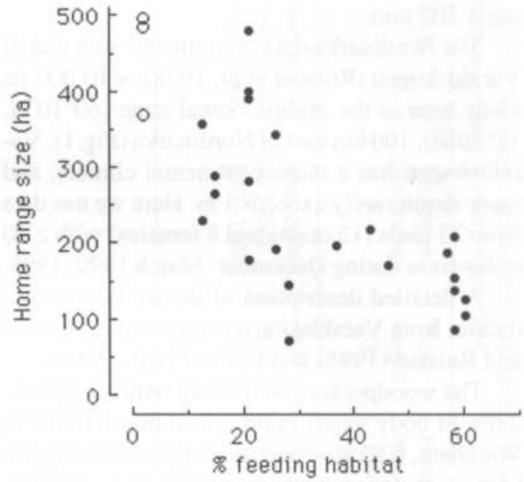

Fig. 3. Home range size plotted against the area proportion of feeding habitat used by Black Woodpeckers at the Nordmarka study area (open circles, n = 3, January–April 1994) and the Varaldskogen study area (black dots, n = 16, year-round 1990–1994). At Nordmarka birds were feeding bark beetles in patches of recently killed old spruce trees that constituted 2% of the total area. At Varaldskogen birds were feeding on ants (mainly carpenter ants) in stumps and logging debris in 15–30-year old spruce plantations. Confer Rolstad et al. (1998) for details about the Varaldskogen data.

Despite a small sample size, we were able to document a marked shift in Black Woodpecker foraging behavior at snow depths of 100–120 cm. Above this level, birds relied on bark beetles and beetle larvae in recently dead spruce trees. Bark beetle attacked stands comprised < 2% of the study area, and most managed forests are virtually devoid of recently dead standing trees. One of the females at Nordmarka had lost 20% of her body mass due to starvation, before she was killed by a pine marten (*Martes martes*) in the roosting hole. Thus, we conclude that inaccessibility to winter food may preclude Black Woodpeckers from snow-rich managed forests, and that this may be the reason for population declines in northern regions (Mikusinski 1995).

Evidence from the Varaldskogen study area suggests that in regions with little snow the clearcutting practice of precent-day forestry favors the food situation for the Black Woodpecker, compared with alternative selective cuttings (Rolstad et al. 1998). Concentrated patches of stumps and logs supply an abundant and predictable food source of wood-dwelling ants. Clearcutting may also increase food availability compared to natural forest stands, depending on the disturbance regime. Contrary, in snow-rich regions forestry presumably worsen the food situation, by removing snags and bark beetle infested trees, thereby preventing woodpeckers access to alternative food sources (Fig. 4). Importantly, this applies both to clearcutting and selective cutting methods. Wildfires and windstorms are natural disturbance agents in boreal forests, giving rise to landscape mosaics of young and old forest stands rich in stumps, logs and snags. By eliminating standing dead trees, present-day forestry practices presumably influence Black Woodpecker populations negatively in snow-rich regions. Probably, this also applies to other woodpecker species as well (Mikusinski 1995, 1997).

We do not have data that shows whether the shift in feeding behavior translated to demography, i.e. that birds suffered higher mortality as a consequence of changed behavior. The male at Nordmarka was killed by a goshawk (*Accipiter gentilis*), and this raptor was the primary predator on Black Woodpeckers at Varaldskogen (unpubl. data). At Varaldskogen birds suffered highest mortality during the winter with most snow (70 cm) (unpubl. data.). The behavioral shift from ground feeding on stumps in dense young plantations, to arboreal feeding in dead trees without the cover of living branches, predicts that the woodpeckers become more susceptible to attacking goshawks. We therefore hypothesize that Black Woodpecker numbers are lower in snow-rich regions due to higher winter mortality. Future studies should explore the causal links between snow cover, availability of alternative feeding substrates, and winter mortality.

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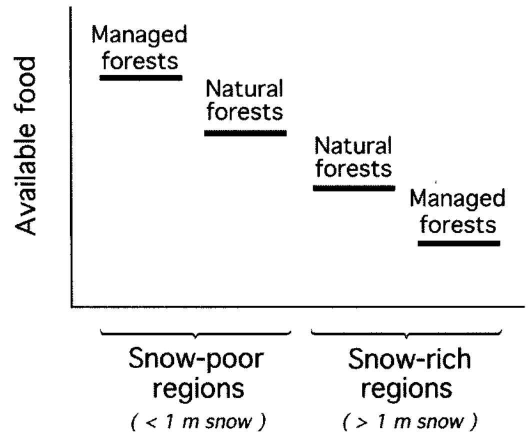

Fig. 4. A general hypothesis of how clearcutting forestry and snow condition interacts on the availability of black woodpecker winter food sources. The hypothesis predicts that clearcutting promotes food availability in snow-poor regions, due to abundant dead wood debris from loggings that supports carpenter ants and other wood-dwelling ant groups. It predicts that clearcutting reduces food availability in snow-rich regions, because loggings debris is covered with snow, and because older forest stands are devoid of standing dead wood structures. Critical snow depth is assumed to be ca. 1 m.

Selostus: **Lumen määrän vaikutus palokärkien ravinnonhankinta käyttäytymiseen**

Pohjoisilla alueilla hevosmuurahaiset ovat palokärjelle tärkeää talviravintoa. Runsaan lumen määrän on oletettu rajoittavan palokärjen mahdollisuuksia hyödyntää avohakkuualueiden kannoista ja hakkuutähteistä löytyviä hevosmuurahaisia. Kirjoittajat vertailivat radiolähettimillä varustettujen palokärkien ruokailukäyttäytymistä runsas- ja vähälumisien alueiden välillä Norjassa. Vähälumisilla (< 1 m) alueilla palokärjet söivät kannoista ja maapuilta löytyneitä hevosmuurahaisia. Runsaslumisilla (> 1 m) alueilla palokärjet söivät pääasiassa sairaiden puiden runkojen alaosista löyty-

neitä hevosmuurahaisia ja kuolleiden pystypuiden rungoilta löytyneitä kirjanpainajia (kaarnakuoriaisia) ja niiden toukkia. Runsaslumisilla alueilla elävien yksilöiden liikkuma-alat olivat suurempia kuin vähälumisilla alueilla elävien lintujen. Saadut tulokset viittavaat siihen, että talviravinnon saatavuuden ongelmat voivat heikentää palokärkien menestymismahdollisuuksia runsaslumisilla talousmetsäalueilla. Lisäksi runsaslumisilla alueilla korkealla puissa tapahtuva ruokailu voi altistaa linnut kanahaukkojen saalistukselle. Kirjoittajat esittävät mallin (Kuva 4), jonka mukaan avohakkuut lisäisivät palokärkien ruokailumahdollisuuksia vähälumisilla alueilla. Sen sijaan avohakkuut vähentäisivät palokärkien ruokailumahdollisuuksia runsaslumisilla alueilla, koska potentiaaliset ravinnonhankintakohteet ovat palokärkien ulottumattomissa paksun lumipeitteen alla. Lisäksi vanhoista talousmetsistä puuttuu yleensä kuolleet pystypuut, joilta palokärjet voisivat hakea hevosmuurahaisille vaihtoehtoisia ravintokohteita.

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