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Examensarbete i ämnet biologi, 2017:5
Department of Wildlife, Fish, and Environmental studies
Umeå
2017

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Credits: 30 HEC
Level: A2E
Course title: Master degree thesis in Biology at the Department of Wildlife, Fish, and Environmental Studies
Course code: EX0764
Programme/education: Jägmästarprogrammet

Place of publication: Umeå
Year of publication: 2017
Cover picture: Jimmy Pettersson
Title of series: Examensarbete i ämnet biologi
Number of part of series: 2017:5
Online publication: http://stud.epsilon.slu.se

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Abstract

Human land use can reduce the amount and quality of wildlife habitats. During recent years, a high moose calf summer mortality have been discovered on Öland. Öland is a predator-free island in Sweden that is dominated by agriculture and presence of humans and grazing livestock. Results from earlier studies indicate that the females are not in bad condition during autumn. However, suboptimal habitat use during winter and the fact that most calves died because of starvation and that they had not lactated, indicate that the females are in bad condition during late gestation. The time from that greenery has started to the start of the parturition, might not be enough for the females to get in condition to be able to lactate and raise a calf. To increase the knowledge about the human impact on moose habitat in an agricultural landscape, I have studied how the forest and agricultural land have change during the last decades in the municipalities Borgholm and Mörbylånga on Öland. Secondly, I have studied habitat selection during calving and compared female moose that successful raised their offspring with those that lost their offspring during summer. My results revealed an increasing trend for the area grazed alvar and a decreasing for area of attractive crops as oats and sugar beets. Number of livestock, especially cows showed an increasing trend in both municipalities. There was also shown an increasing trend for the area agricultural land that was utilized and at the same time there was no unutilized agricultural land in the end of the study period on the island. The part of the land classified as non-forest land was higher 2012 compared to 2000 in Borgholm, while it remained the same in Mörbylånga. The part classified as core forest, however, was higher in both municipalities 2012, while the part classified as edge, corridor and islet was lower. In the north, the females with surviving calf selected more optimal habitat in general than the females with non-surviving calf. In the more agricultural south, there were just two females that succeeded to keep a calf alive during the summer, which made the same comparison between females with surviving calf and females with non-surviving calf difficult in the south. The females that did not succeed to raise their calf did not select poorer habitat than the two females with surviving calf. My results show that there has been an intensification of the agricultural land use on Öland and that the proportion of total forestland has decreased, which may have reduced the quantity and quality of forage for moose especially during winter. It also shows that a good selection strategy during calving is not enough for the females to succeed to raise their offspring, especially where resources is scarce. Land use change could be a factor together with other factors as warmer temperatures and earlier spring, contributing to the high moose calf mortality. But more research is needed to explore how other factors are influencing, for example intra- and interspecific competition. Based on my result, I suggest more research on moose habitats during spring in agricultural dominance landscapes and female moose ability to meet the growing need for energy during parturition and lactation.

Keywords: land use change, habitat selection, moose calf mortality, Öland, agricultural landscapes

Sammanfattning

Människans markanvändning kan reducera mängden och kvaliteten på djurs livsmiljöer. De senaste åren, har en hög sommardödlighet upptäckts bland älgkalvar på Öland. Öland är en predatorfri ö i Sverige, som domineras av jordbruk och närvaro av människor och betande boskap. Resultat av tidigare studier indikerar att älgkorna inte är i dåligt skick under hösten. Men älgkornas användning av suboptimala habitat under vintern och det faktum att de flesta kalvar som dog under första levnadsveckan dog på grund av svält och att de inte hade diat, indikerar att älgkorna däremot är i dåligt skick under sen dräktighet. Tiden från det att det börjar grönska till kalvningen, kan vara otillräcklig för att älgkorna ska komma i form för att kunna producera mjölk och föda upp en kalv. För att öka kunskapen om människans påverkan på älgars habitat i jordbrukslandskap har jag studerat hur skogs- och jordbruksmarken har förändring under de senaste decennierna i kommunerna Borgholm och Mörbylånga på Öland. Jag har också studerat älgkornas habitatselektion under kalvning och jämfört älgkor med överlevande kalv och älgkor med icke-överlevande kalv. Mina resultat visade en ökande trend areal betat alvar och en minskande av areal attraktiva grödor som havre och sockerbetor. Antalet djur, särskilt kor visade en ökande trend i båda kommunerna. En ökande trend visades också för areal utnyttjad jordbruksmark samtidigt som det i slutet av studieperioden inte fanns någon outnyttjad jordbruksmark på ön. Andel mark som klassificerats som icke-skogsmark var högre under 2012 jämfört med 2000 i Borgholm, medan den var densamma i Mörbylånga. Andel mark klassificerad som kärnskog, var dock högre i båda kommunerna 2012, medan andelen kant, korridor och öar var lägre. På den norra delen hade de älgkor med överlevande kalv i allmänhet valt bättre habitat än de älgkor med icke-överlevande kalv. I den mer jordbruksdominerade södra delen av ön, var det bara två älgkor som lyckades hålla en kalv vid liv under sommaren. Samma jämförelse mellan älgkor med överlevande kalv och älgkor med icke-överlevande kalv var därför svår att göra för den södra delen. De älgkorna som inte lyckades föda upp deras kalv selekterade inte sämre habitat än de två älgkor med överlevande kalv. Mina resultat visar att det har skett en intensifiering av jordbruksmarken på Öland och att den totala andelen skogsmark har minskat, vilket kan ha reducerat mängden och kvaliteten på foder för älg, speciellt under vintern. Det visar också att en bra selektionsstrategi under kalvning inte är tillräckligt för att älgkorna ska lyckas föda upp sin kalv, särskilt där resurserna är knappa. Förändrad markanvändning kan vara en faktor tillsammans med andra faktorer som varmare temperaturer och tidigare vår, som bidrar till den höga älgkalvdödligheten. Men mer forskning behövs för att undersöka hur andra faktorer påverkar som till exempel intra- och interspecifik konkurrens. Baserat på mina resultat föreslår jag mer forskning på älghabitat under våren i jordbruksdominerade landskap och älgkors förmåga att möta det växande energibehovet under kalvning och laktation.

Introduction

Today, about 40 % of the terrestrial surface on Earth has been transformed to agricultural land or built-up areas (Ellis *et al.*, 2010). An additional 37 percent, not in use for this purpose, are fragmented and embedded within it. Martinuzzi *et al.* (2015) shows that in southeastern USA urbanization and expansion of agriculture land were the most important drivers for habitat loss. The most vulnerable species were the ones associated with open vegetation like grassland and open woodland. Land use change is considered to be a severe threat to the global biodiversity (Sala *et al.,* 2000). The global increasing trend of transformation and fragmentation of forest land to urban settlements and agricultural land are decreasing the habitat for many forest dwelling species. In some parts of the world however, the opposite land use change is seen, with decreasing agricultural land and increasing forest land like, e.g. in North America (Statistics Sweden, 2013) and European Russia (Sieber *et al.*, 2015). But even though the forest area has increased in some parts of the world, the characteristic of many forest ecosystems have changed. For example, in the Scandinavian ecotone between boreal and deciduous forest, species composition has change drastic during the last 150 years, from a species rich forest dominated by deciduous trees to a forest with few species dominated by coniferous (Lindbladh *et al.*, 2000; Nilsson, 1997). Anthropogenic activities as agriculture and forestry have been addressed to be the main causes. The modern forestry including clearcutting, planting and thinning has created a patchy forest landscape with trees of same species and older (Kouki *et al.*, 2001; Östlund *et al.*, 1997). At the same time many old growth forests and element associated with continuity have got lost (Esseen *et al.*, 1997). Some species, however, have been favored by this forestry practice (e.g., certain spiders and beetles, Niemelä, 1997; capercaillie, Sjöberg, 1996).

Moose is another forest dwelling species that has benefited by the modern way of manage the forest, which has created optimal browsing habitat in respect to accessibility and palatability of individual food plants (Lavsund *et al.*, 2003; Cederlund & Bergström, 1996; Peek *et al.*, 1976). However, moose in the southern range of their distribution have under recent year seen to be under environmental stress (Monteith *et al.*, 2015; Malmsten, 2014; Lenarz *et al.*, 2010; Murray *et al.*, 2006). The cause has among others addressed to a changing climate with higher temperature and earlier plant growth in the spring. The quality of plant as forage is highest in newly developed plants (Van Soest, 1994). For female ungulates, nutritional demand peaks during the period of parturition and lactation (Clutton-Brock *et al.*, 1988). These two peaks when the quality of the plant is highest in the spring and when females have their highest demand for energy have been seen to be closely linked (Monteith *et al.*, 2015; Hebblewhite *et al.*, 2008). An earlier start of the growing season can therefore lead to a mismatch of these two events and may consequently result in lower reproduction performance of females. A warmer climate could also induce heats stress and a lower survival (Lenarz *et al.*, 2009).

Changing land use and transformation of forest to agricultural land could also be a factor decreasing moose populations (Rosvold *et al.*, 2013). During summer, agricultural land can be an important forage habitat for moose, fields of oats are for example very attractive for moose (Ekman *et al.*, 1993). But in general agricultural land is not seen as an optimal habitat for moose (Nikula *et al.*, 2004). Nikula *et al.* (2004) showed that moose winter home ranges included less agricultural land and human settlements than expected if the selection would have been randomized. Moose avoidance towards humans activity and built-up areas have been shown in more studies (Torres *et al.*, 2011; Lykkja *et al.*, 2009) and can generate the same behavior response as the risk for predation, reducing the time for foraging, maternal care, reproduction and other fitness increasing activities (Frid & Dill, 2002). In a Norwegian study, moose selected young forest stands and cultivated land during night, that provides high-quality forage while older forest that provides cover were selected during the day (Bjørneraas *et al.*, 2011). The selection for habitat that provides cover is usually higher for reproducing females than for other individuals (Bjørneraas *et al.*, 2012; Bjørneraas *et al.*, 2011). Moose also search shelter for the heat (Dussault *et al.*, 2004). The upper threshold temperature for moose before showing heat stress symptoms is assumed to be around 14°C in summer time and -5°C in winter time (Renecker & Hudson, 1986). In a study by van Beest and Milner (2013) on female moose living at the southern range in Norway, moose that used young successional forest at cooler temperature and mature forest when temperature was higher lost less in weight during winter and gain more in summer, which also emphasize the importance of shelter towards the heat. In general a good habitat for cervids is a habitat that provides both forage and shelter (Tufto *et al.*, 1996).

On the agricultural embossed and predator free island Öland in the southeast of Sweden, high moose neonatal calf mortality has been reported during recent years. For predator-free areas, a normal moose calf summer survival use to be around 80-90 % (Linnell *et al.*, 1995). Öland, however, has had a summer survival of 15-32 % during the year 2012-2015 (Ericsson *et al.*, 2016; Ericsson *et al.*, 2015; Ericsson *et al.*, 2014; Ericsson *et al.*, 2013). What has been seen is that the calving rate do not differ from other Fennoscandia populations, i.e. the proportion of females that have at least one calf (Allen *et al.*, 2016). Because the probability of becoming pregnant in general is decided by the condition during the autumn (Allen *et al.*, 2016; Monteith *et al.*, 2015; Monteith *et al.*, 2013), this indicates that the females moose were not in bad body condition during the rut. For herbivores maternal condition during late pregnancy it is probably more important for early juvenile survival (Allen *et al.*, 2016; Gaillard *et al.*, 2000; Sand, 1996). For the moose on Öland, most home ranges were dominated by arable land and the selection for arable land increased during winter (Allen *et al.*, 2016). This result is very remarkable because in general the selection for arable land during winter use to decrease (Bjorneraas et al 2011). For the females included in Allen *et al.* (2016) study of the moose on Öland, thicket was the highest ranked habitat selected for during winter. Thicket was also the habitat that most explained the variation in calf survival. The utilization of suboptimal habitat during winter could lead to females in poor body condition during parturition, making them unable to meet the energy demanding process of lactation, with low calf summer survival as a result. About 39 % of the mortality events occurred during the first week and 53 % of the mortality events during the first month. Based on autopsy on the calves that were found dead during the first week, the almost thoroughgoing main diagnosis was starvation (Ericsson *et al.*, 2014). The general perception was that the calves were born alive but that they had not lactated.

Aim

To better understand the effect of habitat change on moose calf survival, I have in this study investigated how the land use has change during the last decades on the island Öland and how that may have impacted the moose habitat. Secondly, I have studied habitat selection during calving and compared females that successful raised their offspring with those that lost their offspring during summer. My study aimed to explore if changing land use could be a likely cause of the high calf mortality on Öland. The following research questions were used to fulfill the aim of the study:

1. How has the forest land changed in respect to forest connectivity and geometry in the landscape?

2. How has the agricultural land changed in respect to acreage pasture- and arable land and number of livestock?

3. Does the selection of habitat differ between females with surviving calf and females with non-surviving calf during the calving period?

Method

Study area

Öland is an island located in southeast Sweden in the county of Kalmar. It is Sweden's second largest island with a land area of 1 342 km^2 and a length of 137 km. The limestone bedrock on the island together with the warm, dry climate and the soil's ability to hold water creates a unique landscape that differs much from that of the mainland. Today about 56 % is made up by agricultural land, 19 % of alvar grassland and 21 % by forest (Allen *et al.*, 2016). Most of the forest is concentrated to the northern and central part of the island. Coniferous dominates the sand embossed northern part, while deciduous trees are dominating the other parts. The alvar grassland consists of a thin layer of nutrient poor, dry vegetation on the top of the limestone bedrock. Several smaller alvar grasslands can be found in the north part of the island and one big in the south called Stora Alvaret, which is about 255 km^2. Hereafter, I will refer to all alvar grasslands as grazed alvar. Together with the so called coastlands, the grazed alvar are the most important grazing land on Öland. Along the east side of Öland near the coast, the coastland can be found stretching out as a wide band of open pasture, creating an open cultural landscape.

The special condition prevailing has made the island particular favorable to farm and the history of cultivation and animal husbandry stretches far back in time (Forslund, 2001). But since the Second World War, the agriculture on Öland has change radically, as for the rest of Sweden, with a significant reduction of number of farmers. However, in contrast to the rest of Sweden, no part of the arable land has been taken out of production. Sweden's entry into the EU in the mid-1990's have also affected the agricultural land and practices on the island (Jordbruksverket, 2011). It resulted in environmental subsidies to the agriculture for management and restoration of meadows and pasture, which for instance implied clearings from small bushes and trees (Jordbruksverket, 2016). The beef premium for bullets over 22 month, is another subsidy that came with the EU entrance and that favored pasture land and led to more grazing animal (Jordbruksverket, 2011).

Added to this a net loss of 33 % (1,86 km^2) of the young forest has occurred during the period 2000 to 2012 (Allen *et al.*, 2016). The Swedish Forest Agency (2016) have recently published feeding forecast for each moose management area based in principal on the area young forest between 1-6 meter. On Öland, only 594 ha of in total 31 966 ha forest land was estimated as forage producing young forest. It corresponds to not even 2 % of the forest land on Öland. This can be compared to the west and the south of Kalmar, just some kilometers away were fodder producing young forest constitute around 10 % of the forest land.

Due to large difference in landscape characteristics, I divided the island in “north” and “south” following Allen *et al.* (2016) approach, using the northern extent of Stora Alvaret to separate the island (Appendix 1). Agricultural land is dominating both the northern and the southern part, however, forest is the second dominating in the north while Stora Alvaret is the second dominating in the south. For the analysis of land use and livestock change, I used the two municipalities Borgholm and Mörbylånga to divide the island. Borgholm is the municipality in the north while Mörbylånga is the municipality in the south.

Change of forest

I analyzed the spatial structure of the forest land through MSPA (Morphological Spatial Pattern Analysis). MSPA is a software that group forest pixels in different classes depending on the geometry and connectivity between them (Vogt *et al.*, 2007). The first step in MSPA workflow was to prepare a binary foreground/background mask, where forest land was foreground and the non-forest land was background. For this I used SMD raster from 2000 and Corine Land Cover from 2012. The spatial structure of forest pixels in relation to the background was then identified through MSPA and divided into four classes; core, edge, corridor and islet (Appendix 2). The background was named non-forest. I then used number of pixels to calculate the percentage of each class of the total land area to be able to compare the forest land 2000 with the forest land 2012.

Change of agricultural land

To study how the agricultural land has change over time, I analyzed annual data for the island on area pasture land and area arable land available in the statistical database of the Swedish Board of Agriculture (Jordbruksverket, 2015). Pasture land included different types (pasture, mown meadow, forest pasture, mountain pasture, grazed alvar, mosaic pasture, unutilized pasture and unspecified pasture). Except analyzing how the total area pasture land has changed, I also analyzed how the area of different pastures has changed. I excluded pasture types with low or none share (mountain pasture, mosaic pasture and unspecified pasture) from the analysis. For the arable land, I analyzed both the total area and then divided in different crops. After reviewing the literature and expert-opinion on what crops that are interesting for moose, I decided to analyze the following crops; oats, brown beans, maize, sugar beets, winter rape, utilized ley for forage and grazing, and fallow land (Dorey, 2014; Svensson, 2008; Ekman *et al.*, 1993). Few observations and irregular time interval made me chose Mann-Kendall trend test to test for trends in the data. To perform the test I used the statistical software XLSTAT. Mann-Kendall trend test is a non-parametric test to detect trends in time-series data based on Kendall rank correlation (Mann, 1945). The test can deal fairly well with missing values and don’t demand high number of observation. To take into account the serial correlation in the data, I chose a method proposed by Hamed and Rao (1998). The test has been shown to perform well when there is auto-correlated data and no obvious trend, which corresponded well to my data-series. Further, I used Sen's slope as a measure of increasing or decreasing trend (Sen, 1968). For the pasture land statistics, data was available for every year between the year 2003 and 2014 while for the arable statistics, data was available between the year 1981 to 2014 but not for every year. I therefore analyzed the change of pasture land between the year 2003-2014 and the change of arable land between the years 1981-2014.

Change of livestock

As well as for the analysis of the agricultural land, I obtained annually data on number of livestock (cows, sheep and horses) from the Swedish Board of Agriculture (Jordbruksverket, 2015) and Mann-Kendall trend test was used to test for a monotonic upward or downward trends. Data was available between the year 1981 and 2014, but as well as for the arable land, not for all years.

Habitat selection during calving

For the second part, to study the habitat selection during the calving season I used available movement data from in total 23 different female moose that were equipped with global positioning system (GPS) neck collars (Vectronic Aerospace GmbH, Berlin, Germany) between February 2012 and February 2015. I only used position data for the calving season, i.e. one week before calving until four weeks after calving. GPS locations were obtained for every 30 minutes and were sent into the wireless remote animal monitoring (WRAM) database system (Dettki *et al.*, 2014). Because the time of calving varies among females, data was taken individually dependent on when they were calving. When a female is calving the position data becomes dense gathered. By carefully studying the females' movement pattern during calving season, the time and place for parturition could be set. To verify and to decide the number of calves born, the place was visited one to three days after this dense cloud of position data had been seen. Thereafter the survivals of the calves were studied thoroughly during their first month. Suspected calf loss based on the females' movement pattern was directly followed by a field check. Otherwise two checks were done during the summer, one four weeks after calving and the other just before the hunt. The study was performed during the four years 2012-2015. Only females that gave birth to calves was included in the analysis, it meant that for the first year, data from 15 female moose was used, for the second year 12 females, for the third year 8 females and for the fourth year 14 females. In total there were 49 calving event. Some of the females got twins. If at least one of the twins survived the summer, the female was classified as a female with surviving calf otherwise the female was classified as a female with non-surviving calf regardless if she gave birth of one or two calves. The summer survival was defined as the survival until the hunt.
I used R version 3.0.2 to do my analysis. Beside of dividing in north and south, I also divided the analysis in three periods, i.e. one week before calving, during calving (+ four days) and three weeks after calving. I did this to be able to more in detail study their habitat selection. The periods were selected for each female in respect to her date of calving that given year. Another reason for why I chose to split the calving season in three periods and study each separately was because many of the females that lost their calf, were without calf already at the monthly check. In particular in the south, 81 % of the females that lost their calf were without calf at that time. In the north the corresponding number was 37 %. Some of the females were

therefore without calf during the period after calving and the habitat selection therefore to some extent mirrors how females without a calf select habitat. The selection of habitat may differ between females with offspring and females without, for example females with offspring generally tend to select more sheltered habitat than females without offspring (Bjørneraas *et al.*, 2011). By analyzing each period separately I hoped to see if the females with non-surviving calf selected habitat differently during the period after calving. Also important to notice is that the habitat selection during the period after calving did therefore not automatically affect the outcome of the calf's survival.

The first I did with the positon data was to calculate each females home range during each of the three periods, using the Biased Random Bridge (BRB) kernel approach (Benhamou, 2011) available in the adehabitatHR package version 0.4.14 (Calenge, 2006). From that a utilization distribution (UD) was derived. UD is a probability density function that examines where an animal is likely to be at a given time. The diffusion coefficient used in the BRB function was estimated with the BRB.D function described in Benhamou (2011) paper. The smoothing parameter was calculated as the mean distance between two relocations divided by two (Benhamou, 2011). I let the grid for which the UDs were estimated in to have a constant resolution among the individuals. Based on the derived UD I extracted the 95 % isopleth (UD95) for each female to get the 95 % home range, i.e. the minimum area on which the probability to relocate the female is equal to 0.95. I then related these home ranges to the underlying habitat, which I obtained from the Corine Land Cover map (Lantmäteriet, 2015). The map is from 2012 and has a spatial resolution of 25 m. After I had connected the moose data to habitat, I updated the areas that had been clear-felled after the time the satellite images were taken and before the moose GPS location, with clear-felled data from Swedish Forest Agency. I grouped and named land classes that had a low representation to “other land classes”, forest between 0-20 years to “young forest”. I renamed the original land class “land principally occupied by agriculture, with significant areas of natural vegetation” to “mixed agrarian/natural vegetated land”, “transitional woodland/shrubs” to “thickets” and the remaining land classes I kept unchanged. Final land classification included: arable land, pasture, mixed agrarian/natural vegetated land, broad-leaved forest, coniferous forest, mixed forest, thickets, sparsely vegetated areas, mires, young forest and other land classes. To test whether habitat selection differed between females that successful raised their offspring and those that lost their offspring during summer, I used General Linear Mixed Model (GLMM) from the lme4 package version 1.1-12 (Bates *et al.*, 2016). However, the GLMM was unsuccessful to detect any differences between these two groups. I thus applied the Manly habitat selection ratio (Manly *et al.*, 2007), which is a ratio that shows whether an individual select or avoid a habitat by comparing how much that is used by how much is available of a certain habitat. For this I used the wiIII function from the adehabitatHS package version 0.3.12 (Calenge, 2006) and the third order selection (Thomas & Taylor, 1990; Johnson, 1980). The third order selection derives the selection ratio by comparing those habitats recorded within each individuals home range, i.e. the GPS locations, with the proportion of habitats found in their home range, in my case the UD95. For the wiIII design the use and availability is measured separately for each individual. A ratio greater than 1 indicates a selection for a certain habitat while a ratio below instead indicates avoidance. For my test I used the significance level of 0.05. Because I had data from multiple years from same individuals, I could not calculate selection ratios for every female each year because that would have violated the test criteria about independence between animals. The test should then have threated individuals as different individuals when occurring during different years. To take that multiple data problem into account, I calculated the average proportion GPS locations for each female within every land class, with the average proportion of every land class available in each female's home ranges. Ratios were calculated separately for females with surviving calf and females with non-surviving calf to be able to compare these two groups.

Result

Change of forest

The non-forest land in Borgholm increased from 68 to 78 % from year 2000 to 2012 whereas the non-forest land in Mörbylånga remained unchanged. The core forest increased in both municipalities, while edges, corridors and islets decreased (Table 1, Appendix 3,4).

	MSPA classes	**2002**	**2012**
Borgholm	Core	18%	20%
	Edge	7%	4%
	Branch	3%	0%
	Islet	2%	0%
	Bridge	1%	0%
	Perforation	1%	0%
	Loop	0%	0%
	Total forestland	32%	25%
Mörbylånga	Core	6%	9%
	Edge	4%	2%
	Branch	1%	0%
	Islet	1%	0%
	Bridge	1%	0%
	Perforation	0%	0%
	Loop	0%	0%
	Total forestland	12%	12%

	MSPA classes	**2002**	**2012**
Borgholm	Core	18%	20%
	Edge	7%	4%
	Branch	3%	0%
	Islet	2%	0%
	Bridge	1%	0%
	Perforation	1%	0%

	Loop	0%	0%
	Total forestland	32%	25%
Mörbylånga	Core	6%	9%
	Edge	4%	2%
	Branch	1%	0%
	Islet	1%	0%
	Bridge	1%	0%
	Perforation	0%	0%
	Loop	0%	0%
	Total forestland	12%	12%

Change of agricultural land

Pasture

The total acreage of pasture land showed a small monotonic decreasing trend in Borgholm between the year 2003 and 2014, while no trend were shown in Mörbylånga (Appendix 5,6). However, looking at the configuration of different types of pasture, trends were shown for both municipalities. In both Borgholm and Mörbylånga, the type named pasture showed a decreasing trend while grazed alvar showed an increasing trend. In Borgholm, mown meadow and forest pasture also showed an increasing trend. There was no unutilized pasture after the year 2007 in the two municipalities.

Arable land

I did not find any trend for the total acreage arable land for neither Borgholm nor Mörbylånga between the year 1981 and 2014 (Appendix 7,8). But as for the pasture land, the configuration of the arable land in regard to which crops that was cultivated during the period, changed. Both in Borgholm and Mörbylånga, oats and sugar beets showed a decreasing trend and utilized leys for forage and grazing an increasing trend. In Borgholm, other unutilized arable had an increasing trend, while the other crops did not show any trend (brown beans, winter rape and fallow land). In Mörbylånga, brown beans showed an increasing trend whereas the other (winter rape, fallow land and other unutilized arable land) did not show any trend.

Change of livestock

The number of cows did show an increasing trend both in Mörbylånga (Sen's slope = 325.3, p-value < 0.0001) and in Borgholm (Sen's slope = 310.5, p-value < 0.0001) between the year 1981 to 2014 (Table 2a). The number of sheep showed a trend just in Borgholm (Sen's slope = 99, p-value < 0.0001). In Mörbylånga no trend was shown (Sen's slope = -44.5, p-value = 0.1; Table 2b). The number of horses did not show any trend for neither Borgholm (Sen's slope = 8.6, p-value = 0.08) nor Mörbylånga (Sen's slope = 5.5, p-value = 0.1; Table 2c).

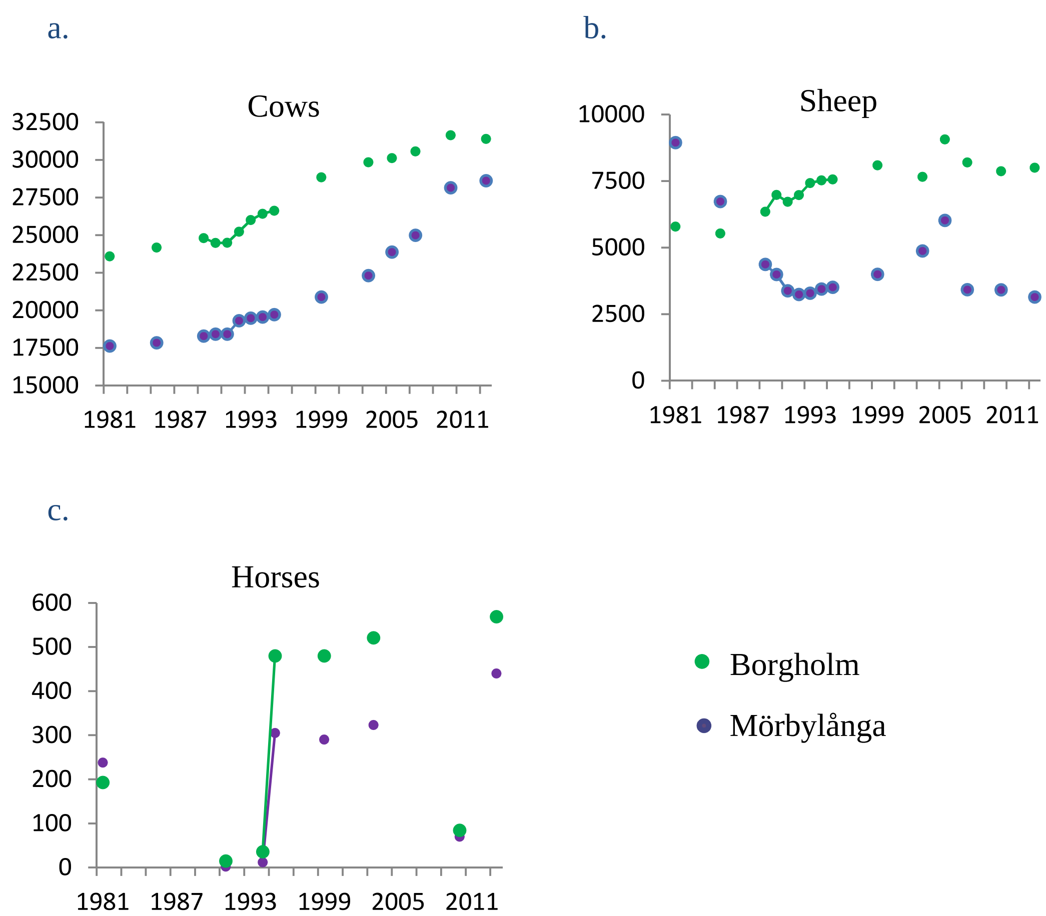

Figure 1. Number of cows (a), sheep (b) and horses (c) in Mörbylånga (purple dots) and Borgholm (green dots) during the year 1981 and 2014. Two subsequent years with available data is interpolated with a line.

Habitat selection during calving

During the week before calving (period 1)

In the north, females with surviving calf showed a selection for broad-leaved forest, young forest and mires during the week before calving (Figure 2a). Mixed agrarian/naturally vegetated land was avoided. In these females' home ranges, thickets and sparsely vegetated land were not available during this period. Females with non-surviving calf used the habitat more proportional to what was available and no clear avoidance or selection was shown.

In the south, there were just two females with a surviving calf during the years of study. The two females had only pasture (also arable land for one female) and sparsely vegetated land available in their home ranges during all three periods and the same pattern was seen through all periods, i.e. selection for pasture and avoidance towards sparsely vegetated land (Figure 2b). Of the remaining eight females that got calves during the years of study, none of their calves survived. The females with non-surviving calf used broad-leaved forest and mixed agrarian/naturally vegetated land more than what was available.

During the first days following calving (period 2)

In the north, females with a calf that survived selected broad-leaved forest and avoided pasture, mires and young forest during calving (Figure 2c). Most of the females did also show avoidance towards coniferous forest. The females with non-surviving calf did not show any clear selection for some habitat. However, young forest was avoided. A small avoidance was also shown towards coniferous forest.

In the south, as mention above, the two females with surviving calf showed the same habitat selection pattern during calving as for the period before calving (Figure 2d). The two females used pasture more and sparsely vegetated areas less. The eight other females with non-surviving calf showed selection for mixed agrarian/naturally vegetated land and avoidance towards arable land, coniferous forest and young forest.

During the three weeks after calving (period 3)

In the north, during the three week following calving, the females with surviving calf used coniferous forest more and agrarian/naturally vegetated land less (Figure 2e). The females with non-surviving calf selected pasture and mixed forest and avoided young forest.

In the south, again, the females whose calf survived used pasture more and sparsely vegetated areas less also during the three weeks following calving (Figure 2f). The females with a non-surviving calf selected in addition to mixed agrarian/naturally vegetated land also mixed forest, avoided coniferous forest, thickets, sparsely vegetated land, young forest and other forest.

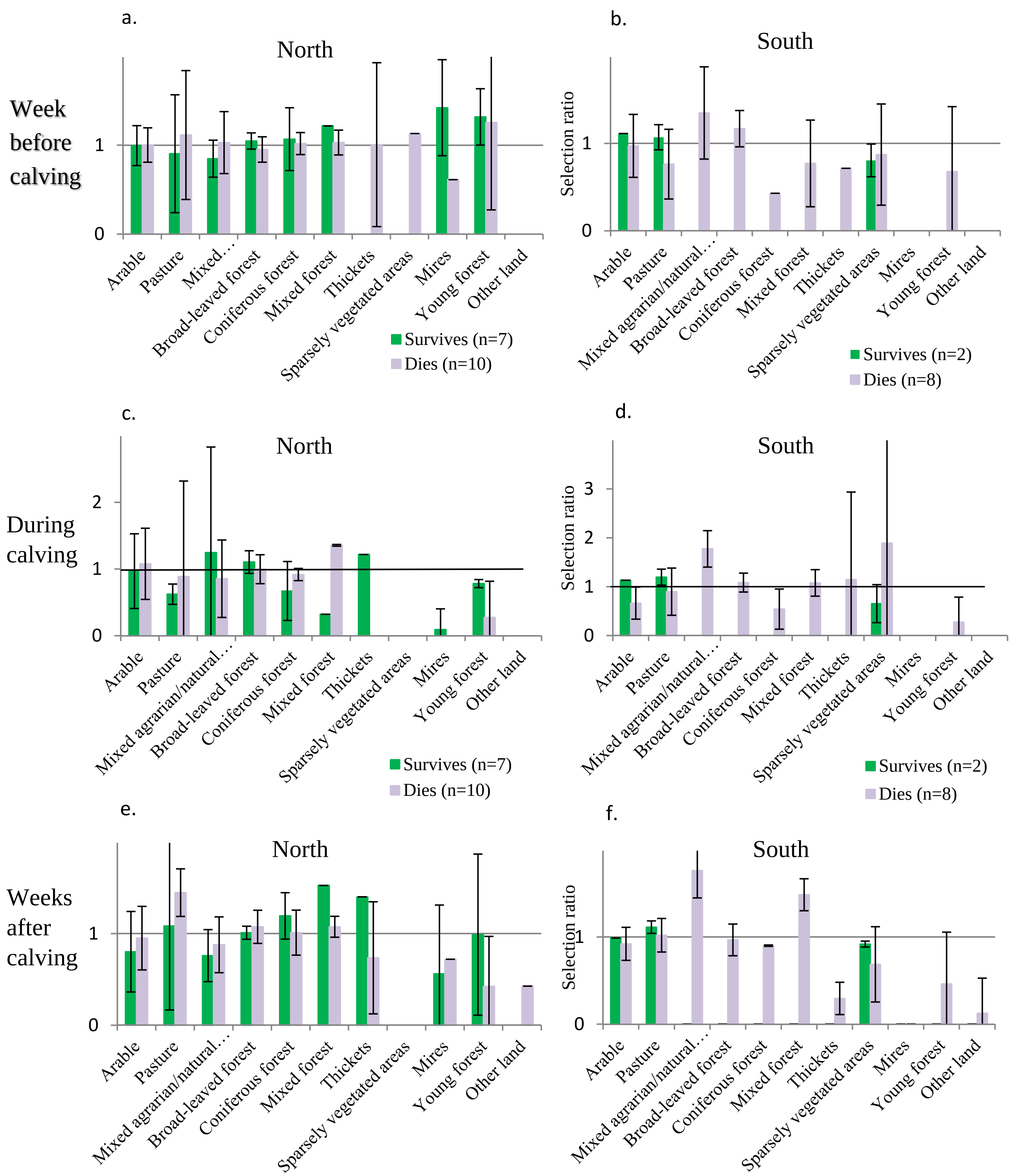

Figure 2. Manly's habitat selection ratio for females with surviving calf (green bars) and females with non-surviving calf (purple bars) before calving in the north (a) and in the south (b), during the calving in the north (c) and in the south (d) and three weeks after the calving in the north (e) and in the south (f).

a.

Week
before
calving

Discussion

Change of forest

Historical decline of moose population have been linked to transformation of forest land to more open cultural landscape (Rosvold *et al.*, 2013). Forest provides both shelter and forage, and are especially important during winter when agricultural crops and plants are not green and during calving for females with calves (Bjørneraas *et al.*, 2012). If we see forest as the only moose habitat, both the north and the south part of the island fall into Andren (1994) critical interval where patch size and isolation effects start to be important on for example population size of a species. According to his hypothesis, this is happen when there is less than 10-30 % suitable habitat in the landscape. Otherwise he argues that the effect of habitat fragmentation would mainly be due to overall habitat loss in the landscape. Patch size and isolation effect could therefore according to Andren (1994) be important factors for the moose population on Öland if we see forest as the only habitat. The good thing is, even though there was a reduction of the overall forest land in Borgholm from 2012 to 2000, the patchiness of forest decreased, i.e. the area islets, edges and corridors was lower 2012 than 2000. At the same time core forest increased in both municipalities. The theory of island biogeography says that bigger size on the habitat patches is good for species richness (Wilson, 1967; MacArthur, 1965) and hence the increase of core forest and decrease of elements as isolated islands, should therefore be a good trend for the moose population. On the other hand, the reduction of edges could be seen as a negative trend. At least in the light of Kurttila *et al.* (2002) reasoning, which emphasizes that edges between forest land and agricultural fields could provide a large and varied selection of food and at the same time proximity to shelter. But Torres et al. (2011) saw that distance to edge could not explain moose occurrence, instead distance to human settlements could. A larger part interior forest and longer distance to urban settlements could therefore be of more importance for moose.

There are other factors that are of great importance and that have not been investigated in this study as for example the quality and composition of forest in respect to older, tree species composition, density, structure etc. and how that might affect the forest as a moose habitat. Known is however that the area of young forest has decreased with 33 % between the years 2000-2012 (Allen *et al.*, 2016). It means that a larger part of the remaining forest is mature. Because regenerated clear-cut areas is recognized as important feeding habitat for moose (Bjørneraas *et al.*, 2011; Nikula *et al.*, 2004), this together with the overall low proportion of forest land on the island could be seen as a negative trend, reducing the amount of available browse and sheltered habitats for moose on Öland.

Change of agricultural land and livestock

Generalist species have an ability to use supplementary resources and adjust their feeding behavior to the prevailing situation (Abbas *et al.*, 2011). For example Abbas *et al.* (2011) found that roe deer took use of the agricultural matrix when the forest resources were scarce, during for example non-mast year. Roe deer at the same study site had also higher body mass in the most open landscape and lowest in the strict forest environment. Even though roe deer is more known to use agricultural land, agricultural land is also used by moose, especially during summer (e.g. Bjørneraas *et al.*, 2011).

My analysis revealed that there has not been so much of change in the total area of pasture land or arable land on the island. However, there have been some changes in the configuration of different types of pasture. Grazed alvar had an increased trend from beginning of 00s until 2014 while land named pasture had a decreased trend. Grazed alvar is mainly classified as thickets or sparsely vegetated areas. The findings by Allen *et al.* (2016) about the selection for thickets during winter as the most important variable explaining the calf survival in a negative sense and that sparsely vegetated areas was one of the least preferred habitats, indicates that the increase of grazed alvar also means an increase of the amount suboptimal habitat for moose.

Some crops that could be of interest for moose have also showed changing trends. Oats steadily decreased in both Mörbylånga and Borgholm, from the end of the 80s until 2014. Sugar beets also decreased, being one of the main crops in the beginning of the 80s to virtually no cultivation in 2014. In a diet analysis performed on ruminant of five individuals that were shot during the autumn 2013 in the center and in the south of Öland, 69 % of the diet was comprised of the agricultural produce apple, winter rape and sugar beets (Dorey, 2014), which further demonstrates that agricultural crops are an important part of the nutritional intake for moose on Öland. However, a good trend is that the yearly annual area of winter rape, even though no trend is shown for the whole study period, has steadily increased since 2002. Since winter rape also is green during winter, it may work as an important substitute in the moose winter diet. However, Allen *et al.* (2016) show that selection for arable field during winter had a small negatively correlation with calf survival, which indicate that the use of rape during winter does not increase the calf survival.

In my analysis of the agricultural land, I also found that from 2007 there was no unutilized pasture on Öland, which is interesting. Nor there was any other unutilized arable land. The fallow land has also decreased since the beginning/middle of the 00s century. At the same time as unutilized land has decreased, utilized ley for forage and grazing has increased, which indicates a more intensive agricultural land use on Öland. The cleaning and restoration of meadows and pasture have probably also affected how the pasture land looks like. For example in the year 1996, EU started a project through the environmental fund LIFE to keep the Stora Alvaret open by for instance removing juniper (Länsstyrelsen Kalmar, 2016) that was spread over large areas after the cessation of grazing and wood-cutting in the beginning of 1900 (Rosen, 1988). This resulted in a large area cleared from juniper, but also an increase number of livestock on the Stora Alvaret (Länsstyrelsen Kalmar, 2016). In 1994, grazing occurred on 60% of the area of Stora Alvaret which can be compared to 98 % of the area that was grazed 2005 (Rosén, 2006). Whether the reduction of juniper is good or bad for moose is not clear. There is paper declaring juniper as a preferable species for moose (Månsson *et al.*, 2007; Bergström & Hjeljord, 1987). But it is questionable if a diet dominating by juniper would meet the nutritional demand (Felton *et al.*, 2016; Ohlson & Staaland, 2001). Juniper also prohibits the growth of native vegetation if the coverage becomes too dense (Rosén, 2006), which may restrict the amount of other forage options for moose. However, the clearance of pasture land did also included clearance of other wooden species, as groves of birch, which may have had bigger impact on the amount of available wooden browse. After feeding on plants and agricultural crops rich in energy and with low content of fiber, it is believed that moose need to compensate it with an intake of twigs and branches (Felton *et al.*, 2016), therefore wooden material may be are important for moose also during summer. Svensson (2008) write that young forest, meadows and pastures, with deciduous trees and juniper are popular resting places and that edge zones towards agricultural fields with small broad-leaved trees and bushes, uncleared power lines and overgrown agricultural land are important feeding areas. According to Svensson (2008), the clearance of juniper and restoration of pasture land and meadows should therefore had reduced the amount of popular feeding habitat for moose.

The general increase of number of livestock on the island, does also point in the direction of an intensification of the agricultural land on Öland. In Mörbylånga, number of cows increased with almost 40 % between the year 1981-2014 and in Borgholm, the number of cows increased with around 25 %. Number of sheep varied more from year to year and it was just in Borgholm sheep showed an increasing trend. Even though no trend was shown for number of horses in the two municipalities it is remarkable that the number grown from being almost none in the early 1990s to be over 1000 in 2013. The overall trend however, was an increase of livestock on the island. Although livestock and moose are not in direct competition for the same food, grazing by livestock can prevent the amount of available browse (Austrheim *et al.*, 2011; Speed *et al.*, 2010). Stewart *et al.* (2002) saw in their study that elk avoided areas used by cattle despite strong patterns of resource partitioning among the two species. The increase presence of grazing livestock could therefore other than indicating on an intensification of the agriculture, also indicating on a negative interference on moose from livestock. But this should be further investigated before any conclusion can be drawn.

Moose habitat selection during calving

In the north

During the week before calving, the females with surviving calf selected broad-leaved forest and young forest. Both broad-leaved forest and young forest is preferable habitat for moose (Bjørneraas *et al.*, 2011; Lavsund *et al.*, 2003). Wam *et al.* (2016) found that moose calf body mass was positively related to the extent of forest clearing, which further strengthen the perception about young forest as a good habitat. Mires were also selected. Mires is not traditional seen as a typical moose habitat (Bergström & Hjeljord, 1987). However, the findings by both Allen *et al.* (2016) and Bjørneraas *et al.* (2011) as well as my results indicate that mires may house some interesting characteristics for moose. Allen *et al.* (2016) saw that the use of mires during summer was positively correlated with calf survival and Bjørneraas *et al.* (2011) found that female moose with calves spent more time in mires than expected by change. The females with non-surviving calf did not show any pattern of nor avoidance or selection. Maternal body condition has been shown strongly affect juvenile survival among ungulate species (Keech *et al.*, 2000; Clutton-Brock *et al.*, 1988). Because the females probably were in bad body condition during late winter due to suboptimal habitat use (Allen *et al.*, 2016), it should be important for the females to choose high-quality forage during the time before parturition to be able to meet the energy consuming process of lactation (Sand, 1998). Because it was shown that the calves that were found dead during the first week after calving had not lactated and that they died because of starvation, indicate that the females of these calves had not succeeded to get in condition to produce milk.

During calving, the females with surviving calf still selected broad-leaved forest while the females with non-surviving calf did neither here show any selection. The females with surviving calf did avoid pasture, mires and young forest during the time of calving. The females with non-surviving calf did just show avoidance towards young forest. During calving and the following months the moose in general search more sheltered habitat (e.g. Bjørneraas *et al.*, 2012; Bjørneraas *et al.*, 2011). Broad-leaved forest offer both shelter and preferable forage (Månsson *et al.*, 2007; Bergström & Hjeljord, 1987), while mires, pasture and young forest are more open habitat types, and might not be optimal in respect to the cover perspective.

During the three following weeks after calving, the females with surviving calf selected coniferous forest. For the first time the females with non-surviving calf also showed a clear selection, selecting for pasture and mixed forest. In particular, mixed forest should be regarded as a good moose habitat during summer offer both shelter and a broad range of different forage opportunities. An intake of different forage items should be important to cover the nutritional need (Felton *et al.*, 2016; Ohlson & Staaland, 2001). What should also be stated is that some of these females lost their calf within the first weeks. Therefore the selection pattern during the three weeks following calving to some extent reflects the selection pattern for females that have already lost their calf. Still however, contrary to the south, in the north most of the females did have at least one calf alive during the first month. A selection towards better habitat after the calves were born was obvious not enough to keep them alive during whole summer. Beside of the land classification and product description of the different land types, exact appearance and characteristics of the habitat is not known. Maybe there are other circumstances that can reduce the quality of habitats, e.g. present of livestock, roe deer, humans etc.

In the south

Firstly, the low number of females with surviving calf, i.e. two females of a total of ten, makes the same comparison between females with surviving and non-surviving calf difficult. However, I will still go through the observed differences.

The females with non-surviving calf, selected mixed agrarian/naturally vegetated land during all three periods. Lantmäteriet (2015) definition of that land class is: “A mixture of small areas consisting of agricultural areas and areas of natural or semi-natural origin, where none of the categories cover more than 75% or less than 25% of the total surface”. That habitat might provide a lot of high-quality food, especially during spring and summer when agricultural crops and other plants are green. But the amount of cover it provides might be limited. However, the two females with surviving calf selected pasture during all three periods, which is an even more open habitat, shows that whether the calf survives is not just a question of shelter. Except selection for mixed agrarian/naturally vegetated land, the females with non-surviving calf did also show selection for broad-leaved forest during the week before calving and mixed forest during the weeks following calving, both habitat consisting of high-quality forage (Wam *et al.*, 2016). The females with non-surviving calf did during the first period not show any avoidance. However, they avoided arable land, coniferous forest and young forest during calving and coniferous forest, thickets, sparsely vegetated land and young forest during the weeks after calving. That they avoided arable land and young forest during calving is not a surprising result, in respect to the preference of sheltered habitat during calving. Coniferous forest is not considered as a bad habitat, especially during winter or when other more preferable species as willow or birch are scarce (Hörnberg, 2001). But low availability of a habitat could also reduce the selection for a habitat (Herfindal *et al.*, 2015; Bjørneraas *et al.*, 2012). The home ranges of the studied females in the south did just consist of about 1-2 % coniferous forest. The low proportion could therefore explain why they avoided coniferous forest. During the weeks following calving, the females also avoided thickets and sparsely vegetated land, which should be considered as a good strategy according to Allen *et al.* (2016) findings. However, since most of the calves in the south died within the first weeks after calving, the habitat selection during this period did in not affect the survival of the calves. This period more depict the habitat selection pattern for the females that have lost their calf. During the time of parturition and the next few weeks following, the females is often very stationary (Testa *et al.*, 2000). If she loses her calves she becomes more mobile. One could therefore assume a more obvious selection for high- quality habitat by these females, since they are relieved the constraint to select habitat in respect of protection of the young. The increase selection of mixed forest and avoidance towards poor habitats may therefore reflect the females' behavior to select habitat to regain body mass and get in better condition.

The two females with surviving calf selected pasture (one of them did also select for arable land during the week before calving and during calving) and avoided sparsely vegetated land, through all three periods. The selection for pasture indicate that agricultural land could be important during the calving period, even though pasture may not be optimal in respect to the cover perspective. But the selection could also be a functional response of high abundance compared to other land classes (Bjørneraas *et al.*, 2012). Stewart *et al.* (2010) saw that grassland was associated with a fragmentary effect on moose distribution in the landscape. The definition for pasture is: "Grass land used for (or has been used for) grazing or haymaking, not under rotation. Trees and shrubs cover less than 30 % of the surface"(Lantmäteriet, 2015). The moose in Stewart *et al.* (2010) study were avoiding pasture in the landscape. Avoidance towards pasture could also be seen in my study for the females with surviving calf in the north. However, this was during the calving, which might more highlight the female demand of sheltered habitats when accompany of a calf. In the north, also the females with non-surviving calf selected for pasture during the weeks after calving, indicating that the habitat might provide some attractive components, when shelter is of less importance. The two females with surviving calf in the south did also avoid sparsely vegetated land during all three periods a land class considered as poor for moose. For the females with non-surviving calf, on the other hand the avoidance towards sparsely vegetated land was just clear for the weeks after calving. Whether the avoidance for sparsely vegetated land was an advantageous strategy for the calf survival can't however be said due to the small sample size.

Altogether, it is difficult to draw any conclusions about habitat-performance relationship for the moose in the south, because of the low proportion of surviving calves. Even though the females with non-surviving calf did show a good habitat selection strategy by selecting wooden areas and areas with semi-natural element, and avoiding more open land during calving, their calf did not survive. Selection for habitat considered as good and avoidance towards poor habitat should be a sign of optimal use of available habitats. However, the question is if there are enough available habitats in the landscape and whether these habitats can full-fill the moose need of shelter and forage. The south part of the island consist mainly of agricultural land and Stora Alvaret, habitat types that is not seen as optimal for moose lacking both shelter and browse, especially during winter. An optimal selection strategy might not be enough, because of a too low abundance of high-quality habitat in the landscape, with the consequences that the females are not able to compensate for the weight loss that most likely occurs during winter (Allen *et al.*, 2016).

In conclusion, in the north, females with surviving calf selected broad-leaved forest and other high-quality habitats to a larger extent than the females with non-surviving calf, which proves some evidence for habitat-performance relationship during the calving season. In the south however, the females, even though they selected high-quality habitats and avoided poor habitat, their calves did not survive. Since Allen *et al.* (2016) found that the female moose on Öland used suboptimal habitat during winter, the females were probably in bad condition after the winter. The fact that the diagnosis for almost all calves that died during their first week of life, was starvation and that it was found that they had not lactated, indicates that the time before parturition might not be enough for the females to get in the condition demanded to lactate and raise a calf, even though they use an optimal habitat selection strategy. Based on my results, I therefore suggest further research on female moose cows in agricultural landscapes and their ability to recover from poor winter condition.

Öland is located in the southern range of the moose distribution in Scandinavia. Moose in the southern periphery have been declining in other places (e.g. Norteastern Minnesota, Lenarz *et al.*, 2010; Northweastern Minnesota, Murray *et al.*, 2006). The cause is not fully understood, but is thought to be due to a combination of factors. Pathogens and diseases, nutritional deficiency, climate change and increasing temperatures are some mentioned. Probably this is also true for the moose on Öland. Allen *et al.* (2016) found that the spring temperature on Öland have increased and also that the growing season starts two weeks earlier comparing the five-years average between the year 2011 and 2015 and 1996 and 2000. The parturition during the year with available moose data (2012-2015) also occurred three weeks later than the start of the green build-up. The spring is often a critical time because body stores may be depleted after winter (Parker *et al.*, 2009). At the same time, lactation approaches, the period when females have their highest demand of energy (Oftedal, 1985). An earlier start of the growing season and a faster rate of green build-up enhanced by warmer temperatures can shorten the period during which high-quality forage is available, which can lead to females unable to build up their reserves needed for gestation and lactation (Monteith *et al.*, 2015; Pettorelli *et al.*, 2007), consequently resulting in a high juvenile mortality. High temperature can also cause heat stress (Renecker & Hudson, 1986). On Öland, the summer temperatures were below 20 ^{o}C (Allen *et al.*, 2016), the threshold for which moose is assume to change habitat to avoid the heat (van Beest & Milner, 2013). But the average daily temperature during the coldest month, January was 6^{o}C warmer than the winter threshold (Allen *et al.*, 2016; Renecker & Hudson, 1986). Heat stress could affect the metabolism, heart and respiration rate and the body mass of moose (van Beest & Milner, 2013; Renecker & Hudson, 1986) and hence could reduce the body condition (Parker *et al.*, 2009). However, there are also studies that questioning the threshold temperature (van Beest & Milner, 2013; Lowe *et al.*, 2010). Heat stress symptom should however not be neglected for the moose on Öland and should be further investigated, which also Allen *et al.* (2016) concludes. Alteration of temperatures is also listed as a factor that can result in disease and parasites into new regions, with a decrease of animal productivity and an increase of animal mortality as a result (Feenstra *et al.*, 1998). Malmsten (2014) found that moose on Öland had more traces of tick-borne *Anaplasma phagocytophilium* compared to moose on the mainland. He also states that infection of tick-borne *A. phagocytophilium* could affect moose health and contribute to calf mortality for calves in poor condition.

Another factor that also should be explored on Öland is whether density-dependent factors from other species, as an increasing number of livestock and the high density of roe deer could act on the moose population. Moose and roe deer normally occupy separate niches with moose consuming mostly browse as coniferous and broad-leaved, while roe deer prefer forage in the field layer, as dwarf-shrubs and forbs (Cederlund *et al.*, 1980). However, Cederlund and Nyström (1981) write that severe winters with deep snow and high population densities could create conditions were competition among the two species can occur. Deep snow on Öland is seldom a problem, however the case of high densities should not be rejected. Even small populations could cause density-dependent competition if the resources is scarce with decreasing body condition, fecundity and survival as a result (Gaillard *et al.*, 1998; Sæther, 1997). The amount of available browse might already be low on Öland, especially during winter when the agricultural crops are not green and a further reduction by other species or among other moose individuals may have huge impact on the total available amount forage. Updated demographic information about the moose population size and the sex- and age ratio is also needed. What is known is that moose hunters on Öland refrained from moose hunting during the year 2001-2005 because of observed low moose density. Overharvest of adult moose and in particular males was believed to be the cause to this decrease. The hunting stop resulted in higher moose densities and a balanced sex- and age ratio (however the calf:cow ratio did not increase). Exactly how the moose population on Öland looks like today is however not known. During the years of study no GPS-marked moose have been seen swim over to the mainland, even though the distance is not far (Ericsson *et al.*, 2016; Ericsson *et al.*, 2015; Ericsson *et al.*, 2014; Ericsson *et al.*, 2013). Which also raise concern for the risk of inbreeding depression and the possible negative consequences that comes with that, as lower birth weight, survival, reproduction and resistance to disease, predation and environmental stress (Keller & Waller, 2002). Small, isolated population and skew sex- and age ratios is considered as risk-factors for inbreeding depression also among moose individuals (Herfindal *et al.*, 2014; Haanes *et al.*, 2013). Because of the earlier problem on Öland with low population size and unbalanced age- and sex distribution this should be further explored. In the light of above reasoning, the high calf mortality on Öland is not just a matter of suboptimal habitat use, but rather a combination of factors.

Declining moose populations in human altered landscape have been seen also in the south of Norway, with declining body condition and recruitment rate of moose (Bjørneraas *et al.*, 2011). Change in forestry practice that has reduced the amount of young and food-rich forest stand has been stated as a possible contributing factor to the decline. Transformation of forest to agricultural land is also believed to have reduced moose population in the past (Rosvold *et al.*, 2013). Öland has long time been an agricultural island. My result indicates that there has been an intensification of agricultural land use during the last decades. At the same time the total area forest has decreased. The suboptimal use during winter and the habitat-performance relationship for the moose on Öland, revealed by Allen *et al.* (2016) indicate that there is not enough habitat for moose on Öland during winter. Also the fact that the females were not in bad condition during autumn, implies that they during summer have the resources needed to build up their energy restore. Summer is the time when the agricultural crops are green. On

Öland, agricultural crops seem to be an important part of the moose diet during summer (Dorey, 2014). The problem on Öland seems more to be the winter condition when no agricultural produce (beside of winter rape) is green and possible also the spring condition, because it seems like the female moose is not able to recover enough to succeed to give birth and raise a calf. Management action could be to increase the amount of forage for the moose during winter through supplementary forage. Milner *et al.* (2013) found that in areas were the forage was scarce, females that had access to supplementary forage lost less in weight during winter than females that did not had access to supplementary forage and concludes that it also would have carryover effects on the summer calf survival. An alternative could also be to decrease the density of moose and/or other species, as roe deer, that could compete for the same forage. Another way to increase the amount and quality of available forage could be to improve the moose habitat. My main conclusion after this study is that recent land use change could have decreased the amount of available moose habitat especially when agricultural crops are not green and that it could be a contributing cause to the high calf mortality seen on the island.

Acknowledgement

I want to give the biggest thanks to Wiebke Neumann for supporting and guiding me from the beginning to the end. Your understanding and belief in me has meant a lot for the completion of this work. I also want to thank Göran Ericsson for giving me the opportunity to take on this topic. I also warmly thank Andrew Allen for all quick answers, comments and valuable advice during the work. Another big thank to Hilda Edlund that have saved me with the statistics. Thanks also to Elin Fries, who have read my work and given me comments and Nils Bodin and Marcus Larsson for your encouragement. Also, you classmates who have been in school during the final stage have meant a lot, no one mentioned, no one forgotten. I also want to thank the people outside the school who have supported me and been there for me. Without all of you, this work would not have been possible!

Appendices

Appendix 1 – Picture on study area

Appendix 2 – Illustration of MSPA analysis

Appendix 3 – Result from Arc Map of the MSPA analysis for Borgholm

Appendix 4 – Result from Arc Map of the MSPA analysis for Mörbylånga

Appendix 5 – Graphs and statistics for Mann-Kendall trend test on pasture land for Borgholm

Appendix 6 -Graphs and statistics for Mann-Kendall trend test on pasture land for Mörbylånga

Appendix 7 – Graphs and statistics for Mann-Kendall trend test on arable land for Borgholm

Appendix 8 - Graphs and statistics for Mann-Kendall trend test on arable land for Mörbylånga

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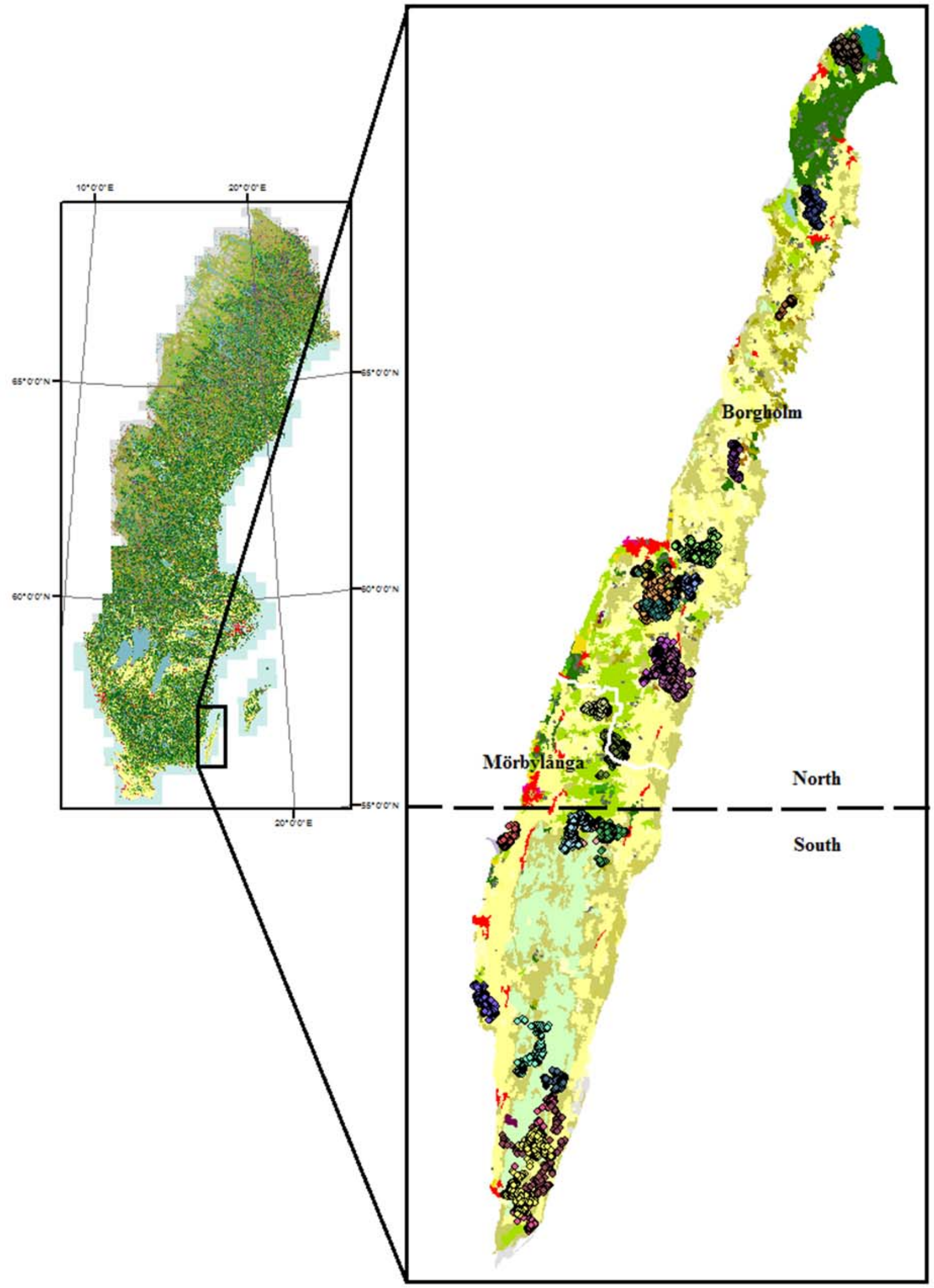
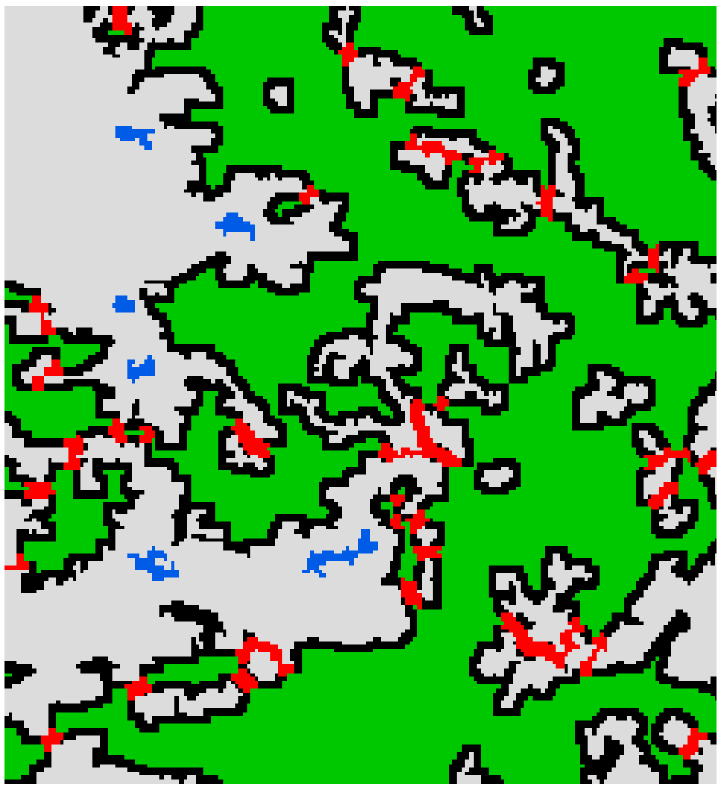
Appendix 1 – The location of the study area, Öland. The black-dashed line are visualizing the border for the north and the south, that were used for the moose habitat selection analysis and the white line show the municipal border for Borgholm and Mörbylånga that were used for the land use analysis. The configuration of different land classes on the island is depicted with the same colors as the Corine Land Cover product from 2012 and the dots in different colors represent the different moose GPS-positions during the calving for the study period.

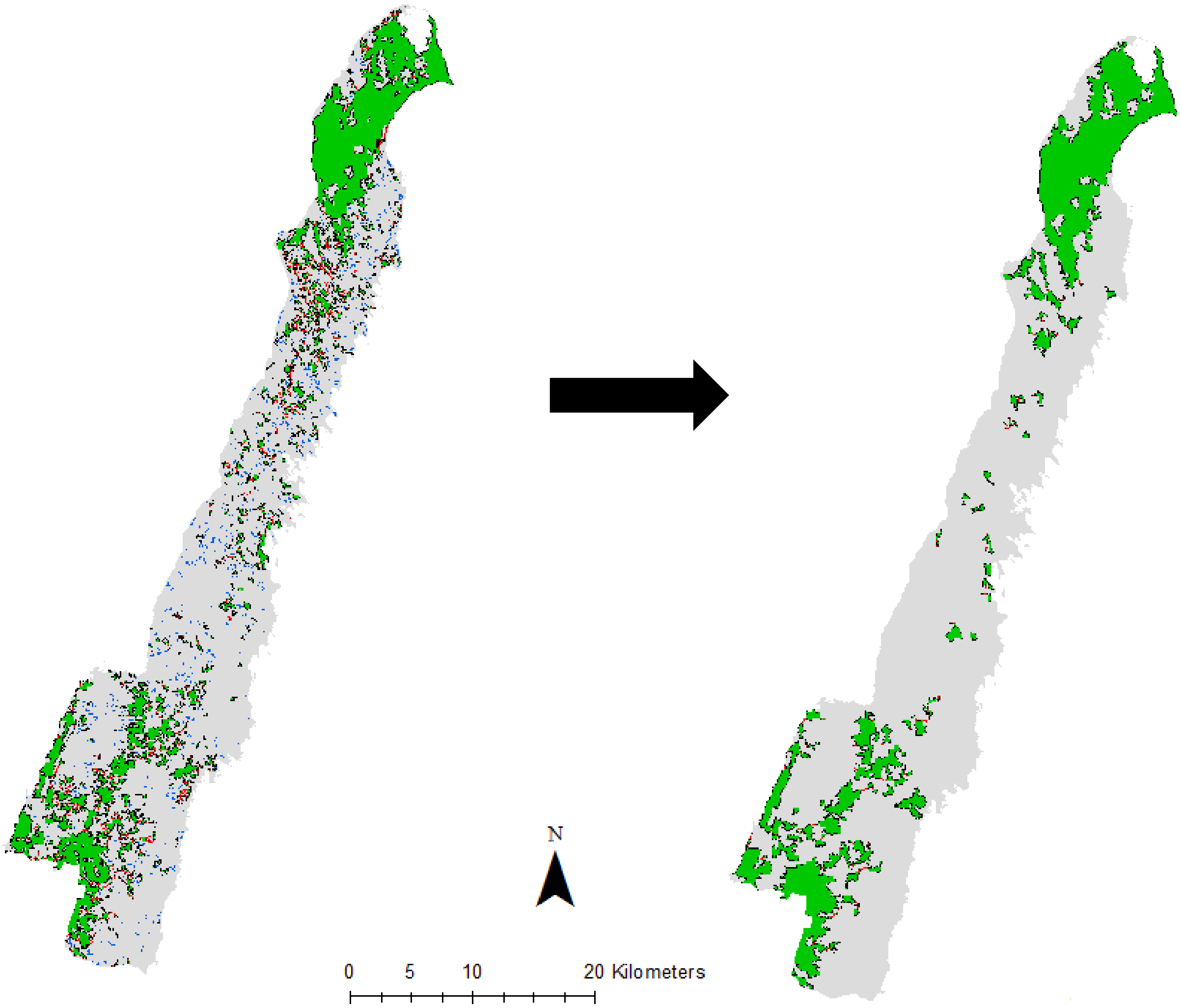


Appendix 2 – The different MSPA (Morphological Spatial Pattern Analysis) classes: core (green), edge (black), corridor (red) and islet (blue) showing the spatial structure of forest pixels in relation to the non-forest pixels (grey).

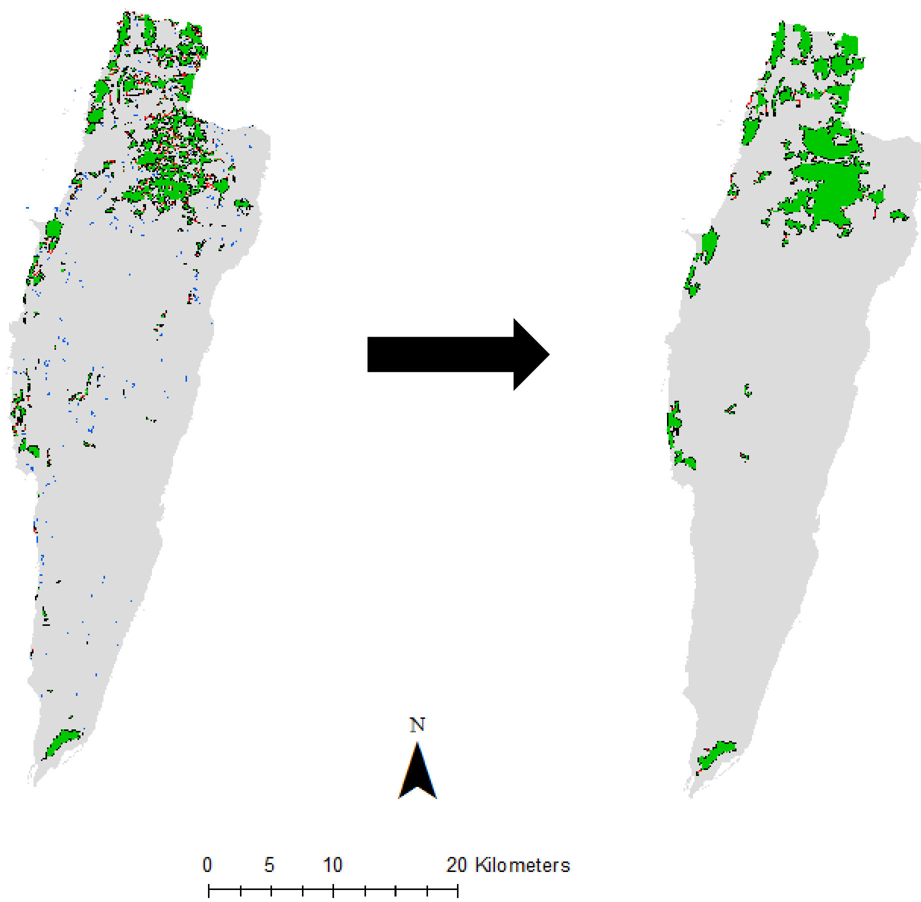


Non-forest
Core forest
Edge
Corridor
Islet

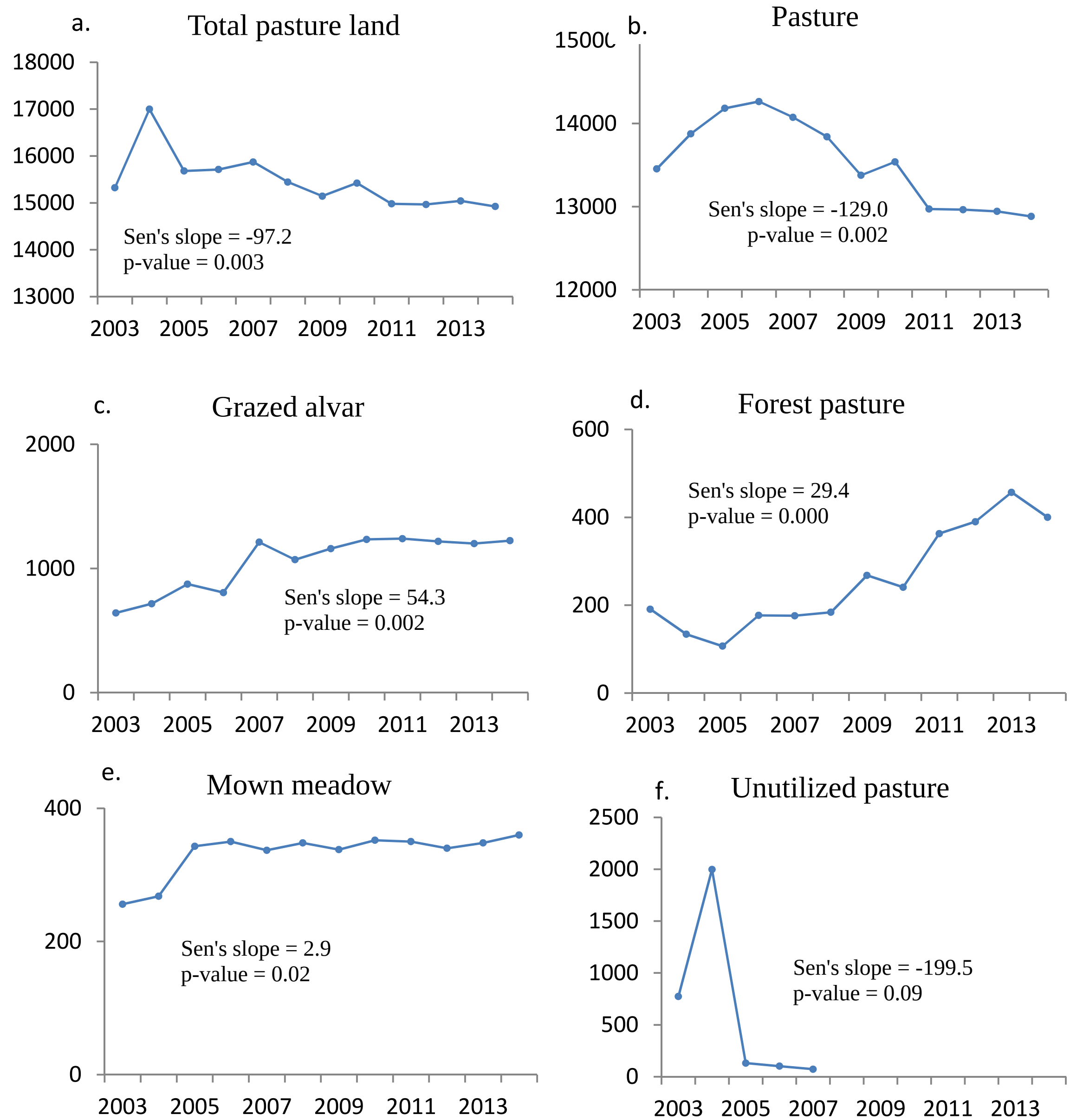
Appendix 3 – The result from the MPSA (Morphological Spatial Pattern Analysis) analysis in Borgholm 2000 to the left and 2012 to the right.


N
0 5 10 20 Kilometers

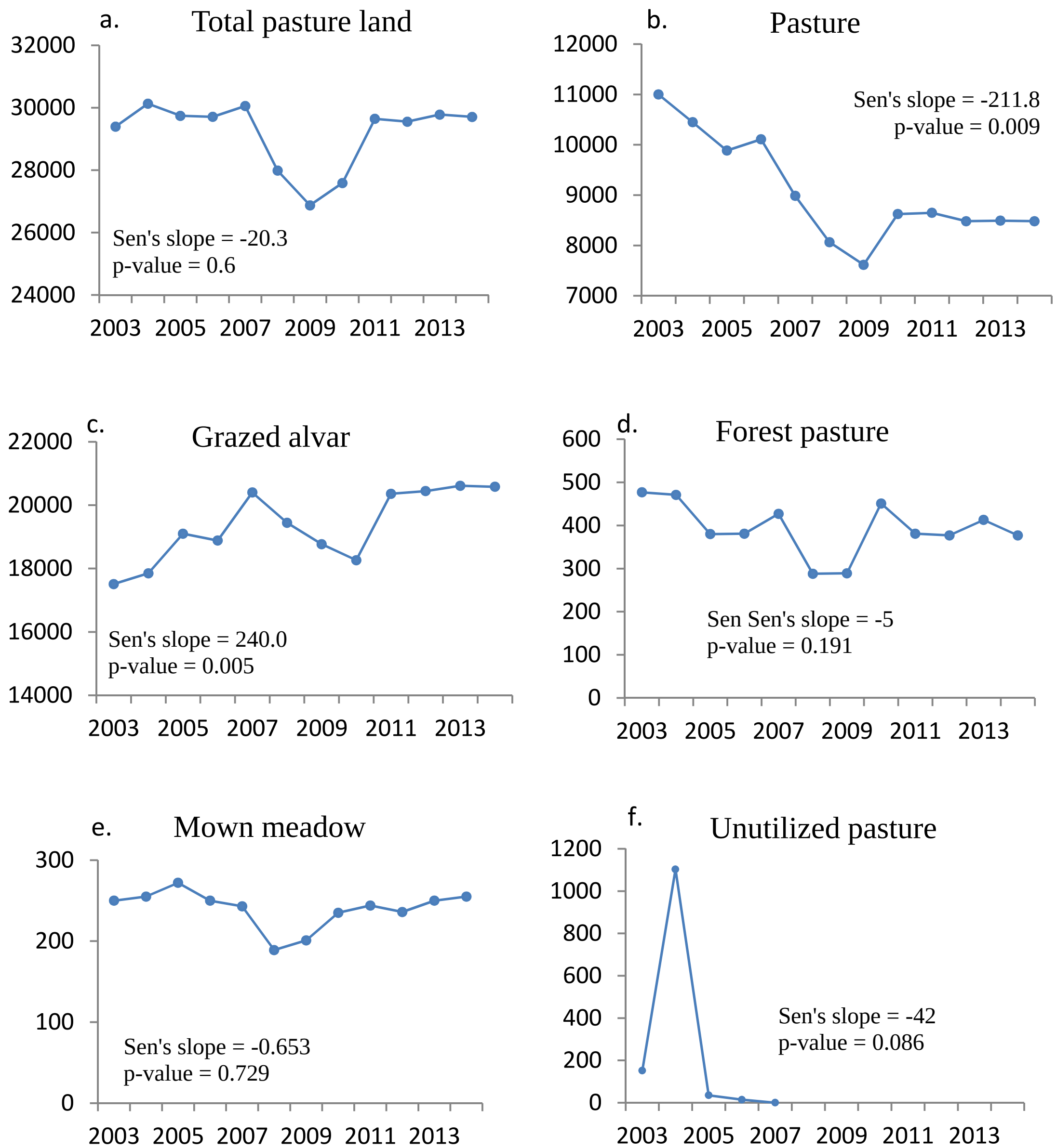
Appendix 4 – The result from the MPSA (Morphological Spatial Pattern Analysis) analysis in Mörbylånga 2000 to the left and 2012 to the right.



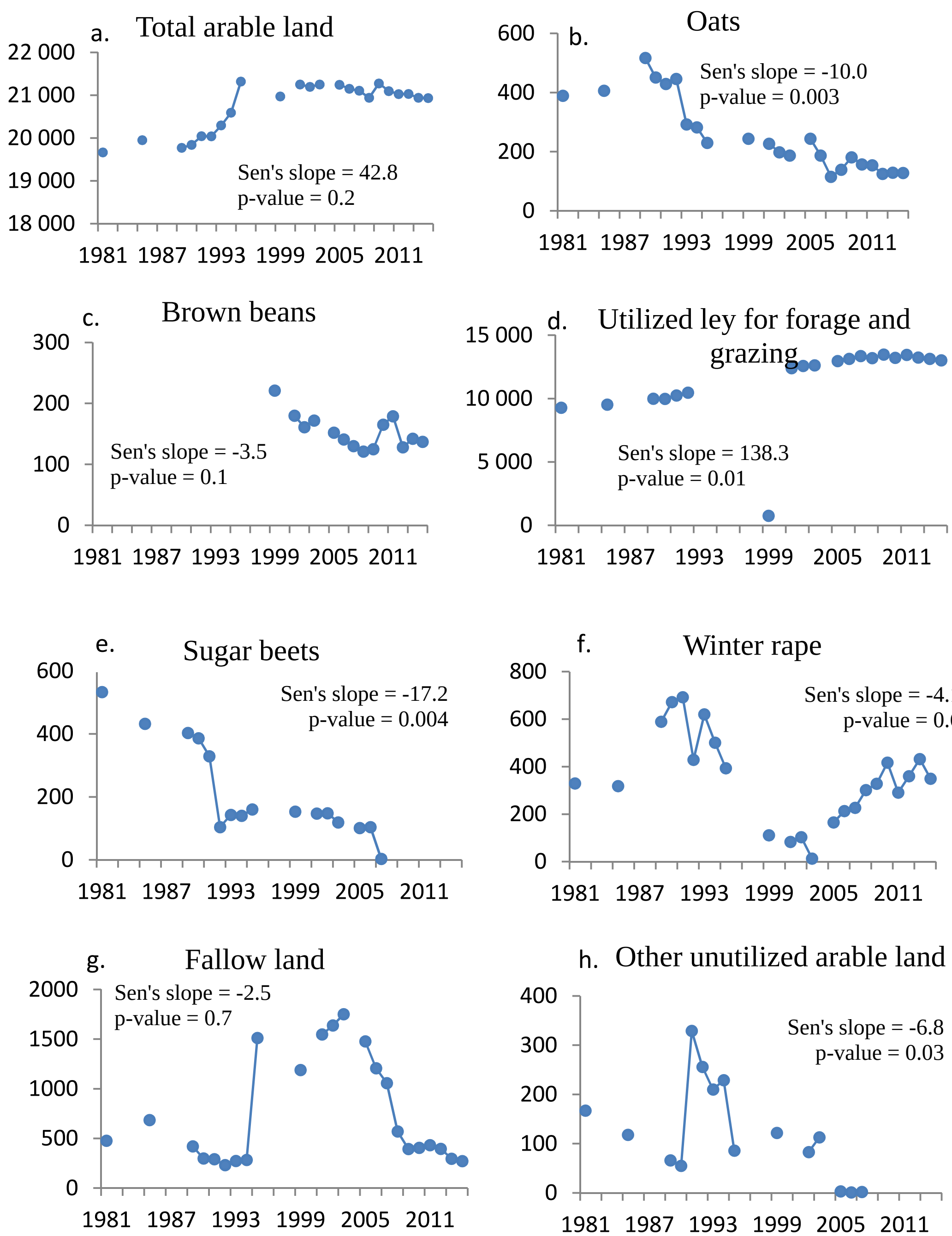
Appendix 5 – The Mann-Kendall trend test for the pasture land in Borgholm. The y-axis represents the area in square meter and the x-axis the year between 2003 and 2014. The value of Sen's slope and the p-value for the Mann-Kendall trend test is displayed in each graph (a-f). From the top-left; total pasture land (a) and distributed per type (b-f), i.e. pasture (b), grazed alvar (c), forest pasture (d), mown meadow (e) and unutilized pasture (f).



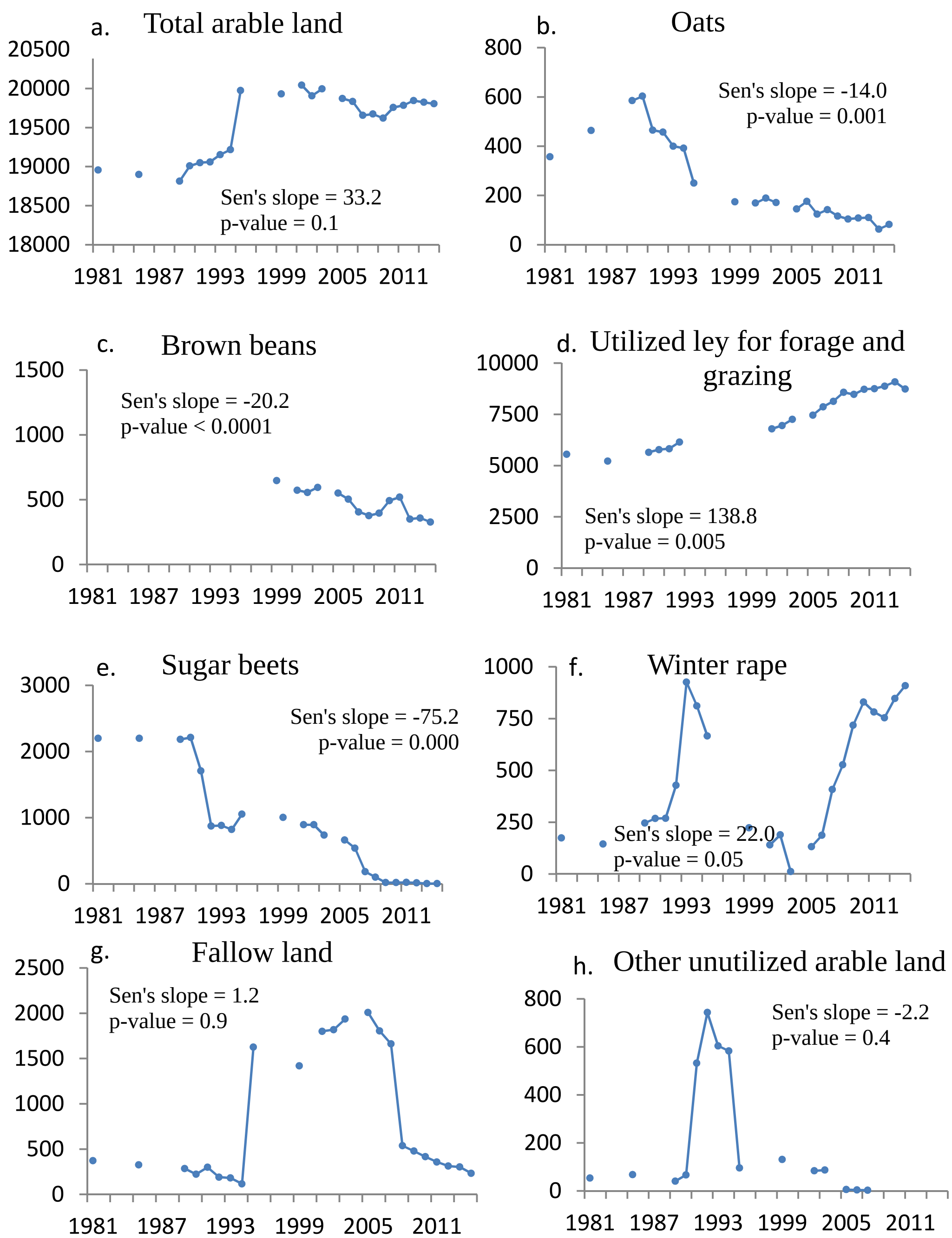
Appendix 6 – The Mann-Kendall trend test for the pasture land in Mörbylånga. The y-axis represents the area in square meter and the x-axis the year between 2003 and 2014. The value of Sen's slope and the p-value for the Mann-Kendall trend test is displayed in each graph (a-f). From the top-left; total pasture land (a) and distributed per type (b-f), i.e. pasture (b), grazed alvar (c), forest pasture (d), mown meadow (e) and unutilized pasture (f).



**Appendix 7 – ** The Mann-Kendall trend test for the arable land in Borgholm. The y-axis represents the area in square meter and the x-axis the year between 1981 and 2014. The value of Sen's slope and the p-value for the Mann-Kendall trend test is displayed in each graph (a-h). From the top-left; total arable land (a) and for different crops (b-h), i.e. oats (b), brown beans (c), utilized ley for forage and grazing (d), sugar beets (e) winter rape (f), fallow land (g), other unutilized arable land (h). Two subsequent years with available data is interpolated with a line.



Appendix 8 – The Mann-Kendall trend test for the arable land in Mörbylånga. The y-axis represents the area in square meter and the x-axis the year between 1981 and 2014. The value of Sen's slope and the p-value for the Mann-Kendall trend test is displayed in each graph (a-h). From the top-left; total arable land (a) and for different crops (b-h), i.e. oats (b), brown beans (c), utilized ley for forage and grazing (d), sugar beets (e) winter rape (f), fallow land (g), other unutilized arable land (h). Two subsequent years with available data is interpolated with a line.



SENASTE UTGIVNA NUMMER

2016:10 Effectiveness of a fish-guiding device for downstream migrating smolts of Atlantic salmon *(Salmo salar L.)* in the River Piteälven, northern Sweden
Författare: Linda Vikström

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Författare: Nils Bodin

2016:12 Extended phenotypes in the canopies of Norway spruce
Författare: Christofer Johansson

2016:13 Comparison of three different indirect methods to evaluate ungulate population densities
Författare: Sabine Pfeffer

2016:14 Estimation of maximum densities of young of the year brown trout, *Salmo trutta*, with the use of environmental factors
Författare: Johanna Wärnsberg

2016:15 Analysis of the successfulness of wolverine (*Gulo gulo*) depredation control in Västerbotten County
Författare: Fredrika Vretling

2016:16 Increased public participation as a potential human – large carnivore conflict mitigation measure
Författare: Ruben Bloemsma

2016:17 Influence of temperature and predation risk on herbivore micro habitat choice in a South African savanna
Författare: Hanna Rogers

2016:18 Elephant utilisation of and impact on a locally threatened habitat, coastal scarp forest, in South Africa
Författare: Matilda Apelqvist

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Författare: Eirini-Lamprini Daouti

2017:2 Reforestation in the far north – Comparing effects of the native tree species *Betula pubescens* and the non-native *Pinus contorta* in Iceland
Författare: Elin Fries

2017:3 Grazing increases albedo of savanna grasslands
Författare: Linda Vedin

2017:4 Timing of ungulate browsing and its effect on sapling height and the field layer vegetation – experimental study using seasonel exclosures during one year
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