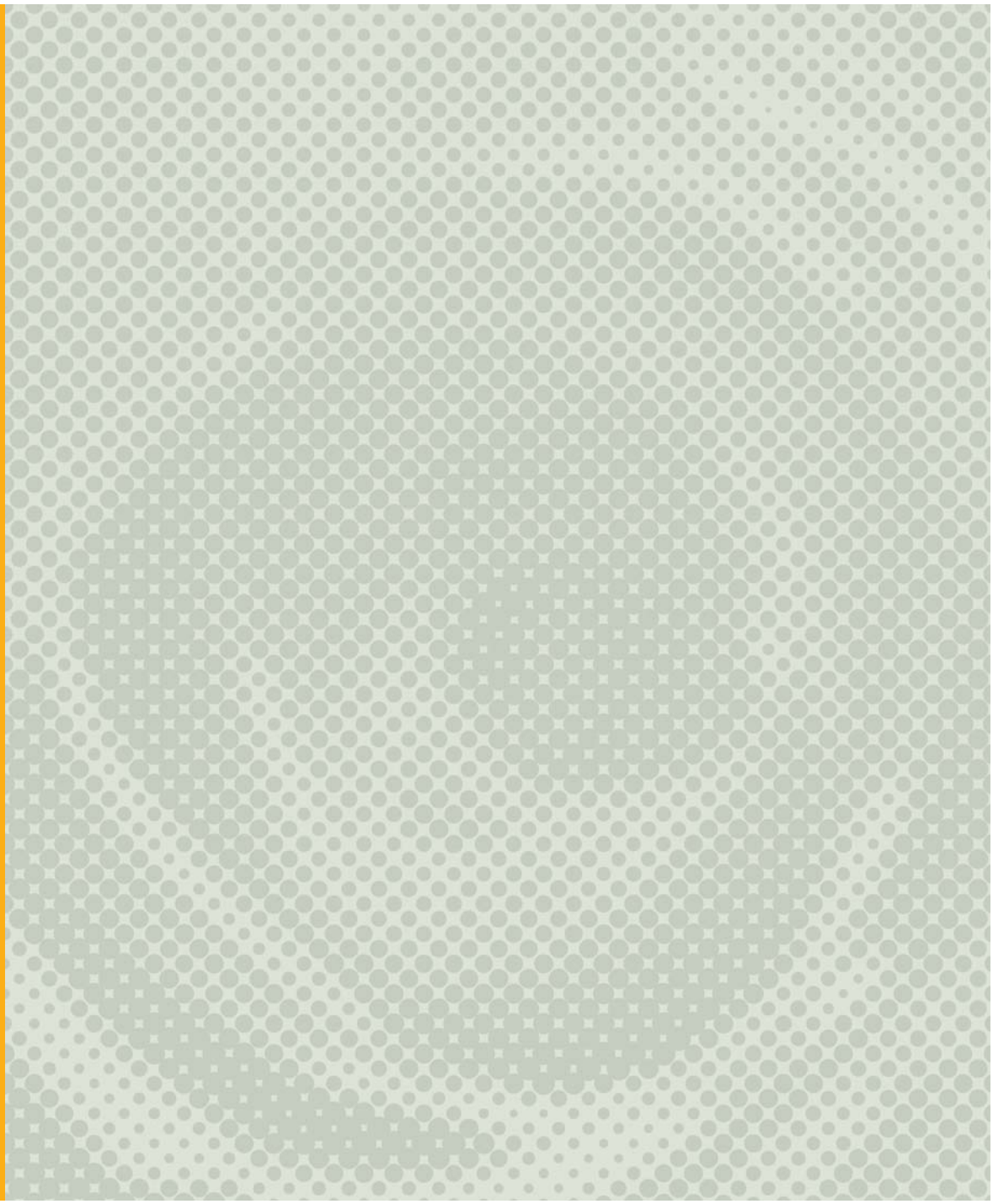
The diet of goshawks (*Accipiter gentis*) during the breeding season: a gradient from coast to inland

Næringsvalget hos hønsehauk (*Accipiter gentilis*) i hekkesesongen: en gradient fra kyst til innland

Turid Verdal

NORWEGIAN UNIVERSITY OF LIFE SCIENCES
DEPARTMENT OF ECOLOGY AND NATURAL RESOURCE MANAGEMENT
MASTER THESIS 60 CREDITS 2007



PREFACE

This work is my Master thesis that completes my Master degree in Natural Resource Management at the Norwegian University of Life Sciences. The fieldwork for this thesis was carried out during spring of 2006 and the thesis was written during the school year 2006/2007.

Several people have contributed to the work of this thesis. First of all, I would especially like express my gratitude to my supervisor, associate professor Vidar Selås, for his useful help identifying the prey material, with statistical work, and ideas and comments on the paper. Solve Sæbø deserve thanks for statistical help. I also wish to thank those who showed me the nesting sites in the three regions; Magnus J. Steinsvåg, Olav Overvoll and Gunnar Bergo. A special thanks to M. J. Steinsvåg that took the time to drive me by boat during the whole field period to the nest site that was located on an island. Further, special thanks go to Jørgen E. Nerland for his support during the whole process of fieldwork and writing, and my brother, Ketil, who donated his car to me. Furthermore, I'm grateful for the funding given from The Directorate for Nature Management and by the County Governor of Hordaland.

Norwegian University of Life Sciences
Ås, May 2007.

_____

Turid Verdal

CONTENTS

ABSTRACT

I investigated the diet of eleven goshawk (*Accipiter gentilis*) pairs during the breeding season 2007 by collecting prey remains from plucking posts. The nests were situated in three regions in Hordaland (Norway) with varying distances from the coastline; Coast, Middle and Inland. A total of 576 prey items were identified, and 39 different prey species were recorded. Birds covered 94.3% of the total diet. Corvids and Small Passerines were important prey groups in all three regions. In addition, Pigeons, Woodcock (*Scolopax rusticola*) and Mammals were important in Coast. Furthermore, Pigeons was important in Middle, and Grouse in Inland. The goshawk's diet was generally diverse, and the diet was significant different between the regions ($p < 0.001$). The highest diet diversities were found in Coast and Middle. There was also a high diet similarity between the three regions (PS = 41.1-66.1), probably because of the high proportion of Corvids and Small passerines in all three regions. The proportion of Grouse in the diet increased significantly from Coast to Inland ($p < 0.05$). There was a significant negative relationship between the proportion of Grouse in the diet and the proportion of open water within the goshawk home range ($p < 0.05$), and between the proportion of Grouse and the proportion of farmland, with region as random effect ($p < 0.05$). The proportion of Woodcock was negatively related to forest and farmland, and positively to open water ($p < 0.05$). In addition, there was a significant positive relationship between the proportion of Small passerines (mainly thrushes) and the proportion of farmland within the goshawk home range, with region as random effect ($p < 0.05$). Mammals were negatively related to forest and farmland, and positively to open water, mainly because of high numbers of mountain hare (*Lepus timidus*) in the diet in some coastal areas. The diet variation found in this and other studies from Norway highlight the goshawks' flexibility and adaptability to local prey communities. This emphasises the importance of having a broad perspective on the goshawks choice of habitat and diet, and that goshawk management needs to focus on both typical and alternative habitats and prey.

SAMMENDRAG

I hekkesesongen 2007 undersøkte jeg næringsvalget til elleve par av hønsehauk (*Accipiter gentilis*) ved å samle inn byttedyrrester fra ribbeplasser. Reirene var lokalisert i tre regioner i Hordaland (Norge) med ulik avstand til kysten: Kyst, Midt og Innland. Totalt ble 576 byttedyr identifisert, og 39 ulike arter registrert. Fugler utgjorde 94.3 % av den totale næringen. Kråker og Små spurvefugler dominerte næringen i alle tre regioner. I tillegg var Duer, Rugder (*Scolopax rusticola*) og Pattedyr viktige grupper i Kyst, Duer i Midt, og Hønsefugl i Innland. Næringsvalget til hønsehaukene var generelt variert, og fordelingen av byttedyrgruppene mellom de tre regionene var signifikant forkjellig ($p < 0,001$). Jeg fant den høyeste artsdiversiteten blant byttedyrene i Kyst og Midt. Samtidig var det en høy næringslikhet mellom de tre regionene (PS = 41,1-66,1), sannsynligvis på grunn av høy andel Små spurvefugler og Kråker i alle de tre regionene. Andelen Hønsefugl i dietten økte signifikant fra Kyst til Innland ($p < 0,05$). Det var en signifikant negativ sammenheng mellom andel Hønsefugl i næringen og andel åpent vann i hønsehaukens hjemmeområde ($p < 0,05$), og andel Hønsefugl i næringen og andel jordbruk, med region som tilfeldig variabel ($p < 0,05$). Andelen Rugder var signifikant negativt korrelert til skog og jordbruk, og positivt til åpent vann ($p< 0,05$). I tillegg var det en signifikant positiv sammenheng mellom andel og antall Små spurvefugler (hovedsakelig troster) i næringen og andel jordbruk i hønsehaukens' hjemmeområde, med region som tilfeldig variabel ($p < 0,05$). Pattedyr var signifikant negativt korrelert med både skog og jordbruk, og positivt korrelert med åpent vann. Dette skyldes hovedsakelig et høyt antall skogsharer (*Lepus timidus*) i næringen hos noen av parene i Kyst. Næringsvariasjonen som ble funnet i dette studiet og i andre studier fra Norge fremhever hønsehaukens' fleksibilitet og tilpasningsdyktighet til lokale samfunn av byttedyr. Dette viser viktigheten av å ha et bredt syn på hønsehaukens habitat- og næringsvalg, og at forvaltningen av hønsehauken trenger å fokusere på både typiske og utypiske habitater og byttedyr.

1.0 INTRODUCTION

One of the most common and widely distributed raptor species in Fennoscandia is the forest-dwelling northern goshawk (*Accipiter gentilis*) (Widén 1985a, Tornberg et al. 2006). The goshawk is a medium-sized raptor that is well adapted for hunting medium-sized and large bird species in forested landscapes (e.g. Hagen 1952, Höglund 1964, Widén 1987, Selås 1989a, Overvoll 1994). Albeit goshawks mainly are related to old, mature forests (e.g. Widén 1989, Bergo 1992, Overvoll 1994) they can be observed in all kind of habitats (e.g. Kenward 1982, Marcström et al. 1990, Beier & Drennan 1997, Reynolds et al. 2006). This flexibility enables goshawks to forage in many different environments and prey on different species. In this aspect, the goshawk could be regarded as a generalist (e.g. Höglund 1964, Opdam et al. 1977, Salafsky et al. 2005), and a large spectre of the prey are taken opportunistic (e.g. Höglund 1964, Selås 1989a, Overvoll 1994). The majority of studies in Norway and Fennoscandia have been carried out in large boreal forests where grouse species have been especially important prey (e.g. Hagen 1952, Sulkava 1964, Lindén & Wikman 1983, Widén 1987, Bergo 1992, Tornberg 1997).

A frequently input of new studies reveal that the total number of goshawks has declined in Fennoscandia during the second half of the 20th century (e.g. Widén 1987, 1997, Grønlien 2004). In Norway, the decline has been especially severe in continental areas (Bergo 1992, Grønlien 2004). In example, there have been reported a decline from twenty to seven active territories in Voss from the 1980s to the 1990s (ibid.). The negative population trend has mainly been related to declining prey populations during the winter due to intensified forest management, but also to direct persecution and effects of pesticides (Sollien 1979, Bergo 1992, Widén 1997, Grønlien 2004, Gundersen et al. 2004). Large-scale deforestation has led to a reduction in preferred hunting habitats and also to a decline in some important prey species such as grouse species and red squirrels (*Sciurus vulgaris*), which are related to mature forests (Tømmerås 1993, Widén 1997, Selås 1998, Knoff 1999, Gundersen et al. 2004). Forestry has also destroyed nesting sites by cutting down nest trees or by leaving nest trees in small islands in deforested areas (Bergo 1992, Tømmerås 1993). In all, prey availability, and especially during the winter, is one of the most important factors that regulate goshawk populations (Widén 1997, Gundersen et al. 2004). Despite these threats, the most recent study has concluded that the population in Norway today has more or less stabilised

(Grønlien 2004). In 2006, the goshawk population in Norway was estimated to 2800-4000 reproductive individuals, but is still regarded as vulnerable (Kålås et al. 2006). The status is based on these three criteria (C1); there is an ongoing population reduction, there are less than 10,000 reproductive individuals and there has been a 10% population decrease in the last three generations (18 years) (ibid.).

Some of the recent studies in Norway have been carried out in less typical goshawk habitats, like urban, farmland and coast-near areas (Overvoll 1994, Grønnesby & Nygård 2000, Johansen 2006). Studies carried out in Hordaland have included both typical goshawk habitats (continental boreal forest in Voss; Bergo 1992) and untypical habitats (urban areas in Bergen peninsula; Overvoll 1994, 1999, and coast-near areas in Stord; Overvoll 1999). These studies revealed different diets, but in common they mainly consisted of birds. In Bergen peninsula about 83% of the prey species were more or less prospering in agricultural areas close to human settlement, and pigeons and corvids dominated the diet (Overvoll 1994). At Stord island corvids, thrushes, pigeons and woodcock were the most represented prey (Overvoll 1999). In Voss, grouse species dominated the diet, while corvids and thrushes were the second most important prey groups (Bergo 1992). Other studies have also showed a diet division between cultural and forested areas. Johansen (2006) found that there was a higher proportion of corvids and lower proportion of grouse in the diet in areas with high proportion of farmland compared to forest-dominated areas. The same pattern was detected in central Norway as the proportion of corvids was highest in areas with 44% farmland and the proportion of grouse was highest in areas with 2% farmland (Grønnesby & Nygård 2000).

According to Overvoll (1994) and Sandvik (1996) prey communities in coastal and cultural landscapes are more diverse than in a forested landscape. This may be due to a higher diversity of habitat types and more edges (ibid). Many animals prefer edges as the variety and density of life are often greatest in and around these (Smith & Smith 1998). Species that are most abundant at edges are e.g. woodpigeons (*Colomba palumbus*), song thrushes (*Turdus philomelos*) and corvids (Inglis et al. 1994, Peach et al. 2004, Smedshaug et al. 2002). Although forest dwelling grouse species have been regarded as important and preferred prey for goshawks, the highest breeding density in Fennoscandia may now be found in regions with good access of alternative prey species, such as pigeons, corvids, other passerines, ducks and waders. In western and central Norway the breeding density has been reported to be higher than in continental areas where grouse species were important prey (Bergo 1992,

Overvoll 1994, Sandvik 1996, Steinsvåg 2002, Grønlien 2004).

This study is a supplement to the understanding of goshawks' ecology and investigates the diet of eleven goshawk pairs during their breeding season at the west coast of Norway. The nests were situated in three regions with different distances to the coast. The main objective of this study was to document the diet of goshawks in the three regions during the breeding season. This means firstly; to see if different prey groups dominated the diet in different regions. Secondly, to compare the diet diversity and diet similarity between the three regions. And finally, to see if there are relations between the diet compositions and the occurrence of different habitat types around the nest sites.

I expected that the diets in the three regions would differ due to a gradient in abiotic and biotic factors from coast to inland. This includes abundance of the different prey groups, as well as the availability, which is "the function of food abundance and a consumer's access to the food" (Reynolds et al. 2006), and vulnerability, which is "the prey's capability to hide or flee once it is detected and its defence ability after attack" (Tornberg 1997). I expected an increase of grouse from coast to inland, based on their preference for continuous boreal forests and mountain forests. In the coast-near region I expected the diet to consist of more ducks and waders. Further, I expected a more diverse diet at the coast than in the inland, based on the assumption that there is a larger spectre of alternative prey species at the coast than in the inland. However, I also expected a high diet overlap between the regions, as previous diet studies have showed a high abundance of thrushes and corvids in the diet in most habitats. Finally, I expected that differences in diet composition could be explained by differences in the composition of habitat types within the goshawks' home ranges.

2.0 METHODS

During May-July 2006, I visited 11 goshawk nest sites seven times for collection of prey remains. The study was carried out in Bømlo, Stord, Fitjar, Os, Bergen and Voss Municipalities, Hordaland County, western Norway (Fig. 1). The nests were located in three regions based on different distances to the coast; Coast (islands of Bømlo and Stord), Middle (Bergen peninsula) and Inland (Voss). Distance, stated in air line, from the coastline to the regions is; Bømlo and Stord islands 0-10 km, Bergen peninsula 30-40 km, and Voss 80-90 km. All nest sites are located in a landscape with quite roughed topography.

2.1 Study area

In the first study area, Coast (59°73´-59°96´N, 05°26´-05°48´E, Fig. 1), four nests were examined (Table 1, Appendix 1). This region is situated in the boreo-nemoral and the south-boreal zone with a strong oceanic climate (Moen 1998). There are relatively high winter temperatures, low summer temperatures, high precipitation levels and high air humidity (ibid). The landscape of the islands consists of coastal heathlands, forests, bogs, small lakes, farmland and urban areas. Scots pine (*Pinus sylvestris*) dominates the forests, albeit deciduous tree species are locally highly abundant. At the ground level heather (*Ericaceae* spp.), moss (*Bryophyta* spp.) and juniper (*Juniperus communis*) are dominating. The study area was situated at an altitude ranging from 0-200 m a.s.l.

In the second study area, Middle (60°22´-60°25´N, 05°38´-05°47´E, Fig. 1), three nests were examined (Table 1, Appendix 1). This region is a part of the boreo-nemoral, south-boreal and middle-boreal zone, and has a clear oceanic climate (Moen 1998). The landscape consists of mainland and a few big islands, and is a mixture of urban areas, forests, small lakes and farmlands. Scots pine primary dominates the forest fragments, and are often found along with downy birch (*Betula pubescens*) and locally with common oak (*Quercus robur*) (Overvoll 1994). Heather dominates the ground vegetation. The forestry is quite intensive at a local level, but a relatively small part of the forest fragments are managed (Overvoll 1994). Norwegian spruce (*Picea abies*) is the most replanted species in clear-cuts. The study area is situated at an altitude ranging from 100-200 m a.s.l.

In the third study area, Inland (60°65´-60°81´N, 06°48´-06°70´E, Fig. 1), four nests were examined (Table 1, Appendix 1). This region is situated in the south-boreal and the middle-boreal zone with a clear to weak oceanic climate (Moen 1998). There are higher temperature variations between winter and summer compared to the Coast, and there are less precipitation levels (ibid.). The nest sites were situated in the eastern parts of Voss which are weak oceanic, and with that the most continental characterized region. Bare rocks and unproductive forests dominate in the region (73.3%) (Voss Municipality 2007). The rest of the area is a mixture of farmland, productive forests, bogs and urban areas. Scots pine primary dominates the forests, while replanted Norwegian spruce dominates locally. Vegetation on the ground is dominated by lichen (*Lichens* spp.), moss and heather. A large share of the forest in Voss is managed, and locally the forestry is intense. Three of the nest sites were situated in forest stands which were influenced by forestry. The study area is situated at an altitude ranging from 200-500 m a.s.l.

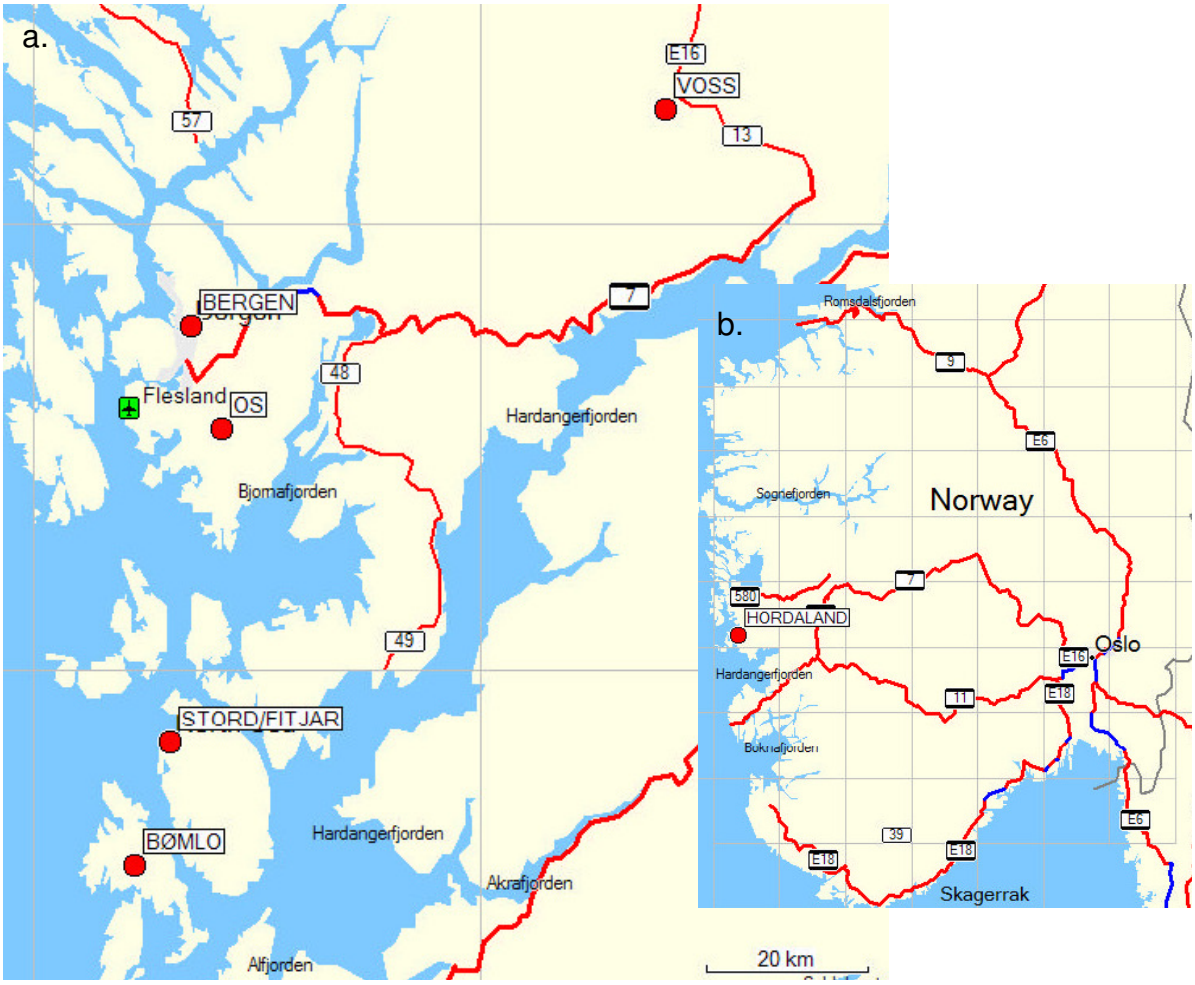


Figure 1 a. The study regions in Hordaland County where 11 goshawk nest sites were visited seven times for collection of prey remains from plucking posts during the breeding season of 2006. The study was carried out in Bømlo, Stord, Fitjar, Os, Bergen and Voss Municipalities (red circles). b. Overview of southern Norway. Red circle = the study area in Hordaland. (Statens kartverk 2003).

Table 1. Nest characteristics for each nest site investigated during the goshawks' breeding period in Hordaland County, 2006. Nest qualities; Altitude (metres above sea level), number of nestlings, and percent of farmland, forest and open water found within a two kilometre radius from the nest site (home range).

	Region	Altitude (m a.s.l.)	No. of nestlings	% farmland	% forest	% open water
1	Coast	38	2	3.0	41.1	47.9
2	Coast	60	3	3.2	70.5	13.6
3	Coast	195	4	1.7	29.8	47.6
4	Coast	20	2	3.0	40.0	31.0
5	Middle	163	2	8.8	74.0	13.1
6	Middle	122	3	7.5	83.0	7.7
7	Middle	180	2	14.8	59.0	7.4
8	Inland	250	2	24.2	72.0	0.0
9	Inland	235	4	14.5	73.4	1.2
10	Inland	483	2	9.2	72.2	8.2
11	Inland	449	2	6.1	74.8	0.0

2.2 Collection of prey remains

At the first visit I searched thoroughly for potentially plucking posts and prey remains under the nest and within a 100 metre radius from the inhabited nest. I searched this distance because it is documented that most posts are located within that distance (Selås 1989b). Typical posts were fallen trees, branches, stones, and elevations in the landscape facing the nesting tree. On later visits I searched all the known posts for prey, and by doing so I searched for prey at the same route at each visit. Old prey were also collected, but not included in the material. Pellets were collected when spotted, but were not systematically searched for. To avoid replication, the materials found in pellets were only counted in the total material when the species was not found as feathers or bones outside the pellets. All remains were collected in bags to avoid replication and marked with locality and date for later identifications.

In the laboratory, the material was identified to species, and if possible to sex and age. Identification was based on reference collections of bones and feathers. To avoid replication when I found feathers or bones from the same species at different plucking posts, the fragments were compared and interpreted to be one or two individuals from features in the material (age, wear and tear, and sex). For the statistical analyses, each prey was classified

into one of eight classes; Grouse, Pigeons, Corvids, Small passerines (thrushes and smaller passerines), Woodcock (*Scolopax rusticola*), Ducks & waders, Other birds and Mammals. I chose this classification based on ecological and systematic logic.

The method of collecting prey remains at plucking posts leaves some biases (Sulkava 1964, Opdam et al. 1977, Nielsen 1986, Widén 1987, Selås 1989b, Sonerud 1992, Nygård et al. 1998, Rutz 2003, Sveen 2006). Some prey items are not brought to the nest. These are mainly small ones which are eaten immediately after capture, because they are not energetically economic to transport to the nest. Hence, prey transported to the nest sites might not be representative for the prey killed. Another factor is that not all prey leaves remains. Small prey might be eaten without plucking, and will thus not be detected by the method I used. But also prey remains, both bones and feathers, of small prey will be more difficult to detect than remains of large ones, because of their small size and because they persists in shorter time in the environment than large ones. This might lead to an underestimation of small prey species. In addition, brightly coloured, pale or contrast rich feathers are easier to detect and identify than dark and plain ones. In all, this might lead to a bias towards an overrepresentation of large and conspicuous prey species which are transported to the nest.

There is also a potential risk of double counting prey from remains, since the goshawk might move prey around at several plucking posts. This risk is highest for common bird species where individuals are difficult to distinguish and for larger prey where the handling time is long. At the same time, prey might be lost to scavengers, especially for the larger prey types that are too large to be transported to the nest in one piece. Despite of these biases, the method has frequently been used in diet studies (e.g. Opdam et al. 1977, Widén 1987, Selås 1989a, Bergo 1992, Overvoll 1994, Tornberg 1997). Recent video studies have revealed frequency inaccuracies by use of the prey remain method (Rutz 2003, Sveen 2006). Sveen (2006) found that video recording was most appropriate to estimate the quantity of each species in the diet, while prey remains was most appropriate to estimate the diversity in the diet and age structure of the prey. But most important for my study is that these biases would most likely be the same in all the studied territories, so that there should be no problems by comparing the diet from the three regions.

2.3 Statistical analyses

To evaluate the diet diversity I used the Simpson's Reciprocal Index (1/D) (Smith & Smith 1998). This diversity index is calculated from the probability that two randomly selected individuals belong to the same species. Species diversity relates to both species richness and species evenness, of which this index takes into account (Smith & Smith 1998). Here the species richness is related to number of species, while species evenness is related to the relative abundance of individuals among the species. The species diversity was calculated from the formula:

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

where n is the number of prey items of a species group and N is the total number of remains of all species (Smith & Smith 1998). Prey items not identified to species were not included in the calculations.

To estimate the diet similarity between the three regions I used Sorensen's coefficient of percent similarity (PS) (Smith & Smith 1998). This test ranges from 0 (no similarity) to 100 (identical diets). To calculate the similarity I used the species abundance in the diet from each region as percent, and added up the lowest percent for each species that the regions had in common. The sum of percents shows diet percent similarity between the two regions.

To see if there were any relationships between the proportion of prey groups in the diet and the availability of habitat types, I mapped the proportion of forest, farmland and open water (sea and lakes) in each home range. Maps were obtained from The Norwegian Forest and Landscape Institute (2007), and managed in ArcView GIS 3.3 (ESRI 2002). A circle with two kilometre (ca. 13 km^2) radius was made around each nest (home range from now on). This radius was chosen due to a general rule that goshawks usually do not breed closer than approximately four kilometres from each other (Grønlien 2004).

The number of prey remains varied greatly between the territories. Some territories had one or more plucking posts that were frequently used, so that large amounts of both bones and feathers were found. At others, the prey remains were more scattered between several plucking posts and thereby more difficult to detect. Because of these differences I used a proportion approach in most of my analyses. I compared my results with results from other

studies in Hordaland; all presented as proportion of prey (Appendix 2). There is, however, a weakness of comparing percent frequencies of prey between different studies (Selås 1989b). That is, if there are large biases concerned to one of the species collections, these biases would give effect on the other prey groups' frequency. For instance, if the lack of a few frequently used plucking posts made it more difficult to detect remains of small prey, then it would be better to use real numbers than proportions when comparing the occurrence of large prey between different nest sites.

I used the statistical programs JMP 4.0 (SAS Institute Inc 2000), SPSS 14.0 (SPSS Inc. 2005) and R 2.4.1 (R Foundation 2006) when analysing the data. To test for differences between the regions with regard to prey group composition, I used a chi-square test. I used both the proportion of the prey group in the diet and the number of items of the prey group as response variable when testing for relationships between each prey group and different habitats. First, I used Spearman rank correlation to test whether the proportion of each prey group was related to the percent of farmland, forest or open water within the home range, and to region. Thereafter, I used linear regression analyses to test for the same relationships, but then I also used multiple models with each prey group as response variable and the different habitats as explanatory variables, and with region as a random effect. Only results from models with normally distributed residuals were used. Univariate and multivariate Poisson or Quasipoisson (if overdispersion) analyses were used to find relationships between the numbers of individuals in the different prey groups and the proportion of habitat within the goshawks' home range, and with region as random effect. All statistical analyses have significance level set at $p = 0.05$ and were two-tailed.

3.0 RESULTS

A total of 576 prey items were identified from the 11 goshawk territories (Appendix 3). Of these, 99.5% were classified to species level. In all, 39 prey species of birds and mammals were recorded, of which 34 were birds. The mean number of prey species found at each nest site was 14.4 ± 3.4, ranging from 9-21. Birds covered 94.3% of the total diet.

3.1 Variation in diet by prey groups in the three regions

At the Coast, 242 prey items were found, belonging to 23 different species of birds and 4 species of mammals (Appendix 3). Bird prey represented 90.1% of the collected material. Small passerines were most important and accounted for 30.1% of all the prey (Fig. 2). Blackbird (*Turdus merula*) was the most numerical species in this group with 37 prey items (50.7%). Corvids accounted for 19.0% of the total material, of which Eurasian jay (*Garrulus glandarius*, jay from now on) and hooded crow (*Corvus corone cornix*) accounted for 39% and 37%, respectively. The most numerical species was woodcock, which alone accounted 41 prey items (16.9%).

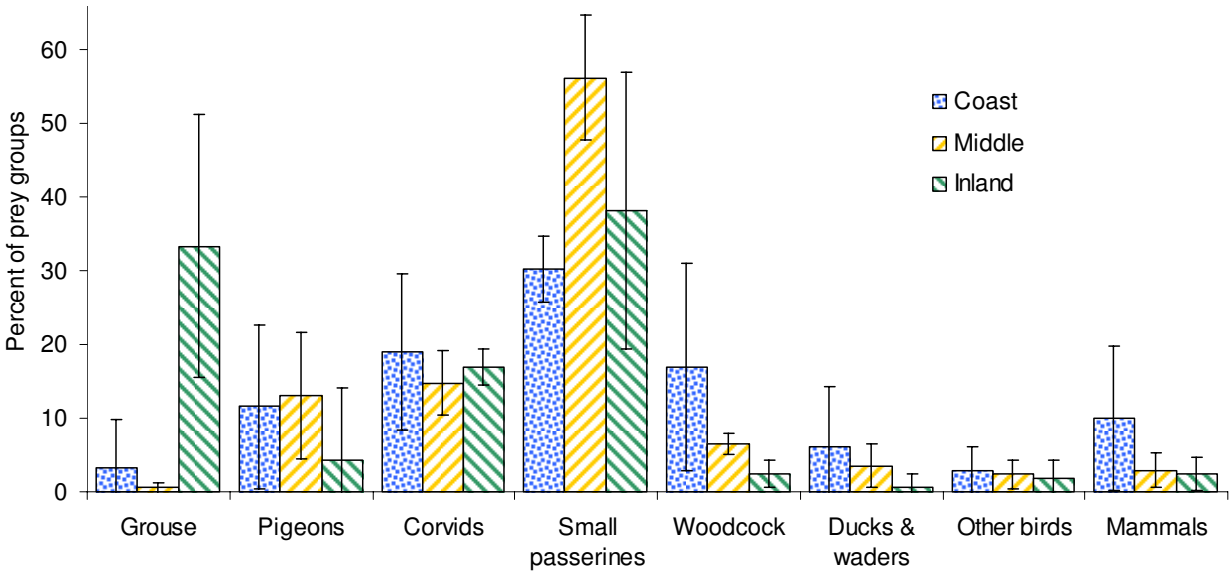


Figure 2. The proportion of prey groups found around goshawks nests in the three regions in Hordaland during the breeding season. Dotted bars = Coast, positive tilted bars = Middle, and negative tilted bars = Inland.

At the Middle 169 prey were registered, with 22 different species of birds and two mammal species (Appendix 3). In all, 97% of the material was bird prey. Small passerines were the most important prey group with 56.2% of all prey items, together with Corvids (14.8%) and Pigeons (13.0%, Fig. 2). Blackbirds accounted for 38% of the class Small passerines, and thus was the most numerical prey species in this class. Black-billed magpie (*Pica pica*, magpie from now on) was the dominating species in the Corvid material (68%). The number of feral pigeons (*Columba livia domestica*) in the diet was 2.6 times higher than the number of woodpigeons.

In Inland 165 prey were registered. The diet consisted of 19 species of birds and two species of mammals (Appendix 3). In all, 97.6% of the material was bird prey. Grouse and Small passerines were the most important prey groups (Fig. 2). The dominant prey species were willow ptarmigan (*Lagopus l. lagopus*) and fieldfare (*Turdus pilaris*). Willow ptarmigan accounted for 71% of the Grouse group and fieldfare accounted for 47.6% of the Small passerines group. The third most important prey group was Corvids, where magpie was by frequency the dominating species (50%).

There was significant more adult prey than juveniles in the data ($\chi^2 = 121.8$, d f= 7, $p < 0.001$). Juvenile prey represented 25.3% of the total prey number, and adult prey 74.4%. Juvenile prey represented 25.3% among Corvids, 46.3% among Small passerines and 45.6% among Mammals.

The goshawk's diet was generally diverse, and there was a significant difference in the relative abundance of the prey groups between the three regions ($\chi^2 = 172.5$, df = 14, $p < 0.001$) (Fig. 2, Appendix 3). Corvids and Small passerines were dominating prey groups in all three regions. More than 80% of the diet in Coast consisted of Corvids, Small passerines, Pigeons, Woodcock and Mammals. In Middle more than 80% of the diet consisted of Corvids, Small passerines and Pigeons, while in Inland Corvids, Small passerines and Grouse made up more than 80% of the total diet.

3.2 Diet diversity and similarity between the three regions

Every species, except unidentified birds, were used in the calculations of the diet diversity. The diet diversity was higher in Middle and Coast compared to Inland (Table 2). However, both the lowest and highest index was found from nests located in Inland (Table 2).

The diet similarity fluctuated around 50% between all the three regions. The highest diet similarity was found between Coast and Middle, whereas the least similar diet was found between Coast and Inland, PS = 66.1 and PS = 41.1, respectively. Diet similarity between Middle and Inland was calculated to PS = 44.5.

Table 2. Diet diversity in the breeding season of goshawks tested by the Simpson's Index in the three regions and at each nest. Species = number of species identified at each region or nest site, n = number of remains found at each region or nest site, 1/D = the Simpson's Index (see 2.0 Method). Unidentified birds are not included.

	Coast	**Middle**	**Inland**	1	2	3	4	5	6	7	8	9	10	11
Species	27	24	21	16	15	14	13	14	15	21	13	10	17	9
n	242	169	165	48	72	53	67	40	51	78	65	19	57	23
1/D	**29.3**	**30.0**	**20.4**	11.5	8.3	9.0	5.3	9.6	8.6	12.3	5.1	13.2	7.8	8.1

3.3 Relationships between prey groups and habitat

The proportion of some of the prey groups in the diet were related to the habitat types found in the goshawks' home range. In the non-parametric correlation models, this was found for Grouse and open water, Woodcock and open water, Woodcock and farmland, and Mammals and farmland (Table 3). None of the other prey groups showed any significant relationship with the proportion of farmland, forest or open water within the home ranges in these analyses.

The linear regression analyses revealed that there was a significant increase of the proportion of Grouse in the diet from Coast to Inland (Table 4). No other prey group showed significant relationships with the explanatory factor region. The same type of test showed a significant negative relationship between proportion of Woodcock in the diet and the proportion of forest within the home range (Table 4). However, this significant result was due to an outlier, and the relationship became not significant when I removed this nest from the test (df = 1, SS = 17.79, F ratio = 1.50, p = 0.255, $R^2 = 0.16$).

The multivariate regression analyses showed that the proportion of both Grouse and Small passerines in the diet was significantly related to percent farmland, with region as random effect (Fig. 3a and b). The proportion of Grouse in the diet was negatively related to farmland within the home range (Farmland %: df = 1, SS = 520.3, F ratio = 7.4, p = 0.020, R^2 = 0.836, Region: df = 2, SS = 3104.8, F ratio = 22.2, p < 0.001, R^2 = 0.721), whereas the proportion of Small passerines was positively related to farmland (Farmland %: df = 1, SS = 1134.1, F ratio = 34.8, p < 0.001, R^2 = 0.349, Region: df = 2, SS = 1389.2, F ratio = 21.3, p < 0.001, R^2 = 0.886).

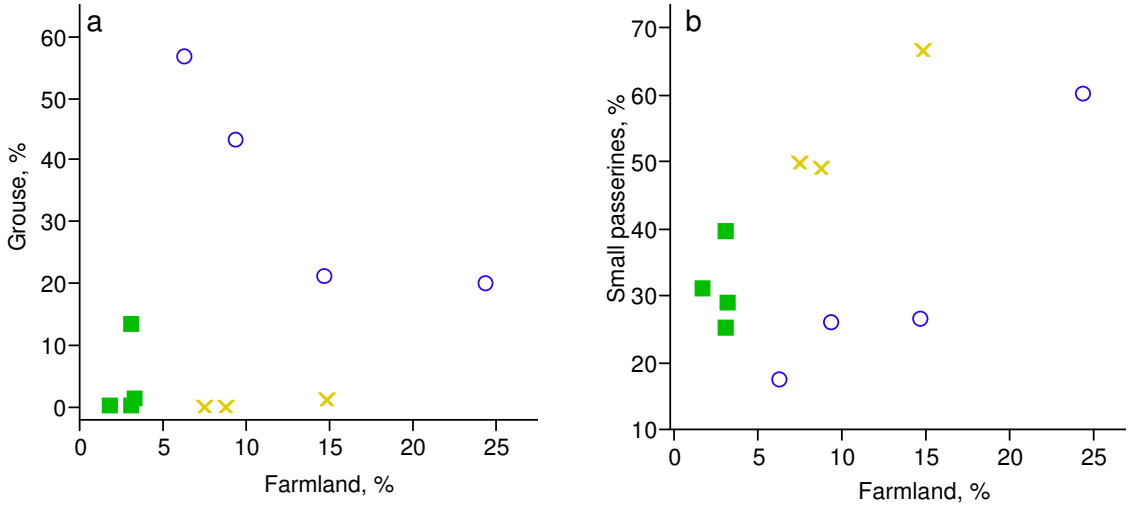


Figure 3. Significant relationships between the proportion of a) Grouse and b) Small passerines in goshawk diets and the proportion of farmland in the goshawks' home ranges, with region as random effect. Blue square = Coast, yellow cross = Middle, green circle = Inland.

Table 3. Relationships between the proportion of goshawks' prey groups and the proportion of habitat around the goshawks' nest sites. Analyses carried out with univariate Spearman rank correlations. R_{h0} = correlation coefficient, n = number of nests, p = significance value. Significant values are marked bold.

	Farmland %			Forest %			Open water %		
	R_{h0}	n	p-value	R_{h0}	n	p-value	R_{h0}	n	p-value
Grouse	0.380	11	0.249	0.261	11	0.439	-0.625	11	**0.039**
Pigeons	-0.021	11	0.952	0.082	11	0.811	0.358	11	0.279
Corvids	-0.150	11	0.952	0391	11	0.235	0.009	11	0.978
Small passerines	0.433	11	0.184	-0.064	11	0.852	-0.178	11	0.601
Woodcock	-0.756	11	**0.007**	-0.482	11	0.113	0.715	11	**0.013**
Ducks & waders	-0.373	11	0.259	-0.423	11	0.195	0.583	11	0.059
Other birds	-0.016	11	0.962	-0.195	11	0.564	0.201	11	0.554
Mammals	-0.016	11	**0.043**	-0.551	11	0.079	0.514	11	0.106

Table 4. Univariate linear regression models with the proportion of different prey groups in goshawks' diet as response variables, and region (random variable) or proportion of different habitat types in the goshawks' home range as explanatory variables. Only results from models with normally distributed residuals are given. Significant values are marked bold. * = significant due to an outlier.

Response	Ex. variable	Effect	df	SS	F ratio	p-value	R^2
Grouse	Region		2	2773.6	10.30	**0.006**	0.721
	Forest %	+	1	469.3	1.25	0.292	0.122
	Open water %	-	1	919.4	2.83	0.127	0.239
Pigeons	Region		2	122.4	0.60	0.568	0.132
	Farmland %	-	1	26.1	0.30	0.622	0.028
	Forest %	+	1	42.7	0.40	0.531	0.045
Corvids	Region		2	10.5	0.10	0.902	0.025
	Farmland %	-	1	7.5	0.17	0.689	0.018
	Forest %	+	1	68.3	1.85	0.207	0.170
	Open water %	-	1	11.6	0.27	0.618	0.028
Small passerines	Farmland %	+	1	904.6	4.84	0.055	0.349
	Forest %	+	1	47.1	0.17	0.692	0.018
	Open water %	-	1	165.3	0.61	0.453	0.064
Woodcock *	Forest %	-	1	468.3	8.07	**0.019**	0.473
Other birds	Region		2	2.2	0.29	0.750	0.069
	Farmland %	-	1	0.1	0.03	0.866	0.003
	Forest %	-	1	0.0	<0.01	0.950	<0.001
	Open water %	-	1	0.2	0.06	0.799	0.007
Ducks & waders	Open water %	+	1	94.6	4.25	0.069	0.321

The univariate Poisson or Quasipoisson regression analyses revealed that the number of both Woodcock and Mammals were negatively related to the proportion of forest in the goshawks' home range (Table 5). The analyses also revealed a significant positive relationship between the number of Woodcock and Mammals and the proportion of open water (Table 5). Poisson and Quasipoisson analyses gave the same results. The relationship between the number of Mammals and proportion of both forest and open water had an outlier, but when I removed this nest the relationships were still significant (Poisson; forest - estimate = -0.040, st. error = 0.008, t-value = -4.946, p = 0.001, open water - estimate = 0.034, st. error = 0.009, t-value = 3.730, p = 0.005). Also the relationship between the number of Woodcock and the proportion of both forest and open water was enhanced by an outlier, and the relationship became not significant when I removed this nest from the tests (Poisson; forest - estimate = -0.017, st. error = 0.015, t-value = -1.164, p = 0.278, open water - estimate = 0.017, st. error = 0.013,

t-value = 1.312, p = 0.226). When including region as a random effect, also the relationship between Small passerines and farmland became significant (Table 6, Fig. 4). The result for Woodcock and Mammals were not changed (Table 6, Fig. 4).

Table 5. Univariate Poisson regression models with the number of different prey groups found at goshawks' nest sites as response variables and the proportion of different habitat types in the goshawks' home range as explanatory variables. Significant values are marked bold. * = significant due to an outlier.

Response	Ex. variable	Effect	Estimate	St. error	t-value	p-value
Grouse	farmland	+	0.051	0.058	0.875	0.404
	forest	+	0.028	0.031	0.899	0.392
	open water	-	-0.052	0.042	-1.244	0.245
Pigeons	farmland	-	-0.053	0.050	-1.058	0.317
	forest	+	0.006	0.018	0.322	0.747
	open water	+	0.010	0.016	0.658	0.527
Corvids	farmland	-	-0.014	0.029	-0.473	0.648
	forest	+	0.002	0.011	0.167	0.871
	open water	+	0.003	0.010	0.253	0.806
Small passerines	farmland	+	0.041	0.023	1.784	0.108
	forest	-	-0.002	0.012	-0.196	0.848
	open water	-	-0.004	0.012	-0.358	0.729
Woodcock *	farmland	-	-0.155	0.082	-1.885	0.092
	forest	-	-0.046	0.012	-3.573	**0.006**
	open water	+	0.042	0.012	3.488	**0.006**
Ducks & waders	farmland	-	-0.097	0.088	-1.103	0.298
	forest	-	-0.026	0.020	-1.288	0.230
	open water	+	0.034	0.018	1.932	0.085
Other birds	farmland	-	-0.047	0.050	-0.931	0.376
	forest	-	-0.008	0.016	-0.520	0.616
	open water	+	0.004	0.016	0.270	0.793
Mammals	farmland	-	-0.145	0.077	-1.869	0.094
	forest	-	-0.048	0.012	-3.399	**0.003**
	open water	+	0.037	0.015	2.389	**0.041**

The multivariate Poisson regression analyses revealed significant relationships between the number of Woodcock and Mammals and the proportion of habitats in the home ranges (Table 6, Fig. 4). These analyses were executed both with and without region as a random effect. There was a significant negative relationship between the number of Woodcock and the

proportion of forest, a significant positive relationship between the number of Woodcock and the proportion of open water, a significant negative relationship between the number of Mammals and the proportion of forest, and a significant positive relationship between the number of Mammals and proportion of open water. The relationship between the number of Mammals and the proportion of forest and open water was still significant when I removed the outlier (Poisson; forest – estimate = -0.040, st. error = 0.008, df = 6, t-value = -4.946, p = 0.002, open water – estimate = 0.035, st. error = 0.009, df = 6, t-value = 3.729, p = 0.009). For the Woodcock, the proportion of both forest and open water were not significant when I removed the outlier (Poisson; forest – estimate = 0005, st. error = 0.011, df = 6, t-value = 0.426, p = 0.685, open water – estimate = -0.017, st. error = 0.011, df = 6, t-value = -1.561, p = 0.169).

In all, the univariate and the multivariate Poisson analyses showed the same significant relationships between the prey groups and habitats. The random variable region was not decisive for the results, except for the relationship between Small passerines and farmland, which was not significant without region as random effect.

Table 6. Multiple Poisson regression models with the number of different prey groups found at goshawks' nest sites as response variables and the proportion of different habitat types in the goshawks' home range as explanatory variables. Region is included as a random variable. Only results from models that were significant are given. * = significant due to an outlier.

Species	Habitat	Effect	Estimate	St. error	df	t-value	p-value
Small passerines	farmland	+	0.094	0.022	7	4.165	0.004
Woodcock *	forest	-	-0.046	0.012	7	-3.572	0.009
	open water	+	0.048	0.012	7	3.488	0.010
Mammals	forest	-	-0.048	0.012	7	-3.992	0.005
	open water	+	0.037	0.015	7	2.389	0.048

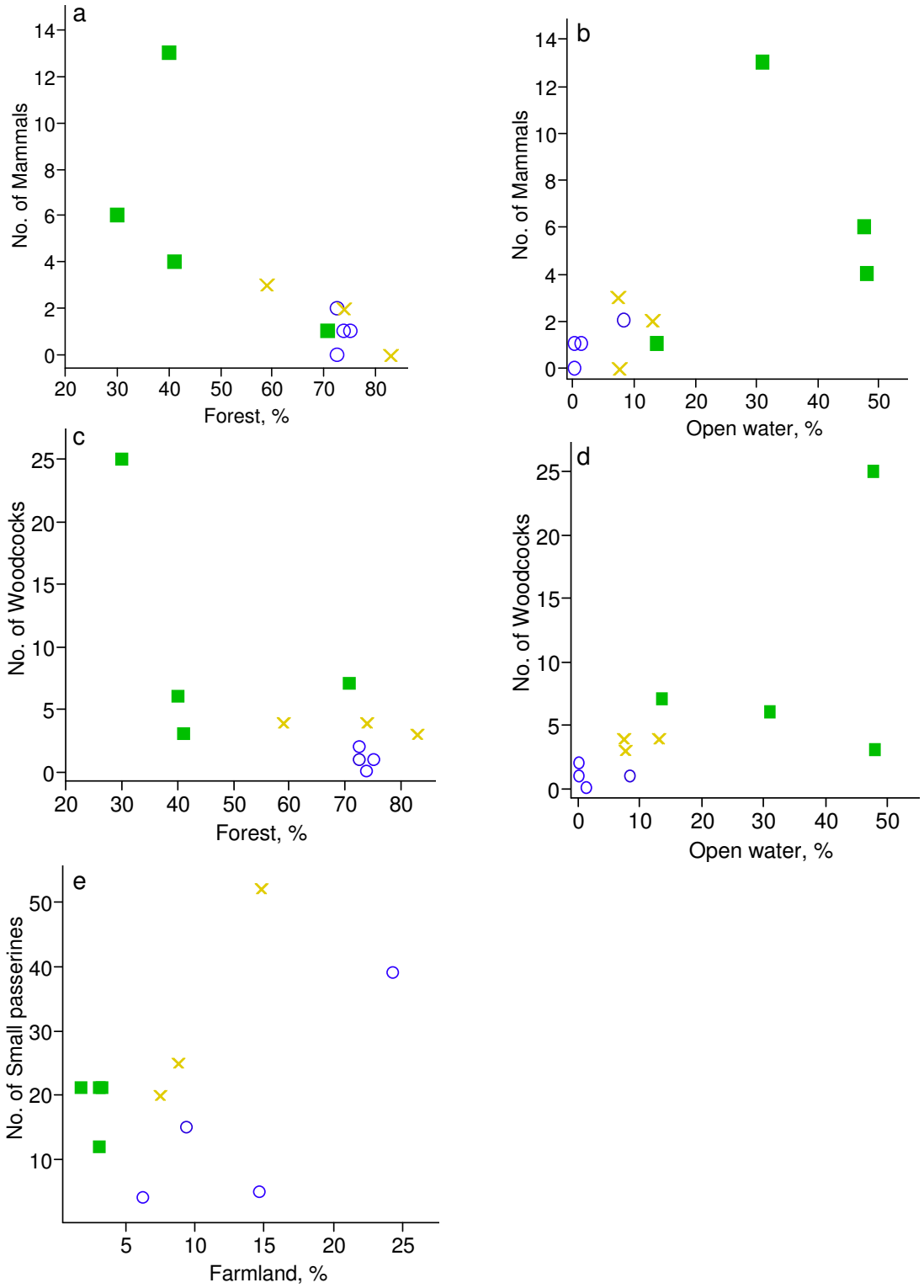


Figure 4. Number of different prey groups in relation to proportion of different habitats in the goshawks' home ranges. Region is included as a random variable. Only results from Poisson regression models that were significant are given. a. number of Mammal and proportion of forest, b. number of Mammal and proportion of open water, c. number of Woodcock and proportion of forest, d. number of Woodcock and proportion of open water, and e. number of Small passerines and proportion of farmland. Blue square = Coast, yellow cross = Middle, green circle = Inland

4.0 DISCUSSION

4.1 Diet composition

In accordance with other studies carried out in Fennoscandia (e.g. Widén 1985b, Selås 1989a, Tornberg 1997, Overvoll 1994, Grønnesby & Nygård 2000), I found that the goshawks mainly hunted birds and that they preyed on various species during the breeding season. In this study, 94.3% of the prey items were identified as birds. A total of 39 species of birds and mammals were identified, of which 34 were identified to birds. The total frequency of juveniles in my study was lower than reported in other studies (Opdam et al. 1977, Selås 1989a). However, this might be due to an underestimation of juveniles because juvenile feathers are more difficult to find (Selås 1989b) or impossible to find because there are no remains (Nielsen 1986, Overvoll 1999) and that identifying bones to be juveniles are often difficult (V. Selås pers. comm.).

The local fauna of potential prey species is not represented in the goshawks' diet as a random sample (Opdam et al. 1977, Tornberg 1997). This is due to several factors. First, goshawks have several characteristics that influence their ability to prey upon different species (Opdam et al. 1977, Tornberg 1997, Toyne 1998, Johansen 2006). Second, prey species differ with regard to characteristics that influence their vulnerability to predation (Höglund 1964, Opdam et al. 1977, Widén 1987, Selås 1989b, Marcström et al. 1990, Reynolds et al. 2006). Their size, colour, age, condition, flying ability, activity pattern, solitary or group activity and habitat use influences their vulnerability to goshawk predation. For example, solitary, slow flying forest-dwelling species like pigeons and jays are more vulnerable than open land-dwelling, competent flyers like gulls (Opdam et al. 1977). Another example is that for some grouse species, females are more vulnerable than males, due to their smaller size and higher degree of exposure during the breeding period (Höglund 1964, Widén 1985a, 1987, Marcström et al. 1990, Tornberg 1997).

As a forest-dwelling raptor, the goshawk may be less efficient when hunting in open and semi open landscapes. However, the goshawk might use different hunting techniques, depending on prey species and characteristics of the hunting habitat (Opdam et al. 1977, Marcström et al. 1990, Grønlien et al. 1993, Beier & Drennan 1997, Johansen 2006). Different hunting

techniques make it possible to utilize more of the habitats, for example areas with fluctuating ground cover or forest stands with variable tree closure (Beier & Drennan 1997).

I found few prey related to open water in the diet, despite of a high frequency of open water around the nest sites at the Coast. This might indicate that open water was not preferred as hunting habitat. This was probably because goshawks depend on surprise attacks and need as such cover to hunt. In Sweden, a study reported that ducks were only predated on land or at watersides (Marcström et al. 1990), which supports this suggestion. There were only two gulls (*Laridae* sp.) predated, both from the same nest site at Coast. That gulls are rarely predated is also found in other studies (e.g. Höglund 1964, Opdam et al. 1977, Grønnesby & Nygård 2000). Höglund (1964) suggested that goshawks disliked gull-meat and thus did not predate gulls, whereas Opdam et al. (1977) suggested that there were more vulnerable species than gulls present, so that goshawks did not practice gull-hunting. Probably, factors like degree of vulnerability and habitat preference of the prey are causing the low proportions of water related species in the diet.

4.2 Grouse in the diet

The linear regression analysis revealed a significant relationship between Grouse and regions. This was as expected, due to a higher amount of grouse habitats and thus higher availability of grouse in Inland than in the other regions (Bergo 1992, Steinsvåg & Overvoll 2003, 2004, 2005, Håland & Mjøs 2006). This gradient was also in accordance with previous studies from Hordaland (Bergo 1992, Overvoll 1994, 1999). The proportion of Grouse in the diets at Coast and Middle was low compared to the diet from Inland, and also compared to some other diet studies from Fennoscandia (Hagen 1952, Sulkava 1964, Wikman 1977, Widén 1987, Marcström et al. 1990, Tornberg 1997). These studies have emphasized the importance of grouse as the main food supply, and suggested that goshawks utilize small prey like thrushes, corvids and pigeons as complementary prey. In my study these complementary species dominated the diet in Coast and Middle. This is similar to diets found in cultivated or urban areas in central and Western Europe (Opdam et al. 1977, Nielsen 1986, Mañosa 1994, Penteriani 1997, Toyne 1998, Rutz 2003), and Norway (Overvoll 1994, Grønnesby & Nygård 2000, Johansen 2006). These studies were carried out in heterogeneous landscapes with mosaics of farmland, urban areas and patches of forest. This indicates that the diet of goshawks reflects prey supply and that goshawks can adapt to local available prey species. In

all, this reflects that generalisation about goshawks' diet is more or less pointless, because goshawks are flexible and adapts to the local prey community.

4.3 Diet diversity and similarity between the three regions

As expected, the diet diversity was higher in the regions Middle and Coast than in Inland. In general, the prey communities in coastal and cultural landscapes are more diverse than in a forested landscape (Overvoll 1994, Sandvik 1996). This is due to higher habitat diversity and higher amounts of edges. Edges contribute to a high prey diversity, which goshawks probably take advantage of. At Coast and Middle the landscapes were highly fragmented and consisted of edges between forest and open water, heather moors/bare fields, farmland or urban areas. The suggestion that woodland edges are preferred rather than open areas or deep woodlands have been supported by studies in farmland dominated landscapes in Sweden (Kenward 1982). In continuous boreal forests in Sweden, however, edges seem to be less important. Here, large patches of mature forests are preferred hunting habitats (Widén 1989). I assume goshawks utilize all available hunting habitats, depending on prey availability, as it is regarded as a generalist and an opportunist. But the higher diet diversity found in Coast and Middle might be partially due to a higher utilization of edges compared to Inland.

Other possible explanations for why the total species diversity in Inland was lower than in the other regions might be that the nesting sites were situated at higher elevations than the nests in Coast or Middle. Penteriani (1997) found a low diet diversity at high elevations compared to lower elevations, due to limitations of number and types of bird species available. In addition, it may be important that the prey group Grouse was most available in the Inland, because when a preferred prey is available the species diversity declines (Lindén & Wikman 1983).

I found the highest number of prey species in the Coast region, with 27 different species. This region has a high amount of edges between forest and open water, and one of the nests was located on a circa 450 km^2 large island, 600-1000 metre from the mainland. The suggestion that edges between forest and water were used for hunting was supported by the occurrence of water related species like terns, gulls, ducks and waders in the diet. However, the frequency of these species in the total diet was rather low. In fact, there are some disagreements to what degree goshawks utilize edges between forest and open water. Overvoll (1994) claimed that there was no typical edge effect between forest and open water, because this is a poor transition vegetation zone and that open water is an unfavourable environment for most terrestrial organisms. On the contrary, Kenward (1982) showed that goshawks tended to

follow water courses, and Steinsvåg (2002) argued that goshawks utilize these edges due to high prey density and cover from the forest when hunting.

The percent diet similarity between the three regions fluctuated around 50%. This high similarity was not surprising, since Corvids and Small passerines were the dominating prey groups in all the three regions. There are several factors that affect the diet diversity and similarity, e.g. geographical variations of abundance and availability of local bird and mammal fauna (Salafsky et al. 2005). My results indicated that the local prey fauna at the Coast and in the Middle were relatively similar, while Inland had a somewhat different prey fauna. This was more or less expected, as Coast and Middle have a more similar climate and habitat composition compared to Inland.

4.4 Relationships between prey groups and habitat

There should be a positive relationship between the availability of a prey species and the occurrence of the habitat type that the species most frequently utilize. Thus, there should also be some relationships between the proportion of different habitat types found in the goshawks' home range and the frequency of species in the goshawks' diet. However, such relationships were found only for a few prey groups in this study. This might be because the goshawk prefer some habitat types and spend most of the hunting here regardless of the abundance of these habitats. Further, the home range estimates used in the analyses may not have been representative for the hunting ranges. The actual hunting range might extend beyond the artificial home range perimeter of two kilometres and more or less in some directions, depending on the availability of preferred hunting habitats.

When interpreting the results, it should be remembered that the explanatory variables are highly intercorrelated, e.g. a high proportion of one habitat means a lower proportion of the other. Based on the species habitat preferences, most of the significant relationships between species and habitats were as expected. Only the relationship between the proportion or number of Woodcock in the diet and habitat types (positive for open water, negative for farmland and forest) may seem somewhat strange, since woodcocks are typically found in woodlands (Haftorn 1971, Cramp & Simmons 1983). However, earlier studies from Hordaland have revealed a similar pattern (Bergo 1992, Overvoll 1994, 1999). At Bømlo and Stord island, the woodcock is regarded as a common species (Steinsvåg & Overvoll 2003,

2004), and was one of the important prey groups in this region. In Bergen peninsula, the woodcock is also is regarded as a common species (Steinsvåg & Overvoll 2005, Håland & Mjøs 2006), albeit the proportion of Woodcock in the diet was not as high as one would expect based on the utilization at the Coast. Woodcock was not an important prey in Inland, possibly because the woodcock is not common in Voss (R. Nilsen pers. comm.). Woodcocks feed mainly on earthworms (*Lumbricidae* spp.) (Haftorn 1971, Cramp & Simmons 1983), which are most common in moist and deciduous forests of high soil quality in compare to dry and coniferous forests. Hence, the explanation for the observed patterns is probably that such forests are rare in Inland, where also the abundance of open water is low, compared to Coast and Middle.

I found a significant negative relationship between the proportion of Grouse and the proportion of open water or farmland in the goshawks' home ranges. In the linear regression analysis there also was an effect of region. The species in this group are found in continuous forests with low or intermediate productivity, and especially where the field layer is dominated by bilberry (Haftorn 1971**,** Cramp & Simmons 1980), and are not directly related to farmland or open water. The negative relation between Grouse and farmland is also supported by Grønnesby and Nygård (2000) and Johansen (2006), who found that the amount of Grouse in the diet increased with decreasing amount of farmland.

The prey group Small passerines consist of both forest and farmland dwelling species, but in the diet, thrushes were dominating. Although thrushes are common in many habitat types, their number will most likely be linked to land productivity, similar to that for the woodcock. The multivariate linear and Poisson regression analyses revealed a significant positive relationship between this prey group and the proportion of farmland, as long as region was included as a random variable. The same tendency was found in a study from central Norway that revealed a higher proportion of thrush-sized prey in the diet from a farmland area compared to a more forested area (Grønnesby & Nygård 2000). In contrast, Johansen (2006) did not find a significant relationship between the number of thrushes in the diet and the proportion of farmland.

The relationship between Mammals in the diet and habitats was mainly due to high numbers of mountain hare (*Lepus timidus*) in the diet in some of the coastal areas. Hare utilize a variety of habitats, but should be expected to be most common in productive and semi-open areas

(Walker 1975, Dahl 2005). Hence, the explanation for positive relationship with open water could be similar to that for the woodcock, e.g. that there is a positive correlation between the occurrence of water and land productivity. Another aspect is that the red fox (*Vulpes vulpes*) has been observed only a few times at the Stord island (Steinsvåg & Overvoll 2004) and does not exist at Bømlo (Steinsvåg & Overvoll 2003). Studies from Fennoscandia have revealed that absence of red foxes may be a requisition for maintaining high populations of hare (Marcström et al. 1989, Lindström et al. 1994).

4.5 Diets now and in the past

In all three regions, my results were quite similar to results from goshawk diet studies from the 1980s and 1990s with regard to the frequency of the four most important prey groups. This might reflect that the prey communities, and thus also the biotic and abiotic environment, have not changed much since the 1980s to present time. The main difference was the high frequency of pigeons in a former study from the Bergen peninsula (Overvoll 1994).

Overvoll (1994) explained the large amount of pigeons in the diet with a high number of dovecotes in the vicinity of the nests. According to Lyssand (pers. comm.), however, there are about the same activity in the homing pigeon society now compared to the 1990s. Also Overvoll's (1994) study was based on prey remains, but humerus bones from pigeons, which are very persistent in the environment compared to other prey remains, were included in the diet even if they came from previous breeding seasons (Overvoll pers. comm.). His pigeon material could be divided into identification by feathers or bones, where the frequency of pigeons identified by feather was 16% and by bones 55.7% (Overvoll pers. comm.). The use of old prey remains may thus have lead to an overestimation of pigeons in the diet.

5.0 CONCLUSION

Both the present and previous goshawk diet studies carried out in Hordaland during the breeding season have showed a high dependency on a few species groups, with passerines (corvids and thrushes) as important prey in all regions. Grouse have been most important in Inland, whereas alternative prey have been most important in Coast and Middle. These differences seem to reflect local prey supply, and shows that goshawks adapt to local prey availability.

There should be more predictable food sources in coastal, urban and agricultural landscapes, as the diversity in these habitats is higher than in a forested landscape (Overvoll 1994, Sandvik 1996). Forestry has in general negative effects on goshawks, by reducing prey populations, hunting habitats and nesting habitats (e.g. Widén 1997, Selås 1998, Gundersen et al. 2004). However, as Johansen (2006) argues, "goshawks are more adaptable to alternative habitats and alternative prey species than previously thought". Hence, the thinking of goshawk conservation needs to include both typical and alternative habitats and prey species. It is such reasonable to have a differentiated view on the regional conservation management of goshawks.

REFERENCES

Beier, P., & Drennan, J. E. 1997. Forest structure and prey abundance in foraging areas of Northern Goshawks. *Ecological Applications,* 7: 564-571.

Bergo, G. 1992. Bestandsstørrelse, reirhabitat og reproduksjonsbiologi hjå hønsehauk. *Fylkesmannen i Hordaland, Miljøvernavdelinga,* Rapport nr 5: 1-31.

Cramp, S. & Simmons, K. E. L. 1980. Handbook of the birds of Europe, the Middle East and North Africa. Vol 2. *Oxford Univesity press, Oxford.*

Cramp, S. & Simmons, K. E. L. 1983**.** Handbook of the birds of Europe, the Middle East and North Africa. Vol 3. *Oxford Univesity press, Oxford*.

Dahl, F. 2005. Life and death of the mountain hare in the boreal forest of Sweden. *Doctoral thesis, Swedish University of Agricultural Sciences.*

Environmental Systems Reseach Institute (ESRI) 2002. ArcView 3.3. *Redlands, California.*

Grønlien, H. (ed) 2004. Hønsehauken i Norge. Bestandens status og utvikling de siste 150 år. *Norsk Ornitologisk Forening*, Rapport nr. 5: 1-37.

Grønlien, H., Høitomt, G. & Opheim, J. 1993. Registrering av skoglige forhold ved 10 hekkelokaliteter for hønsehauk. En vurdering av biotopkrav og bestandsutvikling. *HUJON*, 4: 205-313.

Grønnesby, S. & Nygård, T. 2000. Using time-laps video monitoring to study prey selection by breeding Goshawks *Accipiter gentilis* in Central Norway. *Ornis Fennica*, 77: 117-129.

Gundersen, V., Rolstad, J. & Wegge, P. 2004. Hønsehauk og skogbruk - en gjennomgang av bestandsutvikling, økologi og trusler. *INA fagrapport,* 2: 1-35.

Haftorn, S. 1971. Norges fugler. *Universitetsforlaget, Oslo.*

Hagen, Y. 1952. Rovfuglene og viltpleien. *Gyldendal, Oslo.*

Höglund, N. H. 1964. Über die ernärung des habichts (*Accipiter gentilis Lin.*) in Sweden. *Viltrevy*, 2: 271-328.

Håland, A. & Mjøs, A. T. 2006. Viltet i Os. Kartlegging av viktige viltområde og status for viltartane. *Os kommune og Fylkesmannen i Hordaland,* MVA-rapport 5/2006: 1-44.

Inglis, I. R., Wright, E. & Lill, J. 1994. The impact of hedges and farm woodlands on woodpigeon (*Columba-palumbus*) nest densities. *Agriculture ecosystems & environment*, 48: 257-262.

Johansen, H. M. 2006. Diet of goshawk (*Accipiter gentilis*) nestlings in south-eastern Norway: A comparison of farmland- and forest-dominated areas. *Master thesis*, *Norwegian University of Life Sciences.*

Kenward, R. E. 1982. Goshawk Hunting Behaviour, and Range Size as a Function of food and habitat availability. *Journal of Animal Ecology*, 51: 69-80.

Knoff, C. 1999. Blir bestandsskogbruket hønsehaukens bane? *Vår fuglefauna*, 22: 81-86.

Kålås J. A., Viken, Å. & Bakken, T. (eds) 2006. Norsk rødliste 2006 - 2006 Norwegian Red List. *Artsdatabanken, Norway.*

Lindén, H. & Wikman, M. 1983. Goshawk predation on tetraonids: availability of prey and diet of the predator in the breeding season. *Journal of Animal Ecology*, 52: 953-968.

Lindström, E. R., Andrén, H., Angelstam, P., Cederlund, G., Hörnfeldt, B., Jäderberg, L., Lemnell, P. A., Martinsson, B., Sköld, K., & Swenson, J. E. 1994. Disease reveals the predator: sarcoptic mange, red fox predation, and prey populations. *Ecology*, 75: 1042-1049.

Mañosa, S. 1994. Goshawk diet in a Mediterranean area of northeastern Spain. *Journal of Raptor Research*, 28: 84-92.

Marcström, V., Keith, L. B., Engren, E., & Cary, J. R. 1989. Demographic responses of arctic hares (*Lepus timidus*) to experimental reductions of red foxes (*Vulpes vulpes*) and martens (*Martes martes*). *Canadian Journal of Zoology*, 67: 658-668.

Marcström, V., Kenward, R. & Karlblom, M. 1990. Duvhöken och dens plats i naturen. *AS Trycksaker, Norrköbing*.

Moen, A. 1998. Nasjonalatlas for Norge: Vegetasjon. *Statens kartverk, Hønsefoss, Norway*.

Nielsen, J. T. 1986. Duehøgen (*Accipiter gentilis*) i Vendsyssel 1977-1985. *Accipiter*, 2: 133-174.

Nygård, T., Halley, D. J., Wiseth, B., Grønnesby, S. & Grønlien, P. M. 1998. Hva skjer med hønsehauken? - Foreløpige resultater fra et forskningsprosjekt om hønsehaukens arealkrav, næring, dødsårsaker og vandringer. *Vår fuglefauna*, 21: 5-10.

Opdam, P., Thissen, J., Verschuren, P. & Müskens, G. 1977. Feeding ecology of a population of Goshawk *Accipiter gentilis. Journal of Ornithology*, 118: 35-51.

Overvoll, O. 1994. Breeding ecology of goshawks (*Accipiter gentilis*) in western Norway. *Thesis Candidatus scientiarum. Department of Animal Ecology, Institute of Zoology, University of Bergen*.

Overvoll, O. 1999. Litt om hønsehauken i Hordaland sitt val av næring i hekketida. *Krompen,* 2: 88-93.

Peach, W. J., Denny, M., Cotton, P. A., Hill, I. F., Gruar, D., Barritt, D., Impey, A. & Mallord, J. 2004. Habitat selection by song thrushes in stable and declining farmland populations. *Journal of Applied Ecology*, 41: 275-293.

Penteriani, V. 1997. Long-term study of a goshawk breeding population on a Mediterranean mountain (Abruzzi Apennines, central Italy): density, breeding performance and diet. *Journal of Raptor Research,* 31: 308-312.

R Foundation 2006. The R foundation for statistical computing. Version 2.4.1. *Wien, Austria.*

Reynolds, R. T., Wiens, J. D. & Salafsky, S. R. 2006. A review and evaluation of factors limiting northern goshawk populations. *Studies in Avian Biology*, 31: 260-273.

Rutz, C. 2003. Assessing the breeding season diet of goshawk *Accipiter gentilis*: biases of plucking analysis quantified by means of continuous radio-monitoring. *Journal of Zoology*, 259: 209-217.

Salafsky, S. R., Reynolds, R. T. & Noon, B. R. 2005. Patterns of temporal variation in goshawk reproduction and prey resources. *Journal of Raptor Research*, 39: 237-246.

Sandvik, J. 1996. Hønsehaukens status i Sør-Trøndelag. *NINA temahefte Rapport fra et symposium 23-24 mars 1995 ved NINA Trondheim og Høgskolen i Nord-Trøndelag*, Nr. 5: 16-19.

SAS Institute Inc. 2000. JMP Version 4.0.0. *Carry, North Carolina, U.S.A*.

Selås, V. 1989a. Byttedyrvalg hos hønsehauk *Accipiter gentilis* i hekketida. *Fauna*, 42: 104-110.

Selås, V. 1989b. Analyse av rovfuglers næringsvalg basert på innsamling av bytterester og gulpeboller fra hekkeplassen. *Fauna*, 42: 13-21.

Selås, V. 1998. Hønsehauken i tilbakegang - også i Aust-Agder. *Vår fuglefauna,* 21:149-154.

Smedshaug, C. A., Lund, S. E., Brekke, A., Sonerud, G. & Rafoss, T. 2002. The importance of the farmland-forest edge for area use of breeding Hooded Crows as revealed by radio telemetry. *Ornis Fennica*, 79: 1-13.

Smith, R. L. & Smith, T. M. 1998. Elements of ecology. 4 ed. *The Benjamin/Cummings Publishing Company, Inc*., *USA.*

Sollien, A. 1979. Bestandsutviklingen hos hønsehauk, *Accipiter gentilis*, i Norge de siste 100 år. *Vår Fuglefauna*, 2: 95-106.

Sonerud, G. A. 1992. Functional responses of birds of prey: biases due to the load-size effect in central place foragers. *Oikos*, 63: 223-232.

Statens kartverk 2003. N 250 Norge. *Hønefoss, Norway*.

Statistical Product and Service Solutions (SPSS) 2005. SPSS 14.0 for Windows. *Chicago, Illinois, U.S.A.*

Steinsvåg, M. J. 2002. Kartlegging av hekkestadar for hønsehauk (*Accipiter gentilis*) i Bømlo og Sveio kommunar, Hordaland. *Fylkesmannen i Hordaland, Miljøvernavdelinga,* MVA-rapport 2: 1-21.

Steinsvåg, M. J. & Overvoll, O. 2003. Viltet i Bømlo. Kartlegging av viktige viltområde og status for viltartane. *Bømlo kommune og Fylkesmannen i Hordaland,* MVA-rapport 4: 1-55.

Steinsvåg, M. J. & Overvoll, O. 2004. Viltet i Stord. Kartlegging av viktige viltområde og status for viltartane. *Stord og Fitjar kommunar og Fylkesmannen i Hordaland,* MVA-rapport 3: 1-59.

Steinsvåg, M. J. & Overvoll, O. 2005. Viltet i Bergen. Kartlegging av viktige viltområder og status for viltartene. *Bergen kommune og Fylkesmannen i Hordaland,* MVA-rapport 2: 1-49.

Sulkava, S. 1964. Zur Nahrungsbiologie des Habichts *Accipiter gentilis. Aquilo, Ser. Zoologica,* 3:1-103.

Sveen, B. A. 2006. Collecting prey remains vs. video recording prey deliveries: a comparison of two methods for assessing goshawk (*Accipiter gentilis*) diet during the breeding season. *Master thesis*, *Norwegian University of Life Sciences.*

The Norwegian Forest and Landscape Institute 2007. Kartkatalog. Accessed 16.03.2007. http://www.skogoglandskap.no/seksjoner/kartkatalog.

Tornberg, R. 1997. Prey selection of the Goshawk *Accipiter gentilis* during the breeding season: The role of prey profitability and vulnerability. *Ornis Fennica*, 74: 15-28.

Tornberg, R., Korpimäki, E. & Byholm, P. 2006. Ecology of the northern goshawk in Fennoscandia. *Studies in Avian Biology*, 31: 141-157.

Toyne, E. P. 1998. Breeding season diet of the Goshawk *Accipiter gentilis* in Wales. *Ibis*, 140: 569-579.

Tømmerås, P. J. 1993. Hønsehauken i Leksvik, et offer for det moderne skogbruket. *Fauna*, 46: 180-195.

Voss municipality 2007. Arealbruk i Voss kommune. Accessed 16.03.2007. http://www.voss.kommune.no/Filnedlasting.aspx?MId1=13&MId2=5&FilId=646&back=1.

Walker, E. P. 1975. Mammals of the world. Vol 2. *The Johns Hopkins University press, Baltimore & London.*

Widén, P. 1985a. Population ecology of the goshawk (*Accipiter gentilis*) in the boreal forest. *Doctoral thesis, Uppsala University.*

Widén, P. 1985b. Breeding and movements of goshawks in boreal forests in Sweden. *Holoarctic Ecology*, 8: 273-279.

Widén, P. 1987. Goshawk predation during winter, spring and summer in a boreal forest area of central Sweden. *Holarctic Ecology*, 10: 104-109.

Widén, P. 1989. The hunting habitats of goshawk *Accipiter gentilis* in boreal forests of central Sweden. *Ibis,* 131: 205-213.

Widén, P. 1997. How, and why, is the goshawk (*Accipiter gentilis*) affected by modern forest management in Fennoscandia? *Journal of Raptor Research*, 31: 107-113.

Wikman, M. 1977. Duvhökspredation på skogsfågel i sydvästra Finland 1975-76. *Viltrapport,* 5: 59-72.

APPENDIX

Appendix 1. Nest characteristics at each nest site during the goshawk breeding period of 2006 in Hordaland County. Nest qualities; forest type, forest quality class, nesting tree, nest tree height (metre), nest height (metre) and circumference at breast height (centimetre).

	Forest type	Quality class	Nesting tree	Nest tree height (m)	Nest height (m)	Circum. (cm)
1	coniferous	high	pine	13	7	140
2	coniferous	high	pine	12	8	122
3	mixed	high/very high	pine	12	7	98
4	coniferous	high	pine	8	6	175
5	mixed	high	oak	13	8	120
6	coniferous	high	pine	10	7	129
7	mixed	high	pine	10	7	159
8	coniferous	high	pine	14	10	107
9	coniferous	high	pine	13	10	165
10	coniferous	high	pine	11	6	112
11	coniferous	high	pine	13	9	172

Appendix 2. Results from different prey remain studies at goshawks nest sites in Hordaland during the breeding season. The results from Stord island 1995 are given in Overvoll (1999), Bergen peninsula 1991-1996 in Overvoll (1994, 1999) and Voss 1984-1991 are given in Bergo (1992) and Overvoll (1999). The results from 2006 are given in this study. The study regions are the same, except for Stord island in 2006 which also includes nests from Bømlo. The bold numbers are the most important prey species of frequency.

	Stord island				Bergen peninsula				Voss			
	1995		2006		1991-1996		2006		1984-1991		2006	
	n	% n	n	% n	n	% n	n	% n	n	% n	n	% n
Grouse	2	3.0	8	3.3	19	2.3	1	0.6	44	**33.1**	55	33.3
Pigeons	11	15.9	28	11.6	368	**44.4**	22	13.0	8	6.0	7	4.2
Corvids	17	**24.6**	46	19.0	217	26.2	25	14.8	25	18.8	28	17.0
Small passerines	13	18.8	73	**30.1**	122	14.7	95	**56.2**	32	24.1	63	**38.2**
Woodcock	15	21.7	41	16.9	26	3.1	11	6.5	4	3.0	4	2.4
Ducks & waders	6	8.7	15	6.2	50	6.1	6	3.5	8	6.0	1	0.6
Other birds	2	3.0	7	2.9	17	2.1	4	2.4	9	6.8	3	1.8
Mammals	3	4.3	24	10.0	9	1.1	5	3.0	3	2.2	4	2.5
Total	69		242		828		169		133		165	

Appendix 3. Number of prey remains found at goshawk nests in western Norway during the breeding season of 2006. 1-4 = nests from Coast, 5-7 = nests from Middle and 8-11 = nests from Inland.

Prey species	1	2	3	4	5	6	7	8	9	10	11
Mallard *Anas platyrhynchos*	-	2	-	-	1	-	-	-	-	-	-
Teal *Anas crecca*	2	-	-	-	-	-	1	-	-	-	-
Indet. duck	1	-	-	-	-	-	-	-	-	-	-
Sparrowhawk *Accipiter nisus*	-	-	1	-	-	-	-	-	-	-	-
Goshawk *Accipiter gentilis*	-	-	1	-	-	-	-	-	-	-	-
Capercaillie *Tetrao urogallus*	-	-	-	-	-	-	-	-	-	2	3
Black grouse *Tetrao tetrix*	-	1	7	-	-	-	1	1	1	5	4
Willow ptarmigan *Lagopus l. lagopus*	-	-	-	-	-	-	-	12	3	18	6
Lapwing *Vanellus vanellus*	-	-	-	-	1	-	2	-	-	-	-
Eurasian oystercatcher *Haematopus ostralegus*	-	-	1	-	-	-	-	-	-	-	-
European golden plover *Pluvialis apricaria*	-	-	-	-	-	-	-	-	-	1	-
Woodcock *Scolopax rusticola*	3	7	6	25	3	4	4	2	-	1	1
Snipe *Gallinago gallinago*	-	-	-	-	-	-	1	-	-	-	-
Common sandpiper *Actitis hypoleucos*	3	-	-	1	-	-	-	-	-	-	-
Mew gull *Larus canus*	-	2	-	-	-	-	-	-	-	-	-
Common tern *Sterna hirundo*	3	-	-	-	-	-	-	-	-	-	-
Pigeons *Columbidae* spp.	11	14	-	3	7	11	4	1	4	2	-
Great spotted woodpecker*Dendrocopos major*	-	1	-	-	-	1	1	-	-	1	-
Green woodpecker *Picus viridis*	-	-	-	-	-	-	-	-	1	-	-
Meadow-/ Tree pipit *Anthus pratensis/trivialis*	-	-	2	-	-	-	2	-	-	-	-
European robin *Erithacus rubecula*	-	-	-	-	-	1	-	-	-	-	-
Blackbird *Turdus merula*	5	11	9	12	9	12	15	6	-	1	1
Fieldfare *Turdus pilaris*	3	-	-	1	3	1	5	25	2	2	1
Blackbird/Fieldfare *Turdus merula/pilaris*	2	1	1	-	-	1	5	-	1	7	-
Redwing *Turdus iliacus*	1	2	2	2	2	4	5	4	-	3	-
Song thrush *Turdus philomelos*	1	3	7	6	2	4	10	3	2	2	2
Willow warbler *Phylloscopus trochilus*	-	-	-	-	-	-	1	-	-	-	-
Great tit *Parus major*	-	-	-	-	1	1	-	-	-	-	-
Eurasian jay *Garrulus glandarius*	7	3	3	5	1	2	1	-	-	3	-
Black-billed magpie *Pica pica*	1	4	-	6	6	4	7	6	2	2	4
Hooded crow *Corvus corone cornix*	1	16	-	-	1	2	1	1	2	5	-
Eurasian jackdaw *Corvus monedula*	-	-	-	-	-	-	-	1	-	-	-
Raven *Corvus corax*	-	-	-	-	-	-	-	2	-	-	-
Starling *Sturnus vulgaris*	-	4	-	-	2	-	8	-	-	-	-
Parrot crossbill *Loxia pytyopsittacus*	-	-	-	-	1	1	1	-	-	-	-

Snow buntling *Plectrophenax nivalis*	-	-	-	-	-	-	-	1	-	-	-
Indet. bird	-	1	-	1	-	-	-	-	-	1	-
Squirrel *Sciurus vulgaris*	2	1	1	2	-	2	2	-	1	1	1
Mountain hare *Lepus timidus*	-	-	11	3	-	-	-	-	-	1	-
Least weasel *Mustela nivalis*	-	-	1	-	-	-	-	-	-	-	-
Field vole *Microtus agrestis*	2	-	-	1	-	-	-	-	-	-	-
Brown rat *Rattus norvegicus*	-	-	-	-	-	-	1	-	-	-	-
Total	48	73	53	68	40	51	78	65	19	58	23