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Successional dynamics in boreal forests: What is the impact of moose browsing, and which pathways are preferred by landowners?

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To my family and friends.

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Abstract

Norwegian boreal forests are usually managed for timber production, but also provide other ecosystem services, including game meat, income from hunting licenses, and recreational opportunities. Forest landowners' values and objectives can influence management decisions, and hence the future of Norwegian forests and their potential for multi-use. High moose (*Alces alces*) densities have the potential to impact plant communities, and their influence can be profound. Therefore, ecosystem services can be affected, which presents challenges to forest management. The objectives of this study are to examine the effect of moose exclusion ($n = 16$) on the regeneration of boreal trees after clear-cutting, as well as landowners' perspectives ($n = 12$ interviews) on forest ecosystem management in southeastern Norway. Moose exclusion markedly increased the growth of deciduous trees (*Betula* spp. and *Sorbus aucuparia*). Of the economically important conifer species, Scots pine (*Pinus sylvestris*) was positively affected and Norway spruce (*Picea abies*) was not affected by the enclosures. A broad range of ecosystem services were recognized by landowners, who held a diverse set of forest values. However, landowners' overall management objective was timber production, which corresponds with their visions of future forest use, associating forestry with climate mitigation and energy transition. As moose is a source of disturbance and a valuable resource, it is essential to find a density that is socio-economically viable that fits within ecological bounds. Landowners' perspectives can be important knowledge for developing sustainable forest management systems and policies balancing moose, timber, biodiversity, and other services important for human well-being.

Keywords: *Alces alces*; boreal forest; herbivory; succession; Norway; landowners' perspectives; values; ecosystem services; forest ecosystem management; pathways.

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Introduction

1.1 Background Information and Relevant Theory

The circumpolar boreal zone is the northernmost of the world's major terrestrial biomes located within North America, Russia, and Fennoscandia, and its forests comprise of about one-third of the total forest cover or roughly 1.9 billion ha of land [1, 2, 3]. In general, forests are natural environments that provide habitat for a plethora of flora and fauna, harbor unique biodiversity, protect endangered species, and play an essential role in ecosystem processing and functioning [3, 4]. Boreal forests assist in regulating and mitigating global climate change [3]. However, these forests have been heavily valued and utilized for timber production, contributing as the leading source of the region's economic activity and development [3, 4, 5]. Forests have also been essential for social and cultural activities, providing places for recreation, living, and leisure, and offer a range of other goods and services important for furthering human well-being [4]. Thus, forests' multifunctional role has been recognized, and the development of boreal forests in years to come is of great importance for both global biodiversity and the provision of ecosystem services (defined as "the benefits people obtain from ecosystems") [3, 4, 6].

Succession refers to the process of change in composition, structure, and function of an ecological community over time, and is often initiated by a perturbation or disturbance that opens up large spaces [7, 8]. Disturbance can be thought as "any relative discrete event in the time that removes organisms and opens up space which can be colonized by individuals of the same or different species" [9]. Within the boreal zone, forest fires are the primary natural disturbance, while less significant types include wind throw, snow, gap phase dynamics, insect outbreaks, and browsing by herbivores [8, 10]. However, forestry (e.g. logging) is classified as an anthropogenic disturbance, and is the main disturbance in Fennoscandian forests today [8]. Few species take advantage of disturbances within forest gaps, possessing the ability to grow quickly where light is abundant [11]. These species are deciduous species, often referred to the "early successional species," characterized by rapid growth and a low tolerance to shade [7]. Therefore, disturbance increases the abun-

dance of deciduous habitat [10]. Early successional species will eventually be overgrown and out-competed by coniferous species, or “late successional species,” due to the lack of the ability to recruit in the shade of their own canopy [7]. The length of time required for a forest stand to exit deciduous-dominated early successional stages or a mixed state is variable [10]. Late successional species can tolerate shade and are slow growing as a result of their stress tolerant traits allowing them to grow even if conditions are not optimal [11]. These coniferous species will ultimately dominate the canopy cover unless a new disturbance occurs which would reset the landscape back to early successional stages [10]. In Fennoscandian forests, Norway spruce (*Picea abies*; referred to herein as spruce) is the most dominant species at more productive sites, while Scots pine (*Pinus sylvestris*; referred to herein as pine) and deciduous species such as downy birch (*Betula pubescens*) and rowan (*Sorbus aucuparia*) also occur throughout [12].

Due to an increase in clear-cut forestry practices, a reduction in land-use by husbandry for livestock, the lack of predators, and the introduction of sex- and age-specific harvesting, moose (*Alces alces*) populations have witnessed a strong increase in density across Fennoscandia [13, 14, 15]. In addition to forestry, large herbivores can be considered disturbance factors affecting ecosystem processes due to their direct effects including trampling, defecation, urination, and feeding strategies [9]. Moose are selective browsers, and their preferences for different species depends on the time of the year [16]. However, deciduous habitats are more often linked to moose with twigs and bark constituting their main source of food during the winter months [10, 16]. Moose have a strong preference toward deciduous foliage and is generally preferred over conifers, with pine and spruce being intermediately and least preferred, respectively, due to their nutrient content and chemical compounds [9, 10, 16, 17]. Moreover, the highly preferred species, such as rowan, willow (*Salix* spp.), and aspen (*Populus tremula*) are often the least abundant [16]. Therefore, selective feeding by moose, especially in heavily browsed areas, has the potential to vastly alter the competition between plant species, modify the structure and composition of the plant community, and affect the forest successional rate, which can result in long-term changes to forest ecosystems [9, 18].

In addition to being a source of disturbance, moose is also a valuable resource in itself as it is an important game species in Fennoscandia [15, 19]. Forest landowners could view moose as a problem due to damages to forestry, particularly those of young pine forest stands, caused by winter browsing. Its migration between summer and winter areas could affect landowners differently, some experiencing browsing damages while others benefit from hunting grounds. The right to hunt moose and harvest on their own properties is held by the landowner [19]. However, the hunting rights can be leased (in whole or in part) if the landowner does not wish to exercise their hunting rights [15]. For these reasons, conflict of interests have been generated between forestry and hunting between non-hunting landowners, hunting landowners, and hunters leading to contrasting goals of moose management [15, 19]. In addition to contrasting goals of moose management, conflicting interests regarding forest management also exist, which makes management of boreal forests a challenge [4, 12].

In northern Europe, forest management is mainly a voluntary action with most of the forests being privately-owned. Due to this ownership structure and management history within the region, forest land-use is often characterized by intensive management of relatively small stands [3, 20]. Forest landowners can decide which management activities they pursue in their forest (often aside from the requirement to reforest after final felling) [20]. If management focuses too heavily on the production aspect, other important benefits deriving from forest ecosystems may be degraded or even lost [3]. Different forest strategies and management objectives may influence ecosystem services and produce rather diverse outcomes for land-use [4]. Thus, forests have a role in providing both private and public goods and services contributing to the utility of the owner and society as a whole [4, 21, 22]. As a result, there has been a history of competing uses of forest lands, which can lead to disputes regarding different users' conflicting, and potentially incompatible, interests in land-use management [4].

The most important factors affecting management decisions are forest landowners' objectives and different dimensions of perspectives (i.e. points of view containing their values, beliefs, and attitudes, which are often referred to as "dimensions of human cognition") concerning their forest properties [20]. Further, understanding forest landowners' perspectives can allow forest managers and policy-makers to understand management decisions and behaviors, maximize the acceptability of management actions and policy initiatives, and clarify reasons for potential conflicts that may or may not be visible [20, 23, 24]. Forest landowners' perceptions of the future, challenges, and opportunities of forest use will also effect their actions and influence future forest use [25, 26]. The study of human cognition is a rather neglected area of research, and more emphasis should be given to cognitive dimensions or "the many ways in which people think about their environments, and the ways their thinking is influenced by those environments." Values are the most stable form of human cognition and underpin people's decisions and behaviors and can be useful in understanding differing points of view on how natural resources should be used, experienced, and, ultimately, managed [23, 27].

Values can be defined as "a belief pertaining to desirable end states or modes of conduct that transcends specific situations, guides selection or evaluation of behavior, people, and events, and is ordered by importance relative to other values to form a system of value priorities" [27]. Values do interact with other forms of cognition and act as the foundation for beliefs (i.e. thoughts and opinions concerning an object) and attitudes (i.e. positive or negative evaluation of an object), which can influence intention and/or behavior [5, 27]. This concept can be illustrated as an inverted triangle consisting of values, clusters of basic beliefs, attitudes and norms, behavior intentions, and behaviors. Values are located at the bottom of the pyramid and are few in number and slow to change, while behaviors are at the top and both numerous and change quickly (Figure 1.1) [27]. While there are theoretical differences between values, beliefs, and attitudes, in practice, they do measure closely related concepts and may be used in similar ways. The study of cognition shows that there can be differences in values between groups of people and multiple pathways can exist between these values, beliefs, attitudes, and behaviors toward ecosystems [23].

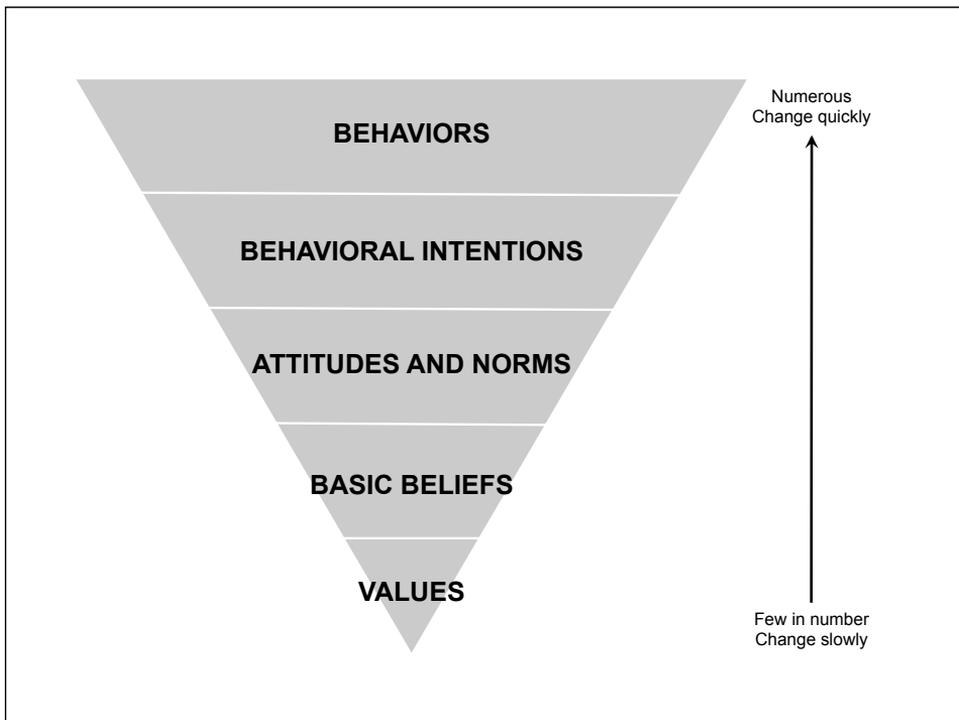


Figure 1.1: Cognitive hierarchy model of human behavior. Concepts toward the bottom are fewer in number and change slowly than those toward the top. Adapted from Ives and Kendal [23] and Jones et al. [27].

The coupling of ecological and social aspects is referred to as a social-ecological system where both human and ecological systems are inseparably linked across multiple scales where people rely upon resources provided by ecosystems and those ecosystems are influenced by people's behaviors and decisions [27]. This study examines two contrasting, but interlinked components, of the social-ecological system that exists within boreal forests in southeastern Norway. Forest landowners' perspectives (including their underpinning values, beliefs, and attitudes) influence their management behaviors and decisions [20]. In managing their forest properties for timber production, browsing by moose has the ability to influence the structure and composition of the forest [9, 18]. Further (although not within the scope of this study), the total supply of ecosystem services and disservices that are delivered back to the forest landowners (and the rest of society) are linked to the forest structure, function, and biodiversity, which are all modified from the forest management practices in place [3, 28]. Evidently, the extent of the multiple goods and services provided by the system is affected immensely by forest management [3]. This can further influence forest landowners' perspectives who may make adjustments in their behaviors and decisions toward forest management, thus repeating the cycle (illustrated in Figure 1.2) [27].

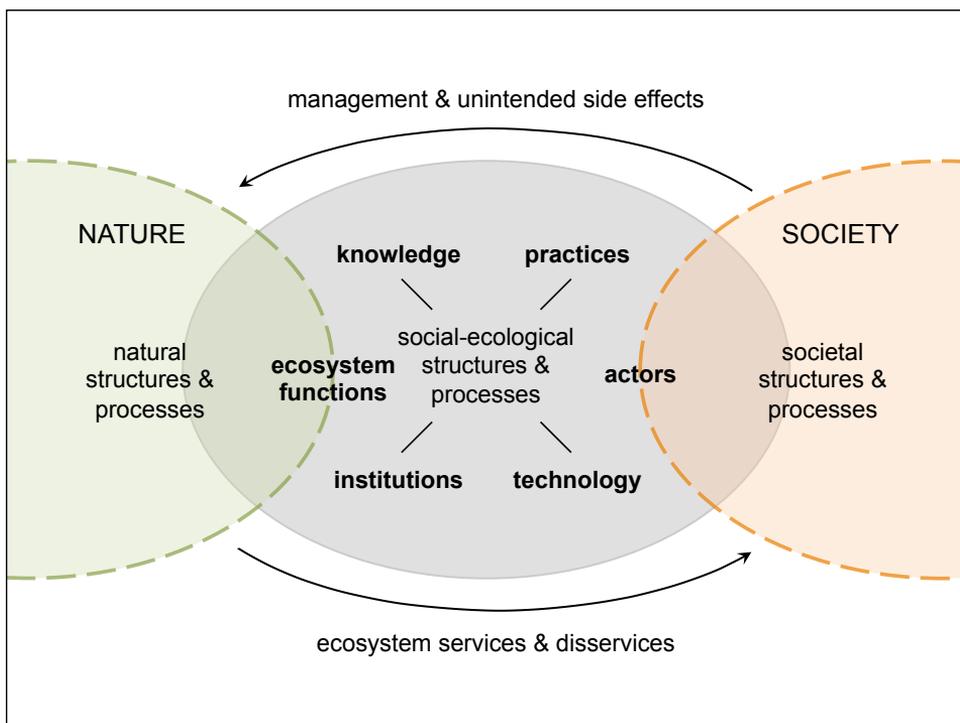


Figure 1.2: A simplified depiction of the basic concept of a social-ecological system. Adapted from Potschin et al. [28].

1.2 Objectives of this Study

The main purpose of this study is to understand two specific (and contrasting) aspects of a social-ecological system that exists within boreal forests in southeastern Norway. Thus, the objectives of this study are twofold: (1) To examine the effect of moose exclusion with the use of an enclosure experimental design on the regeneration of boreal trees after clear-cutting (comprising of the ecological component of the system), and (2) To examine landowners' perspectives of forest ecosystem management, as well as identifying their forest values and perceptions toward future forest use (comprising of the social component of the system). The objectives and aims of the study are presented below with the following study hypotheses (Objective 1) and questions (Objective 2).

1.2.1 Moose Exclusion

Our first objective is to examine the effect of moose exclusion on the regeneration of boreal trees (specifically, the four most abundant species: birch, rowan, pine, and spruce) after clear-cutting within an experimental design in southeastern Norway located in Akershus and Hedmark counties. We aim to understand how height growth and density are affected by moose exclusion. An earlier study conducted in mid and southern Norway by

Speed et al. [12] found that the deciduous species, birch and rowan, were more likely to be browsed than the coniferous species, pine and spruce. Lack of browsing allowed birch to experience a small increase in height growth, while browsing suppressed the growth of rowan larger than ~ 0.5 m. Pine was the most susceptible to browsing with height growth prevented when 30% of shoots were browsed, while spruce was able to maintain height growth when over 60% of shoots were browsed. The researchers had also observed that height growth of pine and spruce did not differ significantly between open and exclosed plots [12]. However, pine will most likely experience browsing due to high densities of moose [29]. Therefore, we expect the height growth of the preferred early successional species to be constrained by browsing, and trees inside the exclosed plots will grow taller than those in the open plots. Since pine is intermediately preferred by moose and susceptible to browsing [12, 16], we expect to see some effect of treatment (i.e. exclosed plot) on the height growth. The likelihood of browsing on spruce by moose is relatively low, and, if browsed, height growth can be maintained. Considering this, exclusion of moose will cause (H1) an increased height growth of birch and rowan resulting in a greater density of trees recruiting to higher height classes, (H2) an increased height growth and density of pine, and (H3) no change in height growth or density of spruce.

1.2.2 Landowners' Perspectives

Our second objective is to examine landowners' perspectives within the same experimental design on forest ecosystem management (e.g. manage for forest/timber or moose production). As forest values and perceptions toward future forest use have implications on forest management decisions and the achievement of prospective policies and initiatives [20, 27, 30], we were also interested in identifying their underpinning forest values and perceptions toward future forest use. This section was completed using qualitative research methods, which are generally exploratory and the researcher has only preconceived ideas about the topics discussed [31]. Slightly similar studies have been conducted in other countries; however, the environment (e.g institutional, economic, social, and cultural environment) of a country determines relevant stakeholders' values and objectives (and beliefs, attitudes, and behaviors), which can make it difficult to develop expectations from these differing countries [32]. Literature pertaining to Norwegian landowners' perspectives toward the aspects of forest ecosystem management that we are applying has been little studied, also making it difficult to develop expectations to the study questions of interest, further adding to the study's overall importance. The following examples illustrate the type of questions raised: (1) What are the landowners' overall primary management objectives? (2) What ecosystem services are recognized by the landowners? (3) What forest values do the landowners hold? (4) What are their perceptions toward future forest use?

Methods

Since this study explores both sides of the social-ecological system of boreal forests in southeastern Norway, two sets of data collection and analyses were performed: (1) Quantitative analyses of tree species community data collected from a moose exclusion experimental design, and (2) Qualitative analyses of landowners' perspectives toward forest ecosystem management, as well as identifying their forest values and perceptions toward future forest use, by conducting interviews.

2.1 Moose Exclusion

2.1.1 Experimental Design

One study region, located in Akershus and Hedmark counties in southeastern Norway, was used to investigate the influence of moose exclusion on the regeneration of recent clear-cut boreal forest (Figure 2.1). The study area consists of sixteen sites comprising of two 20 x 20 m plots, which were chosen in a homogeneous area and randomly allocated to either excluded or open treatments. The sites were selected to cover both productive spruce and less productive pine forests, and they range in elevation from 171 to 347 m above sea level with roughly the same productivity (which refers to the H40 system; the height growth of the ten trees with the largest diameter at 1.3 m after 40 years; Table 2.1) [33]. To minimize edge effects, the excluded and open plots were placed a minimum of 20 m from each other. Enclosures were constructed using 208 cm tall woven-wire fences that are supported by 3 m stakes. Additional wire was added between stakes resulting in fences about 2.5 m in total height.

Additionally, the year of clear-cutting activity and construction of the enclosures varies among the sites. Three sites were clear-cut during 2004/2005, and the enclosures for those sites were put up in 2007. Clear-cutting occurred at six sites in 2007/2008, while the enclosures were erected in 2010. The remaining sites (seven in total) were clear-cut during 2008/2009, and received their enclosures in 2011. Most sites were planted following log-

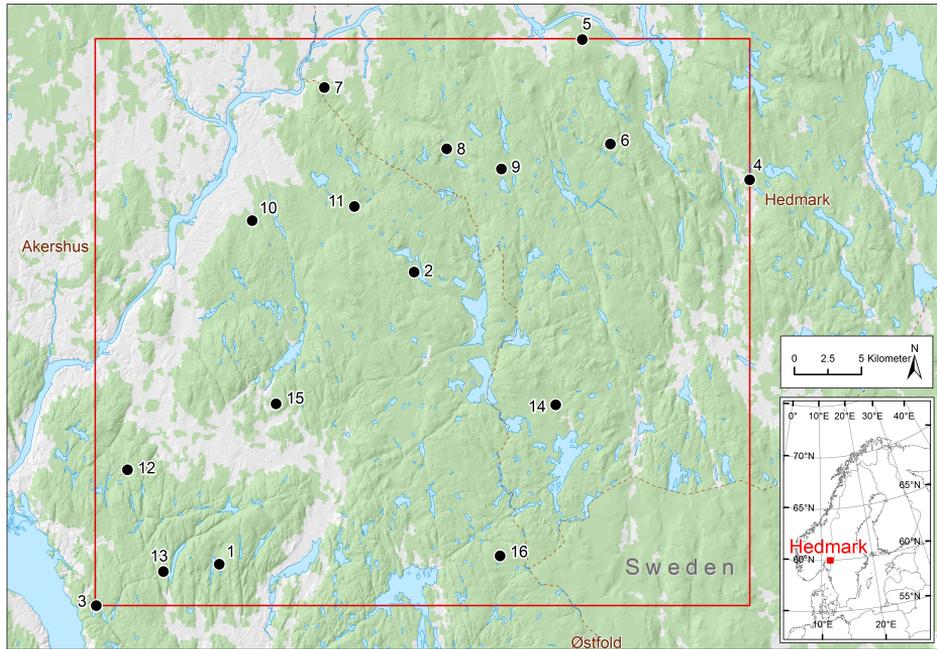


Figure 2.1: Map of field site locations in Akershus and Hedmark counties, southeastern Norway. The numbers refer to site numbers in Table 2.1.

ging, and, those that were not, rely on natural regeneration of pine (Table 2.1). The sites have not been artificially fertilized at any point. In addition, soil preparation, scarification, thinning of non-commercial deciduous trees, or other silviculture activities have not been performed at any of the sites after clear-cutting.

Within each of the enclosed and open plots, four circular subplots with a radius of 2 m were established and marked (Figure 2.2). Within these, each tree species was counted and height was measured and registered within height classes with intervals of 0.5 m (e.g. height class 1 measures < 0.5 m, height class 2 measures between 0.5 and 1 m, continuing up to height class 7 which measures > 3 m). Field work was conducted during early and late spring after the snow had melted, but before the buds had burst, allowing us to examine winter browsing without interference from browsing that may have occurred during the summer months. Sampling of the vegetation began in the year 2013. Therefore, baseline data was not collected (year 0), in addition to data from the first year after exclosure (year 1).

2.1.2 Browsers

Within the study area, there are populations of moose, roe deer (*Capreolus capreolus*), and red deer (*Cervus elaphus*). However, moose is the dominant herbivore and constitutes

Table 2.1: Characteristics of sixteen field sites in Akershus and Hedmark counties, southeastern Norway.

Site number	County	Forest type	Clear-cut (year)	Species planted after clear-cut	Year initiated	Elevation (m a.s.l.)	Productivity index
1	Akershus	Spruce	2007/2008	Spruce	2010	242-243	13
2	Hedmark	Pine	2008/2009	None	2011	242-244	12
3	Akershus	Spruce	2008/2009	Spruce	2011	171-177	14
4	Hedmark	Pine	2007/2008	Spruce	2010	218-220	13
5	Hedmark	Spruce	2008/2009	Spruce and pine	2011	239-249	14
6	Hedmark	Spruce	2008/2009	Spruce	2011	370-374	13
7	Hedmark	Pine	2004/2005	Spruce	2007	188-190	13
8	Hedmark	Spruce	2004/2005	Spruce	2007	273-274	14
9	Hedmark	Pine	2004/2005	Spruce	2007	350-353	14
10	Akershus	Spruce	2008/2009	None	2011	179-184	13
11	Akershus	Pine	2008/2009	None	2011	240	14
12	Akershus	Spruce	2008/2009	Spruce	2011	208-209	13
13	Akershus	Pine	2007/2008	None	2010	279-280	12
14	Hedmark	Spruce	2007/2008	Spruce	2010	218-219	13
15	Akershus	Spruce	2007/2008	Spruce	2010	181-185	14
16	Akershus	Spruce	2007/2008	Spruce	2010	303-307	13-14

Site numbers correspond with labels in Figure 2.1.
a.s.l. = above sea level.

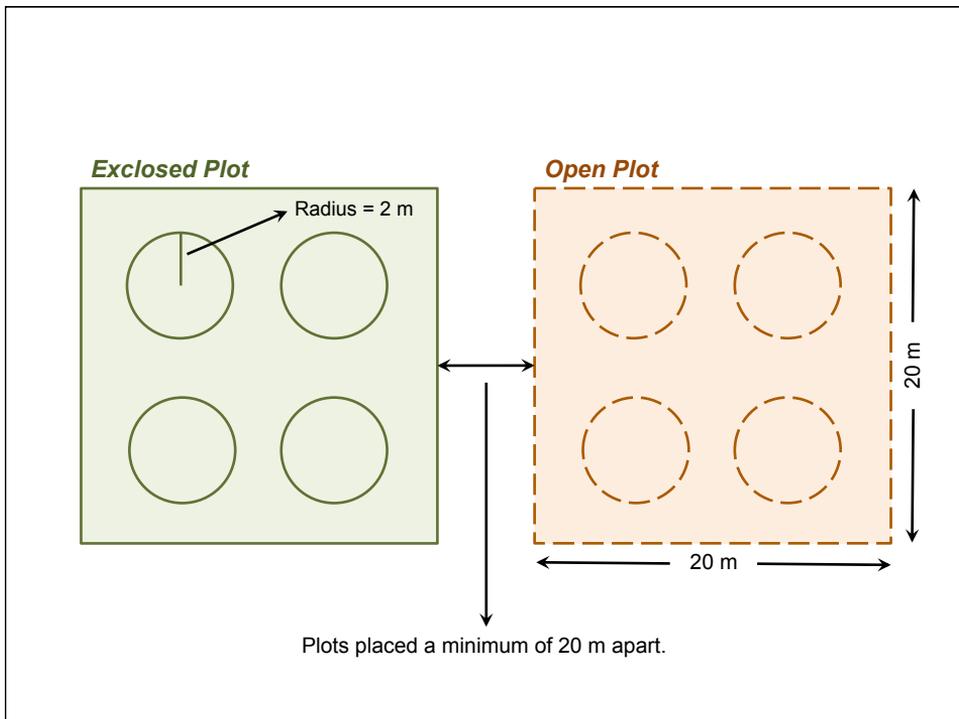


Figure 2.2: Layout of the excluded and open plots, subplots, and related measurements.

the majority of the browsing pressure, while roe deer and red deer occur at lower abundances. Ueno et al. [34] estimated the annual moose density occurring in areas just north and south of our study region (e.g. Solør and Østfold areas, respectively) using several methods consisting of cohort analysis, harvest rate, and youngest age in oldest age group in reconstructed populations. From this, the annual mean moose density occurring in the study region is estimated between 1.51 and 1.60 moose per km² [34]. Unlike large herbivores, hare and rodents are free to enter the exclosures. Grazing by domestic livestock has occurred in the past at a few of the sites, but has not known to have occurred at any of the sites in recent times. Therefore, moose, and to some extent, roe and red deer are assumed to have influenced the vegetation, along with hare and rodents that are not excluded by the fences.

2.1.3 Quantitative Data Analyses

The analyses were performed using R-Studio [Version 1.0.153]. Generalized linear mixed effect models were used to look for any effect of herbivore exclusion over time on the quantity of trees per plot for each species both less than (or equal to) and greater than 1.5 m in height. Breast height (1.5 m) was seen as an acceptable threshold height for the response variables to analyze the effect of the interaction of treatment over time for small (defined herein as ≤ 1.5 m; including height classes 1-3) and large (defined herein as > 1.5 m; including height classes 4-7) trees. The tree species of interest for this study were two early successional deciduous species, birch and rowan, and two late successional coniferous species, pine and spruce. Both downy birch (*Betula pubescens*) and silver birch (*Betula pendula*) were grouped together for the analyses. The years that data was collected has been converted to “years since exclosure” (i.e. time) since not all of the exclosures were erected in the same year. This was done to make it possible to compare same lengths of growth among the sites resulting in years 2 through 10 used in the analyses.

Therefore, quantity of trees per plot both less than (or equal to) and greater than 1.5 m in height were the response variables, while the interaction of years since exclosure and treatment were the explanatory variables and fixed effects within the models. To account for the paired design, a random intercept was fitted for site (also the random effect within the models). Residuals were checked for normality and homoscedasticity of variance within all levels of explanatory variables. Models used either Poisson or negative binomial distributions based on the calculated dispersion parameter, and coefficients are reported on log-link scale (presented later in Table 3.1). A regular generalized linear model was used for rowan greater than 1.5 m in height since the variance of the quantity of trees per plot was significantly different among treatments (i.e. exclosed versus open plots), and treatment difference (calculated as the difference between quantity of trees within exclosed plots minus that of the quantity of trees within the open plots) was used as the response variable, while years since exclosure was the explanatory variable.

2.2 Landowners' Perspectives

2.2.1 Data Collection and Qualitative Analyses

Qualitative methods were used to explore the different dimensions of perspectives of twelve forest landowners within the same moose exclusion experimental design. The data originated from an interview conducted either in person or over the phone in Norwegian or English language (which was chosen by the individual landowner) with each of the landowners. The process of data collection started with a common meeting at one of the field sites (Site 15 in Figure 2.1 and Table 2.1) to view the difference in vegetation within the enclosed and open plots. This was followed by a presentation of the trends of the data collected over the nine-year period. The presentation containing the trends of the data was later sent via email to all of the landowners for future reference. Half of the landowners attended the meeting and presentation. Questions pertaining to the meeting and presentation were included on the interview guide. However, all landowners had access to the results from their own sites, as well as for the region overall. The common meeting and presentation presented an opportunity for the interviewers to meet the landowners before proceeding with the questionnaire and interview that followed.

A questionnaire with basic questions concerning personal information, forest property information, and information regarding management plans, certification schemes, and forest owner organizations was used to describe the landowners (which is presented in the next section) and acted as a basis for the analyses. This was completed and returned via email or post. The questionnaire was intended to take a total of five to ten minutes to complete. The interview guide that was used to conduct the interviews was sent to the landowners via email prior to conducting the interviews to obtain initial answers. Interview guides consisted of mostly open-ended questions regarding current forest management preferences, managing for timber and moose production, effects of moose browsing, managing ecosystem services, and perceptions toward future forest use and potential pathways. The questionnaire and interview guide are presented within the Appendix. Landowners had a choice to respond in either Norwegian or English language. If Norwegian language was chosen, these responses were translated and further examined by Gunnar Austrheim to assure translations were correct and meaning was kept. Answers were examined for additional questions of interest. Landowners were contacted and asked to discuss questions and answers from the interview guide for elaboration, while the conversation was allowed to pursue a natural course and additional questions were asked if necessary. Again, landowners had preference toward the language that the interview was conducted, and, if Norwegian was chosen, Gunnar Austrheim conversed with the landowners. Interviews were one half hour to one hour in length. After this was completed, responses to the questionnaire and interview were sent to the landowners individually before proceeding with the rest of the analyses. Landowners were able to provide amendments if they thought necessary.

Questionnaires and interviews were a voluntary process, and landowners were assured the data they provided and their identities would be and remain anonymous. All twelve landowners participated in the study, and 98% and 97% of the questionnaire and interview guide questions were answered, respectively. It should be noted that analyzing the data

in relation to socio-economic aspects is beyond the scope of this study. Responses were reviewed individually and collectively in groups pertaining to type of landowner (e.g. private, company, or municipality) and study questions (presented earlier in Section 1.2.2) were used to drive the analyses. Part of the analyses is centered around the different ways in which timber and moose are valued by the landowners and their overall forest values. Many valuation types have been developed, and a multidimensional perspective recognizes that people hold diverse values and accepts that the environment is valued in many ways [27]. Trainor [35] has developed a classification system to account for the varying ways in which people value natural resources or non-human nature, which is appropriate and applicable for its application within this study (refer to Table A.1 within the Appendix).

2.2.2 Description of the Landowners

In 2016, the percentage of productive forest area in Norway owned by individual owners (i.e. private forest landowners), private owners except individual owners (e.g. private companies), and local government (i.e. municipal agencies) was roughly 79%, 6%, and 3%, respectively. The remaining 12% is associated with state government, common forest (that is not owned by central government), properties of deceased persons, or other/unknown [36]. Therefore, our sample of eight private forest landowners, two representatives from private companies, and two representatives from two separate municipalities (i.e. local government) is seen as an appropriate sample for the qualitative analyses. All landowners are male, with the exception of one of the municipality representatives (Landowner 12) being female. Professions varied among landowners; however, all but two received education that is forestry-based or based on another related field (e.g. agriculture). Seven of the landowners are involved in other businesses (agriculture included), and, of those, five landowners are involved in grain and/or potato production.

Forest properties range in size and length of ownership (individual and family ownership). The smallest size reported at 100 ha (privately-owned forest consisting of one site), while the largest is 22,500 ha (company-owned forest consisting of three sites). Length of ownership ranges from a minimum of 12 years to over 100 years. All private landowners recorded that their forest parcels have been kept within the family (ranging between 65-250 years), while the owner of three of the company-owned sites also expressed that his forests have been kept within his family for roughly 117 years. The other company representative and one of the municipality representatives have reported that their company/municipality have owned its forests for around 118 and 77-87 years, respectively. All landowners have a forest management plan and are part of a forest owner organization (e.g. Norwegian Forest Owners Association, Norskog, or other). All but one landowner belongs to a forest certification scheme (e.g. Forest Stewardship Council (FSC), Program for the Endorsement of Forest Certification (PEFC), and/or other). For specific information regarding each landowner or representative, reference Tables 2.2 and 2.3. Since participation was voluntary, any questions landowners chose not to answer are deliberately noted.

Table 2.2: Personal information regarding each of the twelve landowners included in this study.

Landowner	Landowner type	Site number	Gender	Profession/position within agency	Forestry education	Additional businesses	Type of agriculture
1	Private	1	Male	Retired	Yes	No	None
2	Private	4	Male	Retired	Yes	No	None
3	Private	5	Male	Technician	No	Yes	Grain
4	Private	6	Male	Forester	Yes	Yes	Grain
5	Private	10	Male	Land/forest user	Yes	Yes	Grain
6	Private	11	Male	Farmer	Yes	Yes	Grain
7	Private	15	Male	Forest owner	Yes	Yes	Grain
8	Private	16	Male	Forest owner	No	Yes	None
9	Company	2, 13, 14	Male	Civil economist & owner of private business Forest and outfield manager	Yes	N/A	N/A
10	Company	7, 8, 9	Male	Owner of company	Yes	Yes	Grain & potato
11	Municipality	3	Male	Forest manager	Yes	N/A	N/A
12	Municipality	12	Female	Forest adviser/counselor	Yes	N/A	N/A

Site numbers correspond with labels in Figure 2.1.

N/A = not applicable.

Table 2.3: Forest property information regarding each of the twelve landowners included in this study.

Landowner	Landowner type	Site number	Forest size (ha)	Ownership length (years)	Family ownership length (years)	Management plan	Certification scheme	Forest owner organization
1	Private	1	500	40	100	Yes	FSC	Norwegian Forest Owners Association
2	Private	4	133	43	~217	Yes	None	Other
3	Private	5	100	36	~250	Yes	Other	Norwegian Forest Owners Association
4	Private	6	5,500	17	120	Yes	PEFC	Norskog
5	Private	10	230	25	150	Yes	PEFC	Other
6	Private	11	250	25	90	Yes	PEFC	Other
7	Private	15	100	12	165	Yes	PEFC	Other
8	Private	16	900	41	65	Yes	PEFC & Other	Norwegian Forest Owners Association
9	Company	2, 13, 14	22,500	118	N/A	Yes	PEFC	Owners Association
10	Company	7, 8, 9	7,200	35	117	Yes	PEFC, FSC, & Other	Norskog
11	Municipality	3	1,800	~77-87	N/A	Yes	PEFC	Norwegian Forest Owners Association
12	Municipality	12	652	Not answered	N/A	Yes	PEFC	Norwegian Forest Owners Association

Site numbers correspond with labels in Figure 2.1.

ha = hectares.

N/A = not applicable.

Results

3.1 Moose Exclusion

3.1.1 Early Successional Species

The interaction of years since enclosure and treatment was not statistically significant at determining the quantity of small birch (≤ 1.5 m) trees per plot ($p = 0.930$). However, the interaction did have a statistically significant effect on the quantity of large birch (> 1.5 m) trees per plot ($p < 0.001$; Table 3.1). Moose exclusion caused a relative decrease in the density of small birch within the excluded plots over time. The density of small birch was greater (mean 1.227 ± 1.294 SD trees per m^2 ; data not shown) in the open plots than in the excluded plots (mean 0.630 ± 0.350 SD trees per m^2) at the end of the study. Conversely, this is coupled with a relative increase in large birch within the excluded plots over time (H1; Figure 3.1). The density of large birch in the excluded plots was 0.011 ± 0.023 SD and 0.855 ± 0.606 SD trees per m^2 (coefficients reported as the means) in years 2 and 10, respectively. Birch experienced a substantial height increase reaching the highest height class (height class 7 which measures > 3 m in height) during the course of the study due to moose exclusion (H1; Figure 3.2).

The interaction of years since enclosure and treatment had a statistically significant effect on the quantity of rowan per plot at all heights ($p < 0.001$; Table 3.1). Moose exclusion caused a relative decrease in density of small rowan within the excluded plots over time. The density of small rowan was greater (mean 0.090 ± 0.099 SD and 0.047 ± 0.042 SD trees per m^2 in years 6 and 10 where $n = 16$ and 3, respectively) in the open plots than in the excluded plots (mean 0.076 ± 0.149 SD and 0.000 ± 0.000 SD trees per m^2 in years 6 and 10). This trend was paired with a relative increase in density of large rowan within the excluded plots (H1; Figure 3.1). The density of large rowan in the excluded plots was 0.000 ± 0.000 SD, 0.066 ± 0.119 SD, and 0.027 ± 0.030 SD trees per m^2 (coefficients reported as the means) in years 2, 6, and 10, respectively. Rowan experienced a moderate height increase due to moose exclusion over the course of the study (H1) reaching mid-

Table 3.1: The estimated effect and standard error of years since exclosure and the interaction of years since exclosure and treatment on the quantity of trees per plot less than (or equal to) and greater than 1.5 m in height for each tree species. Significant parameters are in bold ($\alpha = 0.05$).

Species		Trees \leq 1.5 m in height				Trees $>$ 1.5 m in height			
		Coefficient	Standard error	z-value	p-value	Coefficient	Standard error	z-value	p-value
Birch	Years since exclosure	-0.008	0.041	-0.199	0.842	0.625	0.036	17.326	<2e-16
	Years since exclosure \times treatment	-0.004	0.048	-0.088	0.930	-0.284	0.035	-8.141	3.90e-16
Rowan	Years since exclosure	0.143	0.036	4.029	5.61e-05	-	-	-	-
	Years since exclosure \times treatment	-0.238	0.044	-5.438	5.39e-08	0.338 ^a	0.110	3.078	2.08e-03
Pine	Years since exclosure	-0.085	0.017	-5.102	3.37e-07	0.439	0.038	11.513	<2e-16
	Years since exclosure \times treatment	0.085	0.019	4.446	8.76e-06	0.207	0.038	5.417	6.07e-08
Spruce	Years since exclosure	-0.023	0.041	-0.575	0.565	0.748	0.066	11.303	<2e-16
	Years since exclosure \times treatment	0.029	0.050	0.594	0.553	-0.015	0.071	-0.215	0.830

Values are reported on log-link scale since either Poisson or negative binomial distributions were used for these analyses.

^aA regular GLM was used for analyzing rowan greater than 1.5 m in height. Refer to Section 2.1.3.

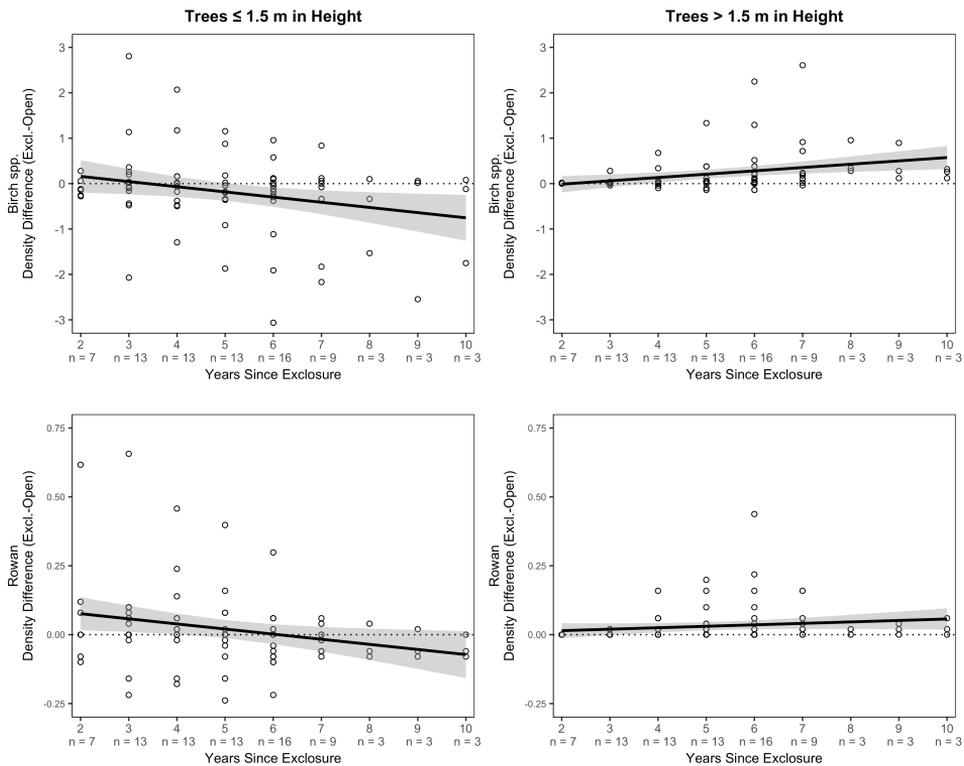


Figure 3.1: Treatment effect (nine years of ungulate exclusion) on density (trees per m^2) of deciduous tree species less than (or equal to) and greater than 1.5 m in height at sixteen boreal forest clear-cut sites. Positive values (above the dashed line) indicate that the density for that property was higher inside the excluded plots compared to outside. Data points represent unique sites and are plotted as circles. Regression line shown with shaded standard error. See Figure A.1 within the Appendix to observe the different trends among the unique sites.

level height classes (height classes 4 and 5 measuring 1.5-2.5 m in height; Figure 3.2).

3.1.2 Late Successional Species

A statistically significant effect of years since exclusion and treatment was observed for determining the quantity of pine per plot at all heights ($p < 0.001$; Table 3.1). At the start of the study, the density of small pine was greater outside (mean 0.452 ± 0.881 SD trees per m^2) of the excluded plots than inside (mean 0.304 ± 0.524 SD trees per m^2). Over the course of the study, there was a relative decrease in the density of small pine in the open plots resulting in a density difference of approximately zero (i.e. the density within the excluded and open plots were roughly equal; mean 0.391 ± 0.506 SD and 0.371 ± 0.467 SD trees per m^2 in the open and excluded plots, respectively). The exclusion of moose caused a relative increase in the density of large pine over time (H2; Figure 3.3). The density of large pine in the excluded plots was 0.006 ± 0.015 SD and 0.431 ± 0.534 SD trees per

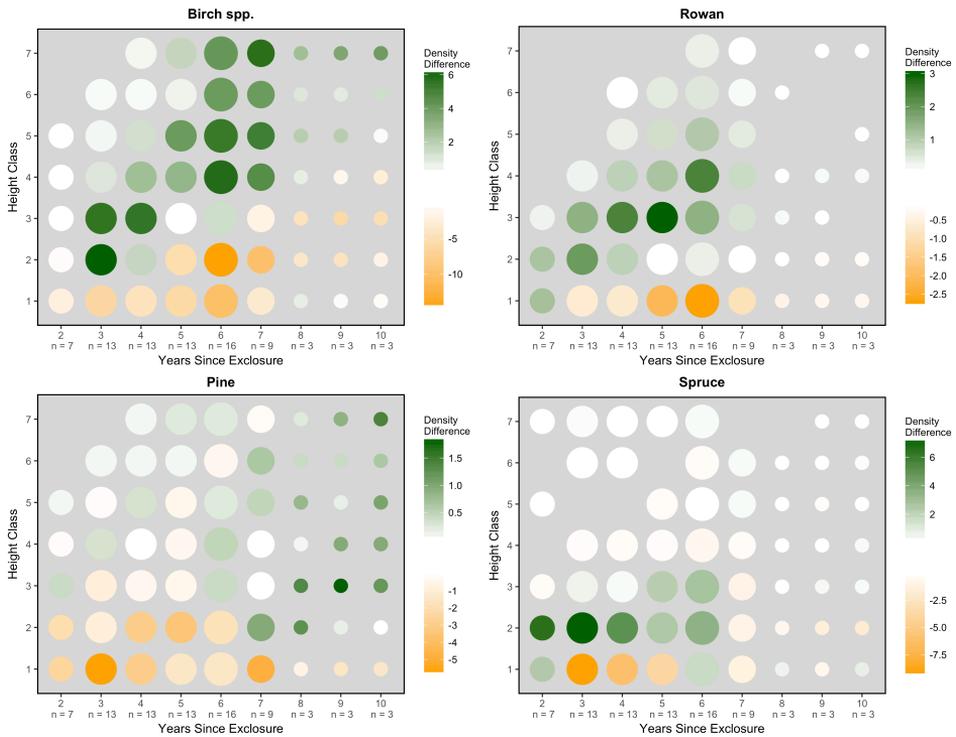


Figure 3.2: The density difference (trees per m^2) in each height class in each year for birch spp., rowan, pine, and spruce. Dots with green hues indicate a greater density inside the excluded plots. Dots with orange hues indicate a greater density outside the excluded plots. Dots that are white in color indicate no difference in density inside and outside of the excluded plots. The size of the dot corresponds to the sample size (number of sites sampled that year), which is reported on the x-axis.

m^2 (coefficients reported as the means) in years 2 and 10, respectively. During the earlier years of the study, there was a higher density of pine measuring up to 1 m in height (height classes 1 and 2) outside of the excluded plots. This is followed by a greater density of trees measuring between 0.5 up to > 3 m (height class 2-7) within the excluded plots starting in years 6 and 7 (where $n = 16$ and $n = 9$, respectively). Pine was able to reach mid-level to high height classes (height classes 4-7 ranging between 1.5 and > 3 m in height; H2) by the middle and end of the study due to moose exclusion (between the years 6-10; Figure 3.2).

No statistically significant effect of years since exclusion and treatment was observed for determining the quantity of spruce per plot at any height ($p = 0.553$ and 0.830 ; Table 3.1). Moose exclusion has not caused a difference in density of spruce between the excluded and open plots (H3; Figure 3.3). The density of small spruce at year 10 was 0.438 ± 0.440 SD and 0.511 ± 0.530 SD trees per m^2 (coefficients reported as the means) in the excluded and open plots, respectively. Conversely, the density of large spruce at year 10 was 0.060

± 0.103 SD and 0.066 ± 0.098 SD trees per m^2 (coefficients reported as the means) in the excluded and open plots, respectively. Spruce did not experience a great height difference between treatments (i.e. excluded versus open plots; H3). There was a slight difference between small spruce from the start of the study until year 6. During this time, there was a higher density of trees outside of the excluded plots < 0.5 m (height class 1), while inside the excluded plots there was a higher density of trees measuring between 0.5-1 m (height class 2), with a small density of trees entering into the 1-1.5 m range (Figure 3.2).

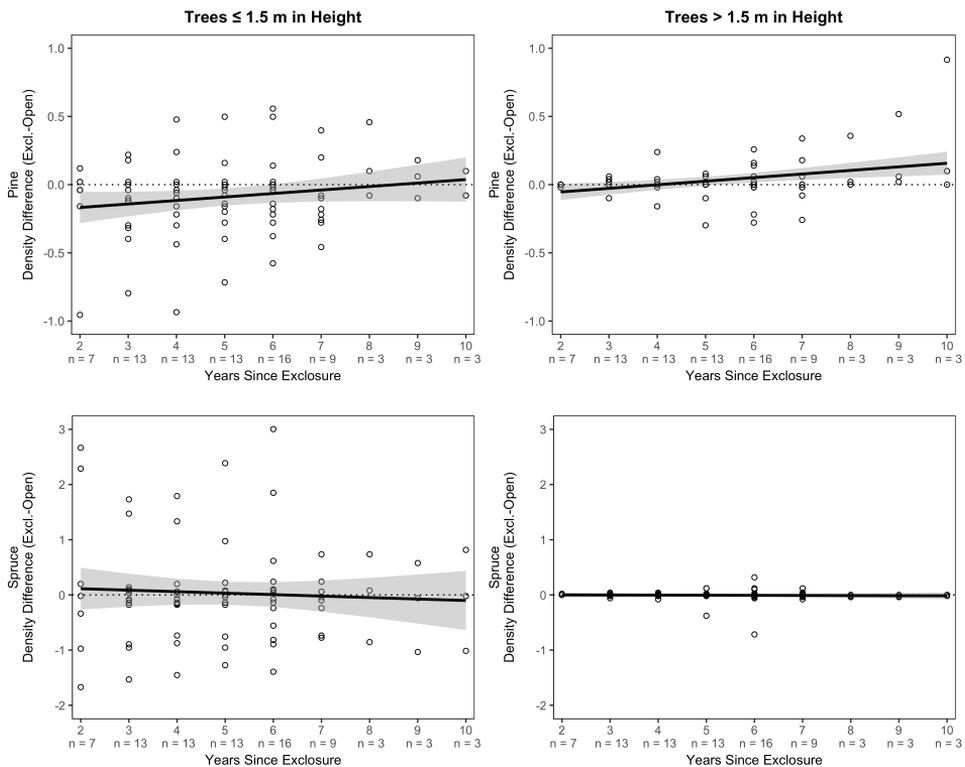


Figure 3.3: Treatment effect (nine years of ungulate exclusion) on density (trees per m^2) of coniferous tree species less than (or equal to) and greater than 1.5 m in height at sixteen boreal forest clear-cut sites. Positive values (above the dashed line) indicate that the density for that property was higher inside the excluded plots compared to outside. Data points represent unique sites and are plotted as circles. Regression line shown with shaded standard error. See Figure A.2 within the Appendix to observe the different trends among the unique sites.

3.2 Landowners' Perspectives

3.2.1 Forest Ecosystem Management Preferences and Objectives

All landowners currently manage their forests for timber production. In addition to managing for timber, the forests are being utilized for hunting of large ungulates and other small game (moose being the most important game species) and its accompanying recreational opportunities. The use of a contractor is used for harvesting timber by all landowners, and Landowner 9 stated their company decides other harvesting aspects such as the spacing of trees planted and cutting. Twelve of the sites are planted with spruce. One private landowner deliberately plants pine (along with spruce; Landowner 3). None of the landowners exclusively manage their forests for moose production, rather choosing to make use of moose as an extra source of utility, engaging in hunting either themselves and/or through the sale of hunting rights to interested parties (e.g. individuals and hunting teams).

In addition to timber production and hunting of moose and other types of wild game, more uses of the forest have been mentioned by the landowners. One private landowner chooses to manage for the collection of fuel wood (which is harvested himself, exclusively Landowner 2), while another manages for tourism (e.g. rental cabins; exclusively Landowner 4), which offers other outdoor recreational opportunities (e.g. fishing, walking, hiking). Municipalities manage for a more multi-use of the forest, which is reflected in their management choices. They not only manage for timber and hunting sales, but for biodiversity (exclusively Landowner 12), recreation and outdoor life (e.g. walking in the forest and opportunities to be present in nature), and utilizing forests as a source of "health care" for citizens of the municipality. Large companies primarily manage for timber production, and one of them offers tourism (and its accompanying recreational opportunities; exclusively Landowner 9) in renting out cabins.

The primary overall management objective across all landowners is production. Landowners emphasized the most important use of the forest is for producing timber/lumber. This was consistent across all landowners. Municipalities differed from the other landowner types in that other objectives were stated as being of equal importance. Representatives from the municipalities did stress that ecological (e.g. biodiversity, well functioning ecosystems) and social (e.g. forests as a source of "health care" in partaking of outdoor experiences) aspects are just as important as utilizing forests for timber production. Overall, all landowners had economically-driven motivations, but municipalities also managed for the well-being of their citizens and ecological purposes. Therefore, municipalities manage more for the provision of public goods and services. Private landowners and companies mostly manage for the provision of private goods and services. Their motivations mainly comes from personal gain either economically (e.g. sale of timber, hunting rights, tourism opportunities) or through utilizing the forest for resources they can consume (e.g. game meat or fuel wood) or take part in themselves (e.g. hunting, outdoor activities, social involvement). However, public goods and services are represented in their management preferences in the form of hunting, outdoor, and tourism opportunities primarily as a service the general public could pay for.

3.2.2 Effects of Moose Browsing and Potential Conflicts

Of the six landowners who attended the common meeting and presentation, opinions of the overall trends of the moose exclusion data were mixed. Three landowners stated the results were not surprising in that they are aware of the influence moose has on the composition of trees and they have seen developments at their own properties. The other three landowners were surprised with the results stating they are impressed with how much vegetation moose can consume. Of the six landowners who did not attend the common meeting and presentation, four landowners chose not to answer the related questions, while the other two stated the results were not surprising for the same reasons as mentioned. Eleven of the twelve landowners possessed neutral attitudes (neither negative nor positive) toward moose browsing. One private landowner did have a negative attitude toward moose browsing, stating moose browse within his oat fields very often and the density of moose at his property is too high. Beliefs toward the density of moose differed slightly among individuals, but leaned in the opposite direction with the rest of the landowners stating they believe the moose density within the area is either too low or at an acceptable level. Among the other seven private landowners, five stated they believed the density of moose is too low, while two landowners stated they believed the current density is satisfactory. The opinions among the municipality and company representatives were split with one representative from each sector stating the density was quite low (Landowners 10 and 12) and the others stating it was sufficient (Landowners 9 and 11). A comment that was mentioned several times was that the hunting quotas are currently somewhat high and could be lowered when considering only a percentage of the quota is able to be fulfilled and the wolf has a considerable negative impact on the density of the moose population. The wolf was the main reasoning as to why they believe the density is presently too low across the area.

The belief that a balance can be obtained in managing for timber production and managing for moose was agreed upon by eleven of the twelve landowners. All of the private landowners stated they do believe a balance can be achieved because the current moose density is not too high and is declining, moose browsing is not an issue with spruce forest, and, if a problem does occur the moose population can be controlled to assure damages on forestry do not persist. A comment that was made by Landowner 7 was that this balance does depend on the forest type and its tree community composition. Among the municipality representatives, they too agreed a balance is possible because browsing pressure can be monitored and the population of moose can then be regulated. One company representative (Landowner 9) stated he does believe a balance can be achieved because both resources give purpose, a certain amount of damage to forestry is accepted, and the moose population can be adjusted if need be. Landowner 10 (company owner) expressed that he does not believe a balance is feasible due to the impacts wolf has on the density of moose. His answer came from an economic point of view in that there will never be enough moose to compete with the higher monetary value of timber resources.

One private landowner experiences a conflict between moose browsing and agriculture (e.g. oat fields). The rest of the landowners stated they do not encounter any major conflicts within their properties. They do recognize that conflict does exist, and particular conflicts that were mentioned are as follows: There could be difficulties between moose browsing

and pine production. The single landowner (Landowner 5) that plants both spruce and pine stated he accepts damages on pine. There could be damages occurring to agriculture, specifically grain production. Larger local densities on site-specific properties with a higher productivity is an issue for some landowners. RAW species (rowan, aspen, and willow) can be negatively affected by moose browsing, which can further affect other species (such as mosses, lichens, insects, and birds) that depend on those deciduous tree species for survival. Forest birds are a concern with clear-cut forestry. A trade-off can occur between utilizing forests for timber production and recreational purposes. The single conflict stated repeatedly was the predation pressure the wolf has on the density of moose within the area. Landowners possessed very strong negative attitudes toward the wolf.

3.2.3 Forest Values and Recognition of Ecosystem Services

Private landowners and company representatives stated that timber and moose are not equally important to them/their companies, and from an economic point of view timber is of most importance. The representatives from the two municipalities expressed that both timber and moose are of equal importance as forest managers/advisers. These two resources were not viewed, valued, or utilized in the same way. Timber is assigned solely economic value. The act of producing timber has cultural value (e.g. small-scale family forestry being passed down from generation to generation) to many of the landowners, while moose is assigned economic, as well as cultural and recreational values (reference Table A.1 in the Appendix for the differing values and concepts of values). Moose provides a smaller source of income through the sale of hunting rights, recreational experiences through hunting (which is often viewed as a traditional activity) and provides opportunity to spend time outdoors (in a socially-oriented setting if hunting is carried out within a team of hunters), and game meat for consumption.

All four categories of ecosystem services (supporting, regulating, provisioning, and cultural services) were mentioned and recognized by the landowners (Table 3.2). Some types were mentioned more than others. Provisioning and cultural services were mentioned most frequently across all landowners. Provisioning services were mentioned in the forms of timber as a raw material and source for construction and bioenergy/biofuel, game meat from the hunting of moose and other wildlife, and the picking of berries and mushrooms. Recreation and outdoor experiences with family and friends, the act of hunting and fishing, and tourism were the cultural ecosystem services of reference. Less frequently and by not many of the landowners were supporting and regulating services specified. Supporting services were mentioned in the form of well functioning ecosystems and the importance of biodiversity in general, but more specifically as in the abundance of deciduous tree species, concern for forest birds and their breeding areas, and forests as habitat for animals and plants. A municipality representative (Landowner 12) identified supporting services on more than one occasion; however, Landowner 11 (municipality representative), Landowners 1, 4 and 5 (private landowners), and Landowner 10 (owner of company) briefly mentioned a few of these examples of supporting services. Regulating services were identified in the form of the importance of forests at providing clean air and water (Landowners 2, 6, and 12; two private and one municipality landowner, respectively) and climate mitigation (discussed by ten of the twelve landowners). Other services provided by forests

Table 3.2: Ecosystem services of specific reference stated by the landowners during the interviews.

Ecosystem service type	Specific reference
Supporting	Well functioning ecosystems Biodiversity in general Habitat for animals and plants Abundance of deciduous tree species Forest birds and breeding areas
Regulating	Clean air and water Climate mitigation
Provisioning	Timber as a raw material Game meat Berries and mushrooms
Cultural	Recreation Outdoor experiences with family and friends Act of hunting and fishing Tourism
Human well-being	Positive effect on public health Providing work places

were acknowledged by one municipality (Landowner 11) and one company representative (Landowner 9) that fall under the category of human well-being. They had stated that forests are essential in providing work places and have a positive effect on public health. Based on this, the landowners hold cultural, economic, ecological, recreational, and social values toward forests (with ecological and social values being newly referenced).

3.2.4 Perceptions toward Future Forests

The landowners possessed positive attitudes toward the importance of forestry and forest use in the future. They believe in an increased importance of forest products, and envision timber becoming more valuable in the future as a source of renewable material for construction and bioenergy/biofuel and aid in carbon storage and mitigation. Landowner 9 (company representative) also hoped forests will provide more work places. Some negative attitudes and concerns did exist. Negative attitudes toward the current management of forest properties were held, and landowners believe forests are not being managed in the proper way (e.g. forest thinning). Landowners were also concerned regarding the market for increased forest products in the future stating they are unsure whether a market will exist. The current environmental shift (e.g. “green” movement) and related politics are believed to be too strong. Potential pathways at reaching their visions mostly consisted of no changes in management (i.e. business as usual). Landowner 1 (private landowner) stated there should be more active management in the form of planting after cutting, proper thinning of the forest, improved roads, and cleaning of forest edges. Landowner 8 (private landowner) believed in a more intensive forest management with the use of fertilizer, possession of larger properties, simpler harvesting methods, more accessible roads, and increased overall production. Landowners 6 and 12 (private and municipality representative,

respectively) hold pathways that consist of more funding and education (e.g. educational courses) at securing a more viable and sustainable forest management in the future.

Discussion

4.1 Discussion of the Results

Much of the scientific literature pertaining to boreal forests is one-sided, focusing on either the ecological aspect or social aspect of the social-ecological system (with little research on the social component), rarely pairing the two together. In this study, we examined the effect of moose exclusion on the regeneration of boreal trees in recent clear-cut areas in southeastern Norway, as well as landowners' perspectives toward forest ecosystem management. In addition, we identified their forest values and perceptions toward future forest use. We have illustrated that large herbivores have the capacity to alter the structure and composition of regenerating boreal trees in recently disturbed areas, such as clear-cuts. Moose exclusion markedly increased the growth of the deciduous trees throughout the nine-year study. Pine was also positively affected by the treatment (i.e. exclosed plots) and increased in height and density, while spruce was not affected by the exclusion of moose. Even though landowners recognized a broad range of ecosystem services and held a diverse set of forest values, we were able to identify landowners' primary management objective as timber production. Municipalities differed by emphasizing ecological and social aspects of the forest. Landowners also possessed positive attitudes toward the future of forestry and forest use, stating forests will become more important, associating forestry with climate mitigation and energy transition.

Our results showed that forest landowners emphasized production as their primary overall management objective. Similar studies regarding private forest landowners' objectives and values have been conducted in Sweden with differing and non-consistent outcomes. Kindstrand et al. [21] and Haugen [4] found that forest owners considered timber production as the most important forest function. Eriksson [24]'s results were similar, in which landowners believed that production (e.g. profitability) was most important, followed by ecological (e.g. biodiversity) and recreational (e.g. hunting and fishing) opportunities. Hugosson and Ingemarson [31] found that the landowners included in their study are moving toward ecological (objectives concerning environmental protection and preservation purposes such as

biodiversity and water and soil quality) interests. To add, Ingemarson et al. [32] found that forest landowners' objectives and values are shifting and broadening to include a multitude of forest objectives (e.g. nature, cultural, water, and soil conservation; forestry tradition, timber production; game production; mushrooms and berries; forest grazing; etc.), and concluded that landowners are not solely driven by economic benefits. Nordlund and Westin [5] found that landowners held strong production and ecological (e.g. preservation) values, preserving areas with high biodiversity and harvesting in other areas.

The primary management objectives emphasized within our study align most with Kindstrand et al. [21], Eriksson [24], and Haugen [4] in that forest landowners focused on the commercial aspect of forest management. The two coniferous species, spruce and pine, are the two most economically important species within Fennoscandian forests [37]. Twelve of the sixteen sites are planted with spruce (Table 2.1), of which, is least likely to be browsed [16]. As expected, moose exclusion did not cause a difference in density of spruce between the exclosed and open plots over time (H3). In addition, there was not an obvious height difference of spruce between treatments (i.e. exclosed versus open plots; H3). We did observe a slight difference in height of small spruce (≤ 1.5 m) in the first six years. However, these densities do level out over the course of the study (Figure 3.3), and this trend does not continue into later years (years 7-10). We were able to observe that this phenomenon is due to a few outlying unique sites (Figure A.2). Although these results are not expected, and contradict Tremblay et al. [38], who found that spruce seedling and sapling abundance was not related to deer density in a study conducted in Anticosti Island, Canada, it will be interesting to observe if this trend continues as younger sites enter into years 7, 8, 9, and 10 ($n = 9$ for year 7; $n = 3$ for years 8, 9, 10).

In addition to timber production, the landowners are utilizing the forests for hunting, primarily moose as it is the most important game species (according to the landowners). Yet, conflicts may arise where landowners could experience browsing damages to young pine forest, since pine is intermediately preferred and susceptible to browsing [12, 16, 19]. Four of the sixteen sites were not planted after clear-cutting, and these sites rely on natural regeneration of pine, while one site is planted with pine and spruce (Table 2.1). We expected to see some effect of treatment over time on this species, and due to moose exclusion pine trees increased in height and density (H2). Heikkilä et al. [39] observed how selective browsing could influence the tree species composition in young stands in Finland, and, found that within managed forests, Scots pine trees were significantly shorter within browsed open areas compared to those within the exclosed areas. These findings coincide with our results where the exclusion of moose allowed for an increased height growth and density of tall pine (> 1.5 m). However, it is important to note that this height and density increase is dependent on the three sites contained in the last three years of the study (Figure 3.2). This trend is due to one particular site with a higher density of tall pine (Figure A.2).

While we observed an increase in density of tall pine trees due to moose exclusion, we did not observe the same trend in small pine. At the end of the study, small pine levels out at a density difference of approximately zero (i.e. the density within the exclosed and

open plots are equal; Figure 3.3). This may mean that browsing has reduced the density of small pine over the course of the study in the open plots. In addition, we observed that height development of pine was not very clear over the course of the study (Figure 3.2). This lack of difference in density of small pine trees between exclosed and open plots (as well as a lack of a clear trend in height growth) may be due to a decrease in moose density after the exclosures were constructed. Moose population densities are often important factors of browsing pressure, especially at small spatial scales (e.g. trees, patches, or stands) [40]. However, correlations between moose population density and browsing damage to pine have been detected at larger spatial scales too [41]. If the region we had collected data had experienced a decrease in moose density (and browsing pressure on pine) after the exclosures were constructed (especially after 2010 when the remaining 13 sites were established), we may not observe such an obvious difference in height growth and density of pine trees between the exclosed and open plots. Like spruce, it will be interesting to observe how the trends in the treatment effect continue to develop as the younger sites become older.

This explanation corresponds with responses from the landowners in that seven of the twelve landowners stated they believe the density of moose is too low presently, while four landowners believe the density is at an acceptable level today. The statement that hunting quotas are currently somewhat too high was mentioned several times. Statistics Norway reported 30,800 moose were shot during the 2016/2017 hunting year, which is a decrease of 300 animals shot compared to the previous year and a 22% decrease from the record hunting year of 1999/2000. Akershus county was able to fulfill 81-90% of the felling quota, while in Hedmark county, only 61-80% of the felling quota was fulfilled during the 2016/2017 hunting year [42]. This decrease in the density of moose could explain why we did not observe an increased density of small pine within the exclosed plots and a clear trend on the height growth of pine in general. This may explain why landowners did not encounter any major conflicts regarding their forest properties with managing for both timber and moose production. The one landowner (Landowner 5) that plants pine (along with spruce) stated he does accept damages on pine trees. Yet, the remaining four sites that are not planted and rely on natural regeneration of pine, of which, damages (or accepting them) was not spoken about by the corresponding landowners. Landowners (with the exception of one landowner) do believe a balance can be achieved in managing for both resources by modifying the density of moose if need be, lessening browsing pressure on commercially important trees, particularly pine.

A decrease in moose densities could also explain why eleven of the landowners had neutral attitudes (neither negative nor positive) toward moose browsing. However, since hunting is also included in their management preferences, which they take part in themselves and/or sell hunting rights to interested parties, the landowners benefit from the presence of moose. This may be a reason why Landowner 5 accepts damages on pine. Even though the landowners do not experience any current problems regarding moose browsing and forestry, conflict regarding moose browsing and agriculture was revealed during the interviews. One private landowner experiences an issue regarding moose browsing within his oat fields, and was also the only landowner that expressed negative attitudes toward

moose browsing. This concern was the only of its kind even though one landowner is a farmer, and six landowners total practice agriculture (e.g. grain and potato production; Table 2.2). A common management practice used to redirect or reduce herbivore impacts from agriculture, forestry, and sensitive habitats, although its effectiveness remains uncertain, is supplementary feeding [43, 44]. Mathisen et al. [44] explored the landscape scale impact of moose browsing in southeastern Norway and found that browsing on pine and spruce was locally high around feeding stations, while browsing damage to pine was high at the landscape scale. Further, van Beest et al. [43] found that browsing on spruce increased after 15-20 years of supplementary feeding. Depending on the locations of the supplementary feeding stations, these kinds of impacts could create the kinds of conflicts that we currently do not see within this study. Potential suggestions consist of reducing the moose density, increasing the availability of preferred browse at the landscape scale, and improving the quality of the supplementary feed used or a combination of these [44].

While timber production was emphasized by all landowners, primary objectives and management preferences did differ among the landowner types. Municipality representatives clearing stated ecological and social aspects were of equal importance to their agencies, which corresponds with Nordlund and Westin [5]'s study. Studies have shown that these kinds of forest benefits can be enhanced with the addition of deciduous species within the stand [45]. Mixed-species stands can provide an increased variety of habitats (compared to monocultures), and will most likely increase levels of soil insulation and rates of nutrient cycling, raise soil quality, and therefore benefit the diversity of vascular plants [45, 46]. In addition, a raised species richness and abundance of birds, understory vegetation, saproxylic beetles, and lichens may be expected when the forest stand has been converted to include more tree species [45, 47, 48]. While recreational preferences have yielded inconsistent outcomes, other cultural and social ecosystem services are enhanced by the inclusion of more tree species [45]. Deciduous trees can provide variation in color and texture that is often preferred aesthetically, and, rowan trees, specifically, provide lush amounts of colorful berries and foliage during autumn months [45, 49]. A common cultural activity within the forests of Fennoscandia is berry collection, especially bilberry, which occurs more commonly in plots with multiple tree species [45, 50, 51]. However, there are trade-offs involved regarding higher logging costs due to increased number of timber assortments, and the potential to experience higher browsing damage from large herbivores (although a higher density of ungulates could be a benefit for those interested in hunting) [16, 45]. However, the potential of increased browsing damage is dependent on local ungulate densities and the availability of quality alternative sources of forage [45, 52].

The results of the study revealed that both deciduous species experienced a response in height growth and density of tall trees due to moose exclusion over the course of the study as expected (H1). Birch was able to reach the highest height class (height class 7), which includes trees > 3 m. Nieuwenhuis and Barrett [53] conducted a study in Ireland to examine the growth potential of birch (specifically downy birch), selecting eight well-stocked, unthinned birch stands for sampling. The researchers had observed that the fastest growing trees were able to grow over 1 m per year during the first 20 years, and, within this period, the maximum height increment was achieved [53]. Likewise, rowan was able to

reach mid-level height classes (height classes 4 and 5), which measures between 1.5 and 2.5 m, during the nine years of moose exclusion. These results are similar to those of den Herder et al. [54] who conducted a large-scale experiment controlling the presence of moose to understand the effects of regeneration on three native pioneer species (e.g. rowan, aspen, and silver birch). They had found that rowan trees were significantly taller inside exclosures due to moose exclusion [54].

Conversely, there was a higher density of small deciduous trees outside of the exclosed plots by the end of the study, although the interaction was not statistically significant for birch (Table 3.1). This indicates moose browsing constrained the height growth of these species. A five-year exclosure study conducted in a productive forest area in Sweden showed that moose browsing had a clear negative effect on the ability of rowan to transition from small (< 1 m) to medium height classes (1-2 m) [49]. This is equivalent to height classes 1 and 2 (measuring up to 1 m) to height classes 3 and 4 (measuring between 1-2 m) in our study. These results and ours have similarities, as the open plots experienced a higher density of rowan that was within height class 1 (until around year 8), while a low density of birch started to enter height classes 3 and 4 during the last few years of the study (where $n = 3$) in the open plots (Figure 3.2). The difficulty for the deciduous species in transitioning to higher height classes may be linked to the depth of snow. We expect the trees above the snow depth to no longer be protected from browsing during the winter months. This said, municipalities could benefit from a reduction in moose density to increase the amount of deciduous trees within their forest stands if biodiversity and social aspects of forests are of equal importance. This can also be achieved by deliberately planting these species, but there are additional ways to increase biodiversity and other ecosystem services deriving from forests. Changes in management actions, alternative to business as usual (i.e. no change in management), such as extended rotation lengths, increased land set aside from harvesting, and reduced thinnings can increase biodiversity and other non-timber benefits [55, 56].

Unlike municipalities, private landowners and companies had a much stronger emphasis on economic forest values as opposed to ecological and social values. According to both the Forest Stewardship Counsel (FSC) and Program for the Endorsement of Forest Certification (PEFC) standards (of which, all but two belong), all certified forest parcels larger than 20 ha must have a forest management plan (of which, all landowners have; Table 2.3). Forest management plans for private landowners are usually standardized (but could promote social values) being largely oriented toward timber production with around 5% land area set aside for conservation [57]. Forest companies apply a forest planning process by first creating long-term plans where harvest levels are set. This is then followed by tactical and operational short-term plans [57, 58]. According to Sténs et al. [57], forest companies include ecological landscape plans in their long-term planning (and is also mandatory according to the FSC standards), but social values have not been explicitly included. Therefore, it seems as if most private- and company-owned forests may only handle ecological and social aspects of forests through their forest management plans and certification schemes to which they belong (refer to Table 2.3 for details).

In regards to types of ecosystem services, all landowner types mentioned provisioning and cultural services the most throughout the conversations, and supporting and regulating services were mentioned least. In fact, a common trade-off exists between managing for provisioning (i.e. material) services and biodiversity and other kinds of ecosystem services (e.g. supporting, regulating, and cultural services) [59]. We also observed that private landowners and companies had motivations that center around personal gain (economically, through the consumption of resources, or forest activities they can take part in themselves). However, Triviño et al. [56] conducted a multiobjective optimization study to identify trade-offs between harvest revenues, carbon storage, and biodiversity to further determine combinations of forest management regimes to achieve these objectives. The researchers found that when giving up 1-5% of timber net present value, biodiversity indicators, such as maximum deadwood and habitat availability, could be achieved to 39-47% and 65-88%, respectively, and carbon storage could be achieved to 66-77%. They further explain that a combination of different management regimes is needed to resolve conflicts among these three objectives [56]. Nonetheless, this research is impactful in conveying messages that managing for non-timber benefits is not an “all-or-nothing” concept, in that small reductions in timber net present value and adjustments in the management of forests can have grander impacts on the provision of other services.

As a result of the increased importance on ecological and social aspects related to forests, how they will be managed in the future has been a key question [5, 26]. Theory suggests that the future is socially constructed in the present, and decision making styles or actions developed by relevant stakeholders are consistent with their social commitments and economic activities that allow for the continued maintenance of their way of life. Lindahl and Westholm [25] carried out an experiment in Sweden to explore stakeholders’ perceptions of the future of the forest sector (including economic, social, and cultural aspects derived from forests and the forestry sector for human well-being). The researchers found that most stakeholders that participated in their study saw the future of the forest sector linked to broader issues associated with climate mitigation and energy transition. Growing forest for carbon storage and an alternative energy source were favored by stakeholders in the forestry and bioenergy sector, respectively [25]. The landowners within our study expressed visions that are in line with the findings of Lindahl and Westholm [25]. They possessed positive attitudes toward the importance of forestry and forest use in the future stating there will be a need for forest products (e.g. renewable material for construction and bioenergy/biofuel and aid in carbon storage/mitigation).

Lindahl and Westholm [25]’s theory is also applicable to the pathway in which many of the landowners stated would be appropriate to reach their visions, business as usual. The belief in increased forest production to meet the demands for wood products relates to debates of a more intensified forestry, which is a main driver for the loss of biodiversity and ecosystem services [5, 59]. To add, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has stated in their most recent regional report that continuing a business as usual approach will prevent the ability to reach many of the United Nation’s Sustainable Development Goals and Aichi Targets (which are part of a

wider 2030 agenda for sustainable development) [59]. In addition, these visions and pathways are supported by the overall production-based objectives and economically-driven motivations (by the private landowners and companies, and, to some extent, municipalities). The landowners' attitudes, beliefs, perceptions, and corresponding pathways toward future forest use have grander implications on the effectiveness of initiatives and policy developments in moving toward utilizing forests for multiple functions in the provision of non-timber benefits, goods, and services for not only the forest landowner, but society as a whole [20, 23, 24].

4.2 Limitations of the Study

Although our results were very insightful and meaningful, that does not imply this study was without its limitations. In regards to the moose exclusion experimental design, the delayed excluded plots having a three-year gap between the clear-cutting and construction of enclosure could have had an influence on the effect of the treatment, as browsing most likely occurred throughout the disturbed area. When analyzing the data, not all of the sixteen sites were included in each year with years 8, 9, and 10 having a low sample size ($n = 3$) compared to those of other years. Moose exclusion is not a realistic situation, and the development of the forest structure and composition within the excluded plots can give us an idea of how the forest may look with a reduction in moose density. Unfortunately, we are unable to pinpoint a specific density of moose. To add, it is important to remember the excluded plots act as a contrast to the open browsed plots rather than a representation of natural succession.

In regards to the landowners' perspectives portion, it is important to note that the theory related to human cognition (Figure 1.1) may not be directly applicable to real-life scenarios, in that, people could potentially hold values that do not influence their behaviors and vice versa (i.e. exhibit behaviors that are not based on their values). Another drawback that was encountered was the general trend in positive attitudes from the twelve landowners included within the experimental design, which may have resulted in a slight bias in beliefs and attitudes. If landowners were willing to take part in the SustHerb project, they may possess more positive attitudes in general, including the role forests play and their uses in the future. In addition, the results pertaining to the landowners' perspectives is only as extensive as what was exchanged via email and said during the interview process. Language barriers hindered the communication between myself and many of the landowners. Lastly, in deciding to partake in a two-part thesis, although considerate of both parts of the social-ecological system, each part (i.e. moose exclusion versus landowners' perspectives) had to be limited in scope and depth.

4.3 Implications of the Study

With the use of an enclosure experimental design in recent clear-cuts, this study shows that the composition of tree species in areas of moose exclusion vary considerably to those exposed to moose browsing. Earlier studies have shown that this may be due to the feeding

preferences of moose for some species over others, and, in turn, these species experience a higher browsing pressure [12, 16]. By foraging selectively, moose can affect the growth and survival of many tree species, which may in turn modify patterns of abundance and vegetation dynamics redirecting succession to shift the overstory composition [60]. We did observe that moose browsing constrained the height growth of the deciduous species substantially. This raises questions whether these species will be able to recruit to the canopy before the late successional species or whether this stage will be skipped altogether in the open plots. Further, it has been hypothesized that moose browsing will accelerate forest succession toward the coniferous species [61], which would be a benefit for the landowners focused on timber production. Although, our results showed both deciduous and coniferous species (to some extent) responded more positively to the excluded plots compared to that of the open plots. Therefore, it may be too early to detect whether these trends will persist in the coming years of succession. All in all, the impact of browsing does have an effect on the regenerating boreal forest in recently disturbed areas (e.g. clear-cuts) during the early years of succession. Due to these changes in the structure and composition of the boreal forest tree species as a result of browsing, final ecosystem services deriving from the forest can be altered [3, 28], influencing landowners' perspectives toward browsing pressure and moose densities, potentially causing adjustments in management decisions (e.g. planting spruce instead of pine, deciding to accept damages on pine trees, etc.). However, these decisions are very much impacted by their underpinning forms of human cognition [20].

Landowners' perspectives (including their values, beliefs, and attitudes) are the most important elements affecting their behaviors and management decisions, which has further implications on the effectiveness and overall success of management plans and policy initiatives [20, 27, 30]. Values research can provide insight as to how individuals may respond to these plans and initiatives as one draws upon their values to evaluate management goals and actions [27]. Individual landowners (i.e. private forest landowners) owned approximately 79% of the productive forest area in Norway in the year 2016 [36]. This means that private forest landowners' decisions about the management of their forest properties have a considerable influence on the provision of ecosystem services that are delivered back to not only themselves as landowners, but the rest of society (refer to Figure 1.2) [62]. This is especially important in Norway, considering the "right to roam" entails the right of the general public to use privately-owned land (forest and open countryside) for leisurely, recreational, and other activities such as picking mushrooms, berries, and flowers. These principles are legally enshrined in the Outdoor Recreation Act of 1957 [63]. Our results revealed that many of the landowners, especially private landowners, had a much stronger emphasis on economic forest values. Therefore, managing for ecosystem services such as supporting (e.g. biodiversity, well functioning ecosystems) or cultural (e.g. aesthetics, sense of place) services could be a challenge for forest managers and policy-makers. For this reason, landowners' perspectives offer important knowledge and is an essential component in moving toward more sustainable forest management systems and policies that promote non-timber benefits and balance moose, timber, climate mitigation, biodiversity, and other services important for overall human well-being.

4.4 Management Considerations

Based on the results of this study, we are able to make several management considerations. Improvements to reduce the impacts moose have on forest vegetation should be implemented by forest managers. This is of great importance, since a well-dispersed increase in food availability, such as those of recent clear-cut areas, over longer periods of time would likely increase ungulate abundance, and, thus, browsing damages [64]. The distribution of herbivores is mainly determined by abiotic factors, such as the distance to shelter and/or water, and, thus, impacts on vegetation may require more flexible and site-specific approaches [65]. The impacts of moose browsing can be altered by supplying alternative forage in areas that are not used for timber production [16]. Keeping a high sapling stem density, through thinning and/or planting, can allow for a higher proportion of stems to escape browsing [60]. In addition to attempts at reducing browsing damages, the density level of the moose population is especially critical on the outcome of vegetation management actions, especially during periods following disturbance [38, 64]. Beguin et al. [64] argues where overabundance of large herbivores exist, a collaborative management approach of forestry and game management practices should coincide and complement one another, while Edenius et al. [17] states that compatible monitoring systems are also needed. Therefore, it is important to find a density of moose that is socio-economically viable (considering moose may damage commercially important tree species and are an important game species for both landowners and hunters) that fits within ecological (i.e. environmental) bounds since browsing has the potential to vastly alter the composition of the deciduous species [66].

As natural resource management is often science-based, our research proves that the social component of the social-ecological system is a critical factor in present and future forest management. Kindstrand et al. [21] examined the views of forest owners and forestry contractors (who are from organizations whose business serves private forest owners) and found that contractors' views did not always coincide with those of the forest owners. Forest contractors regarded timber production as more important than did the forest owners [21]. As all of the landowners included in this study use forest contractors for harvesting of timber (refer to Section 3.2.1), discrepancies between how the landowners believe their forests should be managed and how their forest properties are actually managed may occur. Therefore, forest contractors should be aware of landowners' perspectives (specifically their values, preferences, and overall objectives) toward their properties in making sure these aspects are being represented in the kinds of forest management put forth (e.g. municipalities may want to reduce thinnings to increase biodiversity and improve aesthetic features of the forest). In addition, forest management plans should be consistent with underlying values as well, to have influence on their management activities [32]. Another area of improvement would be to develop collaborative communication strategies, as opposed to traditional forms of one-time feedback, that will help bridge the gap between relevant stakeholders, researchers, and policy-makers [30]. Understanding overall perspectives can offer suggestions on how to convey messages in different ways, such as reasons why managing for non-timber benefits are important, and can be useful in predicting what messages and actions will result in negative responses [23]. In addition, using a bottom-up type of governance with increased participation and stakeholder involvement will help to

integrate diverse values in the design of management plans, policy-, and decision-making while promoting a shared responsibility, which can help mitigate negative attitudes toward desired shifts in sustainable forest management and forestry-related politics (which were also observed within this study; refer to Section 3.2.4) [27, 59].

Most importantly, there is a need to manage the social-ecological system as a whole, integrating our ecological and social knowledge for a more sustainable forest management that promotes the maintenance of ecosystem services and functions. Howe et al. [67] showed that when one stakeholder involved has private interests and one of the services is a provisioning service, trade-offs between ecosystem services are probable. This scenario is highly applicable to the results of this study. Adjustments to forest management can enhance a broader range of ecosystem services deriving from the forest, such as the addition of deciduous species, extended rotation lengths, reduced thinnings, retention of coarse woody debris and/or mature trees, harvesting of stemwoods instead of whole trees, and increasing the land set aside from harvesting [45, 51, 55, 56, 68]. Additional studies have shown that a combination of varying management regimes across the landscape is required to mitigate trade-offs between ecosystem services. Landscapes ranging from “land-sharing” (i.e. permanent set-aside) to “land-sparing” (i.e. intensive forestry) may be needed in order to balance potentially conflicting aims [56, 69]. This is because forests are not uniform in quality [51]. To encourage the acceptance of more sustainable management practices and protection of public interests, new regulations and/or incentives such as certification schemes or payments for ecosystem services may be necessary [70]. A study conducted by Virapongse et al. [30] stated that by integrating both ecological and social components into one management approach can offer great possibility for more sustainable outcomes. The researchers highlighted that transdisciplinary approaches (e.g. co-development among experts and stakeholders for new knowledge), adaptive governance (e.g. individuals, groups, and institutions connect to make decisions), monitoring systems (e.g. social and ecological monitoring systems), and education and training programs are essential in meeting management-related challenges [30]. Lastly, in order to manage the social-ecological system sustainably, social and economic development must remain within environmental boundaries [66].

4.5 Recommendations for Future Work

Through its completion, this study has presented many possibilities for further research. Firstly, since forest succession is a slow process, it is of utmost importance to continue the SustHerb project to be able to see the impacts moose browsing and exclusion have on the regenerating boreal forest in both young (e.g. Speed et al. [12]) and mature forests (e.g. Speed et al. [71]). Long-term studies are needed to understand the effects on both early and late successional dynamics. The SustHerb project is currently ongoing with winter browsing data collection during the spring on an annual basis. Also, this study was conducted from data collection and analyses of just sixteen recently clear-cut sites in southeastern Norway. To get a regional-scale representation of the effects of moose browsing and exclusion on Norwegian boreal forests, a large-scale approach is needed. Other options for future studies would be to conduct research on both direct and indirect effects of moose

browsing on other aspects of the natural system, such as soils (e.g. Kolstad et al. [72]), understory vegetation (e.g. Speed et al. [73]), aboveground carbon stocks (e.g. Speed et al. [74]), and other animal communities (e.g. Mathisen and Skarpe [75]). Considering intensification of forestry is a main driver for the loss of biodiversity and ecosystem services [59], it is crucial to understand how changes in forest management can change the natural system, and, ultimately, alter final ecosystem services (and disservices) derived from these systems (e.g. Felton et al. [45], Gamfeldt et al. [51], and Roberge et al. [55]) [28].

As literature pertaining to Norwegian landowners' perspectives toward forest ecosystem management has not been found, this presents a great deal of opportunity for future studies. While we used qualitative research methods to explore the perspectives of twelve landowners in southeastern Norway, conducting more qualitative studies on landowners' perspectives in other areas of Norway would allow these results to be compared among differing regions. Another option would be to include more landowners (i.e. increased sample size) within the southeastern region and conduct a quantitative study and analyze the results in a statistical manner, linked to socio-economic factors (e.g. Nordlund and Westin [5]). Values studies can be built upon to include the general public (e.g. Haugen [4] and Eriksson [24]) to document the variations in forest values and non-timber ecosystem services of interest and forest contractors (e.g. Kindstrand et al. [21]) to document differing forest management objectives and preferences and whether these are represented in management behaviors. Further, understanding that values and objectives of forest landowners are more stable forms of human cognition and are slow to change, the most important reason for shifts in these values and objectives is the structural change of forest ownership as a new generation become forest owners [27, 76]. This new generation of owners will be younger, but will also have differing views, education levels, occupations, and other characteristics that may influence the objectives of forest ownership and management [4, 5]. This generational change pertains more to private landowners, and we did observe that many of the private landowners included in our study are older (data not shown). It would be insightful to conduct this study again as their forest properties are inherited or sold to a new generation of owners to observe if they hold a more diverse set of values (such as those within Table A.1) and whether these are represented in their management preferences.

Conclusion

To conclude, large herbivores have the capacity to alter the structure and composition of regenerating boreal trees by selective browsing in recently disturbed clear-cut areas. Moose exclusion markedly increased the growth of the deciduous trees. While pine was also positively affected by the exclosures, spruce was not affected by the exclusion of moose. Even though landowners recognized a broad range of ecosystem services and held a diverse set of forest values, we were able to identify their primary management objective as timber production, focusing on the commercial aspect of the forest. Municipalities differed from the private- and company-owned forest landowners by accentuating ecological and social aspects, managing for public goods and services for the care of their citizens. Landowners also possessed positive attitudes toward the future of forestry and forest land-use, believing forests will become more important and associating forestry with climate mitigation and energy transition. Landowners' perspectives can be important knowledge for developing sustainable forest management systems and policies that promote the provision of timber and non-timber benefits for not only the landowners, but the rest of society. As moose is a source of disturbance and a valuable resource, it is essential to find a density that is socio-economically viable that fits within ecological boundaries. In addition, by implementing a bottom-up type of governance with increased participation and stakeholder involvement, a shared responsibility will be promoted, helping to integrate diverse values in the design of management plans, policy-, and decision-making. All in all, it is of utmost importance that the social-ecological system is managed as a whole, incorporating ecological and social knowledge for a more sustainable forest management that promotes the maintenance of ecosystem services and functions.

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Appendix A

Appendix

Table A.1: Classification of the multiple ways in which the environment or natural resource is valued. Taken and modified from Trainor [35].

Value	Concept of value	Examples of entities that are valued
Aesthetic	Beauty	Landscape features
Cultural	Integral to the practice, preservation, and/or reproduction of a culture, group, or community	Religious values; language; cultural heritage; traditional rituals, priorities; customs; etc.
Ecological	Ecosystem health or integrity; ecosystem functions	Nature's services; undisturbed ecosystems; native species
Economic	Preferences; market prices; willingness to pay	Economic development; commodities
Historical or heritage	Links to human past	Historic places, buildings, etc.
Moral	Normative judgments	Preservation and protection of the environment
Recreation	Potential for quality recreational experience	Solitude; opportunities to spend time with family and friends
Religious/spiritual	Pathway to enlightenment or redemption	Hymns, prayers, rituals, faith, devotion; act, event, location that elicits spiritual awareness, growth or development
Scientific	Contribution to knowledge	Endemic and new species; palaeontological discoveries; archaeological sites
Social	Promotes and strengthens social relationships and institutions	Social capital; family integrity; sense of home/place; community; health care, education, and public utilities; jobs for local people

Questionnaire for Forest Landowners / Spørreskjema for Grunneiere

Personal Information / Personlig Informasjon

Landowner Name(s) / Grunneier Navn: OR / ELLER Company Name / Selskapsnavn:	
Profession / Yrke: OR / ELLER Position within Company / Stilling i selskapet:	
Age / Alder:	<input type="checkbox"/> 18–29 <input type="checkbox"/> 30–39 <input type="checkbox"/> 40–49 <input type="checkbox"/> 50–59 <input type="checkbox"/> 60+
Highest Level of Education / Høyeste utdanningsnivå:	
Do you have any education that was forestry- based or related? / Har du noen utdanning som var skogbruksbasert eller relatert?	<input type="checkbox"/> Yes / Ja <input type="checkbox"/> No / Nei
In addition to being a forest owner, are you a farmer or involved in other businesses? / I tillegg til å være skogeiere, er du bonde eller involvert i andre næringsvirksomheter?	<input type="checkbox"/> Yes / Ja <input type="checkbox"/> No / Nei <input type="checkbox"/> Not applicable / Ikke aktuelt
What proportion of your time is for forest, farming, or other work? / Hvilken andel av tiden din brukes for skog, ojordbruk, og andre næringer?	
What type of agriculture do you do? / Hva slags landbruk gjør du?	<input type="checkbox"/> Livestock / Husdyr <input type="checkbox"/> Cereal Production/ Kornproduksjon <input type="checkbox"/> Other / Annen <input type="checkbox"/> Not applicable / Ikke aktuelt
What type of animals do you have? / Hvilken type dyr har du?	
Is it infield or outfield grazing? / Er det innmark eller utmarksbeite?	<input type="checkbox"/> Infield / Innmark <input type="checkbox"/> Outfield / Utmarksbeite <input type="checkbox"/> Both / Begge <input type="checkbox"/> Not applicable / Ikke aktuelt

Does livestock grazing occur within the forest? / Går det husdyr på beite i skogen?	<input type="checkbox"/> Yes / Ja <input type="checkbox"/> No / Nei <input type="checkbox"/> Not applicable / Ikke aktuelt
How much time do you spend in the forest (either your own or other forests)? / Hvor mye tid bruker du i skogen (enten din egen eller andre skoger)?	<input type="checkbox"/> A little / Litt <input type="checkbox"/> Some / Noe <input type="checkbox"/> A lot / Mye <input type="checkbox"/> None / Igen <input type="checkbox"/> Not applicable / Ikke aktuelt
Forest Information / Skogsinformasjon	
Location of Forest & Site Name(s) / Plassering av skogseiendommen & stedsnavn:	
Forest Size / Skogstørrelse:	
If a private landowner / Hvis en privat grunneier:	
How long has the forest been owned by you? / Hvor lenge har skogen vært eid av deg?	
Has the forest been kept in the family? / Har skogen blitt holdt i familien?	<input type="checkbox"/> Yes / Ja <input type="checkbox"/> No / Nei <input type="checkbox"/> Not applicable / Ikke aktuelt
For how long has the forest been in the family? / Hvor lenge har skogen vært i familien?	
What percentage of your income comes from the forest? / Hvilken prosentandel av inntekten kommer fra skogen?	
If the forest is company owned / Hvis skogen er eid av bedriften:	
How long has the company owned and managed the forest? / Hvor lenge har selskapet eid og forvaltet skogen?	
What percentage of company income comes from the forest? / Hvilken prosentandel av selskapsinntekten kommer fra skogen?	

**Forest Management Plan, Certification Scheme, & Organizations /
Skogsforvaltningsplan, Sertifiseringsordning, & Organisasjoner**

Do you have a forest management plan? /
Har du en skogsforvaltningsplan?

Yes / Ja No / Nei

Are you part of a certification scheme? /
Er du en del av en sertifiseringsordning?

Programme for the Endorsement of Forest Certification
(Program for Godkjenning av Skogsertifisering)
 FSC (Forest Stewardship Council)
 Other / Annen None / Igen

Are you part of a forest owner organization? /
Er du en del av en skogsbedriftsorganisasjon?

Norskog Norwegian Forest Owner's Association / Norges
Skogeierforbund Other / Annen None / Igen

This completes the questionnaire. Thank you for participating. Do not forget to click save before exiting the document and sending the final version.

Dette fullfører spørreskjemaet. Takk for at du deltar. Ikke glem å klikke lagre før du avslutter dokumentet og sender den endelige versjonen.

Interview Guide – Hedmark & Akershus County Forest Landowners
Intervju Guide - Hedmark & Akershus Fylke Skogen Grunneiere

Section 1 / Seksjon 1:

What is your main use/management of the forest? [Examples: timber production, wildlife, other]
Hva er din viktigste bruk/ledelse av skogen? [Eksempler: tømmerproduksjon, dyreliv, annen]

Has the forest always been used/managed in this way? If not, how was the forest used/managed in the past?

Har skogen alltid blitt brukt på denne måten? Hvis ikke, hvordan var skogen brukt før?

Section 1A / Seksjon 1A: Timber / Tømmer

How do you harvest timber? [Example: use of contractor, other]
Hvordan høster du tømmer? [Eksempel: bruk av entreprenør, annen]

What are your environmental precautions on harvesting timber?
Hva er dine miljøhensyn for høsting av tømmer?

After harvesting, do you plant new trees? If so, what species are you planting?
Etter høsting planter du nye trær? Hvis ja, hvilke arter planter du?

Section 1B / Seksjon 1B: Game for hunting / Jaktbart vilt

What are your main arguments for hunting in your forest?
Hva er hovedargument for at det jaktes på din eiendom?

What game is hunted in your forest?
Hva for vilt jaktes i din skog?

How is the hunt organized? Who participates in the hunting? [Examples: hunt alone, hunting team, sell hunting rights]
Hvordan er jakten organisert? Hvem deltar i jakten? [Eksempler: jakte alene, jaktlag, selge jaktrettigheter]

Section 2 / Seksjon 2: Forest management for timber and moose production / Forvaltning av skog for tømmerproduksjon og elg

Is it possible to reach a balance between managing for moose and managing for forestry? Why or why not?

Er det mulig å nå en balanse i forvaltningen mellom elg og skogbruk? Hvorfor eller hvorfor ikke?

Are these two resources equally important for you/your company?
Er disse to ressursene like viktige for deg/din bedrift?

Section 3 / Seksjon 3: Effects of moose browsing on forest / Effekter av elgbeiting på skog

Were the results of the study surprising to you? Why or why not?

Var resultatene av studien overraskende for deg? Hvorfor eller hvorfor ikke?

Were you surprised to see the difference in vegetation inside the enclosure compared to that outside the enclosure?

Ble du overrasket over å se forskjellen i vegetasjon i uthegningen sammenlignet med det utenfor uthegningen?

Do you think the density of moose is too low or too high? What is your opinion on today's quotas regarding moose density?

Tror du tettheten av elg er for lav eller for høy? Hva er din mening om dagens jaktkvoter for elg?

Section 4 / Seksjon 4: Managing ecosystem services in forest / Forvaltning av økosystemjenester i skog

In terms of the different nature benefits to people, what are the most important nature benefits to people provided by the forest? [Examples: timber for fuel wood, meat, berries, mushrooms]

Når det gjelder de ulike naturgodene for mennesker, hva er de viktigste naturgodene som skogen gir? [Eksempler: tømmer for drivstoff, kjøtt, bær, sopp]

How do you envision the future of Norway's forests and your forest property?

Hvordan ser du fremtiden for Norges skoger og din skogs eiendom?

How would you reach this future? Are there any management changes needed? [Examples: business as usual, need of management changes]

Hvordan vil du nå disse fremtidsmålene? Er det noen forvaltningsendringer som trengs? [Eksempler: virksomhet som vanlig, behov for ledelsesendringer]

How important are forests to sustainable development in Norway? Please explain your answer.

Hvor viktig er skogene for en bærekraftig utvikling i Norge? Vennligst forklar svaret ditt.

Section 5 / Seksjon 5:

Are there any conflicts regarding timber production, moose hunting or browsing, or other wildlife you would like to emphasize?

Er det noen konflikter mellom tømmerproduksjon, elgbeiting og viltforvaltning, eller annet dyre- og planteliv du vil fremheve?

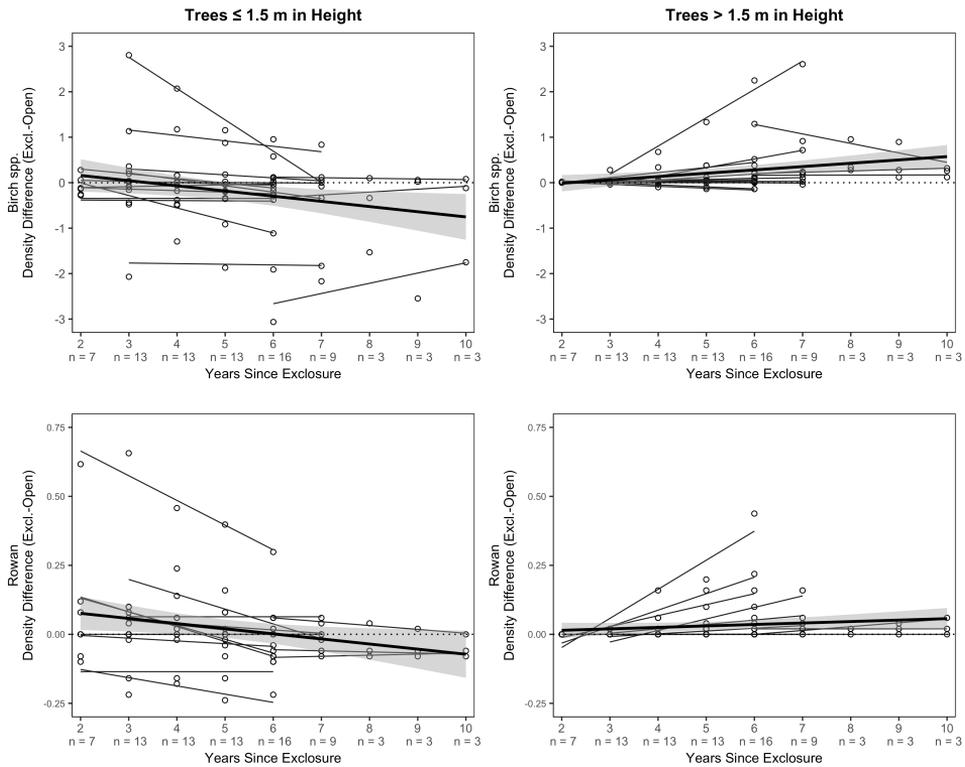


Figure A.1: Treatment effect (nine years of ungulate exclusion) on density (trees per m²) of deciduous tree species less than (or equal to) and greater than 1.5 m in height at sixteen boreal forest clear-cut sites. Positive values (above the dashed line) indicate that the density for that property was higher inside the excluded plots compared to outside. Data points represent unique sites and are plotted as circles. Gray lines show trends for unique sites. Regression line shown with shaded standard error.

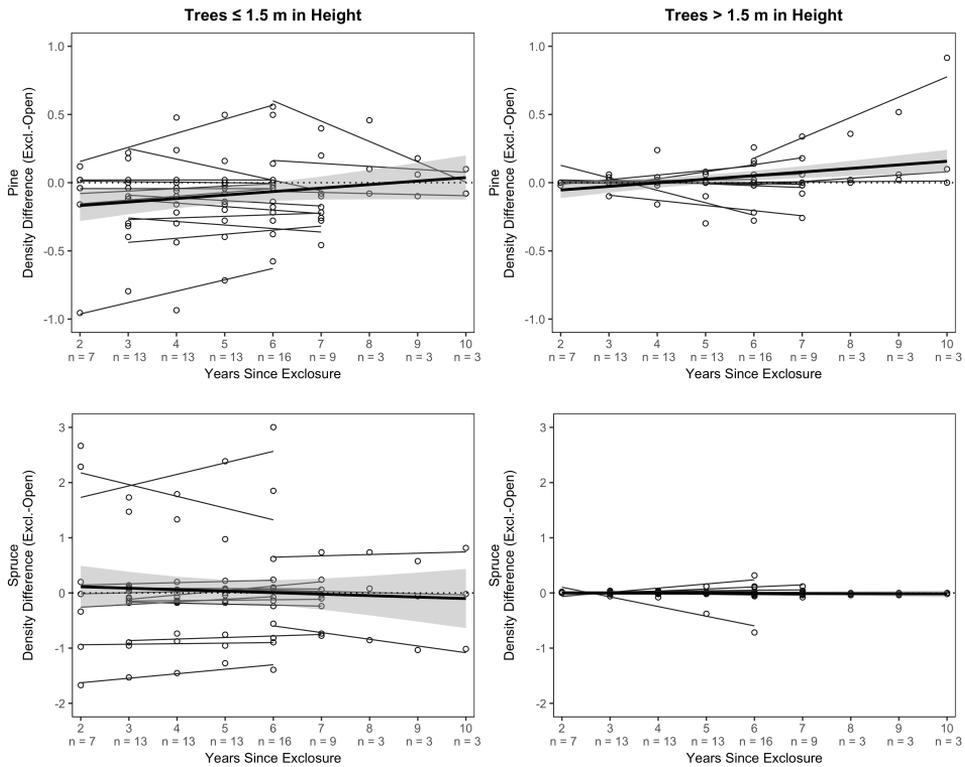


Figure A.2: Treatment effect (nine years of ungulate exclusion) on density (trees per m^2) of coniferous tree species less than (or equal to) and greater than 1.5 m in height at sixteen boreal forest clear-cut sites. Positive values (above the dashed line) indicate that the density for that property was higher inside the excluded plots compared to outside. Data points represent unique sites and are plotted as circles. Gray lines show trends for unique sites. Regression line shown with shaded standard error.