Influence of vole distribution on the habitat use of Weasel and Stoat: how does forestry influence this relationship?

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Preface

During my internship I met and worked with some great people, these people showed me how much I like research based working. Especially fundamental research was something pure and nice. It was nice to know there are still place where direct (economic) profit is not controlling the research.

Also was I motivated to see if something interested me within the big ecological research were I worked for to write about. After working on snow tracking and noticing the small prints of weasel and stoat I got interested in these little ones. The more and more I was reading about them the more I knew I want to write something about these magnificent creatures.

For the chance to work on this project I want to thank especially my supervisor Morten Odden who inspired me to get the best out of this thesis. Furthermore all the field workers that helped me collect the data, of which I want to name the hardest workers and friends Arne Martin and Alvar.

Next to all the field workers, all people that took the time to look into this study and gave me feedback I would like to thank. So thank you, Walter and Willem.

Abstract

In this study I looked at the relationship between small mustelids, Least weasel (*Mustela nivalis*), Stoat (*Mustela erminea*) and voles. The outcome of this was then related to the forestry system in Norway and what could influence this relationship. The overall outcome was discussed and conclusions were made about the influence of the Norwegian forestry system. This was important to look at since there is a European wide concern on the status of Mustelids, more information about this topic is needed. To be able to understand the relationship between these animals, the habitat selection and track distribution was used. This information was collected by live capturing stations for the voles and snow tracking for the mustelids. With the vole capture data logistic regression models was used to show what factor, forest age (cutting-class) or vegetation had the strongest relationship with the capturing of voles. Because several studies showed that Bank voles (*Myodes glareolus*) had a positive relationship with Blueberry (*Vaccinium myrtillus*). I also ran models where the cutting-classes and vegetation types were grouped by blueberry abundance. These models showed that the Bank vole, which was the most caught vole species, had the strongest regression with cutting-classes grouped by blueberry. This outcome made us focus the rest of the study on these cutting-class groups. For the habitat selection of the mustelids compositional analyses were used. This showed that the mustelids did not select the habitat with the highest amount of vole(cutting-class 5) and avoided the open terrain (mountains and bogs).

When I looked at the tracks distribution none of the cutting-classes showed a relationship between the amount of tracks and the amount of available cutting-class on the transects. These results are not in line with what I expected and this can possibly be explained by the following.

1. Weasel and stoat are territorial and thereby have a despotic distribution.
2. During the study period the rodent numbers were high and therefore sub-optimal habitats were sufficient to survive.
3. The bank vole is not the most preferred prey species, the Field vole is and this vole lives in younger forest with grass as ground vegetation.
4. During years with high rodent numbers odder general predators which prey to rodents, these general predators then will hunt in the habitat were rodents are most abundant, and also will prey on the weasel and stoat.

The lack of a clear preference for one cutting-class shows that forestry does not have an influence on weasel and stoat, however forestry has an influence on the voles on which are the main prey species for these mustelids. The forestry system of Norway is a system of clear cuts. These clear cuts create a pioneer stadium which can be shortened by applying scarification and minimizing the soil compaction.

Keywords: Small mustelids, voles, habitat selection.

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1. Introduction

Substantial ecological research is being conducted on the influence of voles on the boreal forest. In this forest ecosystem, voles are important keystone species (Hanski et al. 2001, Huitu et al. 2012). The population dynamics of the mustelids, the least weasel (*Mustela nivalis nivalis*) and stoat (*Mustela erminea*) are greatly influenced by voles since both of them rely on voles as their main food source in the boreal forest ecosystem in Scandinavia (King and Powell, 2007).

Weasel, stoat and voles have been studied extensively in Fennoscandia. However, little is known about how forestry influences the food-web in the boreal forest. Since the mainstay timber harvest method in Norway is clear-cutting, this quick change form climax vegetation to pioneer has a major influence on the boreal forest ecosystem.

Furthermore there is an increasing concern regarding a possible decline in populations of small mustelids in several countries including the UK (REF) and the Netherlands, this concern was also discussed at the European Mustelids Coloquium in December of 2011 (restart of the research group “kleine marterachtigen” at the Dutch Mammal Society)(U.K., Battersby, 2005). However in Norway there is no indication yet of a decline, thus assuring that research can be performed on these animals in a healthy natural environment, with the benefit that inference can be extended to regions with declining mustelids populations.

Problem description

There is already much known about weasel and stoat in Fennoscandia, but a majority of the studies (e.g. by Henttonen) have been done in Finland or in the high north of Scandinavia, where ecological conditions are different from this study, done in south eastern Norway. The south eastern part of Norway is the area where forestry is most intensive, and it is not well known how this can influence habitat selection.

In this study I will look at voles and their relationship with small mustelids. Because of the concern about the decline of mustelids in Europe it was therefore also interesting to look how human activities such as forestry influence the mustelids and the habitat they live in.

Aims and Problem analyses

The basic needs for survival and reproduction for all animals are food and shelter. The weasel and stoat have a really fast metabolism (King and Powell, 2007), therefore the focus will be on food resources. Rodents are the most important food source for weasel and stoat in Fennoscania. It comprises up to 90% of the diet of stoat (Erlinge, 1981), and even more for weasel (King and Powell, 2007). Among the rodent species, both weasel and stoat are for the largest part dependent on those smaller than 80 grams, e.g. voles and lemmings (Erlinge, 1975, 1981). The rest of their diet consists for a major part of bigger rodents up to 250 grams (rats, water voles). Since my study area is on the border of the geographical range of water vole (*Arvicola amphibious* IUCN, 2011) it can be disregarded as an important prey species, and therefore I focus the study on voles.

The population dynamics (cycles) of small rodents have changed and have become irregular in recent years (Selås, 2006, Andreassen, 2010). This has partly been related to climatic changes (Ims 2005, Kyrre et al. 2008). In some vole-species, the cycles have disappeared or exhibit smaller amplitudes (Angerbjörn et al. 2001, Henden et al. 2009). The changes in population dynamics may have pronounced effects on the whole ecosystem (Ims 2005, Ims et al. 2008), and then especially on predators that are specialized on small rodents.

Recent research suggests that the bank vole (*Myodes glareolus*) is the dominating species in boreal forests and that they are closely associated with blueberry (*Vaccinium myrtillus*) (Panzacchi et al. 2010, Selås 2006). In my study I investigated this further by analysing live capture data on voles in relation to vegetation types and cutting-classes. The results were used to investigate habitat selection in weasel and stoat.

This study was aimed to improve the knowledge about the habitat preferences of weasel and stoat in south-eastern Norway, and to be able to predict and respond (i.e. changing harvest methods or protection of certain habitat) to future conservation challenges (i.e. climate change, pollution, extinction of prey species).

Research questions

I will investigate habitat use of small mustelids by analysing snowtracking data from 2011 and 2012 in forested areas in south-eastern Norway. In order to relate habitat use of weasels and stoats to food availability, I will estimate vole density in the same areas based on live-trapping conducted in the summer 2011.

Main question: What is the relationship in habitat use between small mustelids and vole distribution in forests of SE- Norway, and how can forestry influence on this relationship?

Sub questions:
1. What are the influences of cutting-class and vegetation type for the spatial distribution of voles?
2. Is there a relationship between cutting-class and/or vegetation type and small mustelids' habitat selection?
3. Is there a relationship between vole distribution and weasel and stoat densities?
4. Which forestry methods could influence weasel and stoat?

Study area

The study area is situated north-east of the town Rena in the county of Hedmark, south-eastern Norway, and is 241.3 km^2. The altitude of the area ranges between 248 to 1009m. This area is state owned and one of the main training sites for the Norwegian army, during the data collection the military training continued. Because the Shooting range is state owned (single owner) it is much easier for us to obtain permission to conduct our field work. 80% of Norwegian land is private owned (Statskog, 2007) which makes it hard to find large enough study areas

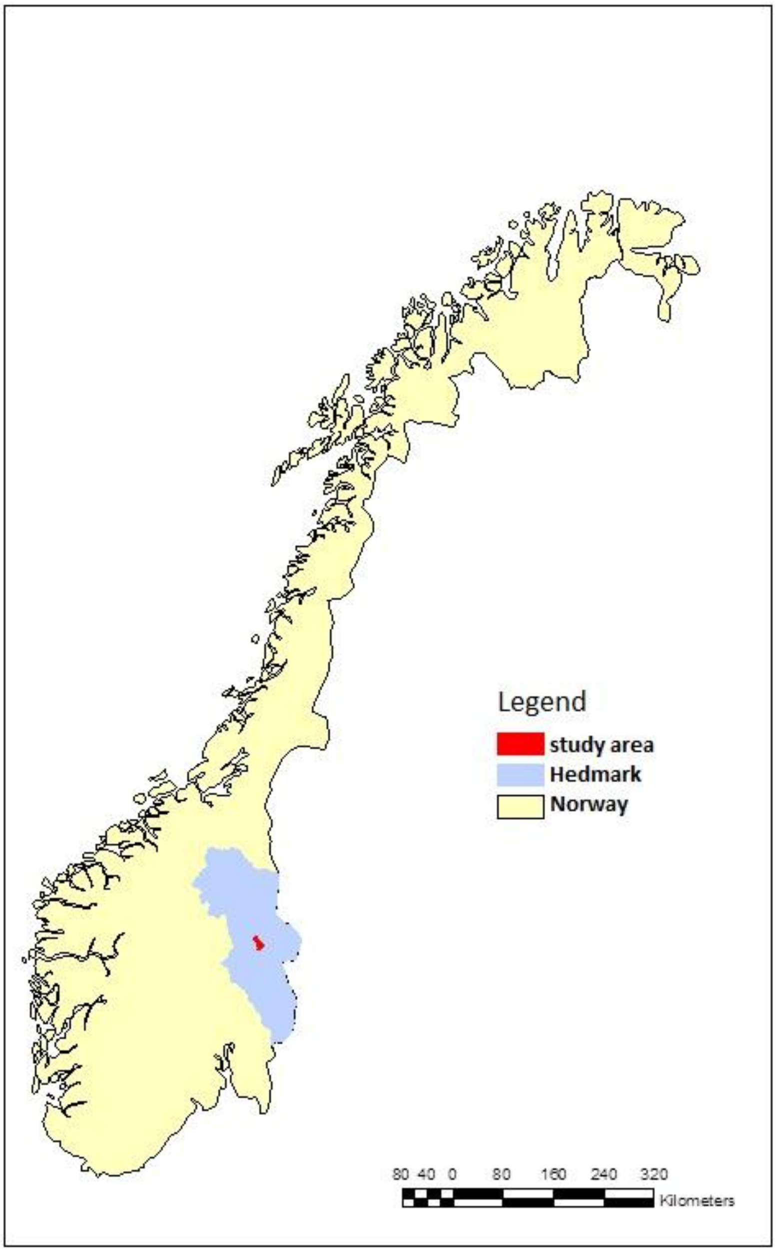

Figure 1 study area

The Boreal forest

The Boreal forest is a circumpolar coniferous forest that represents 27% of the earth's forest (Taiga biological station, 2012). In this forest spruce is dominating the landscape, when looking under the trees, fruit-bearing shrubs are important for birds and mammals in the boreal forest (Taiga biological station, 2012). Wild berries that are common in Norway are cloudberry (*Rubus chamaemorus*), red raspberry (*Rubus idaeus*), blueberry (*Vaccinium myrtillus*) and lingonberry (*Vaccinium vitis-idaea*). Crowberry (*Empetrum nigrum*) is common in the mountain areas and a species of diploid strawberry (*Fragaria vesca*) grows as well all over the country. These berries are also important for voles especially for the Bank vole(*Myodes glareolus*), which has a strong positive relationship with *Vaccinium myrtillus* in South-eastern Norway (Panzacchi et al. 2010). These voles are important species and can be considered as a key stone species in the boreal forest (Hanski et al. 2001, Huitu et al. 2012). This consideration can be made stronger when knowing that Voles and lemmings are the preferred prey of many boreal predators like birds of prey, foxes and mustelids like the pine marten, stoat and weasel (King and Powell, 2007). Of these predators the small mustelids (weasel and stoat) are most specialised in hunting these small rodents (Hansson and Henttonen 1985).

General ecology

Weasel and stoat are the smallest Mustelids and also the smallest member of the order Carnivora. Within the Weasel species there are 3 subspecies. Here in Norway the smallest subspecies is found, the pygmy Weasel (*Mustela nivalis nivalis*). This subspecies together with the stoat has his distribution in Fennoscandia (Denmark, Norway, Sweden and Finland) and Russia (Mitchell-Jones & Amori, 1999). The stoat in Fennoscandia is considered to be the common stoat but does have a smaller size the animals found in the rest of Europe(King and Powell, 2007).

Being weasel-shaped with a small elongated body is a specialisation to be able to hunt in rodent tunnels. (King and Powell, 2007).This specialisation gives them access to rodents year round. However, this body structure and specialisation on rodents gives them a high metabolism and a high heat loss. Furthermore, many other bigger predators are able to prey on the small mustelids.

The reproduction of weasel and stoat differs to some extent, which can influence population growth in vole rich years.
In the least weasel, the implantation is direct after mating which makes it possible to have more than one litter in vole rich years (Deanesly 1944, king 1980c). The first born litter will then also get their first litter in the same year that they are born (King 1980c; McDonald &Harris 2002). The least weasel of Scandinavia can breed under the cover of snow and makes it possible to breed during winters in peak vole\lemming years (Fitzgerald 1981).

IN The stoat, on other hand, The reproductive cycle is controlled by the time of the year, where mating takes place in the end of spring (King & Moody 1982; Herbert 1989). This late mating after the offspring are born there is a stage of delayed implantation (9 to 10 months) and this makes it impossible for stoats to react on high abundance of prey to the same extent as the weasel (King and Powell, 2007).
Because of vole cycles and this reproductive system the population fluctuates together with the voles with up to 1 year delay (Tikhonov et al. 2008).

2. Method

During my internship periods in the springs 2011 and 2012. data on mustelid distribution was collected by snow tracking in the study area. I collected live-trapping data of voles in the same area in the summer of 2011 as well. In total, I obtained data from ca 200km of snow-tracking and ca 300 trapped voles (of which 250 are bank voles, *Myodes glareolus*) in 1152 trap-nights.

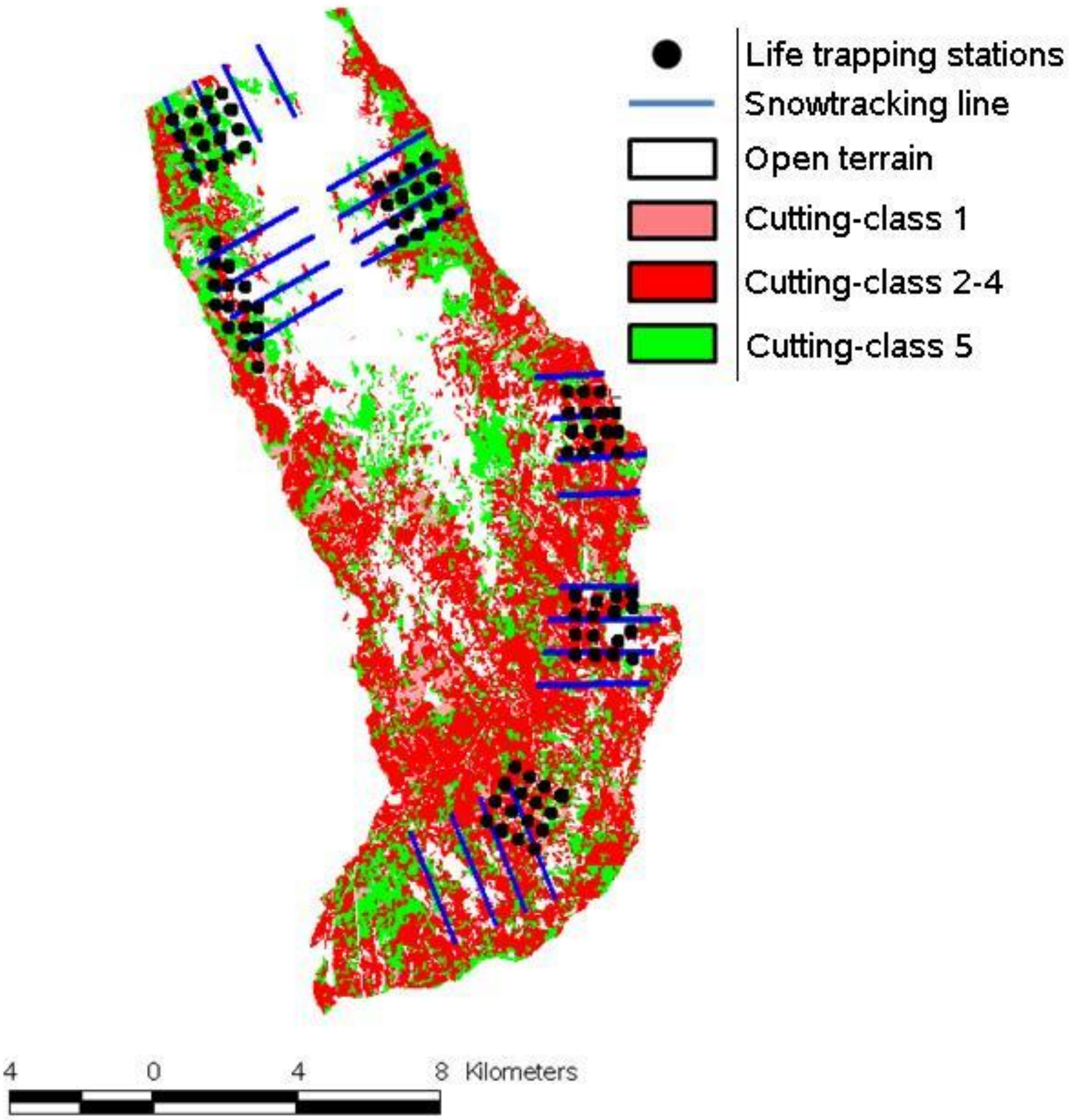

Figure 2: study area showing avalaible cuttingclasses and data collection lines and points

Vole live trapping

Data were collected by life trapping on 384 locations using “ugglan live traps”. As shown in Figure 2, the traps were placed in groups of 4 with a 50 m distance between them along 1.5 km long transect lines. All traps were pre-baited for 3 day following up the traps were closed and the trapping was done for the following 3 days resulting in 1152 trap-nights over all traps. The GPS location (in UTM WGS84 coordinate system) was recorded on each trap site, and habitat information was retrieved form vegetation- and forestry maps of the study area.
From each caught individual the following was registered:

Species:
Bank vole (*Myodes glareolus*; formerly *Clethrionomys glareolus*)
Field vole (*Microtus agrestis)*
wood lemming (*Myopus schisticolor)*
Water vole (*Arvicola amphibius)*
grey sided vole(*Myodes rufocanus*)
Sex
weight: in grams
age: adult, juvenile
reproductive stage: for males if the testicles are visible, for females if the nipples are visible and if they are lactating.

Each individual got its own unique code with nail polish so when animal were recaptured it was possible to recognize the individual vole.

Snowtracking weasel and stoat

The field data was collected by sampling tracks on ca 3 km long transect lines that were located with a minimum distance of 1 km apart.

The following information was recorded for every time a line was sampled:
Line number: given number to each individual transect.
Date: date when transect was sampled.
Observer(s): person(s) who samples the transect line.
Days since snowfall: Minimum 2 days and max depends on snow conditions.
GPS number: the number written on the GPS where all track location will be saved.

Registration of tracks

In each track crossing the transect line the following is recorded.

Species: all species were recorded (this study will only use the weasel and stoat tracks)

Code	Full name
Rod	small rodent
Sq	Red squirrel (*Sciurus vulgaris*)
Weas	Weasel (*Mustela nivalis*)
Stoat	Stoat (*Mustela erminea*)
PM	Pine marten (*Martes martes*)
Hare	Mountain hare (*Lepus timidus*)
Moos	Moose (*Alces alces*)
Wg	Willow grouse (*Lagopus lagopus*)
Bg	Black grouse (*Lyrurus tetrix*)
Caper	Capercaillie (*Tetrao urogallus*)
Fox	Red fox (*vulpes vulpes*)
Lynx	lynx (*Lynx lynx*)
Wolve	wolverine (*Gulo gulo*)
Wolf	wolf (*Canis lupus*)

Table 1: animal species

Waypoint number/GPS location: Every track of each species gets its own waypoint number in the GSP(coordinate system UTM WGS84 region 32).
Number of animals: If more than one track of the same species is found within the distance of 10 meters on the line this number of tracks will be noted as the same location.

Tree species: The dominant tree species at the tracks (more than 1 species is possible)
Cutting-class(Development class): Describes the forest's development class from clear cuts to old forest.
In the current system the following definitions are used:
Development class I: forest under regeneration (non-stocked land and very sparsely stocked stands)
Development class II: regenerated areas and young forest
Development class III: young thinning stands
Development class IV: advanced thinning stands
Development class V: mature forest
(Statistics Norway 2009)
Snow depth: The depth (cm) of snow below the track
Comments: Extra information about the track location or track itself

For Weasel and stoat additional measurements were recorded.

Width of track: Weasel and stoat jump in a way all feet leave 1 track, for the width you measure the whole print form side till side. Three tracks are measured and the smallest and biggest ones are written down.
Distance between tracks: The distance between tracks is measured from front of the print to the front of the next print. Three tracks are measured and the smallest and biggest are written down.

Data analyses

For the statistical analyses three test were used to answer the different questions. Every test gives the P (probability) of the tested relationship. For the relationship to be significant the value has to be equal or smaller then 0.05. When the value is between 0.05 and 0.1 there is still a possibility of a relationship but the closer to 0.1 the weaker the chance of a relationship.

Distribution of voles

For the vole analyses Logistic regression with Rcmdr (Fox 2009) in R (R Development Core Team 2009) was used. The response variables were binomial and showed if a species was trapped during the trapping period in that individual trap. For the models four parameters were made to test the data. Two regarding the cutting-classes(CC1 and CC2) and two for vegetation (VEG1 and VEG2)

The parameter "CC1" expresses the cutting-class in the traditional way with 6 stages: 0 - Open terrain, 1 - Logging area before regeneration. 2 - Newly established young forest. 3 - young trees till first thinning mature forest. 4 - thinning stands that have stagnated in growth. 5 - Older, fully grown mature forests. This parameter describes thus primarily forest age.

In parameter "CC2" the traditional cutting-classes are converted into a concept forestry class based on assessment results from National Forest Inventory in Hedmark (Eriksen, 2008). This is a sample plot based valuation that has estimated coverage of blueberry bushes in different vegetation types and developmental stages in different parts of the country since 1995. The methodology is basically to estimate the coverage of bilberry bushes for four squares of 0.5 X 0.5 meters per flat rate. The same routes are inspected at each rate. This resulted in a forestry class with four classes: cutting-class 0 is the open spaces (minimal or no blueberries coverage), cutting-class 1 is clear-cut areas which also have little or no blueberries coverage. Cutting-class 2, 3 and 4 are young and middle-aged forest with medium blueberry coverage. Cutting-class 5 is the most mature forest with high blueberry coverage.

"VEG1" describes the vegetation with a grouping of the vegetation types in the following way: Open the vegetation types (marsh / mountain), poor, dry forest types (heather bilberry), medium site quality (blueberry forest), richer forest types and forest types with little or no heather. This model is based roughly on the ground productivity. Blueberries ratio in different forest types are determined by the National Forest Inventory results (Eriksen, 2008).

"VEG2" is a parameter which I analysed with "Vegetation Types in Norway" (Fremstad, 1997) and uses numbers from 1 to 3 (none, low and high blueberry coverage) for each of the relevant vegetation type. This was done to make the amount of different vegetation types into manageable groups. Fremstad (1997) describes the vegetation types and plant species using different codes indicating importance. In Table 2 you can see how the vegetation groups are grouped in the new groups for "VEG2".

These parameters were tested individually and in all possible combinations, represented as independent models to determine which one showed the best correlation with the capture data (Table 4).

Table 2: vegetation codes and the new vegetation groups based on blueberry richness (Fremstad 1997). Further details in Appendix 1.

Vegetation	Code	English vegetation name	Vegetation group
Lavfuruskog	A1a	lichen-pine forest	1
Tyttebærfuruskog	A2a	cowberry-pine forest	3
Røsslyngblokkebærskog	A3a	heather-bilberry-pine forest	2
Blåbærgranskog	A4a	blueberry-spruce forest	3
Blåbærfjellkreklingbjørkeskog	A4c	blueberry-crowberry mountainbirch forest	3
Finnskjeggfjellbjørkeskog	A4d	blueberry-mountainbirch forest	3
Småbregnegranskog	A5a	small fern-spruce forest	2
Storbregnegranskog	C1a	big fern-spruce forest	1
Høgstaudegranskog	C2c	high shrubs-spruce forest	1
Fattig sumskog av gran-bjørk-type	E2a	poor birch-spruce bogforest	1
Alpin røsslynghei, tørr type	S1a	alpin heather	1
Blåbær-blålynghei	S3a	blueberry-bluemountain heather	3
	0	open terrain (mountain/bog)	1

Habitat selection of weasel and stoat

To determine the habitat selection of weasel and stoat ”Compositional Analysis” (Aebischer, Robertson, & Kenward, 1993) was used. These analyses were done in the program *Resource selection* (Uni. Of Idaho 2012) Normally this is used for habitat selection of location data and home-ranges, but can also be used when data is collected on line transects. This was done by regarding each line as a sample unit analyses the proportions of available cutting-classes groups are compared with the proportional distribution of used habitats on each line.
For these analyses the calculated “available habitat” and the “used habitat per line” was used. For this the cutting-class was tested in three models (table 3). These models were all based on the outcome of the logistic regression models where cutting-class grouped by blueberry came out the strongest (table 4).

Model (cutting-classes groups)	Name model (Weasel)	Name model (Stoat)	Name model (Weasel v. Stoat)
0,1,2-4, 5	W1	S1	WS1
0, 1-4, 5	W2	S2	WS2
0-4, 5	W3	S3	WS3

Table 3: explaining the three different models for Weasel, Stoat and the relationship between Weasel and stoat.

<u>Available habitat per line:</u>
the available habitat per line was collected from 2 factors the vegetation type and the cutting-class. The vegetation type was obtained from the vegetation map of the study area. In GIS a 60 metre buffer was made on each line to represent the available vegetation on the line. The area of each vegetation type was transformed into a percentage of the line. This was also done for the cutting-classes.

<u>Used habitat per line:</u>
The vegetation of each track was retrieved from the available vegetation map. It was not possible to collect this data in the field since the ground was covert with snow during the field period. For the cutting-class I had next to map data also recorded the cutting-class in the field for each track.

Track density of weasel and stoat

The method used to find the relationship between track densities and available cutting-class was linear regression. For each regression line the R^2 (correlation coefficient) and P (probability) was calculated with the program Minitab 15. With these two numbers the significance of the linear regression was shown. For the test the available cutting-class per line was plotted against the amount of tracks per line. This was done for all cutting-classes.

The density of tracks was defined as the number of tracks per line divided by the length of each line (around three kilometres), divided by the number of days since last snowfall.

3. Results

Weasel or stoat track?

For the weasel and stoat tracks the width and distance between tracks was measured to determine the species, as a back-up for the fieldworkers.
In the field it was clear that the width of the track was greatly influenced by the snow conditions and made it impossible to do accurate measurements. So for the determination of the species and the quality of judgement of the field workers the distance was used. Figure 3 shows that the field workers were able to distinguish the difference between weasel and stoat. The T-test sows that the difference between Weasel and stoat is significant (P=<0.001).

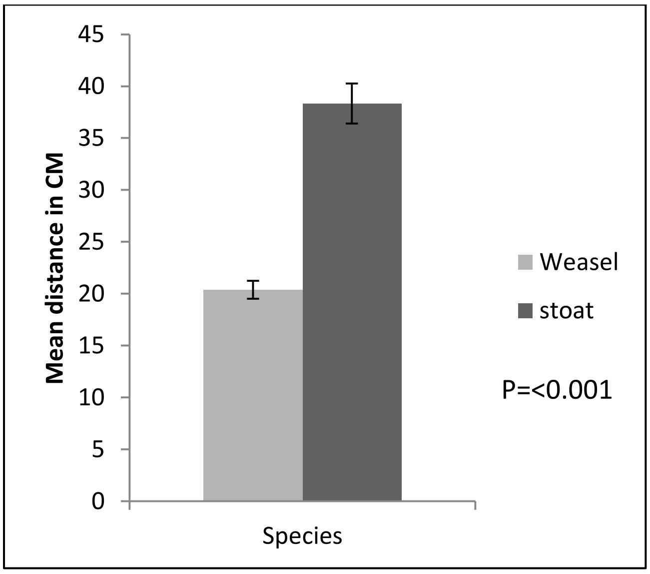

Figure 3: showing the mean distance between track for weasel and stoat.

Vole distribution

During the trapping period the total of caught rodents was 287. The following species were represented in the following numbers 245 bank voles, 36 Field/root vole (hard to distinguish difference in the field)*(Microtus agrestis/-oeconmus)*, 2 water voles *(arvicola terrestris)*, 3 wood lemming *(Myopus schisticolor)* and one Grey sided vole *(Clethrionomys rufocanus)*. The Bank vole was caught in 33% of the traps while the field vole was only caught in 6% of the traps. This explains why the number of bank voles is higher and the most dominant species in the study area. For the analyses we focused on the bank voles since they were by far the most abundant.

In relation to the distribution of traps in different forest types, most bank voles were trapped in old forests - cutting-class 5. In both open areas, harvested areas and in younger forest stands were catching share percentage lower than in older forests (Figure 4).

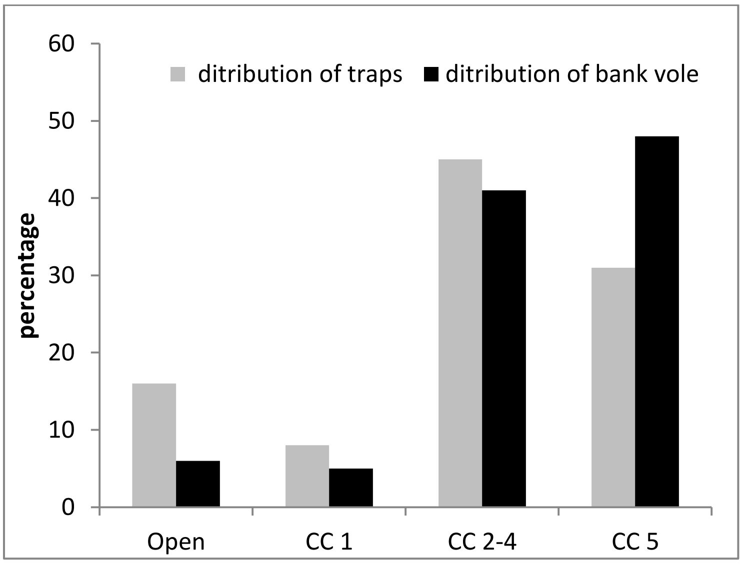

Figure 4: Distribution (%) of traps and captured bank vole within the cutting-classes of the study area. Open = mountain and bog, CC= cutting-class.

Model	Parameters	AICc	Delta AICc
M1	CC1	466.2	5.1
M2	**-1.92(0.30)Int+ 0.60(0.13)HK2**	**461.1**	**0**
M3	VEG1	485.4	24.3
M4	VEG2	486	24.9
M5	CC1+ VEG1	467.9	6.8
M6	CC1+ VEG1 + CC*VEG1	469.5	8.4
M7	CC2+ VEG2	462.3	1.2
M8	CC2+VEG2 + CC2*VEG2	462.4	1.3
M9	CC1+ VEG2	467.7	6.6
M10	CC1+VEG2+CC1*VEG2	469.7	8.6
M11	CC2+VEG1	462.7	1.6
M12	CC2+VEG1+ CC2*VEG1	463.8	2.7
M13	NULL	484	22.9

Table 4: Logistic regression models to explain the trapping success of bank vole in the study area. The response variable was the capture success, expressed as catch / no catch. The best model (M2) includes the parameter estimates (Standard Error in parentheses). Int = Intercept, CC1, CC2, and VEG1 VEG2 habitat classification are based on cutting-class (CC) and vegetation (VEG).

Test results showed that Model M2 (only parameter CC2) has the lowest AIC value of 461.1 (Table 4), and was therefore the best model. This is also the model in which forest types are divided into main-classes: open, young forest and old forest that best explains the variation in the vole captures, that is, the division that was based on blueberry coverage. All other single parameter shows lower significance. The test also shows all possible combinations of the four main parameters, and here we find that the model m7 (HK2 + VEG 2) has the second lowest AIC - value of 462.3 (Table 4). The model explains the results capture the worst-M4 representing parameter VEG2 individual with AIC at 486 (Table 4). The model M13 represents a test with no parameters. M13 has in this case AIC - value of 484.0 (Table 4), and therefore did worse than most other models.

Weasel and Stoat habitat selection

Three models were ran for weasel, stoat and weasel against stoat to determine the habitat selection.

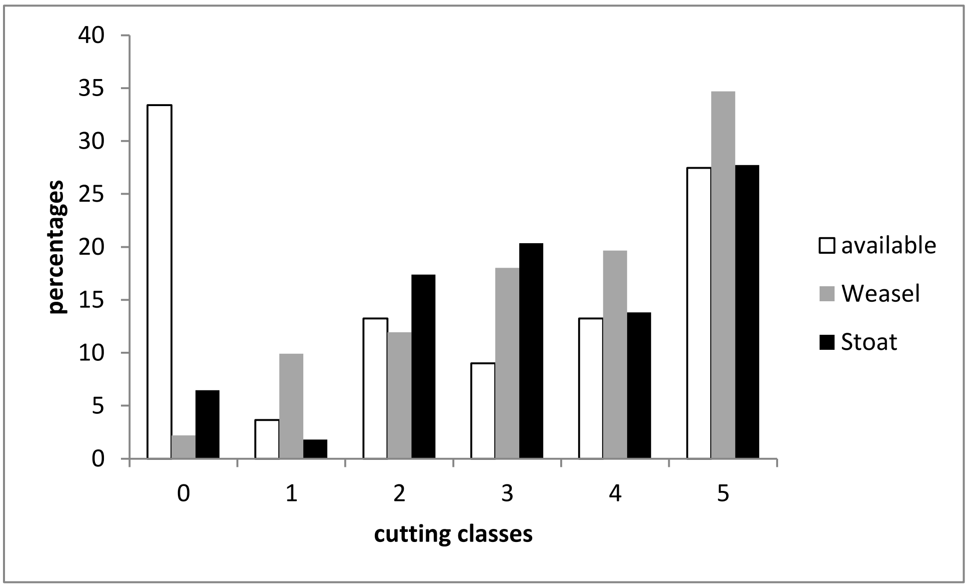

Figure 5: showing the average percentage of the available cutting-classes and the average used cutting-classes for weasel and stoat. Cutting-class 0 = open terrain (mountain and bog).

In figure 5 it is already possible to see that open terrain (cutting-class 0) is avoided. After compositional analyses cutting-classes 1-4 were preferred above 5 (Table 5), but cutting-classes 2-4 are showing the strongest relationship with weasel and stoat. Within these models open terrain had always the lowest rank

Model	Parameters	X2	DF	P	Highest ranked CC
W1	0, 1, 2-4, 5	26.7	3	<0.0001	2-4
W2	0, 1-4, 5	26.1	2	<0.0001	1-4
W3	0-5, 5	2.75	1	0.0969	\
S1	0, 1, 2-4, 5	17.8	3	<0.0001	2-4
S2	0, 1-4, 5	16.9	2	<0.0001	1-4
S3	0-5, 5	2.69	1	0.1008	\
WS1	0, 1, 2-4, 5	4.46	3	0.2156	\
WS2	0, 1-4, 5	1.43	2	0.4886	\
WS3	0-5, 5	0.0015	1	0.9689	\

Table 5: showing the result from compositional analyses. The Insignificant results did not get any ranking. The group "Open terrain" is ranked the lowest in every model. The parameters are the cutting-class groups that were tested for W= weasel, S= stoat and WS= weasel against stoat

Weasel and stoat track densities

In the Analyses of vole distribution, cutting-class 5 was most preferred by the bank vole. At the habitat selection of weasel and stoat the compositional analysed showed a preference for cutting-classes 2-4. Open terrain was avoided by the mustelids in all the models.

After running linear regression on the track densities of weasel and stoat, there was no significant regression shown. In Figure 6 the regression line shows a small incline but this is too small to make it significant, with for weasel (P= 0.712 and R^2= 0.6%) for stoat (P=0.883 and R^2=0.1). For the cutting-classes 2-4 which were selected the most by weasel and stoat, the regression was the strongest but declining for the weasel and not significant(figure 7).

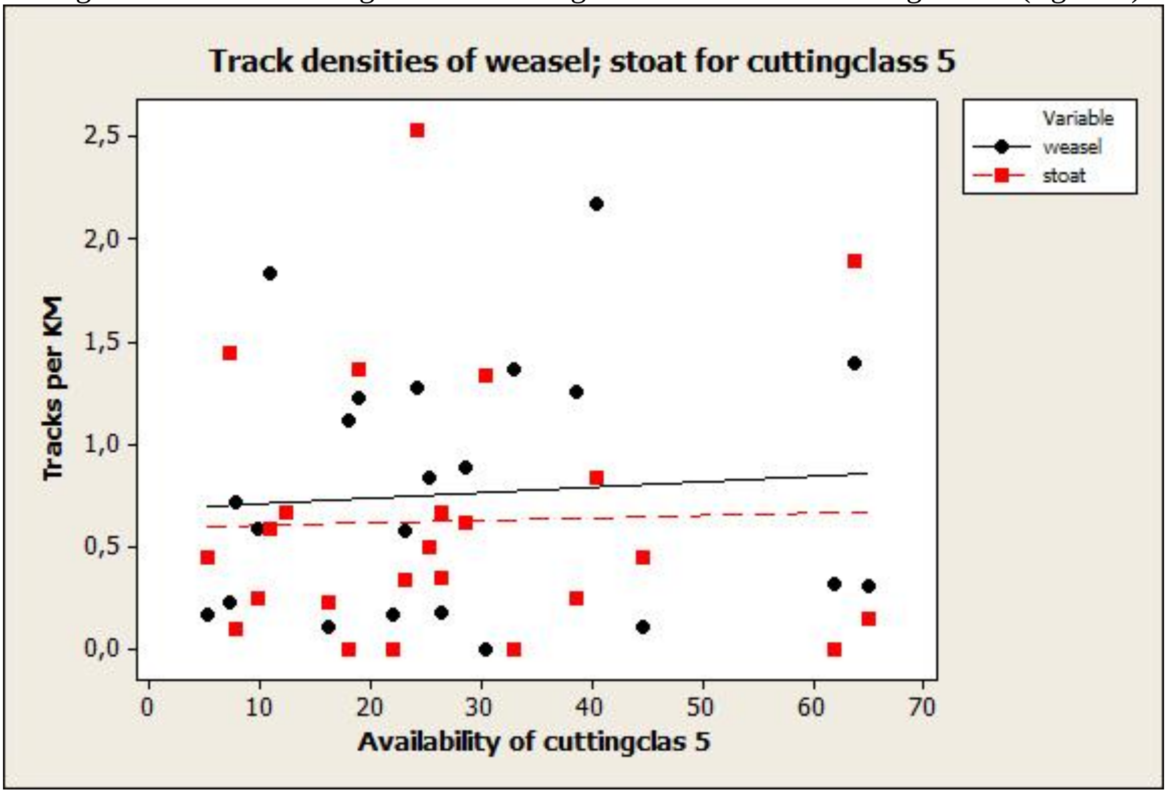

Figure 6 is showing no relation between densities of tracks and available cutting-class 5 . Significance numbers for weasel (P= 0.712 and R^2= 0.6%) and stoat (P=0.883 and R^2=0.1%). Availability

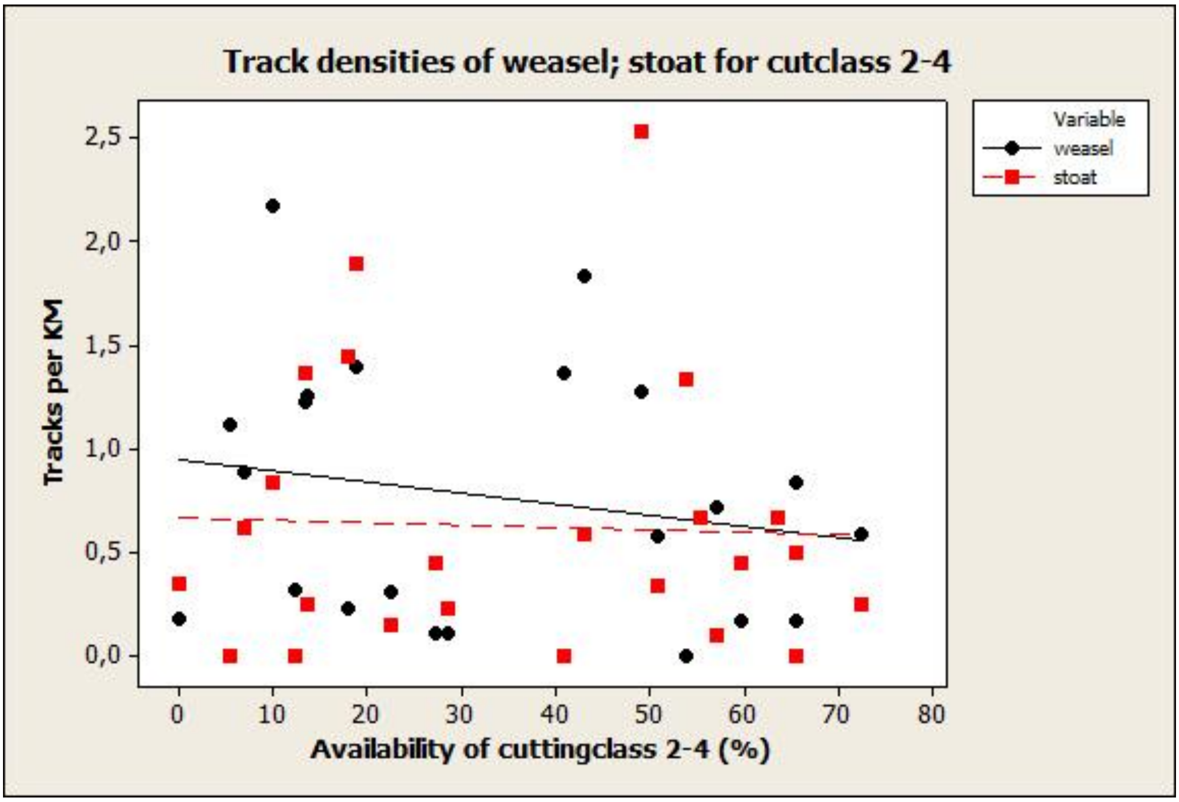

Figure 7 is showing no relationship between densities of tracks and available cutting-class 2-4. Significance numbers for weasel (P= 0.325 and R^2= 4.4%) and stoat (P=0.849 and R^2=0.2%).

From the compositional analyses "open terrain" was avoided and ranked the lowest of all cutting-classes. This avoidance is not shown in the when looking at the track densities.

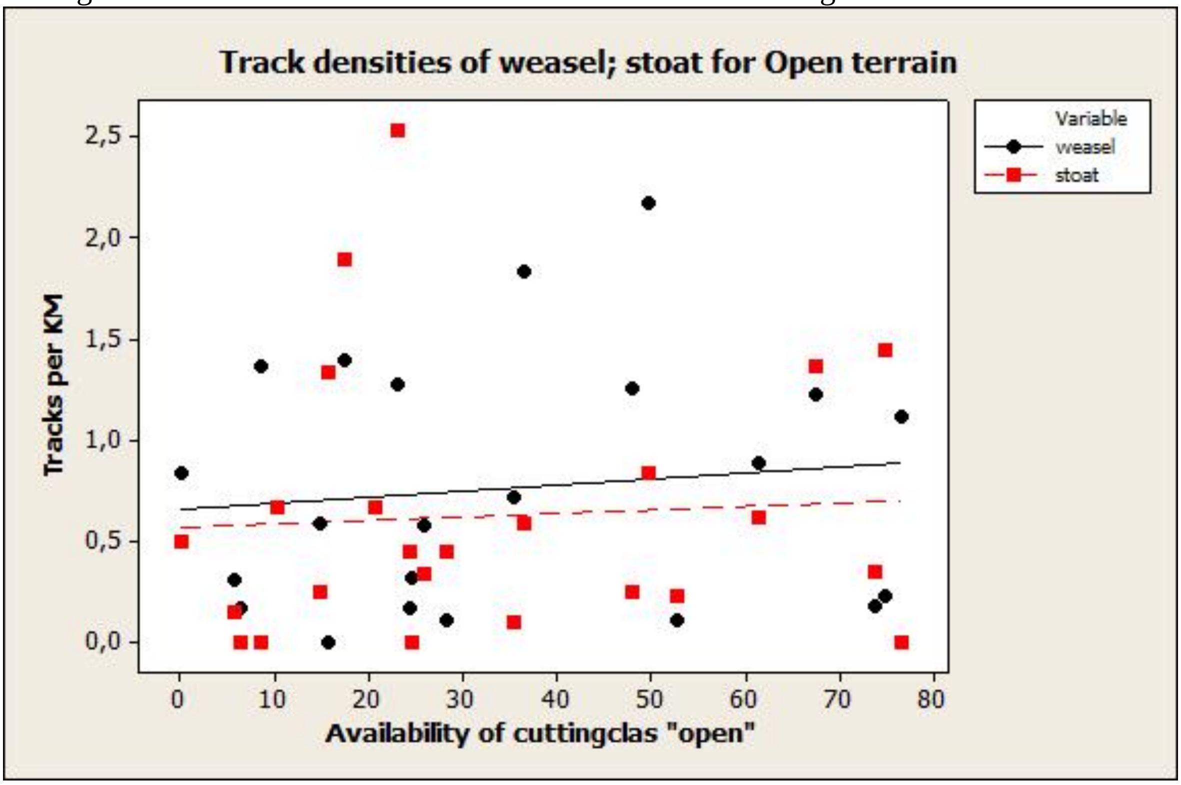

Figure 8 is showing no relationship between densities of tracks and available open terrain. Significance numbers for weasel (P= 0.574 and R^2= 1.5%) and stoat (P=0.766 and R^2=0.4%).

Forestry system in Norway

To be able to understand how the forestry system work in Norway I conducted a small literature study:
As in many countries also in Norway the annual harvest (8.070.780 m3, Statistics Norway, 2009b) is smaller than the annual growth (24.897.000 m3, Statistics Norway, 2009b). Of the annual harvest 85% is final-cut (clear-cut) and of all harvest 91% is done with a tree-processor (harvester)(Statistics Norway, 2009a).
The time between planting/seeding and the final cut is between 70 and 100 years also called rotation age (Bureau of Nordic Family Forestry). With this we can conclude two things; that they do not come in the forest that often during the rotation time and that most of the time there is only a final harvest with heavy machinery. This large amount of final cuts can be due of the fact that the forest is getting older and older, since the annual harvest is smaller than the growth. After clear-cutting not only the trees are gone but the hole ecosystem is back to the pioneer stage which means that species will disappear which are not soothed to these new conditions. According to Palviainen et al. 2005, the ground vegetation will decrease up to 65% in the boreal forest in the first years after that pioneer vegetation took over and an increase of ground vegetation is recorded.

<u>Soil scarification</u>: The thick acid humus layer of spruce and pine needles makes it hard for seed to sprout. To improve the chance of sprouting the humus layer has to be removed or mixed with the mineral layers of the soil. Soil Scarification is the term using in silviculture for the method that is used to improve the chances of seeds to sprout by scarring the soil.
This soil scarification is a difficult process where timing according to weather is very important (Heikinheimo 1937, Sarvas 1962, Jackson & Sweet 1972 and Sahlén 1992).
In Norway however only on 5000 hectares of forest scarification was used of the total 30.000 hectares of forest which had any form of silviculture (Statistics Norway, 2009b). This shows it is not a standard methods to use for silviculture in Norway.

<u>Soil compaction</u>: Heavy mechanized forestry activities are causing soil-compaction and reduces the re-growth of the forest (adams 1981). In the boreal forest the usual soil is potzel, which when the leached horizont is exposed can become hard and impenetrable for water which can stay for several years (Taiga biological station 2012). The compacted is already harder for plant to sprout and together with the podzel can create unsuitable conditions for regeneration of the forest.
In Norway the soil also exists for a great part out of podzel, but because of the rock layer as mineral layer these podzels are not very thick. Furthermore most logging takes place in spring when the ground is still frozen. These factors could make soil compaction less important.

4. Discussion and management advice

Bank voles (*Myodes glareolus*) were the rodent species with the highest abundance with ±80% of the captured rodents, the abundance was highest in CC5 where blueberry cover is the highest. In previous studies vegetation wit blueberry had shown a relationship but, in this study no effect of vegetation types was found, probably because cutting class corresponds better with blueberry coverage than vegetation types.
However, neither weasel nor stoat showed any clear pattern of selecting the habitat types where bank voles were most abundant.

The only thing that was clear was the avoidance of open areas. These were open bogs and mountain areas without vegetation, and therefore not suitable for voles. Knowing this it seemed that the mustelids only avoid areas with very little food resources, but used all other habitats more or less according to the availability. For these results I suggest three possible explanations.

1. Weasel and stoat are territorial, and will therefore exhibit a despotic rather than an ideal free distribution. Hence, the distribution of these mustelids will probably be less correlated with resource density than among non-territorial animals. Animals who are territorial defend their home range or a part of it (Burt 1943). This limits the ability of these animals to distribute themselves according to food abundance. The home ranges of weasel and stoat vary a lot in size among different areas, and this is determined by the abundance of prey. Weasel and stoat will never walk further form the den than needed to find food or a partner (King and Powell, 2007). When the abundance of prey is lower the home range will have to be bigger to be able to supply enough prey animals. This is, however, not the case for breeding female least weasel , as these seem to have a restricted home range of 1-2 ha irrespective of prey abundance (Henttonen, 1987).

2. The main part of the study was conducted in a period with a high abundance of rodents. Although the density of rodents varied among habitat types to some extent, their abundance may have been sufficient to support rather high densities of predators. Because of this high abundance of rodents it is possible that other less preferred habitat had also high enough rodent numbers for the predators to be able to survive and reproduce. According to Erlinge (1974) a least weasel needs at least 10 breading individuals of rodents per ha to survive. Another study suggested that 14 individuals was the minimum number (Trapper 1979). According to Lockie (1966), habitats were abandoned when the total population of voles got under 44 individuals per hectare. These studies focused on the Field vole (*Mircotus agrestis*) as prey species.

3. Although bank voles were the most commonly trapped species it is not certain to what extent this reflects a higher abundance rather than higher trap ability. The difference was very clear and bank voles are probably the most abundant species, but other species such as field voles may have been more common than revealed by the trapping data. Furthermore, the mustelids may show a higher preference for field voles. These aspects may have affected the habitat use of the predators. According to some studies, field vole is the most preferred prey species for the small mustelids and they will habitats where field voles are more abundant (Lockie 1966, day 1968, Erlinge 1974; 1975, Delattre 1983). However, according to King (1980a) the bank voles were the most common food source of M. Nivalis, and they were eaten in the same proportion as they occurred in the area. An experimental study did not show that field voles were preferred above bank voles (Erlinge, 1974). Hence, previous studies show

different results regarding the importance of the different vole species. However, a preference for field vole could explain why the mustelids prefer younger forest, as the field voles live in more tall grass forests/meadows than the bank vole (Panzacchi et al. 2010).

What was shown in our study is that the bank vole does have a strong relationship with blueberry rich habitat types, and that the cutting class corresponded better with vole abundance than vegetation type. This is probably caused by a stronger relationship between blueberry abundance and cutting class than with vegetation type.
Old forest was important for the bank vole, probably because this is where the blueberry is most abundant. However, one should keep in mind that blueberry is not only important for the bank vole but also for other herbivores such as forest grouse and ungulates. Although I did not find a relationship between weasel, stoat and old forest.

The forestry system in Norway should does not need to change according to our results. Human activity will always have a (in)direct influence on the forest, by changing the composition of forest stage. To minimize this effect two activities should be looked at these are the soil scarification and –compaction. These two methods of silviculture should then be used more often and when applied correctly. scarification will increase the numbers of seedlings and thereby accelerate the regeneration of the forest (Hagner 1962, 1965; Béland et al. 2000, Karlsson & Örlander 2002, Nilsson et al. 2002 and Nygaard & Brean 2007). According to Karlsson & Örlander (2002) the numbers of seedlings grows with factor 5 till 10 after scarification. When the soil compaction is minimize the podzel will not be exposed to air and rain and therefor the chances for seedling would increase were water and air is available for the roots.
When these two are both perfected within the forestry the regeneration of forest will be most successful and the influence of humans at its minimum. This will not only benefit the weasel, stoat and voles but the whole ecosystem, including the humans that harvest wood

5. Conclusions

The main question was: What is the relationship in habitat use between small mustelids and vole distribution in forests of SE- Norway, and how can forestry influence on this relationship?
1. What are the influences of cutting-class and vegetation type for the spatial distribution voles?
The influence of cutting-classes grouped by blueberry richness had the strongest relationship with vole distribution. Cutting-class 5(old mature forest) has the highest coverage of blueberry and there it is good habitat for bank voles. Because of this the rest of this study was based on this habitat grouping.
2. Is there a relationship between cutting-class and/or vegetation type and small mustelids' habitat selection?
The expectation was that weasel and stoat would select the habitat with the highest amount of vole. They did not; the mustelids selected all other cutting-classes, except open terrain, more than cutting-class 5.
3. Is there a relationship between vole distribution and weasel and stoat densities?
I could not find any significant relationship between the availability of any cutting-class and the density of tracks. Even the overall avoided "open terrain" did not show a clear negative regression.
4. Which forestry methods could influence weasel and stoat?
Several forestry activities influences the ground vegetation and regeneration of the forest and with that the vole distribution. However there is no clear sign that these activities influence the weasel and stoat on a negative way. When forestry will limit its foot print in the forest by scarification and reducing soil compaction the forest will regenerate faster and will keep a diverse forest where all forest stages are represented.

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7. Appendix

Appendix 1: details about vegetation grouping according to Fremstad (1997)

K: indicator species
M: dominant or highly frequent species
T: present in many vegetationtypes but not often, but if present it is an important indicator

open area(mountain/bog)	0

These are all the areas where no trees are growing and the terrain is open most of it are mountain heathers and bogs.

No vaccinium species present

Lavfuruskog	A1a	lichen-pine forest

A1a is the normal form of A1

Lichen-pine forest has three *Vaccinium* species in the list of characteristic species.

Blueberry (Vaccinium myrtillus)
Cowberry (Vaccinium vitis-idaea) M
Bog billberry (Vaccinium uliginosum)

Oder important species:
Scotish pine (Pinus sylvestris) M
Reindeer lichen (Cladonia spp.) M
common Heather (Calluna vulgaris) M
Ontario dicranum moss (Dicranum drummondii) K

Tyttebærfuruskog	A2a	cowberry-pineforrest

A2a is the normal form of A2

Cowberry-pine forest has three *Vaccinium* species in the list of characteristic species.

Blueberry (Vaccinium myrtillus) M
Cowberry (Vaccinium vitis-idaea) M
Bog billberry (Vaccinium uliginosum)
Important species:
Scotish pine (Pinus sylvestris) M
Norway spruce (Picea abies) M
Northern Running-pine (Diphasiastrum complanatum ssp. Complanatum and chamaecyparissus) K
Creeping lady's tresses (Goodyera repens) T
Green-Flowered Wintergreen (Pyrola chlorantha) K

Røsslyngblokkebærskog	A3a	heather-bilberry-pine forrest

A3a is the normal form of A3

Heather-billberry-pine forest has three *Vaccinium* species in the list of characteristic species.

Blueberry (Vaccinium myrtillus)
Cowberry (Vaccinium vitis-idaea)
Bog billberry (Vaccinium uliginosum) M

Important species:
Scotish pine (Pinus sylvestris) M
Juniper (Juniperus communis) M
Common Heather (Calluna vulgaris) M
Barbilophozia moss (Barbilophozia spp.) T

Blåbærgranskog	A4a	blueberry-spruce forrest

A4a is the normal form of A4

Blueberry-spruce forest has two *Vaccinium* species in the list of characteristic species.

Blueberry (Vaccinium myrtillus) M
Cowberry (Vaccinium vitis-idaea) M

Important species:
Norway spruce (Picea abies) M
Scotish pine (Pinus sylvestris) M
Wavy hairgrass (Deschampsia flexuosa) M
Dicranum moss (Dicranum majus) T+M

Blåbærfjellkreklingbjørkeskog	A4c,d	blueberry-crowberry mountainbirch forrest

A4c is the form of A4 which is dominated by black crow berry (Empetrum nigrum coll.). and has Mountain birch of Pine(Pinus sylvestris) as dominant tree species

Blueberry-crowberry mountainbirch forest has three *Vaccinium* species in the list of characteristic species.

Blueberry (Vaccinium myrtillus) M
Cowberry (Vaccinium vitis-idaea) M
Bog billberry (Vaccinium uliginosum)

Important species:
Scotish pine (Pinus sylvestris) M
Mountain birch (Betula pubescens ssp. czerepanovii) M
Black crowberry(Empetrum nigrum coll) M
Wavy hairgrass (Deschampsia flexuosa) M
Dicranum moss (Dicranum majus) T+M

Småbregnegranskog	A5a	small fern-spruce forrest

A5a is the normal form of A5

Important species:
Norway spruce (Picea abies)
Downy birch (Betula pubescens)
Oakfern (Gymnocarpium dryopteris) M

Wook anemone (Anemone nemorosa) M
Wavy hairgrass (Deschampsia flexuosa) M

No vaccinium species present (the underground is to rich and ferns are taking over the undergrowth)

Storbregnegranskog	C1a	big fern-spruce forrest

C1a is the normal form of C1

Important species:
Norway spruce (Picea abies) M
Lady fern(Athyrium filix-femina) M
Alpine buckler fern(Dryopteris expansa) M

No vaccinium species present

Høgstaudegranskog	C2c	high shrubs-spruce forrest

This high shrub-spruce forest with low herb with scattered high perennial plants. Which means most of the ground is covered with low herbs, often with tall birch.

Important species:
Lady’s mantle(Alchemilla wichurae) M
Wood geranium(geranium sylvaticum) M
Wood millet (milium effusum) M
Stone Bramble (Rubus saxatilis) M
Golden rod (Solidago virgaurea) M

No vaccinium species present

Fattig sumskog av gran-bjørk-type	E2a	poor birch-spruce bogforest

E2a is the normal form of E2.

Important species:
Alder (Alnus spp.)
Grey willow (Salix cinerea) M
Sedges(Carex lasiocarpa, rostrata, acuta, nigra and vesicaria) M
Marsh fern (Thelypteris palustris) K

No vaccinium species present

Rik sumpskog	E4	Rich bog forest

Important species:
Alder (Alnus glutinosa, incana) M
Downy birch (Betula pubescens) M
Norway spruce (Picea abies)
Elongated sedge (Carex elongate) K
Meadowsweet (Filipendula ulmaria) M
Lithuanian mannagrass (Glyceria lithuanica) K

No vaccinium species present

Blåtopp-eng	G2	purple moor grass meadow

Important species:
Purple moor grass (Molinia Caerulea) M
Devilsbit (Succisa pratensis) T

No vaccinium species present

Alpin røsslynghei, tørr type	S1a,b	alpin heather(dry continental type)

Important species:
Common heather(Calluna vulgaris) M
Black crowberry(Empetrum nigrum coll) M
Dwarf birch(Betula nana)

No vaccinium species present

Blåbær-blålynghei	S3a	blueberry-bluemountain heather

Blueberry-bluemountain heather has three *Vaccinium* species in the list of characteristic species.

Blueberry (Vaccinium myrtillus) M
Cowberry (Vaccinium vitis-idaea)
Bog billberry (Vaccinium uliginosum)

Important species:
Dwarf birch (Betula nana)
Wavy hairgrass (Deschampsia flexuosa) M
Black crowberry(Empetrum nigrum ssp. Hermaphroditum) M
Blue mountainheath (Phyllodoce caerulea) K+M