NMBU

Preface

This thesis completes my master degree in Natural Resource Management at the Department of Ecology and Natural Resource Management (INA) at the Norwegian University of Life Science (NMBU).

I would like to thank my supervisors Professor Vidar Selås (INA/NMBU) and Jon Erling Skåtan (SNO). Thanks to Vidar for guidance through this thesis with statistics, discussions, writing and proof reading. I am grateful for your eye for details, patience and support. Thanks to Jon Erling and Tom Aurebekk Udø (SNO) for giving me the opportunity to contribute to their interesting mink project in Oksøy-Ryvingen. I appreciate the great days in the field and your vast knowledge of mink, the area and mink hunting. Jørn Lindseth and SNO Vestfold deserves thanks for hospitality and a great week of mink hunting and testing of the study methods.

I wish to thank Roar Økseter for the tremendous effort with collecting random plots, help with scripting in R, proof reading and making maps for this thesis. He also deserves praise for his patient and support. Further, I want to thank my family for helping with the field work, lending me cars and cabins when needed and supporting me through all these years of studying. Last, but not least, I want to thank my friends and fellow students for all the lunches, fun times, hard papers and support during my study here.

Ås, 15th of December 2014

Kristine Skaiaa Born

Abstract

The American mink (*Mustela vison*) was introduced to European countries in the 1920's, from individuals escaping from fur farms. In Norway, minks are now common throughout the country. This invasive species can cause habitat shifts, reduced breeding success or extinction in colonies of ground nesting or early breeding birds. In Oksøy-Ryvingen special landscape area in Vest-Agder, southern Norway, a mink project has been initiated. The goal the project is to have the bird protection areas free of mink at the start of the birds' breeding season. In my thesis, I have analyzed the minks' preference of resting site characteristics in this area, by comparing resting sites with random plots. Information on resting site selection in mink was obtained by hunting during 2 winters (2012/13 and 2013/14) and resulted in 84 observations, which were compared with 62 random plots collected in the same area. The model that best explained the resting site characteristics preferred by minks was found by using logistic regression. The dominating vegetation type on islands was the variable explaining most of minks' resting site preferences. Most minks were found on islands dominated by shrubs like heather and juniper, which may give shelter from predation, good access to prey and some protection against wind and weather. A preference for islands without rough grazing was also found. Minks were most likely found in a boulder pile, or under a stone, in a slope or on a flat less than 25 meters from the ocean. The selected resting site structures provide both insulation and protection from predation. The study also showed that minks prefer resting sites with low wind exposure. The results from this study may contribute to more efficient management of mink populations. Changes in vegetation, placement of traps in proximity to possible resting sites and more efficient search for mink can be recommended management tools from this thesis.

Sammendrag

Amerikansk mink etablerte seg i Europa på 1920-tallet av dyr rømt fra pelsfarmer. Mink er i dag utbredt i hele Norge. Denne invaderende arten kan forårsake skifte av habitat, redusert hekkesuksess, samt utrydning av kolonier hos bakkehekkende fugl eller arter som hekker tidlig i sesongen. I Oksøy-Ryvingen landskapsvernområde pågår det et minkprosjekt, ledet av SNO, hvor målet er å ha minkfrie hekkeplasser før starten av fuglenes hekkesesong. I denne oppgaven har jeg sett på minkens valg av dagleier i området ved å sammenligne dagleier med tilfeldige punkter. Data på minkens dagleier er samlet gjennom minkjakt over 2 vintersesonger (2012/1 og 2013/14) og ga 84 observasjoner, som ble sammenlignet med 62 tilfeldige punkter samlet i samme område. Den modellen som best forklarer minkens valg av dagleier, ble funnet ved bruk av logistisk regresjon og besto av følgende variabler: dominerende vegetasjonstype på øya, type dagleie, dagleiets plassering i terrenget, øy størrelse, og om dagleiet var vindutsatt. Den variabelen som forklarte minkens preferanser for dagleie best, var dominerende vegetasjon. Flest mink ble funnet på øyer dominert av lavtvoksende forvedet vegetasjon, som lyng og einer. Slik vegetasjon kan beskytte mot predasjon og vær, samtidig som byttedyrtilgangen er god. Mink unngikk også øyer som var beitet. Flest mink finner en mindre enn 25 meter fra vannkanten i en steinur eller under en stor stein, på en flate eller i en skråning. De ønskede dagleiene har beskyttelse både mot predasjon og kulde. Studiet viste også at mink liker dagleier i le. Funn fra dette studiet kan bidra til å utvikle en mer kunnskapsbasert og effektiv forvaltning av mink. For eksempel kan endring i vegetasjon, plassering av feller i nærheten av dagleier og mer søk etter mink i nærhet til vann eller andre matkilder være nyttig strategier for forvaltningen.

Contens

Introduction

The conservation of biological diversity, or biodiversity, is a central question in natural resources management all over the world, to preserve the continued survival of life as we know it. Biodiversity are the full range of variation in life on earth. This complex term has three important levels; species diversity, genetic variation and ecosystem diversity. The world's biodiversity is threatened by overexploitation, habitat destruction, fragmentation and degradation, global climate change, disease and invasive species (Primack 2010). In 2014 just above 22000 species are endangered (IUCN 2014) and this number is increasing.

Due to human activity species are spread out of their natural range much faster, further and in greater numbers than they are by the process of natural dispersal. Introduced species that thrive in their new environment and establish at the expense of native species or ecosystems, are called invasive species. They may reduce natural population by predation, displace native species through competition, or alter the habitat so it no longer is suitable for native species. Invasive species are the leading reason for extinction of birds and other organism groups that are strongly affected by invasive species are fish and plants. In the US 42% of the endangered species are threatened by invasive species (Primack 2010). Among the worst invasive species are alien terrestrial predators, as has been demonstrated for example by the brown tree snake (*Boiga irregularis*) in Guam (Wiles et al. 2003). The greatest problem with invasive species threatening local wildlife and endemic species are in islands and simple systems with a small number of species, just like we have in most of the Norwegian archipelago. Norway has, as many other nations, constructed a list over alien species and their possible ecological impact called "Alien Species in Norway – with the Norwegian Black List 2012", in an effort to keep track and tighten control over invasive species. Among the 217 species at the black list, the American mink (*Mustela vison*) is one of the six species with an action plan (Artsdatabanken 2012; Miljødirektoratet 2014).

The American mink (hereafter mink) is a medium sized Mustelid (males 1.2 kg, females 0.6 kg (Dunstone & Davies 1993; Thom et al. 2004)) that has been introduced to 28 European countries, including Norway (Bonesi & Palazon 2007). The main reason for the introduction, which started in the late 1920's and early 1930's, was fur farming, but in Russia, the species was also introduced for hunting (Macdonald & Harrington 2003). In Norway, individuals that escaped from fur farms – probably a mixture of three or more North-American subspecies (Dunstone & Davies 1993) – very soon established wild populations, and today the species occur all over the country. The mink is r-selected, females give birth to 3–6 (up to 8) kits and start breeding as one year olds, and is thus difficult to control by hunting or trapping (Dunstone & Davies 1993; Stien et al. 2010). Minks are solitary outside the breeding season, but females, which raise their young alone, may tolerate juveniles within their home range. The home range of males may have one or more female range within, and during the breeding season males can leave their territory to look for other females (Dunstone & Davies 1993). The species is adapted to live in semi-aquatic habitats (Halliwell & Macdonald 1996; Ahola et al. 2006), such as archipelagos, coastal mainland, lakes, rivers, reservoirs and wetlands (Dunstone & Birks 1987; Helyars 2006). The extent of minks home range vary from 0.5 km to 6.8 km along rivers and shores, depending on gender, season, age, food and den availability and predator pressure (Dunstone & Davies 1993; Yamaguchi & Macdonald 2003; Bonesi & Macdonald 2004b).

As a generalist predator, the mink feeds on fish, crayfish, small mammals, birds, reptiles, amphibians, invertebrates and can even scavenges opportunistically on carcasses (Gerell 1967; Erlinge 1969; Dunstone & Birks 1987; Dunstone & Davies 1993; Nordström et al. 2003; Ahola et al. 2006; Padyšáková et al. 2009). Negative effects of mink predation, such as habitat shifts, reduced breeding densities, reduced breeding success and local extinction of breeding populations, has been documented for several bird species (Craik 1997; Ferreras & Macdonald 1999; Barreto et al. 2001; Macdonald & Harrington 2003; Moore et al. 2003; Fey et al. 2006; Banks et al. 2008), including red-listed species such as black guillemot (*Cepphus grylle*), gadwall (*Anas strepera*) and Northern shoveler (*Anas clypeata*) (Kålås 2010). The problem seems to be greatest on islands and fragmented mainland habitats (Aars et al. 2001; Bonesi & Palazon 2007), for dense colonies of ground or hole nesting seabirds (Craik 1995; Craik 1997; Clode & Macdonald 2002) and for small-sized birds that breeds early in the season (Nordström et al. 2003; Nordström et al. 2004; Banks et al. 2008). In Norway, negative effects have been found for common eider (*Somateria mollissima*) (Anker-Nilssen 2008) and puffins (*Fratercula arctica*) (Anker-Nilssen et al. 2007). However, Udø (2005) found no effects on the hatching success of common eider, greater black-backed gull (*Larus marinus*) and lesser black-backed gull (*Larus* *fuscus*), and in Finland, Banks et al. (2008) found little effect of mink predation on some bird species breeding late in the season.

In Europe, minks do not compete with many other species with regard to habitat. Its main competitor is the otter (*Lutra lutra*), which seems to be superior and may cause both habitat shifts and decline in the mink population (Christensen 1995; Bonesi & Macdonald 2004a; Bonesi & Macdonald 2004b; Bonesi & Palazon 2007). The otter population in Norway has been declining, possible due to overexploitation in the early 1900 and environmental pollutants (Heggberget 1996). Since 1990 the otters have been expanding southwards and are now numerous as far south as Hordaland and some are found around Oslofjorden (Dijk et al. 2011). Interspecific competition are known between mink and all three larger carnivores, otter, pine martens (*Martes martes*) and red fox (*Vulpes vulpes*), which can all kill and eat minks (Direktoratet for Naturforvaltning 2011). In competition with the European mink (*Mustela lutreola*) the American mink is superior and suppresses the first. The main predators on mink are golden eagle (*Aquila chrysaetos*), Eurasian eagle-owl (*Bubo bubo*) and the white-tailed eagle (*Haliaeetus albicilla*), which Salo et al. (2008) showed to modify the activity pattern of mink. Human hunting affect the territory size of minks (Birks & Linn 1982; Dunstone & Birks 1985), and may be the largest threat to a mink population. As protection from predation, harsh weather and cold temperatures, minks seek to dens, such as holes in the ground, space under rocks, trees, rock cavities, old rabbit (*Leporidae spp.*) burrows, human constructions and other confined spaces with shelter (Dunstone & Davies 1993; Bonesi & Palazon 2007).

The action plan against American mink in Norway (Direktoratet for Naturforvaltning 2011) has as one of its goals to "remove or reduce mink populations in nature preserves of high priorities in order to fulfill objectives for the preservation" (Direktoratet for Naturforvaltning 2011). In the process leading up to this plan, a group of researchers at the University of Tromsø pointed out some aspects of mink ecology that should be explored further in order to aid the control and eradication of mink. Further studies of minks current distribution, seasonal use of costal and terrestrial systems, diet in different habitats, home range size and dispersal, demographic parameters, vulnerable prey species and home range and den site characteristics should be initiated (Stien et al. 2010). In the current study den or resting site characteristics was analyzed by using data collected during mink hunting. Such knowledge of the mink biology and use of habitat may contribute to a better and more effective approach to mink management. Minks mostly use structures that already exist in their environment for resting sites, but can expand holes and can insulate their home with grass and other material for insulation during winter (Birks 1981; Dunstone & Davies 1993). The objective of the current study was to reveal any preferences in resting site selection, in order to answer the question: “Which factors affect the minks’ choice of resting site?” I hypothesized that cover from avian predators and food availability as well as adverse weather is particularly important.

Method

Study area

The study area is Oksøy-Ryvingen special landscape area in Vest-Agder County. It stretches from Oksøy lighthouse (58º 04´ N, 8º 03´ E) in Kristiansand municipality in east, through the archipelago of Søgne municipality and ends at Ryvingen lighthouse (57º 58´ N, 7º 29´ E) in Mandal municipality. The special landscape area is approximately 100 km^2, of which 86 km^2 are ocean and 14 km^2 are land and freshwater (Fylkesmannen i Vest-Agder 2003; Figure 1).

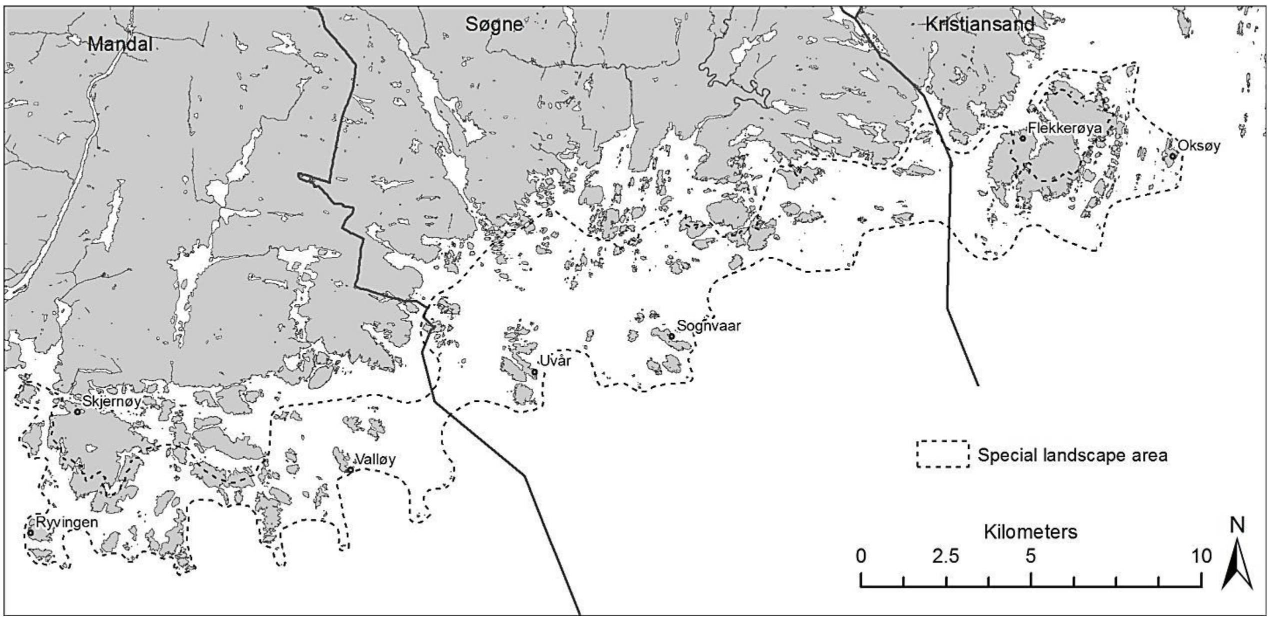

Figure 1: Map covering the municipalities of Mandal , Søgne and Kristiansand. Oksøy-Ryvingen special landscape area is mark by dotted line.

The special landscape area was protected in 2005 to preserve a representative part of the South-Norwegian archipelago. The landscape is characterized by archipelago with low islands and skerries with the typical Norwegian outports, used for centuries by fishermen. The islands vary greatly in size from small skerries (5 m^2) to big islands like Flekkerøya (6.6 km^2) and Skjernøya (6 km^2) (Fylkesmannen i Vest-Agder 2003). The area is also a popular recreation area with many cabins and piers mostly outside the protected area. Boat tourism, fishing and tenting is popular during the summer months.

The suboceanic climate could contribute to a high diversity flora, but acidic and nutrient-poor bedrock limits the flora in the area (Fylkesmannen i Vest-Agder 2003). The dominating vegetation type in the area is coastal heathland, which is now overgrowing with juniper (*Juniperus communis*), birch (*Betula ssp.*) and scots pine (*Pinus sylvestris*). Heathlands consists mainly of common heather (*Calluna vulgaris*) with elements of crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos uva-uris Spreng.*), cross-leaved heath (*Erica tetralix*), and cowberry (*Vaccinium vitis-idaea*) i.e. There are also some grasslands and forested areas. Towards the waterline and the splash zone there are mostly slopes of naked rock, but also some seacoast vegetation. Rough grazing and burning of wooded vegetation, like birch, juniper, pine and heathers are facilitated to preserve the coastal heathland in the area (Fylkesmannen i Vest-Agder 2003; Danielsen et al. 2010). There are 10 smaller special protective areas located inside the special landscape area, with their own protective regulation, all protecting the birdlife living or breeding in the area. Bird species that breed in the area are typical seabirds like lesser black-backed gull, greater black-backed gull, common eider, herring gull (*Larus argentatus*), common tern (*Sterna hirundo*) i.e. and other species like Eurasian oystercatchers (*Haematopus ostralegus*), great cormorant (*Phalacrocroax carbo*), common goldeneye (*Bucephala clangula*) and mute swan (*Cygnus olor*). The Norwegian Nature Inspectorate (SNO) are conducting a mink removal project in Oksøy-Ryvingen special landscape area on behalf of the park management board and Fylkesmannen in Vest-Agder. The goal of the project is mink-free islands, in the ten bird protection areas, at the beginning of the birds breeding season. The mink removal is conducted with trapping and hunting with dogs, in accordance with the action plan instructions (Appendix 1) (Direktoratet for Naturforvaltning 2011; Skåtan & Udø unpubl.). The organized mink eradication started in 2011, but minks have been hunted in the area for many years (Skåtan & Udø unpubl.).

Data collection

The data on mink resting site characteristics were collected during hunting in the periods from 1st January to 4th April in 2013, and 14th January to 15th April 2014. In addition, there was some autumn hunting in 2013; 24th –26th September and 4th October. Resting sites are in this study defined as a place where mink rest and seek shelter (Birks et al. 2005) once or regularly. No natal dens are registered, due to dates of hunting, but some of the resting sites may be used as natal dens in summer. The hunting was conducted during daytime by use of boats and trained dogs (Finnish spitzs and Swedish elkhound). When the dogs localized a resting site with mink, the SNO-employee would try to take out the mink, and then register the characteristics of the resting site in a form (Appendix 2). In cases where the mink fled from the primary resting site to seek shelter elsewhere, only characteristics from the primary resting site was registered.

Resting sites used by mink were compared with random habitat plots, which I described during the summer of 2014. The software ArcGIS was used to distribute 200 random plots to the land area in my study. It was specified that there should be minimum 100 m between each plot and none plots below sea level. Only even numbered plots were used in this study due to few observations of mink resting sites. The plot coordinates were exported from the software into a handheld GPS (Garmin, GPSmaps S62). In the field I used the GPS to guide me to the plots. I followed the direction marker on the GPS as straight as possible towards the plot and when approaching the GPS scale was set to 20 m, to achieve the same accuracy every time. The GPS has an “arrived” function and this was used to establish the plots position. After location the plot was described in the same manner as the mink resting sites. I gathered only 94 random plots, strong winds at the time of field work made the trip to Uvår and other islands far from shore unreachable.

Data treatment

The original dataset consisted of 183 observations, with 30 different variables. Due to inadequate data or missing values, several variables (e.g. weather, fauna and distance between islands) were not used in the analysis. Some were also omitted do to their character, such as identification variables like time, date, place etc. All random plots collected on bare rock (n=37) were, after some preliminary statistical analysis (Figure 2), removed from the data set, due to lack of suitable structures for resting sites. This left me 8 variables describing the mink resting sites (n=84), and random plots (n=62). The first 5 variables describe the resting site and the remaining 3 describe the island or a larger area surrounding the resting site or plot (Table 1). The first variable was resting site structure. I simplified the categories by combining all boulder pile sizes in one category, and crevasse was included in the category underground holes. The categories “others”, “Human constructions” and “snow cave” were taken out due to very few observations. The second variable was the sites placement in the terrain with the options of the site being in a depression, on a top, on a flat or in a slope. Cover around the resting site was registered as “yes” or “no”, answering if the mink could enter and exit the resting site without exposing itself. The wind exposure of the resting site was also a yes/no decision made in the field.

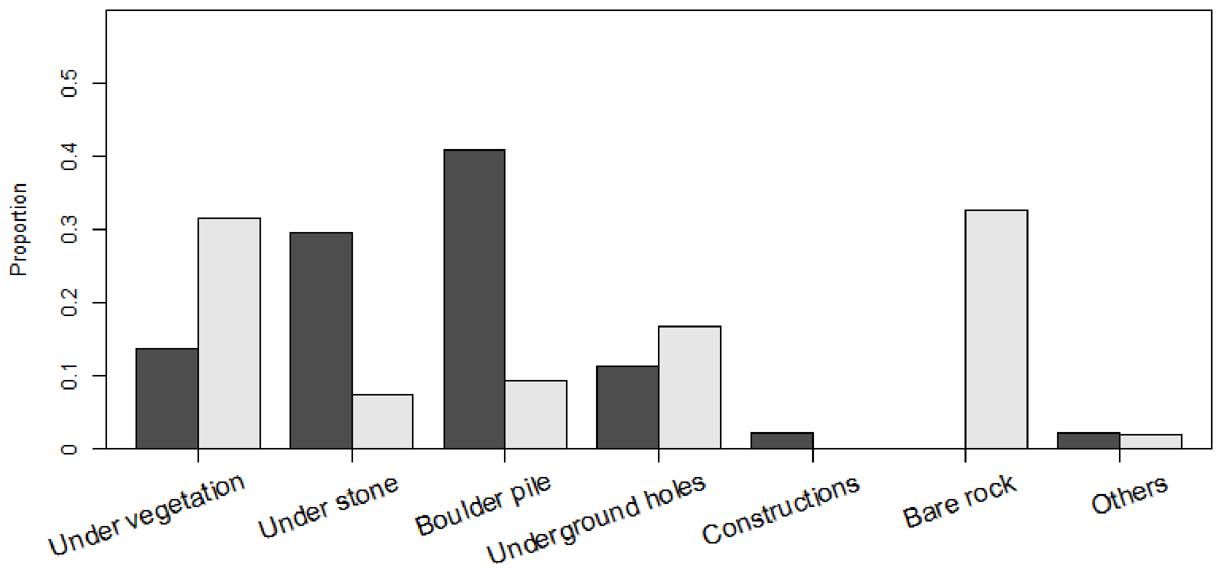

Figure 2: Difference between structures of resting sites used by mink (dark columns) and random plots (light columns) in Oksøy-Ryvingen.

Distance from the ocean to the resting site was registered in categories to simplify the field work: 0-25 meters, 26-50 and more than 50 meters. The size of the island was measured with width across the narrowest middle. The categories being less than 100m across, between 100-500m and more than 500 m across. We also registered the dominating vegetation type and degree of grazing on the island. The vegetation type categories were simplified to naked rock, grass, forest, shrub or mix. Mix was mostly the combination of shrubs and naked rock, but other combinations were also found. The grazing scale starts at no grazing in areas without sheep or goat, or in areas where there has not been grazing for a long time. Barely visible grazing are areas with few animals or low effect on vegetation and extensive grazing are trampled and most vegetation are strongly effected by grazing. Normal grazing gives effect on the vegetation.

Table 1: The variables used and the categories within each variable.

Variables	Categories
Structure	Under vegetation, Under stone, Boulder pile, Underground hole
Placement in terrain	Depression, Top, Flat, Slope
Cover	Yes, No
Wind exposure	Wind, No wind
Distance from ocean	0-25 m., 25-50 m., Over 50 m.
Island size	0-100 m., 100-500m., Over 500m.
Vegetation type	Naked rock, Grass, Forest, Shrub, Mix
Degree of grazing	No grazing, Barely visible, Normal, Extensive

Statistical analysis

All computations, analyses and plots are made using the statistical program R in combination with RStudio (R Core Team 2014). In this thesis I used logistic regression to test the difference between the characteristics of mink resting sites and random plots. Generalized Linear Models (GLM) with binominal link were used since the response variable, resting site (1) or random plot (0), was binominal (Crawley 2011; Wood 2014). A simple GLM with one explanatory variable and the response variable was computed for each of the variables and all their categories.

In model building, it is the variables' (parameters') contribution to the model that is important. Therefore, the single parameter's contribution to the model for minks' choice of resting site was evaluated. The model in this study was found by the method of backwards selection (Wood 2014). The selection process started with a full GLM model including all the 8 variables (Max model). The selection process is based on *p*-values from a likelihood ratio test (LRT). The least significant variable, the variable with the highest *p*-value, was removed, and a new model with the remaining variables was fitted (Model 1, Model 2 etc.). This process was done using the drop1-f unction with a LRT, and repeated until all remaining variables were statistically significant ($p < 0.05$). The models from each step were reported with the variables' fit (χ^2) and the level of significance (p). The Akaike Information criterion, AIC (Akaike 1974) were reported for each model since this value is used as a selection criterion in a forward selection. All AIC values in this thesis are corrected for small sample size, AICc. All AICc were compared against the lowest, in the best model, and reported (ΔAICc).

Results

Out of the 84 resting sites used by mink in this study, 36 (42.8%) were located in a boulder pile, 26 (30.9%) under stone, 12 (14.2%) under vegetation and the last 10 (11.9%) in underground holes (Figure 3). Of random plots almost half were registered under vegetation (48%) and another quarter were underground holes (25%) (Figure 3). I found a significant difference between mink resting site choice and random plots for all categories except for underground holes (Figure 3).

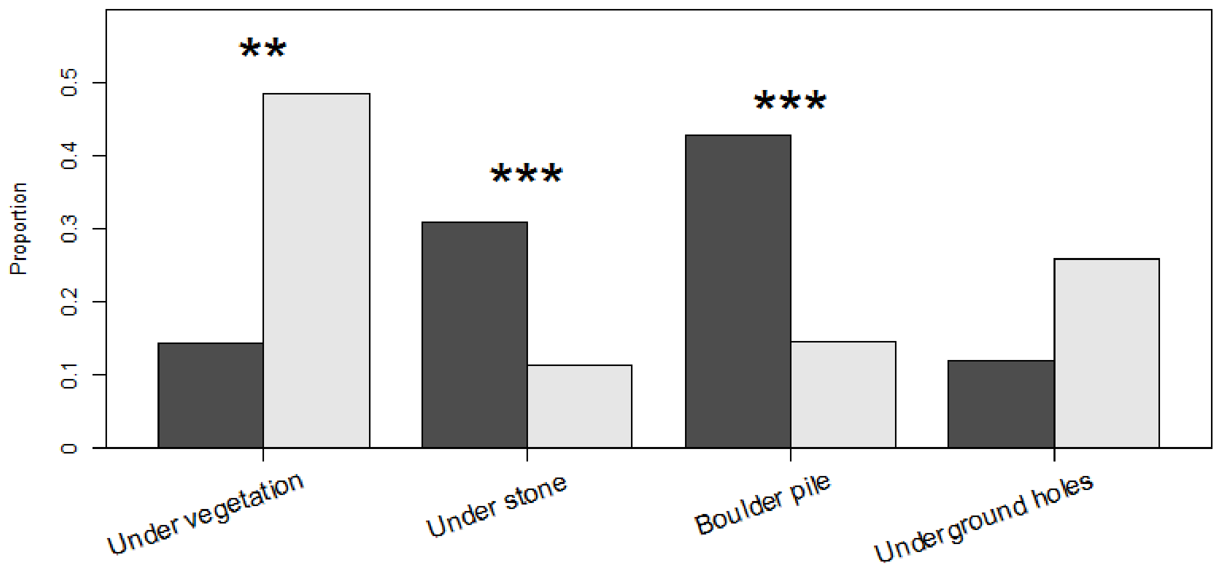

Figure 3: Difference between resting sites used by mink (dark columns) and random plots (light columns) in Oksøy-Ryvingen, in relation structure. Level of significance is marked by stars ($p < 0.01$, *** $p < 0.001$) placed above column states the variable levels *p*-value (factors). No star on column means no significant difference ($p > 0.05$) found for the level.**

Most mink resting sites were found on flats (46.4%) and slopes (32.1%) (Figure 4a) and sheltered for wind (83.3%) (Figure 4b), whereas 39% of the random plots were found in depressions. The study also showed that 72.6% of the mink resting sites were situated less than 25 meters from the ocean, while only 43.5% of the random plots where located within this zone (Figure 4c). Finally 65.4% of the mink resting sites were located on islands that were between 100 and 500 meters wide (Figure 4d).

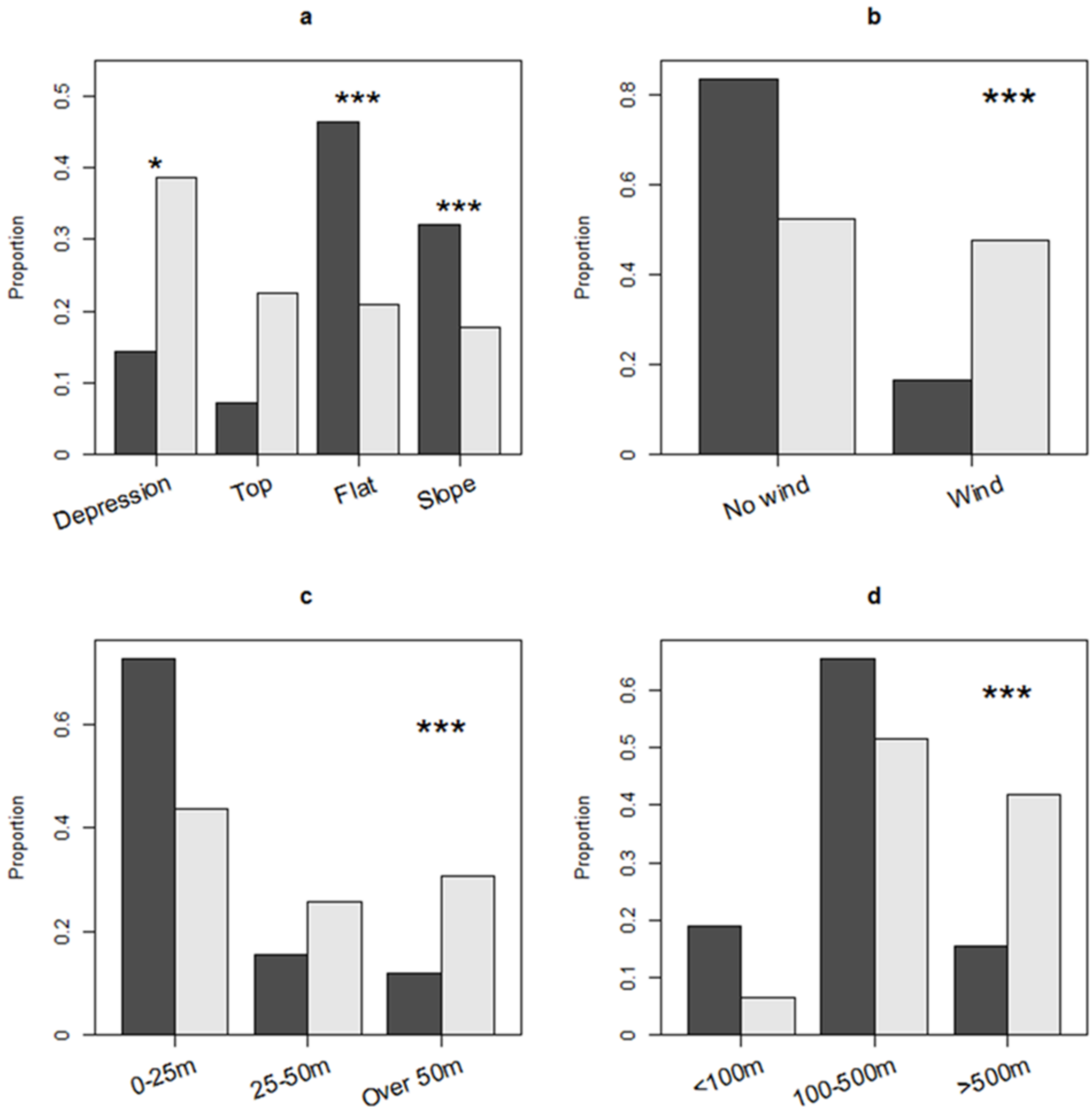

Figure 4: Difference between resting sites used by mink (dark columns) and random plots (light columns) in Oksøy-Ryvingen, in relation to a) placement, b) wind exposure, c) distance to ocean and d) island size. Level of significance is marked by stars (*p < 0.05, *** p < 0.001), when placed in right upper corner it is the *p*-value of the variable (continuous), and stars placed over column states the variable levels *p*-value (factors). No star on column means no significant difference (p > 0.05) found for the level.

Over half (53.6%) of the resting sites were found on islands where the dominating vegetation was shrubs (Figure 5a), but the most usual vegetation types was mix (50%) and grass (24%). In relation to grazing there were more mink resting sites (34.5%) on islands with no grazing than expected from a random distribution (22%) (Figure 5b). I found no difference between mink resting sites and random plots with regard to cover ($p = 0.19$).

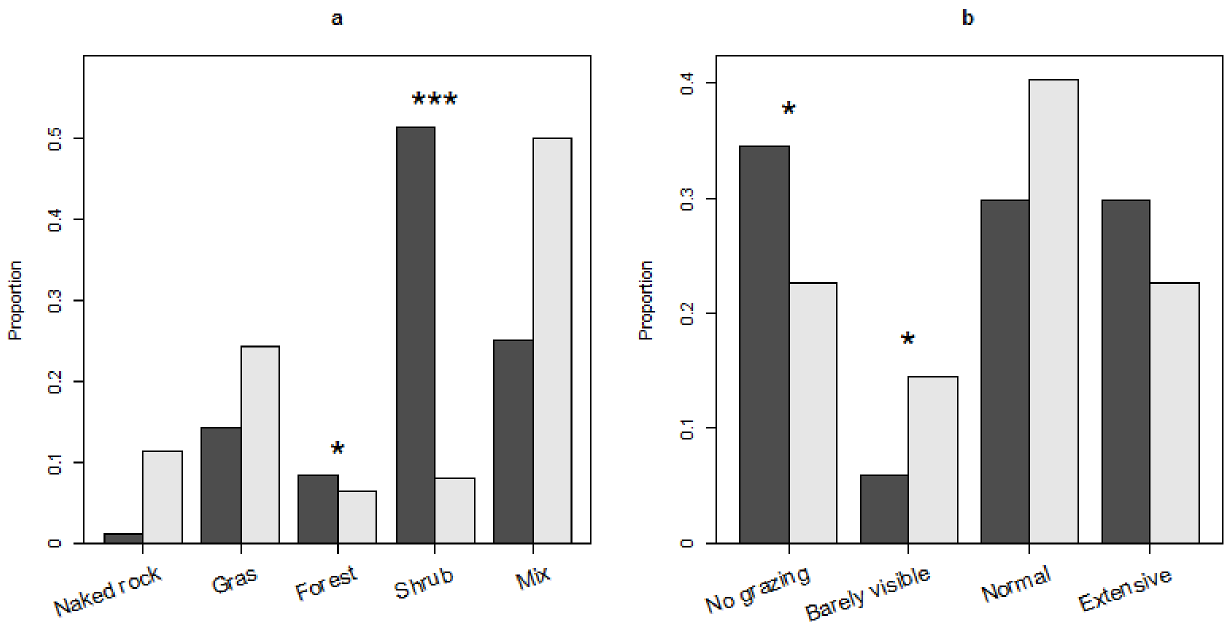

Figure 5: Difference between resting sites used by mink (dark columns) and random plots (light columns) in Oksøy-Ryvingen, in relation to a) vegetation type and b) degree of grazing. Level of significance is marked by stars (*$p < 0.05$, *** $p < 0.001$) placed over column states the variable levels *p*-value (factors). No star on column means no significant difference ($p > 0.05$) found for the level.

Models

The single parameter tests showed that 6 of the 8 parameters gave significant results (Table 2). Vegetation was the single most important explanatory variable ($\chi 2 = 39.296$).The best model (model 3) included the vegetation type on islands, the resting sites placement in the terrain and its structure, the wind exposure of the resting site and island size (Table 3). The second best (model 2) also included degree of grazing on islands.

Table 2: Likelihood ratio test on single parameter GLM models with response variable mink resting sites (n=84) and random plots (n=62). The parameters are dominating vegetation type on island, placement in terrain, wind exposure, structure of the resting site, island size, degree of grazing on islands, distance from plot/resting site to ocean and cover. The model fit ($\chi 2$) and *p*-value from drop1 with LRT and corrected AIC for each single parameter GLM-model are reported. Significant *p*-values are reported as stars (* $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$) insignificant ones as values. The ΔAICc is calculated in comparison of the lowest AICc value in the modeltesting (Model 3, AICc = 120.78 (Table 3)).

Parameter	$\chi 2$	*p*	AICc	ΔAICc
Vegetation	39.30	***	170.20	49.42
Structure of resting site	35.03	***	172.33	51.55
Placement in terrain	24.60	***	182.76	61.98
Wind exposure	16.18	***	185.25	64.47
Island size	14.71	***	188.44	67.66
Distance to ocean	12.85	***	190.30	69.52
Degree of grazing	6.32	0.097	201.03	80.25
Cover	1.73	0.188	201.42	80.64

Table 3: Model testing based on a likelihood ratio test with response variable mink resting sites (n=84) and random plots (n=62). The parameters are dominating vegetation type on island, placement in terrain, wind exposure, structure of the resting site, island size, degree of grazing on islands, distance from plot/resting site to ocean and cover. The model fit ($\chi 2$) and *p*-value from drop1 with LRT and corrected AIC for each single parameter GLM-model are reported. Significant *p*-values are reported as stars (* $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$) insignificant ones as values. The ΔAICc is calculated in comparison of the lowest AICc value in the model testing (Model 3).

Model	Variable	$\chi 2$	*p*	AICc	ΔAICc
Max model				124.43	3.65
	Vegetation+	26.17	***		
	Placement in terrain+	19.84	***		
	Structure +	11.42	**		
	Wind exposure+	12.26	***		
	Island Size+	4.54	*		
	Grazing+	7.18	0.066		
	Distance to ocean+	1.96	0.162		
	Coverage	0.07	0.787		
Model 1				121.89	1.11
	Vegetation+	27.47	***		
	Placement in terrain+	19.79	***		
	Structure +	11.51	**		
	Wind exposure+	14.12	***		
	Island Size+	4.63	*		
	Grazing+	7.51	0.057		
	Distance to ocean	2.10	0.148		
Model 2				121.42	0.64
	Vegetation+	28.51	***		
	Placement in terrain+	20.33	***		
	Structure +	15.08	**		
	Wind exposure+	13.29	***		
	Island Size+	4.70	*		
	Grazing	6.85	0.077		
Model 3				120.78	0.00
	Vegetation+	28.09	***		
	Placement in terrain+	22.91	***		
	Structure +	20.18	***		
	Wind exposure+	12.12	***		
	Island Size	5.40	*		
Model 4				123.78	3.00
	Vegetation+	32.72	***		
	Placement in terrain+	25.88	***		
	Structure +	23.04	***		
	Wind exposure+	10.69	**		

Discussion

In the current study of mink resting site selection I compared resting sites found by hunting to random plots. The model that best explained which resting site characteristics minks preferred included 5 of the 8 variables tested. I used the method of backwards selection in this thesis, but my best model also had the best AICc-values which are the criterion used in forward selection. The variable that explained most of the minks' resting site preferences in this model was the dominating vegetation type on the island where the resting site was found. The second best explanatory variable was the resting site placement in the terrain, which was the third best variable in the single parameter tests. The best multiple model also included whether or not the resting site was wind exposed, the structure of the resting site and the island size. Resting site characteristics preferred by minks are known to be recognizable for different individuals, indicating an active choice from the availability (García et al. 2010).

In Norway the habitat use by mink is scarcely documented (Stien et al. 2010), but foreign studies have shown that den and resting site characteristics are important and that lack of suitable resting sites can limit the distribution and density of mink populations (Halliwell & Macdonald 1996; Haan & Halbrook 2014). The movements of minks may be restricted in areas without suitable cover (Gerell 1970; Dunstone & Davies 1993; Yamaguchi et al. 2003; García et al. 2010), which is probably an important factor for mink survival (Zielinski et al. 2004; Haan & Halbrook 2014). Most models for mink resting site selection have elements of vegetative cover, indicating that these features are important both in river and coastal environments. In his study in coastal habitats in Alaska, Johnson (1985) found terrestrial slope, wood debris, grass cover, bedrock, boulder cover and prey abundance to be important. I did not have data on prey abundance, but believe that it may have an important effect on the minks' habitat use. River based studies often have water depth or width as a parameter, but this was of little interest in the archipelago where water make up so large part of the environment.

Boulder piles were the most frequently used resting site structure in my study. The second most used structure was single stones and these were often quite large (0.5 m in diameter). Both stones and boulder piles can provide both cover and the opportunity of multiple exits. These findings indicate that minks prefer complex structures with multiple exits, as Zabala et al. (2007) also found in Biscay, while Melero et al. (2008) on the other hand discovered no such preference in their study in Catalonia. Anyway, the results from my study corresponds well with Dunstone and Davies (1993) statement that the ideal coastal habitat for minks are rocky sheltered shores. The third most used structure for resting sites was under vegetation. In the coastal areas of Vest-Agder the most common bush is juniper, but also birch and heathers cover some of these islands.

Minks in different environments use different resting site structures depending on availability (Zabala et al. 2007; Haan & Halbrook 2014). Along inland rivers and further south in Europe, vegetative cover like root cavities and bramble (*Rubus sp.*) bushes are more commonly used than rock covers (Zabala et al. 2003; García et al. 2010). The distribution of bramble is scarce and scattered in my study area, therefore I did not considered it as a separate category as it is unlikely to have any great importance for the mink. Old rabbit burrows appear to be the preferred resting site in the United Kingdom (Ireland 1990; Yamaguchi et al. 2003). European rabbits (*Oryctolagus cuniculus*) are not native in Norway and nor introduced to the study area (Bjärvall & Ullström 2005), so no rabbit burrows are available for the minks.

That boulder piles are preferred above tree roots are also known from Swedish river studies of mink (Gerell 1970). In my coastal study this may simply be due to lower availability of trees, as the arboreal growth in the coast is limited by salt water and weather. Mink resting sites were mostly situated close to the water (<25m), whereas forests mostly grow in the center of larger islands, like Flekkerøya and Udø. This makes the forests of the archipelago less suitable for minks. The fact that minks are found close to water also affects the results for island size preference. While random plots were collected all over the islands most resting sites were placed close to water, leaving an larger amount of land “too far” from water on large islands. The distribution of island size is also skewed, with many middle sized island and few large ones. The island size categories are also unevenly set, affecting the results. Still minks are found more frequently in small and medium sized islands than expected from random plots.

The thermal insulation effect of resting sites is important for minks due to their small body size, elongated body shape and high metabolic rate (Iversen 1972; Dunstone & Davies 1993). Insulation against cold temperatures are, despite their water-repellent and insulating fur, important for the semiaquatic mink due to the increased loss of heat in water (Dunstone & Davies 1993). Pine martens choose more insulated resting sites in Fennoscandia and Russia than further south in Europe, due to lower winter temperatures, which can lead to higher winter mortality

(Zalewski 1997). Dense shrubs may have an insulating effect (Birks et al. 2005), but the temperature is usually more stable in underground structures, and this may be a reason for finding minks more frequently underground in Scandinavia. In addition, in my study area, most boulder piles and stones were covered by insulating shrubs. It can also be hard to detect stones and cavities underneath dense shrubs, unless the shrub is removed, so in some studies, the preference for vegetation as resting site may have been overestimated.

Wind exposure is another factor that can affect temperature in resting sites and heath loss from the body. Minks showed a clear preference for resting sites sheltered from the wind in this study. This corresponds well with the type of resting site structures used, inside a boulder pile or under a stone the mink would mostly be sheltered from adverse weather. In this respect, dense vegetation may not be so optimal. As coastal habitats are exposed to more wind than river systems in the inland, we might see a clearer preference in my study. However, I found more minks on flats and slopes than in depressions, in contrast to what would be expected if wind exposure and thermal insulation was the most important variable affecting minks' choice of resting sites. On the other hand, there will be more stones and piles of boulder in slopes, where the bedrock is eroded by weather and water, and on flats where they would end up if thorn from the bedrock. There are few resting site alternative structures on tops and a mink would here be more vulnerable for both weather and predators. In the study area there are quite many steep and short up and down hills and ravines and the juniper in the area tend to grow very dense, often covering the ravines completely. This habitat may be too wet or uncontrollable for the minks.

Over 50% of the resting sites were found on islands where the dominating vegetation type was shrub, and another 25% were found on islands with mixed vegetation type, confirming that minks have a preference for habitats with vegetative cover and avoid open fields (Gerell 1970; Birks & Linn 1982; Yamaguchi et al. 2003; Zabala et al. 2007; Haan & Halbrook 2014).The vegetation in Oksøy-Ryvingen special landscape area is partly managed to conserve or reestablish the coastal heathlands. The conservation tools used are rough grazing and burning regimes (Danielsen et al. 2010). The interval and amount of area burnt vary strongly between islands and years. The conservation is mostly conducted by local landowners and farmers, and no common policy is applied in the maintenance of this old tradition. Minks in the study showed a preference for islands with no grazing, probably due to greater amounts of shrubs. In areas with grazing, shrubs are reduced due to trampling and browsing by some year-around grazing sheep and goats. I found no preference when testing for the importance of cover around the resting site, but as earlier mentioned, different types of shrub are the dominating vegetation in the study area, and 80% of the observations had cover. Hence, minks may prefer cover in proximity to their resting site, but in this area cover would be sufficient almost regardless of the minks' choice. Even for open fields with high availability of prey, minks preferred to stay in vegetative cover (Gerell 1970), indicating that the risk of predation is greater than the need for added foraging.

The predation on mink is not investigated in Norway, but in other areas large birds of prey are known to prey on minks. In the special landscape area there is at least one breeding pair of white-tailed eagle, and annual observations of the Eurasian eagle-owl that breeds close by on the mainland of Søgne. Young golden eagles are observed foraging in the study area during winter (Bentsen NOF 2014 pers. com.). Common Kestrel (*Falco tinnunculus*), short-eared owl (*Asio flammeus*) and Northern goshawk (*Accipiter gentilis*) are the most common of the smaller raptors and long-eared owl (*Asio otus*) is yearly observed (Fylkesmannen i Vest-Agder 2003). Of these smaller raptors, only the goshawk hunts prey similar to mink and is a potential predator. Of mammalian threats to minks, besides trapping and hunting, red foxes and pine martens are present on some of the island. Cats (*Felis silvestris catus*) and dogs (*Canis familiaris*) may be present in parts of the area during summer, but none of these are expected to have any significant effect on the mink population (Dunstone & Davies 1993; Melero et al. 2008). Mink preference for vegetative cover might be an inherited trait caused by moderate predation pressure, but predation is probably not affecting the populations of mink in the study area without a great human effort.

In addition to thermal insulation and cover from predation, vegetative cover may provide minks with foraging sites and the cover they need to successfully hunt prey (Ireland 1990). It may also provide an undisturbed site to consume prey and rest. Minks' food selection will depend on food availability (Ireland 1990), due to their opportunistic way of foraging. Proximity to preferred foraging sites is important for the choice of resting sites in small mustelids in general (Birks & Linn 1982; Zabala et al. 2003). In my study, three quarters of the mink resting sites were located less than 25 m from the ocean, where Udø (1995) found the most important winter forage for coastal mink. Along the coast of south Norway, fish was the most important prey, constituting

60% of food mass during winter and 46% in summer. Birds and crustaceans each constituted 20% of the winter food, whereas no mammalian prey was found. During summer, mammalian prey constituted 11% of the food and bird prey 25% (Udø 1995). Studies by Dunstone and Birks (1987) in Britain and Gerell (1967) in Sweden showed that the diet of coastal minks consisted mainly of fish during winter, and that the amount of mammalian prey increased in summer. Inter guild competition with large gulls and crows for the food resources are also suggested in the archipelago of Vest-Agder (Udø 2005). Large gulls can kill mink kits and bully adults, probably as a defense mechanism (Gerell 1975; Udø 1995), (Udø 2005). This hostile behavior may have developed also in other bird species, making the mink careful in interaction with bird colonies.

The mink project aims to locally eradicate the mink and is one of the first of its kind in Norway. Local knowledge and experiences from other nations in combination with great effort makes eradications in smaller areas possible, but good control of mink in a larger area is the greater goal. The local control and eradication is executed by heavy effort, resources and man power, with 50–60 working days each year. The birds in the protected area are also counted each year, so effects on bird populations can be monitored. However, starting in the coastal areas where the mink is regarded to pose the greatest danger for local wildlife is not straightforward, because most mink studies have been conducted in inland river, marsh or lake systems. My study may contribute with some knowledge based information on resting site selection in mink that can be used by management to better control mink populations. For example I would recommend that traps should be placed close to potential resting sites, for efficient trapping. This means close to water (<25 m), close to boulder piles or large stones on slopes or flats in close proximity to covering vegetation. This is common sense for experienced mink hunters, but can be very useful for the education of new hunters. Support of local initiatives against mink, like education of new hunters, are one of the six pillars in the action plan against mink, along with gathering more information through monitoring and research (Direktoratet for Naturforvaltning 2011).

Most studies of mink habitat or resting site selection propose that minks may be manipulated by habitat change and resting site availability (Halliwell & Macdonald 1996; Bonesi & Palazon 2007; Zabala et al. 2007; Melero et al. 2008). However, changes in habitat features may affect other species harder than the targeted species. Shrub control has been proposed in many studies as a measure against mink (Halliwell & Macdonald 1996; Zabala et al. 2007), but the effects on other, maybe endangered, species like ground nesting birds and the water vole are unknown. On the other hand, I found that minks preferred islands without grazing animals. Grazing reduces the vegetation and is already an important management tool to preserve coastal heathers in the study area. Hence, continued grazing should be recommended, not only in order to manage the vegetation as such, but also as a contribution to the control of mink populations in coastal areas of southern Norway.

To conclude, my study gives some insight into coastal minks’ use of resting sites, which may be useful to improve the control strategies for this invasive species. But many aspects of the mink's ecology are still unknown, and more knowledge is needed to explore its effects on our nature.

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Appendix 1

Instructions for mink hunting with dogs from Action plan against American mink in Norway (Direktoratet for naturforvaltning 2011).

Instruks:

Bruk av hund ved uttak/ registrering av mink

Innledning

Det er mulig å fjerne den siste minken fra øyer og øygrupper og i ettertid dokumentere at området er fritt for mink. Denne metodikken er basert på erfaring systematisert av Tom Aurebekk Udø og bygger på bruk av trenede hundeekvipasjer (hund og hundefører). For sikker dokumentasjon av om et område er fritt for mink er det ikke tilstrekkelig med passive metoder som feller eller sporrammer, da en stasjonær mink periodevis kan ha et ganske begrenset aktivitetsområde og således ikke avsløres uten ved aktivt søk.

Felling og registrering

Generelt:

- Flere øyer og holmer inngår ofte i en minks leveområde. Arbeidet bør derfor organiseres slik at en går systematisk over områder som utgjør en enhet, og ikke kun enkeltøyer/holmer.
- Er områdene utsatt for årlig innvandring av nye individer vil det være en fordel å foreta utryd- ningsarbeidet i perioden etter nyttår og frem mot yngletida. Da er territoriene etablert og den flytende bestanden av individer er lavest.
- Antallet dyr som om høsten/tidlig vinter strømmer inn igjen i utrenskede områder vil si noe om arealet som er valgt som bekjempningsområde er stort nok.
- De som skal foreta minkuttak må ha kunnskap om spredningsdynamikk territorie-/leveområde- størrelse hos mink. Dette er viktig for å ha for- ståelse av potensiell bestandstetthet og spredning.

Viktige områder:

- Dagleieområder under steiner, i fjellsprekker, i vegetasjon som tett- og lavtvoksende einerbusker, i jordhull, brygger, plankestabler eller i bygningskonstruksjoner og lignende. Vanligvis innenfor 100 m fra stranden.
- Hi med yngling ligger ofte i nærheten av pytter med ferskvann og på steder med litt dybde på jordsmonnet.

Søk:

- Hunden søker fritt etter mink i det utvalgte området, i de fleste tilfeller en øy/holme.
- På mindre holmer er minken like gjerne midt på holmen som ved stranden.
- Hunden vil som regel påvise/markere der det er gammel lukt etter mink (flere dager gammel- opp- til ca en uke).
- Er det lukt fra siste døgn vil de fleste hunder være synlig ivrige, men forflytte seg og søke videre for å finne minken.
- GPS peilesystem på hunden vil gi god dokumenta- sjon på hvordan hunden dekker området.

Hundefører:

- Holder øyekontakt med hunden for å tolke søket og se hvor hunden beveger seg. Nyttig å bruke GPS peilesystem som tillegg for å finne ut hvor hunden er og har vært. GPS-track-log kan så i ettertid brukes til å dokumentere hva som er avsøkt.
- Sørger for at hunden får søkt av potensielle dag- leie- og hilokaliteter. Særlig

erfaringsmessig mye brukte steder.

- Tolker hva hunden holder på med ut fra dens opp- førsel.
- Går på større holmer i nærheten av sjøkanten slik at hunden kan fange opp sporstrengen fra vannet og opp til dagleie fordi minken er i sjøen så og si hver natt på næringssøk.

Hunden:

- Skal ha vidt nok søk og følge førers marsjretning.
- Kan forsvinne ut av syne, men bør komme innom fører jevnlig hvis det ikke er ferske spor.
- Skal påvise minkens eksakte posisjon når den er funnet.
- Skal bare gi los/klynke når den finner minken, helst ikke lose/klynke på gammel sporløype/sportegn.
- Skal raskt oppdage at minken rømmer gjemme- stedet.
- Skal raskt forfølge mink som rømmer skjulestedet og presse den til å ta nytt skjul. Får minken for mye tid kan den gjemme seg på steder hvor man ikke får tak i den.
- Skal alltid søke etter minken igjen hvis den først er funnet og har rømt gjemmestedet.
- Bør påvise stedet på stranden hvor minken har flyktet i ut i vannet.
- Bør ikke fange minken selv.
- Må ha god evne til å ta seg fram. Kortbeinte hunder som ofte tar seg litt langsom fram i ulendt terreng, funger best i kombinasjon med raskere hunder. Raskere hunder presser minken til å søke skjul på i løpet av kort tid og da ofte på mindre trygge steder.
- Må være utholdende og ha stor jaktlyst. Utredning av sporene krever ofte mye arbeid av hunden.

Tidsbruk:

- Varierer etter hundens effektivitet, antall poten- sielle dagleie- og hilokaliteter, tetthet av mink, størrelse og framkommelighet på holmen/øya. I snitt vil man bruke mellom ca 2-10 min/daa på søket.
- Svært forskjellig ved søk i områder hvor mink har oppholdt seg siste døgn kontra minktomme områder.
- Varierer etter værforhold, transportlengder, for- hold for fortøyning av båt mm.

Appendix2

Form for registration of characteristics of mink resting sites and random plots.

Registrering av dagleier for mink

Observatør: Klokkeslett:

Dato:________/________/_______. Lokalitet:

Værforhold

Vær: Opphold ☐ Regn☐ Sol☐ Snø ☐

Vindretning:________.

Temperatur: _______ *C

Om lokaliten.

Sted: Øy: ☐

Liten: Under 100m bred) ☐ Middels(over 100m bred) ☐

Stor (over 500m bred) ☐

Avstand nærmeste øy : ‹100 m ☐ 100-300 m ☐ 300m–500 m ☐ >500 ☐

Fastland: ☐

Havstand: Flo☐ Fjære☐

Havis: Nei ☐ Ja ☐ Drivis/ isflak ☐

Sporsnø: Ja☐ Nei☐

Konstruksjoner: Hytte ☐ (Ant: ____) Helårsbolig ☐ Brygge ☐

Vinterlagring av båt ☐ Annet: _____________________.

Vegetasjonstype (Dominerende):

Svaberg/ fjell ☐ Gress ☐ Skog ☐ Einer/Lyng (busker etc.) ☐

Annen fauna: Rev ☐ Oter ☐ Mår ☐ Annet : ________________________.

Beitedyr: Nei ☐ Type:____.

Beitegrad: Knapt synlig☐ Synlig ☐ Hardt beite ☐

Dagleie

Funnsted: I vegetasjon (einer, lyng ect.) ☐ Under stein ☐

I liten steinur ☐ I stor steinur ☐ I jordgang☐ I snøhule/gang ☐

Bergsprekk ☐ Tre-konstruksjon ☐ Steinkonstruksjon ☐ Annet___________.

Terrengplassering: I søkk/dal ☐ På topp/rygg ☐ På slette ☐ I li/ bratt skrent etc. ☐

Vegetasjons/dekning til/fra dagleie: Ja ☐ Nei☐

Tele i bakken: Ja ☐ Nei ☐

Snødekke: Nei ☐ Ja:_______cm

Avstand fra havet:

0-25m☐ 25-50 m ☐ Over 50m ☐

Himmelretning:__________.

Vindeksponert: Ja ☐ Nei ☐ Soleksponert: Ja ☐ Nei ☐

Individ opplysninger:

Nr:

Avlivet: Ved dagleie☐ Etter flukt ☐ Nei ☐

Kjønn: Hunn☐ Hann☐ Ukjent☐

Alder: Årsunge☐ Voksen ☐ Gammel☐ Ukjent☐

Vekt: _________gram

Norwegian University
of Life Sciences

Postboks 5003
NO-1432 Ås, Norway
+47 67 23 00 00
www.nmbu.no