A comparison of Goshawk summer diet in three areas with different breeding density in western Norway

Turid Verdal & Vidar Selås

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In Norway, Goshawk *Accipiter gentilis* populations have declined in continuously forested areas in the inland, possibly because of decreased populations of grouse. The highest breeding densities are now found in landscapes dominated by farmland and urban areas, and in some areas close to the coast. In western Norway, we have compared the summer diet of Goshawks breeding at high densities in one island area and one urban area with that of Goshawks breeding at lower densities in an inland area at higher altitudes, approximately 90 km from the coast. Birds dominated the diet in all areas, but the diet diversity was lower in the inland than in the two other areas. The number of pigeons, Woodcock *Scolopax rusticola* and ducks/waders found at nest sites decreased with altitude, whereas the number of grouse increased. We conclude that Goshawks in the inland are more dependent on grouse because of lower availability of alternative prey.

Key words: altitude, coast, diet, Goshawk, grouse, Norway

Turid Verdal and Vidar Selås (correspondence), Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway. E-mail: t_verdal@hotmail.com. vidar.selas@umb.no.

INTRODUCTION

The Goshawk *Accipiter gentilis* is a medium-sized raptor well adapted for hunting large bird prey in mature forests (Kenward 2006). In boreal forests in Fennoscandia, where grouse have been important prey (Hagen 1952, Sulkava 1964, Lindén & Wikman 1983, Widén 1987, Tornberg 1997), there has been a long-term decline in Goshawk populations, probably because intensified forest management has led to reductions in preferred hunting habitats and prey numbers (Widén 1997, Tornberg *et al*. 2006). The decline has been less severe in areas with a strong influence of farmland and urban areas (Grønlien 2004, Selås *et al*. 2008). However, in Norway, the highest densities are presently found in some coastal areas in western and central parts of the country (Bergo 1992, Overvoll 1994, Sandvik 1996, Steinsvåg 2002, Grønlien 2004).

Most Goshawk males stay in their territories in winter (Widén 1985), and prey availability in late winter has been regarded as the most important factor for territory sizes and thus breeding densities (Newton 1979, Widén 1997, Kenward *et al*. 1999, Kenward 2006). In Fennoscandia, forest grouse (Tetraonidae), Jay *Garrulus glandarius* and Red Squirrel *Sciurus vulgaris* could be expected to be the most important prey during winter in forests, and Magpie *Pica pica*, Hooded Crow *Corvus cornix*, Jackdaw *C. monedula* and

Feral Pigeon *Columba livia* in mixed forest-farmland landscapes (Widén 1987, Tornberg & Colpaert 2001). During the breeding season, the proportion of grouse in the diet has been highest in forest-dominated areas, whereas the proportion of corvids has been highest in forest-farmland areas (Grønnesby & Nygård 2000, Johansen *et al*. 2007). Hence, differences in the availability of winter-resident prey have been reflected also in the summer diet, when larger samples can be obtained with less field effort.

In western Norway, the number of territorial Goshawk pairs has been estimated to 5.3 per 100 km^2 productive forest in an inland area, which is a relatively high breeding density for a forest-dominated area, whereas the corresponding numbers for two coastal areas were 11.1 and 14.3, respectively (Overvoll 2004). The difference can hardly be explained solely by different forest management strategies. Previous studies on Goshawk diet indicate that grouse is important as prey only in the inland (Bergo 1992, Overvoll 1999), but because the studies have been carried out in different years and with varying field effort, the results are not directly comparable. The main objective of our study was to compare estimates of the summer diet of Goshawks in the three areas, by using a standardized diet analysis technique during one breeding season, and by controlling for the proportion of different habitat types in each Goshawk territory. Our hypothesis is that the higher breeding density of Goshawk in the two coastal areas reflects higher availability of alternative winter-resident prey, which has buffered the negative impact of forestry on grouse numbers.

MATERIAL AND METHODS

The study was carried out in Hordaland County, western Norway, in three areas where Goshawk breeding density has been investigated through systematic surveys since the early 1990s. One area is situated at the island of Bømlo, Stord and Fitjar municipalities (59°73'-59°96'N, 05°26'-05°48'E, 0-200 m a.s.l., hereafter the island area), one in an urban coastal area in Os and Bergen municipalities (60°22'-60°25'N, 05°38'-05°47'E, 100-200 m a.s.l., hereafter the urban area), and one in an inland area, in Voss municipality (60°65'-60°81'N, 06°48'-06°70'E, 200-500 m a.s.l., hereafter the inland area), approximately 90 km from the coast. The two former (coastal) areas are characterized by mild winters (mean January temperatures 1960–1990: 1.9°C and 0.6°C, respectively), whereas in the inland, winter temperatures are lower (mean January temperature 1960–1990: -4.6°C).

In all areas there is a quite roughed topography. The island landscape consists of heath-lands, forests, bogs, small lakes, and some farmland and urban areas. The urban area has a higher proportion of urban areas, intermixed with forests, small lakes and farmland. The inland area is dominated by high-altitude bare rocks and low-productive forests, intermixed with bogs, farmland and urban areas. In all areas, Scots Pine *Pinus sylvestris* dominates the forests, albeit deciduous tree species are locally highly abundant in the two coastal areas. Norway Spruce *Picea abies* is the most replanted species in clear-cuts. In the late 1990s, older thinned stands and mature forest (development class IV and V) constituted approximately 61, 73 and 58% of the productive forest areas in the island, urban and inland area, respectively.

We have collected prey remains from plucking posts near nests, a method that in general underestimates small prey (Sulkava 1964, Rutz 2003, Tornberg & Reif 2007). However, the method should be suitable for comparing different regions in one particular year, as long as the field work is conducted by equal effort and by the same persons. Prey remains were collected from four nest sites in the island area, three in the urban area and four in the inland (Table 1). Each nest was visited seven times during May-July 2006. To avoid replication, remains from the same species collected at different plucking posts at the same day were compared and interpreted to be one or more individuals. A species found in pellets was counted only if not found also among other prey remains during that visit.

We evaluated prey diversity by using Simpson's Reciprocal, and addressed diet similarity between areas by using Sorensen's coefficient of percent similarity (Smith & Smith 2006). When comparing prey group composition between the three study areas, prey species were classified into seven classes, similar to those used by Johansen et al. (2007); thrushes, Jay, farmland corvids, pigeons, grouse, Red Squirrel and «other prey».

Because nest sites in the two coastal areas were situated at lower altitudes than inland nest sites (Table 1), we used both region (dummy variable) and altitude as explanatory variables (predictors) when comparing the occurrence of common prey species or groups of prey species at Goshawk nest sites in the inland (region 1) with that of the two coastal areas (region 2). Because of overdispersal in our count data, we used a generalized linear model with quasi-Poisson error distribution and a log link, weighted according to the total number of prey found at each nest site. The numbers of prey species or prey groups found at a nest site are ultimately proportions and therefore not independent. We therefore adjusted α-levels by using Bonferroni correction.

To control for the possible impact of variations in habitat composition within Goshawk home ranges, we used the same method as Johansen et al. (2007), i.e. we made circles of 2 km radius (ca. 13 km^2) around each nest location on GIS maps, where we mapped the percent of different habitat types (Table 1). Maps were obtained from the Norwegian Forest and Landscape Institute (http://www.skogoglandskap.no), and managed in ArcView GIS 3.3 (ESRI 2002). The habitats used as predictors in the statistical models were the percent of lakes and sea, and for the land area, the percent of urban areas, farmland, forests and other habitats (mainly heathlands, bogs and mountains). The proportion of lakes and sea correlated significantly with the proportion of other habitats ($r=0.65$, $p=0.032$) and almost so with altitude ($r=-0.52$, $p=0.098$), and was therefore used as predictor only for the occurrence of ducks and waders in the diet.

RESULTS

From prey remains collected at the 11 Goshawk nest sites, we identified 576 prey items, including 34 bird species and five mammal species (Appendix 1). The relative abundance of prey groups differed between the three areas ($\chi^2=164.9$, df=12, $p<0.001$; Fig. 1). The diet diversity was higher in the island (SRI=29.3) and urban (SRI= 30.0) area than in the inland (SRI=20.4). The diet similarity between the island and urban area was 66.1%, between the island and the inland area 41.1% and between the urban and the inland area 44.5%. Corvids and especially thrushes were common as prey in all study areas (Fig. 1).

In the quasi-Poisson regression models, altitude was a better predictor than region for most of the prey groups that differed in occurrence between the two coastal areas and the inland area (Fig. 1), except of the group other prey. However, the occurrence of the most common species in this group, the Woodcock *Scolopax rusticola*, as well as that of ducks and waders (exclusive Woodcock) pooled, was best explained by altitude. When including habitat in the models for pigeons and Woodcock, the occurrence of pigeons, Woodcock and ducks/waders decreased significantly with altitude, whereas that of grouse increased (Table 2), even by Bonferroni-correction (number of tests = 8, $\alpha=0.0063$). Willow Grouse *Lagopus lagopus* and Capercaillie *Tetrao urogallus* were found as prey only in the inland, whereas Black Grouse *Tetrao tetrix* was found also in the two coastal areas. For ducks and waders, the occurrence was better explained by altitude ($p=0.002$; Table 2) than by the proportion of lakes and sea ($p=0.088$).

Thrushes, Jay, farmland corvids and Red Squirrel did not show any relationships with region or altitude. The Fieldfare *Turdus pilaris*, which inhabit open habitats, was positively related to the proportion of farmland ($p<0.001$), whereas the occurrence of the remaining thrush species correlated positively with the proportion of urban areas ($p=0.005$). For the forest-dwelling Jay, there

Table 1. Information about habitat composition around Goshawk nests in the island (IS1–IS4), urban (UR5–UR7) and inland (IN8–IN11) study area in Western Norway, where prey remains were collected in summer 2006. The proportion of lakes and sea (of total area), and of urban areas, farmland, forest and other habitats (of total land area), refer to a circle with radius 2 km and the Goshawk nest in center.

Nest number	Altitude m a.s.l.	Lakes/sea %	Urban areas %	Farmland %	Forests %	Other %
IS1	38	47.9	0	5.8	78.9	15.4
IS2	60	13.6	0	3.7	81.6	14.7
IS3	195	47.6	0	3.2	56.9	39.9
IS4	20	31.0	0	4.3	58.0	37.7
UR5	163	13.1	2.3	10.1	85.2	2.4
UR6	122	7.7	1.7	8.1	89.9	0.2
UR7	180	7.4	4.9	16.0	63.7	15.4
IN8	250	0.0	0	24.2	72.0	3.8
IN9	235	1.2	0	14.7	74.3	11.0
IN10	483	8.2	0	10.0	78.6	11.3
IN11	449	0.0	0	6.1	74.8	19.1

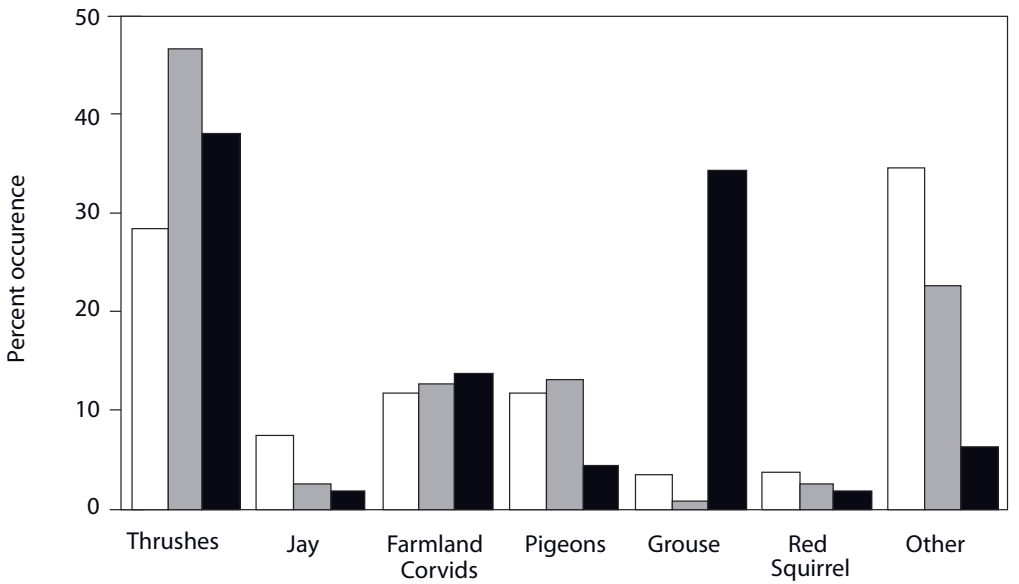

Figure 1. Proportion of different prey groups identified from prey remains at 11 Goshawk nests in Hordaland County, western Norway, 2006. White bars: island area; grey bars: urban area; black bars: inland area.

Table 2. Results from weighted generalized linear models (quasi-Poisson error distribution and a log link) where the response variable is the number of prey found at Goshawk nests (n = 11) in Western Norway, weighted according to the total number of prey found at each nest. Predictors are the altitude at the nest site and the proportion of different habitat types within 2 km radius from the nest. Cumulative values are given for the proportion of the total deviance explained by the model (Dev. expl.).

Prey	Variable	Estimate	SE	t-value	p	Dev. expl.
Grouse	Intercept	-0.226	0.608			
	Altitude	0.007	0.002	4.67	0.0012	0.73
Pigeons	Intercept	-1.883	1.056			
	Forest	0.057	0.013	4.35	0.0025	0.44
	Altitude	-0.005	0.001	-3.70	0.0061	0.82
Woodcock	Intercept	1.693	0.311			
	Other habitats	0.040	0.009	4.54	0.0019	0.57
	Altitude	-0.006	0.001	-4.31	0.0026	0.88
Ducks/waders	Intercept	3.053	0.208			
	Altitude	-0.007	0.002	-4.32	0.0019	0.74

was a negative relationship with the proportion of farmland and urban areas combined (p=0.019), whereas the Magpie, which is closely connected to human settlements, tended to be positively related to farmland and urban areas (p=0.088).

DISCUSSION

Most of the significant relationships between the occurrence of prey at Goshawk nests and habitat composition within 2 km from the nests were in accordance with the habitat preference of the prey species in question, suggesting that regional differences in Goshawk diet mainly reflected differences in prey abundance. Goshawk diet differed between the three areas, but the similarity between the island and urban area was relatively high. Diet diversity was higher here than in the inland. In western Norway, prey communities in coastal and urban landscapes are in general more diverse than in forested landscapes (Overvoll 1994, Sandvik 1996), probably due to both higher habitat diversity and higher land productivity (Norwegian Forest and Landscape Institute; *http://www.skogoglandskap.no*). Prey groups that were related to region or altitude with regard to their occurrence at Goshawk nests were grouse, pigeons and «other prey».

The major difference between the areas was the high proportion of grouse, especially Willow Grouse, in the Goshawks' diet in the inland. Grouse populations often exhibit strong inter-annual variations in density (Angelstam *et al*. 1985, Ranta *et al*. 1995), but such variations are usually synchronized over large areas, and should thus be of less importance for the comparison of our relatively close study areas. Our result is also in accordance with the former studies; grouse constituted only 2.3% of 828 prey collected in the urban area during 1991-1996 and 3.0% of 69 prey collected in the island area in 1995 (Overvoll 1999), whereas in the inland area, they made up 33.1% of 133 prey from 1984-1991 (Bergo 1992). In South Norway, there usually is a decline in grouse abundance along the altitude gradient from the coast to the inland, but it should also be taken into account that in our study, individual

Goshawks had larger territories in the inland, and thus probably exploited grouse from larger areas than those breeding close to the coast.

The occurrence of pigeons, i.e. Feral Pigeon and Wood Pigeon, was negatively related to altitude and positively to the proportion of forest. Feral Pigeons are common only in urban areas in the lowland, but in western Norway, Goshawks also frequently kill domestic pigeons *Columba livia domestica*, and the correlation with forests may have been influenced by the location of homing pigeon lofts (Overvoll 1994). In accordance with the study of Overvoll (1999), we found that the Woodcock was most important as prey in the island area. The negative relationship with altitude probably reflects the impact of land productivity. The Woodcock depends on earthworms (van Gils & Wiersma 1996), which are most common in moist and high-productive deciduous forests. Land productivity may also explain why the occurrence of other waders and ducks in the diet was better explained by altitude than by the proportion of lakes and sea.

Thrushes constituted a large proportion of Goshawk prey numbers, and their occurrence did not differ between the areas. Their importance is in accordance with results from video recordings at Goshawk nests in other regions of Norway (Grønnesby & Nygård 2000, Johansen *et al*. 2007). Although their contribution will be less with regard to biomass, they appear to make up a significant proportion of Goshawk food in Norway in summer. Neither did the occurrence of corvids, which in contrast to thrushes are present throughout the year, differ between the study areas.

Our study supports the hypothesis that the high breeding densities of Goshawk in our coastal study areas, where grouse densities are low, can be explained by higher availability of alternative winter-resident prey species, which may have buffered negative effects of forestry and declining grouse numbers. These prey species are probably favoured by the general higher land productivity, and/or by higher habitat diversity. Besides, due to the mild climate in the coastal areas, individuals of Wood Pigeon (Feral Pigeons are winter-resident), Woodcock and ducks may stay throughout the winter (Falkenberg 1999, 2000, 2003, Steinsvåg & Overvoll 2003, 2004, 2005), in contrast to the situation in the inland, where Goshawks have few alternatives to grouse hunting during winter.

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SAMMENDRAG

En sammenligning av hønsehaukens næringsvalg i tre områder med ulik hekketetthet på Vestlandet

Hønsehauken *Accipiter gentilis* har vist en generell bestandsnedgang i skogslandskap i Norge, sannsynligvis i første rekke som følge av en nedgang i bestandene av hønsefugler. Tettest hekkebestand av hønsehauk finner vi nå i jordbrukslandskap og urbane områder, samt i enkelte kystnære områder. Vi har sammenlignet næringsvalget hos hønsehauk i et kystøylandskap og i et kystnært urbant område på Vestlandet med næringsvalget i et område med lavere hekketetthet ca 90 km fra kysten (innland). Fugl dominerte dietten i alle områdene, men artsdiversiteten var lavere i innlandet. Antallet av rugde *Scolopax rusticola* og våtmarksfugler funnet ved hønsehaukreir var negativt relatert til reirets høyde over havet, mens det var en positiv korrelasjon for hønsefugler. Undersøkelsen indikerer at hønsehauken er mer avhengig av hønsefugler i innlandet på grunn av lavere forekomst av alternative byttedyr.

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Appendix 1. Prey remains found at Goshawk nest sites in western Norway in 2006. Nest numbering as in Table 1.

Prey species	**IS1**	**IS2**	**IS3**	**IS4**	**UR5**	**UR6**	**UR7**	**IN8**	**IN9**	**IN10**	**IN11**
Anas platyrhynchos	-	2	-	-	1	-	-	-	-	-	-
Anas crecca	2	-	-	-	-	-	1	-	-	-	-
Indet. duck	1	-	-	-	-	-	-	-	-	-	-
Accipiter nisus	-	-	1	-	-	-	-	-	-	-	-
Accipiter gentilis	-	-	1	-	-	-	-	-	-	-	-
Tetrao urogallus	-	-	-	-	-	-	-	-	-	2	3
Tetrao tetrix	-	1	7	-	-	-	1	1	1	5	4
Lagopus lagopus	-	-	-	-	-	-	-	12	3	18	6
Vanellus vanellus	-	-	-	-	1	-	2	-	-	-	-
Haematopus ostralegus	-	-	1	-	-	-	-	-	-	-	-
Pluvialis apricaria	-	-	-	-	-	-	-	-	-	1	-
Scolopax rusticola	3	7	6	25	3	4	4	2	-	1	1
Gallinago gallinago	-	-	-	-	-	-	1	-	-	-	-
Actitis hypoleucos	3	-	-	1	-	-	-	-	-	-	-
Larus canus	-	2	-	-	-	-	-	-	-	-	-
Sterna hirundo	3	-	-	-	-	-	-	-	-	-	-
Columba palumbus	3	4	-	3	4	1	1	1	4	2	-
Columba livia	8	10	-	-	3	10	3	-	-	-	-
Dendrocopos major	-	1	-	-	-	1	1	-	-	1	-
Picus viridis	-	-	-	-	-	-	-	-	1	-	-
Anthus sp.	-	-	2	-	-	-	2	-	-	-	-
Erithacus rubecula	-	-	-	-	-	1	-	-	-	-	-
Turdus merula	5	11	9	12	9	12	15	6	-	1	1
Turdus pilaris	3	-	-	1	3	1	5	25	2	2	1
Turdus merula/pilaris	2	1	1	-	-	1	5	-	1	7	-
Turdus iliacus	1	2	2	2	2	4	5	4	-	3	-
Turdus philomelos	1	3	7	6	2	4	10	3	2	2	2
Phylloscopus trochilus	-	-	-	-	-	-	1	-	-	-	-
Parus major	-	-	-	-	1	1	-	-	-	-	-
Garrulus glandarius	7	3	3	5	1	2	1	-	-	3	-
Pica pica	1	4	-	6	6	4	7	6	2	2	4
Corvus cornix	1	16	-	-	1	2	1	1	2	5	0
Corvus monedula	-	-	-	-	-	-	-	1	-	-	-
Corvus corax	-	-	-	-	-	-	-	2	-	-	-
Sturnus vulgaris	-	4	-	-	2	-	8	-	-	-	-
Loxia pytyopsittacus	-	-	-	-	1	1	1	-	-	-	-
Plectrophenax nivalis	-	-	-	-	-	-	-	1	-	-	-
Indet. bird	-	1	-	1	-	-	-	-	-	1	-
Microtus agrestis	2	-	-	1	-	-	-	-	-	-	-
Rattus norvegicus	-	-	-	-	-	-	1	-	-	-	-
Sciurus vulgaris	2	1	1	2	-	2	2	-	1	1	1
Lepus timidus	-	-	11	3	-	-	-	-	-	1	-
Mustela nivalis	-	-	1	-	-	-	-	-	-	-	-
Total	**48**	**73**	**53**	**68**	**40**	**51**	**78**	**65**	**19**	**58**	**23**