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Grey-sided vole and bank vole abundance in old-growth forest patches of different size and connectivity

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Gråsiding och skogssorkars antal i förhållande till gammelskogsfläckar av varierande storlek och konnektivitet

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Keywords: Grey-sided vole, bank vole, habitat patch size, old-growth forest, connectivity, population decline, environmental monitoring, boreal forest

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Abstract

Vole populations in northern Scandinavia vary in cycles with peaks every third or fourth year as described by the National Environmental Monitoring Programme of small mammals (NEMP). Some vole species have declined in population numbers since the NEMP started in 1971, especially the grey-sided vole (*Myodes rufocanus)* which is nearly extinct in the forested region. Since small mammals are an important food source for several avian and mammalian predators, the decline in vole numbers is expected to have consequences for the whole food chain, especially if other vole species start to decline in numbers. This study tried to test the hypothesis that presence and abundance of *M. rufocanus* (a specialist species) and *Myodes glareolus* (a generalist species) can be predicted by patch size and connectivity of forest patches >60 years old with a minimum of 15% pine >100years old. I found no dependence on patch size or connectivity for either species, possibly due to too small sample size of forest patches. However, I did find a higher occurrence of *M. rufocanus* and abundance of *M. glareolus* in nature forests in this study compared to the situation in managed forests surveyed in the NEMP.

Sammanfattning

Sorkpopulationers bestånd i norra Skandinavien varierar kraftigt i cykler med toppar vart tredje eller fjärde år, som följs av Nationella Miljöövervakningens program för smådäggdjur (NMÖ). Vissa sorkarter har visat en tydlig nedgång i antal sedan NMÖ startade år 1971, detta gäller särskilt gråsiding *(Myodes rufocanus*) som är nästan helt försvunnen i det brukade skogslandet. Smådäggdjur utgör en viktig födokälla för flertalet rovfåglar och rovdäggdjur och minskningen kan förväntas ha konsekvenser genom hela födokedjan, särskilt om fler sorkarter börjar uppvisa en minskande trend. Denna studie syftade till att utreda möjligheten att förutspå förekomst och beståndsantal av *M. rufocanus* (en specialistart) och *Myodes glareolus* (en generalistart) genom att se på storlek och konnektivitet i skog >60år med minst 15% tall >100 år. Jag fann inget beroende av fläckstorlek eller konnektivitet hos någon av arterna, vilket kan bero på en för liten provstorlek, d.v.s. att för få skogsfläckar av varje kategori undersöktes.. Jag fann dock en signifikant högre förekomst av *M. rufocanus* och ett högre antal *M. glareolus* i naturskogar jämfört med den brukade skogen som används i NMÖ.

Introduction

In northern Scandinavia, vole populations vary in 3-4 year cycles (see Fig. 1) and several explanations such as disease (Niklasson et al. 2006), predation (Korpimäki et al. 1991) and varying food supply (Hörnfeldt et al. 1986) have been proposed and reviewed (see also; Krebs & Myers 1974, Hansson & Henttonen 1985, Oksanen & Oksanen 1992, Hörnfeldt 1994). The National Environmental Monitoring Programme of small mammals (hereby referred to as NEMP) is a survey, performed each spring and fall, that supplies data on small mammals that can be used to interpret changes in their reproduction and abundance. The NEMP sites were initially selected randomly in the managed forest landscape of northern Sweden (see fig. 1 in Hörnfeldt 1994). Since NEMP started in 1971 a decline in population numbers have been observed for grey-sided vole (*Myodes rufocanus*, Sund.), bank vole (*Myodes glareolus*, Schreb.) and field vole (*Microtus agrestis*, L., Hörnfeldt 1994, 2004, 2011), though it is especially evident for *M. rufocanus* (Hörnfeldt et al. 2006, Hörnfeldt 2011). This is evident because all three species have shown a decline in numbers in spring, but *M. rufocanus* shows a decline in autumn as well, which is not the case with the other two species, indicating an external factor (Hörnfeldt 2004, 2011). It has been shown and indicated that changes in landscape structure (such as fragmentation and habitat loss) influence both the presence and abundances of *M. rufocanus* (Ecke et al. 2002, 2006, 2010, Christensen & Hörnfeldt 2006, Hörnfeldt et al. 2006 Christensen et al. 2008, Panzacchi et al. 2010). Since the voles are an important food-source for many predators (Hörnfeldt et al. 2005) many species may be negatively affected by their reduced abundance. As the presence of *M. rufocanus* is positively correlated with patch size (Christensen et al. 2008), protected areas of larger size is of importance for the conservation of the species. Large forest patches in the landscape are modified by modern clearcutting practices used by the forestry industry resulting in fragmented, smaller patches.

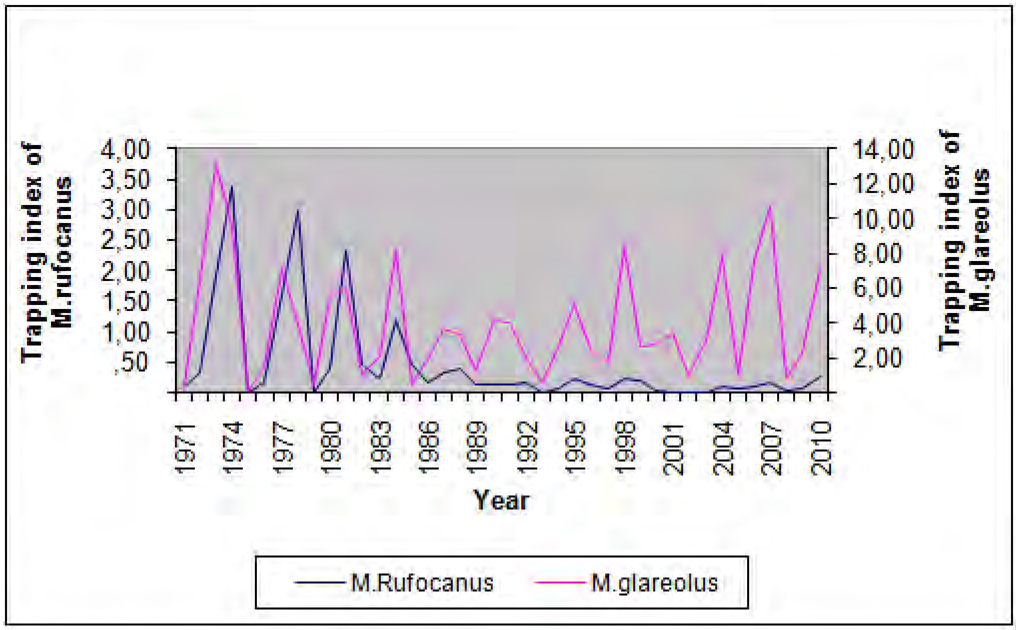

Fig. 1. Number of trapped individuals of *M. rufocanus* and *M. glareolus* per 100 trapnights in spring and autumn 1971-2010, starting autumn 1971 (Hörnfeldt 2011).

The aim of this study was to investigate the dependence of occurrence of *M. rufocanus* in nature forests by comparing trapping indices between nature forest and managed forest patches. Also, the importance of forest patch size and connectivity for *M. rufocanus* and *M. glareolus* voles in >60 year old forests was tested. I predict that the abundance and presence of both study species will be higher in nature forest as well as in patches with large size and high connectivity.

Terminology: Fragmentation and Connectivity

Many of the terms used when discussing fragmentation are in need of clearer definition (Franklin et al. 2002). Franklin et al. (2002) presented a flowchart (Fig 2) to differentiate the terms, but as pointed out by Christensen (2006), the terminology is still quite unclear, even after the long time that have passed since MacArthur and Wilson (1967) first introduced the theory of island biogeography. As stated by Christensen (2006), true fragmentation might, according to the intermediate disturbance hypothesis (Connell 1978), increase general biodiversity while habitat loss most often results in it being lowered (Fahrig 2003), a great example of the importance of proper understanding and definitions of the terminology. For connectivity, the definition “landscape connectivity is the degree to which the landscape facilitates or impedes movement among resource patches“(Taylor et al.1993) is used. One should keep in mind that because of this, connectivity is a relative scale as the hindrance offered by the matrix is perceived by the individual species and therefore affects species differently.

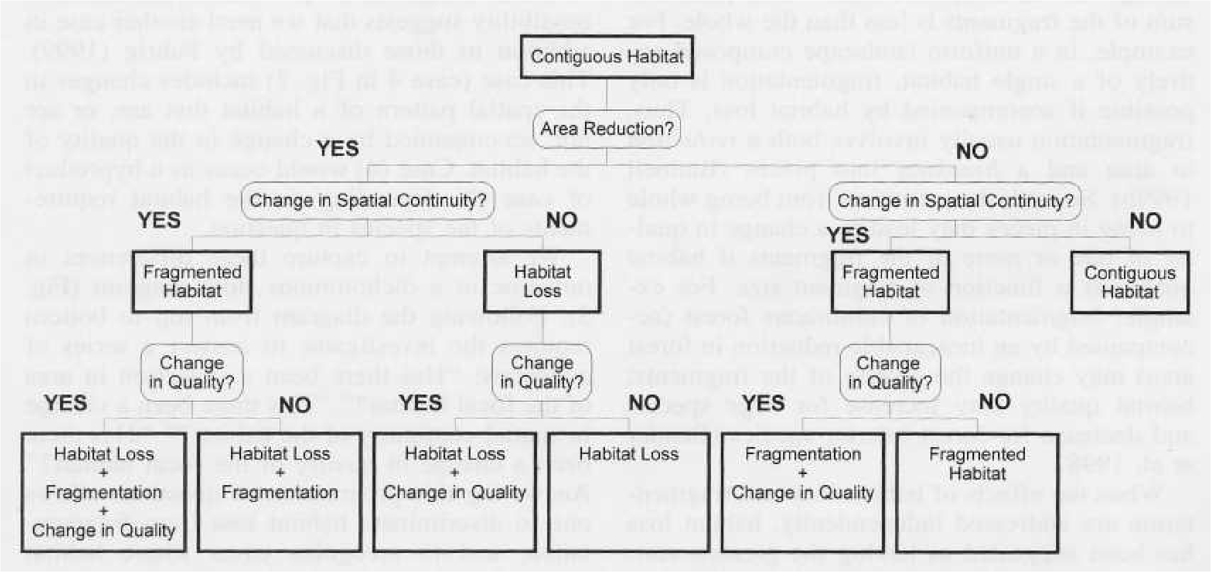

Fig. 2. Flow chart to “help differentiate between landscapes experiencing habitat loss, habitat fragmentation and changes in habitat quality” (Franklin et al. 2002).

Material & Methods

Study areas

Ten trap-stations with five snap traps at each trap-station were placed with ten meter intervals along transects running diagonally in randomly chosen hectare squares of forest patches in protected forest reserves. The inventory method follows the same procedure as in the NEMP (see fig.1 in Christensen and Hörnfeldt 2006). The selected forest patches had an age >60 years old, with at least 15% pine forest >100 years old as they were thought to be a preferred habitat of *M. rufocanus* according to Christensen et al. 2008. Adjacent areas, not fulfilling these criteria, were not considered as part of the patch. A circular study area with a radius of 70km, centered on Fredrika in northern Sweden (see Fig. 3) proved to contain a high amount of older forest with pine and was accordingly selected. All surveyed patches fulfilled the criteria of being larger than 80 ha (Large area) or smaller than 25 ha (Small area) with high or low connectivity using 1000 m as a maximum dispersal distance of the grey-sided vole between different forest patches (based on Oksanen et al. (1999)). All the selected forest patches were part of a protected area in the Swedish reserve system (including not formally protected woodland key-habitats).The process of selecting patches was carried out in ArGIS 9.3 (Environmental Systems Research Institute 2009) with the use of GRASS (Geographical Resources Analysis Support System; GRASS Development Team 2006) for calculating the connectivity index (IIC-index; Pasqual and Saura 2006) of each forest patch. The data on volume of pine forest and the relevant forest age-data were derived from *k*NN-Sweden 2005 (Anonymous 2005) as it was the only data set containing the required information. The selection of forest patches was then set up according to the factorial design presented in Table 1.

Table 1. Factorial design for the selection of subareas that are defined by different combinations of landscape structure (forest patch size and connectivity). In total 16 trapping plots in 16 different protected areas were studied.

Patch size	Connectivity	Abbreviation	No. of replicates per combination
Large	High	LH	4
Large	Low	LL	4
Small	High	SH	4
Small	Low	SL	4

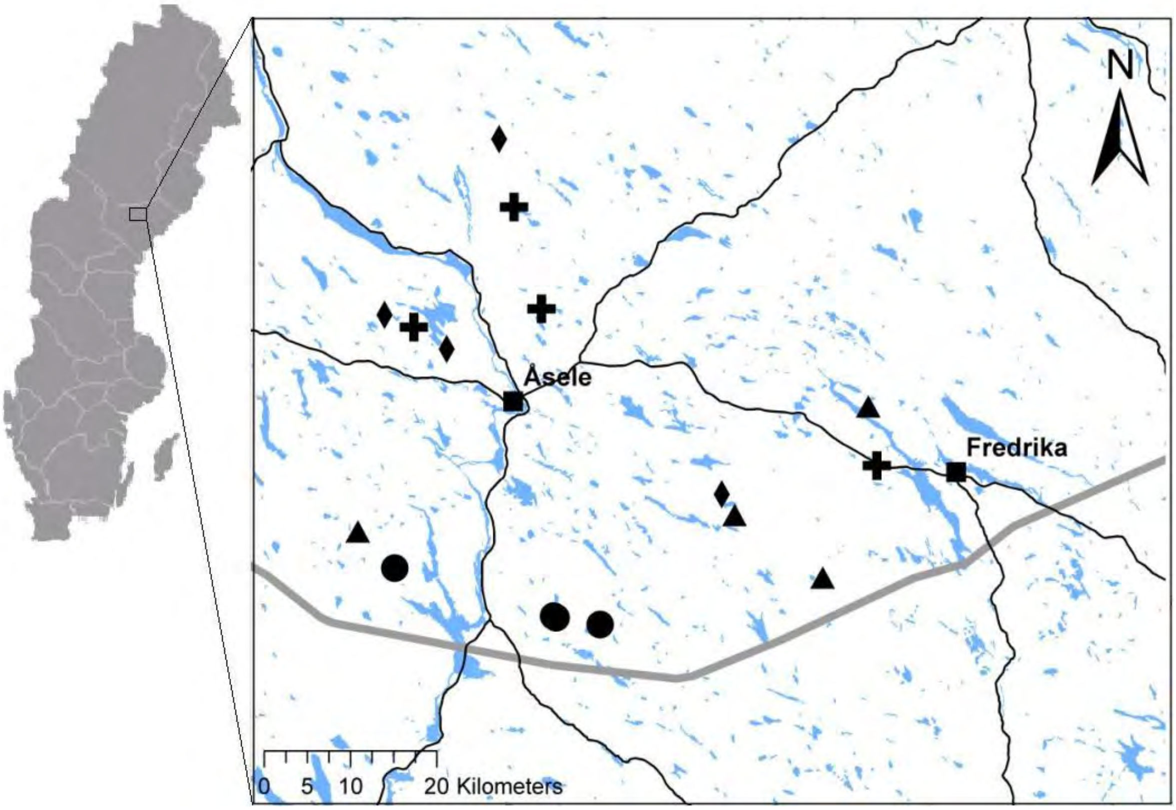

Fig 3. Map over the study area landscape with surveyed protected areas (*N*=16) divided into four area types. Symbols indicate studied forest patches where ▲ indicates a patch of area type LH 1), ♦ a patch of area type LL 2), ● a patch of area type SH 3) and ✚ a patch of area type SL 4) (see Table 1 for abbreviations).

Study Species

Myodes rufocanus populations are strongly dependent on the amount of naturally occurring holes in the ground (Kalela 1957) and boulders (Kalela 1957, Siivonen 1968, Johannesen & Mauritzen 1999) with no obvious preferences regarding soil-type (Kalela 1957). The females keep territories (Ims 1987, Löfgren 1989, 1995) approximately 1350 m^2 in size (Löfgren 1995) but decrease in size as the quality of the area increase (Ims 1987). Their diet consists mostly of bilberries, forbs, green parts and leaves of a wide variety of plants in the summer (Kalela 1957, Hansson & Larsson 1978) and of bark, green parts of most *Vaccinium*-species and lichens in the winter (Kalela 1957, Hansson 1985) while high quality food such as seeds, berries and insects are consumed when available (Siivonen 1968). While Kalela (1957) found no evidence of any wild individuals who survived the age of 2 years, Siivonen (1968) reports of a few individuals reaching the age of 3 years.

Myodes glareolus can survive to become 3 years and lives in most types of forest as well as on clearcuts and meadows (Siivonen 1968) and other areas associated with herbs and grasses (Johannesen & Mauritzen 1999). The sizes of the female territories are almost four times that of *M. rufocanus*'s (Löfgren 1995). They feed mainly on forbs, *Vaccinum*-berries, moss and bark (Siivonen 1968, Hansson & Larsson 1978). Unlike in central Europe, *M. glareolus* in northern Scandinavia barely feed on any seeds or insects but increase their consumption of fungi and lichens instead (Hansson & Larsson 1978).

Statistical Analyses

All tests were done using R (Ihaka and Gentleman 1996) version 2.10.0. χ^2-tests were run to test for difference in presence of *M. rufocanus* between nature forest patches and managed forest sites in the NEMP. ANCOVA's (Analysis of Co-Variance) were used when testing the effect of forest patch size and connectivity on presence and abundance for *M. rufocanus* and abundance of *M. glareolus* in the different subplots according to the factorial design described in Table 1. χ^2-tests were also run for testing the within variance of trapping indices in each group of areas (Table 2) to see if it could be considered to be representative for the factorial design (see Table 1) as it could be a potential source of error otherwise. As small patches with low connectivity (SL) were thought to be the least habitable of the four patch-types, ANOVA's were run to test the effect of SL on presence and abundance of *M. rufocanus* and the abundance of *M. glareolus*. All tests on abundance were made using the trapped number of voles per 100 trapnights.

Results

χ^2-tests revealed a significantly higher presence of *M. rufocanus* in surveyed forest patches (N=16) compared to the trapping sites in the NEMP (N=58, χ^2=14.23, $p=<0.001$). Similarly there was a higher abundance of *M. glareolus* (N=58, χ^2= 4.44, p-value = 0.035) in the nature forest plots than in the managed forest in the NEMP. No tests were run on the presence of *M. glareolus* as this species was present in all the plots. No effect of size, connectivity or these two variables as covariates for presence were found for *M. rufocanus* (all p-values >0.05) (see Table 3) nor for abundance of both species (all p-values >0.05) (Table 4, 5 & 6). No effect on presence and abundance was found for area-type SL (all p>0.05) (Table 6, 7 & 8).

Table 2. The mean trapped number of *M. rufocanus* in all LH, LL, SH and SL patches per 100 trapnights (a) and the mean trapped number of *M. glareolus* in all LH, LL, SH and SL patches per 100 trapnights (b).

a)

Area type	Mean	Within variance
LH	0.50	df=3 $\chi^2=0.67$; $p>0.05$
LL	1.99	df=3 $\chi^2=19.00$ $p<0.05$
SH	3.33	df=3 $\chi^2=30.52$; $p<0.05$
SL	1.17	df=3 $\chi^2=14.01$; $p<0.05$

b)

Area type	Mean	Within variance
LH	15.17	df=3 $\chi^2=4.42$; $p>0.05$
LL	17.17	df=3 $\chi^2=2.55$; $p>0.05$
SH	20.5	df=3 $\chi^2=7.21$; $p>0.05$
SL	15.67	df=3 $\chi^2=0.54$; $p>0.05$

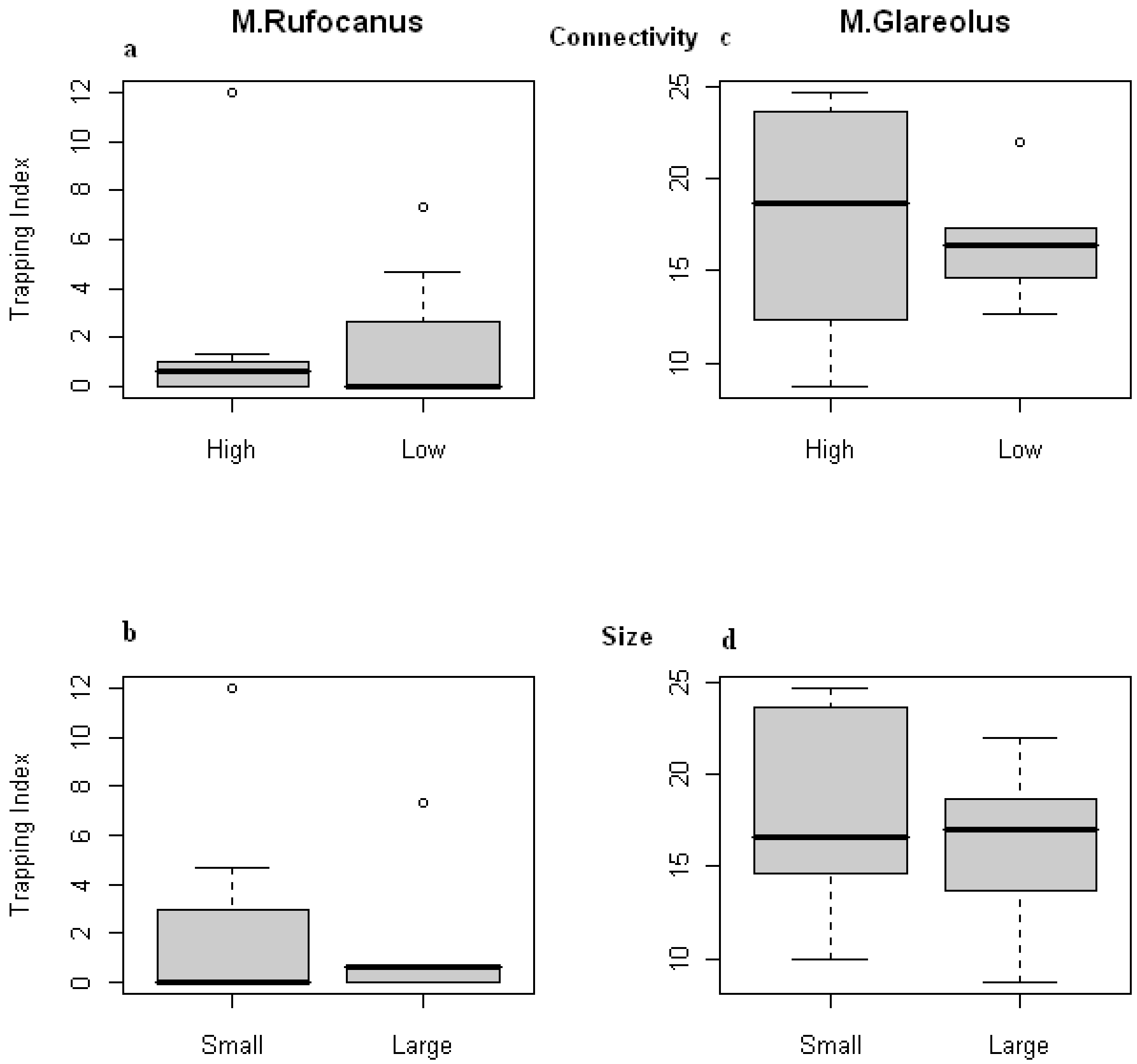

Fig. 4 Box plot showing the abundance of (a,b) *M. rufocanus* and (c,d) *M. glareolus* in forest patches with high or low (a & c) connectivity and large or small (b & d) size respectively. The circles indicate highly influential data points considered to be outliers (included in the calculations).

Table 3. ANCOVA table showing the relationship of forest patch size and connectivity, individually and as covariates with the presence of *M. rufocanus*.

	Df	Sum Sq	Mean Sq	F value	p-value
Size	1	0.25	0.25	0.8571	0.37
Connectivity	1	0.25	0.25	0.8571	0.37
Covariates	1	0.00	0.00	0.00	1
Residuals	12	3.50	0.29167		

Table 4. ANCOVA table showing the relationship of forest patch size and connectivity, individually and as covariates with the trapped number of *M. rufocanus* per 100 trapnights.

	Df	Sum Sq	Mean Sq	F value	p-value
Size	1	4.00	4.00	0.3073	0.59
Connectivity	1	0.444	0.444	0.0341	0.86
Covariates	1	13.444	13.4444	1.0327	0.33
Residuals	12	156.222	13.0185		

Table 5. ANCOVA table showing the relationship of forest patch size and connectivity, individually and as covariates with the trapped number of *M. glareolus* per 100 trapnights.

	Df	Sum Sq	Mean Sq	F value	p-value
Size	1	14.694	14.694	0.6599	0.43
Connectivity	1	8.028	8.028	0.3605	0.56
Covariates	1	46.694	46.694	2.0969	0.17
Residuals	12	267.222	22.269		

Table 6. ANOVA table showing the relationship of area-type SL with the presence of *M. rufocanus*

	Df	Sum. Sq	Mean Sq	F-value	p-value
SL	1	0.3333	0.3333	1.2727	0.28
Residuals	14	3.6667	0.26190		

Table 7. ANOVA table showing the relationship of area-type SL with the trapped number of *M. rufocanus* per 100 trapnights.

	Df	Sum. Sq	Mean Sq	F-value	p-value
SL	1	1.815	1.8148	0.1475	0.71
Residuals	14	172.296	12.3069		

Table 8. ANOVA table showing the relationship of area-type SL with the trapped number of *M. glareolus* per 100 trapnights.

	Df	Sum. Sq	Mean Sq	F-value	p-value
SL	1	11.34	11.343	0.4882	0.50
Residuals	14	325.30	23.235		

Discussion

There was a significant difference in presence of *M. rufocanus* between the protected areas and the managed forest areas in the NEMP in fall 2010. Although there is no information on the forest composition in the managed forest investigated by the NEMP, I conclude that the nature forests in forest reserves have a higher presence of *M. rufocanus* than managed forest. As previously predicted and shown (Christensen & Hörnfeldt 2006, Christensen et al. 2008) the presence of *M. rufocanus* seem to be positively influenced by the presence of old-growth forest as the species was only found sparsely in the forested region of the NEMP, but in 50% of the nature forest plots in our study area. Our trapping-index based on captured *M. rufocanus* during autumn 2010 turned out to be 5 times higher than the index in the NEMP for autumn 2010 (1.33 and 0.26 respectively) and almost 2.5 times higher (17.6 and 7.11 respectively) for *M. glareolus*. Even if I did not find any significant dependence for *M. rufocanus* and *M. glareolus* on forest patch size and connectivity, this study could help to identify important factors for presence and abundance of *M. rufocanus* and *M. glareolus*, such as an undisturbed ground layer and the presence of naturally decomposing trees. Forest characteristics present in nature forests.

A fact that should be taken into account when interpreting the results of this study is that *M. rufocanus* is currently a rare species in managed forest, creating a problem with obtaining sufficient amount of data points, even during peak years. High local patch quality seems to be an important factor for occurrence of *M. rufocanus* (Christensen et al. 2008) and high quality patches causes females to keep smaller territories and stay closer to their natal sites (Ims 1987) while males disperse independent of external cues (Ims 1989). As a consequence, non-permanent testing plots (as all plots in this study should be considered to be) could probably benefit from a focus on reproductive females rather than accounting for every individual (see Van Horne 1983). By removing all non-reproductive females from the data set used in this study (alternatively conduct a new, preferably larger, study), a follow-up study on this data might reveal significant results since it would focus on females who are relatively stationary within their home range (Ims 1987, 1989, Löfgren 1995), though it is unlikely due to the small amount of voles that would be available.

As the analysis of data began, a problem with the measurement of forest patch size and connectivity were found. As the only thing needed for an area to fulfill the requirements to be included as an area with low connectivity is a distance greater than 1000 meters to the nearest forest patch. Vegetation types different than forest types such as mires and swamps with trees present were automatically considered as a hostile environment even though they may act as suitable habitats for *M. rufocanus* (Siivonen 1968, Christensen & Hörnfeldt 2006). This was especially clear in area-type SL were the only plot with *M. rufocanus* was adjacent to a mire and contained the third highest number of *M. rufocanus* in the study and may therefore have been an important contributing factor to the lack of significant results as the within variance increased significantly. If a follow-up study is to be made with this data, the classification of each plot should be re-evaluated, taking the surrounding landscape into consideration.

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SENASTE UTGIVNA NUMMER

2010:5	Daily rests of wild boar Sus scrofa sows in southern Sweden. Författare: Charlie Persson
2010:6	Determinants of winter browsing intensity on young Scots pine (*Pinus sylvestris*) by moose (*Alces alces*) across a bio-geographical gradient in Sweden. Författare: Lenka Vyšínová
2010:7	Reintroduction of the noble crayfish in the lake Bornsjön. Författare: Susanna Schröder
2010:8	Human attitudes toward large carnivores bear, wolf, lynx and wolverine. A case study of Västerbotten County. Författare: Robert Mannelqvist
2010:9	The distribution of Moose (*Alces alces*) during winter in southern Sweden: A respons to food sources? Författare: Mikael Wallén
2010:10	Training identification tracking dogs (*Canis familiaris*): evaluating the effect of novel trackdown training methods in real life situations. Författare: Erik Håff
2010:11	Hotade arter i tallmiljöer på Sveaskogs mark i Västerbotten och Norrbotten. Skötselförslag och analys av potentiell habitatutbredning. Författare: Karin Lundberg
2010:12	Migration losses of Atlantic salmon (*Salmo salar* L.) smolts at a hydropower station area in River Åbyälven, Northern Sweden. Författare: Stina Gustafsson
2010:13	Do grizzly bears use or avoid wellsites in west-central Alberta, Canada? Författare: Ellinor Sahlén
2011:1	Pre-spawning habitat selection of subarctic brown trout (*Salmo trutta* L.) in the River Vindelälven, Sweden. Författare: Erik Spade
2011:2	Vilka faktorer samvarierar med användandet av viltkött, vildfångad fisk, bär och svamp i svenska hushåll? – Stad vs. Landsbygd. Författare: Jerker Hellstadius
2011:3	Konsekvenser av födoval och minskande sorkstammar för populationer av sorkätande ugglor och rovfåglar. Författare: Katie Andrle
2011:4	Tjäderns (Tetrao urogallus L.) vinterdiet i norra Sverige: Är gran (Picea abies) viktig i vissa habitat? Författare: Staffan Öberg

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