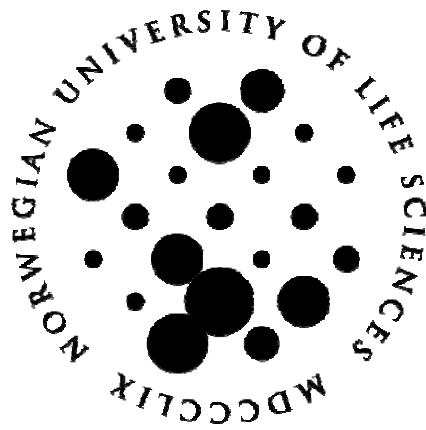


EFFECTS OF RECREATIONAL HOMES ON WILLOW PTARMIGAN (*LAGOPUS LAGOPUS*)

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Abstract

Norway has experienced a rapid increase in construction of recreational homes over the last ten years. The ecological impact of moderate construction in nature has not received much scientific attention. I hypothesize that presence of cabin areas will affect populations of willow ptarmigan (*Lagopus lagopus*) negatively by increasing human disturbance and attracting predators. Cabin areas can provide suitable habitat for microtine rodents, an important food source for red fox (*Vulpes vulpes*), and attract corvids (*Corvidae*). Human disturbance could cause the willow ptarmigan to avoid areas close to cabins. If cabin areas attract predators and cause a higher predator activity in nearby areas, this should result in decreasing nest predation and increased relative number of broods with increasing remoteness. I found no difference in distribution of male ptarmigan on territorial display in May, or in the August distribution of broods and non-broods near cabin areas and in areas further away. I found that the abundance of microtine rodents was high, but not significantly different between cabins, roadsides, forests, summer pastures and bogs. Predation on artificial ground nests was significantly higher in areas near recreational homes than in areas further away. However the key nest predators, red foxes and corvids, showed no pattern in distribution in relation to cabin areas. High microtine rodent availability could have mitigated mammal predation on ptarmigan leaving the pattern in artificial nest predation to be mainly due to corvids.

Table of contents

Abstract	- 1 -
1. Introduction	- 3 -
2. Study area	- 5 -
3. Materials and methods.....	- 8 -
3.1 Cabin areas	- 8 -
3.2 Selection of sampling sites	- 9 -
3.3 Distribution of willow ptarmigan	- 11 -
3.3.1 Territorial males.....	- 11 -
3.3.2 Distribution in autumn	- 11 -
3.4 Distribution of small rodents	- 11 -
3.5 Predation on artificial nests.....	- 12 -
3.6 Distribution of red fox	- 13 -
3.7 Distribution of corvids	- 13 -
3.8 General	- 14 -
4. Results	- 15 -
4.1 Distribution of willow ptarmigan	- 15 -
4.1.1 Territorial males.....	- 15 -
4.1.2 Distribution in autumn	- 15 -
4.2 Distribution of small rodents	- 16 -
4.3 Predation on artificial nests.....	- 16 -
4.4 Distribution of red fox	- 18 -
4.5 Distribution of corvids	- 18 -
5. Discussion.....	- 19 -
6. Conclusion.....	- 23 -
7. Acknowledgements	- 24 -
8. References	- 25 -

1. Introduction

This study reports on the impact on willow ptarmigan from recreational homes. The study was conducted in the central mountain areas of Norway in 2007. This year Norway had a population close to 4.7 million people and a total of 383 112 recreational homes. The last eight years contributed with an average increase close to 5000 new recreational homes each year (SSB 2007). In many areas this has caused existing concentrations of cabins to expand in size, but also new areas have been opened to meet the increasing demands. The impacts of recreational homes on wild animals have not received much scientific attention compared to the tremendous increase in construction activity. With more cabins in new areas the need for new and better infrastructure increases. It has been shown that wild reindeer (*Rangifer tarandus*) (Nellemann et al. 2001; Vistnes et al. 2004) and other animals (Forman & Alexander 1998; Spellerberg 1998) are disturbed by roads and power lines in such a way that habitats are being fragmented. Habitat fragmentation also increases the edge effect of predation (Storch et al. 2005) and can increase spillover predation (Oksanen et al. 1992). Considerable ptarmigan mortality by collisions with power lines has been well documented in southern Norway (Bevanger 1998). Watson & Moss (2004) found that development of a ski area in Scotland increased willow ptarmigan (*Lagopus lagopus*) mortality by wire collisions and attracted crows causing increased predation. Traditionally many cabins in mountain areas of Norway have been placed within a zone of birch and willow close to the tree line. In Scandinavia this zone represents the transition between the coniferous forests below and treeless mountains above. This zone is especially important for willow ptarmigan in early life stages as they hatch here before moving uphill above the tree line (Andersen et al. 1986). I hypothesize that presence of cabin areas will affect populations of willow ptarmigan negatively by increasing human disturbance and attracting predators.

Human activity in and around cabin areas can disturb willow ptarmigan and render these areas less favourable for reproduction and rearing of broods. To reveal this potential spatial effect of human disturbance on reproduction and demography I recorded the relative distribution of male willow ptarmigan during territorial display in early May, and the relative distribution of broods and non-broods in the autumn. Construction of cabins and appurtenant infrastructure can alter the vegetation in close

vicinity by clearing forest and creating patches of exposed soil, both of which will increase the amounts of grass (e.g. Uotila & Kouki 2005). Some cabin owners also make a lawn around their cabins. This shift towards more grass can favour microtine rodents which again enhances prey availability for red fox (*Vulpes vulpes*). I therefore recorded number of small rodents around cabins, along roadsides and in reference areas in August, and red fox scat distribution on foot trails. Remnants after human activity such as garbage and food leftovers can also attract predators through smell and food availability. Attraction of predators such as red fox and corvids will make nearby bird nests more vulnerable to predation. Thus I registered the relative distribution of corvids from point transects, and the presence of nest predators by measuring predation on artificial ground nests.

2. Study area

The study area (Figure 1) was located in Hedmark and Oppland counties, south-eastern Norway, and included parts of the municipalities Ringsaker, Lillehammer, Øyer and Stor-Elvdal. In January 2007 Hedmark county had a total of 76 387 houses and 31 429 recreational homes. The entire study area is relatively flat with low hills except the Åstdalen valley in the north-eastern parts. The Sjusjøen area in the southern part of the study area is Norway's largest area of recreational homes covering 5.6 km² and containing 1329 recreational homes (Bloch & Steinnes 2003).

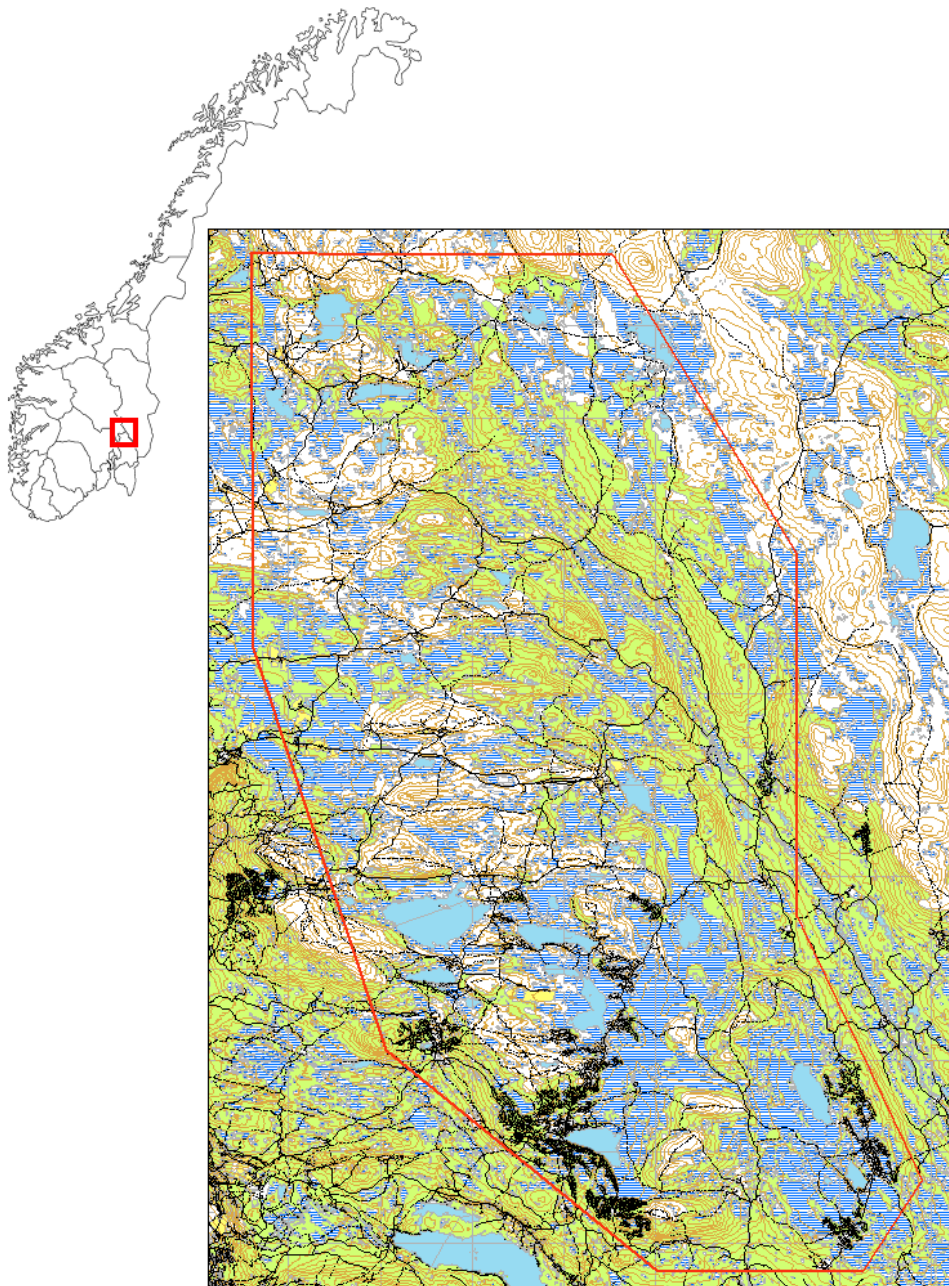


Figure 1: Map over the study area in Hedmark and Oppland counties in Norway.

The study area was approximately 500 km² and contained close to 5700 buildings equating an overall density of 11.4 buildings per km². Most of these buildings were cabins concentrated in various clusters in the south-eastern parts of the area. Usage of cabins varies greatly throughout the year. Some cabins are used almost every weekend, and most cabins are used during summer (June to August) and winter (January to February) vacations. The most concentrated activity is probably during Easter holidays followed by a period with very low activity during snowmelt. The study area contains 4 km² of cultivated land, mostly grassy pastures in close vicinity to summer farms. There are approximately 50 summer farms in the area, but less than 10 of these are still in active use. Most summer farms are located in the mid-western parts of the study area. There is an extended network of gravel roads covering most of the area adding up to a total of 383 km. The study area provided a gradient in human presence from high densities in the south via areas with summer pastures and some spread out cabins, towards more remote areas in the north-east with only a few single cabins and no roads. Hikers and sport fishermen frequently use the network of foot trails that covers most of the area, and during winter the area is popular for cross country skiing.

The area is dominated by large bogs with heather (*Calluna vulgaris*) and dwarf birch (*Betula nana*), and forests of birch (*Betula pubescens*) in areas below the tree line (980 meters above sea level). The forests in the south-western part of the study area consist mainly of scattered Norway spruce (*Picea abies*) with bilberry (*Vaccinium myrtillus*). Areas above the tree line have a belt of *Salix*-species followed by low-growing vegetation dominated by dwarf birch, heather and shrubs. The entire area is used by grazing domestic sheep (*Ovis aries*) in summer, and some patches in the forest have been cleared as outlying pastures in addition to cultivated areas near summer farms. Moose (*Alces alces*), semi-domestic reindeer (*Rangifer tarandus*) and elk (*Cervus elaphus*) can be found throughout the area. Ground predators are mainly red fox and mustelids such as stoat (*Mustela erminea*) and least weasel (*M. nivalis*). Larger avian fauna consists mainly of hooded crows (*Corvus cornix*), ravens (*C. corax*), black-billed magpies (*Pica pica*), common gulls (*Larus canus*), black-headed gulls (*L. ridibundus*), willow ptarmigan, capercaillie (*Tetrao urogallus*), black grouse (*T. tetrix*), wood pigeon (*Columba palumbus*), common cuckoo (*Cuculus canorus*) and whimbrel (*Numenius phaeopus*), in addition to various waders and ducks. Annual autumn census of willow ptarmigan density shows that the northern ³/₄ of the study area has had a stable density

of approximately 30 birds per km² from 2004 to 2006 (Solvang et al. 2007). In 2007 the density was 31 ptarmigan per km² (Øyer Fjellstyre 2008), which was high compared to neighboring areas, but approximately average for south-eastern parts of Norway (Framstad 2007). Based on 183 observations from ptarmigan census (Øyer Fjellstyre, unpubl. data and this study) the breeding success in the study area for 2007 was 4.5 chicks per two adults. This is relatively high compared to six other areas in Norway (ranging from 1.6 to 4.7, mean 2.8) the past two years (Framstad 2006; Framstad 2007).

3. Materials and methods

3.1 Cabin areas

There were 5659 buildings within the study area. I defined cabin areas as areas where five or more buildings were less than 150 meters apart. This definition was well in accordance with my opinion of a cabin area *in situ*. Using ArcGis 9.1 (ESRI 1999) I added a 75 meter circular buffer around every building, dissolved the borders where buffers overlapped and excluded areas containing less than five buildings. This resulted in a total of 72 cabin areas within the study area. The largest cabin area covered 8.6 km² and contained 1977 buildings. The most dense cabin area had 310 buildings per km² and was 2.1 km². Both of these areas were in the Sjusjøen area. Some data was analysed against larger cabin areas with ten or more buildings. The locations of all buildings and cabin areas are shown in Figure 2. Differences between the two definitions of cabin areas are shown in Table 1.

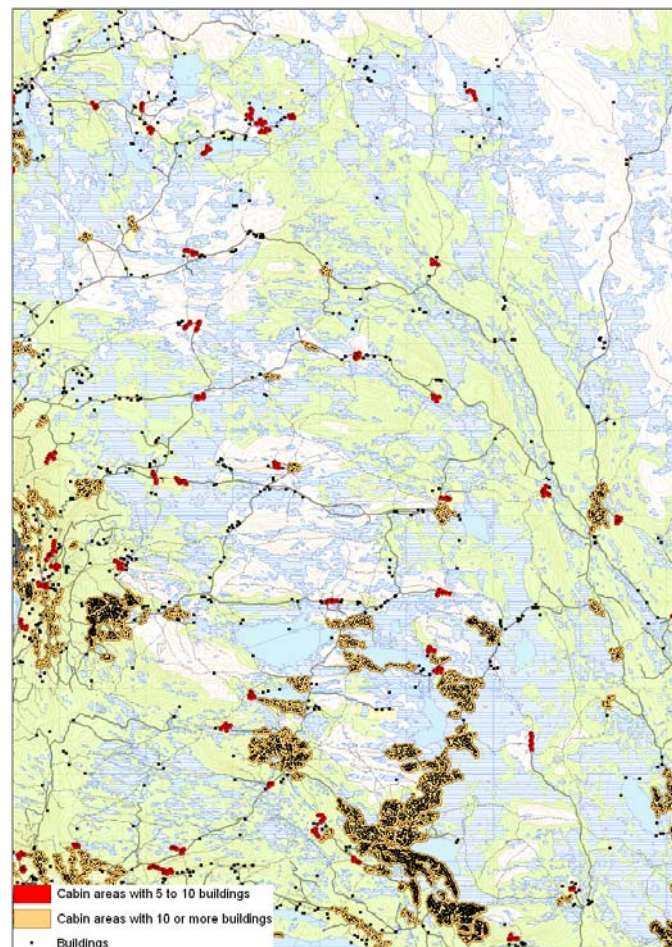


Figure 2: A map showing cabin areas with ten or more buildings (brown) and five or more buildings (brown + red).

There are many different types of cabins and different terms are being used to differentiate between them. Some would claim that most cabins in my study area should be called recreational homes or second homes due to their high standard. I assume that the impact of all types of cabins in this study is similar and thus do not differentiate between various types.

Table 1: Key data on cabin areas within the study area showing the difference between areas with five or more buildings and those with ten or more buildings.

Cabin area	N	Median number of buildings	Median size (km ²)	Median buildings pr km ²
5 or more buildings	72	9.00	0.10	97.10
10 or more buildings	34	29.50	0.75	118.72

3.2 Selection of sampling sites

The whole study area was divided into 1 km² squares. Using GIS I first selected 1 km² squares from the Universal Transverse Mercator (UTM) grid that had an altitude between 850 and 1100 meters above sea level to avoid bias from altitudinal differences. To avoid bias in vegetation composition I also excluded squares that contained more than 50% of bogs or lakes, and those without forests. The vegetational similarity of squares in relation to distance to nearest cabin area is shown in Figure 3.

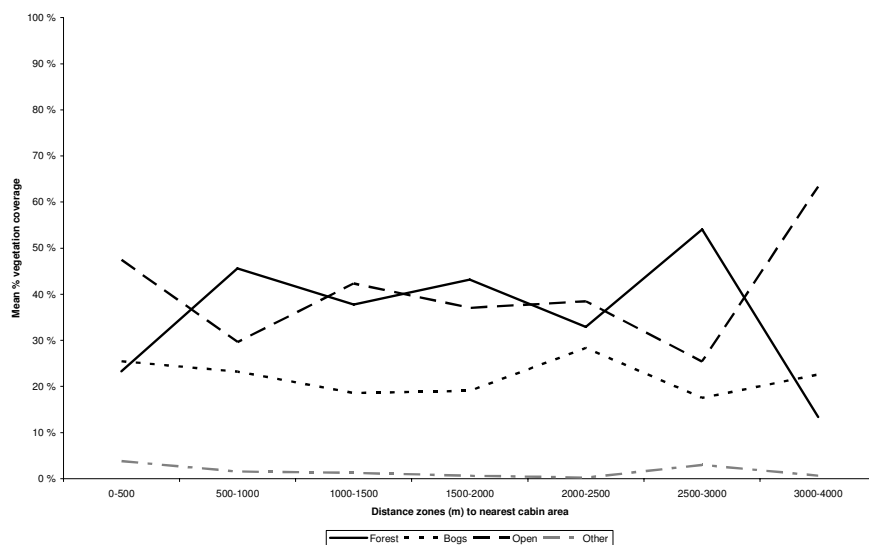


Figure 3: Mean vegetation coverage of forest, bogs, open areas (grass, heather above tree line) and other types (cultivated pastures) for all km-squares used for artificial nests in 500m zones of distance to nearest cabin area.

Linear regressions show that Bogs ($t = -1.33$, $r^2 = 2.0\%$, $p = 0.187$) and Open areas ($t = -1.53$, $r^2 = 2.6\%$, $p = 0.131$) had no relation to distance from nearest cabin area. The amounts of Forest ($t = 2.77$, $r^2 = 8.2\%$, $p = 0.007$) and Other areas ($t = -3.27$, $r^2 = 11.1\%$, $p = 0.002$) showed significant but weak negative linear relationships to distance, indicating no clear pattern in vegetation composition. To make sure all distances to cabin areas were represented I distributed the squares in 12 equal categories according to their distance to the nearest cabin area. Among these I randomly selected 5 squares in each category to ensure that all categories were represented. I then added adjacent squares to increase the sample size. This resulted in a total of 88 squares (Figure 4).

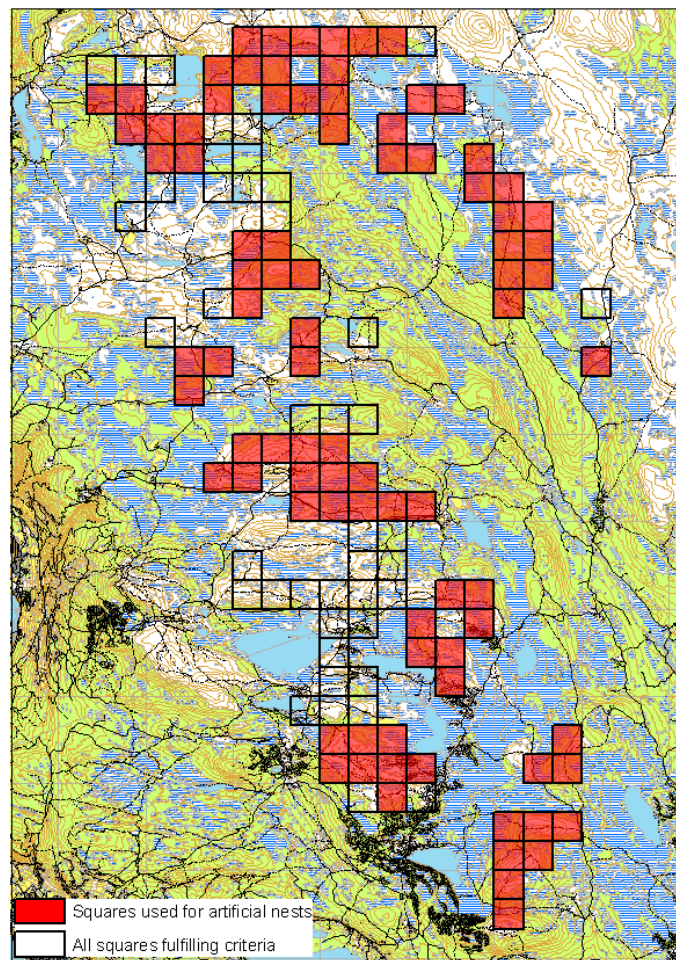


Figure 4: Map over all UTM squares fulfilling criteria set to avoid bias in the study design (open), and the squares used for artificial nests (red).

3.3 Distribution of willow ptarmigan

3.3.1 Territorial males

To estimate the spring density distribution of male willow ptarmigan I selected 33 km-squares among the 88 used for artificial nests and included two adjacent squares to increase the sample size. The squares had to be easily accessible from snowmobiles and were distributed to cover most of the study area. In each square I selected one site at the border between forest and bogs or open areas. All sites were visited around sunrise (between 03:15 and 06:30) in the period between 1st and 3rd of May 2007. At each site I recorded how many different male willow ptarmigan I could hear making territorial display calls during 10 minutes regardless if the ptarmigan were inside or outside the square. To avoid noise from the snowmobiles scaring the birds, no observations were made the first 5 minutes after the engine was stopped. The distance from each site to nearest cabin area was measured in GIS. I analysed the data statistically using a regression with number of males observed versus distance to nearest cabin area.

3.3.2 Distribution in autumn

Willow ptarmigan distribution and demography was investigated between 7th and 19th of August 2007 by experienced hunters with pointing dogs seeking through squares as if they were hunting, trying to locate as many ptarmigan as possible. Each hunter was equipped with a handheld GPS allowing a detailed track of their movements. All observations were recorded with GPS position, number of birds and demographic composition if possible. The observations were divided into groups of broods and non-broods. Broods were defined as observations of three or more birds, or two birds if one of them was a chick. Non-broods were defined as observations with two or fewer birds where chicks were not present. The differences between the groups in distances from each observation to nearest cabin area were tested using Students t-test.

3.4 Distribution of small rodents

In the period between 11th and 15th of August I caught small rodents using standard snap traps with fresh potato (*Solanum tuberosum*) as bait. This was done to investigate the possible difference in abundance and species composition of small rodents in different areas and habitat types. I created 72 trap sites distributed in five categories; cabins (12 sites), roadsides (15 sites), summer mountain pastures (12 sites), forests (17 sites) and bogs (16 sites). Sites of all categories were spread out to cover the study area. Each site

had 20 snap traps distributed in a square with 2 – 3 meters between each trap. In roadsides the traps were put out in a line parallel to the road, and in summer pastures the traps were put out along a bordering fence as I were not allowed to enter into pastures in use. Traps in roadsides, summer pastures and around cabins were placed in grass. Sites in roadsides and summer pastures were dominated by tufted hair-grass (*Deschampsia cespitosa*). Grass around cabins consisted of various species (e.g. *Deschampsia cespitosa*, *D. flexuosa*, *Festuca spp.*). Traps around cabins were placed within 2 meters of the cabin peripheral. Traps in bogs and forests were placed in heather/dwarf birch and bilberry respectively. All traps were checked chronologically after one night. Combining all the sites gave a total of 1440 trap nights. Species of *Soricidae* were differentiated from the other species *in situ* and excluded from the analyses as they are insectivores. All non-*Soricidae* were identified to species and analysed with Kruskal-Wallis for differences between categories.

3.5 Predation on artificial nests

In all of the 88 km-squares I created two artificial nests. Both nests were created at the border between bogs or open areas and forests. Preliminary fieldwork in 2006 (Heid, unpubl. data) showed a significant correlation between vegetation cover and predation on artificial nests (binary logistic regression, $z = 4.13$, $n = 105$, $p < 0.001$) (*sensu* Storaas 1988).



Figure 5: A typical artificial nest created at the vegetation border with 50% vegetation cover.

Visual estimates of vegetation cover *in situ* correlated well ($t = 29.59$, $r^2 = 76\%$, $p < 0.001$) with measurements of cover using Gap Light Analyzer software (Frazer et al. 1999) on pictures taken with a Nikon Coolpix 4500 digital camera mounted with a Nikon Fisheye Converter (FC-E8). The fisheye lens allowed a ~180 degrees picture of the vegetation above. Based on this I created artificial nests in 2007 only in sites with estimated *in situ* vegetation cover as close to 50% as possible allowing up to 10% variance if no better site was within range (Figure 5). The two nests were located at a minimum of 200 meters apart. When creating nests I used disposable vinyl examination

gloves and always tried to leave as few visual and scent traces as possible. In each nest I pressed two coloured wooden golf pegs into the ground and placed two medium sized brown domestic hen (*Gallus gallus*) eggs on top. GPS positions (± 5 meters) for each nest were recorded using a handheld non differentiated GPS, and used to relocate the nest later. The golf pegs allowed me to relocate depredated nests easier and assure that the correct location was found if both eggs were removed. The 176 artificial nests were created between 7th and 11th of June 2007. Based on predation rates from preliminary fieldwork in 2006 I recorded the predation chronologically after 12 days to obtain the maximum contrast in relative predation as close to 50% total predation as possible. A nest was considered depredated if one or more eggs were removed or damaged. The artificial nests were not meant to mimic real willow ptarmigan nests, but simply to reveal presence of nest predators in the area. The differences in distances from each nest to the closest cabin area for depredated and not predated nests were tested using Student's t-test.

3.6 Distribution of red fox

Red foxes frequently use foot trails when moving from one area to another, and use their scats actively to mark territories (Goszczyński 1990; Goszczyński 2002). To estimate the distribution pattern of red foxes, 148 km of foot trails covering the study area was searched during June and July 2007. All fox scats encountered were recorded with GPS positions. The track of the observer was also recorded using a handheld GPS. Using GIS with Hawth's analysis tools (Beyer 2004) I calculated an index of the number of scats recorded per km of searched foot path within each 1 km² square. All squares with less than 500 meters of registration were excluded. This index was then regressed against the distance from each square to nearest cabin area.

3.7 Distribution of corvids

Human settlements can attract scavenging birds such as corvids (Marzluff & Neatherlin 2006). Ravens and hooded crows are well known predators on grouse nests (Erikstad et al. 1982; Sonerud & Fjeld 1985; Storaas 1988). Additionally, black-billed magpies and common gulls were present in the study area. However Erikstad et al. (1982) found that they were not important contributors to ptarmigan nest predation. To estimate the relative distribution of corvids, I selected 35 sites spread out to cover most of the study area. Each site was visited in early morning between 05:00 and 09:30 from 4th to 6th of

July 2007, and all sighted corvids were registered during a 15 minute interval. The data was analysed by regressing number of corvids observed against the distance from the observation point to nearest cabin area.

3.8 General

All statistical tests were conducted in Minitab 15 (2006). The GIS digital maps used for analyses were licensed through the Norwegian Institute for Nature Research (NINA) at Lillehammer and their licence at Norge Digitalt.

4. Results

4.1 Distribution of willow ptarmigan

4.1.1 Territorial males

Male willow ptarmigan were present in 33 of the 35 locations (Figure 6). The number of male willow ptarmigan showed no linear relationship when regressed to distance from nearest cabin area ($df = 34$, $r^2 = 1.1\%$, $p = 0.54$).

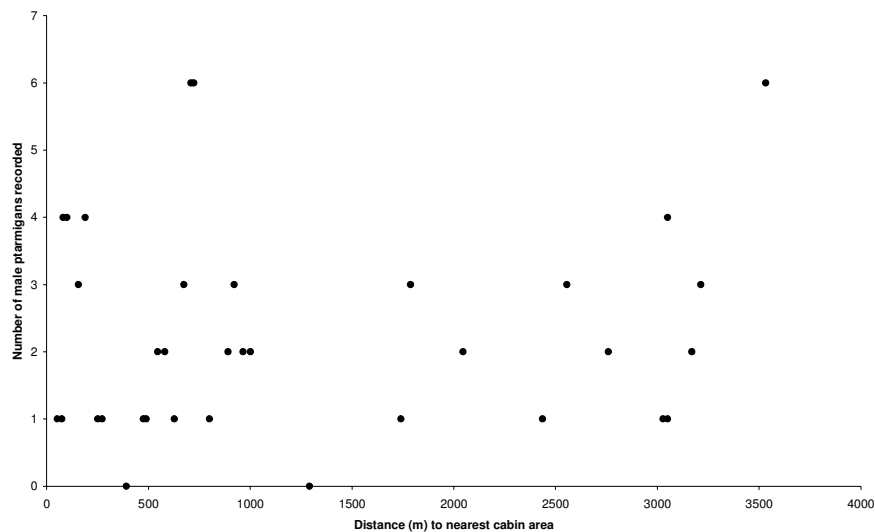


Figure 6: Number of male willow ptarmigan observed in relation to distance to nearest cabin area.

4.1.2 Distribution in autumn

Hunters with pointing dogs searched a total of 116.3 km in 71 km-squares covering the study area fairly well. This resulted in 69 observations with 31 males, 22 hens, 161 chicks and 2 unidentified individuals. Breeding success based on these observations alone is 6.1 chicks per two adults. Observations were categorized into 21 non-broods and 48 broods. There was no significant difference ($t = -1.37$, $df = 60$, $p = 0.177$) in occurrence of broods and non-broods in relation to nearest cabin area (Table 2).

Table 2: Distribution of broods and non-broods of willow ptarmigan in relation to distance to nearest cabin area.

Group	N	Mean distance	SE Mean	St. Dev.
Non-broods	21	740.0	91.4	419.0
Broods	48	927.0	101.0	701.0
All	69	869.9	76.0	631.4

4.2 Distribution of small rodents

The 1440 trap nights resulted in a total catch of 125 small rodents and *Soricidae* sp. This equals a total frequency of 8.7 per 100 trap nights, and a frequency in forest sites alone of 13.24 per 100 trap nights. The species distribution was 65 *Soricidae* sp., 36 bank voles (*Clethrionomys glareolus*), 15 tundra voles (*Microtus oeconomus*), 8 field voles (*Microtus agrestis*) and 1 northern birch mouse (*Sicista betulina*). A Kruskal-Wallis test showed no significant difference in number of microtine rodents among the five categories (cabins, bogs, forests, pastures and roadsides) ($H = 3.73$, $df = 4$, $p = 0.444$). The number of microtine rodents per site in the five categories is shown in Figure 7.

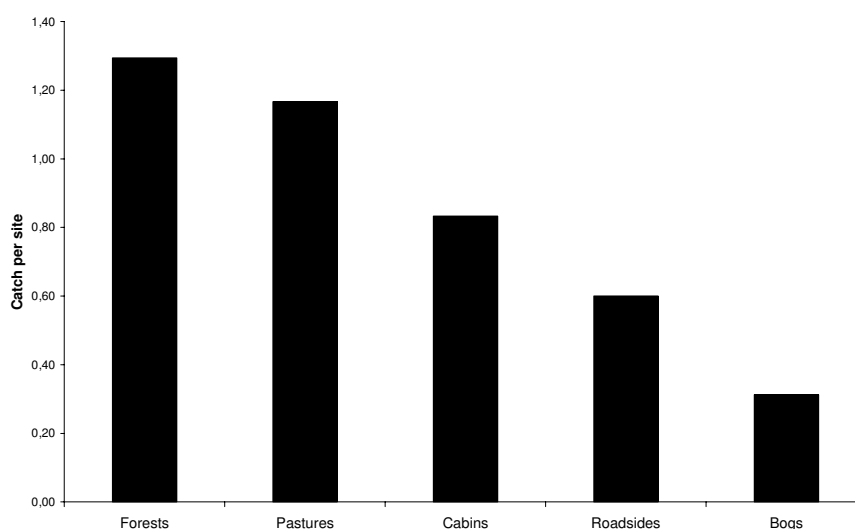


Figure 7: Number of microtine rodents per site (20 traps) in the five different habitat categories.

4.3 Predation on artificial nests

A total of 111 of the 176 artificial nests were depredated (Figure 8). This gives a total predation of 63%. Both eggs were depredated in 106 nests and eggshell remains were found in 31 of the depredated nests. Distances for depredated and not depredated nests were normally distributed in relation to nearest building, nearest cabin area with five or more buildings and cabin area with ten or more buildings (all Kolmogorov-Smirnov p -values > 0.05). Depredated nests were significantly nearer cabin areas with five or more buildings than not depredated nests ($t = 3.10$, $df = 123$, $p = 0.002$). The same effect of predation was found when analysing the results against distance to nearest single building ($t = 3.21$, $df = 104$, $p = 0.002$). When reducing the cabin areas to only include

those with ten or more buildings I found no significant effect of distance on predation ($t = 0.93$, $p = 0.355$, $df = 136$). Table 3 shows the range of distances for depredated and not predated nests in the three categories of cabin areas.

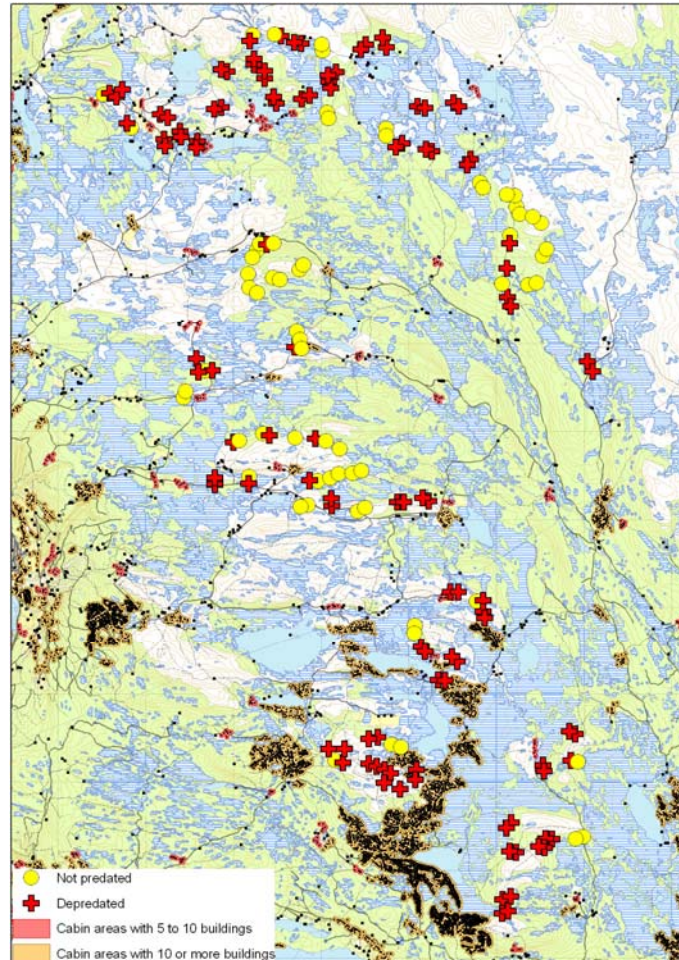


Figure 8: Map over the distribution of depredated (red cross) and not predated (yellow circle) artificial nests.

Table 3: Maximum, mean and minimum distances of depredated and not predated artificial nests in relation to nearest building, cabin area with 5 or more and 10 or more buildings. Zero values on min. distance indicates that at least one nest was within a cabin area.

	One building**		Cabin area 5+**		Cabin area 10+	
	Depredated	Not predated	Depredated	Not predated	Depredated	Not predated
Max. distance	2081	2904	4274	3643	11061	10106
Min. distance	24	102	0	0	0	0
Mean distance	747	1066	1241	1723	3822	4304

4.4 Distribution of red fox

A total of 180 fox scats were recorded along 148 km of searched foot trails. This gives a mean frequency of 1.22 scats per km. When squares with less than 500 m searched paths were removed, the dataset were reduced by 67 scats and 3.7 km of trails. A linear regression showed a weak positive trend for the fox scat index in relation to distance from nearest cabin area, but did not fit the data well ($n = 113$, $r^2 = 2.8\%$, $p = 0.078$). The fox scat index for km squares in relation to the distance from the square to the nearest cabin area is shown in Figure 9.

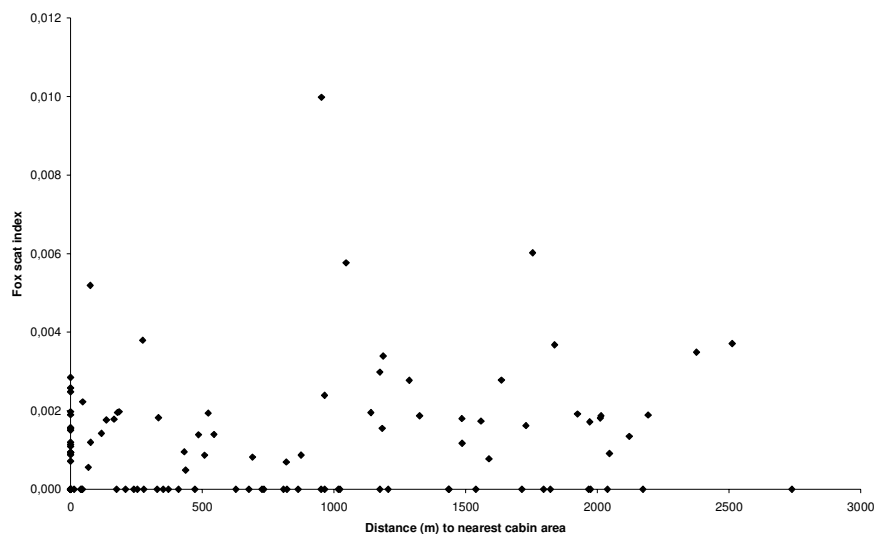


Figure 9: The fox scat index in 1 km² squares (number of scats per km searched footpath) in relation to distance from each square to nearest cabin area.

4.5 Distribution of corvids

Corvids were observed in 8 of the 35 locations. A total of 23 corvids were registered. I found no trend when regressing the number of corvids against distance to nearest cabin area ($n = 35$, $r^2 = 4.1\%$, $p = 0.241$).

5. Discussion

Areas near cabins can be poor habitat for willow ptarmigan reproduction due to frequent disturbance from humans resulting in lower reproductive success. However, I found no difference in distance to cabin areas for territorial male willow ptarmigan in the beginning of May. This suggests a good availability of males for females and a good basis for reproduction in the area. It also suggests that males seem to establish even in areas close to cabins. Schieck & Hannon (1989) found that breeding site fidelity in willow ptarmigan is high, especially in males. They also found that paired males did not switch breeding sites dependant on previous partner survival. This should imply that male willow ptarmigan will re-establish in areas near cabins even though the predation here is higher than in more remote areas. This could explain the observed evenness in male ptarmigan distribution, but does not explain why young males establish in areas near cabins for the first time. If nests and broods are more exposed to predation near cabins this should cause a difference in spatial distribution of broods and non-broods. My data showed no such difference. This implies that egg and chick survival near cabin areas may not be different from more remote areas. The registrations of territorial males were severely obstructed by poor snow conditions resulting in a much lower sample size than eligible. Ptarmigan near cabin areas could be more accustomed to noise than ptarmigan in more remote areas, causing noise from the snowmobiles during sampling to underestimate male ptarmigan presence in remote areas. Autumn census of ptarmigan was reduced due to poor weather conditions. This caused a gap in the data especially in north-eastern parts of the study area. Accordingly there were a larger sampling effort in areas close to cabins and weaker data in more remote areas.

Main predators on juvenile and adult willow ptarmigan are red fox, stoats and raptors such as gyrfalcon (*Falco rusticolus*) and goshawk (*Accipiter gentilis*) (reviewed in Hannon & Martin 2006). Mortality of juvenile grouse is highest the two first weeks after hatching, primarily due to predation and weather exposure (Hannon & Martin 2006). Wegge & Kastedalen (2007) found that predation accounted for 90% of the observed mortality in 115 capercaillie juveniles. Following the alternative prey hypothesis (Hagen 1952) generalist predators may switch between different prey species according to their availability. Cyclic small rodent populations (e.g. Steen et al. 1996) will cause the red fox to switch to alternative prey when small rodent density is low (see

however Dell'Arte et al. 2007). Depending on the relative density of small rodents the predation on eggs and chicks is supposed to vary between years (Wegge & Storaas 1990). A nearby study in Hedmark county provided a time series on vole populations and showed a peak in 2005 (G. Sonerud, unpublished data). Still the population did not reach a bottom until early spring 2007 and remarkably recovered already by the autumn the same year (G. Sonerud pers. comm.). This concurs with my findings showing a near-peak density in forest sites when compared to the time series from G. Sonerud. If small rodent availability for red fox were low in early spring this could cause high predation on ptarmigan eggs. The predation on broods may however have attenuated later in summer as small rodent numbers increased towards the autumn. High chick production in 2007 might reflect high microtine abundance and low mammal predation. Near peak densities for microtines would have reduced the relative impact from predation to mainly measure corvid activity. Consequently the main ptarmigan predation in 2007 would be on eggs rather than broods.

Forests and summer pastures had the highest amounts of microtine rodents per trap night followed by cabins, roadsides and bogs respectively. I hypothesized that presence of cabins and roads could result in higher densities of microtine rodents through increased habitat availability. My findings do not support this hypothesis as the frequency indices of microtine rodents were not significantly different among habitat categories.

Key predators on willow ptarmigan nests are corvids, stoats and pine martens (*Martes martes*) (Hannon & Martin 2006; Pedersen & Karlsen 2007). The use of artificial nests has been widely discussed and criticized (King et al. 1999; Major & Kendal 1996; Part & Wretenberg 2002; Wilson et al. 1998; Zanette 2002). Storaas (1988) found that predation on artificial ground nests in Hedmark County, Norway, did not mimic that of real capercaillie and black grouse nests. I used artificial nests merely as an indicator of predator presence. However, some nests may have been ignored by sceptical predators and remained unpredated even though predators were present. The method I used will overestimate avian predators as all nests were ~50% visible from above and uncovered by incubating hens. Camouflage by incubating hens will make nests harder to find for visually searching predators (e.g. Wiebe & Martin 1998). However, Schieck & Hannon (1993) argue that camouflage from vegetation is mainly to reduce predation on the

incubating hen or to reduce incubation energy cost rather than to conceal the eggs. Furthermore, the method probably underestimates predation from ground predators using smell in search for food as natural nests are incubated and adult birds are easier to locate than eggs alone. Hens moving in and out of the nest will leave scent traces and make visual cues for olfactory and visually searching predators respectively (Pedersen & Karlsen 2007). In general, artificial nests will mostly measure predation from corvids.

For most depredated nests both eggs were removed and remains could rarely be found near the nest site. This is in accordance with similar studies (Storch et al. 2005) and pinpoints the difficulty of using egg shell remains to identify the predator. Sonerud & Fjeld (1985) found that hooded crows carried away eggs and cached them up to 200 meters away with a median distance of 65 meters. Increased predation on artificial nests near cabin areas probably reflects a presence of more corvids near cabins or higher corvid activity in these areas. This implies that predators are affected by the presence of cabins. A decrease in significance when reducing the cabin areas to only include those with 10 or more buildings could imply that nest predators are affected even by single and small clusters of buildings.

Other predators such as stoats (McDonald et al. 2000; Park et al. 2002), pine martens and the Eurasian red squirrel (*Sciurus vulgaris*) (Bayne et al. 1997) can play a role in ground nest predation but were not investigated in this study. The effect of stoats, pine martens and red squirrels are probably not enough to explain the overall predation pattern. The south-western parts of the study area contains most coniferous forest, making it more suitable for red squirrels, which could have caused bias if the predation effect of red squirrels was considerable. Simultaneous fieldwork on artificial nests with motion detection cameras did not capture any mammalian predators, but showed that domestic sheep sometimes step on nests causing eggs to break in such a way that they can be mistaken for being depredated (Heid unpubl. data). This was also found in a camera monitoring study of ground nesting lapwings (*Vanellus vanellus*) in North Wales (Bolton et al. 2007). The entire study area has a high density of grazing sheep, but the impact of occasional damage by trampling is assumed to be insignificant.

Fox scats distribution was not related to distance from cabin areas. The red fox is regarded as strictly territorial (Goszczynski 2002), and home ranges do not change

seasonally or due to changes in food availability (Meia & Weber 1995). Measurements of home ranges in 21 European studies (reviewed in Cavallini 1996) showed an average home range of 20.6 km², with variation ranging from 2.9 km² to 51.7 km². Winter tracking of red fox in a 16 km² study area in Northern Norway showed that home ranges varied between 4.9 km² and 5.8 km² over three years, and that the area marked by urine and scats were on average 30% smaller than the total home range (Frafjord 2004). According to average home ranges in Europe, the present study area (500 km²) could contain approximately 24 territories, assuming that the entire study area has an even distribution of suitable habitat. Many small and well marked territories could cause the observed distribution of scats to be evenly spread in the study area.

Several studies have found that corvids are positively associated with urban areas and can cause increased nest predation (reviewed in Chace & Walsh 2006). Marzluff & Neatherlin (2006) found that corvids had higher reproduction close to human settlements, and that local densities of American crows (*Corvus brachyrhynchos*) increased near populated areas as home ranges overlapped extensively. Increased crow activity with increased human development was also found by Watson & Moss (2004). I found no pattern in the distribution of corvids, but the data should have included more sites and several replicates to be of conclusive quality. The method used may underestimate the number of territorial crows compared to non territorial crows as territorial individuals may be travelling less and thus may be spotted less frequently. Erikstad (1982) found that territorial hooded crows are more important than non-territorial crows as predators on willow ptarmigan nests.

No investigation on food-scraps availability was carried out, but it was a general impression of many participants in the field-work that leftovers and garbage were very well taken care of and placed in closed containers leaving very little for scavengers.

6. Conclusion

Assessment of the influence of one factor on ecological systems involves understanding all interacting components and being able to measure them correctly. I investigated the key disturbance factors from cabin areas on willow ptarmigan. Territorial males did not seem to avoid cabin areas in early spring. This could partly be explained by high breeding site fidelity despite earlier predation events. Relative distribution of broods and non-broods in autumn did not vary with distance to cabin areas. Microtine rodent densities were not significantly different in forests, summer pastures, roadsides, cabin areas and bogs. Consequently, red fox were probably not attracted to cabin areas. Corvids, however, are well known predators on ground nests and are also known to be attracted to human settlements. Predation on artificial ground nests was higher in areas near cabins. I believe this was due to higher corvid presence even if my data on corvid distribution was insufficient to be conclusive. The impact of increased predation on naturally occurring willow ptarmigan nests due to presence of cabin areas should be investigated in further studies focusing on corvid predation.

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